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NAVAL HYGIENE

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BY

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Prepared by Direction of the Bureau of Medicine and Surgery,
and Published by Permission of the Navy Department

WITH EIGHT COLORED PLATES
AND 105 OTHER ILLUSTRATIONS

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In St. John's Churchyard, Hampton, Virginia, one can find the following inscription which, of singular interest to the Members of the Medical Corps of the United States Navy, has been selected to occupy this dedicatory page:

TO THE MEMORY OF

DOCTOR GEORGE BALFOUR

WHO WAS BORN AT LITTLE ENGLAND IN THIS COUNTY
ON THE 26TH SEPTR., 1771
AND DIED IN THE BOROUGH OF NORFOLK
ON THE 28TH AUG., 1830

In 1792 he entered the Medical Staff of the U. S. Army, and braved the perils of the West under the gallant Wayne, who at a subsequent period, on Presque Isle, breathed his last in his arms. In 1798 on the organization of the Navy he was appointed its Senior Surgeon, and performed the responsible duties of that office until 1804, when he retired to private practice in Norfolk where he prosecuted his profession with distinguished reputation to himself and with eminent usefulness to that community, till the time of his decease.

He was courteous in his address: of a high sense of personal honor: of a generous and noble heart: and a firm believer in the Gospel, the precepts of which guided his course through life, and lifted his passage to the tomb.

His remains here mingle with those of his father and mother, who were buried on this spot and whose memory he ever cherished with truly filial affection. Two of his children sleep beside him, and a third erected this stone to mark the burial place of his sires.

HIS EPITAPH WRITTEN BY HIMSELF

Long had my spirit wandered in this vale of tears,
Fearful, yet anxious still, to venture home,
Till trusting wholly in God's grace, it left its fears,
Then boldly cried— I come— I come— I come!
His blood as shed in Christ can wash the sinner white,
His blood can heal each raging, rankling wound!
'Tis His to raise the mouldering dead again to light,
Crowned with glory triumphant from the ground.

PREFACE.

The object of this book is to furnish a text on Naval Hygiene that meets the requirements of the naval service. The demand for a guide in safeguarding the health of crews has been apparent for many years and has increased as the Navy has expanded in personnel and developed in construction of ships.

The author has been an interested observer of the growth of the Navy and has followed the changing conditions of naval life as they have modified hygienic problems and imposed new and increased obligations upon naval sanitarians. It has been an interesting period in naval history as the old navy has given way to the new, and the educational features of the change have been even more marked from a hygienic point of view than from the purely structural or architectural point of view.

The modern navy is characterized not only by development in engines of war, but also by development along educational lines. Every branch of the service has increased its educational facilities and is requiring advanced work in the united effort to promote service efficiency.

For a number of years the author, as instructor in Naval Hygiene at the Naval Medical School, has enjoyed exceptional advantages in arriving at an understanding of the educational requirements of the service from a hygienic point of view. He has constructed this text to meet those requirements, to facilitate instruction at the School, to increase the interest in hygiene on the ships, and to stimulate the research that results from an understanding of essentials and an appreciation of hygiene as representing the highest aim of the medical mind.

But the efforts of the Navy to advance the efficiency of its personnel are not represented solely by its own increasing educational facilities, as they also find expression in the demands made upon those seeking admission to its corps and examined for promotion from their various grades. Therefore, the hygienic requirements of the service relate not only to the School and the ships, but also to the work demanded by the Naval Medical Examining Board. The intention to write this book was formed when the author was a member of that Board, and it was the combined duty, instructor at the School and examiner on the Board, that forced him to recognize the necessity for including in this text certain subjects in general hygiene about which candidates for examination find the most difficulty, as well as those special applications to naval conditions in regard to which information seemed most desirable.

Among the special or characteristic features of this work recognition is asked of the importance of the attempt to base a navy's hygiene upon the vital statistics of that navy, under the belief that systematic or well adjusted effort to improve the health of a naval service depends primarily upon knowledge of the *damage* it receives from each disease and from all diseases and the varying amount of damage from year to year.

No comprehensive dissection of the vital statistics of our navy has been made and all dependable work in that direction may, therefore, be regarded not only as important, but also as new. However, in that connection the writer has subordinated all other considerations to what has seemed to him to be the main object of such an inquiry—the calculation of *damage* from disease.

The statistical report of the health of a navy or an army usually contains the statement that the health for the year has been good or satisfactory. Yet it is apparent that, in the absence of method of measuring or computing damage from disease, no naval or other military organization can declare how satisfactory or unsatisfactory its health has been, no means having been employed to make exact comparison of the health of one year with that of another, and thus to evolve a standard to which any given year can be referred.

It also seems fair to state that no naval or military service appears to have found it practicable to arrange its diseases in order of importance as measured by the damage each inflicts, or to compare with any exactness the health of one ship, station, or post with that of another, or to determine when a ship, station, or post may be regarded as unhealthy, or whether length of commission has relation to state of health, it having been considered in the old days that the longer a wooden ship remained in commission the more unhealthy the crew.

Such questions are undoubtedly fundamental in the consideration or construction of a navy's hygiene, and recognition is asked of the method employed by the writer to secure definite answers and to show their applications in a naval service.

J. D. G.

United States Naval Medical School,
Washington, D. C., July, 1909.

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NAVAL HYGIENE.

CHAPTER I.

THE VITAL STATISTICS OF THE NAVY.

AN INTRODUCTION TO THE STUDY OF ITS HYGIENE.

6 Information of the health of the Navy and Marine Corps during recent years is obtained from the vital statistics of the service covering that period. The compilation of such statistics is onerous and their interpretation difficult, but the importance of the work is appreciated when it is realized that without knowledge of present conditions and comparison with the past it is impossible to know the directions in which effort should be made for improvement and to measure the results of such effort. It is undoubtedly true that improvement of health lies in appreciation of present conditions and that without such standards as may be derived from the dissection of vital statistics there can be no such appreciation.

Of all statistics, those in which the medical mind is interested seem to be the most difficult to gather with accuracy and to express in satisfactory form. Statistics of morbidity are very instructive when reasonably reliable, and when associated with such information that they can be interpreted with a fair degree of accuracy. But, so frequently is a given result utilized to advance claims even diametrically opposed that many look with doubt upon any table of figures relating to the physical ills of mankind. They recognize the difficulties to such an extent, or have been misled so frequently, that they are unwilling to accept results for which only approximations can be claimed. Much might be advanced in favor of their view, but, nevertheless, they do not seem to recognize the enormous value of approximations in all walks of life.

A rifle is an instrument of precision in the hands of a few, with many only approximations are secured, and with most it is only the chance shot that hits. Yet the rifle is the best instrument so far devised for use in the ranks, and it kills many against whom it is directed, but wounds more. It is the approximation that counts in the long run, but that is secured by a definite aim. The rifle remains the same, irrespective of the hands by which it may be held. It is the application that may be disappointing, but, nevertheless, the value is in approximations.

The study of the pure mathematics leads the mind to the contemplation of absolute accuracy—to a conception of the possibility of perfection. But it is an abstract study and, applied to the affairs of everyday life, should not disappoint when very often only approximations are secured. In applied mathematics important results depend very frequently upon data not mathematically true. In planning a bridge the strains and stresses are calculated with great care, but experimental data are used in arriving at use of material, and, in recognition of the approximate value of such data, a factor of safety is finally applied. Yet some bridges collapse.

Some of the minds that decline to accept vital statistics in any form do not hesitate to accept their own results from CO_2 observations and to make calculations of air supply based upon such observations. Yet, all such calculations give results that are merely approximate, however carefully they are made, as the assumed or standard excretion of CO_2 by each individual is in any particular case only approximate. The calculation of air supply by the direct method in vogue gives only a coarse approximation to the truth. An anemometer even after the stated error has been applied is not an instrument of such precision that it can be used with satisfaction in connection with experimental and mathematical work relating to the movement of air at high velocities in pipes.

The fact is that in most of the practical affairs of life men utilize standards known to be mere approximations and find them of the greatest value. Human progress, while associated with ideals, has depended upon guides that, like the compass, never point a true course. It was such a guide that made the discovery of America possible. A statistical table necessarily has a mathematical appearance, but it should never be regarded as having mathematical accuracy. Because it is not exactly what it seems it does not follow that it is of no value for practical purposes. And if it does not always lead to determinate results it should not be forgotten that even in pure mathematics there are such terms as "method of approximation," "indeterminate analysis," "indeterminate form," "indeterminate problem," "indeterminate quantity" and "indeterminate series."

The vital statistics of the Navy may be defined as the results obtained by the application of mathematics to the health records of the naval personnel. They do not include any relation to births, marriages, and differences of sex, but are strictly confined to men in the Navy, their condition on coming in, the various diseases from which they suffer or die or are discharged, and those influences that affect vitality or conditions attending naval life that relate to physical usefulness or efficiency. They represent an analysis which is necessarily at the very foundation of all inquiry of sanitary conditions and sanitary progress.

While it is true there are no births in the Navy, there is a most important analogon in the recruit who may be considered as brought into naval being at the time of enlistment. In a civil community a high death rate may be due to a high birth rate, and a zero birth rate for a few years would lower the death rate during those years. In an expanding navy the recruiting rate is higher and there is a more or less corresponding effect on morbidity and mortality, as the recruit being new to the life does not know how to make the best of his surroundings. He lacks knowledge and needs discipline and, in addition, is much more susceptible to adverse influences in his environment. He does not know how to take care of himself under the new conditions and for a time is not impressed with the necessity of knowing. He is in the midst of dangers he does not appreciate, is dealing with forces he little understands, does not know when to get out of the way, and is more often hurt.

A higher recruiting rate tends to a higher morbidity rate, a somewhat higher death rate and a much higher discharge rate for physical disability, as the greater the number of first enlistments, the greater the number of mistakes in selections at the recruiting stations and the greater the number of discharges for disability existing prior to enlistment. A lower recruiting rate tends to a lower death rate. Unlike a civil community, the aged do not remain to die. A man is in the navy to give efficient service and the aged have, therefore, generally returned to civil life or have found a snug harbor in the Naval Home.

In drawing conclusions from statistical data great care has to be taken to avoid fallacies. Before any attempt at interpretation is made it is necessary to know the conditions under which the data were collected and the methods employed. In the interpretation of naval vital statistics and in comparing the various years, the first essential is the recognition of this dominating influence of new men. During recent years the navy has been expanding rapidly and in the study of the statistical tables of the period it will be seen how many difficulties that fact has introduced into the problem. It will be clear that, unless the influence is kept in mind all the time, reasonable interpretations will be impossible.

It will also be well to recognize that any effort expended in arriving at an understanding of those tables will not be wasted with reference to the future. It is a very common error to regard statistics as useless because not up to date. The statistics of any one year, however recent, have little value except that evolved through comparison with those of prior years. It is true that statistics of any recent years have some values peculiarly their own, but also other very important values that depend exclusively upon comparison with the statistics of antecedent years. With an understanding of the methods employed and of the data relating to recent years, it will be practicable for anyone to utilize the material available in any future year and to make the comparison that may be desired.

An appreciation of present conditions would be greatly enhanced if the naval vital statistics of today could be definitely compared with those that might have been gathered in each of the historical periods of the past—the wooden sailing ship of long voyages and wet decks, the wooden ship with auxiliary steam power and wet decks but without distilled water and artificial ventilation, and the wooden ship with distilled water and shellacked decks but without artificial ventilation. A primary object of all vital statistics is to afford the means of comparing the health of the present with that of the past. In that comparison the statistics of the past are of as much importance as those of the present.

The vital statistics of the Navy and Marine Corps relate to the *active list* only. When a man is discharged for physical disability he is as truly lost for all naval purposes as if he had died, and consequently at the moment of discharge he ceases to be a factor in the study of naval life. A stream of humanity is passing from civil life through the navy back to civil life. It is made up largely at the beginning of selected men commencing their enlistments for four years and it ends chiefly in those who have been discharged by reason of expiration of enlistment, by sentence of court-martial, and on account of physical disability. If all persons who entered the navy remained until death, those persons who are now discharged or retired for physical disability would of course continue to have statistical value for naval purposes, but as the health histories of all the men who have left the navy for any cause cease to be known from the date of discharge, the sick days and termination in the cases of men discharged for disability could not be utilized even if known, the individuals comprising that class having been forever separated from the total number of men that furnished the cases. Therefore, a discharge for physical disability, when considered as representing damage caused by disease or injury, is equivalent from a service point of view to a death.

In naval vital statistics relating to morbidity the chief disturbing factor is the mistake in diagnosis. In civil life, as the statistics of morbidity are meager, the difficulty is more apparent in the returns of causes of death. In the navy where every condition causing excuse from duty must be given a name from the prescribed nomenclature, however short the course of the disease or the opportunity for observation before transfer from ship to hospital, the tendency to error is greatly increased. Transfers from ships to naval hospital often have to be made during the first days, or even hours, and therefore before there has been opportunity to arrive at a definite conclusion. Movements of ships are uncertain or a ship may be scheduled to sail in a few hours or next day in the early hours. In civil life a case is followed, as a rule, by one mind to its termination, yet, even under continued observation, errors of diagnosis are necessarily not uncommon. Exigencies of the naval service certainly tend to multiply such errors and, in utilizing health records for statistical purposes and in the interpretation of some results that may be obtained, that source of error has to be given much weight.

It is evident that errors in diagnosis increase the number of cases in naval medical returns. They do not change the number of persons sick or the number of days they are sick. A man may furnish a number of cases while continuously on the sick list, but it is only one man sick, and for each day that he is sick he can give only one sick day whatever the diagnosis may be. A man transferred with a wrong diagnosis to hospital was included in the ship's returns with that diagnosis during the time covered by the statistical tables to follow. When received in hospital he contributed some sick days under that diagnosis, but when the diagnosis was changed he was returned from the hospital as a new case and thus increased the number of cases. Such an increase in cases changes the relation of deaths from a disease to the number of cases of that disease—the mortality rate of a disease. It does not change the death rate from a disease per 1,000 of strength or men in the service.

For instance, at the end of 1894 there were five cases of typhoid fever in the naval hospitals, during the following eleven years there were received from the ships and stations 636 men with that diagnosis, and from changes of diagnosis in all other cases under treatment and from other men (convalescents and members of the hospital corps) at the hospitals, 277 additional cases were returned—a total of 918. As 16 cases remained under treatment at the end of 1905 there appear to have been 902 concluded cases. Those cases terminated in 91 deaths and therefore the mortality rate from that disease in the naval hospitals seems to have been $\frac{9100}{902} = 10.088$ per cent. But as some of the 636 cases received from ships and stations were not typhoid, the mortality rate is too low, the denominator of the fraction being too large. The true rate was about 10.833. It is evident that as all of the 91 deaths were caused by typhoid fever the relation of death from that disease to the total force remains unaffected by change in number of cases.

While the mortality rate in the hospitals from lobar pneumonia appears to have been 8.964 per cent. during the same period (1,014 cases and 90 deaths), the true rate was about 9.78.

Not a few cases of typhoid fever are received in hospital after having been treated for some days in the ships at sea often under adverse conditions. The cases of pneumonia occurred for the most part among healthy picked men and the average age at death from that disease was 28.39 years. The idea that to die of pneumonia is almost the natural end of old people does not apply to the active list of the navy and marine corps on which there are few old people.

Another consideration of importance in relation to naval vital statistics, based upon records made from 1895 to 1905, is that while such records are utilized for statistical purposes, they were not made primarily for that purpose. In all those records there were evidently two governing influences,—to meet the daily requirements of the service by placing on the sick list all men excused from duty on account of disease or injury, and to supply medical histories that might be of value in deciding claims for pension. It is obviously necessary on board ship to clearly designate the men considered unable to do duty. Records of all such cases are made in a manner that necessitates their appearance in the statistical report. But there were many additional men under treatment whose cases do not appear in the statistical returns unless in the opinion of the medical officers there were likely to be sequelæ bearing upon claims for pension.

The pension feature has been the most important one in the medical returns for permanent record. This has led to the inclusion of all seemingly important cases from that point of view and of all cases causing excuse from duty, but it has led to the exclusion of many cases that might be considered of importance from a purely statistical point of view. For instance, it is not possible to ascertain the number of cases of seasickness in the navy during a given period, but only the number that caused excuse from duty. All cases of syphilis appear in the returns whether they involved excuse from duty or not, but it is true that many cases of uncomplicated gonorrhœa, especially repeated attacks, not having been considered by the medical officer of sufficient severity, under the conditions of naval life at the time, to cause excuse from duty, were not regularly admitted and therefore are lost for statistical purposes.

There are some cases of venereal disease that are never discovered. That is largely due to the influence of the "restricted list"—a list of all men having venereal disease and through which they are deprived of the much-desired liberty. It is a list kept by regulation and represents in part an attempt to prevent the spread of disease on shore—an attempt not reciprocated by any civil community of English-speaking people.

While it may appear that all cases of the venereal diseases should, even from a pension point of view, be available for statistical purposes, it is not clear that a statistical report satisfactory to every one is feasible, and it is certain that a perfect report from a mathematical point of view is impossible.

Nevertheless, as the excuse from duty and the claim for pension seem to form the only practicable line of demarcation between the sick and the well in naval life, the statistical tables have to be considered under that limitation and the interpretations made accordingly. And the fact that the admission ratios of those diseases which frequently cause trivial cases are stated much too low does not prevent important conclusions, as the relative number of cases returned from year to year may be regarded as indices of relative prevalence.

For instance, it will be seen that the cases of scabies that were returned increased enormously during the period, although many medical officers do not place such patients on the sick list believing from experience that at the moment proper treatment is instituted on board ship the disease ceases to be communicable. But the number of cases returned each year after 1900 and their corresponding number of sick days show in no uncertain way the increased damage from that disease and the increased importance it has claimed from a hygienic point of view. There are also at times methods of drawing relatively fair conclusions of actual prevalence. For instance, while it is apparent that the admission ratio of gonorrhœa is much too low, it can be taken that the admission ratio of gonorrhœal rheumatism is fairly correct. Experience indicates that the cases of gonorrhœal rheumatism are about 2 per cent. of the cases of gonorrhœa.

Finally, in connection with such interpretations it should be appreciated that there is a tendency to loss in sick days. Sick days of officers taken sick while traveling from one duty to another and of the relatively small number of men left in foreign hospitals are examples. The latter does not affect the number of cases, but it will be seen that any loss of sick days lowers the calculated daily average of patients. In securing the data upon which the tables covering the period to be considered were based, it has been necessary to find lost sick days, including those from officers on sick leave and persons in other than the hospitals of the service.

In the general question of invaliding from service, the retirement of an officer for disability from disease or injury has been regarded as equivalent to discharge. From a naval statistical point of view any transfer to a hospital for the insane has also to be considered as a discharge from service for disability, as such persons are not returned to duty. A man so transferred is as much a loss from the service point of view as if he had died or had been discharged. In fact it will be seen that in estimating the damage, received by the Navy and Marine Corps from disease and injury, a discharge from service for physical disability has been given the same value as a death, the loss of service being complete, and therefore the same in each.

In the study of naval vital statistics it is necessary to know the meaning of the following terms:

1. **Average strength** is the daily average number of persons in the service during the year or period under examination. Each enlisted man is allowed a ration daily. Therefore, the total number of rations issued and commuted during the year or period divided by the number of days in the year or period is the average strength of the enlisted force for that time. To the result must be added the average number of officers in order to obtain the average strength or force of the service. The same result is obtained from calculations based upon the total amount of money regularly paid to the Hospital Fund, each person contributing at the rate of 20 cents a month to that fund. The average strength includes the sick and the well and is the total of the average strengths of the force afloat (in the ships) and of the force ashore (navy yards, shore stations and hospitals). The average strength of a ship is the same as its average complement. Ratios per hundred (percentages) and ratios per 1,000 of the average strength or force are very generally expressed. An admission rate is usually expressed as a ratio per 1,000 of strength and may be expressed for all diseases or injuries or for any disease or injury. If expressed for each disease and injury, the total is the total admission rate.

2. **Daily Average of Patients.**—If one man is on the sick list every day of the year he will give 365 sick days during a year of 365 days. The same is true of 365 men on the sick list one day. Two men on the sick list every day of the year would give 730 sick days, as would ten men on the sick list 73 days. In all cases the number of sick days during a year, or any period, divided by the number of days in the year or period, equals the daily average number of persons on the sick list—the daily average of patients or non-effectives—for the year or period. If $a =$ the required daily average of patients, $s =$ the sick days and $t =$ the days in the year or period, then $a = \frac{s}{t}$. The daily average of patients may be obtained as the total average or as the average for any disease or injury, the total sick days from the disease or injury being divided by the number of days. If expressed for each disease and injury, their total is the same as the total daily average of patients.

3. **The "percentage of sick"** is the daily average of patients expressed in percentage of the average strength. For instance, if the daily average of patients is 20 and the average strength 1,600, then the question

is simply what per cent. of 1,600 is 20? $\frac{20}{1600} \times 100 = 1.25$ per cent. In other words, if 1.25 per cent. be taken of 1,600, the result will be the daily average of patients or the average number of people who have been on the sick list each day. If $p =$ percentage of sick, $a =$ daily average of patients, and $f =$ the average strength or force, then $p = \frac{a \times 100.}{f}$ But it was shown under "Daily Average of Patients" that $a = \frac{s}{t}$. By substituting that value for a in the above, there results $p = \frac{s \times 100}{f \times t}$. In other words, the percentage of sick for a year or any period equals 100 times the total sick days of the year or period, divided by the product of the average strength by the number of days in the year or period. In the same way the percentage of sick can be obtained for any one or more diseases or injuries, the total sick days of the disease or injury being used in place of the total sick days from all diseases and injuries returned during the year or period.

In obtaining the daily average of patients or the percentage of sick for any year, it is plain that 365 days is used for a common year and 366 days, for a leap year, and that ordinarily for a period of four consecutive years the average year contains 365.25 days. But the mean length of the solar year is 365.2422 days, the difference under the Gregorian rule causing the centurial year 1900, though divisable by four, to be a common year. From 1895 to 1905, inclusive, there were only two years of 366 days and as it has been considered necessary to eliminate 1898, a time of war, the length of the average year of the remaining ten years—the period selected—has been considered as 365.2 days. The separation of 1898 from the other years is necessary in an attempt to ascertain the damage from disease under usual conditions. The future year will ordinarily be a year of peace and the statistics of that year cannot be fairly compared with those of the average year of a period that included a year of war. War has its own problems from a hygienic point of view, but the statistics of a period of war should be compared with those of a similar period. It is doubtful whether the naval conditions of 1898 will ever be sufficiently duplicated to make a fair comparison practicable.

4. **The average number of sick days per man in the service** can be obtained by dividing the total number of sick days by the average strength. The average number of days each case was treated is apparently shown by dividing the total number of sick days by the total number of admissions, but such a result is of little value on account of multi-

plication of cases by errors of diagnosis. The average number of days the individual remained on the sick list would be of some value, but it is clear that the number of admissions and the number of individuals are not the same. The average time a case of a given disease requires before the individual is ready for duty is obtained theoretically by dividing the total number of sick days from all cases of the disease by the number of cases. But the result is not free from the question of diagnosis and when applied to men actually returned to duty there must be a calculated allowance for death and discharge for disability.

5. **The death rate, invaliding rate, and admission rate** are expressed in ratio per 1,000 of the average strength. Ratio per 1,000 is the rate or proportion per 1,000. For instance, if the average strength for the year was 45,156 and the number of deaths during the year was 275, then the annual death rate would be found by dividing 275 by 45.156 as in 45156 there are $45\frac{156}{1000}$ thousands. Therefore, $\frac{275}{45.156} = 6.09$ = total annual death rate per 1,000 of strength. The same result would be obtained by proportion: $45156:275::1000:x \therefore x = \frac{275000}{45156} = 6.09$. Percentage is ratio per 100, and therefore 6.09 per cent. of a number is that number multiplied by .0609. But the above is ratio per 1,000, and therefore that ratio would be applied by multiplying by .00609. Thus, $45156 \times .00609$ or $45.156 \times 6.09 = 275$ = the actual number of deaths during the year. The same method is employed in calculating the annual death rate of a particular disease, the deaths caused by that disease being multiplied by 1,000 and the product divided by the average strength. The method applies to the invaliding rate and the admission rate.

6. **Damage.**—As the personnel of a navy (or an army) is damaged each year by disease (and by injury), it is of the first importance to ascertain the extent of such damage and, by comparison of the loss of one year with that of another and of the conditions under which the damage was received, to appreciate the sources and their comparative importance and thus be able to formulate a plan of action for their removal or limitation.

If one takes up the statistical reports of any navy or army for the purpose of ascertaining even the total damage it has received from disease and injury during any year or series of years, he will find merely a number of items which being *unlike* quantities cannot be combined by addition to form the sum total desired. For instance, in the statistical report of the navy of Great Britain for 1900 the *death rate*, *invaliding rate*, and *ratio per* 1,000 *of force sick daily* are given as 7.27, 35.83 and 37.62 (*percentage of sick* 3.762), respectively. But such terms cannot be added to form the total damage any more than houses, land, and horses can be added to give the value of property, and as the items vary from year to year a definite comparison of damage cannot be made unless they are expressed in terms of some common standard.

In the case of property, value is expressed in a standard of money as also is damage to that property by fire or other agents. In a naval or military organization the loss from disease or injury is one of service—a country expects each man in its navy or army to do his duty. It is clear, therefore, that the damage a service receives from any disease or injury or from all diseases and injuries is measured chiefly by three results—the daily average of patients (non-effectives), the number of deaths, and the number of persons invalided. Those results are all that involve loss of service and are expressed in percentage of sick, death rate, and invaliding rate. If percentage of sick expresses loss of service in definite terms, it is evident that the total loss of service or total damage can be obtained if death rate and invaliding rate can be expressed in terms of percentage of sick, and it is equally evident that if a death or discharge can be shown to represent a definite loss of service, the total damage can also be represented if percentage of sick can be expressed as death rate or invaliding rate. In the former case the damage is in terms of percentage of sick and in the latter case in terms of death rate or invaliding rate. To obtain such results it is of course necessary to devise a method by which death rate and invaliding rate can be expressed in percentage of sick, and percentage of sick can be expressed in death rate or invaliding rate. That has been done as follows:

a. **Damage in Terms of Percentage of Sick.**—Damage in percentage of sick may be defined as the *total* damage expressed in terms of "percentage of sick" or in percentage of force sick daily. It would therefore be the sum of the percentage of sick and of the death rate and invaliding rate *expressed in percentage of sick.*

From a naval point of view, loss from disease or injury is measured by loss of service. Therefore, a death has the same value as a discharge from service for disability providing they occur on the same day, as in each case the services of one man are lost for the same length of time. It is also apparent that a disease which keeps a given number of men on the sick list every day causes the same loss of service during the year as if it had caused the deaths or discharges of the same number of men at the beginning of the year and no sick. For instance, if a disease keeps 20 men on the sick list every day of the year it has the same damaging effect upon the service *during that year* as if it had caused 20 deaths, or 20 discharges for disability, at the beginning of the year, as in either case the services of 20 men are lost for the entire year.

But in making this comparison it is necessary to realize that men do not die and are not invalided on the first day of the year more than on other days of the year. In fact, as an average it may be assumed that about as many men die in the service or are discharged from the service for disability after the midday of the year as before that day. Therefore, the death or discharge of 20 men at the beginning of the year is equivalent in loss of service to the death or discharge of 40 men throughout the year, the average death or discharge being assumed to occur on the midday of the year and to involve the loss of service during that year of one half the year or, in a year of 365 days, of 182.5 days. It follows then that 40 deaths or discharges for disability occurring during the year represent the same damage as that caused by a disease which keeps 20 men on the sick list every day of the year. It does not make any material difference whether they are the same 20 men or not, as the services of 20 men, whoever they may be, are lost. Therefore, the conclusion is that 2 deaths or discharges for disability during the year have on the average the same damaging effect on the navy *in that year* as one person on the sick list every day of the year. It follows then that if the damage from death or from invaliding is expressed in ratio per 1000 it can be expressed in percentage of sick by dividing the ratio by 20.

While that may be self-evident, it can be shown in mathematical form as follows:

If r = ratio per 1,000 of strength that dies or is invalided, p = percentage of sick, and f = average strength for the year, then $\frac{f\,r}{1000}$ = number of deaths or discharges per 1,000 of strength. If those deaths or discharges be referred to the midday of a year of 365 days, the corresponding loss in sick days is $\frac{f\,r}{1000} \times \frac{365}{2} = \frac{365\,f\,r}{2000}$. To convert those sick days into percentage of sick they must be multiplied by 100 and divided by the product of the average strength and 365. Therefore, $p = \frac{365\,f\,r}{2000} \times \frac{100}{365f} = \frac{r}{20}$.

Suppose that tuberculosis in the Navy and Marine Corps has its percentage of sick expressed by .179045, its annual death rate per 1,000 by .6228177 and its invaliding rate by 2.4497499, what is its total damage during a year in percentage of sick? Obviously, $\frac{.6228177 + 2.4497499}{20} + .179045 = .3326734$. If this damage-percentage be applied to an average strength of 45,000 men, the result is as follows: $45000 \times .003326734 = 149.7$. In other words, the total damage during the year from tuberculosis is equivalent to 149.7 men on the sick list every day of the year with no deaths and no discharges for disability from that disease.

Of course, the same method can be applied in ascertaining the total damage from all diseases or all injuries or from both. For instance, suppose in any one year the total percentage of sick from disease and injury is expressed by 3.293594, the death rate by 6.1713875 and the invaliding rate by 32.3110295, what is the total damage in percentage of sick? $\frac{6.1713875 + 32.3110295}{20} + 3.293594 = 5.2177$. If this damage-percentage be applied to an average strength of 45,000 men, the result is as follows: $45000 \times .052177 = 2347.96$. In other words, the total damage during the year from disease and injury is equivalent to 2347.96 men on the sick list every day of the year with no deaths and no discharges for disability.

b. **Damage in Terms of Death Rate or in Terms of Invaliding Rate.**—From the foregoing it appears that damage from death or from invaliding, expressed in ratio per 1,000, can be expressed in percentage of sick by dividing the ratio by 20. It is equally evident that damage expressed by percentage of sick can be expressed in ratio per 1,000 of strength by multiplying it by 20. This may be expressed as follows: If p = percentage of sick, f = average strength for the year, r = the required ratio per 1000 of strength and a = daily average of patients, then $a = \frac{pf}{100}$. As $\frac{pf}{100}$ people on the sick list every day cause the same damage during the year as if $\frac{2pf}{100}$ people died during the year or were discharged during the year for disability, $r = \frac{2pf}{100} \times \frac{1000}{f} = 20\,p$.

Suppose that tuberculosis in the navy and marine corps has its percentage of sick expressed by .179045, its annual death rate per 1,000 by .6228177 and its invaliding rate by 2.4497499, what is its total damage during a year in ratio per 1,000 of strength (deaths or discharges)? Obviously, $20 \times .179045 + (.6228177 + 2.4497499) = 6.6534$. If that rate per 1,000 be applied to an average strength of 45,000 for the year, the result is $45000 \times .0066534 = 299.4$. In other words, the total damage caused by tuberculosis during the year is equivalent to 299.4 deaths during the year and no person on the sick list from that disease at any time during the year.

The same method can be applied in ascertaining the total damage from all diseases or all injuries or from both. For instance, suppose in any one year the total percentage of sick from disease and injury is expressed by 3.293594, the death rate by 6.1713875 and the invaliding rate by 32.3110295, what is the total damage in ratio per 1,000 of strength? $20 \times 3.293594 + (6.1713875 + 32.3110295) = 104.354$. If this damage-ratio be applied to an average strength of 45,000 men, the result is as follows: 45000×.104354=4695.9. In other words, the total damage *during the year* from disease and injury received by an average force of 45,000 men was equivalent to 4695.9 deaths occurring during the year or nearly 13 deaths each day of the year. As 4695.9 deaths occurring during the year are equivalent in loss of service to 2347.95 deaths at the beginning of the year, the total damage in men would be represented by the total loss in action or otherwise on the first day of the year of the crews of at least three first-class battleships, the service to remain without disease or injury during the rest of the year.

The necessity for some such system or method of representing the total damage from disease in the naval service is very apparent. Deaths, discharges for disability, and the daily number of non-effectives, considered as separate items and varying each year, leave one without a reasonable understanding of the degree of damage and do not permit comparison of one year with another. Deaths can be compared with deaths, invaliding with invaliding, and non-effectives with non-effectives, but the conclusions are necessarily indefinite and confusing. If a building is damaged by fire the items are ascertained and the total loss is expressed in dollars or in labor and material. If the naval service is damaged by disease, the items are ascertained and by the method proposed are expressed in non-effectives or in deaths and invalidings.

In this method the actual number of cases of a disease or injury or of disease and injury has no place. The year's damage cannot be measured by actual number of cases, for the course of some diseases is short and of others long, the number of deaths from some diseases large and from others small. The number of persons that a disease keeps on the sick list daily is an important factor and, as the total number of sick days from the average strength is not changed by any number of errors in diagnosis and the total number of deaths and invalidings cannot be changed by error in diagnosis, the general conclusions in the method proposed are based upon data of considerable accuracy. It may even be claimed that the damage ascertained in the case of any one disease is a sufficiently close approximation for all practical purposes as causes of death and invaliding are given, as a rule, with sufficient accuracy, and mistakes in diagnosis affect percentages based on sick *days* very much less than percentages based on number of *cases*.

However, it can be successfully urged that the damage-percentage or damage-ratio proposed do not meet all mathematical requirements. Some may claim that more deaths occur prior to the midday of the year than subsequent to that day, and others can claim that a relatively small number of men are invalided a short time prior to expiration of enlistment. If the former be true the damage-value of a death is increased, while in the latter case the damage-value of a discharge for disability is diminished. There is thus a maintenance of the approximation claimed which is further confirmed by the facts that a discharge for disability is a bar to reenlistment and that about 57 per cent. of those entitled to reenlist are reenlisted.

The navy is also damaged in other ways than in loss of service. There is a money damage that may be partially ascertained in the cost of maintaining a medical department and in the payment of pensions. A single case of smallpox, of yellow fever, of cholera, or of other quarantinable disease may cause the detention of an entire crew, and such diseases may render a ship useless for considerable periods. The effects of alcohol on a service are not even chiefly shown in the sick list, but must be found in the list of punishments and be derived from a study of the records of courts-martial. But on the other hand, there are no satisfactory standards by which the majority of damages can be estimated in all directions, and yet such estimates as are made in every-day affairs are of very great value.

Under the foregoing definitions and explanations the following table has been constructed to show the calculated damage, in terms of percentage of sick, and also in terms of death rate or invaliding rate, received from *disease* by the Navy and Marine Corps during each year of the period selected:

STATISTICAL TABLE 1.

Year	Percentage of sick	Rate per 1000 of strength		Total damage in percentage of sick	Total damage in ratio per 1000
		Deaths	Discharges for disability		
1895	2.853	5.307	11.599	3.6983	73.966
1896	2.493	4.508	14.722	3.4545	69.090
1897	2.432	3.559	17.859	3.5029	70.058
1899	2.676	4.563	21.615	3.9849	79.698
1900	2.924	5.009	26.435	4.4962	89.924
1901	2.888	4.279	31.965	4.7002	94.004
1902	2.898	4.097	30.314	4.6185	92.371
1903	3.183	4.403	36.093	5.2078	104.156
1904	2.772	3.205	30.921	4.4783	89.566
1905	2.778	3.122	26.045	4.2363	84.727
Average	2.8331	4.038	27.189	4.3945	87.890

In the study of this table and of all the other statistical tables, it is desirable to apply different factors to some assumed average strength in order that the value of variations in terms of the same character may be appreciated. Slight changes in a percentage of sick represent marked changes in the daily average of patients. For instance, if an average strength of 45,000 men be assumed and the percentage of sick of 1897 be applied, the daily average of patients would be $45000 \times .02432 = 1094.4$; but if the percentage of sick of 1903 be applied, the daily average of patients would be $45000 \times .03183 = 1432.35$. In the latter case the sick list would average 338 more men *daily*, a number much greater than any one of the hospitals would accommodate even as late as 1909. A percentage of sick of 2.432 is equivalent in damage to a death or discharge rate of 48.64 per 1,000 of strength, and a percentage of sick of 3.183 to a death or discharge rate of 63.66. Applied to a force of 45,000 men the number of deaths or discharges in the former case would be 2188.8 and in the latter 2864.7—a difference of 676. In the one case there would be actually 338 more men daily on the sick list on the average. In the other case the 676 more deaths or discharges during the year is merely a calculated amount of damage in terms of deaths or discharges corresponding to the increase of 338 in the sick list. Corresponding calculations can readily be made to show the value of variations in death and discharge rate.

The table shows that the service received the smallest damage from disease in 1896 with a damage ratio of 69.09, and the greatest damage in 1903 with a ratio of 104.156. The difference is very great and can be best appreciated by application of the factors. The damage in a force of 45,000 men corresponding to the factors of 1896 would be an average daily sick list of 1554.5 men with no deaths or discharges for disability or 3109 deaths or discharges during the year and no sick list; while the factors of 1903 would give a damage equivalent to a daily sick list of 2343.5 or 4687 deaths or discharges—789 more men *daily* on the sick list or 1578 more deaths or discharges during the year. In considering these results it should be distinctly understood that they relate to the effects of disease only, all injuries having been excluded, as the effects of the explosion of a boiler or of the premature discharge of powder give no information relating to the movement of disease and the sanitary conditions of ships and shore stations.

While the table is a general one and therefore does not supply information for conclusions in detail, it is well worthy of close study. The making of a statistical table is troublesome, but its interpretation is difficult because it involves a consideration of circumstances and influences not all of which may be known or appreciated. For instance, a professional writer who happened to be in San Francisco during the earthquake (1906), in narrating his experiences and in giving his observations in a popular magazine, stated that with the people gathered in the squares there were very many more dogs than cats. He drew the conclusion from that observation that mankind loves dogs more than cats. While that conclusion may be correct, he does not state whether there were as many cats as dogs in the city, and in making his interpretation he does not seem to have considered the very essential facts that the dog is a lover of persons but not of cats, and is a following animal, while the cat is a lover of locality but not of dogs, and in time of fear and departure has to be caught as well as carried. When a ship is abandoned at sea the cat is often necessarily left on board. And yet if the dogs in the squares of San Francisco had outnumbered the cats 50 times it seems that he might have made a ratio—the love of mankind for dogs is to the love of mankind for cats as 50 is to 1.

From the table it might be very natural to draw the conclusion that the health of the navy is deteriorating and that it is becoming less suitable as a dwelling-place for men, the influence of disease becoming stronger on account of some change in naval conditions. But on more close inspection it will be found the results show very clearly that the health of the navy is primarily in the hands of the medical officers at the recruiting stations or with recruiting parties. The enormous increase in discharges for disability which chiefly makes the increase in calculated damage was not due to an increase in the relative number of undesirable terminations of cases originating in the service, but chiefly if not entirely to the very large percentage of discharges for disability from causes existing at the time of enlistment. In that connection it is advisable to consider the large increase in number of discharges shown in the *table* relating to epilepsy. The same was true of myopia, valvular disease, and many other conditions. Some light, though not entirely direct, is thrown upon the relation between recruiting and increased damage due to discharges from disability by Statistical Table 2, on next page

One complication in that table which takes something away from its direct application is that the *number accepted for enlistment* includes reenlistments as well as first enlistments. If it had been practicable by use of the published records to consider only the first enlistments, which were of course always the larger part and owing to expansion increasingly so, and the death and invaliding associated with them, the showing made would be even more conclusive that the death rate tends to follow the enlistment percentage, and the invaliding rate has a very close relation to the actual *number* of first enlistments. No one would claim that epilepsy originates to any extent in the service, yet there was an enormous increase in its invaliding rate. Much of the invaliding from disease of the visual apparatus was due to errors of refraction and even to color-blindness, and it would be impossible to show that the very greatly increased invaliding rate chiefly among working men was due to increasing adverse influences in the service. It is understood that at the Naval Academy there is about 5 per cent. of acquired myopia, but many of the cases are not invalided and at least until the latter part of 1903 the number at that school was each year a decreasing percentage of the naval personnel. It is believed that the same relation to recruiting is partially shown in the invaliding ratios of tuberculosis which but for the influence since 1902 of transfers to special hospital for such cases would have apparently followed the ratios of the visual apparatus.

STATISTICAL TABLE 2.

Year	Average strength	Accepted for enlistment		Ratio per 1000 of strength		Invaliding ratios		
		Number	Percentage of strength	Deaths from disease	Invaliding from disease	Visual apparatus	Tuberculosis	Epilepsy
1895	13191	6246	47	[1]5.31	11.60	.455	1.592	.455
1896	14196	7677	54	4.51	14.72	.916	1.972	.282
1897	15734	7390	46	3.56	17.86	.699	1.906	.826
1899	20819	11175	53	4.56	21.62	.816	2.593	1.297
1900	23756	15456	65	5.01	26.44	.926	2.905	1.052
1901	26873	14574	54	4.28	31.97	1.488	3.336	2.158
1902	31240	16275	52	4.10	30.31	2.497	[2]2.625	1.697
1903	37248	18698	50	4.40	36.09	2.819	2.389	1.879
1904	40555	16139	40	3.21	30.92	2.687	2.589	1.208
1905	41313	17510	42	3.12	26.05	2.904	2.130	1.331
	264925	131140	49	4.04	27.19	1.966	2.449	1.359

[1] The smaller the average strength the greater the change in a ratio by some unusual or adventitious event affecting the numbers upon which the ratio is based. In that year there happened to occur nearly 20 per cent. of all the deaths from valvular disease of the heart returned during the *ten years*. Such deaths are more apt to be from the older men of whom at that time there were quite a relatively large number of the old school whose enlistments were authorized in view of very long service and perhaps at times more or less in spite of physical condition.

[2] On this year a change of policy was made and the invaliding ratio disturbed by transfer to hospital in New Mexico (*See* Table of Tuberculosis.)

During 1905 the average strength of the Navy and Marine Corps was 41,313. The total number discharged from the service for disability, including those transferred as insane, was 1254. Of that number 32.93 per cent. were discharged during the first six months of enlistment, as is shown by the following table:

STATISTICAL TABLE 3.[1]

Medical Surveys Held on Enlisted Persons of the Navy and Marine Corps within Six Months of Enlistment during the Year 1905.

Conditions	Number
Heart Troubles.	
Valvular	70
Functional	5
All	75
Nervous System.	
Insanity	24
Weakmindedness	7
Neurasthenia	4
Hysteria	2
Epilepsy	21
Catalepsy	1
Chorea	1
Partial paralysis	1
Vertigo	1
Defective speech	1
All	63
Deformities.	
Bones, joints, old fractures	32
Flat feet	17
All	49
Visual Apparatus.	
Defective vision	53
Color-blindness	23
Others	6
All	82
Rheumatic affections	11
Poor physique	16
Tuberculosis	16
Auditory troubles	17
Genito-urinary Troubles.	
Retention of urine	1
Undescended testicle	1
Nephritis	7
Syphilis	6
Chronic gonorrhœa	2
Gonorrhœal rheumatism	1
Diabetes	2
Enuresis	11
All	31
Hernia	23
Defective teeth	5
Venous Troubles.	
Varix	6
Varicocele	1
Hæmorrhoids	1
All	8
Additional	
Drug habit	4
Nasal catarrh	1
Deficient vitality	1
Chronic dysentery	1
Prolapsed rectum	1
Chronic pleurisy	1
Aneurysm	1
Asthma	2
Goitre	4
Skin disease	1
All	17
Total	413

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[1] The data were collected from original records by Surgeon F. M. Furlong, U. S. Navy.

Of these surveys 281 were on enlisted men of the Navy and 122 on enlisted men of the Marine Corps. As the number of persons accepted for the Navy during the year seems to have been 13,421 and for the Marine Corps 4,089, it appears that the percentage for the latter was about 3 and for the former about 2. It is considered that the recruiting errors of the two services are at least in that proportion. All of the recruiting errors are not included in the table, as of the 841 additional men discharged during the year some were invalided for causes existing prior to enlistment and of course a number of others not discharged were under treatment for conditions present at time of enlistment.

In recruiting, the responsibility of the examiner may in a given case be confined to the individual, as in a deformity or in a hernia. It may be merely centered there as in a case of tuberculosis or of itch, for such cases when placed in the service act as sources of infection, especially at training station or receiving ship that may be overcrowded in an expanding service or on a cruising ship where there is necessarily a marked concentration of human beings and which receives its men from station or receiving ship. Faulty recruiting therefore has an influence on the health of the service irrespective of any question of discharge from service for disability.

Cases of diseases that come into the service directly with the recruit have no relation whatever to hygienic conditions in the navy. Because, for instance, an increasing number, especially in a growing service, are discharged a few days or a few months after enlistment on account of errors of refraction, valvular disease, or tuberculosis cannot be taken as evidence of increasing adverse conditions in the Navy causing those diseases.

It is equally true that the health of the Navy is very strongly influenced by conditions on shore that are not in any degree under the control of the Navy. *A man in the navy is in much more danger from disease when ashore on liberty than when on his ship.* For instance, typhoid fever—a scourge of many armies in time of war—is little known during war in a modern navy that is able to keep the sea. During the months of hostilities in 1898 only one case of that disease was returned from the entire Asiatic Squadron as the crews were to a very great extent confined to their ships. During the same period only twelve cases were returned from the whole North Atlantic fleet and most of those came from *one* ship. The ship in question was free from the disease until it received from the Army for transportation troops from Camp Alger, Va. The troops remained on board from July 8 to July 25, and a short time after their departure an outbreak of typhoid fever occurred among the crew. A corresponding record of comparative freedom from disease for the same period could be shown in the case of venereal diseases—a class of diseases that certainly has very little direct causative relation to insanitary service conditions.

The experience in relation to typhoid fever goes far to show the general purity of water and food supplies of naval vessels, and when considered in connection with the records of a number of other diseases emphasizes the well-known fact that the health of the navy is greatly affected by conditions on shore not under the control of the service—the health of ports where ships may happen to be.

Considering Statistical Tables 1, 2, and 3 and other tables to follow, the evidence appears to be sufficiently satisfactory to prove that the increased damage shown in Table 1 was more the direct consequence of recruiting than of increasing defects in naval sanitation.

In an expanding navy mistakes in recruiting are not without effect on sick days and, therefore, on the daily average of patients as shown by percentage of sick. If relatively more men with physical disabilities due to causes prior to enlistment were admitted to the service, there was an increase in sick days due to that cause. That would perhaps be especially true of tubercular cases since 1902 and also of cases not discharged from the service but relieved by surgical interference. In considering the percentage of sick, given in Table 1, in relation to additions necessarily resulting from cases not incident to the service there is, to say the least, a strong suggestion that *naval* conditions became during the ten years progressively less conducive to disease.

The recruit himself, irrespective of discoverable defects at time of enlistment, is more inclined to disease than other men, and that fact was strongly emphasized by returns from training stations where with overcrowding, unsatisfactory quarters and facilities, and *greater susceptibility* there was an increasing relative number of cases of disease, but with most of the personnel on cruising ships and with *more advantageous climatic conditions during the winter months since* 1898 there was a marked diminution in diseases with large admission rates, such as bronchial and rheumatic troubles. The effects of malarial disease were also greatly lessened during the period as a result in part of the general crusade against the mosquito on shore. There were increases, dengue, beriberi, and especially venereal diseases, but the prevalence of such diseases depends intimately upon conditions on shore and not upon conditions on the ships. It will be clear, however, that the diminution of disease originating on ships as an incident of service, was more the result of a change in climatic conditions than improvements in the ships themselves.

Preventive medicine has undoubtedly at this time a large and important place in the naval service that can only be filled by close study of conditions and by well directed effort. The many changes in naval construction, many efforts to improve the ships as fighting machines, involve new problems for the medical mind, and such changes are made so rapidly that they demand attention even before old problems have been solved. But a new problem does not become important because it is new, or an old problem less important because it is old.

The fact that tropical cruising very greatly lessened the bronchial and rheumatic troubles originating on the ships during the ten years (see Tables on those diseases), not only on account of the direct effect of climate, but also because the men could wash their clothes and the deck without exposure to cold, only emphasizes the heavy penalty paid for cleanliness in home ports in the winter and, owing to drafts in cold weather, the inability of our ships to adapt themselves to varying climatic conditions. It is something of a calamity for a large crew to be caught in one of our own North Atlantic ports in winter, and that fact shows how much remains to be done to make the modern metal ship a suitable habitation for men in cold climates.

Probably no other habitations than ships designed to house from 200 to 800 persons in the winter and depending upon artificial ventilation, could have been found during the period covered by these statistics without some system of warming air supply. The fact that the naval habitation is built of metal and furnishes a small cubic air space per man only emphasizes the danger of a lack of equability of temperature in all living quarters. It is along such lines that any person familiar with service conditions can utilize statistical figures to construct a picture of such conditions and to show in what respects the picture is lacking.

In Statistical Table 1 the averages are given in the last line. They represent the average year of the period and therefore the year with which comparison with any future year or period should be made. It might be called the expected year based upon the conditions prevailing during that period. Each item—average percentage of sick, average death rate, average invaliding rate, average damage-percentage and average damage-ratio—is the total of the corresponding items of each disease. The importance of a disease is measured by the damage it inflicts and, therefore, for the purpose of ascertaining what diseases caused the greatest damage and what was their relative importance, it has been necessary to expand the items of the average year into their several component items in the form of the following table which gives the individual diseases (and injuries) and the average value of each in computing the total average damage:

STATISTICAL TABLE 4.

Diseases	Percentage of sick	Ratio per 1000		Total damage in percentage of sick	Total damage in ratio per 1000
		Deaths	Discharges for disability		
CLASS I					
Parasites and Parasitic					
Scabies	.047177	. . . . .	.0188732	.0481206	.9624132
Tinea	.004880	. . . . .	.0075494	.0052574	.1051494
Other diseases of this class	.003338	.0037747	.0264226	.0048478	.0969573
All diseases of this class	.055395	.0037747	.0528452	.0582258	1.1645199
CLASS II					
General Infectious (non-venereal)					
Malarial	.118517	.0603944	.1396621	.1285198	2.5703965
Epidemic catarrh	.064307	.0075494	.0264225	.0660056	1.3201119
Cholera	.000357	.0377465	. . . . .	.0022443	.0448865
Cholera morbus	.001573	.0188732	. . . . .	.0025167	.0503332
Dengue	.017450	. . . . .	. . . . .	.0174500	.3490000
Diphtheria	.036778	.0415212	.0075494	.0392315	.7846306
Dysentery	.031637	.0905917	.1321129	.0427722	.8554446
Erysipelas	.004014	.0113241	.0113241	.0051464	.1029282
Typhoid fever	.063083	.5133528	.0452958	.0910154	1.8203086
Cerebrospinal fever	.002016	.1056903	.0452958	.0095653	.1913061
Pneumonia (lobar)	.046573	.4680570	.0679437	.0733730	1.4674607
Measles	.027385	. . . . .	.0150986	.0281399	.5627986
Beriberi	.006918	. . . . .	.0188732	.0078616	.1572332
Mumps	.027502	. . . . .	.0075494	.0278795	.5575894
Rheumatism, art., acute	.074364	.0301972	.4491837	.0983330	1.9666609
Rheumatism, art., chr.	.050416	. . . . .	.6945361	.0851428	1.7028561
Rubella	.005549	. . . . .	. . . . .	.0055490	.1109800
Scarlet fever	.005055	.0301972	.0037747	.0067536	.1350719
Smallpox	.004176	.0641691	. . . . .	.0073845	.1476891
Tuberculosis	.179045	.6228177	2.4497499	.3326734	6.6534676
Vaccina	.014657	. . . . .	. . . . .	.0146570	.2931400
Yellow fever	.000400	.0377465	. . . . .	.0022873	.0457465
Other diseases of this class	.005572	.0717185	.0075493	.0095354	.1907078
All diseases of this class	.787344	2.2119468	4.1219212	1.1040374	22.0807480

STATISTICAL TABLE 4.—Continued.

Diseases	Percentage of sick	Ratio per 1000		Total damage in percentage of sick	Total damage in ratio per 1000
		Deaths	Discharges for disability		
CLASS III Constitutional Disorders of Nutrition					
Anemia	.018662	.0075494	.2076059	.0294198	.5883953
Senile debility.	.004463	. . . . .	.1019156	.0095588	.1911756
Diabetes mellitus	.002942	.0188732	.0830423	.0080378	.1607555
Other diseases of this class .	.005773	.0037747	.1283382	.0123786	.2475729
All diseases of this class . .	.031840	.0301973	.5209020	.0593950	1.1878993
CLASS IV Nervous System					
Apoplexy Hemiplegia Paraplegia	.009780	.2151552	.1396622	.0275209	.5504174
Dementia Mania Melancholia Neurasthenia Neurosis, hysteroid Paranoia . . .	.063053	.0264225	2.7554968[1]	.2021489	4.0429793
Epilepsy	.016550	.0149198	1.3588752	.0852397	1.7047950
Simple continued fever Ephemeral fever . .	.032585	. . . . .	. . . . .	.0325850	.6517000
Thermic fever Heat exhaustion	.005893	.0490704	.0226479	.0094789	.1895783
Seasickness	.002966	. . . . .	.1925073	.0125914	.2518273
Locomotor ataxia Spastic paralysis Progress. mus. atroph. Multiple sclerosis Myelitis .	.004303	.0113239	.1056902	.0101537	.2030741
Other diseases of this class .	.055173	.0792677	.9549872	.1068857	2.1377149
All diseases of this class . .	.190303	.3961595	5.5298668	.4866043	9.7320863
CLASS V Visual Apparatus					
Amaurosis Amblyopia Optic neuritis Retinitis	.013065	. . . . .	.4454090	.0353354	.7067090
Conjunctivitis	.016505	. . . . .	.1170142	.0223557	.4471142

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[1] Includes transfers to hospital for the insane.

STATISTICAL TABLE 4.—Continued.

Diseases	Percentage of sick	Ratio per 1000		Total damage in percentage of sick	Total damage in ratio per 1000
		Deaths	Discharges for disability		
Iritis	.008801	. . . . .	.0754930	.0125756	.2515130
Other diseases of this class	.025723	. . . . .	1.3286780	.0921569	1.8431380
All diseases of this class	.064094	. . . . .	1.9665942	.1624237	3.2484742
CLASS VI Auditory Apparatus					
Otitis media	.025852	.0037747	1.0720015	.0796408	1.5928162
Other diseases of this class	.009810	. . . . .	.4680570	.0332128	.6642570
All diseases of this class	.035662	.0037747	1.5400585	.1128536	2.2570732
CLASS VII Olfactory Apparatus					
Rhinitis	.005268	. . . . .	.1396621	.0122511	.2450221
Other diseases of this class	.000503	. . . . .	.0075494	.0008805	.0176094
All diseases of this class	.005771	. . . . .	.1472115	.0131316	.2626315
CLASS VIII Nutritive Apparatus Subsidiary Class 1, Digestive Apparatus					
Appendicitis	.033999	.0981498	.1132396	.0445685	.8913694
Gastric catarrh Nervous dyspepsia	.025680	.0075494	.2642257	.0392687	.7853751
Intestinal catarrh Simple diarrhœa	.044883	.0415212	.1094649	.0524323	1.0486461
Anal fistula	.012654	. . . . .	.0377465	.0145413	.2908265
Hæmorrhoids	.027396	. . . . .	.2302538	.0389087	.7781738
Hepatitis	.004025	.0905916	.0301972	.0100644	.2012888
Tonsillitis	.082922	. . . . .	.0566198	.0857530	1.7150598
Other diseases of this class	.048979	.1321129	.3774653	.0744579	1.4891582
All diseases of this class	.280538	.3699249	1.2192128	.3599948	7.1998977
Subsidiary Class 2, Circulatory Apparatus					
Aneurysm	.003281	.0868170	.0415212	.0096979	.1939582
Angina pectoris	.002548	.0188732	.0981409	.0083987	.1679741
Dilatation, heart Hypertrophy, heart	.002956	.0528451	.1094649	.0110715	.2214300

STATISTICAL TABLE 4.—Continued.

Diseases	Percentage of sick	Ratio per 1000		Total damage in percentage of sick	Total damage in ratio per 1000
		Deaths	Discharges for disability		
Palpitation, heart	.018062	. . . . .	.8832688	.0622254	1.2445088
Valvular disease, heart	.021739	.2038313	1.5136359	.1076124	2.1522472
Varix	.008870	. . . . .	.1849580	.0181179	.3623580
Lymphadenitis	.028496	. . . . .	.0566198	.0313270	.6265398
Other diseases of this class	.008918	.0868170	.2415778	.0253377	.5067548
All diseases of this class	.094870	.4491836	3.1291873	.2737885	5.4757709
Subsidiary Class 3, Respiratory Apparatus					
Asthma	.007286	.0075494	.2491271	.0201198	.4023965
Bronchopneumonia	.013221	.1132396	.0150986	.0196379	.3927582
Bronchitis Bronchial catarrh	.096335	.0377465	.6605643	.1312505	2.6250108
Laryngitis	.005996	.0037747	.0415212	.0082608	.1652159
Pleurisy	.028781	.0188732	.2302538	.0412373	.8247470
Other diseases of this class	.008106	.0226479	.1056902	.0145229	.2904581
All diseases of this class	.159725	.2038313	1.3022552	.2350293	4.7005865
CLASS IX Motory Apparatus					
Arthritis	.011340	. . . . .	.1736340	.0200217	.4004340
Bursitis	.003933	. . . . .	.0301972	.0054429	.1088572
Myalgia	.040735	. . . . .	.3359441	.0575322	1.1506441
Synovitis	.012994	. . . . .	.1132396	.0186560	.3731196
Other diseases of this class	.022967	.0037747	.4491837	.0456149	.9122984
All diseases of this class	.091969	.0037747	1.1021986	.1472677	2.9453533
CLASS X Cutaneous Apparatus					
Abscess	.074082	.0150986	.0717184	.0784228	1.5684570
Eczema	.020033	. . . . .	.1660847	.0283372	.5667447
Boil	.021003	. . . . .	.0075494	.0213805	.4276094
Ulcer	.032382	. . . . .	.1056902	.0376665	.7533302
Other diseases of this class	.050116	.0037747	.1472115	.0576653	1.1533062
All diseases of this class	.197616	.0188733	.4982542	.2234724	4.4694475
CLASS XI Venereal					
Syphilis	.234037	.0452958	2.5554402	.3640738	7.2814760

STATISTICAL TABLE 4.—Continued.

Diseases	Percentage of sick	Ratio per 1000		Total damage in percentage of sick	Total damage in ratio per 1000
		Deaths	Discharges for disability		
Chancroid, Gonorrhœa and complications	.512228	. . . . .	1.9175238	.6081042	12.1620838
All diseases of this class	.746265	.0452958	4.4729640	.9721780	19.4435598
CLASS XII Genito-Urinary Apparatus (non-venereal)					
Nephritis	.017810	.2378031	.2793243	.0436664	.8733274
Varicocele	.018942	. . . . .	.4152118	.0397026	.7940518
Other diseases of this class	.042735	. . . . .	.7511559	.0802928	1.6058559
All diseases of this class	.079487	.2378031	1.4456920	.1636618	3.2732351
CLASS XIII					
Cysts and new-growths	.012260	.0603944[2]	.1396621	.0222628	.4452565
Undetermined	. . . .	.0037747[3]	. . . . .	.0001887	.0037747
All diseases	2.833139	4.0387088	27.1888256	4.3945157	87.8903144
CLASS XIV Injuries					
Burn and scald	.020911	.0528451	.0188732	.0244969	.4899383
Contusion	.060474	.0113239	.1056902	.0663247	1.3264941
Fracture	.088858	.2189298	.4303104	.1213200	2.4264002
Hernia	.070469	. . . . .	1.6985939	.1553987	3.1079739
Luxation	.011111	.0150986	.1245635	.0180941	.3618821
Sprain	.052337	. . . . .	.1207889	.0583764	1.1675289
Wounds	.107659	.5095781	.3170708	.1489914	2.9798289
Drowning	.000396	.8681702	. . . . .	.0438045	.8760902
Other injuries	.021965	.2000566	1.2494102	.0944383	1.8887668
All injuries	.434180	1.8760023	4.0653011	.7312451	14.6249034
CLASS XV Poisons					
Alcoholism	.011656	.1434368	.1094649	.0243011	.4860217
Others of this class	.014619	.1132396	.2038313	.0304725	.6094509
All of this class	.026275	.2566764	.3132962	.0547736	1.0954726

[2] Principally carcinoma.

[3] A marine found in the woods days after death without mark of violence. No autopsy seems to have been practicable.

STATISTICAL TABLE 4.—Continued.

Diseases	Percentage of sick	Ratio per 1000		Total damage in percentage of sick	Total damage in ratio per 1000
		Deaths	Discharges for disability		
All injuries and poisons	.460455	2.1326787	4.3785973	.7860188	15.7203760
All diseases	2.833139	4.0387088	27.1888256	4.3945157	87.8903144
Unclassified.	. . . .	. . . . .	.7436066[4]	.0371803	.7436066
Grand Total	3.293594	6.1713875	32.3110295	5.2177148	104.3542970

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[4] Relates entirely to retirement of officers for physical disability. The item would be distributed among the other items in accordance with causes, but reports of retiring boards are not records of the Bureau of Medicine and Surgery. The small fragments into which the item would be broken could affect individual items but very little.

As has been stated, the table was prepared for two principal purposes: 1. To make evident the individual diseases from which the service received (and is receiving) most of its damage and to ascertain the relation and total importance of each. 2. To permit comparison to be made of the health of the Navy and Marine Corps during any year of peace, or any series of such years, with that during the average year of the given period of ten years, not only in relation to total damage, but also with reference to the damage received from individual diseases. The former should indicate the direction of effort to diminish damage from disease and the latter should furnish a method of appreciating the results of such efforts and of other influences.

The table shows that the average daily sick list (diseases and injuries) was about 3.3 per cent. of the strength. With a force of 45,000 men the sick list would have averaged 1,485 or sufficient to man two first-class battleships. Of those men about 1,278 (2.83 per cent.) would be incapacitated on account of disease and 207 (0.46 per cent.) on account of injuries—the average daily number on the sick list from disease having been more than 6 times as many as from injury. With reference to the 0.46 per cent. it should, however, be understood that the calculations were made for the purpose of showing the expected year and therefore, with reference to *injuries*, great disasters not belonging to the expected or average year were excluded. During the ten years of peace under consideration there were several such disasters, notably the powder explosion on the Missouri in 1904 which caused 34 deaths and the boiler explosion on the Bennington in 1905 which caused 66 deaths. While from the nature of the service disasters even in time of peace may be expected, such extensive loss of life does not belong to the normal conditions of any one year of peace. Such disasters did not, however, appreciably affect the average sick list from injuries during ten years, but would affect the death rate from injury changing the 2.13 of the table to 2.51 and the total death rate from 6.17 to 6.55, *the items relating to disease being of course unaffected.*

In addition to the sick list of 1485 with an average force of 45,000 men there would be about 278 deaths during the year of which 182 (4.04 per 1,000) would be caused by disease and 96 (2.13 per 1,000) by injury, disease having caused nearly 2/3 of the deaths. With the sick list at 1,485 and the deaths at 278 there would be invalided from the service about 1,454 men during the year, or sufficient to man two additional first-class battleships. Of the men invalided 1,252 (27.19 per 1,000) would be discharged on account of disease and 202 (4.38 per 1,000) on account of injury. The total damage would be equivalent to a daily sick list of 2,348 without death or invaliding, or to 4,696 deaths or discharges during the year and no sick list. Such a sick list would be composed of 1,992 (4.39 per cent.) cases of disease and 356 (0.786 per cent.) of injury, showing a total damage from disease about 5.6 times that from injury. The damage in deaths or discharges would of course be caused by disease and injury in that same proportion, 3984:712.

While the foregoing is an outline of the average year of the period indicated, it cannot be assumed, outside of any consideration of hygiene, that the average year of the next succeeding ten years of peace will be quite the same. There should be improvement as there are a number of influences making for better results. In 1895 the average strength was 13,191, while in 1905 it was 41,313, an increase of more than 213 per cent. Such a percentage increase during the succeeding ten years would make the average strength 129,392 in 1915, but that does not seem probable. With a corresponding increase from year to year the picture unaffected by additional hygienic measures would, however, be much the same, as recruiting seems to have been a dominating factor in damage. The lowest death rate from disease in any one of the years was 3.12 per 1000 in 1905, and from injury (including poison) 0.98 per 1000 in 1896, which suggests a possible total death rate of 4.10. Incidentally it may be mentioned that for 1898 (year of Spanish-American War) the death rate from disease was 4.92 and from injury, including the Maine disaster, 13.13. The invaliding ratio was 30.94 for disease and 6.9 for injury. The percentage of sick seems to have been about 2.44 for disease, and 0.60 for injury, but it is not by any means clear that all the sick days have been accounted for. The total damage expressed in percentage of sick would therefore seem to have been 4.23 for disease and 1.60 for injury (total, 5.83) and the damage-ratio, 84.66 for disease and 32.03 for injury (total, 116.69).

Preliminary to a consideration of the principal diseases of the Navy disclosed by the table, it seems advisable to take up certain statistical material which either does not lend itself to presentation in tabular form or it has not been considered necessary to present in that form. The sick of the service are divided in accordance with location into three main groups—in the sick-bays of ships (cruising and receiving); in the sick quarters of navy yards, marine barracks, and other shore stations; and in the naval hospitals.

During the period under consideration there were on the average about 1.19 per cent. of the strength of the Navy and Marine Corps on the sick list of ships (0.89 from disease and 0.30 from injury), but on the cruising ships the percentage was 1.035 of the total force and about 1.63 per cent. of their own average complements (varying from 1.92 in 1895 to 1.29 in 1905, chiefly with relative number of transfers to hospital). In the sick-quarters of the stations the sick list averaged 0.36 per cent. of the strength of the service (0.30 from disease and 0.06 from injury) and about 1.65 per cent. of their average complements, varying greatly at different stations in accordance with locality and facility for transfer to naval hospital. They transferred about 20 per cent. of their complement to hospital during the year, while the cruising ships averaged about 9.3 per cent. In the hospitals the number of patients averaged 1.69 per cent. of the total force (1.51 from disease and 0.18 from injury). In addition to these percentages officers on sick leave were about 0.05 per cent. of the strength and there was a smaller percentage of the force in other hospitals, making the total sick list about 3.3 per cent. of the total average force (2.83 from disease and 0.46 from injury). Therefore about 36 per cent. of the sick were in the ships (31.4 in the cruising ships), 11 per cent. at the stations, and over 51 per cent. in the hospitals.

If special disasters be considered, more deaths occurred on the ships than in the hospitals. In the absence of such disasters, that is in the normal year, the average number of deaths from all causes in the entire service was 6.17 per 1000 of strength (4.04 from disease and 2.13 from injury). That average appeared, however, to be tending toward a lower figure, as the death rate from disease in 1904 was 3.21 and in 1905, 3.12. Of the average number of deaths in a year of peace without a specially disturbing factor, such as a boiler or turret explosion, about 35 per cent. occurred afloat, and of those about 64 per cent. resulted from injuries, most of the deaths from disease associated with the ships occurring ashore in the hospitals. The great cause of death afloat in the average year is drowning, 28 per cent. of all deaths afloat having been due to that cause and 14 per cent. of all deaths in the service. At the navy yards and other shore stations about 17 per cent. of the deaths occurred. Therefore, about 48 per cent. of all deaths were in the hospitals or elsewhere, but of those over 84 per cent. were from disease.

The average number of sick on a cruising ship is some guide in the determination of the accommodations that should be provided for them, although where a ship is cruising without opportunity to transfer its sick to hospital the average may be greatly exceeded. If a ship has an authorized complement of 800 men, the sick list in accordance with the average would be about 13 if the complement were full. On such a ship there would be four or five members of the hospital corps who have to be quartered somewhere and should have quarters in the sick-bay, as such arrangement greatly tends to efficiency. It appears, therefore, that the number of berths in the sick-bay of such a ship should be at least 17, or 2.125 per cent., of the complement.

The average number of sick will of course be exceeded at times, but on the other hand the complement is rarely complete and there are always some of the sick who are not strictly bed patients and can swing at night in their own billets if necessary. An isolation-room with accomodations for three or four persons is practicable on the larger ships, and in view of its importance should always be provided, but as that space can usually be utilized for general patients it can be regarded as a part of the sick-bay in the calculation of accommodations required.

The question is intimately associated with facilities for transfer to hospital and the question of a hospital ship. The necessity for such a ship is very apparent in time of war. To the medical mind the need is also apparent in time of peace, in all cruising of a fleet away from hospital accommodations, to supplement the facilities of the medical departments of the ships, to secure a better distribution of patients at the naval hospitals, and to keep a personnel trained in the special duties pertaining to such a vessel.

The percentage of the complement of a cruising ship transferred to hospital during a year varies greatly on different vessels and appears to depend upon a number of factors, including the opportunity for such transfers and the standard of the medical officer in deciding what is a hospital case. The percentage of sick, or the average number on the sick list of a ship in relation to its average complement, therefore varies so greatly that it cannot be employed as a standard in comparing the health of vessels. Ordinarily the published health records of different vessels consist of the average complement for the year and the number of admissions, sick days, transfers to hospital, discharges from service for disability, and deaths, and the ratios. Such data are similar to the unlike terms in an algebraic equation and leave one without conclusion in regard to the comparative health of vessels.

It is very common to read in statistical reports of navies and armies and of individual ships or commands that the health has been satisfactory or relatively good, but it never is clear how much better or worse it has been, what standard is assumed and what method is employed in arriving at conclusions. It seems from a naval hygienic point of view that there should be some method of comparing the health of the personnel of different ships—ships of the same class and of different classes, ships doing similar duty and dissimilar duty, and ships having different lengths of commission—with a view to the ultimate determination of a standard of health under varying conditions.

The method of computing the damage-percentage or damage-ratio already described might be utilized for that purpose. To apply that method to a ship it is necessary to have, in addition to the published data indicated, the following information: 1. The average number of days a person remains on the sick list after the transfer to hospital. 2. The percentage of persons transferred to hospital who are invalided from service. 3. The percentage of persons transferred to hospital who die. If those three items are represented respectively by x, y, and z, and p = percentage of sick of the ship, h = number of transfers to hospitals, d = number of deaths on the ship, i = number on ship invalided from service, and f = average complement of the ship for the year, then the damage expressed in percentage of sick during a year of 365 days will be represented by the following:

$$p + \frac{h\,x}{3.65\,f} + \frac{100\ (d+i) + h\ (y+z)}{2\,f}$$

From calculations based on the records of the ten years indicated it appears that the average values of x, y, and z were 49.4, 16.16, and 1.9848, respectively. If those values be substituted in the formula given, the expression for the damage-percentage of a ship during that period becomes for a year of 365 days:

$$p + \frac{22.6\,h + 50\ (d+i)}{f}$$

For a year of 366 days the factor 22.6 becomes 22.54. In using the formula for any particular year the values of x, y, and z should be determined for that year.

The application of the formula may be shown by comparison of two ships having the following records for a year of 365 days:

Name of ship	Average complement	Number of sick days	Ratio per 1000 of force sick daily	Number transferred to hospital	Number invalided from service	Number of deaths
No. 1	631	2658	11.53	34	2	0
No. 2	758	2584	9.32	85	0	0

In the record of No. 1, $p=1.153$, $h=34$, $d=0$, $i=2$ and $f=631$. The damage in terms of percentage of sick is therefore 2.529 and the damage in terms of death rate or invaliding rate, $2.529 \times 20 = 50.58$ per 1000 of average complement. The damage would therefore be equivalent to a daily sick list of 16, or 32 deaths or discharges during the year.

In the record of No. 2, $p=0.932$, $h=85$, $d=0$, $i=0$ and $f=758$. The damage-percentage is therefore 3.466 and the damage-ratio 69.32, a daily sick list of 26, or 52 deaths. Therefore the damage received on No. 1 may be expressed by 50.58 and that on No. 2 by 69.32 and the healths may be considered as having been in that proportion, the smaller number representing the healthier ship.

While the formula necessarily has a mathematical form the results obtained by it are only coarse approximations. Nevertheless it furnishes a method by which not only the health of different ships can be compared, but also the health of the same ship during different periods of the cruise. In the case of the old wooden ship it was considered that the health deteriorated after a commission of three years. It is of interest and value to decide whether in a metal ship length of commission has relation to the health of crews. The formula might also be utilized to arrange for each year a list of ships in the order of relative damage inflicted on each by disease with the view of ultimately fixing some standard or furnishing some reply to the question— What is a healthy ship or when should a ship be regarded as unhealthy? Yet it is of course clear that the indiscriminate use of the formula in comparing the health of different ships would under the present system of making returns lead at times to very erroneous conclusions. If a ship has been engaged at any time during the year in the transportation of the sick of any other ship or ships and such records are included in the computation the comparison will be unfair. It is also true that the first months of a commission are associated with a larger sick list and a greater number of transfers to hospital as a new crew is very apt to contain more physically undesirable men. In the comparison of the health of ships as in the comparison of men or anything else there is room for judgment, and even discretion, whatever the method.

The fact that the daily average number of patients in the hospitals was 1.69 per cent. of the total force during the period of ten years may not be utilized without many allowances in arriving at a conclusion as to what should be the total number of beds available. A very large percentage of the total force of the navy is afloat at all times and therefore the situation is very variable. There is of course a tendency toward the different navy yards and that fact governs the location of a hospital; and the importance of the navy yard and the tendency to use adjacent waters as an anchorage for the fleet should decide the importance or size of the hospital. But a fleet or squadron, perhaps after some months away from hospital accommodations, when arriving in port will have a number of hospital cases, and during the period in port, especially in cold weather, will transfer a number of men for whom accommodations have to be provided. It is this varying demand that must be considered, as any one hospital may be receiving for a time cases from a very large percentage of the entire force afloat.

A hospital ship would do much to remove that difficulty as, without interfering with the movements of a fleet, the sick could be more nearly distributed among the hospitals in accordance with available accommodations at the time. No fighting ship or any other ship used for ordinary naval duties has accommodations suitable for that purpose.

At the beginning of 1907 the number of beds in the naval hospitals was 1405 or 3.4 per cent. of the total force. With the average number of patients at 1.69 per cent. of the total force a percentage of 3.4 should be sufficient to meet all requirements in time of peace *if patients could be distributed in accordance with capacity of building*, but during the year it was very evident that the accommodations were insufficient, one of the larger hospitals having an overflow in tents. With an expanding navy the tendency is toward crowding the hospitals, as usually hospital construction does not keep pace with service expansion, and the tendency to crowd certain hospitals is increased because with a larger force afloat there is a greater concentration possible at particular ports generally used for anchorages.

In Statistical Table 4 is given the diseases which damage the Navy. It is apparent they are the same diseases that damage civil communities. It is not clear that there is any disease peculiar to the sea as even seasickness has its counterpart in car-sickness and swing-sickness. The movement of ships modifies conditions at times, but there has been no accurate determination of the effect of the storm at sea upon serious cases or of the noise on ships incident to the daily routine. There is, however, a mental condition not infrequently observed in recruits which grows out of the situation away from an accustomed environment and which complicates otherwise trivial cases. It is not so much a degree of nostalgia or lypothymia as an aggravation, by perhaps unconscious self-suggestion, of discoverable conditions that should ordinarily go on speedily to recovery. It is a mental attitude, sometimes difficult to separate from malingering which is very much more common than is ever declared by statistics and which is an intentional misrepresentation or aggravation incident as a rule to dissatisfaction, usually confined to the first six months of enlistment and associated with desire for discharge from service or change of duty. Myopia is frequently feigned and the symptoms of varicocele often greatly exaggerated. There is a backache among recruits ascribed by them to sleeping in hammocks and enuresis is common but very often assumed and generally cured by segregation at night and frequent calls.

In the firerooms and coal bunkers there is a common form of heat prostration in which cramps of muscles of extremities, back, and abdomen are the prominent signs, certain muscles even showing recurring lumps or protuberances and always giving pain that may be excruciating and which is disabling. In those cases there is often anuria, but in many there is no loss of consciousness though probably dizziness and headache. Generally the predisposing causes are quiet outside air of rather high temperature and high humidity with diminished general movement of air within. However, it is not clear that standing under ventilators when covered with perspiration and nearly stripped and after drinking ice-water may not have some causative relation at times. That idea receives some support from the fact that the condition is only observed on some ships shortly after assisted or forced draft has been applied.

The diseases of our Navy are the diseases of all other navies, but there seems to be no way of determining with even a reasonable degree of accuracy whether the relative importance of the different diseases is much the same in the different services. There are not only differences in nomenclature but also of methods, which are more disturbing in attempts at comparison. Navies are not much interested in the comparison of their vital statistics with those of armies, but much good could be accomplished by *an international convention for the adoption of a nomenclature of diseases to be used by all naval services, and an international form of returns* that could be utilized for comparison in connection with a detailed statement of methods employed. The statistics of disease depend in some directions upon the liberality of governments. For instance, while in one navy men having tuberculosis are, as a rule, immediately returned to their homes, in another they are kept in the service for long periods and segregated in hospital specially maintained for their treatment. In the latter case there is an amount of damage assumed by the government which would make comparison impracticable, except in regard to prevalence, *provided there was no return to duty in either case.*

From Statistical Table 4 the relative importance of the diseases of our navy can be obtained. If the total damage inflicted by all diseases be expressed by 100 the following table may be considered as a list of the principal diseases arranged in order of importance in accordance with percentage of damage inflicted by each:

STATISTICAL TABLE 5.

Number	Disease	Percentage value	Number	Disease	Percentage value
1	Gonorrhœa[1]	13.84	29	Hæmorrhoids	.88
	Chancroid		30	Ulcer	.86
2	Syphilis	8.24	31	Retinitis	.80
3	Tuberculosis	7.57	32	Simple fevers	.74
4	Mental diseases[2]	4.60	33	Lymphadenitis	
5	Bronchitis	2.98		(simple)	.71
	Bronchial catarrh		34	Anemia	.67
6	Malarial diseases	2.92	35	Eczema	.64
7	Valvular disease		36	Measles	.64
	(heart)	2.45	37	Apoplexy	.63
8	Rheumatic fever	2.24	38	Mumps	.63
9	Typhoid fever	2.07	39	Conjunctivitis	.51
10	Tonsillitis	1.95	40	Boil	.49
11	Rheumatism,art.chr.	1.94	41	Asthma	.45
12	Epilepsy	1.94	42	Broncho-pneumonia	.45
13	Otitis media	1.81	43	Varix	.41
14	Abscess	1.78	44	Dengue	.40
15	Pneumonia	1.66	*	Iritis	.29
16	Epidemic catarrh	1.50	*	Cerebrospinal fever	.22
17	Palpitation (heart)	1.41	*	Thermic fever	.22
18	Myalgia	1.31	*	Heat exhaustion	
19	Diarrhœa	1.19	*	Beriberi	.18
20	Scabies	1.09	*	Smallpox	.17
21	Appendicitis	1.01	*	Scarlet fever	.15
22	Nephritis	.99	*	Rubella	.13
23	Dysentery	.97	*	Cholera	.05
24	Pleurisy	.94	*	Yellow fever	.05
25	Varicocele	.90	*		
26	Diphtheria	.89		Total	83.33
27	Gastritis	.89		Other diseases	16.67
28	Arthritis	.88			
	Synovitis			All diseases	100.00

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[1] Represents the two diseases and their complications, but owing to form of published returns it has not been practicable to separate the damage.

[2] See Statistical Table 19.

* Included on account of general interest. See Statistical Table 4 for diseases causing greater damage.

Groups of these diseases may be formed and their relation to other groups or to individual diseases observed with profit. For instance, the damage received from four simple diseases of the cutaneous apparatus (abscess, ulcer, eczema, and furuncle) was equal to 3.77 per cent. of the total damage and was greater than that received from measles, mumps, smallpox, scarlet fever, diphtheria, cerebrospinal fever, rubella, cholera, and yellow fever together which was only 2.93 per cent., and from typhoid fever and pneumonia together which was 3.73 per cent. If syphilis and scabies be grouped with the four skin diseases indicated it will be seen that the combined damage, 13.10 per cent. of the total damage from disease, was greater than that received from tuberculosis, typhoid fever, and the malarial diseases. Scabies damaged the service more than dysentery or diphtheria or nephritis; rheumatic fever more than diarrhœa and dysentery; and chronic rheumatism and myalgia more than the malarial diseases. Tonsillitis damaged the service more than pneumonia and nearly as much as typhoid fever.

The venereal diseases caused 22.08 per cent. of the total damage from disease. While that fact is most striking it is not singular. There are no reliable means of making comparison with any corresponding class in a civil community, but it is evident civil communities, especially perhaps certain classes of such communities, suffer much greater damage from those diseases than is generally recognized and that the disease resulting from prostitution takes more of the strength of nations than all wars and accidents. Taking at random the statistical reports of the navy of Great Britain, it appears that the average annual total damage received from disease during the three years, 1897–1899, can be expressed by a damage-ratio of 95.44 and of that total damage 24.26 per cent. was caused by the venereal diseases. In that service the damage-ratio of all disease in the year 1900 was 100.55 and of venereal disease 19.63—a percentage of 19.52. In our service for the same year the damage-ratio of disease was 89.92 (*see* Stastical Table 1) and of venereal diseases 21.49, the greatest received during the ten years (*see* Statistical Table 6)—a percentage of 23.89.

From an examination of Statistical Table 4, it appears that the damage (22.08 per cent.) caused by the venereal diseases as a class was only exceeded by that received from all the non-venereal general infectious diseases (25.12 per cent.). However, if all the effects of the venereal diseases were traced, for instance into a number of cases of chronic rheumatism, iritis, chronic rhinitis, etc., they could readily be held accountable for more than 25 per cent. of all the damage from disease. In this connection it may be of interest to note the small amount of damage caused by spinal sclerosis. When dependent upon syphilis it is a late manifestation and, in view of the relatively small percentage of re-enlistments during the ten years, the expression of venereal disease in that form was necessarily very limited.

Considering the venereal diseases as responsible for at least 25 per cent. of all the damage received from disease, it is evident that insanitary service conditions have very little direct causative relation to at least that percentage. Cases of venereal disease in the service not contracted in the usual way are not unknown but rare, and recruiting errors have little relation to the prevalence of such diseases. Although prophylactic service measures in relation to those diseases have been limited, the large amount of damage received should not be passed over without serious consideration.

The following table shows the damage from venereal diseases and their returned relative prevalence during each of the ten years:

STATISTICAL TABLE 6.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Total damage in percentage of sick	Total damage in ratio per 1000
			Deaths	Discharges for disability		
1895	86.195	.7613	. . .	1.364	.8295	16.590
1896	81.501	.6792	.0704	2.113	.7884	15.767
1897	80.907	.6769	.0635	3.241	.8421	16.842
1899	96.786	.8056	.0960	3.987	1.0097	20.195
1900	95.134	.8053	.0421	5.346	1.0747	21.494
1901	94.061	.7384	.0744	4.800	.9821	19.642
1902	92.317	.7090	. . .	3.393	.8786	17.573
1903	107.549	.7624	. . .	6.040	1.0644	21.288
1904	120.503	.7539	. . .	5.992	1.0535	21.070
1905	129.402	.7305	.1210	4.163	.9447	18.894
Average	103.776	.7462	.0453	4.472	.9721	19.442

As a subject of very great importance any practical conclusion that can be reasonably deduced from the table should be of value. It does not appear that any such conclusion can be derived from the point of view of the moralist, although it is believed that the moral well-being of any people or any class of people is very closely related to its physical well-being. While venereal disease is permitted to be a part of the wages of immorality, it is a very variable part and therefore cannot be used as a measure in contrasting different communities—especially communities differing in floating population or differing in management in relation to prostitution, particularly in its bearing upon secret prostitution. In any particular class of men who expose themselves the prevalence and intensity of the disease among them will depend upon the prevalence and intensity of the disease among the class from which it is derived. If the men are non-residents and were free from the disease, they may suffer great damage without having contributed in any degree to the prevalence of the disease among their temporary associates.

The experience of different ships shows conclusively that the prevalence and intensity of venereal diseases differ greatly in different localities, in different ports, and on different stations. Therefore, if for any reason the ships or forces on shore are moved from localities of less prevalence and intensity and concentrated in areas where there is much greater prevalence and intensity, there will be a larger increase in the number of cases and of complications and in damage without any change whatever in the degree of morality. That is what happened after the Spanish-American War as is shown in the table given above.

The admission-ratios do not show actual prevalence. They may furnish a basis for the comparison of the prevalence of one year with that of another, but not in our navy with any other service, for such comparisons of prevalence can only be made when the methods are alike. For instance, if all admissions were represented in terms of the three venereal diseases the admission-ratio would be very much less. A patient admitted with gonorrhœa and after some days discharged to duty may later be admitted with orchitis and after some days discharged to duty, and then eventually he may be admitted with prostatitis or stricture or gonorrhœal rheumatism. If those admissions were expressed in terms of gonorrhœa it would be one case. In the table each admission goes to form the ratio. Any service can compile its statistics so as to make the admission rate of venereal disease large or small. If might, indeed, have been made much larger in our service if all the medical officers had admitted every case of venereal disease during the period without regard to the necessity for excuse from duty or to claim for pension. It is evident that in calculating damage the admission ratio can have no place.

The percentage of sick was influenced by the amount of invaliding and by the liberality, based to a certain extent on hygienic considerations, shown in the length of time excused from duty, especially in syphilitic cases. It seems to be true in the navy that syphilitics are kept in hospital after they would be at work in civil life, but the time does not appear to have varied much from year to year and seems to have averaged about 11 or 12 weeks for men returned to duty.

Cases not returned to duty but invalided were not necessarily more severe or less curable. Mess attendants, cooks, and members of the Hospital Corps were invalided for syphilis as a rule without regard to severity of case. In a rapidly expanding service with increasing number of patients there may be an increased tendency to discharge for disability not originating in the line of duty, particularly in otherwise undesirable men and especially at hospitals near the larger navy yards.

However, the table considered from any point of view shows a rapid increase of venereal disease after the Spanish-American War. The increase occurred in the force afloat and in that on shore and seems to have been due chiefly to the liberty given in the tropics, in Asiatic, and in other than home ports, where, however, the disease is well known to be much too common. For instance, in the Atlantic fleet the liberties commonly given in a few ports of the West Indies seem to have been especially disastrous and the service evidently received much additional damage from the routine in that respect not uncommon in the winter months.

The diseases contracted at such places not infrequently appeared together in the same person and seem to have had unusual virulence which was displayed in the number of complications, especially adenitis. It was not uncommon for a medical officer to report that 50 per cent. of all cases of venereal adenitis occurring during an *entire year* were directly traceable to liberties given during *three or four days* only at such a port. Such a report may be coupled with the recommendation that the place be not again visited until there is some assurance of diminished danger of infection. It appears that in 1905 the city authorities of San Juan "by the establishment of special hospitals for the treatment of venereal diseases, and in other ways, began to make serious efforts to diminish the prevalence of venereal diseases." The same measures may have extended to Ponce and should be inaugurated in certain other ports in the West Indies in as great need and where a single liberty had a decided crippling effect.

The question to a very great extent relates to solicitation often in localities in the West Indies where there are few general amusements, where at times even suitable sleeping-quarters and desired food can be obtained by the men with difficulty, if at all, and where alcoholic drinks are everywhere in evidence, often served in the East by prostitutes themselves in drinking-shops and dance-houses. But those attendants do not appear to have had the disease to the extent found among the lowest classes in some of the West Indian ports who seem to have been capable of infecting in a day or two more than ten per cent. of a crew. Such places should not be selected for liberty, not for the purpose of escaping disease, but with a view to its limitation. Definite information could be gathered and might form a part of confidental information utilized in other directions. It would then be free from the element of encouragement and simply be an unrecognized measure of protection.

The frailties of mankind always make an ugly picture which for that reason, if for no other, is often avoided or covered. "He conquers who conquers himself" has an additional and very pertinent meaning in connection with naval or any military life, and work along that line can and should be aided by instruction. But knowledge is not character and in general the civilized world accomplishes much and is busily engaged in limiting the cause of disease, even in directions in which the damage directly follows habits that are beyond municipal or governmental control. If alcoholic drinks are allowed to be sold they must now conform in quality to law, and if a community must allow prostitution, and it does allow it, the prostitute should not be permitted to cause disease. Entire countries seem to cling to the belief that the venereal diseases represent a necessary punishment or result following the breaking of law. It does not appear that any naval service can accept the dogma or that the medical mind can accede to it, as very many diseases are known to result from the breaking of law which are nevertheless not accepted as necessary and some of which are being abolished or greatly limited.

Besides, the great object of punishment is to deter, but if the naval records, especially the results shown in the next table, are any indications of the tendency of man, it is clear that the danger of infection, the knowledge of which is common, does not deter and that a large proportion of unattached men do not endeavor to repress their sexual cravings. They can be taught the truth that the health of man does not suffer by such repression, but such negation can have little force in the face of the knowledge derived from almost daily observation, and which does not deter, that health suffers severely under present conditions and practices.

But naval authority must, as a rule, confine its efforts for the betterment of health to its own sphere. It properly has no function ordinarily which relates to the regulation of the health of civil communities, however great the damage it receives from them. It can only do everything in its power to protect itself from all unnecessary damage with a view to the conservation of efficiency. A ship avoids a port where yellow fever prevails when there is no absolute necessity for being there. In view of the wide prevalence of the venereal diseases a crew does not escape contact with them, but the contact can be limited by selecting ports where the diseases are less prevalent and the results of contact may be limited by personal prophylaxis.

Men must be allowed to go on liberty. A certain percentage do elect to go into danger that very many civil communities know is in their midst but from which they do not try to protect. Where a man goes into danger it is not peculiar for him to take precautions unless he blunders into the danger under the influence of alcohol which is not only a sexual stimulant, but also a paralyzer of the inhibitory control exercised by the will, and therefore all efforts that actually diminish the amount of alcohol consumed on liberty tend to diminish the number of cases of venereal disease, other conditions remaining the same. But in the navy other conditions did not remain the same and therefore (see Table on Alcoholism) there resulted the unusual record of an increase of venereal diseases associated with a decrease in drunkenness.

The necessity for personal prophylaxis may be deduced from Table 7 on the next page which relates to syphilis and gonorrheal rheumatism (taken out of the combination in which they appear in the previous table) and includes an estimation of the actual prevalence of gonorrhoea.

The actual prevalence of syphilis may be considered as shown by its admission-ratio, but that is not true of gonorrhœa or chancroid, as many cases of each in the naval service, as in other services, when uncomplicated and not causing much disturbance did not cause admission to the sick list. In the last column of the table is given the estimated number of cases of gonorrhœa per 1000 of strength. While the result is a coarse approximation, being based upon the actual number of cases of gonorrhœal rheumatism, it seems to accord fairly well with experience. There appears to be no possible way of making a calculation of the actual prevalence of chancroid during the ten years, but if it be considered as having had one-third the prevalence of gonorrhœa, the actual prevalence of the venereal diseases in the service during the period would be expressed by an average ratio of 237.5 per 1,000 of strength, or more than twice the prevalence indicated by the admission ratio of Table 6. Of course such a ratio does not declare number of individuals, but only actual number of cases of three diseases, as an individual may have gonorrhœa or chancroid several times in a year. Nevertheless, if the cases are represented by even 20 per cent. of the force there is apparent a very important personal question of a personal damage not expressed in sick days and invaliding.

The inquiry, therefore, is very pertinent whether the service is not justified in employing every reasonable measure in its power to lessen the frequency of these affections and whether the personal interest of the men is not sufficiently mingled with official interest for the service to afford them opportunity to protect themselves. To teach a man that he may lessen his danger by micturition and by securing cleanliness immediately after intercourse might not excite much opposition, but such teaching only differs in degree from advice based upon the precaution advised by Dr. Conton or relating to additional local treatment after, or preventive measures prior to intercourse. The argument against such instruction

STATISTICAL TABLE 7.

Year	Syphilis					Gonorrhœal Rheumatism					Gonorrhœa
	Admission ratio	Percentage of sick	Ratio per 1000			Admission-ratio	Percentage of sick	Ratio per 1000			Cases per 1000 of strength, estimated[1]
			Deaths	Discharges	Damage			Deaths	Discharges	Damage	
1895	14.8	.248	. . . .	.98	5.94	2.0	.030	. . . .	.075	.675	100
1896	14.0	.197	.07	1.48	5.49	1.9	.029.	. . . .	.070	.650	95
1897	12.4	.196	.06	1.84	5.82	2.7	.035	. . . .	.635	1.335	135
1899	15.5	.203	.09	2.16	6.31	2.3	.031	. . . .	.432	1.052	115
1900	16.2	.242	.04	3.28	8.16	2.5	.041	. . . .	.799	1.619	125
1901	17.4	.221	.07	2.71	7.20	2.9	.046	. . . .	.818	1.738	145
1902	16.7	.245	. . . .	2.21	7.11	3.4	.059	. . . .	.576	1.756	170
1903	19.6	.251	. . . .	3.54	8.56	4.1	.050	. . . .	1.449	2.449	205
1904	18.8	.218	. . . .	3.08	7.44	4.6	.062	. . . .	1.800	3.040	230
1905	20.3	.257	.12	2.23	7.49	3.6	.050	. . . .	.968	1.968	180
Ten yrs.	17.5	.234	.04	2.56	7.28	3.3	.047	. . . .	.932	1.870	165

[1] Cases of gonorrhœa estimated from cases of gonorrhœal rheumatism on the assumption that for each 100 cases of gonorrhœa there are about 2 cases of gonorrhœal rheumatism. The result is a coarse approximation but tends to show that many cases of gonorrhœa do not appear in admission-ratio, and to declare the fallacy of depending upon admission-ratio of that disease to declare actual prevalence.

and the furnishing of such means *on application* is that they appear to favor immorality. The statistics do not tend to give force to the argument, but they do give force to the contention that "the practical problem is the prevention of disease and not the enforcement of moral precept."

The great influences against personal measures are alcohol and public sentiment. The influence of the former may be limited by providing clubs for the men in each city where there is a navy yard, by encouraging sports and other general amusements, and *by systematically rewarding only the sober and efficient*. The latter may be changed by giving marked publicity to the enormous damage caused in all communities by the venereal diseases and by provoking discussion, but in that work a naval service may have little part. There are societies for the prevention of tuberculosis, but the interference with nutrition by syphilis occupies a larger place among the predisposing causes of that disease than may be commonly supposed.

In Statistical Table 7 are declared the prevalence and damage of syphilis and of gonorrhœal rheumatism. Vital statistics appeal not only from the side of preventive medicine, but also from that of the practice of medicine. It does not do for a medical officer to be so impressed with the idea of preventing disease that he minimizes his relation to the treatment of it. Prevention is the higher function, but the presence of disease is an urgent fact.

The amount of damage received from gonorrhœal rheumatism may be somewhat surprising as it was more than 25 per cent. of the total damage received from syphilis and very greatly increased during the ten years. For about every five persons on the sick list daily with syphilis there was one with gonorrhœal rheumatism, and for every eight persons discharged from the service on account of syphilis there were about three discharged on account of the effects of gonorrhœal rheumatism. Of the cases of gonorrhœal rheumatism more than 28 per cent. were discharged from the service, while of the cases of syphilis 14.63 per cent. were invalided. In the case of the former the discharges represent undesirable terminations, as a rule, and show very clearly the necessity for improved methods of treatment.

In a force of 45,000 men there would be 148 cases of gonorrhœal rheumatism during the year and 42 of them would be discharged from the service, many as cripples. In that one complication of gonorrhœa is found a most interesting and a very important field for investigation from a naval point of view. The hope of relief and of diminution of damage from the point of view of the practice of medicine seems to be in the work of the bacteriologist who appears to have already secured brilliant results in some cases by the use of a vaccine controlled by the state of the patient or by the opsonic index. All improvement in treatment tends to lessen damage, and it may be that a general hypodermatic treatment of syphilis will show its effect in the vital statistics of future years.

While in civil life extragenital infection is common, it is according to the records much more rare on the ships themselves than one would imagine from the condition of naval life. *Syphilis insontium* is, however, not unknown, and gonorrhœal ophthalmia, while very much less common than would be expected from the large number of cases of gonorrhœa and the chance of infection incident to the great concentration of human beings as one family on a vessel, does some damage.

The best general safeguard against extragenital infection by syphilis is energetic and long-continued treatment including the giving of careful attention to mucous patches. But the treatment in no case of syphilis or gonorrhœa should be commenced without a strong attempt to impress the patient with the fact that he is a distinct source of danger to his fellows and that of course he does not want to be responsible for extending his trouble to anyone else. Most men are very readily impressed by such verbal advice and will carefully refrain from *tattooing* others or from allowing their pipes, partly used cigars, cigarettes, or chewing tobacco to be used by another or from using those of others when they have been specifically advised in that respect.

A man with gonorrhœa can be very much impressed with the danger of infecting his own eyes and therefore with the necessity fo an immediate careful washing of hands after touching the genitals. He can also be made well aware of the danger of allowing his towel to be used by another and of the advisability of protecting his clothing by cotton as a plug or in a bag and of securing cleanliness of the genital region. It is best for all syphilitics to mess together and to have their mess gear in boiling water after each meal, and no person with venereal disease should act as cook or mess attendant for other messes.

The prophylaxis of one infectious disease has much in common with that of another. For instance, many of the measures on a ship to avoid the extension of venereal disease apply to tuberculosis, tonsillitis, diphtheria, and other diseases. A source of danger is use in common of the drinking cups at the scuttle butt. That method should give way to the device by which water can be obtained directly from the flow with waste going into feed-tanks. But when drinking cups are used they should be maintained free from nicks, imperfect edges and roughness of surface and immediately after use immersed in a weak formaldehyde solution. On most ships the instruments of the band are government property. A bandsman with syphilis should receive special caution, and when transferred from the ship with that disease, or on account of tuberculosis or other communicable disease, the instrument blown by him should be disinfected. In the practice of vaccination which is so general in the service the greatest care should be taken to secure cleanliness and to avoid danger of transmission of disease from one person to another. Moreover, every person in the Navy and Marine Corps should be taught the nature and prophylaxis of venereal disease and printed slips should be prepared giving a very short summary of such teaching emphasizing the danger of infection, means of minimizing that danger if one is exposed, and the necessity for immediate treatment on discovery of the slightest thing wrong.

But as a practical question, experience has clearly demonstrated the inadequacy of purely educational methods. There are medical officers who have assiduously instructed the men in the prevention of venereal diseases, and after many years have become discouraged in view of the large and undiminished number of sick days returned from their ships as due to such infections. On the other hand, experience has shown that such work acquires special value when associated with a degree of compulsory prophylaxis as leading men to appreciate measures undertaken for their protection, an appreciation greatly accentuated by results.

Assistant Surgeon G. L. Wickes, U. S. Navy, reported in 1907 a system used on the U. S. S. Wilmington from which excellent results were obtained. A copy of the liberty list was furnished the sick bay and all men returning from liberty were sent there, either to receive treatment or to be immediately dismissed according to their statements. Men who admitted having exposed themselves to the danger of venereal infection received the following routine treatment: 1. The penis thoroughly washed with green soap and water. 2. The penis then washed with a solution of bichloride of mercury (1 to 2000). 3. An anterior urethral injection of 2 per cent. solution protargol. 4. The penis then rubbed with a mixture of calomel and lanolin, equal parts, particular attention being paid to the region of the frænum. The mixture allowed to remain all day, the clothing being protected by a suitable dressing.

In this routine an essential element was that the men did not come before the medical officer, but the treatment was administered under the direction of a member of the hospital corps, the object being to have the men unembarrassed and without tendency to make misleading statements when questioned in regard to exposure. A record was, however, made on the liberty list of all such denials.

The results reported for five months, that being the period from the inauguration of the system to the time of report, were as follows: 1. No cases of syphilis, although most of the time was spent in Chinese ports where the disease was common. 2. Fourteen cases of gonorrhœa—8 contracted in the Philippines where prophylactic measures were not enforced and 6 of Chinese origin, the majority of which developing before men returned to their ship or among men breaking liberty. 3. No case of chancroid. At Canton, China, during a similar period of five months, 25 complete excisions of inguinal glands had been necessary.

The report concludes with the statement that such prophylaxis should be made routine on every naval vessel in the interest of service welfare and efficiency, if not for humanitarian reasons. Subsequent experience has clearly demonstrated the great value of similar measures and if they became routine the venereal diseases would not only cease to be prominent in the service, but would occupy a trivial place.

Tuberculosis was, considering the ten years, next in importance below syphilis, as will be seen by reference to Statistical Table 5. However, the lines of damage of the two diseases crossed in 1904, as is shown in Statistical Tables 7 and 8, and during that and the subsequent year the damage from tuberculosis exceeded the damage from syphilis. In the time of scurvy, that disease, typhus fever, and dysentery were the death dealers on ships; to-day scurvy and typhus fever have no place and dysentery excites relatively little attention, but tuberculosis, typhoid fever, and lobar pneumonia cause very nearly 40 per cent. of all deaths in the navy from disease and with bronchopneumonia more than 42 per cent. (tuberculosis 15.42, typhoid fever 12.71, lobar pneumonia 11.59, and bronchopneumonia 2.80). Yet those diseases in their total damage (11.75 per cent. of all damage from disease) were greatly exceeded by venereal diseases (22.08 per cent.) which caused only 1.12 per cent. of the deaths from disease. But in the scale of naval diseases tuberculosis ranks very high and, in view of its infectious nature, the long period of suffering and its great death-dealing power demands attention. Yet, as a naval problem it presents some features that prevent complete solution. That problem is presented in part in Table 8 on the next page.

The table shows that after the Spanish-American War there was a large increase in the relative number of *known* cases of tuberculosis. The disease has therefore assumed much greater importance from a hygienic point of view, but the very fact that the increase was so closely associated with service expansion more than suggests that it was due in no small degree to that cause. The fact that in 1905 there were 4.6 cases of tuberculosis admitted from each 1,000 men in the service and in 1895 only 2.6 would lose much of its emphasis if it could be shown that in 1905 40 per cent. of the cases were due to recruiting, and in 1895 only 17.8 per cent. That 40 per cent. of the cases in 1905 were incident to recruiting seems to be a matter of record, and if reference be made to Statistical Table 2 it will be seen how the invaliding ratios of tuberculosis and epilepsy have tended to follow the increase in the general invaliding ratio from disease incident to service expansion. No one would claim that the marked increase in epilepsy and in errors of refraction since the Spanish-American War was due to conditions within the service. It would be as illogical to make such a claim in the case of tuberculosis.

STATISTICAL TABLE 8.

TUBERCULOSIS

Year	[1]Admission ratio per 1000 of strength	[2]Admission ratio per 1000 of strength incident to service	Percentage of sick	Ratio per 1000 of strength			Damage in ratio per 1000
				Deaths	Discharges for disability [3]	Total deaths and discharges	
1895	2.653	2.181	.115	.531	1.592	2.123	4.423
1896	2.959	2.177	.097	.423	1.972	2.395	4.335
1897	2.987	2.168	.104	.889	1.906	2.795	4.875
1899	3.362	2.246	.074	.528	2.593	3.121	4.601
1900	3.914	2.325	.103	.589	2.905	3.494	5.554
1901	4.093	2.087	.123	.446	3.336	3.782	6.242
1902	3.361	1.798	.114	.512	2.625[4]	3.137	5.417
1903	4.886	2.179	.206	.778	2.389	3.167	7.287
1904	5.079	2.668	.267	.814	2.589	3.403	8.743
1905	4.623	2.774	.327	.557	2.130	2.687	9.227
	4.080	2.377	.179	.623	2.449	3.072	6.653

[1] After eliminating errors of diagnosis whenever practicable.

[2] Estimated from change in general invaliding ratios from disease incident to recruiting, the records showing that about 40 per cent. of cases of tuberculosis in 1905 were incident to recruiting.

[3] Does not include retirements of officers.

[4] After that year patients were kept much longer in the service, many having been transferred to hospital in New Mexico and treated in camps at Mare Island, Pensacola, and San Juan. This diminished invaliding ratio and increased deaths in the service, percentage of sick, and damage.

Taking the ascertained fact that 40 per cent. of the cases in 1905 were incident to recruiting, leaving 60 per cent. as incident to service, and calculating for each year the percentage of cases incident to recruiting and service in accordance with variations in the general invaliding ratio from disease, it appears as shown in the table that there was not much variation in the relative number of cases attributable to service conditions and that such small increase as did occur was subsequent to the adoption of the policy of retention in service with treatment in special hospital and in camps, from which latter there were not a few cases returned to duty as cured, some of which were subsequently admitted as new cases during another enlistment. Besides, if a relatively larger number of cases of a communicable disease is brought into the service there may be an expected increase in the number of cases incident to service.

There is, however, another phase of the question which practically declares the problem of prevalence to be an indeterminate one, but which nevertheless suggests the probability that there has been a decrease in tuberculosis incident to service and possibly a decrease in the service as a whole. The increase in the admission ratio can only be taken as conclusive proof of an increase in the relative number of *known* cases. Knowledge of a fact is something very different from the fact itself. The American continent had its present position before the days of Columbus and the tubercle bacillus existed centuries before its discovery by Koch. The researches of Richard Bright, published in 1827, were followed by an enormous apparent increase in diseases of the kidney characterized by albuminuria and dropsy and the same thing has occurred in the case of appendicitis since the days of James Jackson.

Phthisis is a very old disease, but the compound microscope did not become a useful instrument until 1835 and the vital cause of the disease was not known until 1882. It was five or six years after that before bacteriology had a recognized place in the schools and some time later before the hunt for tuberculosis became well established. In 1895 there were at work only three immersion lenses in the naval service that belonged to the Government, while in 1905 there were 89 in use and, as the Naval Medical School had been revived in 1902, there was from that time much greater enthusiasm and more practical knowledge about all things bacteriological. It appears, therefore, that from 1895 to 1905 there was an increasing opportunity to make early, definite and even more frequent diagnoses of tuberculosis. Some cases formerly regarded as bronchitis and invalided as such were now found to be tubercular, and it seems probable that some increased tendency to make the diagnosis of tuberculosis was developed without regard to bacteriological work. In fact, as shown by tuberculin test, there are many cases of tuberculosis in which bacteriological examinations give negative results. Tuberculosis has always been more extensive than was supposed, cases similar to some now reported as recoveries recovering without a true, or perhaps any diagnosis having been made. Certainly, the discovery of relatively more cases under present conditions does not necessarily, or perhaps even probably, mean an actual increase in the relative number of cases.

Definite comparisons with other naval services probably cannot be made, but taking the total of the admission ratios of the five last years and striking an average by dividing by five it appears that the ratio of the German navy was about 2.4, of the British 3.2, and of the United States 4.4. In other words, from a force of 45,000 men the admissions for tuberculosis in those navies during a year would be about 108,144 and 198, respectively. As the prevalence of tuberculosis in the United States navy has a close relationship to recruiting, comparison with the German navy may not be feasible. In one navy a recruit presented himself because he was anxious to enlist and in the other compulsory service may tend to the declaration of any known weakness and may very well cause higher physical standards on enlistment. In the German navy the admission rate is about the same as that calculated for our navy as incident to service. For definite comparison with the British service it would be necessary to know the relative recruiting rates. In the Japanese navy the average admission ratio during the seven years, 1895–1901, seems to have been about 7.724, being as high as 10.76 in 1897 and as low as 5.46 in 1895. In 1901 that service had an admission ratio of 7.48 and the disease was considered to be increasing.

The admission-ratios of tuberculosis, while they are large for that disease, are small when compared with those of such a disease as *bronchitis*. The increase in cases of the former disease might, for instance, be obtained entirely from the latter or in part from some other diseases as the result of more definite diagnosis without much change in their apparent prevalence or *indeed any change*, as it is not uncommon for a diagnosis of chronic bronchitis, pleurisy, or other disease to precede the diagnosis of tuberculosis. The following table in which *bronchopneumonia*, *bronchitis*, and *bronchial catarrh* have been combined may possibly have some relation to that phase of the question:

STATISTICAL TABLE 9.

BRONCHOPNEUMONIA, BRONCHITIS, AND BRONCHIAL CATARRH.

Year	[1]Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	58.14	.132	.152	.227	3.019
1896	54.45	.117	.141	.211	2.692
1897	47.79	.115	.063	.445	2.808
1899	33.43	.102	.144	.528	2.712
1900	43.19	.100	.210	.252	2.462
1901	40.75	.118	.112	.930	3.402
1902	39.98	.153	.352	.960	4.372
1903	41.99	.149	.134	1.342	4.456
1904	27.86	.080	.099	.838	2.537
1905	25.68	.062	.097	.218	1.555
	38.17	.1096	.151	.675	3.018

[1] All admission ratios are too high as they include errors of diagnosis.

The average damage from those affections was 3.45 per cent. of the total damage from disease as will be seen by reference to Statistical Tables 4 and 5, but as is shown in the above table it was a diminishing damage with a greatly diminishing admission rate, much greater than could possibly be accounted for by any assumption of relation to the increase in the tuberculosis rate. Therefore, whatever borrowing there may have been on the part of tuberculosis, a marked diminution remains to be accounted for by other influences. But probably of the affections included in the table, tuberculosis would be most apt to draw from *chronic bronchitis*, the statistics of which are given in the following table:

STATISTICAL TABLE 10.

CHRONIC BRONCHITIS.

Year	[1]Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	3.19	.031	.076	.152	.848
1896	3.31	.027	. .	.211	.751
1897	3.43	.026	. .	.190	.710
1899	2.06	.028	. .	.336	.896
1900	1.86	.017	. .	.168	.508
1901	4.17	.033	. .	.744	1.404
1902	3.29	.049	.303	.800	2.083
1903	3.70	.034	.152	1.154	1.986
1904	2.12	.021	. .	.641	1.061
1905	1.55	.012	.152	.218	.610
	2.767	.027	.034	.536	1.110

[1] All admission ratios are too high as they include errors of diagnosis, some of the cases having been ultimately returned as tuberculosis.

It therefore appears that while in general the admission ratios of tuberculosis were increasing, those of chronic bronchitis were decreasing. It may be noted that the prominent years of exception, 1901 and 1903, were also years when the general invaliding rates were highest, as is shown in Statistical Table 2, but it seems that the general tendency exhibited in the table is alone worthy of consideration, as the diagnosis of bronchitis tends to precede that of tuberculosis, and in view of the diminution of bronchial affections shown in Table 9, there may very well have been other causes for the decrease in chronic bronchitis.

In continuation of the inquiry from the same point of view and also to facilitate such separate consideration as those interested may consider desirable, the following tables are given:

STATISTICAL TABLE 11.

BRONCHOPNEUMONIA.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.455	.002	. .	. .	.045
1896	.775	.005	.141	. .	.237
1897	.763	.004	.063	. .	.141
1899	.528	.009	.144	.096	.422
1900	3.030	.009	.210	. .	.400
1901	1.041	.006	.112	. .	.230
1902	4.289	.032	.224	. .	.864
1903	3.275	.033	.080	.027	.767
1904	1.356	.009	.098	.024	.491
1905	.702	.004	.048	. .	.120
	1.812	.0132	.113	.015	.392

STATISTICAL TABLE 12.

PLEURISY.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	3.714	.028	.152	.076	.788
1896	3.663	.039	. .	.281	1.061
1897	2.796	.032	. .	.190	.830
1899	3.026	.016	. .	.192	.512
1900	3.704	.023	. .	.252	.712
1901	4.018	.034	.037	.223	.940
1902	3.233	.030	.032	.320	.952
1903	4.805	.037	. .	.295	1.035
1904	3.378	.027	. .	.246	.786
1905	3.364	.022	.024	.169	.633
	3.624	.029	.019	.230	.825

STATISTICAL TABLE 13.

PNEUMONIA (LOBAR).

Year	[1]Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			[2]Deaths	Discharges for disability	
1895	4.77	.048	.758	.076	1.794
1896	4.65	.033	.775	.070	1.505
1897	3.30	.039	.508	.063	1.351
1899	5.62	.054	.720	.048	1.848
1900	4.17	.035	.337	.042	1.079
1901	6.81	.060	.818	.112	2.130
1902	5.06	.043	.256	. .	1.116
1903	8.45	.083	.564	.188	2.412
1904	3.84	.034	.246	.049	.975
1905	3.51	.029	.266	.024	.870
	5.11	.0465	.468	.068	1.467

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[1] Includes errors in diagnosis.

[2] Marked decrease in death rate in relation to admission rate may show connection with increased admissions and deaths from tuberculosis. "There is a form of acute phthisis that may closely simulate ordinary pneumonia."

STATISTICAL TABLE 14.

TUBERCULOSIS—PNEUMONIA—BRONCHOPNEUMONIA—CHRONIC BRONCHITIS—PLEURISY.

Year	Percentage of sick	Ratio per 1000 of Strength		
		Deaths	[2]Discharges for disability	Total deaths and discharges
1895	.224	1.517	1.896	3.413
1896	.201	1.339	2.534	3.873
1897	.205	1.460	2.349	3.809
1899	.181	1.392	3.265	4.657
1900	.187	1.136	3.367	4.503
1901	.256	1.413	4.413	5.826
1902	.268	1.327	3.745	5.072
1903	.393[1]	1.574	4.053	5.627
1904	.358	1.158	3.549	4.707
1905	.394	1.047	3.541	4.588
	.2947	1.257	3.298	4.555

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[1] Increase in that year and subquent years due to keeping tubercular cases in service longer, but *nevertheless the death rate from the five diseases subsequently diminished.*

[2] Ratios in this column follow quite closely the general invaliding ratios of the service and show the influence of recruiting.

While the question of increased prevalence may be unanswerable, it is, nevertheless, a fact that during the ten years the relative number of known cases increased and that, however much of the increase was due to recruiting, cases of tuberculosis continued to appear under service conditions. The knowledge that the disease has a specific living cause imposed certain responsibilities in regard to its spread and the actual increase of cases incident to the growth of the service led to special consideration for its prevention.

An additional damage subsequent to 1902 (Statistical Table 8) was assumed in delaying discharges for disability in order that the infected might have the benefit of a suitable change of climate and thus better opportunity to recover or improve sufficiently to become self-supporting. By treatment in special hospital there was also a more rapid removal from the general hospitals and thus less chance of the spread of infection. The treatment of such cases in special hospital is certainly in accord with the teachings of hygiene, but in connection with that policy is developed the danger of a serious breach of *naval hygiene which requires not only that each case of tuberculosis shall be removed from ship or barracks as soon as practicable, but also that the individual so removed shall not again become a menace to the good health of the service through the "discharge to duty."* Undoubtedly a percentage of tubercular cases recover, but *from a service point of view no individual should be discharged to duty because he appears to have recovered, but only when it has been conclusively proven that he has recovered, and that cannot be shown by the absence of the physical signs of the disease or by negative bacteriological examinations.*

It was in 1902 that the transfers of tuberculous cases to special hospital began. Only a few such transfers were made that year, but there were many in the subsequent years. And in December, 1903, an experimental camp for tubercular patients was established on the hospital grounds at Pensacola, Fla. A similar camp was established at San Juan, P. R., in February, 1904, and there was also such a camp at Mare Island, Cal. It is shown in Statistical Table 8 that in 1903 there appeared for the first time a wide difference between the admission ratio and the total ratio of deaths and discharges. The strong inference is that with the establishment of those special places for the treatment of tubercular cases there developed a marked tendency to return patients to duty.

In 1905, out of 99 cases treated at Pensacola, 21 were discharged to duty as well—more than 21 per cent.—and at Mare Island out of 56 cases 6 patients were reported as cured, but it is noticeable that 9 were found after admission to the camp not to have had the disease, so the reported recoveries were 12.8 per cent. At San Juan, in 1904, 22 patients were under treatment and 6 were discharged to duty—over 27 per cent. There were then at those camps 168 cases with 33 apparent recoveries—nearly 22 per cent. in climates not generally considered favorable. The record at Mare Island exhibits the growing tendency to make the diagnosis of tuberculosis, which unduobtedly has some relation to the apparent increase of that disease in the service. It also shows the necessity for more definite means of diagnosis in all doubtful cases than were employed during the period.

An examination of the records seems to show that some patients with undoubted tuberculosis did recover and after discharge to duty served out the remainder of their enlistments—in many cases short—without return of trouble. The majority did not reenlist and therefore long-continued observation in many cases was not practicable. But undoubtedly there was, apparently, complete recovery in some cases, yet it is noticeable that in not a few of those reported as recovered the general nutrition was never seriously affected, the tubercle bacillus was never found at the camp and there was never any absolute proof in those cases of the presence of the disease. It also appears that in no case discharged to duty from the camps was there a tuberculin test, that some cases of tuberculosis were permitted to leave the service by expiration of enlistment and not by survey, and that some cases so discharged and some others discharged to duty did re-enlist and were subsequently surveyed on account of tuberculosis, such cases appearing in the records as new cases, accounting for some of the apparent increase in the service of that disease and acting as foci of infection.

Even if cases have recovered, the individuals should not be considered as having, as a rule, the resistance suitable for a naval life, and therefore, if not capable of infecting at the time of discharge they more readily become so. It is undoubtedly proper to maintain special places for the treatment of this disease, but such places should be for the benefit of the men and, in the segregation, for the benefit of the service. It is clear, however, that they are capable of becoming a source of damage not only to the service, but also to the men themselves, who at least on apparent recovery could have useful lives at high altitudes, but who are not suitable for work at the sea level, especially in ships.

There may very well be some exceptions in cases of specially valuable men declared by extensive observation or entirely by some reliable test to have certainly recovered, but as a rule no man in the service clearly *shown to have had tuberculosis should ever be returned to duty* and no enlisted patient having had or having the disease should be discharged in any other way than by medical survey in order that the character of discharge may forever be a bar to reenlistment. This should be regarded as one of the laws of naval hygiene.

There is some revival of confidence in the tuberculin test made with much smaller doses than those originally used but including relatively large increases. The absence of tubercle bacilli even when associated with the absence of physical signs is not proof of recovery; and just as tuberculin is largely used in many places, and should be used in the service, to clear a doubtful diagnosis so it can be used to establish recovery. But as a general rule the patient who recovers in a given climate should continue his life in the same or a similar climate and not expose himself to reinfection under climatic and other conditions of environment that have already been shown to be sufficient to overcome his power of resistance. Such reinfections generally lead to death, especially perhaps if the recovery has been secured at high altitudes.

The knowledge that tuberculosis has a living specific exciting cause is of inestimable value in all direct methods undertaken for its limitation or abolition, but there is danger in that knowledge if it be allowed to hide or obscure the necessity for such measures as are required to maintain or secure those conditions of the body which together form the basis of immunity. Tubercle bacilli are so common in localities where men congregate that the large majority of persons are necessarily exposed to the cause of the disease. It, however, seems true that not a few who escape infection would contract the disease if exposed to the cause in greater concentration or when suffering from inflammation or congestion of the tonsils or respiratory passages, from diabetes, syphilis, or when the metabolic processes of the body have been lowered or perhaps altered, as the result of any disease or any habit that diminishes the power or opportunity of the body to properly nourish itself. In the treatment of persons with tuberculosis the most important measures are the abolition of habits that depress body function, more or less forced feeding with food easily assimilated, and increased opportunity to obtain from the air unmixed with the waste products of life the oxygen necessary for its utilization; so to avoid the disease it is as advisable to maintain the nutrition of the body, especially at that period of life where there is a tendency to lose sleep and strength in the excessive pursuit of pleasure, as it is to try to avoid the exciting cause.

There is a certain basis upon which each infection is apt to rest and that is an acquired or hereditary interference with or lowering of the nutrition. The recruiting officer should consider the hereditary lowering of nutrition perhaps even more than the acquired if tuberculosis is to be perceptibly lessened in the navy under a relatively large recruiting rate. The appearance of the tuberculizable individual is much more significant and very different from that of the man who is seeking enlistment at some recruiting station on the Great Lakes because owing to the interference of navigation by ice he has been deprived of his occupation and thus of sufficient food.

As the tubercle bacillus tends to find lodgment in the depressed body, much of the prophylaxis in tuberculosis is found within the domain of general hygiene and should be gathered from consideration of such subjects as ventilation, light, heating, food, bathing, exercise, and clothing and their applications to conditions of life in ship and barracks. So far as those subjects have direct relation to the statistics of tuberculosis during the ten years, the question of food does not appear to demand exploitation, as on the ships and in all naval barracks every man received more than sufficient food. As the fuel of the body cannot be properly utilized without sufficient air free from that admixture of waste products common in crowded spaces, the subject of ventilation in relation to tuberculosis during the period requires some consideration. It is ventilation which also does much to prevent the concentration of the specific cause of tuberculosis and of some other diseases. Yet during the ten years there was an increasing amount of air supplied to the spaces of ships, with the important exception of gun deck spaces, but that was not true in regard to conditions on shore where increasing number of recruits were crowded in naval barracks in which the ventilation and, in some, the heating was far from satisfactory. And it was the recruit in whom tuberculosis developed most frequently.

The standard of ventilation of ships in view of the necessary concentration of men and the consequent limitation of air space has never been as high as hygiene demands. During the ten years the plenum system was becoming more popular than the exhaust, and drafts associated with ventilation much more frequent especially as with the change there was no provision for warming the air supply in cold weather. The popularity of the plenum system has depended upon the great increase in tropical cruising since 1898, as under that system ships in hot climates are very much more comfortable, the drafts are agreeable, the heat generated within the ship more rapidly diminished and the ventilation generally improved. Cruising in northern waters in winter became much less common, but in the absence of any method of heating air supply a ship that happened to be north was either dominated by drafts or lacking in ventilation. That was especially true of some crowded receiving ships, the lack of ventilation, for instance, having been very much in evidence on the Minneapolis at League Island during the winter of 1902–03, when there was much sickness due to overcrowding. There was also much sickness at the same place during the subsequent winter due to overcrowding of recruits in naval barracks.

But while bronchitis and bronchial catarrh were rife in those northern latitudes, the presence of the great preponderançe of the force in tropical climate was sufficient to cause a marked diminution in bronchial affections (Statistical Table 9). So far as the statistics of the ten years are concerned, the relation of bronchitis to tuberculosis as a predisposing cause is therefore negatived or much obscured. But the differences in the admission ratios of tuberculosis are relatively small, and there was a concentration of new recruits north in winter, and the apparent increase in tuberculosis is intimately associated with recruits. It is undoubtedly true that during the ten years the movement of disease was much greater at the training stations than elsewhere and that very much of it was due to overcrowding and also to exposure to cold and dampness incident to the system of washing clothes, a cause of disease not found in tropical cruising. It is not, therefore, by any means clear that tuberculizable recruits did not find conditions early in their naval careers which predisposed to infection. But in the cruising ships where most of the personnel were placed during the ten years, whatever predisposing influence to tuberculosis there may be in bronchial affections was greatly diminished.

While bronchial affections were a diminishing influence on the cruising ships, there were certain increasing influences afloat predisposing to tuberculosis. The tonnage of ships was steadily increasing as well as the number of ships. That caused less division of the men into groups and, as tuberculosis is a communicable disease, brought more men at any one time under the possible influence of any particular case of the disease. On a large ship there are greater opportunities for a certain class of men to affect the lower parts of a vessel, such as storerooms, away from natural light, and that class is apt to show anæmia and to furnish a larger percentage of tuberculosis. It is also true that while the navy in the tropics gives a smaller admission-ratio for bronchial affections, there is tendency to a lowered nutrition from the effects of heat. This is especially marked in the case of cooks and stewards, though apparent generally in a crew. It is also more or less marked in the engine-room force, but such men during the ten years were more carefully selected, while a good cook, steward, or musician was apt to be passed into the service on a lowered standard.

In a crew of 800 men it requires only two tubercular cases a year to make the calculated average during the ten years of cases incident to service and most of them came from the classes indicated. *A higher physical standard* in the case of cooks and stewards and the selection of men of our own unmixed races for that work, as orientals seem more prone to the disease, would have done much to have diminished cases from that class, and more personal attention to the needs of yeomen, storeroom keepers and the like, requiring them to spend more time on deck in the open air and to take more exercise, even changing their duties from time to time as practicable, would have lowered their tubercular ratio. The more rapid removal of heated air from fire and engine rooms and less regard for appearances and more encouragement to the men who work there to pass more time on deck when not on duty, in and out of port, would have done much to have helped that class.

While it is common knowledge that continued residence in the tropics tends to physical degeneration, it would be difficult to make that evident in a naval service by statistics applied to the total force, the greater part of which is afloat and frequently changing climate. Cruising in the tropics during our winter months and coming into colder waters during the warm months save a crew from many physical ills in view of the character of the life and of the habitation of a sailor. Since the Spanish-American War the greater part of the force afloat still remained on the Atlantic coast cruising in the tropics during the winter. The part of the force afloat in Philippine waters remained in those waters more closely the years immediately subsequent to that war, but later there was more cruising north in the most objectionable tropical months. From the way the statistics were compiled it has not been practicable to apply the figures of anæmia directly to the force (in great part members of the Marine Corps) that was more or less continuously in the tropics on shore. It is not clear, however, that much would be gained if that could be done as admissions to the sick list are more apt to be for other diseases than for the predisposing anæmia or debility.

While experience has shown very clearly that a navy should avoid the tropics as much as practicable during the more objectionable months, if the crews are to be kept in good general condition, and that the crew of a ship, as the force ashore, when left continuously in the tropics will show the debilitating effect of climate much more at the end of the second year than of the first, the statistics of *anæmia* given in the following table do not greatly emphasize the lesson that has been learned from observation and experience, although there was a considerable increase in the admission-ratios during the years immediately subsequent to 1898 when more of the navy was associated with the Philippines during our summer months:

STATISTICAL TABLE 15.

ANÆMIA.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.98	.0046	. .	.152	.244
1896	1.83	.0154	.141	.141	.590
1897	1.01	.0115	. .	.191	.421
1899	1.87	.0152	. .	.144	.448
1900	3.16	.0278	. .	.463	1.019
1901	1.82	.0280	. .	.223	.783
1902	1.28	.0155	. .	.128	.438
1903	2.49	.0238	. .	.295	.771
1904	1.94	.0177	. .	.172	.526
1905	1.43	.0167	. .	.194	.528
	1.84	0.187	.007	.207	.588

There were three infectious diseases—*follicular tonsillitis*, *diphtheria*, and *epidemic catarrh*—which were more common among recruits and had very large admission ratios during the ten years as is shown by the following tables:

STATISTICAL TABLE 16.

TONSILLITIS.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	37.3	.053	. .	. .	1.060
1896	41.9	.063	. .	. .	1.260
1897	37.6	.059	. .	.063	1.243
1899	37.1	.059	. .	.048	1.228
1900	39.7	.064	. .	. .	1.280
1901	53.1	.081	. .	.111	1.731
1902	52.5	.079	. .	.032	1.612
1903	59.8	.114	. .	. .	2.280
1904	68.6	.104	. .	.148	2.228
1905	58.0	.087	. .	.072	1.812
	52.3	.083	. .	.056	1.715

STATISTICAL TABLE 17.

DIPHTHERIA.[1]

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	. .	. .	. .	. .	. .
1896	.070	Negligible	. .	. .	.001
1897	.063	Negligible	. .	. .	.006
1899	.096	Negligible	. .	. .	.008
1900	.337	Negligible	.042	. .	.058
1901	3.467	.022	.074	. .	.514
1902	2.080	.010	.064	. .	.264
1903	16.645	.149	.107	.054	3.141
1904	4.783	.037	.024	. .	.764
1905	3.461	.042	.024	. .	.864
	4.25	.037	.041	.007	.784

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[1] Epidemic diseases in the navy, during the period, depended chiefly upon conditions at the training stations directly incident to service expansion, the number of recruits (minors and young adults—minors chiefly) being far in excess of the accomodations provided for them. *Overcrowding*, poor ventilation, lack of steam laundry and at times dampness and even insufficient heating were prominent factors together with insufficient provision for the segregation of newcomers and disinfection of their clothing and persons. Recruits received from such stations (Newport, League Island, Norfolk, San Francisco) infected the ships, especially the training ships (Buffalo, Monongahela, Mohican, and Adams). See table on Scabies and that on Measles.

STATISTICAL TABLE 18.

EPIDEMIC CATARRH.

Year	[1]Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	49.8	.107	.076	.076	2.292
1896	28.2	.042	. .	. .	.840
1897	37.7	.072	. .	.063	1.503
1899	32.3	.068	. .	.048	1.408
1900	71.5	.123	. .	. .	2.460
1901	48.9	.117	. .	.037	2.377
1902	28.1	.042	. .	.032	.872
1903	41.0	.064	.027	.027	1.334
1904	26.1	.036	. .	.024	.744
1905	22.4	.030	. .	. .	.600
	36.7	.0643	.008	.026	1.320

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[1] Much too high, including many errors in diagnosis, but is of general value showing marked variations of an acute infectious disease without prophylaxis. The disease varies greatly in type and thus its causative relation to tuberculosis and bronchopneumonia has varied, but such influence has been apparent during each year.

The place or places where the tubercle bacillus effects lodgment or entrance has been the subject of discussion for years. Recently the tonsils have been given a prominent place in the question and therefore Statistical Table 16 may be considered of interest in relation to tuberculosis from that point of view as tonsillitis also had an increasing prevalence not varying greatly in relative amounts from that of tuberculosis. The relation seems, however, to be more associated in the service with the common age at which both diseases are most prevalent. There are a number of diseases more apt to attack the young than the old. The increased prevalence of tonsillitis and diphtheria in the naval service was undoubtedly primarily incident to an increase in the relative number of minors and young adults. It has been commonly thought that tuberculosis is most likely to appear in that class.

It is not clear why those diseases tend to select the young so frequently, but in the case of tuberculosis it is not unusual to find in men deteriorating physically in the early years of manhood an excessive zest in seeking the pleasures of life, either normal or abnormal, or in following some pursuit involving loss of moderate exercise in the open, or perhaps loss of sleep to further some ambition, laudable or otherwise. In the naval service it is the young man who has the great change involved in breaking away from home ties and taking up an unusual life and upon whom any irregularities when ashore on liberty have the greater effect. Then there are of course the necessary peculiarities of naval life involving loss of sleep and it is noticeable how very many of those admitted to the sick list will sleep for hours on the day of admission and also how common it is to find men sleeping about the decks especially after liberty during which there has also been that chance of tubercular infection which always belongs to the relation with the shore.

The average age of the personnel is least during the period of maximum recruiting and there are relatively more people between 18 and 25 years of age. That in itself may declare a greater tendency to tuberculosis in the navy subsequent to 1898, although in civil life there are some statistics to show that the danger from tuberculosis does not diminish as age increases. In the study of predisposing causes, Statistical Tables 6 and 7 should also be given consideration.

As was stated in considering syphilis, the prophylaxis of one infectious disease has much in common with that of another. Many of the measures on a ship to prevent any extension of venereal disease apply to tuberculosis, tonsillitis, diphtheria, epidemic catarrh, pneumonia and, to a certain extent, even to measles, mumps, and scarlet fever, as measles is communicable some time before eruption appears and generally before the medical officer is aware of the presence of the case. *There is danger in the material that passes from the mouth* and therefore danger in the use in common of the drinking cups at the scuttle butt, in the careless disposition of swabs used on throats, in the clinical thermometer and tongue depressor without disinfection, in the use of pipes, cigars, cigarettes, and chewing tobacco and blowing musical instruments in common and in *spitting on any deck.*

Every effort should be made in the routine care of a ship to prevent the fluids of the mouth of one man from gaining access to the body of another. With that end in view, all mess gear and dishcloths after each meal should be subjected by machine or otherwise to hot water, spitkids containing water should be in place, every man should be required to be at the spitkid when he expectorates, and spitting on any deck day or night should be punished. At each crew's water-closet there should be an attachment for a steam hose to be used in the morning watch for the disinfection of spitkids and floor and woodwork of the head. Linoleum should be kept in good condition, in contact with the deck it covers, and frequently shellacked. In all cases in which the contact has been broken disinfection should be practised prior to repair. Damp cloths or swabs, to be daily put under the steam hose or disinfected, should be used for cleaning between decks, but a vacuum system of cleaning might be applicable even under the conditions afloat. The air between decks carries much dust, not a little of which can be readily shown to have been derived from the men themselves, including mouths and nares (coughing, sneezing, spitting, and speaking), their clothing, and food. The use of the broom between decks should be discarded and every means employed to keep as dry a ship as possible consistent with cleaning without dust.

The diagnosis of tuberculosis should be made as early as practicable, and for that purpose there should be a *zealous* investigation of the sputum in any case that is at all suggestive. An individual whose physical condition, when compared with that of his fellows, is surely and steadily deteriorating from causes not ascertainable should be removed from a ship as also should anyone in whom the physical signs though not conclusive are strongly suggestive, but the diagnosis of tuberculosis should not be made unless evidence is conclusive. Any case of tuberculosis should be transferred to naval hospital so soon as practicable, and pending the transfer the case should be kept under direct supervision. There should be an attempt to impress the walking patient that he is a source of danger to others, and if a pulmonary case that danger is in his sputa which he must endeavor to keep from affecting others. The hands should be kept clean and all sputa should be deposited in the spit cup containing a disinfectant in solution, there should be a separate drinking cup or glass and they, as all articles including handkerchiefs, gauze, or mess gear that come in contact with mouth or sputa, should be systematically sterilized in boiling water. In the case of a musician the instrument he has been blowing should be disinfected. In any case the deck about the man's billet should be disinfected when the diagnosis is made, as should the clothing and hammock unless transfer is made without delay.

In barracks, where there is no ventilation by fan, the air space per man should even in northern climates never be less than 600 feet, *scrubbing floors should be carefully avoided*, and there should be the same care to prevent expectoration on floors and stairs and to avoid dust. Drinking water should be obtained from a jet and *except for purposes of drill all clothes should be washed in steam laundry.* All dormitories should be aired and the men should not be allowed in them except to sleep, when those spaces should be dry, of reasonable temperature and well ventilated. *A cold, stagnant, crowded dormitory* is especially dangerous, and when the temperature is too low ventilating apertures will be closed. When sleeping in hammock there is a stronger tendency for covering to fall and in addition a low temperature in a crowded room does not in itself facilitate ventilation and dryness.

At no station should there be a swimming tank without a white internal surface and a suitable continuous flow, and any intentional pollution of the water should be a very serious offense. Such tanks should never be overcrowded, the time of exposure should be short, the ventilation and heating good, and one section should never be allowed to follow another until there has been a reasonable time for renewal of water. There should be no swimming tank at any station unless the supply of water for that purpose is practically unlimited.

Many of these measures are matters of routine for the prevention of a large number of diseases afloat and ashore and they should also include more frequent disinfection of decks and floors with corrosive sublimate solution and the fumigation of sick bays with formaldehyde, especially when cases of follicular tonsillitis or diphtheria are occurring. In epidemics of the latter disease all minors especially exposed should receive every three weeks a preventive inoculation of serum until cases cease to appear. The admission rate of tonsillitis, chiefly follicular, at the Newport training station in 1905 was 179.8 when the general admission rate of that disease was 58; of diphtheria 10.8; of lobar pneumonia 34.5; of bronchial affections 67.08 and of cerebrospinal fever 14.8. During the preceding year the diphtheria rate was 184, the tonsillitis rate 41, and the pneumonia rate 27, with no case of cerebrospinal fever.

The relation of tubercular infection to food is at present the subject of much dispute. There is a strong attempt to overturn the teaching that the germs of the disease are generally inhaled directly into the lungs and to substitute the belief that those persons in whom the disease develops have had the tubercle bacillus carried into the alimentary canal in milk during childhood, the lungs becoming ultimately affected even in adult life by way of the blood and lymphatics. Tuberculosis is commonly a disease of slow development and there is much evidence to show that the tubercle bacillus can remain more or less latent within the body for very long periods. Undoubtedly the vital cause of the disease to a certain extent propagates itself within the body much more often than signs of the disease during life would indicate in view of the findings at autopsies on persons dead from other diseases. At this time, while one certainly would not be justified in accepting the dogma that the majority of cases of tuberculosis are infected by way of the intestinal canal, it cannot be denied that some cases originate in that way and that consideration of raw milk and other uncooked food, especially pork, enters into the question of the prophylaxis of the disease. Certainly, the last word from scientific workers in that direction has not been spoken and the discussion has advanced to such a stage that the importance of general hygiene in relation to the development, as well as of the purity of the milk supply in prevention of infection, has been very much emphasized.

On naval vessels food coming from the galley is very thoroughly cooked, but that the men did have access at times during the ten years to uncooked food is shown by the fact that tænia was not very rare and that occasionally an epidemic of typhoid fever was considered due to milk. Fresh milk was, however, not a feature in the navy ration until July, 1906, and its use by the messes was generally discouraged. However, commutation of rations in vogue during the period and the tendency of some to uncooked sausage when on shore opened a way to the occasional consumption of uncooked food. In oriental countries not a little human manure is used on the fields, making fresh vegetables dangerous when uncooked, but that danger was very generally avoided during the period. In almost all communities the milk supplied is very questionable, and while as a choice of evils its use is proper in the treatment of the sick, it is not suitable for general use in the raw state on a naval vessel so long as the method of gathering it remains in its present primitive state. In probable though perhaps debatable relation to the question of method of infection it appears that over 90 per cent. of the cases returned during the ten years were of the pulmonary type.

There is a widespread belief that a sea life or even a single voyage of any length at sea is good for "weak lungs." A reflection of that belief from parents or guardians is observable at the recruiting stations and should serve to induce a corresponding caution on the part of examiners. There is an even more extensive belief that the navy makes men out of weaklings, and it was certainly a pleasing observation during the period of training ships to note the difference between the physical condition of men at the time of arrival and of transfer three months later, showing that whatever may be the disadvantages of naval life the balance is strongly in favor of good health under ordinary conditions at sea.

But the navy is not a sanatorium any more than it is a reform school, and if the meshes of the system at the recruiting stations are too large objectionable material will pass through. A young man who from lack of memory cannot be sent to a nearby grocery store for a pound of butter without having the address, the article, and the amount in writing presents many difficulties to those studying domestic economics, and it is not remarkable that in quite a percentage of such difficulties a way of removal is sought in naval enlistment. Therefore, in an expanding navy, mental diseases as well as many others tend to become more prominent irrespective of naval conditions themselves which necessarily involve those influences that tend to induce nostalgia and kindred affections.

The mental diseases have been made to include *dementia, mania, melancholia, paranoia, neurasthenia, and hysteroid neurosis,* the statistics of which during the ten years are given in the following table:

STATISTICAL TABLE 19.

MENTAL DISEASES.

(Dementia, Mania, Melancholia, Neurasthenia, Neurosis (hysteroid), Paranoia).

Year	[1]Admission ratio per 1000	[2]Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000	[5]Ratio per 1000 transferred to asylum
			[3]Deaths	[4]Discharges for disability		
1895	5.53	.063	. .	1.743	3.003	.910
1896	4.79	.052	. .	1.761	2.801	1.127
1897	3.87	.041	. .	2.097	2.917	.953
1899	5.66	.067	. .	2.209	3.549	1.393
1900	6.73	.069	.042	2.736	4.158	1.768
1901	8.26	.084	. .	3.237	4.917	1.525
1902	6.05	.071	.032	2.913	4.365	1.312
1903	6.36	.063	.054	3.006	4.320	1.101
1904	6.19	.055	. .	3.180	4.280	1.307
1905	5.39	.053	.073	2.638	3.771	1.283
	6.04	.063	.026	2.756	4.042	1.295

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[1] These ratios are high, as diseases of this class are feigned from time to time. Increase due in part to neurasthenia but chiefly to recruiting. Admission ratio for dementia, mania, melancholia, and paranoia about 3.15.

[2] Small percentage of sick due to transfers of insane to asylum.

[3] Deaths in asylum not included.

[4] Includes transfers to asylum. Is rather low as it does not include retirements.

[5] Included in discharges for disability.

By reference to Statistical Table 3 it will be seen that of 413 surveys held in 1905 on persons during the first six months of enlistment 15.2 per cent. were on account of diseases of the nervous system and of those more than 60 per cent. were on account of mental disease, excluding epilepsy which was 33 per cent.—a total of more than 93 per cent. Diseases of this class are feigned from time to time for various purposes, including desire for discharge or to escape discipline, and it was not unknown for men, who were regarded as suffering from aphasia, mentally deficient or even dangerous lunatics on ship or on certain stations they were very desirous of leaving, to improve in the most marked manner on other ships carrying them to hospital. The number of such cases was not large, but they served to affect statistics and to designate some men so lacking in self-respect as to be undesirable for service. A man is an undesirable citizen and an undesirable sailor who sound in mind can bear to be regarded as having a mental disease. But feigning did not cause transfer to asylum during the ten years and therefore *comparison* of relative prevalence during the different years can be best made from the figures in the last column expressing the ratios of such transfers. Cases of mere mental deficiency that existed at time of enlistment are of course actually invalided from service and the effect of faulty recruiting can be observed by comparison of the figures in the column of discharges for disability with the general invaliding ratios from disease shown in Statistical Table 2.

In relation to conditions of service conducive to mental disorders experience has shown very clearly that it is a mistake for a medical examiner at recruiting station to accept any person who has a ludicrous peculiarity of body or of speech. Such persons become butts and either already have mental peculiarities or tend to develop them among men who naturally form bands for purposes of amusement. For example, at some time during the ten years there was in the service one who on enlistment was exceedingly bald with a large "skull and cross bones" tattooed on the top of his head. At times and especially when in swimming over the side he presented a very ludicrous appearance. In spite of his relatively high position among his fellows as machinist he developed a true but mild form of melancholia.

The mental diseases caused 4.6 per cent. of the total damage from disease and with epilepsy, 6.54 per cent. thus approaching the damage from tuberculosis. In the following tables are given the statistics of neurasthenia, hysteroid neurosis and epilepsy:

STATISTICAL TABLE 20.

NEURASTHENIA.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	[1]Discharges for disability	
1895	1.82	.015	. .	. .	.300
1896	2.46	.033	. .	.211	.871
1897	1.71	.015	. .	.763	1.063
1899	2.49	.039	. .	.382	1.162
1900	2.82	.036	. .	.337	1.057
1901	2.94	.023	. .	.558	1.018
1902	2.43	.024	. .	.416	.896
1903	2.60	.031	. .	.618	1.238
1904	2.64	.028	. .	.739	1.299
1905	2.01	.025	. .	.315	.815
	2.44	.027	. .	.472	1.012

[1] Does not include retirements and therefore the column relates entirely to the enlisted force. This disease is given as the cause of sick leave to officers in a relatively large number of cases. Taking the years in sequence the numbers of such sick leaves seem to have been as follows: 5, 5, 2, 13, 11, 2, 8, 20, 14, 12. Of those 92 officers, some were of course retired. The damage column is therefore also too low and would consequently reflect more prominently some of the results of increased worry and responsibility incident to the increase in size and in complications of the modern ship.

STATISTICAL TABLE 21.

NEUROSIS HYSTEROID.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.379	.0012	. .	. .	.024
1896	.141	.0002	. .	. .	.004
1897	.190	.0002	. .	. .	.004
1899	.240	.0031	. .	.096	.158
1900	.463	.0029	. .	.295	.353
1901	.633	.0041	. .	.260	.342
1902	.576	.0043	. .	.256	.342
1903	.537	.0031	. .	.188	.250
1904	.394	.0015	. .	.074	.104
1905	.532	.0026	. .	.121	.173
	.449	.0026	. .	.147	.199

STATISTICAL TABLE 22.

EPILEPSY.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	1.516	.012	. .	.455	.695
1896	1.549	.011	. .	.282	.502
1897	1.970	.017	. .	.826	1.166
1899	2.401	.022	. .	1.297	1.737
1900	2.652	.018	. .	1.052	1.412
1901	3.423	.026	. .	2.158	2.678
1902	2.240	.022	. .	1.697	2.137
1903	2.926	.019	.080	1.879	2.339
1904	2.466	.016	. .	1.208	1.528
1905	1.549	.010	.024	1.331	1.555
	2.344	.017	.015	1.359	1.704

If the total of corresponding items of Statistical Tables 20 and 21 be taken from similar items of Table 19 the result will be the statistics of dementia, mania, melancholia and paranoia in combination. While during the ten years the enlisted force was increasing rapidly the number of officers did not change greatly but their responsibilities increased enormously in view of the increase in number of men, the marked development of ships as fighting machines, and the greater naval activity subsequent to 1898, especially in the tropics. One of the results was a rather large percentage increase in the actual number of officers on sick leave with neurasthenia. With the large increase in the enlisted force the increased damage among officers caused by neurasthenia was not strongly reflected in admission ratios relating to the total force. In the statistical table of epilepsy the ratios of discharges give a better idea of actual prevalence than the admission-ratios themselves, the difference chiefly representing feigning or subsequent attacks in men returned to duty from the hospitals where there were doubts of original diagnosis due to absence of convulsions or manifestations while under observation. Comparison of those ratios of discharges with the general invaliding ratios from disease is of interest and importance as has been shown (*see* Statistical Tables 2, 3 and 8).

The malarial diseases caused 2.92 per cent. of all damage from disease, exceeding that from typhoid fever (Statistical Table 5). However, the damage lines of those diseases crossed in 1905 as appears from comparison of the following table with Statistical Table 26:

STATISTICAL TABLE 23.

MALARIAL DISEASES.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000	Admission ratio of force ashore	Admission ratio of force afloat
			Deaths	Discharges for disability			
1895	69.2	.298	.076	.152	6.188	133.2	59.5
1896	59.8	.208	. .	.141	4.301	115.9	49.8
1897	53.4	.121	. .	.317	2.737	84.7	49.9
1899	50.9	.138	.096	.240	3.096	89.8	45.6
1900	46.0	.119	.126	.168	2.737	79.4	37.4
1901	41.4	.103	.036	.186	2.282	69.5	33.5
1902	45.1	.119	.192	.192	2.764	79.3	36.7
1903	32.7	.104	. .	.054	2.134	67.7	25.0
1904	39.8	.099	. .	.123	2.103	106.2	23.0
1905	24.8	.066	.072	.024	1.416	54.9	16.4
	42.0	.1185	.060	.139	2.570	81.6	32.8

The above table is as interesting and as difficult of interpretation as that relating to tuberculosis. In this there are a diminishing admission ratio and damage; in that an increasing. In this the expectation, in view of more intimate association with the tropics, would be for increase; in that, in view of better hygienic conditions, for decrease. The reverse was the case and *in part* for much the same reason—more definite methods and better facilities for making diagnosis. It seems likely there has always been more tuberculosis in the navy than was discovered and less malarial disease than was thought. It might be agreeable to ascribe all of the remarkable change shown in the table to naval prophylaxis, but in considering the admission-ratio of the force afloat it is evident that such could not have been the case as the ships remained unprotected from the mosquito during the entire period, except such protection as choice of anchorage might give, but there is little evidence of change in that respect.

The admission-ratios began their fall prior to the Spanish-American War and it is an interesting question how much of the decline has been due to the general crusade against the mosquito on shore. There is internal and external evidence in favor of reduction from that cause, much of which is sufficiently apparent without elucidation. In 1895 nearly 25 per cent. of all the malarial cases in the service and nearly 70 per cent. of those from the force ashore were returned from enlisted men at Washington and were ascribed to local conditions following work on the channel of the Anacostia

River. All the seamen and 80 per cent. of the marines at that navy yard were attacked. In 1896 there were from the same cause only about 16 per cent. of all cases and 50 per cent. of those from the force ashore. The number steadily decreased until in 1905 cases from that source were very few. Should the work be renewed without fully reclaiming the flats in that river the history promises to repeat itself.

Considering the mosquito diseases to be the malarial, filarial, dengue, and yellow fever, little can be obtained from the service statistics of the last in view of the small and irregular damage received during the ten years, but the results of the crusade against the mosquito in the homes of that disease are well known, and doubtless the service has profited to some extent. The statistics of dengue and yellow fever are given in the following tables, from which it is seen that since the intimate relations with the tropics began the influence of the mosquito in dengue has shown the same tendency to decrease as in the case of malaria, permitting the deduction that the destruction of the mosquito in general and the limitation of its propagation has been a factor in reducing the number of cases of disease:

STATISTICAL TABLE 24.

DENGUE.[1]

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000	Admission ratio of force ashore	Admission ratio of force afloat
			Deaths	Discharges for disability			
1895	. .	. .	. .	. .	. .	. .	. .
1896	. .	. .	. .	. .	. .	. .	. .
1897	. .	. .	. .	. .	. .	. .	. .
1899	14.26	.022	. .	. .	.440	72.2	1.9
1900	14.14	.026	. .	. .	.520	41.9	5.0
1901	15.89	.024	. .	. .	.480	41.3	7.1
1902	16.99	.029	. .	. .	.580	49.6	6.8
1903	11.30	.019	. .	. .	.380	34.3	5.4
1904	10.16	.019	. .	. .	.380	37.2	2.8
1905	6.12	.011	. .	. .	.220	15.5	3.5
	10.10[2]	.017	. .	. .	.349	33.3[3]	3.9[4]

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[1] As the ratios are based upon numbers that include many men who were not in the Philippines, the intensity of the disease in that locality must have been great.

[2] For the seven years, 12.07.

[3] For the seven years, 38.5.

[4] For the seven years, 4.7.

STATISTICAL TABLE 25.

Yellow Fever.[1]

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	. .	. .	. .	. .	. .
1896	. .	. .	. .	. .	. .
1897	. .	. .	. .	. .	. .
1899	.384	.0012	.240	. .	.464
1900	.084	.0006	. .	. .	.012
1901	. .	. .	. .	. .	. .
1902	.064	Negligible	.064	. .	.065
1903	. .	. .	. .	. .	. .
1904	.024	Negligible	.024	. .	.024
1905	.290	.0017	.048	. .	.082
	.094	.0004	.0377	. .	.046

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[1] Of the total number of cases only 7 occurred on the ships during the ten years, a record in sharp contrast with the prior history of the navy. For example: U. S. S. Jamestown (1867) 59 cases, 21 deaths; U. S. S. Resaca (1867) 77 cases, 19 deaths; U. S. S. Saratoga (1869) 37 cases, 17 deaths; U. S. S. Monongahela (1874) 3 cases and 2 deaths, (1875) 11 cases (deaths not given); U. S. S. Lancaster (1875) 4 cases and 3 deaths; U. S. S. Marion (1879) 25 cases, 3 deaths; U. S. S. Plymouth (1878) 7 cases, 3 deaths, and (1879) 2 cases, 1 death. In 1894 the U. S. S. Newark was infected at Rio. There were 4 cases and 1 death. In the above table, of the 7 cases on ships 6 occurred on the U. S. S. Boston at Panama in 1905 with 2 deaths. On that ship the *stegomyia* was found on board and the larvæ in some of the division tubs which contained a little water for preservation. The mosquitoes probably found their way on board from a tug that brought visitors, but possibly with a bunch of bananas. The Jamestown and Resaca were also infected at Panama, the Saratoga at Havana, the Monongahela, Lancaster, and Marion at Rio and the Plymouth at St. Thomas or Santa Cruz. The ships are probably as open to attack as ever, but they are constructed of different material (facilitating destruction of mosquitoes by disinfection), there is more knowledge in combating spread of the disease, better facilities, and, with steam, more rapid change of climate or communication when necessary with quarantine stations which are better equipped. There is also less yellow fever in communities on shore with screening of cases and the crusade against the mosquito. The majority of the cases ashore included in the table occurred at the U. S. Naval Station, Havana, in 1899 and 1900.

In Statistical Tables 23 and 24 the marked differences in the admission ratios of the force afloat and force ashore emphasize the dangers of life ashore and induce the belief that much of the disease afloat caused by mosquitoes was not incident to infection on the ships, but to infection on shore when on liberty. The same is undoubtedly true ordinarily of primary cases of typhoid fever, though not true of succeeding cases, the disease having repeatedly shown ability to propagate itself on board. As the recorded prevalence of malarial disease has frequently been regarded as having association with the prevalence of typhoid fever and the so-called simple fevers, owing to mistakes in diagnosis, the statistics of those diseases are given in the following tables:

STATISTICAL TABLE 26.

TYPHOID FEVER.[1]

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	2·35	.038	·455	. .	1.215
1896	3·94	·049	·704	. .	1.684
1897	3·30	·037	·254	. .	·994
1899	6.43	.082	·528	.048	2.216
1900	7·36	.109	1.052	·042	3·274
1901	3·90	.058	·521	. .	1.681
1902	4·00	·049	·448	. .	1.428
1903	5·04	.064	·537	.161	1.978
1904	4·78	.061	·518	·049	1.787
1905	4.16	.064	.266	.072	1.618
	4·65	.0631	·513	·045	1.820

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[1] Some of the increase is probably apparent only, being due to better diagnostic methods, but there has been some actual relative increase from a number of causes, among which may be the increase in contact cases incident to larger crews and, consequently less separation of men, and the increase of the disease during the period in one or two of the important ports on our Atlantic coast. The primary cases are due to causes on shore and result from liberty often, but sometimes from infected milk or other food brought on board. There are conditions in the ships themselves that are worthy of consideration in this connection.

STATISTICAL TABLE 27.

SIMPLE CONTINUED FEVER AND EPHEMERAL FEVER.[1]

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	19.63	.027	. .	. .	·540
1896	24·79	.038	. .	. .	·760
1897	16.39	.026	. .	. .	·520
1899	29·54	·045	. .	. .	·900
1900	30.81	.052	. .	. .	1.040
1901	23·44	·034	. .	. .	.680
1902	19.17	.027	. .	. .	·540
1903	17.21	.023	. .	. .	·460
1904	19.38	.027	. .	. .	·540
1905	20.77	·034	. .	. .	.680
	21.63	.0326	. .	. .	.652

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[1] The diagnosis in these cases is generally made with some reluctance as they are short runs of fever from causes not determined. Some are cases of auto-infection, some are perhaps an expression of functional disturbances of the nervous system and others from specific but unknown causes. The ratio has remained about the same in spite of the more extensive use of laboratory methods of diagnosis. In the better diagnosis of malarial fevers there has been no apparent increase in the relative number of cases of simple fever, inducing a belief in actual diminution in prevalence of malarial disease.

In the prophylaxis of malaria and of other mosquito diseases on shore the destruction of the mosquito and the abolition of breeding places have first place, and mechanical protection against the mosquito the second. In localities where such diseases are originating both measures should be combined, the methods employed being those generally known and including petrolizing, emptying, or screening all standing water, drainage or filling in, limitation of shade, removal of brush, the use of wire or other netting in barracks or camps, and, especially in the case of yellow fever, the placing of the sick at once under netting and as soon as practicable in previously fumigated screened quarters, the disinfection by sulphur (or pyrethrum?) of infected quarters and the control and frequent inspection of those who have been exposed.

In any locality where a mosquito disease is a feature or likely to be a feature the men should be made fully aware of the source of danger and the necessity for self-protection, and such advice should be emphasized by strict sanitation, enforcement of the use of netting, and a systematic crusade against the mosquito within and without quarters which is facilitated in barracks by light walls and ceilings, thorough screening of all windows, or, when that is very objectionable on account of interference with air movement, by careful use of mosquito nets and attention to tubs, barrels, flower-pots, bottles, troughs, gutters, and even the smallest depression of ground where water stands. Mosquitoes should be sought for especially in dark corners of quarters and during the forenoon, and men should be detailed for that purpose.

On ships the primary object is the avoidance of mosquitoes by the selection of anchorages more or less remote from shore in suspected ports that have to be visited, when practicable to windward of, and at a distance of at least one mile from probable sources of infection. Infected ports should be avoided when practicable, but upon arrival in any port information regarding its health should be immediately sought. In ports where yellow fever is known to be present there should be no liberty and no more communication with shore than exigencies of service require and *such communications should be limited if practicable to daylight hours prior to 1 p. m.* If a port is regarded, from its more or less recent yellow fever history, to be merely questionable, liberty should be restricted and confined to men on special or first-class conduct grade. It is best to modify the routine so as to limit the hours to those between 7 a. m. and 1 p. m., but all should be on board before sundown at any rate. In all such ports there should be no sleeping on shore at anytime, *places not well lighted should be avoided even in the daytime*, no covered in or partially covered in harbor boats should be allowed alongside and bunches of bananas, as possible mosquito carriers, should be excluded.

On the ship there should be no uncovered standing water and every effort should be made to make early differential diagnosis in fever cases. On ships as elsewhere the trouble from yellow fever generally follows non-recognition of the first case. And it is during the first three days of the disease that a yellow fever patient is dangerous and requires screening, though if the infection was on board there is already at least one mosquito capable of infecting.

The difficulty was exhibited on the Boston where there was quite a large percentage of the crew subject to recurring attacks of malaria following service on shore the previous year. The differential diagnosis was complicated, especially as, in at least one case of yellow fever, the malarial parasite is reported to have been found. On that ship no enlisted man had been on liberty and officers had returned on board before sundown. The *stegomyia* was found on board especially in the wardroom and to that part of the ship all cases were referred. As all the recognized cases appeared almost simultaneously it can be claimed that they resulted from infection on board especially as three of the patients had not been ashore for several weeks.

The measures adopted were *immediate transfer of sick to hospital on shore*, *fumigation* of ship with sulphur or pyrethrum, which latter stupefies mosquitoes that have to be collected and burned, and *keeping under observation every subsequent case of fever*, but there was not another case of yellow fever.

When the disease occurs on a vessel at sea it is better, as a rule, to run into a cold latitude unless there are suitable facilities for general disinfection of ship near at hand. In such an emergency such sulphur as may be on board should be used for fumigating the *part of the ship from which the case came* and tobacco may even be utilized in place of pyrethrum if good closure is obtained.

It is generally and properly conceded that quinine has value as a prophylactic against malaria, but the advisability of its long-continued use for that purpose and even the best method of administration are somewhat in dispute. While the drug exercises, as a rule, a true specific action on malaria when used in therapeutic doses in a particular case, it cannot be regarded as altogether favorable to the economy when made a part of the daily ration, and the susceptibility of different individuals varies greatly.

If the action of quinine on the parasites is dependent entirely upon contact with them it is difficult to see how, as a rule, its effects are much more satisfactory during the intermission or period prior to time of expected attack *when patient is in bed*. It seems to be a fact that manifestations are encouraged even under treatment by exposure to variations of temperature, that sudden exposure to the sunlight especially on the back of the head or neck and that fatigue are exciting causes.

There are patients who without regard to renewed infection cannot rid themselves of the parasite even under treatment without change of climate, and there are persons who though repeatedly bitten by infected mosquitoes remain unaffected among their fever-stricken comrades. There are persons who after a single manifestation in a malarial climate remain for months or even years in a non-malarial climate with blood apparently free from the parasites and then without reinfection have the paroxysm and furnish the parasites. There are those from whom the parasites, though often in sexual form, can be obtained for very long periods who have never given other manifestation of the disease. There is therefore a relation between the parasites and the general condition of infected persons that is little understood and which cannot be ignored.

The long-continued use of quinine does have effect upon the general condition of persons irrespective of any effect upon parasites. The long-continued use of a drug which in large doses causes deafness, vertigo, headache, muscular weakness, tremor, staggering gait, dilatation of pupils, amblyopia even to total blindness and can be made to produce convulsions and death is worthy of some consideration in spite of the voluntary employment by the human race of such drugs as alcohol and nicotine for which a large degree of tolerance is generally readily established. Alcohol has also been used in enormous quantities in some cases of typhoid fever without causing an approach to intoxication, and morphine has been employed in dysentery with good results in amounts that in health would have caused death.

On naval vessels, in the mouth of the Congo, sulphate of quinine has been given in solution up to 70 or 80 grains in 12 hours without marked or even any apparent cinchonism and with very good effect. But when quinine, whose action is cumulative and which tends to disturb the digestion, is given to a large number of men daily in doses even as small as five grains there will be some who will rebel, *especially if the usual solution be used*, and capsules, even if the supply should be sufficient, do not always keep well in the tropics ashore.

Moreover, the men themselves will soon be aware that cases of malaria are appearing among them and serious or even fatal cases, and the idea, whether true or not, is evolved that those taking quinine daily do not respond as readily to treatment. Under those circumstances lining up the men every day, especially when quinine is given in solution, may be subversive of discipline. It is astonishing how many cases of tertian will yield to quinine in two-grain doses thrice daily, but Chomel gives twenty-two cases of intermittent fever with nineteen spontaneous recoveries, the others, a quartan and two quotidians, requiring quinine for a cure. It is, however, decidedly dangerous in a malarial country, especially with newcomers, to consider spontaneous recoveries.

If quinine is given in prophylaxis the general opinion is that six or even four grains daily give better results than larger intermittent doses—eight to fifteen grains every four to eight days; but it seems probable that, if compulsory, the latter method of administration could be more readily carried out in view of the disgust the daily administration produces in some, unless the dose is administered in a palatable form. In any method allowance should be made for specially susceptible individuals. And it is very much better to hoard a limited supply of quinine for treatment than to expend it in prophylaxis. Should, under some special circumstances, as on the Ticonderoga, when the entire complement was attacked, the supply be exhausted, it is much better to resort to any simple bitter infusion, all cinchona preparations having been utilized, than permit a general knowledge of deficiencies. But a commanding officer is the ready and proper confidant in official troubles.

It was in the early eighties that the Kearsarge went to the anchorage inside Banana Point at the mouth of the Congo. She remained about 10 or 12 days and was driven from the anchorage to a point a mile outside by the malarial intoxication of members of her crew. Some of the men dropped upon the deck as if they were drunk. All rapidly recovered under very large doses of quinine and had no returns. The cases very soon ceased to appear *after a change of anchorage*, only about ten per cent. of the force having been affected.

The Ticonderoga had been at the same anchorage sometime before and remained about the same length of time. She put to sea with fever that eventually affected nearly every individual. There was the same lack of protection at the anchorage, and if quinine had been used in prophylaxis on the Kearsarge it might have been claimed that it saved ninety per cent. from any manifestation of the disease.

During the tour of inspection of the canal route by the Nicaraguan Canal Commission in 1895 there were twenty white men unaccustomed to the climate who were in the swamps about one month. They were all provided with mosquito netting, but were nevertheless repeatedly bitten. It is a curious fact that the only one who had a malarial paroxysm was the one who had resorted to quinine as a prophylactic.

In 1904 on the Isthmus of Panama many of the engineers and clerks used quinine daily in five-grain doses, and it has been stated that some of the medical officers thought that the cases of malaria from them required much larger doses of quinine in treatment, but that opinion was not uniform. Nevertheless, in 1906 and 1907 quinine, given perhaps in an ounce of rum to facilitate administration, was being used rather extensively on the Isthmus in daily doses of four grains to perhaps 2,500 people. The administration was not compulsory, but its use was encouraged especially in localities showing malarial intensity or among newcomers. It is understood that in spite of such extensive experience there was some difference of opinion among medical observers in regard to ultimate utility, though the question was not considered in an experimental stage by the controlling influence, as admissions were reduced in selected localities during time of trial.

In 1904 the Yankee received at Colon 375 officers and men of the Marine Corps who were returning home after a year's service on the Isthmus. The medical officer who was serving with them at the time stated that all had received ten grains of quinine each day for three weeks prior to embarkation. Yet during the eleven days they were on board about 3.5 per cent. had malarial paroxysms.

In this connection it should be recognized that the knowledge of malaria has done little to modify the treatment in vogue prior to discovery of cause, that in giving quinine as a prophylactic you tend to mask the frank expression of the primary paroxysm, that there are more resistant and less resistant varieties of the same parasite which may have relation to growth under the degree of opposition which decides the survival of the fittest, that the sexual forms of the aestivo-autumnal variety are the most resistant in regard to stage of development and that such forms appear rather late and may have importance in view of the teaching of Schaudinn as to development by parthenogenesis, that the continued use of quinine is not as a rule favorable to nutrition, and that, therefore, it may be practicable to accomplish more good in the long run by prompt attack of the parasites with doses of quinine sufficient to kill them than to prevent their possible multiplication in more resistant form or their development to more resistant stage before recognition.

However, the advisability of the continued use of quinine in prophylaxis will be determined by experience as its therapeutic use was determined. The weight of evidence is that in prophylaxis its primary effect is a diminution in number of admissions, but with many complaints in the long run from the effects of the quinine itself when administration is compulsory. Only by experience can it be determined whether in a year more work can be accomplished in a malarial locality by men using it in prophylaxis and whether such use diminishes mortality, the drug always to be used freely in treatment. It is undoubtedly true that the trend of opinion at this time, especially in Italy, is strongly in favor of the use of quinine in prophylaxis.

If a force afloat or ashore is temporarily exposed to marked malarial influences or if cases of malaria are occurring among such a force it seems reasonable to expect that the number of cases will be diminished by the use of quinine in prophylaxis and thus the efficiency increased during that period. The same is propably true in regard to new arrivals in such localities, but it is at least doubtful whether during more or less permanent residence in a malarial locality there will be gain in the long run by the continued use of quinine in prophylaxis. It is undoubtedly better whenever practicable, to change the location of a force by a change of anchorage or camp than to remain in the locality where malarial cases are occurring and trust to the prophylactic use of quinine. Often a slight change of anchorage and at times even of camp will give very much better results than can be obtained by the use of quinine.

Typhoid fever caused 2.07 per cent. of the total damage from disease during the ten years and about 12.71 per cent. of the deaths from that cause. Its statistics for the period have been given in Table 26. The disease on ships seems to have been very rarely if ever considered during the ten years to have been associated with question of the purity of any ship's water supply, though the chance of contamination, especially in harbor by leakage of circulating water of distiller into the condensed water which leaves the apparatus much below a killing temperature, should not be ignored. The water at the distiller should be repeatedly tested with nitrate of silver solution during each watch, such test indicating whether the apparatus is working efficiently; all water from distiller should be first collected in one of the tanks selected for that purpose, and its water as a whole should be tested in the same way before distribution.

There should be absolutely no connection anywhere between the fresh-water pipes and the flushing system, but there should be a steam connection by which the pipes can be disinfected at any time the occasion may arise. Water can always be disinfected *in situ* by use of a steam hose. Circulating water of distiller should not be passed into flushing system, as it at least unfits the supply, on account of high temperature, for general bathing purposes. Fresh water in tanks should be kept free from dust, and to that end manhole plates should be, when practicable, on the side rather than on the top and be kept tightly clamped on gaskets. If the tanks are cement washed, tendency to unnecessary cleaning will be removed. All cleaning should be under supervision as to cleanliness of manner and person and to freedom from disease. No person unless feeling perfectly well should be allowed to have anything to do with the work, and it is better, all things considered, to whitewash lightly the entire surface with good lime recently mixed. But with properly constructed tanks and careful attention and liberal use of water, the necessity for cleaning as shown by sediment should be very rare.

In all cases of extension on the ships during the ten years there was more or less doubt as to cause, opinion depending upon a balancing of testimony, all circumstantial. In fact, the different methods by which the disease may be propagated are many and one or more may be in operation at the same time. The means by which the bacillus may find admission to the mouth are so numerous that the routine care already indicated for the prevention of such diseases as tuberculosis, tonsillitis and others enumerated are just as applicable to prevention of typhoid fever. For instance, the handling of the drinking cup in common by men not all of whom, to say the least, wash hands after stool and from whom cases of the disease are obtained which at time of admission already give temperatures of 103° or 104° F; the avoidance of dust, and the care of clinical thermometers, tongue depressors, swabs used on throat cases and, more especially in this disease, of the hands of nurses, who may not only make the routine applications in throat cases and take temperatures, but who also bring from the ice machine the supply for the sick-bay and put it into a cooler from which many obtain water and from which water is drawn frequently during each day in giving medicine to men from various parts of the ship.

Typhoid fever is not in the ordinary sense a contagious disease, but in view of the concentration of men on a ship and the consequent intimate relation of one part to others it should be treated in segregation as such to the extent that is practicable, for the spread is often largely by what seems to be personal contact. While infection of water remains the most common origin of the epidemic outbreaks in civil communities, that does not seem to be the case on ships. It is true that some outbreaks have been ascribed to raw milk brought on board as on the Texas in October and November of 1898 when nearly all the 17 cases which appeared in rapid succession, with some on the same day, came from three messes in which milk obtained from one dairy was extensively used, the marines in whose mess no milk had been served remaining exempt; but generally, as on the Pennsylvania in 1906 when from about 800 men there were 44 cases with nineteen days' interval between the first and second, the method of infection was never traced.

The line of demarcation between the variety of infectious diseases regarded as non-contagious and that other variety known to be contagious is not always very definite. In any infectious disease there is a living exciting cause and the invasion may be by any route, but if that invasion is by direct association with the primary source the infectious disease is contagious. Yet in some case of scarlet fever the primary source may have been hundreds of miles away and a trunk opened by the unsuspecting may have carried the infecting agent. In a particular case of typhoid fever the primary source may have been some one who infected the water of a river many miles up stream, but another patient in the same ward may be a nurse infected by fingers that carried the infection directly from the other case. In the case of scarlet fever the infection is considered to have gained access through that material medium called the air, while in the case of typhoid fever it was transferred by the more visible material of which the finger or a fly or the food is made, or *perhaps* even by the ordinarily equally invisible though exceedingly numerous particles in the air, called dust, some of which may be fecal matter.

No hospital apprentice on a ship can prevent his fingers from becoming contaminated sometimes from the typhoid case, but he can keep them from remaining so by *never* leaving any case of fever without at once *immersing* the hands in disinfecting solution provided, washing throughly with soap and water and then reimmersing in the solution. The result will be not only greater security for himself, but also for the man whose throat he may have to swab a few minutes later, for while on any ship the members of the hospital corps may be sufficient for the usual routine work, there have been times when with night watches the duty has been more generally distributed than seemed advisable for all concerned, certainly without the strictest precautions.

No hospital apprentice is able to keep clothing, bedding and locality of patient free from some degree of contamination though the amount may be often greater than necessity requires. And the ship may be so situated that the absolute avoidance of flies may be impracticable. Every sick-bay should have wire screens for doors and ports that can be placed when required, and even when such screens are in use fly-paper should be constantly utilized and other means employed at least twice each day in a crusade against such flies as may be present.

Every typhoid patient strongly tends to foul the locality by his excreta, and unless the greatest care is exercised there may be opportunity for wide dissemination of the infection. The opportunity will be greatly limited by the use of the rubber sheet, bedside disinfection and cleanliness *especially if the measures be employed in isolation or segregation* or at least with the patient as far from others as practicable, but every case of typhoid should be transferred to hospital at the first opportunity.

In carrying out bedside disinfection the deck itself in the neighborhood should not be neglected, the disinfection of which should not be limited to known contamination by carelessness in handling a bedpan or urinal, but at least twice daily on what may appear to be a clean deck a disinfecting solution should be applied and there should be no attempt to remove dust except with the swab wet with such solution. The bacillus of typhoid leaves the infected in the fæces and in a large percentage of cases in the urine, both of which therefore require disinfection and protection from flies, but it may be present in the sputum which consequently should not be neglected. On ships disinfection of locality by fumigation as well as by disinfecting solutions after removal of case treated in isolation is too simple a procedure to be neglected in view of the extension of the disease in ways that do not seem to be well understood.

Patients sent to hospital should not be returned to duty until their effects have been disinfected and their excretions no longer contain the bacillus, and there is some evidence to show that infection may remain for months after convalescence and may even be carried by some who have never manifested the disease. Prior to the Spanish-American War little was read concerning the prevention of typhoid fever that did not rest almost entirely upon the acknowledged fact that it is a water-borne disease. Since that time contact has been made to fill a large place in explanation of method of extension.

While a pendulum swings, the evidence is certainly sufficient to lead to the conclusion that in naval life the typhoid case should be treated in segregation whenever practicable, that in the routine care of ships, water supply is not the only, if indeed the chief thing to be considered in regard to extension, but that typhoid fever comes to some extent into the sphere of those routine influences employed against communicable disease in general.

There are, however, several other phases of the question of extension of typhoid fever on ships by use of water that may not have received due attention. Much of the water supply of a ship is taken directly from over the side and the water there is also used for exercises in swimming. In almost all the ships there are salt water faucets as well as fresh water faucets at the sinks in pantries. That is for the purpose of limiting the expenditure of fresh water, the supply never being as great as is wanted. Infected harbor water would be more extensively used in pantries for washing dishes and glasses if it were not usually salt, and also perhaps making the result visibly unsatisfactory, thus adding to the labor required. It is there, however, available for such use, and the water, as at League Island, is not always salt and mess attendants are not infrequently careless. In any port where the water of the harbor is relatively fresh it is also not unknown for men in boats, in spite of caution or orders, to surreptitiously drink it perhaps when cleaning the side rather than take the trouble to slake thirst with the water provided. It was in 1896 that cases of the disease appeared on the Massachusetts at League Island, 42 days after going in commission there. The following statement was made in regard to origin: It is impossible to say whether the disease germs came aboard in the milk or fresh vegetables or from the water alongside, which was probably sometimes used by the men.

During the ten years there were also connections at bath-tubs between the fresh water and flushing systems as water from both systems could only reach a tub through a faucet in common, just as in the case with cold and hot water ordinarily in bath-tubs on shore. But on ships the pressure in the flushing system carrying raw water from over the side having been maintained by pump, was many times greater than that in the fresh water pipes fed by gravity tank, and that led at times to the backing of water from salt water pipes into fresh water pipes. *It was demonstrated to be quite possible for water drawn from a fresh water faucet in a pantry adjacent to a bathroom and used for drinking water to be a mixture of distilled water and raw water from over the side.* It is not clear that salt water faucets in pantries save the fresh water supply to any great extent and they are not safe. The supply of salt water to bath-tubs should be by independent faucet under any circumstances. It is important to avoid complication in a ship's plumbing and there should be no *chance* of a mixture of distilled water and harbor water.

Swimming is a splendid exercise and there are additional reasons why it should be encouraged in a naval service. But it has its dangers in relation to disease not only in regard to otitis, cases of which invariably appear among a crew that is taking to the water, but also perhaps to typhoid fever, cholera, or dysentery, especially when a case of those diseases is on board or, may be, even on another ship anchored as in fleet in the same line. A ship may seem to be an ideal place for the disposal of the excreta of a typhoid patient, but it is not unusual to see fecal matter floating alongside, especially at slack tide or in harbors where there is little tide. Men go in swimming from the port side, a ship swings to tide or wind and the port water-closets are fouling the water, especially the surface. When in harbor the careful disinfection of typhoid or cholera excreta may be even more necessary than on shore, but with such a case on board, especially if the sick-bay water-closet is on the port side, the men should keep out of the water, as should also always be the case when the disease is appearing on board, and at any time when swimming is to be the amusement the port water-closets of the crew should be locked at least a half-hour, depending upon the tide, before the event. Swimming should not be permitted at all except in clear water, as in harbors receiving the refuse of a people it is not safe. It is noticeable that crews indulging indiscriminately do not enjoy good health.

Cholera has much in common with typhoid fever in methods of infection. Its brief period of incubation accentuates the intensity of outbreak caused by infected water, but the methods of contact infection do not appear to differ materially from those of typhoid fever. In both diseases the infectious material is in the discharges and to take effect must be swallowed, and communication by dust seems unsupported, but while the vibrio is readily destroyed by drying, it generally takes several hours. It is another case of flies, fingers, and food, especially raw vegetables obtained from fields on which human manure has been used, as in the East, and of infected water. In regard to first cases it should be considered that it is possible for a case to be so mild as to escape all recognition or even attention and that the vibrio has been demonstrated in many healthy persons, who have been in daily attendance upon cholera cases. As in the case of typhoid fever, convalescents may continue to furnish the infecting agent for many days.

The vibrio is readily killed by an acid, especially in the presence of pepsin, but that action tends to be delayed in the presence of peptone. A healthy stomach may be a guard against infection, but dyspepsia, more common in drinkers, is a predisposing cause, as well as fatigue, worry, and food tending to diarrhœa, such as fruit not in sound condition. In the distilled water supply of a ship the vital cause of the disease would probably live generally but a short time, as in sterilized distilled water it dies in 24 hours, but in natural water it may live for weeks; yet where infected water is the cause of a continued epidemic, reinfections of the water are generally occurring. In prophylaxis Haffkine's vaccines have been used. The recent inoculations seem to protect in considerable degree, but case mortality is not reduced. In the face of this disease reliance cannot be placed in the prophylactic use of drugs, including the acids, *but in all cases at least the same precautions should be taken as in typhoid fever*.

During the ten years Shanghai, China, seems to have been responsible for many of the cases of cholera on the ships. For instance, on the Boston in 1896 the primary case appeared in a man who was infected on liberty at Shanghai. He was transferred to hospital, his effects were burned, most of the ship was fumigated with sulphur dioxide, and then the berthing spaces were washed with bichloride solution. Hammocks and clothing were aired. *But a second case* appeared eight days after the first had been transferred and the patient had not been out of the ship for a month. Three days later the third case occurred, and on the subsequent day two cases were admitted. The fumigation and washing were repeated, *all water was pumped out of the tanks*, which were then cleaned and disinfected before being again filled with distilled water, and all clothing and other articles were disinfected. No other cases occurred. However, the extension in this instance seems very much like that of typhoid in a number of instances in which the water supply was not questioned, though that bacillus can live in distilled water for months. In 1895 the one case on the Machias resulted from infection ashore at Shanghai, but on the Bennington in the same year a single case occurred at Honolulu. The patient had not been ashore for 20 days, and *it was considered that the disease was contracted by bathing in water of the harbor.* Also after that case the ship was fumigated.

Most authorities do not enjoin fumigation in connection with cholera, but very strict bedside disinfection and protection from flies and other insects. It is not necessary to burn effects, though on ships the mattress and pillow should be wrapped in a sheet wet with disinfection solution and then destroyed. But it is necessary to destroy immediately the infection in the stools, in the vomited matter and sputum, though perhaps not usually containing the infection, and on everything that has come in contact with patient—by the use of formalin or carbolic acid solutions or lime or in case of clothing, bedding, towels, and similar articles by heat. Yet cholera is a very serious disease with a case mortality of 50 per cent. and, at least in the locality where the case has been treated even for a short period, fumigation with formaldehyde or sulphur dioxide and wetting surfaces with a disinfecting solution are too simple precautions to be discarded on a crowded ship in face of the fact that in spite of every apparent caution the disease has shown a tendency to spread on the ships.

One should also remember that the first case treated is not always the first case, or the only case on board at the time, and, therefore, bedside disinfection on a ship may not destroy all the infection in the ship, in view of the fact that a man capable of infecting others may not even feel sick and there may be some other case with so little diarrhœa as not to suggest cholera, though all such cases, in the face of cholera, should be treated with all precautions.

It is always best to avoid the infected port and *if in port to go immediately to sea on the first appearance of cholera ashore* rather than remain even with liberty abolished, as it should be, and take unnecessary chances. In all ports where cholera is not infrequently found no fruit should be allowed on board or any fresh vegetables that do not have to be cooked, and raw milk is not suitable for use on a cruising ship at any time. It is, however, apparent from the statistics during the ten years given in the following table that the disease was almost rare in the Navy, especially afloat, and the damage, 0.05 per cent. of the total damage from disease, trivial.

STATISTICAL TABLE 28.

CHOLERA.[1]

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.152	.0003	.152	. .	.158
1896	.352	.0010	.070	. .	.090
1897	. .	. .	. .	. .	. .
1899	. .	. .	. .	. .	. .
1900	. .	. .	. .	. .	. .
1901	. .	. .	. .	. .	. .
1902	.352	.0017	.192	. .	.226
1903	.054	.0001	.027	. .	.029
1904	. .	. .	. .	. .	. .
1905	.242	.0004	. .	. .	.008
	.113	.0004	.037	. .	.044

[1] Prior to 1902 the small damage was confined to ships. Two-thirds of all cases occurred ashore in the Philippines. The mortality prior to 1905 was 50 per cent. In 1905 there seem to have been 10 cases without a death. The damage the service received from this disease and from yellow fever was trivial—a fact of importance showing the result of progress in sanitation and the value of vigilance.

Dysentery and diarrhœa caused 2.16 per cent. of the total damage received from disease during the ten years (dysentery 0.97 and diarrhœa 1.19). The statistics of each are given in the following tables:

STATISTICAL TABLE 29.

DYSENTERY.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000	Admission ratio force afloat	Admission ratio force ashore
			Deaths	Discharges for disability			
1895	1.51	.007	.076	.076	.192	1.9	.4
1896	1.27	.008	.070	. .	.230	1.4	1.1
1897	.95	.004	. .	. .	.080	1.0	1.1
1899	3.26	.020	.048	. .	.448	1.3	12.7
1900	8.28	.059	.210	.210	1.600	3.1	23.9
1901	5.54	.042	.074	.149	1.063	1.5	16.9
1902	5.63	.065	.160	.160	1.620	1.6	18.4
1903	3.84	.033	.162	.322	1.144	2.4	9.8
1904	1.89	.016	.025	.197	.542	1.1	5.0
1905	2.13	.031	. .	.048	.668	1.5	4.3
	3.58	.0316	.091	.132	.855	1.7	10.7

STATISTICAL TABLE 30.

Diarrhœa.[1]

(Acute and Chronic Intestinal Catarrh and Simple Diarrhœa.)

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	36.6	.041	. .	.076	.896
1896	31.7	.052	.070	.141	1.251
1897	33.4	.058	. .	.063	1.223
1899	43.2	.058	.096	.144	1.400
1900	36.7	.075	.168	.168	1.836
1901	25.9	.056	.037	.149	1.306
1902	25.0	.046	.096	.064	1.080
1903	19.3	.034	. .	.080	.760
1904	19.1	.033	. .	.098	.758
1905	16.7	.029	. .	.194	.774
	26.0	.045	.041	.109	1.048

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[1] While this table shows increased prevalence and damage in 1899 and 1900 it gives evidence that diarrhœal disorders have greatly diminished in the naval service. The purity of the water supply of ships has been maintained and the dietary has been improved. It seems probable also that the influences tending to diminish bronchial catarrhs have contributed to the diminution of intestinal catarrh.

Prior to the Civil War a ship on the Asiatic Station would have more deaths from dysentery than all the ships of the service had annually after the general introduction of distilled water. Since that change the force afloat has been relatively free from the disease that in the old days was a scourge of the sea. The history shows clearly that, as is the case with typhoid fever and cholera, dysentery is generally a water-borne disease and that *the prophylaxis is much the same.*

The large admission rate of the force ashore subsequent to the Spanish-American War, as shown in Statistical Table 29, and the relatively small changes in the rates of admission afloat indicate where the infection usually occurred, and, inasmuch as there was always a considerable part of the strength ashore elsewhere than in the tropics, the intensity of the disease among those in the tropics was undoubtedly marked. Yet, while the table shows one of the results of more intimate association with the tropics and gives some additional idea of the health of crews in contrast with the health of those ashore in tropical countries (see Tables 23 and 24), it also indicates how greatly the conditions were being improved.

The rheumatic affections caused 5.49 per cent. of the total damage from disease (rheumatic fever 2.24, chronic articular rheumatism 1.94, and myalgia 1.31). In the absence of satisfactory knowledge of the bacteriology of one or more of these diseases, prevention is based entirely upon experience as to predisposing causes. But throughout the service that experience has been sufficient to leave little doubt of the chief conditions under which rheumatic cases as a whole are multiplied. The occupation of a sailor is generally considered as in itself a marked predisposing cause, and certainly, in the case of rheumatic fever, youth predisposes to the disease.

Especially in recent years very much has been made of the relation to more protein in the daily diet than the body needs, and there is strong evidence that the Navy ration contains much more protein than is advisable for maximum strength and efficiency, if the human being is to be considered as a machine and therefore amenable to absolute control as such in regard to kind and quantity of fuel provided. During the ten years the average age of the enlisted man of the Navy was decreasing, and after 1902 the diet became more liberal, especially in protein, yet, as is shown in the following tables, rheumatic affections decreased in a marked degree, especially chronic articular rheumatism and myalgia:

STATISTICAL TABLE 31.

RHEUMATIC FEVER.

Year	[1]Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	15.9	.128	.076	.076	2.712
1896	10.9	.072	. .	.211	1.651
1897	9.5	.066	.127	.381	1.828
1899	11.4	.079	.048	.336	1.964
1900	12.1	.092	.042	.568	2.450
1901	11.3	.075	.037	.484	2.021
1902	8.5	.067	. .	.160	1.500
1903	8.8	.062	. .	.590	1.830
1904	9.4	.069	.024	.764	2.168
1905	8.1	.068	.024	.436	1.820
	10.0	.0744	.030	.449	1.966

[1] Admission rate probably influenced to some extent by errors of diagnosis in cases in which gonorrhœa was causative.

STATISTICAL TABLE 32.

CHRONIC ARTICULAR RHEUMATISM AND MYALGIA.

Year	[1]Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	33.9	.140	. .	.834	3.634
1896	30.3	.128	. .	.845	3.405
1897	26.9	.127	. .	1.271	3.811
1899	23.0	.088	. .	.768	2.528
1900	22.7	.116	. .	.568	2.888
1901	17.8	.104	. .	1.639	3.719
1902	17.1	.103	. .	1.504	3.564
1903	15.4	.070	. .	1.074	2.474
1904	14.8	.066	. .	.937	2.257
1905	14.2	.061	. .	.774	1.994
	19.2	.091	. .	1.030	2.853

[1] A marked and more or less regular decrease during entire period. But the damage-ratio suggests some relation to venereal disease in a percentage of cases. Effects of tropical cruising and dry ships shown also in table relating to bronchial diseases.

A study of these tables (31 and 32), especially if considered in connection with the results of observation within the service, discloses the fact that in our Navy the influence of climate on ship life is the controlling factor in the prevalence of rheumatic affections, but that upon the statistics as a whole the effect is not as marked in the case of rheumatic fever, which has more relation to age and which was not so markedly diminished owing to the concentration at the naval stations on our own coasts during the winter months of young men recently enlisted. The prophylaxis in our service would, therefore, seem to depend chiefly upon the limitation of the effects upon men in barracks and in ships of our own climate during the colder winter months by not having ships north during cold weather longer or more frequently than can be avoided, by providing means of properly heating the air supply and thus limiting drafts, by keeping a dry ship between decks and not wetting the upper decks in cold weather more than is necessary, and requiring every man engaged in that work or in any washing of clothes, or during a wet watch, to wear rubber boots, which must be replaced by shoes and dry socks in quarters so soon as that work has been completed; by protecting with suitable clothing, including raincoats, when needed, those necessarily exposed to weather, and requiring wet clothes to be shifted as soon as practicable; and, in overcoat weather, by having the men provided, and refusing liberty to those unprovided with such protection and suitable shoes

When a metal ship is in cold waters there is a marked tendency to loss of internal heat by conduction and the effect is marked upon those billeted near the ship's sides. Within the perceptible area of this influence the effect in general varies inversely as the square of the distance from the metal, and that effect, where there is a marked difference between internal and external temperature, and the body is in proximity, is equivalent to a draft of cold air. This great lack of equability of temperature, causing one side or part of the body to lose heat rapidly and the other slowly is emphasized in the case of the sleeper who in turning exposes alternately to the influence of the ship's metal side, surfaces warm and more or less perspiring. Cork paint properly applied lessens the effect but leaves much to be desired. On the most modern ships the use of non-conducting ceiling or sheathing on sides in connection with a dead air space has very greatly limited the chilling effect of plates, and the same ceiling with ventilated air space has markedly reduced the wild heat of ships. On ships unprovided with sheathing and which happen not to be crowded, men can be required to swing more inboard, and in officers' quarters and in sick-bays of such ships bunks should be inboard. As sheathing with wood is not allowable on a fighting ship, the use of metal ceiling covered within with cork or cork paint has been necessary and has secured a more or less satisfactory solution of the problem.

In the case of barracks the first essential is construction designed to meet the requirements as to site, air space, heat, dryness, and ventilation and the second a routine care of building and personnel that avoids wetting floors, secures clean comfortable rooms for all purposes at all times and protects the men from the effects of their own carelessness or lack of knowledge. Observation emphasizes the danger, especially in cool or cold weather, of a system of washing clothes that requires them to be scrubbed with brush on the floor or concrete. It generally means a congregation of men under unhygienic conditions—a humid room atmosphere, general exposure of soiled and sometimes infected clothing of many men in a closed space, more or less wetting by water and perspiration of clothing worn and, without rubber boots or even with them, wet feet followed often by immediate exposure to outside conditions of weather. Such a method was undoubtedly during the ten years a strong predisposing cause of disease—the rheumatic diseases and others. In these observations the similarity to those made in connection with care of barracks in relation to tuberculosis, bronchitis, tonsillitis, and diphtheria is evident. The influences that tend to increase the number of cases of bronchitis (compare Tables 9 and 32) have a similar tendency in rheumatic affections. There is a supposed connection between tonsillitis and rheumatic fever, but follicular tonsillitis is a communicable disease with strong epidemic tendencies and in the statistics of the service as a whole the relation, if such exists, is not apparent (Tables 16 and 31), the disease extending to the ships with tendency to spread in the manner of diphtheria.

Heart affections are represented chiefly in Statistical Table 5 by valvular disease and palpitation. Information of some other diseases of the circulatory apparatus can be obtained from Statistical Table 4. Inasmuch as not less than half of all cases of valvular disease are caused by rheumatism, it might be expected that with a rapidly diminishing admission rate for rheumatism there would have been a diminishing admission rate for valvular disease during the ten years, but on the contrary such was far from being the case, as is shown in the following table:

STATISTICAL TABLE 33.

VALVULAR DISEASE (HEART).

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	1.89	.038	.758	.379	1.897
1896	.98	.011	.070	.352	.642
1897	.76	.014	.127	.445	.852
1899	2.02	.017	.384	.960	1.684
1900	3.11	.019	.252	1.094	1.726
1901	2.86	.023	.335	1.451	2.246
1902	3.36	.026	.256	2.176	2.952
1903	2.25	.018	.134	1.557	2.051
1904	2.37	.018	.099	1.652	2.111
1905	3.09	.031	.024	2.565	3.206
	2.48	.022	.203	1.513	2.152

By reference to Statistical Table 3 it will be seen that valvular disease was the cause of about 17 per cent. of all surveys held on enlisted men of Navy and Marine Corps within six months of enlistment and of more than 20 per cent. on account of all disease. The conclusion is therefore unavoidable that, as in the case of epilepsy, of *tuberculosis*, and of some other affections, Statistical Table 33 also shows the increased damaging effect of faulty recruiting on an expanding service. In other words, very many of the cases of organic heart disease did not originate in the service, but were found in the service because they were not excluded at the recruiting stations. The chief measure of prophylaxis from a service point of view is therefore very evident and need not receive additional attention here. In 1895 the death rate from valvular trouble was much the greatest. In that year nearly 20 per cent. of all deaths from that cause during the ten years occurred, and it seems likely that most of them were ascribed to causes incident to service. The fact is singular but is thought to have been associated with the presence of a number of old men, some of whom were reenlisted in view of long service when near the twenty-year period that entitled them to admission in the Naval Home.

The relation of heart trouble to athletics is receiving more attention daily and would seem to require some medical supervision of those training for swimming, boxing, and boat-racing contests. Work in firerooms and coal bunkers also greatly tests the functional capacity of hearts and usually under adverse conditions that may be reduced to a mininum by careful plans for the removal of overheated air. It is true that a normal muscle is developed by exercise, the anabolism being increased by work within physiological limits. Much of the work of the heart is expended in carrying on the circulation under ordinary circumstances, and when additional demands are made its degree of ability to respond without injury to itself will depend primarily upon its freedom from disease, proper development, and the degree of coordination secured between its action and the other involuntary muscles of the circulatory apparatus which control arterial tension. The proper development of the heart depends upon exercise of the muscles within its functional capacity which under any system of exercise or work should be by tasks graded to the degree of development at that time. The ordinary difficulty, even in individuals free from disease, is that under graded tasks the loads are apt to be increased too rapidly, or ultimately made too great, as the voluntary muscles are capable of more rapid development, and perhaps even greater proportional development, than the involuntary, and thus the skeletal muscular strength and endurance become sufficiently great to incite the individual to feats beyond the functional capacity of the involuntary muscles.

Continued high arterial tension also interferes mechanically with nutrition of parts subjected to the pressure and is doubtless a prominent factor in arteriosclerosis and in the heart itself tends to damage by dilatation. The damage of hearts resulting from excessive gymnasium work, and overtraining in athletics generally, is becoming so prominent that in many quarters athletes, in not a few cases, are beginning to be regarded as those who have practically made voluntary sacrifice for the many thus incited to seek a greater degree of physical excellence through an appreciation of the high physical standard necessarily treasured and fostered by any non-decadent people. With that appreciation is also implanted the knowledge that physical excellence is closely associated with right living.

In view of the object of a navy, it is evident that the life must be one of mental and physical training in its own special work and that from physical contests, in the form of sports, is evolved much of that power of initiative necessary. The best results are, however, not generally secured without definite plan, especially when in an expanding navy there is a larger percentage of men new to the life, and every game has to be played up to if success is to be secured, and played under rules or personal initiative is carried to excess. As a general rule, the crew of a ship should improve physically with length of commission and, except in time of exigency, should not be pushed in haste to maximum tasks. Experience also shows that no man or set of men can be *kept in training* in the athletic sense—the period of maximum efficiency for a navy is the time of war and the best that should be accomplished in time of peace is to keep the physical condition within relatively easy reach of the war condition. The physical efficiency of men in firerooms and coal bunkers should be secured more or less gradually, just as the ability of an army to march is secured by graded practice. Short runs of a ship like short marches are the logical preliminaries to longer and quicker work during the process of breaking in. In time of peace certain ships could also be used for the physical training of men about the fires and in the bunkers by short runs with *sufficient additional men to shorten watches* during several months. Man has a wonderful power of adaptability, but he requires time. And in this connection the value of a policy that would keep ships from being short-handed in firerooms and bunkers is evident.

The service received during the ten years an amount of damage from palpitation greater than one-half that from valvular disease. Table 34, on the next page, gives the statistics for the period.

The table shows the recognized tendency of this affection to appear in recruits. It seems to be associated in some way with the change in manner of living which may include the use of more and stronger tobacco. Yet the cause undoubtedly varies and is often obscure. More than one-third of the cases admitted are invalided, and not a few can be traced to neurasthenia or unstable condition of the nervous system prior to enlistment. The subject is an interesting one for investigation as there does not seem to be sufficient information of just what naval influences cause so many recruits to appear at sick calls complaining of more or less precordial pain and palpitation. They represent a class as distinct as those recruits who complain of long-continued backache, many of whom are dissatisfied to the point of worry and hopeful of discharge by medical survey.

STATISTICAL TABLE 34.

PALPITATION (HEART).[1]

Year	[1]Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	1.36	.018	. .	.227	.587
1896	1.55	.014	. .	.352	.632
1897	1.21	.011	. .	.381	.601
1899	2.02	.013	. .	.336	.596
1900	2.90	.034	. .	1.263	1.943
1901	3.35	.028	. .	1.451	2.011
1902	2.21	.019	. .	.928	1.308
1903	2.33	.013	. .	1.128	1.388
1904	2.19	.017	. .	1.109	1.449
1905	2.15	.012	. .	.678	.918
	2.24	.018	. .	.883	1.244

[1]Compare this table with that of neurasthenia.

Apoplexy, hemiplegia, and **paraplegia,** while appearing in the naval nomenclature as diseases of the nervous system, have very generally a causative relation to diseases of the circulatory apparatus. Their combined statistics are given in the following table:

STATISTICAL TABLE 35.

APOPLEXY, HEMIPLEGIA, AND PARAPLEGIA.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.985	.015	.379	.152	.831
1896	.845	.009	.564	.070	.814
1897	1.080	.018	.254	.064	.678
1899	.528	.008	.384	.096	.640
1900	.884	.010	.253	.211	.664
1901	.447	.010	.112	.223	.535
1902	.320	.009	.032	.064	.276
1903	.778	.012	.295	.242	.777
1904	.296	.010	.123	.148	.471
1905	.339	.004	.145	.072	.297
	.569	.0098	.215	.139	.550

The cases returned as apoplexy were about 26 per cent. of the total number of cases included in the table. The mortality of cases returned as apoplexy was, while in the service, more than 80 per cent. The table is probably somewhat complicated by subsequent admission's of some cases of apoplexy as hemiplegia or paraplegia. That would make the admission ratio of the table rather high and the case mortality too low. The table is, however, important as it relates to diseases that produced 5.3 per cent. of all deaths from disease during the ten years.

Alcoholism, syphilis, and chronic nephritis are generally given prominent places among the causes and the rheumatic and uric acid diatheses are also regarded as having relation to those arterial changes favoring cerebral hæmorrhage. Doubtless all those causes played their part in the production of cases and it seems probable that muscular strain and exposure to excessive heat were at times predisposing causes.

Rheumatic influences were decreasing during the period and the uric acid diathesis was apparently not given prominence. The syphilitic influence was increasing, *but the percentage of older men was decreasing.* The alcoholic influence was decreasing, there was little change in the relative number of cases of chronic nephritis, and the effects of excessive heat were diminishing.

Under those varying influences the relative number of cases of apoplexy and paralysis were decreasing. In that modification of prevalence, the dominating factor seems to have been age. Owing to naval expansion the percentage of men above 35 years of age diminished and the admission ratio of cerebral hæmorrhage decreased. Such a decrease does not deny the influence of syphilis or lessen the importance of the careful continued treatment of syphilitic cases. A lâte manifestation of syphilis cannot be declared by figures relating to a force diminishing in average age. Also, while apoplexy is to a certain extent a rather late manifestation of heredity, it is at times directly dependent upon questions of morality and moderation in eating and drinking. Of course age itself tends to arterial change and probably a high protein intake assists materially in producing that result.

Appendicitis is a disease in which rheumatic tendencies, such as are expressed perhaps in tonsillitis, may play a more or less important rôle. But in the naval service during the ten years the statistics of this disease as given in the following table throw little light upon predisposing causes other than age:

STATISTICAL TABLE 36.

APPENDICITIS.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.91	.011	.076	. .	.296
1896	1.55	.017	. .	. .	.340
1897	1.27	.012	.127	. .	.367
1899	2.39	.021	.144	. .	.564
1900	2.14	.017	.043	.295	.678
1901	3.20	.029	.112	.037	.729
1902	3.84	.041	.096	.160	1.076
1903	3.54	.041	.107	.242	1.169
1904	3.45	.038	.148	.075	.983
1905	4.89	.059	.072	.121	1.373
	3.15	.034	.098	.113	.891

It appears that the records of appendicitis have been under some of the influences that affected those of tuberculosis, the tendency to make the diagnosis having increased during the period. Such a view receives some support from the fact that an average case mortality of only 3 per cent. suggests an unnecessarily high admission rate. Knowledge of the disease became more definite and the table appears to reflect the condition in civil communities where apparent prevalence of the disease greatly increased. There was, however, very probably some actual increase incident to the much larger number of minors and young adults as a result of service expansion. The admission rate was also increased to some extent by acceptance at recruiting stations of men who had been operated upon for appendicitis more or less recently, such conditions, as in the case of varicocele, not infrequently leading to complaints of inability to pull in boats without pain especially by those who may be inclined to make the most of appearances.

When there is any actual increase in relative number of cases of appendicitis, the admission rate also tends to be increased by recurrences. At any rate, as in the case of tuberculosis the record does not justify the conclusion, in spite of the enormous relative increase in cases of appendicitis, that there have been corresponding changes in naval life predisposing to that disease. The fact that there was no increase in the death rate and that nearly the smallest death rate was with much the largest admission rate are worthy of note in this connection, but may also have relation to more uniform surgical interference.

The fact that with the increase in relative number of cases of appendicitis there was also an increase in tonsillitis may or may not be worthy of more attention than the decrease in epidemic catarrh which has also been considered as having causative relation to appendicitis. There was also a decrease in diarrhœal troubles.

Varicocele furnishes an even more striking example than valvular disease of results of faulty recruiting in a rapidly expanding service. The statistics given in the following table also emphasize the fact that rapid recruiting increases the percentage of malcontents as it is during the first few months of enlistment that men unaccustomed to restraint find difficulty or develop disinclination in adjusting themselves to the new order of things, and discover that varicoceles which they have carried through hard work on shore unfit them for work afloat:

STATISTICAL TABLE 37.

VARICOCELE.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.15	.0003	. .	.076	.082
1896	.14	.0005	. .	. .	.010
1897	.89	.0050	. .	.063	.163
1899	.62	.0052	. .	.144	.248
1900	3.03	.0170	. .	1.767	2.107
1901	2.23	.0181	. .	.744	1.106
1902	1.95	.0200	. .	.256	.656
1903	2.55	.0237	. .	.617	1.091
1904	2.46	.0217	. .	.123	.557
1905	3.99	.0371	. .	.169	.911
	2.20	.0189	. .	.415	.794

The admission ratio of varicocele represents only a percentage of the cases that are seen at sick calls and treated by cross-examination and mutual understanding of the real cause of complaint, combined with the prescription for a suspensory bandage. The medical examiner at recruiting stations should recognize the difference between the mental attitude in relation to varicocele of the man enlisted and the man seeking enlistment. He should never accept under the belief that the condition can be relieved by operation because the service is not conducted on the principle of giving outfits and pay to men who from causes existing prior to enlistment are to remain in hospital for uncertain periods without making returns. Besides, the records show that of those admitted 19 per cent. were discharged from service, and at times as high as 50 per cent., the recruit often not desiring operation but, without a sufficient trial of naval life, seeking discharge.

While varicocele, myopia, and enuresis are not usually regarded as epidemic diseases, they tend to become so in quarters where they are found by recruits to be easy roads to medical survey. It was not so very unusual for men reported to have had normal vision at time of enlistment to find themselves a few months later apparently unable to do better than 4/20. Yet mistakes were made in recording vision at recruiting stations just as men were accepted with varicoceles sufficiently large to have impressed their minds unduly.

However, a certain percentage of increase in admissions for varicocele may be considered due to the increasing tendency during the period to relieve by operation, such operation, nevertheless, having relation to faulty recruiting, as a rule. In general, the history of varicocele during the ten years shows the effect of expansion upon naval vital statistics, but the large number of cases reaching the hospitals and the small number of discharges in 1904 and 1905 show that operation has to a very great extent taken the place of discharge. Of 118 cases admitted to naval hospital in 1905 four were discharged from service, a result tending to show increasing tendency to operate and increasing disciplinary control of cases in relation to operation.

Hæmorrhoids caused damage nearly equal to that of varicocele (Statistical Table 5), but as appears from the following table without as much change from year to year:

STATISTICAL TABLE 38.

HÆMORRHOIDS.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	3.8	.025	. .	.152	.652
1896	5.2	.031	. .	.211	.831
1897	4.1	.019	. .	.064	.444
1899	3.8	.016	. .	.192	.512
1900	4.7	.027	. .	.253	.793
1901	3.8	.024	. .	.298	.778
1902	5.1	.033	. .	.384	1.044
1903	4.4	.030	. .	.349	.949
1904	5.2	.028	. .	.197	.757
1905	5.2	.029	. .	.097	.677
	4.6	.0274	. .	.230	.778

The condition was never during the period a marked cause of discharge, averaging 5 per cent. of cases and in 1905 less than 2 per cent. There were as many discharges in 1899 from 79 cases as there were in 1905 from 215 cases. It is not clear what influences were most prominent in affecting the admission rate. The conditions included under hæmorrhoids may be due to a number of causes, but the chief source of such trouble is the prolonged presence of fecal masses in the rectum resulting, as a rule, from neglect of personal hygiene, though, as in some cases of weak digestion, hereditary tendency seems at times to be an element and to make precautionary measures earlier in life more imperative.

To any one showing a tendency to hæmorrhoids the following advice seems appropriate: Avoid the use of alcoholics and food not readily digested, take some exercise daily, secure a bowel movement every 24 hours, but endeavor to accomplish that result at night just before turning in rather than in the morning after breakfast, and take a general bath every morning on turning out during which cleanse the anus thoroughly with castile soap and water.

To secure the bowel movement so necessary in prophylaxis it is better to avoid purgatives and to put faith in drinking water and the habit of invariably going to stool at the time prescribed, thus educating the rectum to empty itself without much straining. In using water for the purpose it is best to take most of it four or five hours before bedtime and to keep one's thirst as much as practicable until that time, the amount depending largely upon the amount of perspiration lost by the body during the day, and taken if most agreeable with the last meal in spite of its supposed interference with digestion. Persons leading a sedentary life can usually teach themselves to avoid drinking, after the orange juice, if practicable, and the cup of tea at breakfast which in these cases is to be much preferred to coffee, until evening and then the thirst is usually a sufficient guide, though the total amount taken in convenient quantities should not be less than a pint even in cold weather. Before turning in it is also well to take a glass of water unless repeated experience demonstrates that the amount is large enough to cause desire to micturate before the usual time for turning out after sleeping comfortably warm. Generally with the water at bedtime bicarbonate of soda is advisable, especially if stools tend to be offensive or there is tendency to fermentative acidity. The soda may be taken as 20 to 30 grains dissolved in the water or more conveniently as soda-mint tablets in equivalent amount.

It is best for such individuals to keep the body surface *rather* warmer than others, both night and day, and to make the first meal simple if it is practicable to use a liberal menu at the last meal from which has been excluded such articles of diet as close observation has be to demonstrated against the best interests of the stomach. In such cases a moderate amount of smoking may be advisable, especially if the stomach tends to feel food a short time after ingestion. At any rate, an after-dinner cigar without coffee or tea generally tends to facilitate the night stool and may be utilized by those individuals to whom the habit is not objectionable.

While at stool, sufficient time should be given to permit the act of defecation to be entirely completed. It should be remembered that the mass of fæces which perhaps has descended into the rectum a short time before going to stool does not ordinarily represent the entire amount awaiting expulsion and that usually a little additional time will permit the rectum to receive material released by the muscularis, and which if not expelled at that time will remain in the rectum ordinarily for 24 hours when nature intended that organ to remain free from any accumulation during the normal interval between evacuations.

In relation to hæmorrhoids as well as to the general comfort of the men it is very advisable for every ship to afford proper facilities for each member of a crew to have access to the water-closets at such time as may represent the termination of the normal interval between evacuations in his case. To that end the total seating capacity of the crew's water-closets should not be less than 5 per cent. of the crew complement, and cleanliness should be the rule at all times. Urinal troughs should be provided, toilet paper supplied, and it should be a punishable offense to drop anything upon the floors or seats. In the construction and management of a crew's water-closet there should be continuous flushing without splashing if a trough is used, and the trough should be so shaped as not to facilitate the catching of fecal matter and, from smooth internal finish, not to hold it. It is best not to have individual seats in the case of a trough, but to have all woodwork removable and readily scrubbed. With concrete floors, facilities for use of steam hose, a proper routine, exhaust system of ventilation, and two heads, those parts of a ship can be kept free from at least much of the objection to which such places tend to give rise.

Hernia may be considered at this time to advantage, especially if the statistics given in Table 39, which appears on the next page, be considered in comparison with those of varicocele.

In our naval service hernia is not considered a disease, but an injury. It therefore does not appear in Statistical Table 5, but its relative position in the scale of damage can be readily calculated from the data in Statistical Table 4. Although the condition caused no death during the ten years, it damaged the service nearly as much as pneumonia and typhoid fever together and more than the malarial diseases. It caused nearly four times as much damage as dysentery, and nearly half the damage of tuberculosis with which in connection with percentage increase it may be compared (Statistical Table 8), as the intention at recruiting stations is to exclude all cases of both, and the increase in each is intimately associated with recruiting. It is not clear that naval life has been any more conducive to increase in the one than in the other.

STATISTICAL TABLE 39.

HERNIA.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	3.33	.028	. .	1.137	1.697
1896	3.52	.032	. .	1.479	2.119
1897	4.06	.047	. .	1.652	2.592
1899	4.37	.058	. .	2.257	3.417
1900	5.77	.069	. .	2.104	3.484
1901	5.21	.063	. .	1.786	3.046
1902	5.60	.084	. .	1.792	3.472
1903	5.58	.089	. .	1.449	3.229
1904	5.05	.073	. .	1.849	3.309
1905	5.45	.087	. .	1.404	3.144
	5.05	.0704	. .	1.698	3.107

In navies prior to 1815 all drinking water was carried in casks of which on each day a sufficient number had to be hoisted from the hold. *At sea* in the ships of that day such work was not infrequently the hardest and most dangerous duty of seamen and, next to pressure on the abdomen while lying on yards in furling sails, was believed to be the most potent factor in the production of hernia. But in this period both of those causes are inoperative and from a study of cases it would be difficult to find causes that have taken their place.

The common use of the steam launch as the running boat and as towing boat for stores has tended to diminish work at the oars, and while work in the firerooms and coal bunkers has been regarded as causative in some cases, it does not appear to have been particularly potent or more so than coaling ship. A number of cases have been attributed to going up or falling down ships' ladders, but in most of those cases the condition of the inguinal canal on the unaffected side would seem to declare predisposition.

Not a few hernias seem to originate, and do originate, in the service, but many are either due to marked predisposing conditions at time of enlistment or at times even to reappearances subsequent to enlistment. But the work of the examiner at recruiting stations is far from easy in relation to predisposing causes, as a very large percentage of men who may seem to have relaxed inguinal rings never develop hernia, and the question of impulse is one of judgment, but should cause rejection on reasonable suspicion. He is endeavoring to exclude all hernias and realizes that subsequently malingering can have no place, but his attitude toward varicocele is to accept such as he thinks will not give trouble under the realization that the condition can be used to give expression to discontent with naval life.

In Statistical Table 3 it will be seen that in 1905 nearly 6 per cent. of all medical surveys held within six months of enlistment were on account of hernia. They were about 40 per cent. of all discharges during the year for hernia and more than 10 per cent. of the cases, but did not represent the total number associated with recruiting, especially as operations for radical cure were common. The radical operation is a preventive operation and belongs to the domain of prophylaxis in surgery. In a case in which the alcoholic habit is marked the truss will often give better result than operation, but at least no enlisted man should remain in service with hernia as in view of the character of the duty it should be cure or discharge.

Alcoholism is another state which is not classed among diseases in the naval nomenclature, but in Statistical Table 4 it will be found under "Poisons." The abuse of alcohol is more evident in courts-martial records than in the records of sick, but the medical statistics for the ten years are given in the following table:

STATISTICAL TABLE 40.

ALCOHOLISM.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	14.2	.023	.152	.076	.688
1896	14.1	.017	.211	.211	.762
1897	11.9	.016	.381	.127	.828
1899	9.2	.010	.192	.192	.584
1900	10.4	.017	.167	. .	.507
1901	8.6	.011	.149	.112	.481
1902	7.9	.008	.256	.064	.480
1903	6.6	.009	.054	.134	.368
1904	6.4	.009	.074	.197	.451
1905	6.9	.009	.048	.048	.276
	8.6	.0117	.143	.109	.486

The table is only an index and therefore does not indicate actual prevalence, but merely relative prevalence. It, however, declares that the use of alcoholics greatly diminished during the ten years—a conclusion in accordance with observation. A man is rarely admitted to the sick list because he is drunk, but only, as a rule, when he remains unfit to do required duty after having been intoxicated. A person diseased or injured while under the influence of liquor is admitted with the disease or injury and not with alcoholism. In the consideration of any statistical table the first essential is an understanding of what the figures are intended to mean. In Statistical Table 40 the admission ratio 6.9 for the year 1905 does not mean, for instance, that during that year there were only 6.9 persons in each 1,000 of men in the service who at any time during the year were intoxicated or drunk. It is intended to mean that of every 1,000 men there were 6.9 cases of unfitness for duty, from the after-effects of alcohol, as a rule, in men expected to do duty in accordance with naval routine. If a man who had not been on liberty was found under the influence of liquor he was subject to the laws of the Navy in relation to discipline and put in confinement, not on the sick list. If a man returned on time from liberty under the influence of liquor he was not confined unless disorderly, but was allowed to sleep off the effects, perhaps under sentry's charge for safekeeping.

The men admitted to the sick list on account of alcoholism were, as a rule, such as presented themselves because on account of debauch they were unable to do duty, and some who might be considered in danger from the direct effects of alcohol. Under such limitations the admission ratio is not a measure of the amount of alcohol consumed in general, but rather an index of relative tendency to drunkenness during the different years. It cannot be used with reference to other naval services in the determination of relative *amounts* of alcohol consumed. For instance, in our service there seem to have been 50 admissions per 1,000 of force for alcoholism to 1 in the German navy and about 10 to 1 in the navy of Great Britain. But that cannot be taken to mean that there were 50 or 10 times as much alcohol consumed per man. In fact, it seems highly probable that there is much more alcohol consumed per man in foreign navies than in our own, inasmuch as alcoholics have been excluded from our canteen for many years and the opportunity to drink is present, as a rule, only when on shore; while in most foreign navies alcoholics either form a part of the daily ration or are sold on board and there is the same opportunity to drink on shore. When alcoholics are served daily on board there is little opportunity on account of limitation of amount to show alcoholism, although the *total* amount consumed during the year may be large, and such consumers when on shore have available the additional degree of resistance to the effects of the drug, less inclination to excess especially with companions, more knowledge of individual resistance and, if an habitual consumer of beer, a disinclination, as a rule, to consume spirits.

It also seems not improbable that the American sailor has more money to spend on shore, which with the multiplicity of saloons conveniently placed greatly facilitates the system of treating and accentuates the tendency in company to displays of generosity. All sailors ashore are in the class of unknown travelers. There is an absence of home ties and of that propping which few recognize, but to which many are subjected as known members of a fixed community, and there is an inclination for men to remain together in groups for various causes.

The effect of prohibition on amount of drunkenness where there is occasional chance for abuse, as there always is, is well shown in the above table and the comparison with other navies. There is great opportunity on ships to prevent the use of alcoholics on board and in our service very little is ever consumed there by any member of a crew and then only by difficult smuggling in port or very occasional forced access to alcohol kept for making shellac mixture. Yet apparently a much larger proportion of men are made sick by alcohol in our service than in other naval services.

From the point of view of general efficiency a satisfactory conclusion may be difficult. It seems to be mainly a question of the nature of the balance between the habitual use of alcohol in regulated quantity and general abstinence with occasional abuse leading to unnecessary and greatly increased exposure to cause of disease and injury on shore. In men unaccustomed to the use of alcohol its use even in moderate quantity while at work diminishes, as a rule, the quantity and value of prolonged work, and it has seemed that such men receiving alcohol on the completion of work, such as a watch in the fireroom, are not, as a rule, as well fitted to take up work at the next watch. There was no experience during the ten years in our service of effects on work of habitual use of alcohol in regulated quantity and it would require an exhaustive inquiry under very adverse conditions to arrive at satisfactory conclusions in that respect or to determine the effect on general health by comparison of our vital statistics with those of other services.

The general conclusion from a service point of view may seem to be that prohibition tends to increase the number of intoxications, inasmuch as the service in which there have been prohibitory laws, for perhaps 40 years apparently returns the largest number of cases of alcoholism. The table, however, also demonstrates that either the abuse of alcohol diminished greatly in a rapidly expanding service or that since the Spanish-American War there has been less opportunity for liberty. It seems probable that both have been factors, though observation declares the former to have the greater value and that the service as a whole showed improvement during the entire ten years.

Few medical officers would advocate a return to the days of grog, but not a few claim that the sale of beer would diminish intoxication among men who are not, as a rule, total abstainers from choice. Statistics appear to substantiate that view. It seems to be conceded, however, that he who takes a few drinks of spirit every day suffers in the long run more than the man who occasionally drinks more, and it appears in comparison of our navy with that of Great Britain that the regular issue of spirits also diminishes intoxication. It would seem, therefore, that the advocates of the sale of beer on ships are endeavoring to effect a compromise and base their advice upon the relative harmlessness of alcoholics not the result of distillation as well as upon their demonstrated greater influence in the diminution of drunkenness. They also claim that the ability to obtain the lighter drinks tends to produce contentment among those men who feel that they are deprived of choice and the more or less common privilege of those in civil life. That view has its force and is indeed responsible for tobacco and the liberal ration in the Navy, as in every naval personnel resulting from voluntary enlistment comparison with conditions in civil life are important. Yet, it may be doubted whether prohibition affects rate of enlistment, especially as it appears that an increasing rate lessens intoxication.

However, as a practical problem in naval hygiene the question, like that of the venereal diseases, is to a very great extent outside of naval control depending upon the dominating influences in public control. In regard to venereal diseases public sentiment does not permit the acknowledgment of the existence of the prostitute, while in relation to alcoholism there is a widespread influence to prevent the manufacture and sale of alcoholics. It recognizes the influence of alcohol because the people see the drunken, know the poverty, read of the crimes, and support the criminals and the insane to a great extent.

So far as the problem from a practical point of view lies within the domain of naval hygiene, the following service influences may be regarded as lessening intoxication: Fostering a spirit in opposition by placing a premium on sobriety, through a system of rewards for the sober, by giving ratings and the most desirable duty only to the sober and efficient, and by extending their privileges as in more frequent and much more extended leaves when opportunities occur, thus making the standing of such men dependent in great degree upon steadiness and trustworthiness, and placing them as not only worthy of imitating, but worth while to imitate; by getting the men out of ships that happen to be at anchor in harbors not affording opportunities for regular liberty, thus encouraging them to engage in sailing races, seine-hauling, beach bathing, fishing, and sports on shore; by providing place in the various navy yards and encouraging the men to give some entertainments there under their own auspices, ship's or navy yard band furnishing music, thus affording men of good conduct opportunities to make returns for kindnesses received and to emphasize distinctions between desirable and undesirable companions; by recognizing that the period of liberty is the time away from work and the feeling of restrictions—the period of amusement for which other places should be conveniently available than the saloon and resorts for which guides under the pay of others are seeking customers—and thus the advisability of enlisted men's clubs, perhaps in the navy yards and therefore erected and equipped by Government appropriation, but with the men themselves having a requisite measure of control by responsible boards of managers; by encouraging the various associations established in the cities for the comfort, instruction and entertainment of men of the service; by such associations, service papers, and other available influences engaging in a creation of public sentiment that the location of saloons with reference to navy yards should be within the law applicable to schools, and by some authoritative devising of means by which a government undertakes to secure testimony in its own country against any engaged in placing the sailor in a disabled condition for the purpose of robbing.

In Statistical Table 40 the figures are intended to relate to the effects of ethyl alcohol, but it seems quite probable from consideration of the death rate that records have included some of the cases of wood-alcohol poisoning that belonged in accordance with nomenclature under another heading. For some time during the period wood alcohol was used on the ships for mixing shellac and there are methods of separating the alcohol from the mixture. Methyl alcohol has also been used rather extensively on shore in making a number of toilet articles, including some bay rums, and it was not unknown for such preparations to occasionally find their way on board. Deaths from methyl alcohol were not so very rare during the period. For instance, from a cursory examination it appears that on the Montgomery in 1899 a man returned from liberty under the influence of liquor, continued his debauch by taking wood alcohol from shellac, and died; on the Wisconsin in 1901 there was a death from the same cause, and at Naval Station Dry Tortugas in 1904 a private marine, who had been for some time a hard drinker at every opportunity and would when intoxicated drink bay rum and toilet waters, procured a quart of wood alcohol and drank it at intervals during 36 hours. He died as the others after a period of total blindness.

Gastritis may also have some relation to records of alcoholism, as the large majority of cases are acute and not infrequently associated with liberty, though generally ascribed to dietary indiscretions. With a marked diminution in bronchial and intestinal catarrhs the following table shows there has been little change in the relative number of gastric catarrhs:

STATISTICAL TABLE 41.

GASTRITIS (AND DYSPEPSIA).

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	6.9	.014	. .	. .	.280
1896	8.1	.026	. .	.282	.802
1897	7.5	.023	. .	.127	.587
1899	9.9	.030	. .	.144	.744
1900	9.2	.027	.042	.210	.792
1901	7.2	.028	.037	.484	1.081
1902	8.3	.031	. .	.416	1.036
1903	7.6	.025	. .	.322	.822
1904	7.9	.025	. .	.246	.746
1905	6.8	.021	. .	.145	.565
	7.8	.0257	.007	.264	.785

These stomach disorders damaged the service as much as diphtheria and had half the importance of pneumonia, but admission ratios are much too small to express even the amount of discomfort caused by cooks. During the entire period there were many medical reports calling attention to the needs for better cooks and warmer, and thus more appetizing, food.

In every naval service there should be a school of cookery where under expert instruction men are taught how to make the most of the navy ration with such appliances as are practicable on ships. While great advances have been made in variety of material to be cooked and in appliances, it does not appear in modern navies that a corresponding advance has been made in the ability of the men who do the cooking. In the old days there was small comfort at meals with tarpaulin spread on deck, but that difficulty has been overcome by the use of folding tables and benches stowed overhead when not in use, and by much more liberal supplies of mess gear. A further advance should be made by providing good cooks of naval food, hot food on tables, and sterilized mess gear and dish cloths.

It seems advisable to state that coppers and coffee kettles should not be brightened by the use of any poisonous substance. On the Independence in 1899 a private marine while recovering from the effects of an alcoholic debauch accidentally swallowed a portion of a solution of oxalic acid contained in a mess bowl which the ship's cook had put in the galley preparatory to cleaning the coppers. On the Yankee in 1904 more than a dozen men from one mess suffered from poisoning produced by drinking coffee poured from a kettle in the spout of which there was a portion of the Putz Pomade that had been used in brightening the outside. Fine brick dust on a damp cloth may be used for such purposes, but special supervision is required to prevent men from using on mess gear dangerous material then so extensively employed on ships in cleaning bright work. But, bright work is disappearing from ships.

It seems to be generally recognized that the meal hour should be respected, every man being entitled, so far as exigencies of service permit, to sufficient time in which to ingest food without undue haste. Undoubtedly stomach troubles would be greatly diminished if men could be brought to cultivate the habit of thorough mastication. It cannot be denied that the very large majority of men bolt their food and that the practice not only leads to the consumption of too much food, especially protein, but also to reception by the stomach of material in such coarse division that from a purely mechanical point of view the digestive organs are unable to reduce even the requisite amount to a state suitable for absorption without undue labor against which they often rebel. Such a practice is most uneconomical from the body point of view, as the time the food is within the mouth is the period of opportunity to secure that correlation of functions necessary for the proper coordinate action of the digestive apparatus. The man who avails himself of the opportunity also adjusts the total amount of work to the capacity, secures more nourishment, and greater strength, and at the same time greatly lessens the work of the body in disposing of material.

Yet, it is difficult to see how these facts can be brought home to the average mind, or how even if the knowledge were acquired it would make much difference in naval practice except in a percentage of the cases already showing distress. The attempt to teach proper mastication is much like the attempt to teach grammatical speaking to those who have formed the other habit of speech around the home table. Yet, in all cases of dyspepsia or gastric catarrh, however trivial they may seem, the medical officer has opportunity to not only instruct in regard to articles of diet, but also to impress with the necessity for thorough mastication. It seems not improbable that if the majority of persons could be induced from youth to thoroughly masticate their food the circulation within and about the teeth would be so greatly improved that there would be less need of dentists and more chance of future generations having the incisors and grinders with which nature equipped the race.

Nephritis in its statistics for the ten years given in the following table showed about as little tendency to change in relative number of cases as gastritis:

STATISTICAL TABLE 42.

NEPHRITIS.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	1.29	.030	.530	.227	1.357
1896	1.12	.018	.282	.070	.712
1897	1.58	.021	.254	.381	1.055
1899	1.49	.020	.096	.336	.832
1900	1.72	.022	.379	.084	.903
1901	.93	.014	.112	.298	.690
1902	1.47	.017	.288	.256	.884
1903	1.39	.012	.188	.322	.750
1904	1.48	.017	.172	.271	.783
1905	1.84	.019	.266	.436	1.082
	1.47	.0178	.2378	.279	.873

The etiology of nephritis is generally as obscure in naval life as it is in civil communities. About 41 per cent. of all cases were returned as acute. Exposure to cold and dampness seems to have been a decreasing factor inasmuch as rheumatism and bronchitis were diminishing during the period. Syphilis and malaria are generally considered rather rare causes, and while the habitual use of alcoholics is ordinarily regarded as a predisposing cause, it could not have been very much of a factor in the service in view of prohibitory laws, except perhaps to a certain extent in the case of stewards. Besides there was decrease in relative number of admissions for alcoholism. Young adults are more commonly affected and the average age of the personnel was decreasing. In general the engineer force was becoming more important during the period, and there is evidence to show that exposure in firerooms was a causative factor. One ascertainable factor in connection with the statistics is the recruiting influence, and it seems that about 10 per cent. of cases were discovered within six months of enlistment. The influence of food preservatives is not apparent from the records, as under service conditions it would be difficult to establish connection in that direction between cause and effect. Besides, with increasing facilities for cold storage, fresh foodstuffs should have been more common during the period.

There is a growing belief that the excessive protein diet so common in nearly all walks of life in our country predisposes to nephritis by the large amount of work it requires of the kidneys. The navy ration is rich in protein, and the amount was greatly increased in 1902, the average daily consumption per man from that date until the end of the period having been about 151 grams. It cannot be definitely deduced, however, from the statistics that the change increased the relative number of cases of nephritis, as in 1897, 1899, and 1900 when the amounts were smaller the admission ratios were higher than in any subsequent year except 1905. The possible relation is, however, worthy of consideration and represents a problem that the statistics of future years may help to solve. The great importance of information of etiology is declared in Statistical Table 4, where it appears that the average death rate from disease was 4.038 and from nephritis 0.2378. In other words, nephritis caused nearly 6 per cent. of all deaths from disease.

Certain diseases, such as scarlet fever, measles, and diphtheria have relation to nephritis, and during the period, as will be seen by reference to the proper tables, such diseases were increasing. The nephritis under those circumstances is, however, generally a part of the case, but when such diseases are prevalent the statistics of nephritis may be influenced by cases considered to be sequelæ.

Thermic fever and **heat exhaustion** in a navy also perhaps have some relation as a predisposing cause to nephritis. About 90 per cent. of all troubles ascribed to heat come from a part of the service—the engineer force in cruising ships serving under conditions that put a large load on the kidneys while depriving them of the fluid necessary to flush themselves properly. The result is a great concentration of irritating urine and perhaps even anuria if, while the body is bathed in warm sweat, there is a sudden checking of perspiration and rapid chilling of bodies under ventilators or fans.

In studying the following table it is very necessary to realize that while the admission ratio applies to the whole service, including of course the Marine Corps, the cases came chiefly from firerooms and coal bunkers, and that even where ratios are given for cruising ships the cases came almost entirely from only those parts of crews working below, the figures, therefore, being very much too small to indicate the intensity of such troubles among those about the fires of ships:

STATISTICAL TABLE 43.

THERMIC FEVER AND HEAT EXHAUSTION.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000	Admission ratio cruising ships
			Deaths	Discharges for disability		
1895	6.97	.0074	.076	. .	.224	9.92
1896	4.16	.0059	.070	. .	.188	5.12
1897	5.15	.0069	.063	. .	.201	7.08
1899	7.39	.0124	.048	.048	.344	10.26
1900	5.39	.0085	.210	. .	.380	6.02
1901	3.53	.0064	.037	.074	.239	5.18
1902	3.04	.0044	.032	.032	.152	4.68
1903	2.52	.0024	.054	.027	.129	3.92
1904	2.27	.0045	. .	. .	.090	2.96
1905	3.87	.0049	. .	. .	.098	4.98
	3.96	.0059	.049	.022	.189	5.46

These conditions, unlike the malarial and venereal diseases, dengue, and many others, originate for the most part on the ships and are therefore distinctly due to naval life. The admission ratios in the last column of the table are not only made up, in very large percentage, of cases from the engineer force, but also chiefly from only a part of that force—firemen and coal-passers. If it is desired to apply the ratios to the last-named it seems probable that the figures of the final column should be multiplied by about 10. Such a result would approximate the admission ratio per 1,000 of firemen and coal-passers, but would still fail to give a reasonable conception of the *intensity* of conditions in firerooms of ships *underway*, inasmuch as more days were passed in port than at sea where practically all the admissions occurred. It seems probable in the ten years of peace that in the ships *at sea* the admissions per year of firemen and coal-passers for heat affections was at the *rate* of about 40 times the figures in the last column of the table. That is, for instance, if during the year 1905 all the firemen and coal-passers had been at sea the entire time, there would have been about 200 admissions for heat troubles from each 1,000 firemen and coal-passers so employed, and in the year 1899 about 400, *other conditions remaining the same.*

The intensity has relation, however, to atmospheric conditions while underway and to the course of the ship in relation to wind, high outside temperature with high relative humidity and relative state of calm producing the maximum result. The hearts and kidneys and stamina of men, if much speed is maintained, are then greatly tried, especially if new men, some perhaps not well selected, are working as coal-passers. It would, therefore, seem that, in a general way, tropical cruising, especially in our summer months, and an increasing percentage of recruits in the engineer force tend to that condition in the service known as heat prostration. For instance, the records show that in 1898, when, owing to the Spanish-American War, there were a relatively large number of recruits and several summer months of general tropical cruising, though chiefly at reduced speed, the admission ratio for cruising ships was 29.4, or nearly 3 times the maximum of the table.

There were some very hot ships engaged in that war, notably the Cincinnati, Puritan, and Amphitrite, and there were some firerooms in which it was difficult to keep men at work; and the fireroom is a very important part of a ship, especially in war. The table, however, distinctly declares that during the ten years the firerooms were being greatly improved. It is also believed that during the time there was increasing attention given to the degree of physical development of applicants for enlistment in the engineer force, the recruiting officer having eventually no discretion in waiving departures of weight, chest measure, and expansion from the prescribed standard such as he could within limits in other cases.

It is noticeable that the forms of heat prostration common in navies does not greatly threaten life, as the case mortality was a little over 1 per cent. and not a few of those deaths were not traceable to firerooms, as each year there are some deaths in the force ashore from the common form of heat stroke in civil communities. The large majority of cases on ships are characterized chiefly by cramping of the voluntary muscles associated often with excruciating and disabling pain. The condition is one inviting investigation. It is primarily due to excessive physical work in heat, but it is not clear that it is due to the direct effect of heat as it is apt to be precipitated by sudden change to assisted or forced drafts though not uncommon in any unusually hot fireroom. Undoubtedly the prophylaxis is found primarily in careful selection of the men intended for work as firemen and coal-passers and the proper ventilation of the spaces in which they work with a view chiefly to the limitation of wild heat and the removal of overheated air. In that ventilation, properly placed and assisted exits are of unusual importance as well as a recognition that air from inlets tends to travel in a direct line to the furnaces and thus greatly facilitates the banking of hot air above the line of the furnace intakes, presenting a special problem in ventilation and also a question of construction on metal ships as the heat, especially perhaps in the wake of boilers, tends to find its way to sleeping-quarters and to dominate the condition of their contained air in tropical cruising.

Diseases of the cutaneous apparatus, non-parasitic and non-venereal, caused as a class about 5 per cent. of the total damage from disease (Statistical Table 4), greatly exceeding the damage from diseases of the visual apparatus, and nearly equaling that from diseases of the respiratory apparatus. They were responsible for loss equal to 45 per cent. of that caused by all diseases of the nervous system, to 62 per cent. of that from diseases of the digestive apparatus, and to more than 81 per cent. from diseases of the circulatory apparatus. They had an importance equal to 67 per cent. of that of tuberculosis and caused damage considerably greater than typhoid fever and pneumonia together.

Abscess, ulcer, eczema, and furuncle were most important diseases of the class and their statistics for the ten years are given in Tables 44, 45, 46, 47 and 48 on following pages.

Measles, mumps, scarlet fever, small-pox, yellow fever, and cholera, by virtue of their striking characteristics and intense local demands, obtain attention by force, as it were, but it is well to observe that all those diseases together did not damage the service during the ten years as much as abscess—a single disease of the cutaneous apparatus. The service suffered more injury from abscess than from pneumonia and, considered together with furuncle, more than from typhoid fever. These four simple diseases of the cutaneous apparatus—abscess, ulcer, eczema, and boil—damaged the service as much as measles, mumps, scarlet fever, small-pox, yellow fever, cholera, and typhoid fever together, did half as much damage as tuberculosis, and more than four times as much as diphtheria.

The epidemic diseases have claimed the attention of mankind, and great advances have been made in their prophylaxis, but the naval record emphasizes the importance in the service of the study of diseases of the skin. Extreme care is taken to destroy the morbific agents of the epidemic diseases, but it does not seem that as much attention is given to avoid the dissemination of the agents of suppuration by cleanliness, local disinfection, careful dressing and immediate proper disposal of old dressings. A pus case, especially of hands or feet, however trivial it may be, is worthy of close attention on a ship where the concentration of men is necessarily great and handropes, oars, and other parts of the equipment so frequently come in contact with human bodies. Tendency to formation of pus may also become apparent in sick quarters at times, and there is reason to believe that there is not sufficient routine disinfection by fumigation of operating-rooms and other parts of ships set aside for the treatment of sick and injured. The time may come when there is recognition that, in spite of all effort on the ship, the concentration of human beings tends to develop tendency to disease and, therefore, the ship as a whole should be as regularly disinfected as docked and that no ship should be commissioned in time of peace until all construction work has been completed and the vessel has been thoroughly cleaned and disinfected. *For it is the constantly acting and often small adverse influences that cause the greatest loss* rather than the striking and crippling effects resulting from the occasional visits of the epidemic diseases.

STATISTICAL TABLE 44.

ABSCESS.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	22.36	.056	. .	.076	1.196
1896	20.22	.048	. .	. .	.960
1897	22.94	.076	. .	. .	1.520
1899	20.84	.063	. .	.240	1.500
1900	22.81	.078	. .	.084	1.644
1901	22.85	.072	. .	.074	1.514
1902	22.86	.081	.032	. .	1.652
1903	23.65	.081	.054	.134	1.808
1904	20.49	.078	. .	.024	1.584
1905	23.94	.078	.024	.072	1.656
	22.43	.074	.0151	.072	1.568

STATISTICAL TABLE 45.

ULCER (CUTANEOUS).

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	5.38	.030	. .	. .	.600
1896	4.15	.029	. .	. .	.590
1897	4.13	.032	. .	.254	.894
1899	5.14	.035	. .	.240	.940
1900	6.36	.033	. .	.168	.828
1901	4.88	.035	. .	.149	.849
1902	5.22	.031	. .	.032	.652
1903	5.39	.034	. .	.080	.760
1904	5.00	.034	. .	.049	.729
1905	4.36	.029	. .	.121	.701
	5.02	.0324	. .	.105	.753

STATISTICAL TABLE 46.

ECZEMA.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	2.35	.016	. .	.076	.396
1896	3.03	.025	. .	.282	.782
1897	2.22	.013	. .	.063	.323
1899	3.94	.022	. .	.096	.536
1900	3.37	.026	. .	.299	.819
1901	3.94	.024	. .	.223	.703
1902	3.68	.021	. .	.160	.580
1903	2.89	.023	. .	.268	.728
1904	2.79	.013	. .	.123	.383
1905	2.39	.019	. .	.048	.428
	3.07	.020	. .	.166	.566

STATISTICAL TABLE 47.

BOIL.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	16.22	.024	. .	. .	.480
1896	14.37	.023	. .	. .	.460
1897	14.99	.025	. .	. .	.500
1899	12.87	.022	. .	.048	.488
1900	10.48	.019	. .	. .	.380
1901	12.02	.024	. .	. .	.480
1902	11.01	.021	. .	.032	.452
1903	12.00	.014	. .	. .	.280
1904	12.08	.020	. .	. .	.400
1905	10.91	.019	. .	. .	.380
	12.17	.021	. .	.007	.427

STATISTICAL TABLE 48.

ABSCESS AND BOIL.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	38.58	.080	. .	.076	1.676
1896	34.59	.071	. .	. .	1.420
1897	37.93	.101	. .	. .	2.020
1899	33.71	.085	. .	.288	1.988
1900	33.29	.097	. .	.084	2.024
1901	34.87	.096	. .	.074	1.994
1902	33.87	.102	.032	.032	2.104
1903	35.65	.095	.054	.134	2.088
1904	32.57	.098	. .	.024	1.984
1905	34.85	.097	.024	.072	2.036
	34.60	.095	.0151	.079	1.995

The uniformity of the admission-ratios of cutaneous suppurations is very striking (Statistical Table 48) as well as of cutaneous diseases as a class. Much too little is known of the etiology of the many diseases of the skin, and even in the case of the more damaging suppurations it seems impracticable to determine satisfactorily the dominating influences of ships, though undoubtedly the multiplicity of small injuries, often too slight to be remembered, was responsible for many of the abscesses, as abrasions, particularly over the tibia, were for many ulcers. While it is recognized that the staphylococci and streptococci are the active causes of suppuration, and that cocci are common on the skin, though generally in some attenuated form, it does not seem to be so generally recognized that aside from the virulence of infecting bacteria their number is an important consideration and that undoubtedly cleanliness of skin and clothing limits the tendency to suppurative processes and to wound infection, as the Japanese seem to have demonstrated in actual warfare. Of course, experience in preparing the hands of the operator demonstrates the futility in the daily routine of life of any attempt to *free* the skin from all infecting agents.

There then appears in this connection the important subject of cleanliness of person and clothing, which are considered elsewhere from the point of view of a naval service. It is apparent, however, that those affections again emphasize the necessity for steam laundries at naval stations, and cannot be separated from the available supply of water on ships and its proper employment in bathing to prevent the skin excretions of one man from becoming associated with the skin of another. The limitation of fresh water on ships reduced the crews' general bathing to shower baths of salt water, to swimming, or to buckets of fresh water, or to all three during the ten years, and frequently the facilities were not sufficient. The tendency to utilize the fresh water available was at times so strong that it was not unknown, though probably somewhat rare, for buckets of water to be used in common, the same small amount of water going over the bodies of at least two men, and at times the same towel or towels.

The method of stowing clothing, not always dry, in canvas bags away from air, and the use of hammocks tightly lashed each morning and stacked together to remain without light or air until opened at night for use, represent constantly acting adverse influences favorable to the development of suppurations of the skin as well as to the development of other diseases. And it does not appear that any one has offered anything more suitable for naval life than the bag and hammock, though many have emphasized the necessity for much more frequent airing and sunning of clothing and bedding.

In fact it would not be difficult to show that the entire routine care of ship and crew from a hygienic point of view, including the limitation of dust in all quarters, and including even the navy ration itself, has prophylactic relation to suppurative diseases of the skin. Certainly it is quite a general belief in the service that too many days of sea ration develops a tendency in that direction. It seems that the diminution in the admission ratios of boils (Statistical Table 47) may have relation to improvement in the ration, but more particularly to increased facilities by supply ships, and through cold storage on the ships themselves, for obtaining fresh food. Voyages were also becoming shorter in time and fruit in tropical ports is generally plentiful and cheap.

There seems to be good reason, at least in logic, why many diseases of the skin should come within the scope of the question of immunity. It is a very extensive living tissue or organ vitally concerned in the important function of regulation of body temperature, and capable in connection with that function of causing very marked and serious disorders of the body as a whole. It is subject to marked changes in circulation, has intimate nerve connections, is under the influence of hereditary influences, may be educated in its relation to the body as truly as the skeletal muscles, has modifications of nutrition as marked as those of the lungs and other organs, and may be under the influence of similar diseases, including tuberculosis. Many of its diseases can therefore have intimate relation to constitutional states and can be an expression of those states. Some of the vital causes of its diseases may, therefore, be inoperative if their action is exerted against a skin not only in good health from direct attention, but also from the good condition, or favorable condition, of the body as a whole. In fact, brilliant results have been obtained in some cases of furunculosis by treatment with vaccines or prophylactics of the causative organism, thus placing the disease on much the same plane as a number of others in which the question of immunity is prominent.

The parasitic diseases of the skin found expression chiefly as scabies. The damage from tinea was only 11 per cent. of that from scabies, and while *pediculus pubis* was common it occupied only a small place in the records. Cases of the latter were not all contracted on liberty, but at times during the ten years there were crews showing the condition to such an extent as to indicate extension from water-closets, thus emphasizing faulty design and construction (individual and often cracked seats that harbored vermin and could not be properly cleaned), lack of steam hose connection, or need of care. *Tinea* also did not appear extensively in returns, but the different varieties of the disease were not uncommon, and there were a few instances in which *favus* assumed almost epidemic proportions. There were cases of tinea sycosis, and in the tropics, especially in relation to the Philippines, similar troubles of the axillæ and genitocrural regions. However, of all the parasitic diseases scabies was by far the most important (Statistical Table 4). Prior to 1900 the disease was rarely found in the service, many medical officers doing duty for years without seeing a case, but after that date it became very common, as is shown by the following table:

STATISTICAL TABLE 49.

SCABIES.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.98	.006	. .	. .	.120
1896	.42	.002	. .	. .	.040
1897	.19	.001	. .	. .	.020
1899	.48	.005	. .	. .	.100
1900	1.26	.008	. .	. .	.160
1901	11.72	.067	. .	. .	1.340
1902	7.78	.044	. .	. .	.880
1903	22.55	.095	. .	. .	1.900
1904	16.84	.065	. .	.074	1.374
1905	12.88	.063	. .	.048	1.308
	10.09	.0472	. .	.018	.962

The prevalence subsequent to 1900 was, for reasons given elsewhere, much greater than the table declares. For very many years prior to that date, the disease was certainly rare in our Navy in comparison with others, and even in 1900, when the admission rate in our service was 1.26 per 1,000 of strength, in the navy of Great Britain it was nearly 23, a record about the same as that given in the table for the year 1903. Indeed, it seems fair to assume that at no other time was scabies so prevalent as it became during the latter five years of the period.

The total cause of the increase is not easy to find, though undoubtedly a large part of it is accounted for by conditions at the training stations where, as a result of extensive recuiting, there was overcrowding and inadequate facilities in many directions, including means for the detention of newcomers until found free from disease. Most of the cases on the ships were considered to result from conditions at the training stations from which the crews were received. But the records of certain diseases in a navy are often indices of conditions or tendencies in civil communities from which men are recruited or into which they go on liberty, and it is believed that during the period scabies, perhaps as the result of enormous immigration, was rapidly increasing in the United States, thus greatly adding to the tendency of the disease to appear on the ships and at the stations. However, while the frequent importation of the disease greatly complicated the problem, conditions at the stations favored extension as in the case of measles and mumps.

In the endeavor to appreciate the relative importance of scabies, it will be seen by reference to Statistical Table 4, that its average damage was nearly as great as that caused by both of those diseases. In some years it greatly exceeded their combined damage as well as the combined damage of yellow fever, cholera, diphtheria, and cerebrospinal fever. It also appears, from comparison of Statistical Tables 13, 26, and 49, that in 1904 and in 1905 the damage from scabies was greater than that from pneumonia, and in 1903 greater than that from the same disease during any one of the ten years except 1901 and 1903. It also in 1903 exceeded the damage from typhoid fever during seven of the years. It seems remarkable at first sight that a disease which is so clearly preventable should be permitted to have a prominent place in a navy, but that the problem of extension is not so easily solved is evident from the records of other navies as well as those of our own. It is evident in our service that its control or elimination has had close relation to deficiencies in the care of recruits and has had intimate connection with conditions not altogether avoidable, from a service point of view, which have favored the extension of a number of other diseases.

In a broad way and from a hygienic point of view, no naval service should be required, at least in time of peace, to recruit beyond its accommodations to care for recruits. The care of the recruit not only requires suitable quarters, but also a sufficient number of officers and responsible petty officers. In a rapidly expanding service the relative scarcity of the latter is always evident and lack of the former naturally results when provision is not made in time for an increase commensurate with the increase in enlisted men. With a lack of sufficient number of officers and responsible leading men, and a concentration of newly enlisted men who do not know how to look out for themselves, there is unavoidably an insufficient supervision and an inability to make the most of such facilities as may be available. If to that situation is added insufficient quarters, there will be a number of diseases on hand, and the tendency to spread will at times be greater than the means available for control.

Undoubtedly in every navy there is also need of a much wider diffusion of the knowledge of hygiene from the lack of which situations result, including degrees of concentration of men, that might be changed more or less if there were a full appreciation of requirements. But, when a large number of men are to be quartered on shore in barracks, large expenditures of money are required for suitable buildings, which should not only be of proper design, with not too many persons under one roof, but erected on a dry site and in a suitable climate. A certain multiplicity of buildings is necessary to limit the influence of extrinsic diseases and, by separation of men, to diminish the tendency to the importation of disease. In an expanding navy there is generally developed a situation resulting from obtaining men more rapidly than ships in the endeavor to have the men more or less trained and suitable to man those ships, but in the meantime, owing to the expenditures of money required, there are apt to be insufficient, unsuitable, and overcrowded quarters on shore, the quarters being lacking as well as the ships.

When a small navy, that has been living entirely in ships, develops into a large navy utilizing barracks as well, there is also a tendency to make the routine in barracks agree as nearly as possible with that of ships and to care for barracks as if they were ships. In these days every ship has a very large degree of artificial ventilation and will stand an amount of crowding, if blowers are kept running, that is impracticable in barracks without the same degree of ventilation. Besides, ships change locality, going into the tropics, as a rule, in winter, while barracks are stationary. In ships doing tropical cruising blowers are run, if for no other reason, to remove overheated air, ports are kept open as much as possible, and drafts are agreeable. In barracks during cold months there is a marked tendency to keep buildings closed, natural drafts are disagreeable and even dangerous, and at night there are apt to be few internal sources of heat, except the men themselves who are also mingling many excreta with the stagnant air. On ships clothing is washed in the open air chiefly and in climates that very often permit bare feet in our winter months; in naval barracks during the ten years clothing was frequently washed by the men in places away from suitable light and air, improperly heated and of insufficient area, thus permitting not only a too intimate association of clothing not subjected to hot water, but also exposing the men while at work to humid conditions unfavorable to health. On ships only the deck in the open air is deluged with water, in barracks there is no floor in the open air, and scrubbing floors as part of the routine means damp quarters strongly conducive to disease, a tendency always greatly increased by insufficient ventilation.

Hammocks are used on ships and also in naval barracks. On ships they permit as excessive crowding as in barracks, but under artificial ventilation. The practice of overcrowding ships, when extended to barracks, tends to permit hammocks to be placed much too closely together, especially in cold weather when, with the usual apertures closed and lack of artificial ventilation, the contained air is not as rapidly changed as on ships. Thus the use of the hammock permits a degree of crowding in barracks, when it is sought to place as many persons in one building as possible, that would not be practicable with beds, each person to have a bed, though it is common knowledge that the degree of crowding practicable with beds has been responsible for most of the ills of barrack life.

On cruising ships the degree of overcrowding possible could never be as great as at times in the naval barracks during the period, if the means usually provided for ventilation were utilized. In one instance, however, where a cruising ship was utilized for a time as a receiving ship, the heating was by boiler on shore, and the lighting by the dynamo of the navy yard. As that ship did not have steam on her own boilers, the ventilating plant was not utilized. The normal complement of the ship was 520, but at the time cerebrospinal fever appeared there were about 1,460 men quartered on board. In that case, in the absence of barracks, the men were placed in camp, where the disease disappeared. In the following winter hastily constructed barracks were utilized, and during the next spring, when they became greatly overcrowded, the disease reappeared and the camp was again utilized with good result. During much of the period of crowding, measles and mumps were also common, as well as scabies. In fact, in our service the histories of measles, mumps, and scabies have been closely entwined, as will be seen by reference to the statistical tables of those diseases.

Too much should not be expected from the use of detention buildings, but if newcomers are carefully and repeatedly examined during a suitable period of detention before being allowed to mingle with others, a marked cause of epidemic disease would be removed. If the clothing and skins of all newcomers were disinfected at time of arrival, an additional source of trouble would be eliminated. But such a course requires buildings available for detention and a place suitable for disinfection.

In the limitation of skin troubles it is very desirable, indeed necessary, to have the full assistance of the executive branch which can, in addition to securing cleanliness of clothing, building, person, and locality, cultivate a spirit among the leading men that it is in the interest of all to have diseases of the skin promptly detected. Such persons have opportunities of seeing the men stripped, especially in warm weather, and also of impressing others with part of the zeal they themselves display in the discharge of duty. It is evident that the spirit displayed by the medical officers themselves will have much to do with results obtained along the lines indicated. It is necessary for a medical officer to have all the confidence that can be obtained by steadiness, alertness, attention, and tactful discharge of duty that does not include a too early expression of sensitiveness in the case of individuals suspected of malingering, cultivation of opposition by discharging men to duty before they feel they have received every consideration reasonably due, and lack of careful investigation of cases, especially, perhaps, those that may have found their way to him through the attention they have attracted from other men. In the tropics, on ships, where there is a fine display of naked bodies in the morning watch, the men themselves can exert influences to get to the sick-bay a man who is showing skin troubles if a belief has become diffused that all such cases are wanted. *Knowledge of the presence of the contagious case is the first requisite* in prophylaxis, outside of that general routine undertaken for the good health of all.

Whenever men are to be transferred to a ship, *early opportunity* should be given the medical officer of receiving ship or station, and he should be required, to observe the naked body of each. Whenever men are received on a ship *early opportunity* should be given the medical officer of the ship, and he should be required, to examine each man stripped and at the same time to determine advisability of revaccination. During such examination there should be no mixing of the clothing of different men. It is a matter of interest that almost any crew after passing through receiving ship will give 25 per cent. of successes on revaccination and the same is apt to be true toward the latter part of a cruise or of men received during the cruise.

On all ships and at all stations men doing duty as barbers have important relation to abnormal conditions of the face or scalp. The income from cutting hair and shaving is sufficient to justify a sufficient number of clean towels, or of paper napkins, and clean apparatus. The hygiene of a navy requires it, and there should be means provided to utilize hot water for that purpose. All barbers should be free from communicable disease, keep themselves clean, and wash hands before going from one man to another. A barber also has relation to the men that can be utilized, and he should not be allowed to decide whether to shave or cut the hair of men presenting unusual conditions.

At all stations during the ten years the parasitic diseases of the skin did their part in emphasizing the necessity for steam laundries. On the large ships the influences during the ten years in favor of laundries on board were increasing in view of the recognized dangers and inconveniences resulting from the employment by officers of laundries in port. The question is intimately associated with amount of space and of fresh water available. In tropical ports clothing on shore is not subjected to hot water, is often washed on rocks in running streams, and retained in houses not infrequently questionable from a hygienic point of view. In hot countries a dusting powder of boric acid, zinc oxide, and starch used freely on axillæ and groins after the morning bath has considerable prophylactic influence. In relation to scabies it should be remembered that the itching in some cases causes little trouble, that in diagnosis important indications can be obtained, as a rule, from penis and scrotum, that, while all persons may be susceptible, the disease is not as readily communicated as was formerly supposed, that some cases reaching ships having been under treatment may present only patches showing the disease, that every case of scabies placed under proper treatment should, if the clothing also receive attention, become at once incapable of transmitting the disease, but demands frequent inspection, that it is the unknown case that is to be discovered and treated and that each individual should be made to feel that he is interested in having the cases known.

The common epidemic diseases, other than those already given, have their statistical importance shown in Tables 50, 51, 52, 53 and 54.

Many of the remarks made in explanation of the prevalence of scabies during the ten years apply equally to these diseases. There was, however, in relation to measles and mumps an additional cause of prevalence of prime importance found in the very much larger number of recruits obtained from the less populated districts, thus greatly increasing the relative number of susceptible persons. Receptivity, in the case of variola, measles and mumps, may be regarded as practically general, but against small-pox there is a vital process of prophylaxis through which a marked degree of immunity is secured, while in the other diseases the restraining influence is the condition resulting from prior attack. It therefore follows in their case that an increase in the number of susceptible individuals becomes a dominating factor in prevalence. The training stations thus became the foci of infection, the concentration of recruits having been greatest there.

STATISTICAL TABLE 50.

MEASLES.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	2.73	.016	. .	. .	.320
1896	1.06	.007	. .	. .	.140
1897	3.56	.025	. .	. .	.500
1899	1.78	.010	. .	. .	.200
1900	6.73	.027	. .	. .	.540
1901	5.99	.033	. .	.037	.697
1902	7.84	.045	. .	. .	.900
1903	6.71	.035	. .	. .	.700
1904	9.44	.035	. .	. .	.700
1905	2.93	.017	. .	.048	.388
	5.52	.0274	. .	.015	.563

STATISTICAL TABLE 51.

MUMPS.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.07	.0002	. .	. .	.004
1896	2.18	.007	. .	. .	.140
1897	2.86	.016	. .	.063	.383
1899	4.51	.025	. .	. .	.500
1900	5.55	.029	. .	. .	.580
1901	5.69	.025	. .	.037	.537
1902	10.56	.038	. .	. .	.760
1903	18.92	.065	. .	. .	1.300
1904	5.40	.016	. .	. .	.320
1905	5.86	.019	. .	. .	.380
	7.37	.0275	. .	.007	.557

STATISTICAL TABLE 52.

SCARLET FEVER.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.227	.004	. .	. .	.080
1896	.281	.002	. .	. .	.040
1897	1.334	.010	.127	. .	.327
1899	1.393	.014	.096	.048	.424
1900	. .	. .	. .	. .	. .
1901	.186	.001	. .	. .	.020
1902	.448	.005	. .	. .	.100
1903	.402	.004	.027	. .	.107
1904	.295	.002	.024	. .	.064
1905	1.258	.010	.048	. .	.248
	.585	.005	.030	.004	.135

STATISTICAL TABLE 53.

SMALLPOX.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.076	.0008	. .	. .	.016
1896	.352	.0023	. .	. .	.046
1897	.191	.0030	. .	. .	.060
1899	.288	.0016	.192	. .	.224
1900	.421	.0020	.210	. .	.250
1901	.818	.0057	.037	. .	.151
1902	.736	.0041	.096	. .	.178
1903	.644	.0102	. .	. .	.204
1904	.369	.0044	.049	. .	.137
1905	.242	.0022	.048	. .	.092
	.449	.004	.064	. .	.147

STATISTICAL TABLE 54.

Cerebrospinal Fever.[1]

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	. .	. .	. .	. .	. .
1896	.070	.0001	.070	. .	.072
1897	. .	. .	. .	. .	. .
1899	.096	.0001	.096	. .	.098
1900	. .	. .	. .	. .	. .
1901	.297	.0019	.112	. .	.150
1902	.032	.0009	. .	. .	.018
1903	.805	.0073	.215	.242	.603
1904	.246	.0022	.123	.049	.216
1905	.508	.0021	.218	.024	.284
	.276	.0020	.106	.045	.191

[1] But for the relatively large mortality rate and the disturbing influence of this disease when present on receiving ship or in barracks, it would not merit a separate table. It is worthy of note that its largest admission rate was in 1903, when pneumonia was especially prevalent. During that year the cases occurred at League Island, on the receiving ship Minneapolis, when very greatly overcrowded (normal complement 520, complement at that time 1,460) and ventilating blowers were not used. The following year there was a recurrence of the disease at that station, but in overcrowded and poorly constructed barracks. In 1905 the cases occurred at Newport Training Station.

It is more than doubtful whether any community of susceptible individuals, having even a slight association with other communities in which there are cases of measles and mumps, can be kept free from those diseases which in cities are affections of childhood because they are too contagious to permit mankind to travel far along the road of life without feeling their influence. They do not belong to childhood, but are able to attack a large percentage of those who enlist in the naval service without having been previously exposed. Besides, measles is generally considered the most potent of all the exanthemata in causing repeated attacks, yet there is much evidence to show that its power in that respect has been overrated, many of the so-called repeated attacks being so considered on account of prior or immediate errors in diagnosis. However, in spite of the great contagiousness of measles, its morbific cause does not seem to remain long in even a moderately well ventilated locality after the removal of the case and effects. It seems that where the case, *on the appearance of eruption*, is at once removed from occupied quarters, disinfection of those quarters is often powerless to prevent some additional cases, the morbific cause frequently being in the bodies of one or more susceptible persons then already in the stage of incubation, and yet, often prompt removal of the case, even without disinfection of quarters, is not followed by others.

Under any circumstance, early isolation greatly limits tendency to spread and there is always chance that the morbific cause may fail to find susceptible persons along its line of travel. However, ordinarily, *where there is much susceptible material present*, the first case when found in the stage of eruption will be followed by others, but with prompt removal or isolation of all cases the disease will appear in successive crops at almost regular intervals. The number of crops will vary, but often the number in the first crop will be greatest and other crops will soon appear as single cases.

This is illustrated in the history of the Yankee on which measles appeared in 1903, again in 1904, and again in 1905. During that period the ship was utilized for training purposes. Her complement was about 750, of whom 350 to 400 were young men received at intervals from the training stations. In 1903 the first cases were three, May 7, 11, and 14, all found in the stage of eruption and promptly removed from the ship. The successive crops were only two and in that instance happened to consist of one case each, May 29, and June 14. In 1904, when cruising in the West Indies, the first case appeared on February 11. It was in every way typical and had been contracted on liberty at Kingston, Jamaica. It was found on the day of eruption, men as a rule not appearing at sick-calls when they believe they have merely a simple cold. The case was promptly removed from the ship. As most of the men were quartered on an open gun deck and the ship was crowded, general disinfection was not attempted, but temporary place of isolation was disinfected with formaldehyde, as was done in 1903. The first crop did not begin to appear until March 2, twenty-one days. It consisted of six cases, March 2, 3, 4, 5, and 7, all mild and in the stage of eruption. The next crop was four cases, March 19, 20, and 23. The next crop was one case, March 29, and the last, one case, April 9. In 1905 the influence was from training station, Norfolk. There were three primary cases, January 16, 19, and 21, all found in stage of eruption. There was only one crop. It consisted of two cases, February 2 and 3. The number of susceptible persons present was large. There was no general disinfection. No case was discovered until in the stage of eruption. All cases were promptly removed from the ship except the second crop in 1904, which, owing to nature of cruise, had to be kept isolated on board for a while. Places of isolation were promptly disinfected.

Measles during the ten years was, as a rule, of a mild type, and cases were commonly not recognized or even under observation until the day of eruption, Koplik's spots, apparently, not being available under the circumstances for purpose of early isolation. With so many susceptible individuals living as one family and sleeping as it were in one room, the appearance of cases in such well-defined and limited crops is difficult to explain under the idea that so contagious a disease is always propagated directly through the medium of the air. The history suggests some additional or intermediate way of extension at least prior to eruption on skin. Ultimate extension by atmosphere can apparently alone account for many cases. On the Yankee, a marine on guard to prevent approach to a place of isolation containing four cases, visited the place himself for a moment under some mistaken idea of duty and contracted the disease though the exposure was momentary.

It seems, however, in view of the long intervals between the first case on that ship in 1904, and the cases comprising the first crop, that infection may have been primarily one of locality. The records in a number of instances indicate the contagiousness of measles during the primary catarrhal stage. An epidemic of mumps, in which disease the salivary secretions are apparently the chief source of infection, is apt to have about the same characteristic run as measles when all cases have been isolated or removed from the ship as they appear. In fact, in all these diseases these cretions of the mouth or respiratory tract have much to do with extension. When cases are not promptly isolated the sequence is changed in accordance chiefly with the number of susceptible persons present, cases appearing perhaps daily but, nevertheless, even then the period between the first and last case shows either that susceptibility was not constant or that the poison was not uniformly diffused.

At any rate, the evidence is sufficient to suggest that in the presence of many susceptible persons the chance of spread would be diminished, if cases were promptly isolated, by use of bichloride solution on decks and paintwork of quarters each day from the discovery of first case until primary cases cease to appear, then, after a period of six days from the appearance of first case, each day until the last case of the first crop and so for each crop until the disease failed to appear. Such a course may be feasible when on a crowded ship even a single *general* fumigation may not be feasible away from quarantine, either from lack of material or other facilities. All during the period special and strict precaution should be taken to prevent spitting on decks, and spitkids should contain water and be disinfected with steam hose daily, preferably in first one head and then the other, that the steam may be extended to that locality. Drinking cups at scuttle butt should be immersed in formaldehyde solution, the best ventilation practicable secured at all times, and, in fact, the sanitary routine indicated elsewhere strictly carried out.

While in all these diseases, locality and clothing are dangerous, the case is certainly freeing the poison. It should, therefore, be always promptly isolated *with effects* and any degree of isolation is better than none. In view of the concentration of human beings, prompt removal of cases and effects from the ship is by far the best form of isolation, but, when that has been accomplished, there should be immediate disinfection by fumigation, whenever possible, of locality utilized as place of isolation pending transfer. When closure is not practicable, disinfecting solutions should be employed. When transfer to hospital is not possible, transfer to hulk or to tent on shore may be practicable. But, wherever the case may be treated out, the individual, effects, and locality should be disinfected at its conclusion, and during the treatment there should be strict bedside disinfection. In all these cases the mild antiseptic gargle should have place in treatment, and, during the period, a run of mumps on the Texas was considered by the medical officer to have its spread limited and ultimately checked by resort to the free use of bichloride gargles in treatment.

On the training ship Prairie, during 1901–2, cruising in the tropics, the medical officer, Surgeon H. G. Beyer, finding himself confronted by measles in a crew of over 700 men without suitable place of isolation, placed reliance upon bedside disinfection carried to its limit. The following is his description of method: A clean white sheet is spread upon the deck of the sick bay and upon this the patient steps and leaves all his clothes, including shoes. All the clothes excepting the shoes are wrapped in the sheet and put aside for steam sterilization, the shoes being separately disinfected with solution of bichloride of mercury. The patient receives, first, a thorough scrubbing with warm water, soap, and a sterilized brush, going over every square inch of his surface, after which he is sponged over with a solution of bichloride (1:5000), enveloped in a clean sheet moistened with the same solution, put to bed and covered with blankets. The bichloride bath is repeated three times daily during the period the eruption is at its height, twice daily during the remaining period. His mouth, throat, and nose are cleaned by gargling and douching daily with normal salt solution to which once daily a minute quantity of some antiseptic is added, either carbolic acid or bichloride (1:20000). He is kept constantly supplied with a large gauze handkerchief soaked in bichloride solution to receive any expectorated matters or nasal discharges; he is directed to hold the handkerchief in front of his mouth and nose, while coughing or sneezing, to catch the spray. Urine and bowel discharges are disinfected and thrown overboard after standing the required time, the vessels cleaned, disinfected, and dried, kept ready for use. Immediately after a patient had been admitted to the list, the clothes he had worn and the contents of his bag as well as his mattress and hammock were exposed to running steam for two hours. His boots and shoes were sponged or washed out with a strong solution of bichloride (1 : 1000) and allowed to dry in the open air. The average number of days between admission to the list and discharge to duty was 8.58. All the patients were treated in the sick-bay of the Prairie, without any precautions being taken as regards the possibility of their transmitting the disease to other patients lying right next to them; nor were any other precautions taken by the attendants than that they were warned to wash their hands and face before sitting down and taking their meals and yet, in not a single instance was the disease communicated from any of the patients in the sick-bay to anyone.

An examination of the records of the Prairie during 1901 and 1902 shows that there were two runs of measles on board, one from December 30, 1901, to Jan. 30, 1902, consisting of 15 cases and the other from September 28, 1902, to November 21, 1902, of 6 cases. In the first run the second case appeared on January 3 and therefore its source of infection was not the first case. Then nine cases appeared, January 13, 14, 16, and 17. The next batch consisted of 4 cases, January 25, 26, 27, and 30. In the second run the first case was on September 28, 1902, and the other cases appeared October 12, November 7, and November 21. Considering the circumstances the results obtained seem to indicate that the method employed was as efficient as place isolation and might be, as Dr. Beyer claims, as efficient in the case of scarlet fever or variola. It was, however, designed in the absence of suitable place of isolation and is not intended to diminish the urgency for transfer, especially in cases of scarlet fever or variola, diseases fortunately uncommon in the service, but demanding all the isolation possible, and if at sea a change of course for the nearest port affording facilities through the health officer for transfer. The onset of those diseases is generally sufficiently severe to lead to observation, often in isolation, from beginning of active stage. Yet the type of scarlet fever or small-pox may be sufficiently mild to present some of the difficulties of measles in early discovery of cases. In those diseases there should also be as much general disinfection of ship and clothing as is practicable, always including the locality that contained the patient's billet and, in the case of small-pox, vaccination of entire personnel, though each person during his entire service should be afforded such protection from small-pox as is secured by vaccination.

Receptivity in measles and small-pox is equally general. The difference of prevalence (Statistical Tables 50 and 53) may be considered due in great part to vaccination ashore and afloat, within and without the service. A large percentage of the cases of small-pox were returned from the Asiatic Station with which there was a more general intimacy subsequent to the Spanish-American War. The type varied greatly, but it cannot be considered as having been generally very mild, as the mortality was about 14.3 per cent. Some of the cases were from recruits who were in the stage of incubation at the time of enlistment but, allowing for those cases, the disease was more prevalent than it should have been. In spite of the large number of vaccinations the experience was that all persons reaching the cruising ships from the receiving ships or shore stations, were not protected to the extent that is possible by vaccination. It also appears that in 1902 and 1903, marines going to the Philippines were not sufficiently protected. The increased prevalence of measles was due primarily to the presence of a larger number of susceptible individuals. In the case of small-pox there should never be an increase in relative number of susceptible individuals in view of the degree of protection a naval service can secure by vaccination. Under circumstances so favorable to the spread of measles the damage from small-pox should not have been as great as 26 per cent. of that from measles

The records clearly teach that not only should each person be vaccinated on enlistment, but all persons who have not been successfully vaccinated during the enlistment should be revaccinated on the cruising ships and, in the absence of success and of good scars, again revaccinated. The records also show that each member of a crew starting for the Asiatic Station and all persons selected for duty in the tropics should be carefully revaccinated. The best prophylaxis in small-pox is protection by vaccination but, if the indications here and there through the records of the ten years are trustworthy, it would seem that about 15 per cent. of the force at any given time could have been successfully vaccinated.

Small-pox is considered to be infectious during all stages, but to be least infectious during the stage prior to eruption. The eruption is not as marked in those who have ever been successfully vaccinated, a fact probably tending to show a diminution in degree of spread of infection in their cases which, though not diminishing the necessity for isolation, increases the probability of its effectiveness on a ship. The disease is most infectious during the suppuration and drying periods, a fact intensifying the necessity for as early transfer as possible, a necessity also marked in scarlet fever which some authorities do not believe to be infectious until desquamation. In both diseases, isolation, early transfer, and disinfection should be more potent in preventing subsequent cases than in measles. In relation to all these diseases it is very advisable to isolate at once the case exciting suspicion and thus recognize the great importance of the first case which even in its miidest form is capable of causing a sequence of cases. In fact, the mild case on account of difficulty of diagnosis is often the most dangerous.

It was common during the ten years for recruits at time of enlistment to show no vaccination scar. From the vaccination of such persons the percentage of success was frequently not above 50, while that from those showing one or more good scars was over 20. While it is *absolutely essential for the virus to be good* and for *the operation to be carefully performed*, it is also essential to recognize a varying susceptibility to vaccine.

It may happen, especially in warm weather or at any time when lymph has been kept too long, that some may be still capable of securing results when the remainder may be inert. It is therefore important to vaccinate men as soon as practicable after receipt of virus even when attempt is made to keep it in low temperature. A thorough cleaning of site and prolonged friction in applying lymph to abrasion are necessary, and it is advisable for the individual to be vaccinated to see that precaution has been taken to avoid transference of anything from any arm to his own. In every instance a list should be kept of all who are vaccinated which should also show the presence or absence of scars, and in all cases of non-success the operation should be repeated with fresh virus when a good scar is not found.

The importance of revaccination in view of varying susceptibility cannot be overestimated, and men showing no scar should be included in every set of men vaccinated until success is obtained, or at least three unsuccessful attempts have been made with virus above suspicion, a list of such persons being kept for that purpose. A crew collected on a receiving ship for a certain ship should be examined as long as practicable before transfer and every person who has not been successfully vaccinated since enlistment should be revaccinated. Such a course lessens the number of cases of vaccina on cruising ships, thus interfering little with efficiency in active service.

The diseases of the auditory apparatus were represented chiefly by *otitis media* (Statistical Table 4). Table 55 gives the statistics of that disease during the ten years.

While this disease appears to have been responsible for few deaths, it seems probable that its relation in that direction is not fully expressed in the table, extension of inflammation from the middle ear having found expression under other diagnoses. The disease was of increasing importance and damaged the service more than pneumonia, twice as much as diphtheria, and not much less than typhoid fever. In fact, after 1900 its damage exceeded that received from the last mentioned disease.

If comparison is made with tuberculosis (Statistical Table 8) it will be observed that the increase in prevalence has been much the same and there is evidence that the prevalence of both diseases was intimately associated with faulty recruiting. Taking the year 1903, when the admission rate was highest, it appears that 20 per cent. of the cases were returned from the Newport training station. The medical officer of that station after a careful investigation of all cases found that 76.7 per cent. were due to causes existing prior to enlistment. The conclusion follows that if ear drums are carefully examined at recruiting stations the prevalence of middle ear disease will be markedly decreased. Of course some cases originate in the service as sequelæ of measles, tonsillitis, pneumonia, and other diseases, but very many of those cases recover. The table shows that about 26 per cent. of all cases are invalided from service, at times nearly 40 per cent. A source of cases is also found in swimming over the side and in insanitary swimming tanks.

STATISTICAL TABLE 55.

OTITIS MEDIA.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	2.12	.014	. .	. .	.280
1896	1.55	.010	. .	.141	.341
1897	1.84	.016	. .	.318	.638
1899	2.54	.018	. .	.432	.792
1900	2.90	.018	. .	.505	.865
1901	5.50	.029	. .	1.451	2.031
1902	4.67	.036	.032	1.280	2.032
1903	5.77	.039	. .	2.147	2.927
1904	4.98	.026	. .	1.430	1.950
1905	4.57	.025	. .	.944	1.444
	4.15	.026	.003	1.072	1.595

The diseases of the visual apparatus found expression chiefly as *retinitis*, *iritis*, and *conjunctivitis*. The statistics of those diseases during the ten years appear in Tables 56, 57 and 58.

Retinitis increased in prevalence during the ten years, but not more than can be reasonably accounted for by recruiting and feigning. Cases originating in service often suggest syphilis imperfectly treated. Toxic amblyopia does not appear to have had much influence on the record in spite of the extensive use of strong tobacco in the service, yet that influence and the drinking of impure spirit while on liberty are worthy of consideration. The admission ratios, as in iritis, are probably too high, some cases having been returned to duty and then eventually invalided as new cases; but, even taking the record as it is, the treatment was evidently most unsatisfactory, as more than 50 per cent. of the cases were invalided. There should be a most careful supervision of all cases of syphilis, and transfers from one ship to another or from hospital to ship should not cause a cessation of treatment in any case before a cure has been effected.

STATISTICAL TABLE 56.

AMAUROSIS, AMBLYOPIA, OPTIC NEURITIS, AND RETINITIS.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	.379	.015	. .	.303	.603
1896	.634	.009	. .	.352	.532
1897	.699	.010	. .	.064	.264
1899	.480	.009	. .	.192	.372
1900	.758	.013	. .	.252	.512
1901	1.116	.013	. .	.558	.818
1902	.960	.014	. .	.448	.728
1903	1.074	.013	. .	.644	.904
1904	.937	.013	. .	.616	.876
1905	1.017	.016	. .	.484	.804
	.879	.0131	. .	.445	.707

STATISTICAL TABLE 57.

IRITIS.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	1.44	.009	. .	. .	.180
1896	1.27	.009	. .	. .	.180
1897	.70	.007	. .	.127	.267
1899	1.25	.007	. .	.144	.284
1900	.93	.009	. .	.084	.264
1901	.89	.009	. .	.074	.254
1902	1.28	.009	. .	.064	.244
1903	.86	.010	. .	.027	.227
1904	1.03	.008	. .	.024	.184
1905	.94	.010		.072	.272
	1.03	.0088	. .	.075	.251

STATISTICAL TABLE 58.

CONJUNCTIVITIS.

Year	Admission ratio per 1000	Percentage of sick	Ratio per 1000 of strength		Damage in ratio per 1000
			Deaths	Discharges for disability	
1895	5.38	.015	. .	. .	.300
1896	5.07	.012	. .	. .	.240
1897	4.19	.009	. .	. .	.180
1899	4.51	.013	. .	.048	.308
1900	4.17	.015	. .	.042	.342
1901	5.66	.015	. .	.112	.412
1902	4.93	.021	. .	.224	.644
1903	4.48	.018	. .	.215	.575
1904	4.48	.021	. .	.123	.543
1905	4.50	.015	. .	.145	.445
	4.69	.0165	. .	.117	.447

Syphilis was the chief influence in causing iritis. Some cases of syphilitic iritis do not appear in the table, the condition having been regarded as a complication and recorded under the diagnosis of syphilis. There are, however, a number of cases of iritis which are thought to be syphilitic but in which the history is not altogether clear. The rheumatic influences in the Navy were decreasing during the ten years, and the syphilitic influences were increasing, but the relative number of cases of iritis admitted as such do not seem to give an indication of what the dominating causative influences were. Probably the prophylaxis is found chiefly in the careful treatment of all cases of syphilis.

Conjunctivitis had little change in relative prevalence during the ten years. The large majority of cases were of the simple or catarrhal variety and therefore little relation can be traced between prevalence and infection. A mucopurulent acute conjunctivitis is certainly often contagious and it is best in all cases of conjunctival inflammation to take the precaution that there is at least no use of towel in common. During the battle of July 3, 1898, the fumes of smokeless powder caused tonsillitis, bronchitis, and rhinitis, the inflammation in several instances producing closure of Eustachian tubes and more or less complete temporary deafness. Coal dust is also responsible for some cases. But generally the cause was ascribed to exposure to cold or drafts. If that were the dominating cause the admission ratio should have decreased. It seems more likely in many of those cases that exposure was merely selected as the more probable source. In such cases a predisposing cause can at times be found in the condition of the stomach contents, especially in relation to acidity resulting from abnormal processes of fermentation. Some cases of conjunctivitis are produced by the use of soap or other irritant for that purpose and some are caused by eye-strain often incident to errors of refraction that were present at time of enlistment.

This study of the vital statistics of the Navy and Marine Corps has been made under the belief that an essential part of the foundation of the hygiene of a navy is knowledge of its diseases. Diseases are effects. They are the breakdowns in the human machine, and hygiene aims to acquire and apply knowledge necessary to avoid such breakdowns. A part of its object is to trace effect to cause, and by removing cause to prevent disease. The study of the diseases of a navy is, therefore, the first essential step toward their prevention. Hygiene must classify diseases in relation to cause or source, and naval hygiene cannot be effective unless its operations are based upon a knowledge of the cause or source of the diseases of a navy. A knowledge of the relative importance of those diseases gives a relative value to the efforts made for their prevention. It represents that knowledge of the disposition of the forces of an enemy so essential for successful attack or defense. Effort should have a definite aim. All work should be directed to secure desired results and the energy employed should be in proportion to the work to be accomplished.

However, it has not been the intention to seek conclusions in every possible direction, but only along such lines as appeared most important. Every great subject offers opportunities to many workers and generally the outline precedes finished work. The object here has been to declare method, to excite interest, and to help to make a suitable foundation for a most important structure that can be erected only by naval workers. That structure must be made of interdependent facts selected in accordance with plan devised to meet the requirements of naval hygiene. In general terms, *naval hygiene* deals with the factors and conditions which concern the preservation, promotion, and improvement of health and the prevention of disease in the naval personnel. It seeks to prevent premature death and to secure health and happiness in the navy *under essential service conditions*. *Naval sanitation* is that division of naval hygiene that acquires and applies knowledge necessary for the control or abolition, *under essential service conditions*, of those factors in the *environment* of the naval personnel that tend to produce premature death by causing disease.

From this study of naval vital statistics it is quite evident that while the diseases of the service may be divided into those due to intrinsic and those due to extrinsic causes, as is indicated in above definitions, such a division is misleading unless it is associated with the conclusion, derived from those same statistics, that predisposing causes are often as influential in producing disease as exciting causes and that such predisposing causes may be either intrinsic or extrinsic. Even scurvy was not entirely an intrinsic disease, though it depended fundamentally upon the absence of certain salts in food, for its prevalence and intensity bore a marked relation to confinement in bad air, indolent habits, and depression of spirits. Though not strictly a disease of the sea, it found something in the conditions of ship life, outside of the question of food, conducive to its propagation. When Portchester Castle could not accommodate the French prisoners in 1798 a number were removed to a ship in an adjoining creek, where many exhibited scurvy, though the diet was the same on the ship as on shore where the disease did not appear. Time and again that trouble has occurred on ships when men in garrison have remained free from it, though living on the same diet. The predisposing causes were lack of dryness, cleanliness, and ventilation and also lack of exercise and recreation.

But even when the exciting cause of disease is vital, it is often inoperative in the absence of predisposing cause. The large number who escape infection by the tubercle bacillus and the many who, even when infected, are able by improvement of general condition to apparently free themselves of that living cause of disease, demonstrate the value of general hygienic measures—of those measures that tend to increase the vital resistance by which the living machine is enabled to withstand with more or less success the influences in its surroundings that tend to affect it unfavorably.

The tendency of the medical mind is to concentrate its attention and efforts upon the vital causes of disease. The discovery of the vital cause of disease has been of vast importance in prevention, but general well-being goes a long way toward happiness, to the doing of successful work, to the making of good fighting ships, and to the warding off of disease. The vital agents of disease excite tissue changes and recognized symptoms, but it seems clear that they are not able at any and all times to act without the intervention of predisposing causes. Minds are naturally impressed by concentration more than by diffusion—by combustion caused by concentration of the sun's rays rather than by the great work performed by the sun in sending its heat and light over the whole earth. Microscopic work has placed sanitation on a scientific basis, but it should not be allowed to draw attention from those factors that, unlike the rapidly acting vital causes of disease, slowly lessen the vital resistance of the body. Filth, foul air, insufficient food, insufficient work or exercise, insufficient recreation, lack of object in life, excesses of various kinds, immorality and the like, while less striking in their effects because of the slowness with which they often produce results, are more harmful in the long run than those epidemic diseases that come seldom but take lives with great rapidity.

Scurvy was banished from the sea by diet and, during recent years, the Japanese have practically eliminated beriberi from their naval personnel by diet. In that service the question of the infectious nature of the disease has become more or less academic. It is shown that for the six years prior to 1884 the average admission rate of beriberi was 324.5 per 1,000 of strength, that during that year a ration was devised solely for the purpose of preventing the disease, and that since that year the admission rate has been almost always much less than 1 per 1,000 of force, averaging during the sixteen years subsequent to 1885 only 0.6. While the disease is believed to be due directly or indirectly to a special organism, the study of disease is not merely an intellectual pursuit, but is undertaken for diagnosis, treatment, and, above all, for prevention. In this case it would make no practical difference whether the disease that was crippling the Japanese navy to the point of inefficiency was eliminated without direct attack upon its exciting cause. If they were able to secure an efficient navy through the removal of a disease by the abolition of its predisposing cause, the result is even better than would have been obtained by destruction of exciting cause as a higher general health was also made practicable. This disease is generally considered to be infectious, as its exciting cause appears to cling to buildings on shore, and require disinfection in prophylaxis. Yet, it has been asserted that if all rice were steamed before being milled the cause of beriberi would be removed.

While scurvy, on account of its great prevalence, its disgusting characteristics, its great mortality, its association with some of the most remarkable expeditions in history, and its practical abolition from the sea in 1796, has attracted the eye of all, typhus fever has been a more grievous and general cause of sickness and death. That disease is highly contagious, but its abolition from navies was not due to destruction of exciting cause. If citric acid may be regarded as a preventive of the one disease, soap properly employed may be considered as almost of equal force in the other. No one denies that typhus fever finds its cause of extension in air contaminated by foul exhalations, derived in great part from the living human body and incident to the crowding of human beings in filthy and contracted spaces. If the English channel fleet in 1780 was so overrun with scurvy and fever that it was unable to keep the sea after a cruise of only ten weeks, present conditions are not so much the result of the discovery of the exciting causes of disease and of their destruction as of the work of general hygiene. That such a situation was practicable in those days is found in the simple statement, in the language of the period, that in 1739 the vessels in the squadron at anchor at Spithead stunk to such a degree that they infected one another and that the men became so dangerously ill from want of air that they were put ashore to recover their health.

From the point of view of physical ills the venereal diseases are the most prominent curse of mankind afloat and ashore. So far as naval efficiency is concerned it does not appear that their prevalence on ships has been, though it should be, and without doubt is about to be perceptibly affected by destruction of vital cause. The discovery of the gonococcus does not promise to greatly lessen the general prevalence of gonorrhea among men. It will not generally add anything to the knowledge that the only reliable prophylactic measure is sexual purity, and the knowledge some utilize of the method of prevention of venereal disease introduced in the time of Charles II has not been affected.

It is not the intention to decry the prevention of disease by destruction of vital cause, which is of very great importance, but only to emphasize one of the important conclusions to be derived from a study of the naval vital statistics of to-day, which is that just as in the days of yore men strongly tend to foul their abodes chiefly by their own excreta and that it is as necessary for the naval medical officer to know the ways of preserving and promoting the health of, and preventing disease among men concentrated in naval vessels by, among other things, the proper disposal of the excreta of those very men as it is to prevent the access to them of the causes of disease, directly or indirectly, from other men.

The proper disposal of the excreta of men concentrated on naval vessels or in naval barracks involves a study of proper ventilation of ships and barracks, as the contained air receives excreta from respiratory passages, skins, and to some extent from alimentary canals. Even some of the food dropped from hands and mouth finds its way into the contained air. It is not only the gases and vapors from the body that seek the atmosphere, but also all material, such as sputa, capable under the circumstances of passing into dust. The proper disposal of excreta also involves a study of heating the contained air which so markedly by temperature as well as by drafts influences the evaporation on the surface of the body; and of the proper use of water in securing a proper humidity of air and cleanliness of skin, clothing, bedding, and locality. It involves a study of clothing itself which not only receives much of the solid excreta of the skin and much of its water before reaching the air, but also by material and texture modifies the excretion of heat by the body and its control by convection and evaporation. Excreta from the alimentary canals and urinary organs demand proper construction and care of water-closets and clean hands, and disposal of excreta from skins and mouths includes care of towels, mess gear, washrooms, spitkids, and the like.

In fact, the routine care of men involves measures based upon the knowledge that prophylaxis is a series of methods or procedures whereby disease is restricted and prevented as much by suppressing or removing its predisposing causes or conditions as by destroying or modifying the exciting causes. It therefore includes, for instance, a proper ration as well as an uninfected ration, a proper amount and use of water as well as uninfected water, a proper amount and renewal of air as well as uninfected air, proper kind and care of clothing as well as uninfected clothing; and yet a study of the vital statistics of the service also declares that man himself and other animals are the principal source of infection, their excreta the primary principal vehicles, and other animals, air, and water the secondary principal vehicles. It therefore follows that the proper disposal of man's excreta as well as the protection of man from other animals, such as infected mosquitoes and fleas or flies and other insects carrying infective agents, is also the best means of preventing infection. *And in the presence of epidemic disease disinfection or the destruction of the agents causing infection becomes of first importance.*

It is necessary for a naval medical officer to recognize that the general shape of a ship is fixed by unalterable laws without regard to hygiene, and that the great concentration of men on a fighting ship is an essential service condition. It therefore follows that there is a singular necessity for as complete an adaptation of the construction of a ship to sanitary requirements as her efficiency as a fighting ship permits, and that in view of the concentration of men it is imperative for that construction and routine care of the ship, as well as of the personnel, to be directed to the proper disposal of the excreta of those very men as well as to the protection of those men from the excreta of other men, as, for instance, in the provision and care of apparatus for the distillation of water as a measure against all water-borne diseases.

To him who studies the vital statistics of a navy it should be very clear that the primary problem of naval hygiene is the prevention of disease by the preservation, promotion, and improvement of general health, and that the satisfactory solution of that problem can only be found in the study of air, food, water, clothing, exercise, work, recreation, and the like in their application to the naval personnel. The naval human being has relation to natural conditions surrounding him that are intensified by concentration, but he also has social relations that in view of special circumstances require special consideration and has, as all mankind, thoughts, feelings, and desires which require self-regulation and control. Naval hygiene then involves a study of the man himself in the navy as well as of his surroundings *under essential service conditions.* It involves an understanding of the practicable circumstances that tend, under good discipline, to increase moral tone and to produce contentment.

But it has been very evident from a study of these statistics that there is very much disease in a navy that does not originate there. If service in a navy never caused disease there would still be a sick-list of considerable size depending upon the relative number of recruits and the method of recruiting. To anyone who may consider naval vital statistics it will be evident that duty at the recruiting station is one of the most responsible a medical officer can perform. In fact, it has been clearly shown that *the health of a navy is primarily in the hands of the medical officer at the recruiting station.*

CHAPTER II.

THE AIR WITHOUT THE SHIP AND THE AIR WITHIN THE SHIP.

The naval personnel lives at the bottom of one ocean and on the surface of another—on the sea level where air and water meet. Both of those substances are of vital interest, and the history of navies declares that the diseases of sea-faring people have been largely due to lack of proper relation to those fluids which have constituted the surroundings of all ships in all ages. Seagoing vessels are limited to a certain shape and it is this form that has had much to do with disease and death at sea. A human being placed within the hollow spindle-shaped body called a ship which is half immersed in water, divided by horizontal and vertical partitions, with few openings connecting its spaces with the outside atmosphere and crowded with stores, implements of war, and men, finds himself in a situation that demands a proper adjustment between the spaces within the ship which constitute his immediate environment and those outside conditions which are the ship's surroundings. His loss has invariably been in proportion to the degree of that adaptation which in the old days was so incomplete as to cause a number of voyages to be associated with loss of almost entire crews by disease, and which in these days is not yet sufficient to prevent a considerable percentage of sickness due to that cause alone.

Water, being a liquid, is an inelastic fluid or one that expands indefinitely only by evaporation. Air, being gaseous, is an elastic fluid or one that tends to expand indefinitely while preserving its homogeneity. It is a more perfect fluid than water inasmuch as it flows much more readily, offering less resistance to forces tending to change shape without altering size. It is a fluid that is readily compressed or condensed, its volume being inversely proportionate to pressure, while water being a liquid is regarded as practically incompressible. For each degree of temperature added to the heat of air it expands a certain constant fraction of its volume, but water expands under cold to form ice, contracts from 0° to 4° C., and then expands again by more and more per degree of increase of temperature. Water is a chemical compound of gases, and its composition can therefore be expressed by a chemical formula, but air is a mechanical mixture of gases and thus without fixed composition. From a given amount of pure water, a certain amount of H and a certain amount of O can be obtained, but every specimen of air will vary and, as it is a mechanical mixture, it is not practicable to state in exactly what proportion its various gases should be to constitute purity, as can be done in the case of water.

But undoubtedly pure air, as pure water, is not found in nature. Water is a solvent of gases and of many solid materials. By the time it reaches the earth it has collected gases from the atmosphere, and after that it gathers material from almost everything with which it comes in contact. The atmosphere is, by virtue of its weight and gaseous state, in most intimate contact with earth and water. It is even more eager for water than water is for air, it receives gases of putrefaction, combustion, and respiration, and, as it sweeps the earth, gathers, as water does, solid material of innumerable kinds. Water without dissolved air is insipid and thus unsuitable for consumption, and air without water-vapor unduly dries the exposed tissues of the body, acts as an irritant and is unfit for respiration. Air is necessary, and always found, in water, but is not a part of it; it is forced out of water by heat. Water is necessary, and always found, in the atmosphere. It is regarded as its most varying constituent, for though air is practically almost always seeking water it cannot always find it in a given locality, or a given quantity of the air may not remain in contact long enough to satisfy its nature, or it may have its capacity to take water greatly diminished by cold as it is cold that forces air to part with its water as dew.

Yet, from the point of view of the chemist, water-vapor may be regarded as no more an essential part of the atmosphere than air dissolved in water is part of the water. In the analysis of air the first step is to deprive it of water, in view of its greatly varying quantity in different samples. The results of such air analyses are, therefore, commonly expressed as the percentage of different gases in dry air. However, that method should not be allowed to obscure the fact that, apart from oxygen and its dilution by nitrogen, water-vapor is from a hygienic point of view the most important constituent of the atmosphere and is in its variations and relations to man, especially at sea, responsible for many of his ills.

From the point of view of the chemist, atmospheric air consists essentially of nitrogen and oxygen in the proportion of about 4 vols. N: 1 vol. O. It may seem remarkable that the gases invariably found as constituents of the atmosphere remain so intimately mixed that there is little variation in air collected in the open and considered dry. Oxygen is heavier than nitrogen (1.105:0.967) yet both gases are practically in uniform proportion in the atmosphere. That is primarily due to diffusion which is of course assisted by the mixing power of wind and all movements of air due to variations in weight caused by difference of temperature. Molecules, especially gaseous molecules, have the power of moving among each other. Diffusion is the intermixture brought about by that power. By diffusion gases mix with each other in opposition to gravitation, and when mixed always remain so. However, the rate of diffusion of gases varies inversely as the square roots of their relative weights. Oxygen is 16 times as heavy as hydrogen and therefore hydrogen will mix with gases four times as fast as oxygen ($\sqrt{16}:\sqrt{1}$).

CO_2 is a heavy gas, more than half as heavy again as atmospheric air and therefore its rate of diffusion is comparatively low. It thus tends to accumulate in confined spaces in which it may have a source, to take position in accordance with its relative weight, as perhaps modified by temperature, and to mix somewhat slowly, thus permitting different degrees of concentration in different parts of the same space, especially where there may be corresponding differences of temperature. CO_2 is also a constituent of the atmosphere, but in very small proportions. It has to be present because the ocean of air is the receptacle for all gaseous emanations, and CO_2 finds its way from the surface of the earth all the time as the result of vegetable and animal decay, and chemical changes in limestone, marble, and chalk which form such a large part of the earth's crust. The waters of many springs are highly charged with it, and some of them discharge very many pounds of the gas into the air daily. The oxygen in the atmosphere is also everywhere supporting combustion and respiration. All fuel and food contain a large percentage of carbon, and its oxidation, in combustion or in the chemical changes incident to animal life, results in the formation of CO_2 given to the atmosphere.

Man has no direct use for the CO_2 in the atmosphere. It is one of his own excretions which with all his gaseous exhalations he is obliged to entrust to the atmosphere for conveyance from him. As excreta they are deleterious to him, and the sooner he parts company with them the better. To him it is like the CO_2 to the fire of the furnace—unless it is carried away it will stop the combustion or oxidation. Fortunately, diffusion, winds, and differences of temperature soon mix it in with the ocean of air, though it is least at high altitudes; and plant life is eager for it, decomposing it under the action of sunlight and building it into those complex substances forming tissues and preparing it to go back into animal life as food for use as fuel to produce internal or external heat.

But in passing, it is very advisable to note that, while diffusion is sufficient to prevent the gases of the atmosphere from taking position in accordance with their specific gravities, thus defending man from suffocation by carbon dioxide, though with miles of oxygen just above, it is much too feeble to be entrusted with the work necessary to effect the important exchanges required between the atmosphere and the contained air of spaces occupied by men. Any warm-blooded animal condemned to try to continue its existence at the bottom of a bottle of air will fail as the exchanges by diffusion through the neck of the bottle will be altogether insufficient. The accumulation of CO_2, not considering other excreta, will go on to the point of suffocation though sufficient oxygen remains to satisfy requirements for a longer period if the gaseous exhalations from the creature itself were removed.

From the point of view of air exchanges, a ship is much like a bottle of air. From its lower spaces the movement by diffusion is through relatively small openings, called hatches, in the deck above or ceiling, and the deck below or bottom is crowded with those warm-blooded creatures called men who are not only using up the oxygen of the contained air but, what is more important, also adding their gaseous excreta. Diffusion takes place to some extent through bricks, provided they are not plastered, and through stone, but no more through the metal sides of a ship than through the glass of a bottle. To depend upon diffusion for the air exchanges of a ship would be much like trying to make a fire by exposing wood to sunlight. The total amount of heat from the sun is enormous, but it cannot be depended upon to warm a house sufficiently, much less to start a fire.

Diffusion cannot even be depended upon to secure uniformity in the air of a space to which the outside air comes in by a single inlet and goes out by a single exit. Even the fire of a stove establishes a close relation between itself and the cold air coming in through the chinks of a window, the cold air flowing along the floor in well-defined stream lines, and going into the fire, leaving the superimposed air as hot or hotter and as foul as ever. In the days where that hollow canvas cylinder called a windsail deflected the wind and conducted it down a hatch, perhaps in large quantities, it did little toward renewing the air in adjoining spaces if another hatch were somewhat near at hand, as it established a stream of air down one hatch and up another, leaving those sleeping out of line to awaken with headache due to foul air. And to-day where air is forced into the spaces of a ship, if an inlet is quite near a hatch and the direction of entrance is favorable, most of it will go up the hatch and will be lost so far as renewal of the air in the space is concerned, the amount of air going into and coming out of a space not necessarily being an indication of the ventilation of that space. Yet, diffusion even without assistance is sufficient to keep the gases of the atmosphere in practically uniform proportion.

Considered free from water, dust, and all impurities derived from local sources, the air may be considered to have the following percentage composition by volume:

Nitrogen (including *argon, helium, neon, krypton* and *xenon*),	79.013
Oxygen (including its allotropic form, ozone),	20.953
Carbon dioxide,	0.034

Probably the argon, helium, and other elements classed with nitrogen constitute at least 0.9 per cent. by volume of dry air, and the ozone about 0.00015.

It is not intended, however, to represent the above analysis as showing all the gases invariably found in dry air. For instance, there are always appreciable amounts of marsh gas and ammonia in the atmosphere. The amount of ammonia is very small—about 0.0008 per cent.—but it is somewhat larger in impure air, especially where there is tobacco smoke, and the marsh gas may be rather prominent, increasing, in the air of cities and to some extent in that of stagnant harbors especially in the tropics in calm hot weather, to even as much as 0.02 per cent. or more. CO_2 also increases under the same circumstances, perhaps going as high as 0.05 per cent. In cities the oxygen in the open may be reduced somewhat, going as low as 20.7 per cent. in dry air and the ozone is generally absent, having been used in the oxidation of organic matter, the 3-atom molecule of oxygen readily returning to the 2-atom state and furnishing, in the change, nascent oxygen which oxidizes organic matter present in the air. But the amount of ozone is always in very small proportions even at sea where it may be generated by the frictional electricity of wind and wave, or in thunder-storm localities by lightning.

In the air of stagnant harbors sulphureted hydrogen may be in rather large amounts even to the point of rapidly turning lead paint dark, and in the ports of manufacturing cities sulphurous acid gas can also be readily found. In all air there is a minute percentage of nitric acid, though under any ordinary circumstances nitrogen and oxygen exhibit no attraction for each other. Its presence, as in the case of ozone, is also probably due to the action of lightning on the atmosphere. Rain water contains about 1 part per million of nitric acid as nitrates. This fixation of nitrogen by operation of nature's electric discharges on that gas in the presence of oxygen is being duplicated in the laboratory where the nitrogen of the atmosphere is now burned and nitrates produced in commercial quantities for restoring to exhausted land nitrogen in such form that it can be utilized by plant life.

While it has become evident that the determination of the complete composition of the atmosphere, inasmuch as it is a mechanical mixture of gases, is far from simple, it is equally evident that nitrogen, oxygen, carbon dioxide, and watery vapor may be regarded as the principal constituents. Considering the average amount of watery vapor at the sea level as about 1.4 per cent., the following may be taken as the average percentage composition by volume of pure air surrounding ships at sea:

Nitrogen (argon, etc.),	77.90600
Oxygen (ozone, 0.00015),	20.65955
Watery vapor (as a gas),	1.40000
Carbon dioxide,	0.03360
Ammonia,	0.00080
Nitric acid,	0.00005

During recent years, observations upon the amount of CO_2 in the atmosphere have been giving smaller results than were usual fifteen or twenty years ago, as the methods now employed are more accurate than they were, but it is, nevertheless, as evident now as ever that the air of different localities, and even of the same locality, at different seasons or different times of the day contain slightly varying proportions of that gas. On land and over dirty harbors the amounts are larger near the surface, but over water the amounts are apparently somewhat greater in the daytime than at night. At sea the CO_2 may be as small as 0.02 per cent., but will usually be found about 0.03, yet in harbors, where ships of a navy are more than one-half the time, it is apt to be nearer 0.04. For that reason and also because carbonic acid observations, made under the usual conditions within the compartments of ships, generally give results slightly higher than they would be in laboratory, it has been considered advisable in practical work in ventilation to assume the standard amount of CO_2 to be 0.04 per cent., or 4 parts in 10,000 of pure air. Therefore, as a working standard, the percentage composition by volume of pure dry air has been assumed to be as follows:

Nitrogen,	79.01
Oxygen,	20.95
CO_2,	0.04

However much the composition of air may vary in the open, and the variations are remarkably small, its purity on the outside of a ship may be considered as invariably established at sea and as a rule in port. The purity of the atmosphere surrounding a naval vessel is rarely in question, and practically never becomes an urgent question. It is the air within the ship where there is a marked concentration of men that, in view of the necessity for man to excrete impurities, threatens health on account of its long-continued action and specially foul or vitiated condition.

However, when at or in dock or anchored near masses of putrefying animal or vegetable material, the purity of the outside air may not be a matter of indifference. Indeed, a naval vessel is itself capable of rendering the air immediately surrounding it objectionable at times on account of odor from the men's water-closets which, situated in the eyes of the ship, tend, with insufficient flushing or objectional construction, to deposits of fecal matter in scupper pipes, or, with insufficient or improper ventilation and flushing, to accumulations of foul air that may not only find their way aft within the ship, but even outside when the vessel is swinging to wind. In dry dock, the scrapings (barnacles and vegetable matter from the bottom of a ship) undergoing putrefactive changes, especially in hot weather, may cause disagreeable odors, and, at the water-fronts of navy yards, material deposited by rivers and exposed by tidal changes may give out marsh-like odors. Also at such yards, if there has been recent filling in, objectionable material employed for that purpose may cause much discomfort as a result of the putrefactive changes, or the location of a ship near the discharge of a sewer may cause uneasiness from fear of resulting sickness.

The direct influence of foul odors in causing particular diseases has been very much overrated, to say the least. Sewage commonly contains the germs of specific disease, but its gases are almost always, if not quite, free from micro-organisms. Odor is a physical property of some gases and not a vital property. Sulphureted hydrogen, which is a product of the putrefaction of organic substances containing sulphur and is one of the causes of the sickening odor of drains, has always the same odor wherever found. If made in the laboratory, say by decomposing ferrous sulphide with diluted sulphuric acid, it has the same odor as when produced by putrefactive changes. It is at once distinguished from all other gases by its disgusting odor, and that odor depends in no degree upon its source, as it is as much a physical property of the gas as the color of silver is of that metal. When a gas gently finds its way to the atmosphere from a wet surface, or from the surface of water itself, it is very generally free from the cause of specific disease, but, as a chemical substance, it has its full chemical properties and of course may therefore act mechanically in interfering with respiratory exchanges or even be a virulent poison to man. Its influence on man may or may not have relation to odor as some of the most poisonous gases have no odor. Carbon monoxide is very poisonous. It is certainly fatal to breathe air containing 1 per cent. of it, but it is without odor. On the other hand, the effect of hydrosulphuric acid on man is not in proportion to its odor, and such a gas makes its presence known when in small proportion.

Under ordinary circumstances, when gases find their way into the air ocean, although in the locality their presence may be detected by odor, the conditions are unfavorable to concentration and therefore any effect they might be able to have on man is generally much limited. In occupied or closed compartments the reverse is the case; though there are also special dangers from lack of concentration, as a man entering a boiler for the purpose of cleaning or scraping it may be hauled out unconscious, and the same thing may happen in a paint locker or in the double bottoms of ships from lack of oxygen. Yet, even in open air the concentration may become sufficient to cause languor, headache, soreness of throat, nausea, giddiness, and mental confusion, and, in all cases, disagreeable odors also tend to affect the body unfavorably through reflex actions as a nauseating taste would. The general tendency is to disturb assimilation, to cause depression and to lower vital resistance, and, therefore, odors are a useful warning of trouble and a cause for measures for the abolition of source or, if practicable, the removal of ship from disagreeable locality.

But the material causing odor may be fully capable of causing specific disease if it obtains entrance into the body of man, and such entrance may be effected through air which is always ready to take to itself anything that is in the state of dust. Dust is often the direct sediment of water and if, when in the neighborhood of sewers or when ships are anchored in stagnant polluted harbors, the water from over the side is utilized for washing decks and paint work, the transference of infective material to the air breathed by men can be readily accomplished, and the men themselves engaged in such work may also become infected by spattered water or through contaminated hands.

It was in 1901 that the regulation was made at the Navy Yard, New York, that owing to the pollution of the harbor water at what is known as the North Wharf, by the discharge of a large sewer carrying refuse from the city and yard, ships lying at that wharf must not use the river water for washing decks or other purposes, fresh water from the yard-main being employed instead. It appears that with certain conditions of tide and wind there is very little current at that point and the water became so polluted as to render the berth undesirable from a sanitary point of view. The same regulations have been enforced in a number of specially polluted harbors.

Probably the most notable historic stench was that from the Thames in the hot months of 1858 and 1859. It has been described as follows: "For the first time in the history of man the sewage of nearly three millions of people had been brought to seethe and ferment under a burning sun, in one vast *cloaca* lying in their midst. Stench so foul, we may well believe, had never before ascended to pollute this lower air. For many weeks the atmosphere of Parliamentary committee-rooms was only rendered barely tolerable by the suspension before every window of blinds saturated with chloride of lime, and by the lavish use of this and other disinfectants. More than once, in spite of similar precautions, the law courts were suddenly broken up by an insupportable invasion of the noxious vapor. The river steamers lost their accustomed traffic and travellers pressed for time often made a circuit of many miles rather than cross one of the city bridges."

The history of this event clearly records a very acute situation in which the air of the locality was greatly burdened. It was able, however, by virtue of the relatively limitless size of the air ocean, of the power of diffusion operating from all sides, and of air currents, to prevent the degree of concentration probable when even a limited source is within a closed space. The stench was horrible but, as a physical property of the gases, it merely indicated relative concentration. There were very many predictions of pestilence, but the statistics of the period show no increase in specific disease even among the waterguard and waterside custom house officers, who together numbered more than 800. Yet it appears that the steamboat men themselves receiving the gases in greater concentration suffered severely from physical and mental depression, languor, headache, nausea, and giddiness. Among the gases sulphureted hydrogen was prominent as the combination with the lead in the paint work of vessels caused rapid discoloration, a result, however, that was so very common in the days of wooden ships and of little disturbed bilge water, that it excited no great comment in navies, though originating in a confined space it clearly indicated conditions very unfavorable to good health. In the open, man has the advantage of the atmosphere acting as an *ocean* of fluid, but in a confined space, without sufficient ventilation, there is little chance for dilution and any source of noxious vapors, outside of man himself, is adding poisons to air which he himself is vitiating and rendering unfit for human consumption.

The atmosphere in sweeping the earth mingles with it innumerable particles of dust, and even at sea, while the hot gases reaching the atmosphere from the smoke-pipes of ships are lost with most of the particles of carbon from the same source, cinders find their way to ship's decks and even down into ship's spaces. Such cinders, like much of the dust of the atmosphere, are innocuous except in a mechanical way. If the coal from which the cinders were derived contained specific cause of disease, the excessive heat of combustion would of course render all products free from every form of life. While the surface of the earth is teeming with life and, therefore, is quite different from coal in that respect, dust has been subjected to more or less heat in the process of desiccation of soil, and, while the heat may have been insufficient to cause the death of many micro-organisms, the desiccation and light have been more effectual in that direction. Besides, the very large majority of micro-organisms are benign, and most of those that are pathogenic to man are associated with man himself or his habitations or locality as they have been made foul by his excreta. It is, therefore, the dust derived from man himself directly that causes most of the danger of infection from air. The danger of such infection is therefore enormously increased in confined spaces, as it is there that great concentration of dust from human sources is practicable.

In the open air floating particles are in greater degree pulverized soil that has been under the influence of light and heat of the sun and of benign bacteria in the breaking down of organic matter, and is then under the free influence of the oxygen of the atmosphere and the drying effect of wind or air in motion seeking water. It is undoubtedly true that the greater the length of time since the pathogenic bacterium was set free and the longer its voyage, the greater the chances that it will be destroyed or so modified as to be incapable of causing disease. Considering the infected person as the source, his cast off material, when entrusted to the air ocean, is more diluted the farther it goes and its living material has its existence greatly endangered by lack of food, a number of influences including those mentioned, and subsidence by rain or into water or other environment either not favorable to its life or prolonging its voyage.

Yet dust in air is much like sediment in water. Clear sparkling water may be dangerous but is not apt to be, and water with sediment may not be dangerous but is more likely to be. Air containing much dust is more apt to be dangerous than air containing little. But it is, as in the case of water, largely a question of source. Water near the habitations of man requires careful examination to establish purity, and air within and near the habitation of man is often undoubtedly a vehicle for the transportation of disease, though the relative amount of its solid impurities may be small. The immense number of floating particles noticed in a beam of sunlight may be iron oxide, lime, silica, soot, salt, bits of wings, seeds, débris of vegetation, manure dust, pollen, spores of moulds, bacteria, fragments of wood, hair, straw, and the like. Such material may be carried many miles, even out to sea, but no one has ever considered that outside air at sea even near a coast has been a vehicle for pathogenic micro-organisms from shore. In compartments of ships, material of the same nature can readily be found in the air, especially if the degree of ventilation is not marked and there is movement of occupants, and there will also be much epithelium, fibres of clothing material, portions of food, and bits of coal, and a considerable increase in micro-organisms, some of which may be recognized as pathogenic at times, especially in collections of dust which though not then air-borne could readily be made so, or have been so as on the blades of electric fans or on the gauze of ventilating exits.

In this connection it should be recalled that the number of so-called air-borne diseases has been remarkably diminished. Malaria, yellow fever, and dengue are now known to be mosquito diseases. The exciting causes of small-pox, scarlet fever, measles, mumps, and a number of diseases are unknown and therefore their propagation through the medium of the air cannot be demonstrated by an examination of that fluid. Even in water it is very difficult to isolate the typhoid bacillus when its presence has been demonstrated by the logic of events. In air the number of particulate bodies varies very greatly, even from minute to minute, and while bacteria are often conveyed by dust they must have by virtue of their lightness a marked power of flotation of their own. Even where pathogenic bacteria have been intentionally committed to the air of a confined space by dissipating dust known to contain them, it is very difficult and generally impracticable to recover any of them from the air. The use of the plate method leaves too much to chance, and in all aspirating methods, such as the flask method of washing, and methods of filtration, the volumes of air that pass through are not sufficiently large. Besides, the common saprophytes found in such numbers act as a confusing factor. Therefore, at the present time experience is of more importance in reaching conclusions in regard to propagation of disease by air than demonstrations of the actual presence in the air of pathogenic organisms.

Dogmatic assertions that typhoid fever and cholera are *never* air-borne diseases should not be accepted as a basis of practical work, in their prevention on ships crowded with men, in view of the tendency of those diseases to spread among men crowded together by ways that are not completely understood. Frequent disinfection of locality by application of liquid disinfectants should always be part of the routine as well as treatment in isolation, disinfection of clothing, and fumigation of space after occupation has ceased. The typhoid bacillus loses its virulence after comparatively little desiccation, but it retains its vitality in a semi-dried condition and the carrying power of air *under all circumstances* has never been measured. If minute droplets of sputum from the tubercular case can commit the tubercle bacillus to the air, it is not clear that the same may not occur in other diseases in which the scretions of mouths contain the exciting cause. In typhoid fever, however, the saliva of relatively few cases seems to contain the bacillus of that disease and the dry mouth and tenacious mucus of the typhoid case are very unfavorable, as a rule, to propagation in that manner. But minute particles of nearly dried fecal matter or urine, that may be on a shellacked deck or even on bedding of patient or clothing or nails of attendants in unrecognizable amounts, may occasionally be cast afloat in the air of a confined space by rapidity of movement incident to artificial ventilation, or actions of nurses, and remain adrift, in an active form, the fraction of time sufficient to cause infection.

The bacillus of diphtheria is capable of long survival in dust from which it has been isolated as well as from the nares of well persons, and the tubercle bacillus has been frequently found in dust even after months of desiccation. Fortunately, while inspired air contains much life, the moist membranes of the nose and to a less extent of the mouth, especially when healthy, are able to render many micro-organisms inert while retaining them. Expired air in normal breathing contains no bacteria, but, nevertheless, diseased persons, as in cases of measles, mumps, diphtheria, and tuberculosis are, in speaking or sneezing or coughing, entrusting infected sputum and nasal secretions to air, some of it in such minute subdivision that the air is able in its eagerness for water to take up the fine particles before they can reach surfaces of locality. Water is in air in the form of gas or vapor, and bacteria might thus be rendered free. Besides, every person has had the disagreeable experience at some time of talking to one who insists upon face approximation and who cannot talk without perceptibly spraying the mouth secretions.

As a general conclusion it may be considered that the atmosphere may be depended upon not to introduce into a ship, even as ordinarily anchored, the cause of specific disease except by insects carrying infection, but that danger is in the contained air which should be kept as clean as possible by proper ventilation, cleanliness of surface without dust, and the proper immediate disposal or care of excreta that may be capable of going into dust, especially those of diseased persons.

Concentration of men greatly increases danger of infection by tendency to render locality more rapidly unfavorable to the maintenance of general health, by diminishing distance between the susceptible, or those rendered more susceptible, and the source of infection, and by increasing concentration of cause of infection. Care of excreta that may go into dust and cleanliness of surfaces without dust limit source, and proper ventilation secures dilution and, together with suitable food and other measures, preserves the general health, thus increasing vital resistance and at the same time lessening the necessity for any resistance.

But the health of man has relation not only to the composition of the air surrounding him but also to its mere presence as matter or something having weight. The weight of air is as essential to his existence as its composition. As the gases composing the air are invisible, man is not naturally inclined to recognize that he is living at the bottom of an air ocean of great depth which, by virtue of its weight, exerts upon the surface of the earth an enormous pressure—more than 300,000 million tons. Under ordinary circumstances he is not conscious of moving through a substance—a material which, as an elastic fluid offering little resistance to forces tending to change shape, surrounds him completely, conforming to his surface and exerting its pressure from all directions. He, however, becomes conscious of the character of air as mere material when he opposes himself to its power when in motion as wind in a storm at sea, and he learns to respect it as capable of doing enormous damage, of lifting many tons of water and of compelling ships to resort to measures of protection against its violence. This substance in motion was the only power for centuries to drive ships on the surface of the vast ocean of water, and to-day it taughtens the anchor chains and breaks the hold of safety on bottoms.

However, that air has weight can be made directly evident by simple laboratory experiments—by weighing any ordinary stoppered globe when filled with air and weighing the same globe after the air has been exhausted by pump. The weight of the contained air will be *weight of (globe + air) − weight of globe.* But, as gases expand when heated and when atmospheric pressure is diminished, the weight of the contained air, even when dry, will vary unless the temperature and pressure are the same each time the experiment is made. It is an equal volume of air that is weighed in a given globe each time, but it has not the same density.

A navigator, having his ship at sea and, therefore, on the surface of the ocean of water, wishing to ascertain the depth of water uses a deep sea sounding apparatus which enables him to ascertain the distance to the bottom by the effect of the pressure of water at that depth, the pressure increasing with depth. The contour of the entire ocean bed can be determined in that manner and can be charted as valleys, hills and mountains. In the case of the air ocean man has the advantage of being at the bottom instead of on the surface and therefore he can place his apparatus for recording pressure exactly on any desired area of that bottom. In the ocean of water he has a surface to which he can refer the height of all other points on the earth surface; for, by measuring the pressure at the sea level and the pressure at any other point on the bottom of the air ocean, he can calculate the height of the latter above or below that level in accordance with the variation.

The instrument utilized for measuring the pressure at different depths of the air ocean is called a barometer. On every ship there are found two varieties of this instrument—the mercurial barometer and the aneroid barometer. Exact descriptions of those instruments can be readily found, but a study of such descriptions should be followed by an examination of the instruments themselves. It suffices here to note that if one takes a straight glass tube, at least 32 or 33 inches long, closed at one end, fills it with mercury and inverts it into a receptacle containing mercury he will have a cistern mercurial barometer. There must be no air within the vertical tube as it is essential for the space within the tube left by the settling of the column of mercury to be a vacuum.

A column of mercury of a certain height remains within the tube because in spite of its weight it cannot overcome the pressure or weight of the atmosphere on the surface of the mercury without the tube. In fact, the weight of the mercury within the tube balances the weight of a column of air pressing on the mercury in the cistern. The column of air thus balanced extends from the surface of the mercury in the cistern to the top of the air ocean and the area of its base is the same as that of the cross section of the column of mercury. To ascertain the weight of the column of air it is, therefore, necessary to ascertain the weight of the column of mercury it supports.

As the height of the column of air and, therefore, of the mercury varies with every variation in the depth of the air ocean, it is necessary to have some standard to which all variations can be referred. That standard has been taken as the height at the sea level which by long observation has been determined to be 760 mm. or 29.922 inches. The measurement of the height of the column of mercury is made by use of a scale divided into inches and tenths and by vernier attachment reading to hundredths or even thousandths of an inch.

As the height of the column also has relation to temperature, mercury expanding under heat, the height is calculated under a temperature of 0° C., or 32° F., assumed by the nations as standard. The weight of the mercurial column must therefore be calculated under the same conditions.

Now, if the mercurial column be considered to be 29.922 inches high and to have a cross section of one square inch, it will contain 29.922 cubic inches of mercury. As one cubic inch of mercury at 32° F. weighs 3,426.75 grains, 29.922 cubic inches weigh 102,535.2135 grains, or 14.64 avoirdupois pounds. In other words, the weight of a column of the atmosphere which has a height from the sea level equal to the depth of the air ocean and a base of one square inch is generally about 14.64 pounds, inasmuch as such a column is able to balance or support a column of mercury of that weight. The pressure of the atmosphere at the sea level is therefore generally 14.64 pounds per square inch. This enormous pressure is exerted upon each square inch of the earth's surface at that level and of course upon man in common with all other objects. It is calculated that a man of ordinary size sustains a total pressure when at sea of about 14 tons, but the pressure is exerted equally in all directions and may even be considered as permeating the body. The atmospheric pressure is not expressed, however, in pounds or weight, but in height of mercurial column. One does not say that the standard pressure at the sea level is 14.64 pounds per square inch, but 29.922 inches or 760 millimeters at standard temperature, 32° F. or 0° C.

Such an assertion must not be taken to mean that the pressure at the sea level or any point on the earth's surface is invariable—on the contrary, it is always fluctuating within limits. It is subject to regular diurnal and annual changes, and to the irregular variations known as cyclonic and anticyclonic. The varying heat of the sun on the earth's surface and the varying character of the surface do not permit a constant barometer anywhere. Heated air weighs less than cold air, damp air than drier air. The temperature of the air in any locality is constantly varying as well as its humidity and in certain regions it is almost invariably higher than in others. The very causes of the seasons are necessarily causes of pressure variations. Such factors enter into barometric changes and determine air currents or winds, the atmosphere by virtue of its fluid state seeking a constant pressure at each point on the earth's surface at the same level.

The determination of what this constant pressure would be is the determination of the normal or standard barometric pressure of that point and also of its height in relation to the sea level. For as the air is compressible it is evident that its density by virtue of its own weight or pressure varies from the top of the air ocean to its bottom or the earth's surface, but as the land has an irregular surface marked by valley, hill, and mountain its different localities are at varying distances from the surface of the atmosphere, and therefore not only support columns of air of different heights, but also of different average densities or weights, the smallest weight corresponding to the column of least height. It therefore necessarily follows that as heights are ascended the pressure lessens or, in other words, the barometer falls, but, as in ascending, the height of the column of air is not only lessened but there is left below air of greater density, more vertical distance has to be traveled upward all the time to cause corresponding changes in barometer reading. For instance, at the first 917 feet of ascent from the sea level the barometer falls 1 inch, but when 917 feet more have been ascended the barometer falls less than another inch, as the first 917 feet represented the height of a column of greater density and consequently of greater weight than the second 917 feet, the air becoming more rapidly rarefied each foot of ascent. One thousand eight hundred and sixty feet above the sea level the normal barometer reading will be 2 inches less than the standard at the sea level; at 2,830 feet, 3 inches; at 3,830 feet, 4 inches, and at 4,861 feet, 5 inches. But at points above the sea level the barometer is subject to variations as at the sea level where the pressure taken as standard is after all more or less arbitrary.

In this sketch the object has been to merely state general principles in a way to assure such a general understanding as may be necessary in relation to work to be considered subsequently. As a matter of fact, the study of the barometer and the interpretation of its variations is highly complicated from a scientific point of view. Indeed, in this very matter of computing height from barometric readings the actual state of physical science does not permit any high refinement. There are limits of error due to instrument, hour of day, and time of year, unsettled weather, etc. Any formula for computing barometrical heights is thus necessarily merely approximate. The idea here is a recognition that the pressure of the atmosphere is variable everywhere, that those variations are measured by differences in barometric readings, that when air is collected under a high barometer it may be assumed to be more dense or more compressed than when collected under a low barometer and that as, for instance, a cubic foot of air when the barometer is 30 contains more air as a substance than a cubic foot at the same temperature when the barometer is 28 though occupying the same space, it is necessary to always bring all volumes that may be collected for examination to standard pressure in order to arrive at any results suitable for comparison with each other or with results obtained by others.

In view of the special construction of the mercurial barometer on a ship of the navy a sufficiently accurate reading can be obtained, for such purpose as a CO_2 observation, without regard to errors incident to differences of level in cistern, to capillarity, and expansion and contraction of the brass index or scale. The study of the cause of such errors and their method of correction is interesting and can be accomplished by reference to works on that subject where also can be found description of the aneroid barometer which depends for its action upon the movement of an index measured by scale and depending upon changes of shape produced by varying atmospheric pressure on a metal vacuum chamber. Such an instrument has had its scale graduated under the glass receiver of an air-pump with a standard mercurial barometer attached. The air is exhausted, and as the mercury falls inch by inch the aneroid scale is pointed off and graduated from 31 inches to any required range. The aneroid, owing to its portable form, like a large watch, and great sensitiveness in responding to change in pressure (denoting changes in pressure much more quickly than the mercurial barometer) is in very general use, especially where changes of location of instrument are required. It, however, can never be used as an independent standard, should occasionally be compared with the mercurial barometer and, if necessary, adjusted to correspond.

It is in connection with this instrument that the following rule for determining the approximate difference in height between two given places has been stated: Note the reading of the aneroid at one of the points of observation, then at the other, subtract the lower reading from the higher and multiply the remainder by 900, this will give the difference of altitude in feet. For example: The aneroid at the summit of a hill indicates 29.90 inches, at its base 30.18 inches. $\therefore$ $30.18 - 29.90 = .28$; $.28 \times 900 = 252$ feet, or the approximate height of hill. If, however, the temperature of the upper station is 70 or above, or its barometer reading is about 26 inches or below, the use of 1,000 instead of 900 as a multiplier will give better results. There are, of course, a number of other methods of obtaining height, including a determination of temperature of vapor as it arises from boiling distilled water at different pressures. A table of temperatures according with varying barometric pressures is made in laboratory and utilized at any place desired. At a pressure of 29.905 inches distilled water boils at 212° F., while at 23.453 it boils at 200° F.

It is evident that where the height of any point on the earth's surface above or below the sea level is known, its barometric reading at any instant can be referred to the sea level by adding or subtracting the variation due merely to difference in height. For instance, if the barometer reading at a point 4,861 feet above the sea level is 25.18 inches the pressure would be equivalent to 30.18 at sea level, as the height corresponds to a fall of 5 inches. A weather map is made out on that principle, barometric readings at all places selected being expressed as if the surface of the country were all sea level. Then lines drawn through places showing the same pressure are termed isobars, while lines drawn through places of same temperature are called isotherms. The distance between isobars represents variations in pressure of 1/10 of an inch and when such variations represent a diminished pressure to a center of lowest pressure the area enclosed by the outside isobar is called a low or cyclone, while if the variations represent an increased pressure toward a center of highest pressure it is called a high or anticyclone.

The low, the pressure being represented by ordinates corresponding with heights of the mercurial column and the isobars being considered as contour lines, becomes diagrammatically a cup-shaped depression, while the high may be considered as dome-shaped. The rapidity of the spiral movement of air into a low or out of a high has relation to distance of isobars from each other in the low or high, as such distance varies with degree of slope or grade from rim to center of a low or center to base of a high; and whether the spiral be a right or left one depends upon whether the low be south or north of the equator. This subject and many others in meteorology are of much interest, especially to seafaring people, and while they may not be considered, except in a very general way, in a naval hygiene, should excite sufficient interest in the naval medical mind to cause reference to works in which they are treated with sufficient detail to give a very good general understanding of them. They are matters of general education and are of such great interest that they can be properly regarded as suitable material for test questions in ascertaining degree of general education.

Varying atmospheric pressures cause corresponding variations in atmospheric density. The volume of a gas is inversely proportionate to pressure (Boyle's law). If a cubic foot of air at one atmosphere (29.922 inches or 760 mm.) be subjected to a pressure of 2 atmospheres, it becomes 1/2 a cubic foot. In other words, if a sample of air be collected when the barometer reading is 29.90, its volume becomes $\frac{29.90}{29.92}$ of the original volume when expressed at standard pressure (29.92). In going from a smaller pressure to a greater the required volume must be less, and in going from a greater pressure to a less the required volume must be greater. If the change is to be made to standard pressure (29.92) $\therefore$ 29.92 : observed barometer : : given volume : required volume, or required volume $= \frac{\text{observed barometer} \times \text{given volume.}}{29.92}$

If a bottle holds 3,000 c.c. and it is filled with air when barometer is 29.90, what will the volume become at standard?

$$29.92 : 29.90 : 3000 : x$$
$$x = 2997.99 \text{ c.c.}$$

If a man excretes in 24 hours 27,952.458 cubic inches of CO_2 measured dry at 29.92 inches pressure, what would the volume be at 30 inches pressure? It would obviously be less, as it is to be considered as under greater pressure, therefore:

$$\text{Required volume} = \frac{27952.458 \times 29.92}{30} = 27877.918 \text{ cubic inches.}$$

But air expands when heated, therefore a volume of air as of any gas has to be considered not only with reference to pressure, but also to temperature. Air not only expands when heated, but the increase in volume is definite (Charles' law). For each degree of temperature added to air it expands a certain constant fraction of its volume. That fraction is called the coefficient of expansion. For each degree Centigrade the coefficient is 0.003667, or nearly 1/273; and for each degree Fahrenheit 0.0020361 or, about 1/491. One cubic foot of air at 0° C. will become

1 +.003667 at 1° C., and one cubic foot at 32° F. will become 1 +.0020361 at 33° F., and 1 + 2 (.0020361) at 34° F. On the other hand, in going down below standard, 1 cubic foot of air at 0° C. will become 1 −.003667 at −1° C., or 1 −.0020361 at 31° F. and 1 − 2 (.0020361) at 30° F.

On ships of our service barometer scales are graduated in inches and thermometers are Fahrenheit. To convert a reading of an F. thermometer to corresponding reading of a C. thermometer subtract 32, multiply by 5 and divide by 9, the formula being $C. = \frac{5(F.-32)}{9}$. The formula for conversion of Centigrade to Fahrenheit is $F. = \frac{9}{5} C. + 32$. To convert a barometer reading in inches to a corresponding reading in millimeters, multiply by 25.3995, and in going from millimeters to inches, divide by the same number.

In every instance a given volume of air at a given temperature above or below standard is considered to have been a certain volume at standard (0° C. or 32° F.) which if above standard has been expanded to the given volume or if below standard has been contracted to given volume. If that be thoroughly appreciated and it is recognized that in every instance in which the volume of air is to be brought from one temperature to another the first step is to bring it to standard if it is not already there, one should have no difficulty in calculating change of volume due to change of temperature.

If one volume of air at 32° F. becomes 1 + (.0020361 × the number of degrees it is to be raised) then any number of volumes becomes that number of volumes multiplied by 1 + (.0020361 × the number of degrees it is to be raised).

For instance, if 3,000 c.c., cubic inches, cubic feet, or cubic yards of air are considered as being at 32° F., what volume would be occupied at 82° F.?

It is evident that the volume would be greater and that each c.c. cubic inch, cubic foot or cubic yard would become 1 + (.0020361) (82 − 32) or 1.101805. If each c.c. or cubic inch will become 1.101805 c.c. or cubic inch, then 3,000 will become $3000 \times 1.101805 = 3305.415$. If the coefficient of expansion be expressed as the common fraction 1/491, the 3,000 units become

$$3000\left(1+\frac{82-32}{491}\right)=3000\times\frac{491+50}{491}=\frac{3000\times 541}{491}=3305.499.$$

In going from 32° F. to any temperature above, the required vol. = given vol. $\times (1 + .0020361\ (t-32))$, t representing the temperature to which the air is to be raised.

If the air is at any temperature above 32° F. and is to be reduced to that standard it is evident that as it is considered to have been originally brought from 32° F. by multiplying by $1 + (.0020361\ (t-32))$ it can only be brought back by dividing by the same. For instance in considering the above, it is evident that the 3305.415 c.c. at 82° F. were 3,000 at 32° F.

and that as $3000 \times 1.101805 = 3305.415$ so $\frac{3305.415}{1.101805} = 3000$. Therefore, in going from any temperature above 32° F. to 32° F., the required vol. = $\frac{\text{given vol.}}{1+(.0020361\,(t-32))}$

When air is collected for chemical examination or analysis, its volume is always brought to standard temperature and pressure, but there are many calculations relating to volume of air in ventilation, or relative humidity, that involve changes of volume from one temperature to another, neither being standard. For instance, if 40,000 cubic feet of air at 50° F. enter a ship's compartment each hour, how many cubic feet would leave it per hour if the contained air were heated to 70° F.?

Such a problem requires two steps: 1. The reduction of incoming air to standard, and 2. The bringing of the resulting volume to the required temperature. One cannot utilize the coefficient of expansion in going directly from 50° F. to 70° F. because any volume of air is considered to have been a certain volume at standard and the series is an arithmetical progression in which the least term is the unit at standard and not at 50° F., and the constant difference is the coefficient of expansion.

40,000 cubic feet of air at 50° F. become at 32° F., $\frac{40000}{1.0366498}$ cubic feet, and that number of cubic feet at 32° becomes at 70°, $\frac{40000 \times 1.0773718}{1.0366498} = 41571$ cubic feet. (The same calculation could be made with less trouble as follows:

40,000 cubic feet of air at 50° F. become at 32° F., $\frac{40000}{1+\frac{18}{491}}$, and that number at 32° F. becomes at 70° F., $\frac{40000 \times (1+\frac{38}{491})}{1+\frac{18}{491}} = \frac{40000 \times 529}{509} = 41571$ cubic feet.)

It is evident, when working below standard, $1-(.0020361\,(32-t))$ must be substituted for $1+(.0020361\,(t-32))$, and that in going down from standard the factor is used as a multiplier instead of a divisor, and in coming up to standard as a divisor instead of a multiplier.

For instance, 3,000 c.c. of air at 32° F. become at 22° F., $3000 \times (1-(.020361)) = 3000 \times .979639 = 2938.917$ c.c.; and 2938.917 c.c. at 22° F. become at 32° F., $\frac{2938.917}{.979639} = 3000$ c.c. In working with the Centigrade scale the coefficient of expansion for that scale, .003667 or 1/273 must be substituted for .0020361 or 1/491, and the variation above or below 0° utilized accordingly.

By returning to the remarks on correction for pressure, it will be seen that, if desired, the given volume can be corrected for temperature and pressure by use of a single formula. As a rule, air collected in a ship's compartment is above standard temperature and therefore the following formula will be applicable for the double correction:

$$V = \frac{\text{observed height of bar.} \times \text{given volume}}{29.92 \ (1 + .0020361 \ (t - 32))}$$

If a bottle holds 3,000 c.c. and it is filled with air when barometer is 29.90 and thermometer is 72° F., what will the volume be at standard?

$$V = \frac{29.90 \times 3000}{29.92 \ (1.081444)} = 2772.21$$

While there is cold air and warm air or even hot air, with corresponding days, it is not so much temperature of air that ordinarily decides degree of comfort as its degree of humidity, especially when associated with movement of air, as wind or draft.

It has already been declared that air in nature invariably contains water. It can readily be shown to be present, even in the air of the warmest steam heated compartment of a ship, by taking a dry well-polished table glass and putting into it water and cracked ice. As the temperature of the glass is lowered the air in contact becomes more chilled until eventually it is compelled to deposit water on the glass. For at any given temperature air can hold only a certain quantity of watery vapor, and the higher the temperature of the air the more it can hold. It follows that air containing aqueous vapor can always be made to part with water if its temperature is lowered to the degree where as cold air it cannot hold the amount that was readily practicable when warm.

When air contains as aqueous vapor all the water it can hold it is said to be saturated, and its temperature at saturation is called *dew-point.* Where air does not contain all the aqueous vapor possible at its temperature there is always a certain lower temperature at which it would have its maximum amount. To determine that temperature is to determine the dew-point.

With care, use of a thermometer in the table glass, gentle stirring and a gradual addition of ice, leading to gradual lowering of temperature of the contained water, the temperature at which the air begins to deposit water or its dew-point can be ascertained roughly. Such a simple arrangement, while not sufficiently accurate in its results for scientific work, illustrates the principle and is essentially a direct hygrometer or an instrument for directly determining the dew-point of the air, an important step in ascertaining the relative amount of aqueous vapor, the amount of water required by air to be in a state of saturation at different temperatures having been determined and expressed in a table of saturation.

There are a number of direct hygrometers, *e.g.*, Daniell's, Regnault's, and Dine's, but on ships an indirect hygrometer, called the stationary *psychrometer*, is employed for determination of degree of humidity.

An examination of the psychrometer itself is of much more value than any description or drawing of it. But it may be said to consist of two 12-inch standard thermometers mounted side by side on a block of wood with their bulbs extending below. The block is fastened within to the back of a little slatted wooden house, the thermometers being placed vertically and facing the door. Around the bulb of one of the thermometers is a wick which extends below into a small receptacle containing distilled water. This little water cistern has a cover through which the wick passes without being compressed and as the water ascends by capillary attraction the bulb of the thermometer is kept constantly moist.

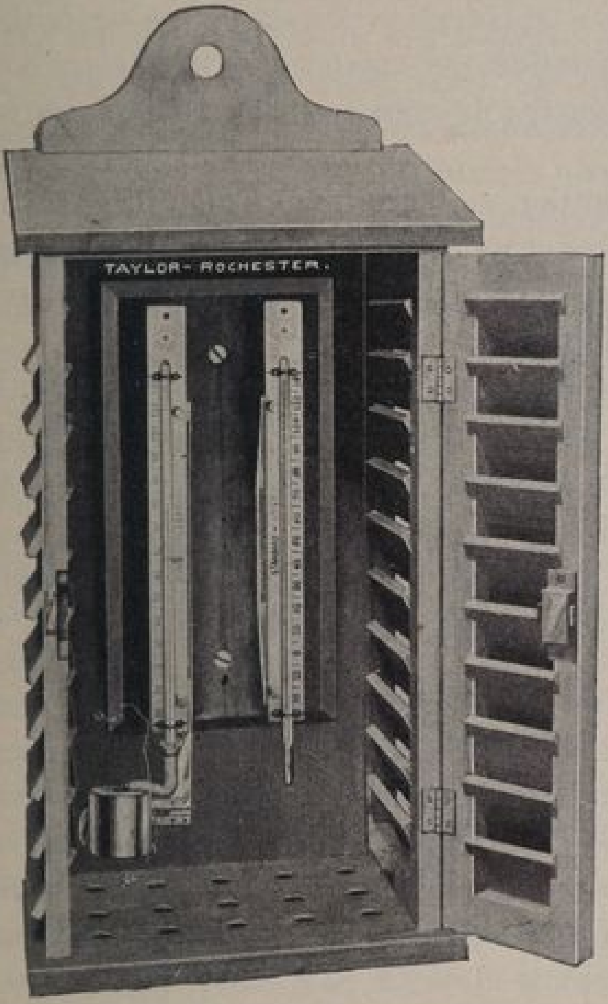

Fig. 1.—The Ship's Psychrometer.

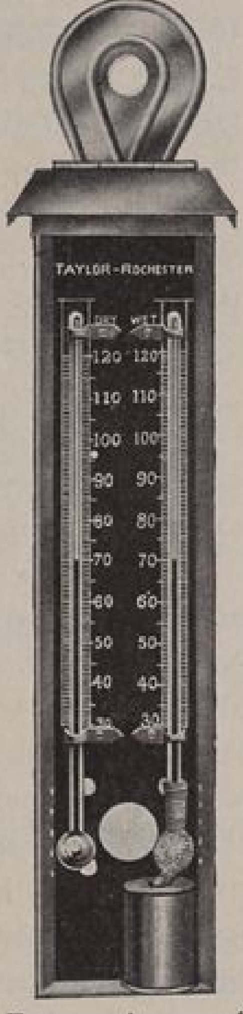

Fig. 2.—A type of Hygrometer (Mason) in common use.

The thermometer with its bulb covered with the moist wick is called the wet bulb thermometer and the other is called the dry bulb thermometer. As the dry bulb is exposed to the air it merely gives the temperature of the atmosphere or of the air in any locality in which the little house may be placed, but, as the air in taking water from the wet wick causes a cooling effect as a result of the evaporation, the wet bulb thermometer will stand lower than the dry bulb except when the air is saturated, at which time, as there can of course be no evaporation, the two thermometers will ordinarily read alike.

The difference between the two bulbs will be a measure of the rapidity of evaporation or the thirst of the air or the drying power of the air, for the more rapid the evaporation the greater will be the cooling effect, and consequently the greater the difference in the readings of the thermometers.

The cooling effect of evaporation is due to the change in physical state of water from a liquid to a gas or watery vapor. When that change is taking place there is a disappearance of heat, the additional heat required to maintain the gaseous state being called latent heat.

The surface of the earth is losing heat much of the time as a result of the drying effect of the air, but the morning dew or frost shows that the process is not continuous as the air must give back water when it is cooled to any extent below its point of saturation.

The air is a poor conductor of heat and therefore a volume of air attains a common temperature as water does by a transfer of particles or convection, the warmer particles rising and the colder descending. When air, as at night, is in contact with a body colder than itself and that body is at the bottom of the air, as the earth is, the cold particles without the operation of wind remain in contact and being chilled below their point of saturation deposit water as dew. Winds sweep the colder particles away before they can be too greatly cooled, and, therefore, are not favorable to the formation of dew or frost, even on an earth losing heat rapidly by radiation as at night.

In the daytime the earth is receiving heat from the sun and warming the air in contact, thus increasing its capacity to take water, the amount of aqueous vapor air can hold depending upon its temperature. The dew therefore disappears, but the rapidity of disappearance is increased by wind, because air left in contact with a moist surface nears saturation as it takes up water, and therefore the longer it is left in contact the less its drying power becomes.

Movement of air, as in wind or draft, therefore increases its drying effect, and the warmer the air and the less water it contains the more rapidly its currents cause any wet surface such as a deck or moist human body to become dry. Evaporation is limited by any confinement of the space into which the water must pass as vapor, and therefore a deck tends to remain wet, in any poorly ventilated compartment or in any part of that compartment, where there is little ventilation or little movement of air. Dryness and ventilation or air movement go hand in hand.

The value of the psychrometer lies in the difference declared between the readings of the dry and wet bulbs. The reading of the wet bulb is of course not the dew-point, but the difference in the readings of the two thermometers and the temperature of the air itself, as shown by the dry bulb, furnish the data from which the dew-point is calculated with the aid of formula and factors. If the dry bulb reading be 53° F. the dew-point is as much below the wet bulb as the wet bulb is below the dry bulb, but above that temperature the wet bulb comes nearer the dew-point, while below, it is further away.

As the result of a series of observations extending over many years Glaisher found that for each temperature of the air as shown by the dry bulb there is a constant relation between the difference of wet and dry bulb and the difference of wet bulb and dew-point. The conclusion was derived from comparison with results of Daniell's hygrometer. The resulting rule is stated as follows: The dew-point is found by multiplying the difference of dry and wet bulb by a constant factor ascertained for that dry bulb temperature (*shown in table*) and subtracting the product from the dry bulb temperature.

The formula may therefore be considered to be as follows:

$$\text{Dew-point} = \text{D B} - \text{F (D B} - \text{W B)}$$

$$\left.\begin{array}{r} \text{In which D B} = \text{temperature of dry bulb)} \\ \text{W B} = \text{temperature of wet bulb)} \end{array}\right\} \text{Fahrenheit.}$$

F = factor standing opposite dry bulb temperature in the table on page 166.

The following may be taken as an example of method of utilizing formula and table: The dry bulb temperature is 70° F. and the wet bulb 60° F.; what is the dew point? Dew point =

$$70 - 1.77\ (70 - 60) = 70 - 17.7 = 52.3^\circ.$$

The determination of the dew-point is the first step in the determination of the relative humidity or percentage of possible humidity. When air is saturated it contains 100 per cent. of all water it can hold as vapor, and its relative humidity is then said to be 100; but if, instead of being saturated, it has only 1/2 or 3/4 of the amount it could hold, its relative humidity is 50 or 75.

The determination of relative humidity is very important because it determines the drying power of air, indicating additional amount of water it would take up, and it also has important relation to power of carrying or taking away heat, moist cold air, especially when in motion, robbing the body of heat by convection much more rapidly than dry cold air of the same temperature. It is moist warm air that declines to relieve the body of its heat by evaporation of perspiration, and it is moist cold air that is most able to deprive the body of its heat by convection. It is also the very dry hot air in a steam-heated compartment in winter that necessitates a high temperature for comfort as it markedly reduces temperature of body by evaporation, and therefore must, through its own high temperature, greatly diminish loss by convection in order to strike the balance required for comfort. It is the same air that irritates the respiratory passages by too rapid withdrawal of moisture from their exposed surfaces.

GLAISHER'S FACTORS.

Dry bulb	Factor	Dry bulb	Factor	Dry bulb	Factor	Dry bulb	Factor
10	8.78	33	3.01	56	1.94	79	1.69
11	8.78	34	2.77	57	1.92	80	1.68
12	8.78	35	2.60	58	1.90	81	1.68
13	8.77	36	2.50	59	1.89	82	1.67
14	8.76	37	2.42	60	1.88	83	1.66
15	8.75	38	2.36	61	1.87	84	1.65
16	8.70	39	2.32	62	1.86	85	1.65
17	8.62	40	2.29	63	1.85	86	1.64
18	8.50	41	2.26	64	1.83	87	1.64
19	8.34	42	2.23	65	1.82	88	1.63
20	8.14	43	2.20	66	1.81	89	1.63
21	7.88	44	2.18	67	1.80	90	1.62
22	7.60	45	2.16	68	1.79	91	1.62
23	7.28	46	2.14	69	1.78	92	1.61
24	6.92	47	2.12	70	1.77	93	1.60
25	6.53	48	2.10	71	1.76	94	1.60
26	6.08	49	2.08	72	1.75	95	1.60
27	5.61	50	2.06	73	1.74	96	1.59
28	5.12	51	2.04	74	1.73	97	1.59
29	4.63	52	2.02	75	1.72	98	1.58
30	4.15	53	2.00	76	1.71	99	1.58
31	3.60	54	1.98	77	1.70	100	1.57
32	3.32	55	1.96	78	1.69		

In the determination of relative humidity from dew-point and dry bulb temperature, it is necessary to realize that what is desired is the relation in percentage between the amount of watery vapor that could be present and the amount that is present. Consequently:

$$\text{Relative humidity} = \frac{\text{Weight of watery vapor actually present} \times 100}{\text{Weight of watery vapor that could be present}}$$

For instance, suppose when the dry bulb is 70° F. the air is found to contain 4.29 grains of water per cubic foot and it is known that air at 70° F. must contain 8.01 grains per cubic foot at saturation. The question merely becomes, what per cent. of 8.01 is 4.29? It is evident that the reply is

$$\frac{4.29 \times 100}{8.01} = 53.5 = \text{R.H.}$$

Now a cubic foot of the atmosphere is composed partly of dry air and partly of aqueous vapor, and the elastic force or tension of each is the weight of each. The tension and consequently the weight of vapor that saturates a given space are the same for the same temperature whether the space contains another gas or is a vacuum. Consequently, a cubic foot of saturated air at 52.3° F. contains an amount of water equal to the weight of a cubic foot of aqueous vapor at 52.3° F. and maximum tension.

The weight of any volume of aqueous vapor is calculated from the weight of same volume of dry air at same temperature and pressure. One cubic foot of dry air at 32° F. and 29.922 inches weighs 566.85 grains, as it is 14.47 times heavier that the same volume of hydrogen at same temperature and pressure. But the density of H_2O as vapor is $\frac{18}{2} = 9$, while the density of dry air is 14.47. Consequently: The density of watery vapor : density of air : : 9 : 14.47. From that proportion it is evident that the density of watery vapor is $0.622 \times$ density of air. Therefore, if a cubic foot of air at standard temperature and pressure weighs 566.85 grains, a cubic foot of watery vapor at *same temperature and pressure* weighs $566.85 \times .622 = 352.5807$ grains.

But the cubic foot of watery vapor at 32° F. must not be considered under a pressure of 29.922, but as merely under a pressure equal to its own maximum tension or the pressure it exerts at 32° F. when derived from evaporation of water into vacuum. That tension or pressure has been found to be 0.181 inch of mercury. Therefore, if a cubic foot of aqueous vapor at 32° F. and 29.922 inches weighs 352.5807 grains it will weigh $\frac{352.5807 \times .181}{29.922} = 2.13$ grains in a cubic foot of saturated air at 32°.

And in the same way, as the maximum tension of watery vapor at 52.3° F. is 0.3925 inches, a cubic foot of aqueous vapor in saturated air at 52.3° F. will weigh $\frac{352.5807 \times .3925}{29.922\ [1 + 20.3(.0020361)]} = 4.41 =$ weight of water in grains in cubic foot of air at 52.3° F. when saturated.

From these calculations it appears that weight of water in grains in a cubic foot of saturated air at any temperature above 32° F. can be found by use of the following formula:

$$W = \frac{352.58 \times E}{29.92\,[1 + (.0020361)\,(t^1 - 32)]}$$

In which E is the maximum tension of aqueous vapor corresponding to the wet bulb temperature and t^1 is the wet bulb temperature.

Of course the weight of a gas per cubic foot is less the higher the temperature, and as in the formula the weight of aqueous vapor (352.58) is given as a cubic foot at 32° F. the correction for temperature has to be made to find its weight per cubic foot at any other temperature.

In regard to elastic tension (E in the formula), it is necessary for an appreciation of what it is to reconsider that a barometer measures the total atmospheric pressure but that, as atmosphere is made up of dry air and of aqueous vapor, the barometer reading is the sum of the two pressures—that of a column of air, considered to be dry but yet attenuated by moisture, extending from the surface of the mercury in the cistern to the top of the atmosphere and having a base equal to cross section of the vertical column of mercury, and of a column of aqueous vapor of same size. Each of these columns is of course considered to have a varying density, lessening with altitude as the lowest cubic foot or cubic inch, or any cubic foot or cubic inch, of each is under the pressure of all the cubic feet or cubic inches of each above to the top of the atmospheric ocean. Consequently the tension or elastic force of aqueous vapor represents the pressure of all the aqueous vapor in the air above the place of observation just as the remainder of the barometer reading represents the weight of all the dry air above the place of observation. One may therefore consider that there is a dry air atmosphere and an aqueous vapor atmosphere, and, as a cubic foot of dry air weighs less than a cubic foot of damp air at same temperature and pressure, aqueous vapor in its varying amounts in the atmosphere modifies its pressure.

But in dealing with saturated air it is of course not merely a question of tension but of *maximum* tension which means the greatest pressure and consequently greatest weight. When water is allowed to evaporate into vacuum, vapor arises from it until its pressure reaches a certain point after which all evaporation ceases. That point depends on the temperature, the higher the temperature the greater the amount of evaporation, but that point for each temperature indicates the greatest vapor pressure possible at that temperature and therefore measures the maximum tension or maximum elastic force. It is evident that at each temperature the weight or pressure of the aqueous vapor is exactly the same as the weight or pressure of the aqueous vapor in the same volume of saturated air at the same temperature. Consequently, if the pressure be expressed in inches of mercury for each temperature there will result a table of maximum tensions showing the pressure exerted by aqueous vapor in saturated air at corresponding temperature.

To use the formula given for the calculation of the weight of water in grains in a saturated cubic foot of air, it is therefore necessary to utilize the following table of maximum tension for each degree Fahrenheit, picking out the value of E corresponding to the temperature desired, which is the dew-point.

TABLE OF MAXIMUM TENSION OF AQUEOUS VAPOR AT DIFFERENT TEMPERATURES.

Temp. F.	Inches of mercury	Temp. F.	Inches of mercury	Temp. F.	Inches of mercury	Temp. F.	Inches of mercury
32	0.181	48	0.335	64	0.596	80	1.023
33	0.188	49	0.348	65	0.617	81	1.057
34	0.196	50	0.361	66	0.639	82	1.092
35	0.204	51	0.374	67	0.661	83	1.128
36	0.212	52	0.388	68	0.684	84	1.165
37	0.220	53	0.403	69	0.708	85	1.203
38	0.229	34	0.418	70	0.733	86	1.242
39	0.238	55	0.433	71	0.759	87	1.282
40	0.247	56	0.449	72	0.785	88	1.323
41	0.257	57	0.465	73	0.812	89	1.366
42	0.267	58	0.482	74	0.840	90	1.410
43	0.277	59	0.500	75	0.868	91	1.455
44	0.288	60	0.518	76	0.897	92	1.501
45	0.299	61	0.537	77	0.927	93	1.548
46	0.311	62	0.556	78	0.958	94	1.596
47	0.323	63	0.576	79	0.990	95	1.646

By using the table of maximum tension in connection with the formula given for calculating weight of water in grains in a cubic foot of saturated air at any temperature the following *table of saturation* is obtained:

WEIGHT OF WATER IN GRAINS IN A CUBIC FOOT OF SATURATED AIR AT DIFFERENT TEMPERATURES.

Temp. F.	Weight in grains of cubic foot of aqueous vapor at maximum tension	Temp. F.	Weight in grains of cubic foot of aqueous vapor at maximum tension	Temp. F.	Weight in grains of cubic foot of aqueous vapor at maximum tension	Temp. F.	Weight in grains of cubic foot of aqueous vapor at maximum tension
32	2.13	48	3.82	64	6.59	80	10.98
33	2.21	49	3.96	65	6.81	81	11.32
34	2.30	50	4.10	66	7.04	82	11.67
35	2.39	51	4.24	67	7.27	83	12.03
36	2.48	52	4.39	68	7.51	84	12.40
37	2.57	53	4.55	69	7.76	85	12.78
38	2.66	54	4.71	70	8.01	86	13.17
39	2.76	55	4.87	71	8.27	87	13.57
40	2.86	56	5.04	72	8.54	88	13.98
41	2.97	57	5.21	73	8.82	89	14.41
42	3.08	58	5.39	74	9.10	90	14.85
43	3.20	59	5.58	75	9.39	91	15.29
44	3.32	60	5.77	76	9.69	92	15.74
45	3.44	61	5.97	77	9.99	93	16.21
46	3.56	62	6.17	78	10.31	94	16.69
47	3.69	63	6.38	79	10.64	95	17.18

Given the dry bulb temperature and the dew-point, the relative humidity can be calculated from either the table of saturation or the table of maximum tension, but more conveniently from the latter.

It has been shown that if a dry bulb reading be 70° F. and the wet bulb reading by 60° F. the dew-point is 52.3°. That shows that the aqueous vapor present is sufficient to saturate the air at 52.3°, but not at 70° F. In order words, the air at 70° F. has an aqueous vapor tension which is the same as the maximum tension at 52.3°. Now from the table of tension it appears that saturated air at 70° F. has a tension of 0.733, while saturated air at 52.3° F. has a tension of 0.3925 which in this case is the actual tension of the air at 70° F. Now it can be proven that just as the relative humidity $= \frac{\text{Weight of water vapor actually present} \times 100}{\text{Weight of water vapor that could be present}}$ so it is necessarily equal to $\frac{\text{Tension actually present} \times 100,}{\text{Maximum tension that could be present}}$; e.g., in this case $\frac{\cdot 3925 \times 100}{\cdot 733} = 53.5$. For the actual tension is a measure of the aqueous vapor present, and the maximum tension is a measure of all the aqueous vapor that could be present.

It can therefore be stated that in any given case:

$$\text{R. H.} = \frac{\text{Maximum tension at dew-point} \times 100}{\text{Maximum tension at dry bulb temperature.}}$$

For instance, the dry bulb temperature is 80° F. and the wet bulb 75° F.; what is the relative humidity? Dew-point $= 80 - 1.68\ (80 - 75) = 71.6°$ F.

$$\text{R. H.} = \frac{\text{Maximum tension at } 71.6° \times 100}{\text{Maximum tension at } 80° \text{ F.}} = \frac{.774 \times 100}{1.023} = 75.6.$$

Of course practically the same result can be obtained from calculations based upon the saturation table, but not so conveniently. If air at 80° F. has a dew-point of 71.6° F., it will when cooled to 71.6° F. contain about 8.432 grains of water per cubic foot; but if air contains 8.432 grains of water per cubic foot at 71.6°, it will contain $\frac{8.432 \times 1.08063}{1.0977} = 8.3$ grains in each cubic foot at 80° F. But air at 80° F. can contain 10.98 grains per cubic foot. Consequently R. H. $= \frac{8.3 \times 100}{10.98} = 75.6$

Utilizing Glaisher's factors and the table of maximum tension in the manner shown, the following Relative Humidity Table has been calculated:

RELATIVE HUMIDITY TABLE.

TABLE of R. H. COMPUTED FROM D. B.—W. B. OF STATIONARY PSYCHROMETER.

Temp. dry bulb	Difference between dry and wet bulb														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fahr.	Relative humidity at saturation = 100														
90	95	90	85	81	77	73	69	65	62	59	56	53	50	47	44
89	95	90	85	81	77	73	69	65	61	58	55	52	49	46	43
88	95	90	85	81	77	73	69	65	61	58	55	52	49	46	43
87	95	90	85	81	77	73	69	65	61	58	55	52	49	46	43
86	95	90	85	80	76	72	68	64	61	58	55	52	49	46	43
85	95	90	85	80	76	72	68	64	61	58	55	52	49	46	43
84	95	90	85	80	76	72	68	64	60	57	54	51	48	45	43
83	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42
82	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42
81	95	90	85	80	76	72	68	64	60	56	53	50	47	44	41
80	95	90	85	80	75	71	67	63	59	56	53	50	47	44	41
79	95	90	85	80	75	71	67	63	59	56	53	50	47	44	41
78	94	89	84	79	75	71	67	63	59	56	53	50	47	44	41
77	94	89	84	79	75	71	67	63	59	56	53	50	47	44	41
76	94	89	84	79	75	71	67	63	59	55	52	49	46	43	40

RELATIVE HUMIDITY TABLE.—Continued.

TABLE OF R. H. COMPUTED FROM D. B.—W. B. OF STATIONARY PSYCHROMETER.

Temp. dry bulb Fahr.	Difference between dry and wet bulb														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Relative humidity at saturation = 100														
75	94	89	84	79	74	70	66	62	58	55	52	49	46	43	40
74	94	89	84	79	74	70	66	62	58	55	52	48	45	43	40
73	94	89	84	79	74	70	66	62	58	54	51	48	45	42	40
72	94	89	84	79	74	69	65	61	57	54	51	48	45	42	39
71	94	88	83	78	73	69	65	61	57	53	50	47	44	41	38
70	94	88	83	78	73	69	65	61	57	53	50	47	44	41	38
69	94	88	83	78	73	68	64	60	56	53	50	47	44	41	38
68	94	88	83	78	73	68	64	60	56	52	49	46	43	40	37
67	94	88	83	78	73	68	64	60	56	52	49	46	43	40	37
66	94	88	83	78	73	68	64	60	56	52	48	45	42	40	37
65	94	88	83	78	73	68	63	59	55	51	48	45	42	39	36
64	94	88	82	77	72	67	63	59	55	51	48	45	42	39	36
63	94	88	82	77	72	67	63	59	55	51	47	44	41	38	35
62	94	88	82	77	72	67	62	58	54	50	47	44	41	38	35
61	94	88	82	77	72	67	62	58	54	50	47	44	41	38	35
60	94	88	82	76	71	66	62	58	54	50	46	43	40	37	34
59	94	88	82	76	71	66	61	57	53	49	46	43	40	37	34
58	93	87	81	76	71	66	61	57	53	49	46	43	40	37	34
57	93	87	81	75	70	65	61	57	53	49	45	42	39	36	33
56	93	87	81	75	70	65	60	56	52	48	44	41	38	35	32
55	93	87	81	75	70	65	60	56	52	48	44	41	38	35	32
54	93	86	80	74	69	64	59	55	51	47	43	40	37	34	31
53	93	86	80	74	69	64	59	55	51	47	43	39	36	33	30
52	93	86	80	74	69	64	59	54	50	46	42	39	36	33	30
51	93	86	80	74	68	63	58	54	50	46	42	38	35	32	29
50	93	86	80	74	68	63	58	54	49	45	41	37	34	31	29
49	93	86	79	73	67	62	57	53	49	45	41	37	34	31	28
48	93	86	79	73	67	62	57	52	48	44	40	36	33	30	. .
47	93	86	79	73	67	61	56	51	47	43	39	36	33	30	. .
46	93	86	79	73	67	61	56	51	47	43	39	35	32	29	. .
45	92	85	78	72	66	60	55	50	46	42	38	34	31	28	. .
44	92	84	78	71	65	59	54	49	45	41	37	34	31	28	. .
43	92	84	78	71	65	59	54	49	45	41	37	34	31	28	. .
42	92	84	78	71	64	58	54	49	44	40	36	33	30	27	. .
41	92	84	77	70	64	58	53	48	43	39	35	31	28	. .	. .
40	92	84	77	69	63	57	52	47	42	38	34	31	. .	. .	. .
39	92	84	77	69	63	57	51	46	42	38	34	. .	. .	. .	. .
38	91	83	75	68	62	56	50	45	41	37	. .	. .	. .	. .	. .
37	91	83	75	68	61	55	49	44	39	. .	. .	. .	. .	. .	. .
36	91	82	74	66	59	53	47	42	. .	. .	. .	. .	. .	. .	. .
35	90	80	72	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
34	89	79	72	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
33	89	78	70	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
32	87	75	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .

This relative humidity table can be used only in connection with a stationary psychrometer. The sling psychrometer or whirling hygrometer is a more convenient instrument for use in occupied compartments as the result can be determined much more rapidly. In the ordinary psychrometer it is necessary for the water in the cistern to have been at the temperature of the surrounding air for some little time before the readings can be regarded as strictly satisfactory. If the water in the cistern is colder than the surrounding air the wet bulb will stand too low. Consequently, in carrying such an instrument from one part of a ship to another there is delay in filling the cistern with water, which should have been standing for some time in the locality to be investigated, and in waiting for the instrument to reach an adjustment. Besides, with rapid movement of partially distributed air incident to plenum system of ventilation there is some difficulty in placing a psychrometer so that the reading will be a fair average, and to take a number of satisfactory readings requires time.

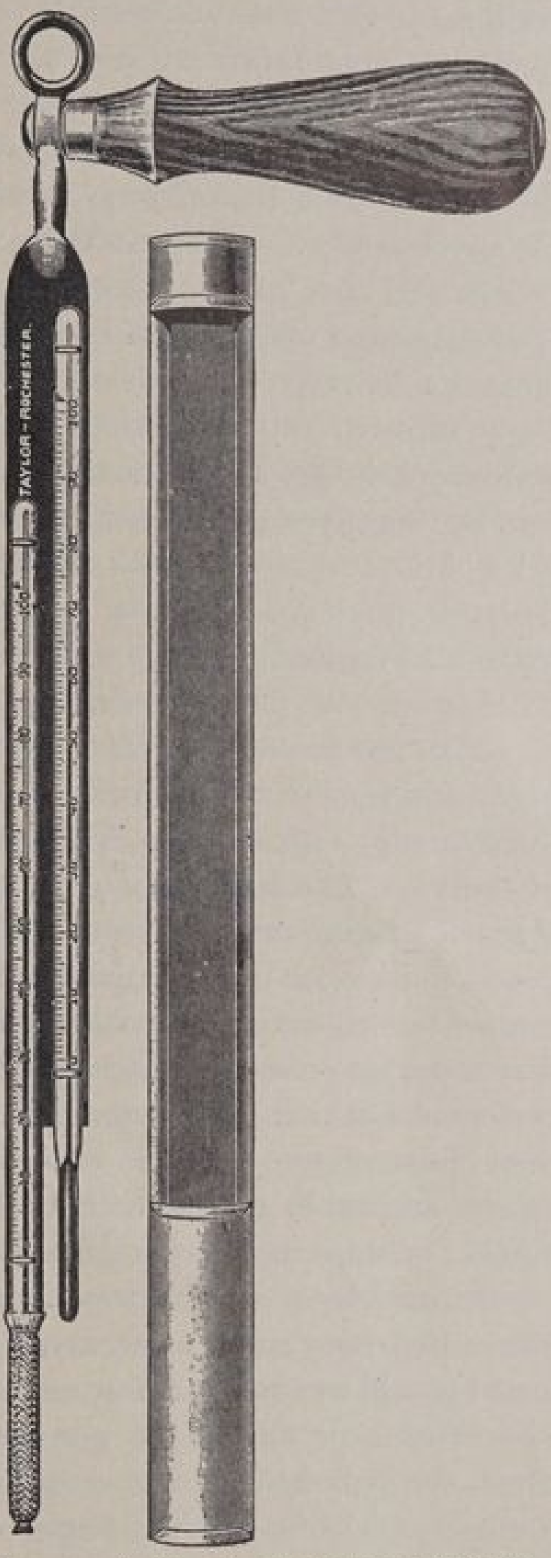

Fig. 3.—A Sling Psychrometer or Whirling Hygrometer.

The sling psychrometer also consists of two thermometers placed side by side but attached to a narrow strip of metal which when in use is made to revolve like the spoke of a wheel around a handle held more or less horizontally and moved by the user to secure the revolution. The wet bulb is generally placed for convenience lower than the dry bulb, and being covered with wicking or silk is made wet by simply dipping the covered end into a cup of distilled water, at temperature of compartment, until thoroughly saturated. The instrument is then whirled 15 or 20 seconds, holding it well away from the body. The wet bulb is read and the instrument whirled for another period of same length and so on until the wet bulb reading is the same or nearly the same for two successive readings. The relative humidity is then found by use of a relative humidity table furnished with the instrument. It is obvious that in whirling the wet bulb through the air rapidity of evaporation is increased, and consequently for the same relative humidity the difference between the wet and dry bulbs will be greater in this instrument than in the stationary psychrometer. The material covering the wet bulb whether wicking or silk will also make a difference in rapidity of evaporation, and consequently each variety of these instruments has its own humidity table. They are, however, convenient and if the relative humidity table has been fairly adjusted and the instrument is properly handled it can be used with more or less satisfaction in relation to ventilation.

Having given such consideration to the composition and characteristics of the atmosphere or air on the outside of a ship as has seemed most desirable in relation to naval hygiene, it seems to be next in order to make a corresponding study of the air on the inside or within the ship in commission—the inhabited ship.

Man has no control over the variations in temperature and humidity of the atmosphere. They belong to the climate of locality and he has to learn to adjust his clothing, food, and habits accordingly, or seek change of climate. The latter is of great importance in navies, as ships can be made to change cruising ground in accordance with season in time of peace, coming out of the tropics in our warmer months and going into or toward the tropics in our colder months. It will or has become evident that a proper control of such movements is of vital interest to a naval personnel, but that even in time of peace it can only be rather general as there must always be some cruising ships north in winter, emergency repairs and other specific conditions, even in time of peace, keeping a number of ships under very undesirable climatic conditions.

In exercising control over movements of ships it should, however, be realized how much of a calamity it is for a naval vessel to be subjected to cold weather and how much the general health of a crew deteriorates when kept during the summer months in the tropics. But such effects can only be traced to cause where there is understanding of naval routine, naval life, and the degree of adjustment to climate of which a naval vessel is capable as a habitation at the present time.

It should, however, be appreciated that it is not advisable to keep men in cold weather in order that they may be able to stand the cold to the best advantage when required, any more than it is advisable to keep men in the tropics in order that they may learn to stand the heat to the best advantage in a possible tropical campaign. If men on a ship are kept under *comfortable* climatic conditions—such conditions as are most conducive to a ship's full routine—they will have, as a rule, the best general health and will be best able to stand a campaign in either hot or cold climates. But, the ship itself as the habitation should be at least as capable of adjustment to climatic changes as the man who lives on board. A ship as a fighting machine may have to go anywhere that she can float. A man can be made to change his food and clothing to accord with climate, and even some modifications of a ship's routine can and should be made to avoid unnecessary harmful exposure and to provide suitable exercise; but a ship is capable of no more adjustment to climatic changes or adaptation to requirements as a living place than her construction and appliances permit under intelligent control. In this adaptation, the control of the condition of the air within the ship is of first importance.

The air within the ship is a portion of the atmosphere as it has been modified by the ship itself, not excluding stores, heating, and lighting, and by the men who are on board, chiefly by their excreta directly or indirectly. A ship in commission modifies its contained air chiefly by the heat it generates, the properties of the material of which it is constructed, its appliances or openings used for ventilation and the water that may gain admission as the result of condition of weather or of the routine care of the ship itself. Stores may influence the air directly or indirectly in a number of ways as by refrigerators and cold-storage rooms in objectionable conditions, meat lacking brine, and gases from smokeless powder in magazines as well as in turrets during firing.

The modern ship is and must be constructed of metal, a substance having high conductivity. It is divided into a number of compartments by bulkheads and even decks of the same material. In one or more of those compartments a very large quantity of heat is generated daily, even in port, by combustion of coal for the purpose of making steam. A very large percentage of that heat goes to waste and much of it is liberated within the ship by exposed surfaces of boilers, steam connections and machinery. This wild or ungoverned heat not only directly causes high temperatures of air in compartments containing boilers or machinery or steam pipes, but also by virtue of the high conductivity of metal decks and bulkheads and of the property of convection possessed by air, tends to invade other compartments, making a large heating surface of bulkheads and decks in localities necessarily utilized as quarters and where as in warm weather or climates artificial heat is most objectionable.

The first essential from a hygienic point of view in the construction of the modern ship is the employment of every practicable means for the control, limitation or abolition of wild heat. Every ship should have ample and controlled means of heating her spaces when it is desired, *but the degree of adaptability of ship to climate depends primarily upon the degree of limitation of wild heat provided for in her construction, and secondarily upon the means provided for the removal of air heated by uncontrolled heat.*

During the Spanish-American War there were ships in the tropics whose sleeping quarters were never below 93° F., whose decks in compartments over boilers and engine-room felt hot to feet within shoes and whose firerooms gave air temperatures as high as 170° F. In at least one of those ships the sick-bay temperature was rarely below 96° or 100°, and frequently above. The result was due mainly to insufficient employment of non-conductors in the construction, and secondarily to insufficient means for the removal by ventilation of the resulting overheated air, especially at its source or in those compartments where the heat was liberated. *It is therefore clear that the ventilation of a modern ship is necessary for the removal of overheated air, even if it were not urgently required for other reasons.*

While the wild heat liberated within the modern ship strongly tends to invade the general crew spaces, the metal side-plates of the ship, in contact with the atmosphere and water without, are having an interesting and often powerful influence on the heated air within. By virtue of its high conductivity the metal forming the sides is robbing of heat the air that is in contact with it within and passing it to a colder atmosphere and colder water without. In winter, when the difference between the inside and outside temperatures is marked this transference of heat is rapid and its effect especially disastrous, but at all times, when a ship is in cold water or surrounded by atmosphere colder than the contained air, as is usual at night when the men in the crew spaces are in their hammocks, the influence is sufficiently marked to menace health, particularly of those swinging outboard or next to the ship's sides.

Under such circumstances the portion of the contained air in contact with side-plates has its temperature lessened and, if the outside temperature permits, and it often does, goes below the dew-point and consequently is obliged to deposit water. The deposition of water under such circumstances is known as the sweating of metal.

Such water represents an unhygienic condition, inasmuch as it is material, derived in part from lungs and skins, that should have passed out in the movement of air incident to ventilation. It is water spread over a large area and containing an increasing amount of organic material which, changed or unchanged, may at anytime be suddenly returned to the contained air as the result of the heat of the sun, change of weather, increased temperature within and variations in ventilation.

But while the presence of the water itself is very objectionable, the immediate and more serious results are due to the inequality of temperature to which the bodies of men are subjected. An essential of any proper living space is equability of temperature as the body of man is very intolerant of exposure of portions of its surface to different temperatures at the same time. That is practically the case in exposure to drafts and is the actual state whenever any person is under the influence on one side of the chilling effect of an outside plate and on the other of the warm contained air, often made warmer by bulkheads heated by wild heat from engine-room, fireroom, evaporator-room, dynamo-room, or steering-engine room. The marked concentration of men on a vessel of war is an essential incident of service and consequently any discussion of it from a sanitary point of view with regard to limitation is profitless provided the size of the crew is not in excess of the maximum requirement in time of war. But such concentration necessitates a small cubic air space per man, and necessarily places a port and a starboard line of hammocks at night very close to outside plates. For practical purposes the chilling effect of a side-plate may be considered to vary inversely as the square of the distance from the plate and consequently the close proximity necessary on most ships in the case of a number of the crew is an insanitary condition, having a marked influence for evil whenever a vessel is in cold weather—the effect varying with difference between inside and outside temperatures.

In officers' quarters the bunk placed outboard probably permits a more intense chilling effect than in the case of the hammock which overlaps the occupant to some extent. A sleeper turning in his sleep exposes first one side of the body and then the other alternately to heat and cold. The heated side, perhaps in a visible state of perspiration, is turned to air unable to take up much water as it is near its dew-point but, on account of its low temperature and high relative humidity capable of rapidly robbing the body of heat by convection. Radiation of heat from that side of the body is also greatly increased in view of the proximity to a good conductor of low temperature. That side of the body next to the plate therefore soon becomes chilled and may be left covered with cold water in form of sweat that has lost its heat to the air by convection.

Until recent years the transference of heat by outside plates was greatly limited in officers' quarters by wood sheathing. As a result of experience in action, wood, as a combustible material and one forming splinters when struck by shells, has been eliminated as much as possible from vessels of war. For some time the use of cork paint was continued in all living quarters, and in storerooms and magazines on such metal surfaces as were directly exposed to chilling by conduction and also on the underside of protective deck, on armor or other surfaces where mass of metal would change temperature slowly. The effect of cork paint in limiting the chilling effect and consequently the sweating of metal is marked, especially when the cork has been properly applied in sufficient number of layers of graded sizes, culminating in a surface on which very fine granules of cork are in maximum quantity. Observation has been sufficient to show that the best result is not always obtained as the work requires much care. Then, too, the best result that can be obtained is also not satisfactory inasmuch as the chilling effect on the bodies of men in close proximity is not sufficiently limited, remaining quite apparent when there is marked difference between inside and outside temperature. It is also clear that the granular surface of cork paint, however fine, is objectionable as it is more apt to retain dust and dirt than a smooth surface. It is therefore important that the paint be not only properly applied, but also strictly limited to metal exposed to unequal temperatures and not applied to all metal surfaces. Beams, inasmuch as they have the same temperature on both sides, and the plating of a steel deck covered with planking should be free from cork and finished in plain white.

On ships in which cork paint only is used, bunks in officers' quarters should be placed inboard, and sick-bays should be arranged so that the sick will be placed as far from side-plates as is practicable. Even when a ship is cruising in merely cool waters recovery from bronchitis and like affections is often delayed by the influence of side-plates, either upon men in bunks or upon convalescents tending to occupy chairs placed near ship's sides. Even during the day the same influence in cold weather is also apparent upon the crew in the living spaces, as where the men congregate a number will be found subjecting themselves to the effects of unequal temperatures.

It was this condition that, together with cold drafts and exposure incident to washing clothes in cold weather, produced much of the sickness on ships passing the time north in winter, and it was wild heat that caused the greater part of the discomfort and much of the debility of crews in the tropics and was responsible for the heat prostration among members of the engineer force. It has become evident in the service that both of those influences must be more greatly limited than has been the case in many ships, before navies can be considered suitable for cruising in all climates.

To that end non-conducting ceiling or sheathing of more or less complicated design has been installed in the modern ships on side plating of living quarters, on radiating bulkheads, and underside of protective deck over engine-room and boiler-room. The construction of this sheathing varies in accordance with location and chiefly with use, the sheathing on side-plates differing essentially from that utilized to prevent the transference of heat from one part of the ship to another.

In all cases the sheathing is formed of inside plating joined to side-plate or bulkhead or protective deck by channel irons, thus leaving an air space which, when in connection with the side-plate, is made as air-tight as practicable but, when in connection with a radiating surface within the ship, is left open that it may be ventilated and thus relieved of the heated air within. This space when closed is only a few inches across, is entirely cork painted within and is made closed to prevent the sweating that would result from circulation of air. While in such closed spaces reliance is put upon cork paint in crews' quarters, in officers' quarters and sick-bays one and one-half inch compressed cork slabs are bolted, over the cork paint, to the inside of the metal sheathing.

In the ventilated spaces a larger distance is left across. On the under side of the protective deck of engine-room, one and one-half inch fire felt is used instead of cork; and in a boiler-room, while no fire felt is employed, there is an air space twenty-four inches across. In those situations a positive movement of air within the spaces is necessary, and for that purpose connection is made with fans, in the engine-room with the engine room system of ventilation, and in the boiler-room with the ship's system, the natural outlet in the latter case, being in the casing around the smoke pipe, and in the former in the engine-room hatch casings.

The diagrams on the next page illustrate the construction of this non-conducting ceiling in officers' quarters and sick-bay, that in the crew's space, as has been stated, being the same, except that compressed cork slabs are omitted.

Considerable advances have also been made in the more recent ships in the direction of limitation of wild heat at its source. These advances have been the result of experience, perhaps not so much in relation to health as to the more economical use of coal, it being evident that wild heat represents waste.

In the attempt to make the most of the coal consumed it may be cited, for instance, that all steam and exhaust pipes, valves and their flanges, separators, feed-water heaters and all feed, suction, and discharge pipes and valves are provided with a covering of sectional magnesia (carbonate of magnesium 85 per cent., asbestos fiber 15 per cent.) and a magnesia covering is used on main cylinders and valve chests, upper cylinder heads, steam cylinders of all auxiliary engines in engine-rooms and boiler-rooms, and boiler drums and other exposed parts of boilers.

Hair-felt put on in sections is used on all parts of main, auxiliary, and dynamo condensers, on feed and filter tanks and evaporators.

Boiler casings are lined with magnesia at least 2 inches thick having inside of such lining asbestos board 1/4 inch thick. Boiler uptakes have the space between outside and middle sheets filled with magnesia, while the space between inside and middle sheets communicates with air space of smoke pipe and is open below, except when ship is under forced draft, thus forming an uptake for hot air by way of air space between inner and outer casing of smoke pipe which may extend without interruption to its top.

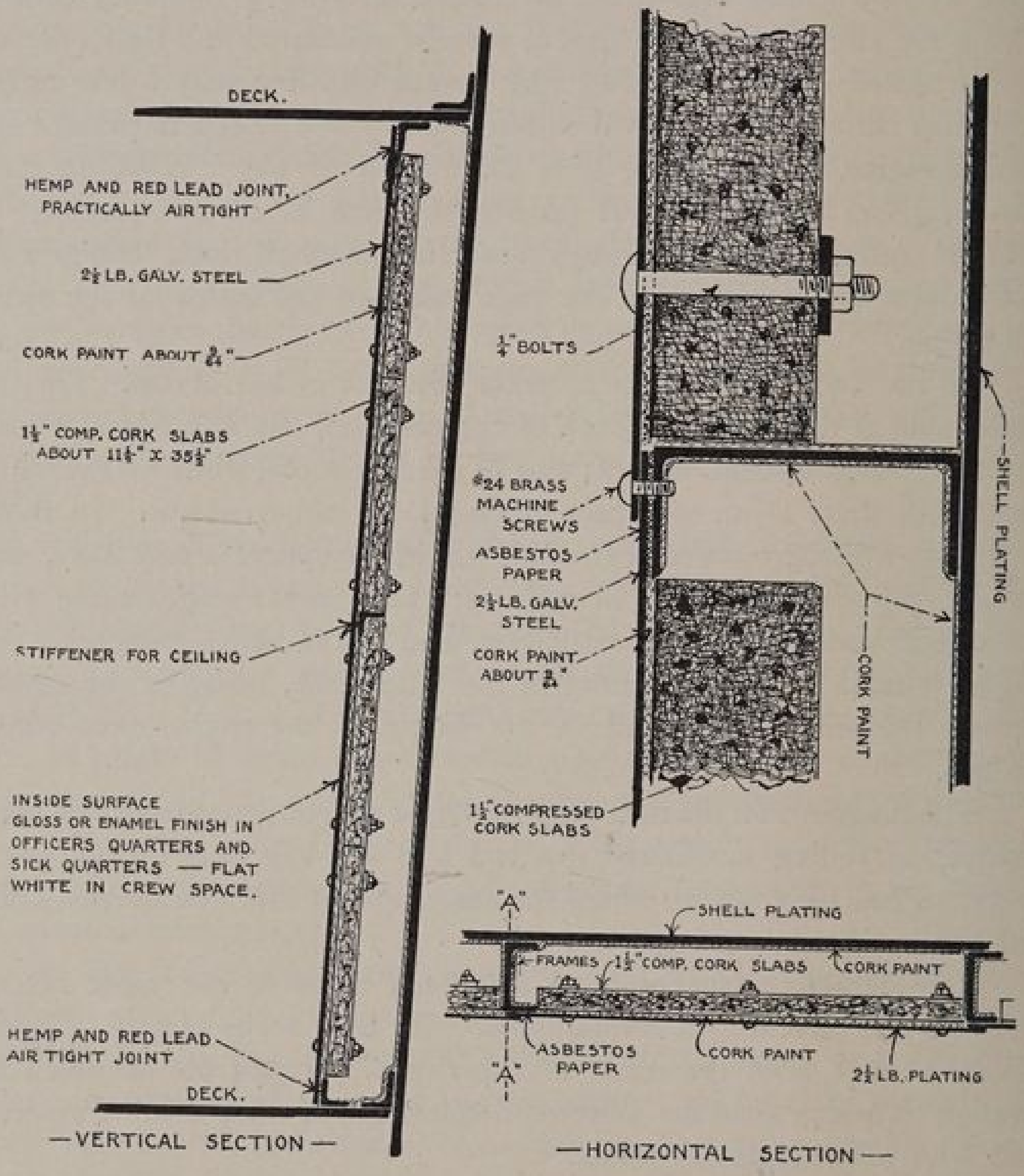

FIG. 4.—Non-conducting Sheathing on Side-Plates.

Openings are also sometimes made into outer casing of smoke pipe just above protective deck to admit air for circulation between the smoke pipe casings. Magnesia is also used in connection with outer casing of the pipe. The following is a general diagram of the arrangement for the removal of overheated air from a boiler-room.

With the increased use of non-conductors as a feature in the engineering department, and the progress that has also been made in more recent ships by the special arrangement of non-conducting ceiling described, to avoid the transmission of heat from engine- and boiler-rooms to other parts of the vessel, a great improvement has been made in that quality of the contained air of quarters represented by temperature.

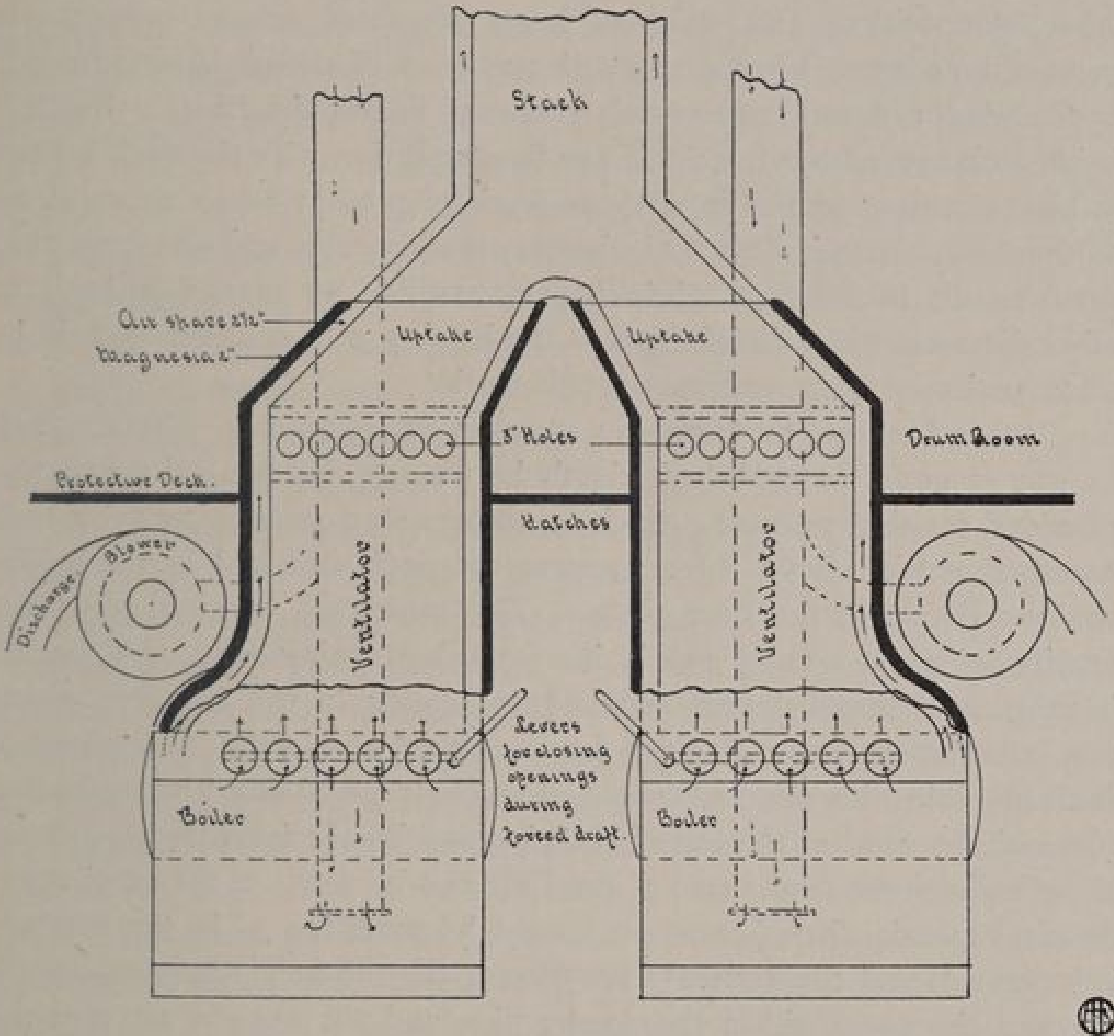

FIG. 5.—Diagram of fireroom showing blowers for forced draft or for assisted draft; ventilators for air-supply in natural draft, and openings and channels provided for escape of overheated air in natural draft.

With a greatly increased use of non-conductors and improvement in their quality and better facilities for the removal of overheated air, the more modern vessels of war should approach a condition of suitability for work in warm climates.

The difficulty in some localities, with all forms of sheathing or covering, from a sanitary point of view, may be to secure and maintain such close apposition that they cannot become receptacles for vermin or for dirt, and thus breeding places of the exciting causes of disease. That is the trouble with linoleum which so far seems to be the best material for deck covering in quarters and in general between decks. It is about 1/4 inch thick laid on the metal deck made smooth by use of cement and strips of composition. It is secured to the deck by water-proof glue or other composition, and strips of brass are fitted around openings to protect the edge. It is covered with two coats of shellac before the ship is commissioned and is frequently shellaced during the cruise. But it is liable to become frayed and to have its connection with the deck broken in places, unless careful supervision leads to prompt repair as required. Without such repair filth finds its way underneath, and the crew may show results in the form of follicular tonsillitis, or even diphtheria or other diseases, when disinfection of the locality with solutions should be made preliminary to necessary repair work.

Into a fireroom an enormous quantity of air enters. The air finds its way in under natural draft chiefly by passing down metal ventilators provided for that purpose. Such ventilators start in large movable bell-mouthed cowls above the superstructure deck and end in the boiler-rooms well above the floor plates. The movement of air down those ventilators while usually greatly increased by turning cowls to the wind is in general terms determined by combustion in the furnaces whose rate in turn depends, with clean fires and good coal, upon the amount of draft possible with size and height of smoke pipe, assisted by aspirating effect of the wind at the top of the pipe and by the increased supply of air to boiler-room from force of wind utilized by cowls of the ventilators. As air expands when heated its weight becomes less as its temperature is increased, and consequently the greater the difference in temperature between the gases within the smoke pipe and the outside air, and the longer the pipe, the more rapid the flow up the pipe or the greater the draft. Therefore, other things being equal, the draft will be better the colder the weather or the heavier the outside air. But at the same temperature damp air weighs less per cubic foot than dry air, consequently the higher the temperature and relative humidity of the outside air the less will be the draft and, if under those circumstances there is no available movement of air as wind, the draft will be least. It is under such circumstances that the distress in firerooms is greatest, and the tendency to heat prostration is most marked. Under those circumstances not only is the amount of air going into the firerooms by ventilators at its smallest, but also the natural ability of that part of the ship to rid itself of overheated air is least.

In any fireroom the *direction* of the movement of air that enters the space by ventilators is dominated by the fires. Such air entering a hot space drops as colder or heavier air, from the ends of the ventilators or ash hoists toward the floor plates and, because of the degree of vacuum at and above the fires caused by the ascent of air in the smoke pipe, and because of proximity to the fires, forms a well-defined stream line from ventilator to furnace intake where it meets the urgent demands of the fire without ever having been distributed about fireroom. While the colder air enters to keep up the fire, the hot surfaces within the fireroom are raising the temperature of all the air above the furnace intake. Such hot air has, in view of its lightness due to high temperature, little or no tendency to encroach upon the stream of cold incoming air held below by greater weight and necessary direction of flow, and even where ordinary openings are above, or additional ventilators installed, the tendency of the hot air to use them as exits is often not as marked as might be expected, as the demands of the fire on incoming air are frequently stronger than the tendency to vacuum by egress of overheated air from the upper part of the space.

Of course, in using any additional ventilators the egress of hot air is assisted when wind is utilized as an aspirating force on the cowls turned away from it, and such a movement is increased when the wind is utilized by other cowls to admit the colder outside air on top of the heated air within. Under such circumstances the best results are obtained when all such cowls on the windward side of the ship are turned to the wind and all those on the leaward side are turned away from the wind. But the movement of cowls by hand demands close attention in view of change of wind and of the course of the ship, and, as has been seen, the period of greatest distress is during the absence of wind, especially in warm damp weather. Besides, the movement of the heated air is influenced by friction and it tends especially to accumulate in pockets or parts of the fireroom partially cut off from the general space. A fireroom is, therefore, considered as a whole, a striking exhibition of the fact that the ventilation of a space cannot be measured by the amount of incoming and outgoing air, as *the results depend as much upon distribution as amount of supply*. It is also a part of a ship in which removal of overheated air is of such great importance that vitiation by occupants is a very secondary consideration.

The same is true of engine-room, dynamo-room, and steering-engine room. In all such places satisfactory results can only be obtained by the liberal employment of non-conductors for the limitation of wild heat and of special means, in some cases both blowers and exhausters, for the supply of cold air and withdrawal of heated air. By the use of such rotary fans, for some of the locations in both systems (plenum and exhaust), it is easily practicable to renew air in engine-rooms and steering compartments in two minutes, in evaporator-room in two and one-half minutes, and in dynamo-room in less than a minute.

But the situation in the fireroom differs in some important respects from that in such hot spaces as engine-room, dynamo-room and steering-engine room, as may be deduced from the study of air circulation in fireroom given above. In all the hot spaces enumerated, there is liberation of wild heat, but in none of them except the fireroom is there combustion. The air supply in a fireroom has direct relation to the rapidity of combustion, or expenditure of coal, the fires not only dominating the air supplied by natural means, but utilizing the supply in hastening the burning of coal.

It follows that in the artificial ventilation of a fireroom there is commonly an increase in coal consumption. In fact, blowers are provided in all firerooms for that purpose, being utilized in assisted draft or in forced draft, when additional speed is desired. Such blowers are shown in the diagram previously given to illustrate the movement of hot air in that part of the ship.

In assisted draft all openings for the removal of heated air are operative, but the ends of the ventilators within the fireroom depended upon to supply air in natural draft are closed, the ventilators themselves acting as air ducts or intakes for the fans.

In forced draft all openings used in natural ventilation are closed, the supply of air being by the fans, and the exit being by the furnace intakes.

It is therefore quite evident that the artificial ventilation of firerooms cannot be separated from questions of coal consumption. In assisted draft each fire will consume perhaps twice the coal it was consuming in natural draft, and in forced draft perhaps five or six times as much. But under those circumstances each fire is generating more steam, and therefore the same power can be obtained with a smaller number of fires. In order to diminish the temperature in firerooms and thus improve the conditions under which the men work, the use of assisted draft is becoming much more common, and by reducing number of fires it seems not improbable that the expenditure of coal may thus be made as economical under assisted draft as under natural draft at ordinary cruising speed.

At present the nature of the so-called heat prostrations in firerooms is not well understood. It appears that when men are working in hot air they are able to perform their duties without much distress, when the standing of the wet bulb thermometer is not much above 81° F., but when that bulb approaches 86° F. to 88° F. the disinclination to work becomes very marked. However, the form of heat prostration may not be due to the direct condition of contained air as shown by thermometer readings, but may be precipitated by rapid variations of skin temperature incident to exposure to drafts under ventilators in natural ventilation or to the currents incident to assisted or forced drafts when applied to a fireroom already containing men who have been subjected to very high temperatures.

At any rate, it has seemed that the tendency to heat prostration has become quite marked at times just after assisted draft has been started. It may be considered that if firerooms were kept under assisted draft the cases of heat cramps would be greatly diminished, but that the use of assisted draft only occasionally to meet special conditions may be responsible for a number of such cases at some particular time.

While the ship herself, as a mere fighting machine or floating fort, is strongly tending to render the contained air unsuitable for a crew and demands much consideration in construction to secure the most liberal and best use of non-conductors and the installation of appliances for the proper renewal of air in order that men may live on board in comfort and in health, the men, who are in fact the most indispensable of all the machines on board, are themselves tending to affect their surroundings in ways that are highly prejudicial to their well-being.

Men as living machines are burning fuel in the form of food, and as a result have excreta as gases and solids which are waste products comparable in a general way to the ashes and gases resulting from the oxidation or combustion of the fuel within the furnace of the ship herself. The gases incident to the combustion of coal, and especially the carbon dioxide, have to be rapidly conducted from the fires by way of the smoke pipe or combustion will cease even with a liberal supply of oxygen, the extinguishing power of carbon dioxide being well known. The action is a mechanical one, as is that of ashes in choking the fires and thus preventing the access of air with its oxygen necessary for combustion. But as man is a living machine, he must, as a machine with a motive power involving consumption of fuel, have not only waste products as excreta that must be rapidly separated from him in order that he may be free from their mechanical action, but also, in view of his complicated chemical changes incident to life, is subject to the action of substances as poisons. He is readily affected by some of his own excreta acting directly either as chemical poisons or as vehicles for the transmission of living organisms which as living poisons are capable of growth and multiplication. Man as a living machine has the properties of a machine and also the properties of life, as he grows, repairs his own mechanisms, and is capable of using his own material as fuel. As a machine, he is subject to wear and tear, but as a living machine he is also subject to breakdowns from other causes known as disease, and thus to the formation of peculiar abnormal and additional excreta.

The fuel that the human machine uses is made up of complicated molecules rich in carbon. In the complete oxidation or combustion of such molecules the products are CO_2 and H_2O which are therefore substances that as gases man exhales with every breath. As the oxygen the body requires is obtained from the air inhaled it follows that inspired air, as the normal air, is rich in oxygen and poor in carbon dioxide, while expired air is relatively poor in oxygen and rich in carbon dioxide. Each member of the crew crowding a vessel of war is, therefore, as a mere machine depriving the contained air of oxgyen and adding carbon dioxide. The result of that double vitiation caused by a well-developed man at rest may be expressed approximately as follows, if the expired and inspired air be considered dry and composed only of oxygen, nitrogen, and carbon dioxide:

	Volume per 100		
	O	N	CO_2
Inspired air contains . . .	20.953	79.013	0.034
Expired air contains . . .	16.033	79.587	4.38
	—4.920	+0.574	+4.346

Expired air of a man at rest contains more than 100 times more CO_2 than atmospheric air and nearly 5 per cent. less oxygen. The result obtained by dividing the percentage increase of carbon dioxide by the percentage decrease of oxygen is called the respiratory quotient. As the diminution in oxygen is greater than the increase in carbon dioxide the quotient is less than unity. From the results given in the table it would be $\frac{4.346}{4.920}=0.883$. As the amount of CO_2 excreted and of oxygen absorbed vary with food, exercise, temperature, and individual peculiarities, the ratio is not a constant.

In dealing with percentage composition in the comparison of a varying mixture, figures are easily misleading as they do not relate to actual amounts, but merely to relative amounts. In this case while there has been a relative increase of nitrogen in expired air there has been no actual increase, for with the withdrawal of a greater volume of oxygen than the added carbon dioxide the total volume of expired air is less than that of the inspired air when measured at standard temperature and pressure; consequently if the actual volume of nitrogen remains the same its percentage is increased. For instance, suppose in a hundred cubic inches of oxygen and nitrogen the amount of each gas is 50 cubic inches or 50 per cent. If 10 cubic inches of oxygen be removed the 50 cubic inches of nitrogen is 55 5/9 per cent. of the remaining 90 cubic inches, though there has been no change in the actual amount of nitrogen. The body in its chemical changes does not liberate nitrogen, but passes it out in its liquid excreta still combined, but in less complex molecules than those in which it was received in the food. The nitrogen found as a gas in the blood is there merely as a result of its presence in the atmosphere or inspired air, and therefore does not represent the product of chemical change by the body.

Reasoning along the same line, the figures expressing diminution in oxygen and increase of carbon dioxide do not accurately express the actual diminution and increase of those gases. If the nitrogen has not changed in actual amount the decrease in volume as calculated from the table given is expressed in per cent. by $100 - \frac{7901.3}{79.587} = .722$; in other words, each 100 volumes of inspired air measured dry at standard temperature and pressure is returned as 99.278 volumes of expired air when measured dry at standard temperature and pressure. Considering the total volume of oxygen and carbon dioxide in inspired air as 20.987 in a hundred it is actually returned as 20.265 volumes, of which about 15.916 volumes would be oxygen and 4.349 carbon dioxide. In other words, of each 100 volumes, measured dry at standard temperature and pressure, of atmospheric air inspired, 20.953 volumes of oxygen are returned as 15.916 volumes, or at a loss of 5.037; and .034 vol. of carbon dioxide is returned as 4.349, or a gain of 4.315.

All such figures should be regarded chiefly as illustrative and as primarily for the purpose of showing the character of the vitiation and that the oxygen is reduced more than the CO_2 is increased. The air breathed in a ship's compartment is not air as rich in oxygen and as poor in CO_2 as the atmospheric air for it is the contained air of the ship vitiated by the human beings on board who necessarily cause a reduction of oxygen and an increase of CO_2. It is also evident that, while the expired air has a smaller volume than the inspired air when each is reduced to standard, it has in reality a much greater volume under any ordinary circumstances, inasmuch as the air coming from the body is at a much higher temperature than that going in and is also expanded by moisture, being in a state of saturation or with a relative humidity of 100.

If a man at each inspiration is taking in 25 cubic inches of air at 70° F. and relative humidity of 70, the volume reduced to 32° F. would be $\frac{25}{1+38\ (.0020361)}=23.2046$, which, if considered to be reduced 0.722 per cent. by greater withdrawal of oxygen than addition of carbon dioxide, would become at standard 23.037 cubic inches. As the air leaving the body has a temperature of about 98° F., the 23.037 cubic inches would be at inspiration $23.037\ (1+66(.0020361))=26.133$ cubic inches, an increase from temperature alone of about 4.53 per cent. of the original 25 cubic inches.

Air at 70° F. can hold 8.01 grains of water per cubic foot as vapor, and therefore at 70 relative humidity does hold $8.01\times.70=5.607$ grains. The 25 cubic inches of inspired air would therefore have $\frac{25}{1728}\times5.607=$ .08112 grain. Air at 98° F. holds 18.73 grains of water as vapor when saturated, and therefore the 26.133 cubic inches, not considering its expansion due to vapor, would have $\frac{26.133}{1728}\times18.73=.28325$ grains, a gain in water of $.28325-.08112=.202$ grains with each breath. If a man breathes 18 times a minute or 25,920 times a day he would, under the circumstances indicated, be excreting by way of the lungs $25920\times.202=5235.84$ grains of water a day or, at 437.5 grains to the ounce, nearly 12 ounces avoirdupois. Of course all such figures must be considered as not much more than explanatory, as they are mere approximations, the air going into the lungs varying greatly in temperature and humidity. If a man were inspiring saturated air at 98° F. he would not be excreting any water at all by way of the lungs. The point is that under ordinary circumstances a man is excreting water in breathing, and even when atmospheric air is saturated, as the increased temperature incident to breathing lowers the relative humidity of inspired air, and therefore gives it capacity to acquire additional water. A conservative estimate of the average excretion of water by the breath is 10 ounces a day for a man at rest.

Returning to the table giving the difference between inspired and expired air when measured dry at standard, it appears that it may be assumed in an approximate way that a man at rest excretes an amount of CO_2 equal to 4.346 per cent. of the expired air. It has been seen that if a man inspires 25 cubic inches of air at 70° F., it is equivalent to about 23.2046 at standard, which is expired as about 23.037 at standard. Assuming that a man at rest expires that amount of air 18 times a minute, he would expire $23.037\times25{,}920=597{,}119.04$ cubic inches of air per day. As about 4.346 per cent. of that would be respiratory CO_2, its total amount per day would be 25,950.79 cubic inches or about 15 cubic feet, an excretion of CO_2 at the rate of .625 of a cubic foot per hour at 32° F., or about .68 at 70° F. The calculation is based upon the assumption of only 25 cubic inches of inspired air at 70° F. Even if the volume of air taken at each inspiration were considered the same, but at a lower temperature the amount of CO_2 excreted would appear greater.

It is ordinarily assumed that a well-developed man at rest and on full diet excretes about .7 of a cubic foot of CO_2 at 32° F. in an hour. A cubic foot of CO_2 at standard weighs about 858.63 grains. Therefore, a man excreting by the lungs .7 of a cubic foot of CO_2 each hour, would excrete in a day 16.8 cubic feet, weighing about 14,425 grains, or 2.06 pounds avoirdupois. As the molecular weight of CO_2 is 44 of which 12 is carbon, the CO_2 excreted per man in a day would contain about .562 of a pound of carbon. A crew of 800 men at rest between decks would therefore add by the lungs to the contained air of a ship in a day about 13,440 *cubic feet of* CO_2 *weighing* 1,648 *pounds, and containing about* 449 *pounds of carbon.* They would also add by way of the lungs about 500 pounds of water and an amount of heat varying in degree chiefly with temperature of inspired air. The air would also be reduced in volume if considered dry at standard as more than 13,440 cubic feet of oxygen would be consumed.

Carbon dioxide is not, however, a poisonous gas. It is a product of man as a machine deriving its motive power from the oxidation of carbonaceous fuel. It can act upon that oxidation in somewhat the same way as it acts upon a fire if allowed to accumulate beyond a certain percentage. It has a smothering effect, settling by virtue of its weight upon the place of combustion, diminishing the access of oxygen and finally extinguishing the flame and stopping the process of oxidation. A taper cannot continue to burn in a confined space until it has exhausted the oxygen, but only until it has produced sufficient CO_2 to extinguish the flame, and so far as the mere CO_2 resulting from respiration is concerned an animal could not live in a confined space until it had exhausted the oxygen, but only until it had charged the contained air with so much CO_2 as to be suffocated, the tension of that gas without the body becoming so great that the blood of the venous circulation in the lungs cannot free itself by diffusion, and there is union of the CO_2 with hæmoglobin, thus diminishing or destroying its oxygen-carrying function.

It does not require a large proportion of CO_2 to produce insensibility, and air containing even less than 20 per cent. of its volume causes immediate suffocation. A man plunging into air containing even much less than 20 per cent. of CO_2 would, in spite of the oxygen present, be as truly suffocated in a short time as if he had remained under water.

Air may support combustion in parts of confined spaces even when there are other parts that are dangerous to men, as carbon dioxide has tendency to accumulate in pockets at the lower levels. *It is also very important to realize that there are some compositions applied to metals which, in a confined space, more or less rapidly deprive the contained air of oxygen and render it very dangerous to man.* There are not only rusting compositions, but also certain mixtures used for the preservation of metals, and not infrequently employed for that purpose within the double bottoms of ships. Commercial red lead is apt to be a compound of the oxide and peroxide of lead. Linseed oil has a marked tendency to become solid when exposed to air and the solidification is attended with absorption of oxygen.. This tendency to solidify is more marked in boiled linseed oil or the oil after it has been treated with certain oxides known as dryers. Such mixtures as red lead and linseed oil are frequently used in double bottoms, and experiments in the Italian navy (C. M. Belli) have shown that after their use the oxygen of the contained air may be reduced to even 3 per cent. Air containing 16 per cent. of oxygen and 4 per cent. of carbon dioxide, which is about the composition of expired air, is not altogether safe and the air in double bottoms on account of reduction in oxygen rather than accumulation of CO_2 is capable of causing sudden death. No one should be allowed to enter a boiler or a double bottom unless a candle burns brightly at all levels and there should be no exploration or work in double bottoms or in the bilges of holds unless portable ventilating sets are renewing the air.

In spite of the suffocating effect of CO_2 when in a certain percentage and its more limited but important interference with proper respiration and nutrition when present in smaller quantity, it may not be regarded as the only important impurity derived by the air from man in confined spaces, but in practice chiefly as an index. For the CO_2 derived from man being a chemical compound is the same as that generated or liberated by purely chemical means, such as the action of hydrochloric acid on calcium carbonate. If chemically pure CO_2 be added to the air of an occupied confined space until it forms 1 per cent., it is breathed without apparent disagreeable results, but if such an amount were added by respiration the effect would be very decidedly deleterious in time; but in the latter event there would also be a greater reduction in oxygen. When the CO_2 derived from respiration is 0.5 per cent., the air is in such condition as generally to cause headache and depression, and when even as low as 0.1 per cent. it represents a condition opposed to continued good health. As the respiratory CO_2 increases, the air becomes progressively more objectionable from a hygienic point of view.

These facts have led most sanitarians to consider that the amount of respiratory CO_2 present is merely an index of the amount of some much more objectionable impurity or impurities designated as organic matter. It is clear that it is an index of the diminution of oxygen as well as of the increase of organic matter derived from occupants and it seems likely that they both play their part in producing the deleterious effects together with the excess of CO_2 itself. It is just here, however, that there is considerable controversy, for while all sanitarians are necessarily in agreement that the change in composition of air due to occupation is progressively deleterious, they are not by any means unanimous as to what the pernicious effects of foul air are attributable.

But one of the effects of occupation of a confined space is a disagreeable odor the air acquires from the occupants. It appears, however, that the odor cannot be ascribed chiefly to the small amount of organic matter in normal expired air. Man is altering the contained air not only by respiration, but also by excreta from the skin and by intestinal gases. The most constant and chief source of odor is the skin itself directly, though material derived from the skin and retained by clothing is a considerable factor. If a number of apparently clean and normal men are examined in a more or less confined space there is little or no odor until they strip, when their bodily presence readily makes itself manifest through the sense of smell. Under such circumstances the effect of clothing when on the body in diminishing odor is very apparent, but the constant and chief source of odor in a crowded compartment is abundantly declared. However, water condensed from normal expired air does contain a minute amount of organic matter yielding a peculiar odor when heated, but the breath of man does not contain a special volatile alkaloidal poison as has been thought. Decayed teeth and catarrhal troubles of the respiratory passages are also conditions always more or less prevalent and exerting influence on contained air.

The skin makes a great change in the air of a compartment by the addition of water and organic matter and by the radiation of heat. A man at rest in air of ordinary humidity and at the highest comfortable temperature may be considered as adding to the air by the way of the skin about 2 pounds of water daily. Of course the amount is very variable, the evaporation of water on the skin being utilized for the purpose of relieving the body of heat. When the temperature of the air is high, or the human machine is doing external work and consequently utilizing more oxygen, excreting more carbon dioxide and producing more heat, the body utilizes the vaso-motor mechanism to pass more blood through the skin circulation for the purpose of radiating more heat and at the same time to influence the sweat glands to secrete more sweat that the evaporation may, in view of the latent heat necessary for the passage of water from the liquid to the gaseous state, aid the body in freeing itself of heat increase, and thus in maintaining its normal temperature.

On the contrary, when the temperature of air is low, and especially under those circumstances when its power of heat convection is increased by drafts or dampness, the body is conserving its heat by withdrawal of blood from the skin, thus diminishing loss by radiation and convection, and, by lessening the amount of sweat, diminishing loss by evaporation as well as convection. Of course, under those circumstances, additional protection has to be secured by clothing which imprisons air and thus depriving it of its power to rob the body of heat by convection, prevents a too extensive or prolonged blanching of the skin, especially in those whose mechanism by custom has narrow limitations, or too rapid or extensive loss of heat.

It is clear, however, that in warm weather clothing can readily be sufficient to add greatly to the amount of sweat, and even in cold weather can be made to keep the body moist and through lack of exercise incapable of sufficiently utilizing the mechanism provided for its own protection. Under ordinary circumstances the average daily amount of sweat of a man at rest has been stated as about 20 ounces, but considering the influence of wild heat on ships and the effects of tropical cruising it seems more likely that in a navy 2 pounds of water may be regarded as about the rate of daily excretion of skin per man in quarters.

Sweat is about 99.42 per cent. water and 0.58 per cent. solid material. Of the solid material 1/3 is chloride of sodium and 2/3 organic acids, fats, cholesterin, extractives, epithelium, and minute quantities of other substances. If a man excretes 2 pounds, or 32 ounces of water, by the skin in 24 hours he would excrete about 32.186 ounces of sweat, of which 0.186 would be solid matter. A crew of 800 men at rest would then excrete about 1,609 *pounds or nearly* 3/4 *of a ton each day, of which* 1,600 *pounds would be water and* 9 *solid matter.* Of the 9 pounds 3 would be chloride of sodium and 6 organic matter.

Most of the water would find its way more or less rapidly to the air by direct evaporation from the body and evaporation from clothing. The solid material remains on the body, gets on and into the clothing, and some portion of it can also be found in the air. Collected from the air it gives a precipitate with nitrate of silver, decolorizes potassium permanganate, blackens on platinum, and yields ammonia. The proper disposal of the solid material on bodies and clothing belongs more particularly to the subject of bathing, and washing, airing, and stowing of clothing and bedding. But the changes in contained air incident to the addition of water, organic matter and odor from the skin and clothing serve to strongly emphasize the effect of occupation on the air within a ship, and the consequent necessity for its proper renewal.

As the air within a ship is merely a portion of the atmosphere as modified by ship and occupants it retains its carrying capacity or power to support solid particles as dust. These particulate bodies or impurities are of course very much more plentiful in contained air than in the air on the outside of a ship, and constitute a distinct class in contradistinction to the gaseous impurities, such as carbon dioxide. They are derived from the ship's stores, including coal and food, and from such normal and abnormal excretions of occupants as after being deposited are capable by drying of passing into dust or, when received directly, by remaining air-borne as the result of increased flotation incident to drying power of air with its relative humidity diminished by heat of ship and occupants. In coal bunkers the air is apt to be charged with coal dust as well as to contain more or less of the gases emanating from bituminous coal in warm places. In firerooms there is not a little coal dust mixed with ashes. Such particulate bodies tend to form deposits in lung tissue and are not altogether free from influences of an irritant character.

In all occupied parts of the ship the solid material from occupants is, on examination of the air, strongly in evidence, especially in quarters where in naval life men have to sleep as well as eat. Of course the solid material from the skin is in evidence directly in many forms, including epithelium and bits of hair and nails. There are also particles of clothing that have been modified by skin excretions and are not sterile. Even material from intestinal canals is not lacking, as with such a concentration of human beings not only may water-closets, and even the men themselves directly, furnish odorous gaseous impurities, but there is a certain soiling of clothing and even hands and some carrying of such material and urine about the ship on shoes even when ordinary care has been exercised by the administration in the way of routine cleanliness. And while expired air is free from particulate bodies, as a rule the air of a ship is not free from solid material derived from respiratory passages. Such material is derived from particles of food dropped from the mouth at meals, from sputa improperly placed, as on decks, from nasal secretions cast off by men not always using handkerchiefs, and from coughing and sneezing, and even talking, which not only deposit material on surroundings to dry and be converted into dust, but also cause such material to reach air in minute particles that may be deprived of water at once when the relative humidity is low.

Material reaching the inside surfaces of a ship can be limited by careful supervision of the men, and a strict routine such as the compulsory use of spitkids, and the length of time such material may remain subject to drying and passage into the air as dust may be limited by cleanliness of person and effects and the routine care of the ship in the way of mechanical cleaning without dust or, as will be seen, too much water; but for the proper disposal of particulate bodies in the contained air it is evident that its systematic renewal or sufficient dilution with outside air is essential.

Of all the particulate bodies, the micro-organisms may be considered the most important, inasmuch as some of them are pathogenic. The gaseous excretions of man, even in relatively small quantities, lessen his vital resistance chiefly by lowering his nutrition, and pathogenic micro-organisms excite or cause specific disease. The number of micro-organisms in a given quantity of air is greatest when men are most concentrated in confined spaces. On the berth deck of a ship in commission at anchor at night with practically all the crew in hammocks, when there has been no liberty, the air space may be considered as between 150 and 200 feet. When that space is increased at sea by the absence from quarters of the watch on deck and below, there is a general shifting about midnight and 4 A. M. with men turning out for the next watch, and then men turning in from the watch relieved. At such time there is a large increase of particulate bodies in the air, including micro-organisms, as not only is their number greatest at the lower levels, but there is also considerable accession from increased dust incident to the agitation caused by the men themselves and the change of clothing involved. If at sea, the atmosphere is practically free of micro-organisms and, it is evident, is in the best condition to dilute the air within, which contains a large number.

In the proper removal of the gaseous excretions of man there is marked diminution in the predisposing causes of disease which, while less striking in their effects because of the slowness with which they often produce results, are probably as harmful or even more harmful in the long run than the exciting causes which may even at times take lives with great rapidity. But in relation to the exciting causes it is evident that man himself is the great primary source of infection whatever may be the part played at times in transmission by other animals, and that it is the excreta of man himself and other animals that are the primary principal vehicles. Men are creatures that strongly tend to foul their abodes, and a knowledge of naval sanitation includes a knowledge of the ways of preserving and promoting health of, and preventing disease among men concentrated in naval vessels by, among other things, the proper disposal of the excreta of those very men. In this struggle to remove predisposing and exciting causes within the ship it is evident that the proper renewal of contained air is of very great importance, inasmuch as it is very evident that such air is the receptacle for large quantities of man's excreta.

With an appreciation of the principal changes taking place in the contained air of a ship the object of ventilation is more clearly evident than would appear from any definition of it, each person being in a position to frame a definition satisfactory to himself. It may, however, be considered as essentially the continuous and more or less systematic renewal of air in a closed space by a properly distributed supply of air in good condition with the object of securing dryness, making up deficiency in oxygen and removing, or sufficiently diluting, gaseous material derived from occupants and stores, overheated air, products of combustion and particulate bodies that may be present. In any effort to accomplish those results thorough knowledge of the physical properties of air, sources and material of contamination, forces available for moving air in desired direction, and the arrangement of inlets and outlets to secure entrance, diffusion and exit of the amount required, it is necessary to realize that a well-ventilated compartment occupied by men on a ship should not only have dry surfaces and comfortably dry air and be free from odor and accumulations of heated air, but also *free from disagreeable drafts and have an equability of temperature.*

It is the necessarily small net air space per man, in connection with the prominence of draft in causing disease, that to-day makes the problem in the ventilation of a ship's living spaces. It is simple enough to determine the amount of atmospheric air required to keep an occupied ship's compartment free from odor of occupants, and it is not difficult to deliver the total amount required, but, in view of the small air space per man, it is an unsolved problem how to deliver that amount without disagreeable drafts. The amount of air in ventilation required per man per hour and recognized everywhere as the standard has so far never been delivered on any ship in cold weather, if at all, on account of the small net air space per man and the drafts it would cause.

Pettenkofer by his experimental room in Munich proved that with an air space of 425 feet, 2,640 cubic feet of air could be *drawn* through in an hour without perceptible draft; in other words, on an exhaust system 2,640 cubic feet of air could be admitted without draft under the best circumstances of temperature, inlets, and outlets, on about 6.2 changes per hour of contained air. But in a naval service it is not practicable to secure the best conditions and it has never been practicable to allot so much as 424 feet of air space to a man, as under such circumstances there would not be sufficient men on a ship to give anything like the maximum efficiency in action in time of war. The requisite number of men must be available even at some sacrifice, and while it seems probable that the number to the size of the ship has reached its maximum, as the all-big-gun ships to which navies are turning will require relatively smaller crews, and there are chances of using more concentrated and more easily handled fuel and having more economy of space in boilers and engines, it is necessary to realize that a cubic space per man much less than 424 feet is an incident of service and that the problem is merely to take the space available and make the best of it.

It may be considered that with all hands in their billets, which, however, is never quite the case, the average on a berthing deck is not as much as 200 feet of net air space per man. With 6.2 changes per hour that would mean less than 1,240 cubic feet of air per hour instead of 2,640 with air space of 424 feet. Besides, the conditions of the experiment made by Pettenkofer are radically different from those demanded by a naval service, and which necessitate more draft for a given air supply. In view of the communication between spaces of a ship and the amount of heat liberated within the ship, to endeavor to renew the air of sleeping compartment by extraction would be to facilitate the movement of overheated air from one compartment to another, and thus to defeat one of the essential objects of ventilation in warm climates. It would also cause the air supply to lack in purity as much of it would be derived not from the atmosphere, but from other compartments. Besides, in experimenting with a single room and a single occupant it is practicable to effect a nice adjustment in inlet and outlet, but in a vessel of war with a compartment occupied by a number of men it is not practicable to have an inlet and outlet for each individual and, in view of the crowding, more than one man will be under the influence of inlet or outlet designed with reference to a number. Even on shore, as in barracks, a minimum of 600 cubic feet has been necessarily substituted for the 424, which, however, was not sufficient under the best circumstances for a standard air supply without perceptible draft, and in hospitals 2,000 cubic feet is not too much.

A full appreciation of relation of amount of air space to the question of renewal of contained air without drafts is essential. If a man has 1,000 feet of air space, 3,000 cubic feet of air can be supplied him per hour on 3 changes of contained air per hour, while if he had only 200 feet of air space it would require 15 changes for the same air supply. This more rapid change of contained air means a more rapid movement of contained air. But even in the small space the trouble is perhaps not so much the rate of movement of the greater part of the contained air as the rate of movement at openings through which the air enters and the contact of such air with the individual before it has had an opportunity for distribution. In a large cubic space there is ordinarily greater opportunity for air to enter through a larger number of openings, but even if the supply comes through one opening the occupant is ordinarily further away and the current mixing with the large volume of contained air is broken and diffused.

In natural ventilation it is generally assumed that there should be at least 24 square inches of inlet per man. If 3,000 cubic feet of air per hour enters by such an opening it has a velocity of $\frac{3000 \times 144}{24 \times 60 \times 60} = 5$ feet per second. If a room of 1,000 cubic feet has a height of 10 feet and a square floor, the distance of the mid-point of the room from a mid-side inlet is five feet, but if the cubic space is only 200 feet with a height of seven feet and a square floor the distance would be only about 2.67 feet. In the former case the ability to get further from the inlet is also very much greater than in the latter in which the air could not be properly distributed before reaching the person and a draft would be felt that could not be avoided. That condition is commonly greatly accentuated on naval vessels by the fact that in supplying air by mechanical means to many men the number and area of inlets is more or less restricted, and therefore air for many not only passes through the 200 cubic feet occupied by one, but also at a greater velocity, perhaps into a berth deck within diagonal armor at 16 feet a second. Under such high velocities there may be a specification renewal of 15 changes an hour or 3,000 cubic feet per hour for each 200 cubic feet, but, except in very warm weather and certainly even in cool weather without a heated air supply, the drafts are clearly prohibitive, especially in relation to all men located near louvers.

Nevertheless, while the lack of sufficient cubic space is the most important obstacle in any attempt to properly ventilate the living compartments of ships, a knowledge of the air supply required for ventilation does not lose importance, as it is necessary for comparison and as an ideal to which the closest practicable approximation is desired. The quantity of air required has been found to depend upon the amount of carbon dioxide the contained air acquires. Whatever may be the nature of the substances derived from man the carbon dioxide present is commonly regarded as a measure of their intensity or concentration and of the diminution of oxygen.

Formerly, when ships were lighted by candles and oil lamps their influence was potent in liberating heat and water and in charging the contained air with carbon dioxide and abstracting oxygen, but, even then, the carbon dioxide was properly accepted as the chief measure of air vitiation. A burning tallow candle of 16 candle-power would remove about 10.7 cubic feet of oxygen and add 7.3 cubic feet of carbon dioxide and 8.2 cubic feet of water vapor an hour, causing the gaseous vitiation of about 11 men. The effect of an oil lamp is equivalent to about 7 men, and an ordinary gas jet of 16 candle-power to about 5. The Welsbach of equal power may be rated as equivalent to 3 men, but the electric incandescent not only does not vitiate the contained air, but its heat is trivial compared with that derived from other sources, the lighted candle giving about 1,400 calories per hour and the ordinary incandescent perhaps about 37. With the system of lighting by electricity it is then evident that the carbon dioxide in the air of a berth deck compartment may be considered as simply that in the air supply plus that added to the air by occupants.

The carbon dioxide added by occupants is called the respiratory CO and is generally considered to be the index of total impurities. The amount of air required in a berth deck space if calculated without reference to wild heat should depend entirely upon the amount of respiratory CO_2 contained air can normally acquire without giving evidence of sensible impurity. The mere fact that the air is contained is sufficient to show that an occupied compartment cannot hold air as free from impurities as the atmospheric air from which it is derived, but to one coming from an open deck there should be no odor of occupants.

On a ship the presence of the odor of men has very close relation to the care of person, clothing, and bedding. The mere fact that the men sleep in hammocks which, containing the bedding, are lashed in the morning immediately after use and stowed closely in bins or hammock berthing away from light and air until reused, except for the routine weekly airing, often omitted on account of weather, complicates the establishment of a standard of purity of contained air of a ship based upon the absence of sensible impurity. Men also sleep in underclothing worn during the day and, in view of limitation in the supply of fresh water, may not infrequently have some difficulty in securing the desired cleanliness of person. In the problem to properly dispose of excreta by ventilation, such circumstances show the importance of some of the subsidiary problems and the interdependence of the questions involved.

The load on the ventilating system should not be increased by unnecessary wild heat, which also increases odor, and by the condition of personal effects indicated. The wild heat may be and should be more greatly limited and so could the odor of hammocks by much more frequent airing but, in view of the concentration on naval vessels, there is no recognized reasonable substitute for the hammock or apparently even for the method of stowing, while conditions of weather at sea and even in port very often render it impracticable to expose bed-clothing to the air. The history of navies, however, clearly shows the advisability of making all necessary requirements clear. A recognition of what is necessary is the first step in its accomplishment. In the very matter of ventilation of ships there were many years before there was any reasonable recognition of its necessity and many more before there was adequate well-directed effort to secure it.

In a berth deck space the greatest concentration of men is ordinarily at night—the men in hammocks. The respiratory CO_2 of a well developed man at rest is when measured at standard about 0.7 of a cubic foot per hour. When the respiratory CO_2 calculated at standard is present in proportion of 2 cubic feet in 10,000 of contained air there should be no sensible impurity, and if bedding has been aired and the men and ship are under a good routine there will be none. Should the respiratory CO_2 equal in amount that usually assumed as normally present in the atmosphere, say 4 in 10,000, there will be some sensation of closeness to one coming from the upper deck and some little odor. Between 6 and 7 the air would be regarded as close and disagreeable and at 9 very close and offensive. It therefore appears that the respiratory CO_2 as the index of impurity should be less than 4 cubic feet in 10,000 of contained air at standard and that, as between 2 and 4, there is a middle ground of some increasing appreciation of difference caused by occupants between contained and outside air, the lower figure about represents the desired standard.

If, then, it is required that the contained air shall have its content of respiratory CO_2 kept down to the proportion of 2 in 10,000 cubic feet, it follows that a man excreting 0.7 of a cubic foot of carbon dioxide an hour will require 3,500 cubic feet of air per hour for that purpose. For, if in 3,500 cubic feet of contained air there is the entire 0.7 of a cubic foot of respiratory CO_2, the proportion is 2 in 10,000, as $2 : 10000 : : .7 : 3500$. This may be stated somewhat differently by taking the amount of respiratory CO_2 required in each cubic foot of contained air rather than in 10,000 cubic feet. In that case 0.0002 of a cubic foot of CO_2 in one cubic foot of contained air is the same proportion as 2 in 10,000 cubic feet. The former proportion would then become $.0002 : 1 : : .7 : x$, or $x = \frac{.7}{.0002} = 3500$ cubic feet.

It is evident from this that the 3,500 cubic feet is merely the amount of air per hour per man that must be *available* to keep the respiratory CO_2 at 2 per 10,000 of contained air when his excretion of CO_2 is 0.7 of a cubic foot per hour. If a man excreting 0.7 of a cubic foot begins the occupation of a space in which he has 3,500 cubic feet of breathing room, he requires no other air than that already in the space for the respiratory

CO_2 to be 2 per 10,000 of contained air at the end of an hour, but if he is to occupy the space for 2 hours it will be necessary for 1,750 cubic feet of air free from respiratory impurities to pass into and be distributed in the space each hour in order that he may have the required 3,500 cubic feet per hour or the total 7,000 cubic feet of available air for the two hours. In other words, it is not merely the air that passes into a space from time of occupation that makes the available air, but also that in the space at time of occupation. With the contained air at 3,500 cubic feet per man and an occupation of 7 hours the space itself would furnish 500 cubic feet per man per hour, and consequently the air delivered should be 3,000 cubic feet per man per hour.

The smaller the breathing space and the longer the occupation, the less the value of air at time of occupation. If the air space is 200 cubic feet per man and the occupation 8 hours the air at time of occupation can be considered as only $\frac{200}{8}=25$ cubic feet per hour, leaving 3,475 cubic feet of air per man per hour to be admitted and distributed if the respiratory CO_2 is to be uniformly 2 per 10,000 at end of occupation. If the occupation is continuous, as in the case of a hospital ward, the value of air at beginning of occupation becomes zero and at least the full 3,500 cubic feet per man per hour becomes necessary. In that case, in view of the abnormal condition of occupants, and the resulting condition of contained air in relation to increased odor and acquisition of organic matter, it is necessary for most satisfactory results to increase the air supply to 4,500 cubic feet per man per hour. It is evident that the larger the air space and the better it is proportioned for distribution of air and of impurities the more readily such a large air supply can be admitted without draft and with uniform results. The conditions in hospitals requiring additional air supply are also the conditions in sick-bays of ships, but as the air space common in hospitals is not available on ships the supply has to be graded in accordance with the requirement of the admission of air without harmful draft.

Returning to the statement $x=\frac{.7}{.0002}$ in which x is the amount of air in cubic feet per hour per man required in continuous occupation, or available air per man per hour, it is evident that if it should be the desire to keep the respiratory CO_2 at 3 per 10,000 the statement would become $x=\frac{.7}{.0003}$, or in other words, in any case the division of the total amount of respiratory CO_2 from each individual, expressed in cubic feet per hour, by the respiratory CO_2 in one cubic foot of contained air is equal to the amount of air that was available in cubic feet per man per hour. This is commonly expressed as $D=\frac{e}{p}$. The formula can be used not only to ascertain standard air supply, but also somewhat modified in various ways to secure other results. Given any two of the quantities, the value of the other becomes evident, and thus given any amount of respiratory impurity per cubic foot of contained air and the CO_2 excretion per hour, the air supply that was available is declared.

In this connection it is essential to recognize that p in the formula is entirely *respiratory* CO_2, and the amount of it in *each cubic foot* of contained air at standard. All CO_2 as a chemical compound is identical. If one ascertains the total amount of CO_2 in contained air, only that is respiratory which was not in the atmospheric air at its entrance. The respiratory CO_2 is therefore the total carbon dioxide minus the carbon dioxide in the air supplied. For instance, suppose the contained air is found to have 8.132 parts of CO_2 in 10,000, or .0008132 of a cubic foot of CO_2 in one cubic foot of air, and the air on admission or the atmospheric air to have 4 in 10,000, the respiratory CO_2 is 4.132 in 10,000 or .0004132 in a cubic foot, and if each occupant excreted 0.7 of a cubic foot of CO_2 per hour the available air per man per hour in cubic feet was $\frac{.7}{.0004132}=1694.09$. If the net air space per man was 200 feet and the occupation 8 hours, the air delivered was $1694.09-\frac{200}{8}=1669.09$ cubic feet per hour per man.

Given the air supply, or D in the formula, the amount of CO_2 that would be present may be calculated, as in the following example: If 20 enlisted men occupy for 7 hours a compartment furnishing 4,000 cubic feet of net air space, what proportion of CO_2 would be present at the end of occupation if 30,000 cubic feet of fresh air have been supplied them per hour, and each man excreted 0.7 of a cubic foot of CO_2 per hour?

$0.7\times20\times7=98$ cubic feet CO_2 exhaled by the 20 men in 7 hours or the total respiratory CO_2.

$30000\times7=210000$ cubic feet of air delivered in 7 hours. As the space contained 4,000 cubic feet of air at beginning of occupation, $210000+4000=214000$, or the total amount of air in cubic feet available for the 20 men in 7 hours.

From the formula $D=\frac{e}{p}$, it is evident that $Dp=e$ and $p=\frac{e}{D}$, in which $e=98$ and $D=214000$. Therefore $p=\frac{98}{214000}=.0004579$ of a cubic foot of respiratory CO_2 in each cubic foot of contained air, or 4.579 in 10,000. Assuming the air delivered to have had 4 parts CO_2 in 10,000, the total CO_2 or the proportion of CO_2 present would be 8.579 in 10,000. The amount is much in excess of the standard which is 6 per 10,000. There would be some odor, although the air was changed 7 1/2 times an hour. The men were assumed to be at rest or excreting 0.7 cubic foot CO_2 per hour per man. If at work the respiratory CO_2 would have been much greater, as at hard work at least 1.8 cubic feet of CO_2 per man per hour are readily excreted, and generally more, and at light work about 0.9 or more.

It should not be assumed that such calculations in practice have the mathematical accuracy they appear to have, as the data rest upon an experimental basis of averages which are not very close approximations. The excretion of CO_2 has relation to diet, size of individual, and manner of life including exercise or work. The amount of CO_2 excreted by a coal-passer is not the same as that excreted by an ordinary seaman, and each man differs more or less. Also in working out standard air supply the respiratory CO_2 assumed as permissible is the one generally accepted, but it rests upon acuteness of the sense of smell, while odor varies with the amount of heat and moisture present as well as cleanliness of persons, clothing, bedding, and locality, an increase of one per cent. in humidity having as much influence on the condition of air judged by the sense of smell as a rise of 4° F. In the damp air of the tropics odors on a ship are increased and, on the other hand, the wild heat of a ship is under any reasonable system of ventilation, constantly *lowering* the relative humidity of contained air, making the most characteristic difference between the contained air of the modern ship and that of the old navy in which the routine wetting of decks, the limited ventilation, and the consequent contained air of high humidity were distinguishing features and, especially in cool weather, fertile sources of disease. Yet, in practice the results obtained by methods given are sufficiently accurate for diagnostic purposes, as from them and the ability to make reasonable CO_2 observations the degree of ventilation can be fairly determined. And judgment of the degree of ventilation by the sense of smell can also be frequently exercised with excellent results.

Ventilation often has an important relation to the relative humidity of contained air. It may be of great value in either removing excessive moisture or in supplying moisture to contained air. Where the supply of air is small and there is not much difference in temperature within and without, the water added by occupants can readily bring up the relative humidity even to 100 or saturation. Such a condition may be found in cool weather in overcrowded barracks especially if much water is used on floors, and on ships if the ventilating appliances are not employed, especially under those circumstances if much water is used between decks and there is no steam in boiler, the heating and lighting being obtained from a navy yard plant. At the same time there will necessarily be a large content of respiratory CO_2 indicating considerable loss of oxygen and excessive amounts of organic impurity. Such conditions have seemed to favor the development near cities of certain specific diseases and at times especially of cerebrospinal meningitis.

The condition may be illustrated by considering a poorly heated and badly constructed overcrowded barracks in which the occupants have, say, about 200 cubic feet of net air space per man, and where small windows have naturally been closed by those near them to keep out cold air and the one or two roof ventilators have been closed to keep out the rain, a damp atmosphere being potent in contributing to the results not only on account of its high initial humidity, but also because of its lightness, most of the ventilation depending upon movement of air incident to difference of weight within and without. If under such circumstances the outside air has had a temperature, for example, of 44° F. and a relative humidity of 90, the inside temperature has been 55° F., and the amount of CO_2 after 7 hours of occupation is 22.625 per 10,000 at 32° F., the contained air may very well be saturated, as it would only require about 1.75 ounces of water per man per hour to produce that result, and the water may be obtained from occupants and from floors not yet entirely dry from the objectionable routine morning scrubbing. For a CO_2 observation of 22.625 at standard (32° F.) means a respiratory CO_2 of about 18.625 and an approximate available air supply per man $= \frac{\cdot 7}{.001862} = 375.837$ cubic feet per hour at 32° F., or 385.02 cubic feet at 44° F. Air at 44° F. is saturated when it holds 3.32 grains of water-vapor, and therefore at 90 relative humidity will have $3.32 \times 0.90 = 2.988$ grains per cubic foot. The 385.02 cubic feet will therefore contain $385.02 \times 2.988 = 1150.44$ grains. But if each man and his surroundings add 1.75 ounces or 765.625 grains per hour the total water available will be $1150.44 + 765.625 = 1916.065$ grains. In the mean time each 385.02 cubic feet at 44° F. will have become at 55° F., $\frac{385.02}{1.0244332} \times 1.0468303 = 393.438$ cubic feet. With the total available water equal to 1916.065 grains, the 393.438 cubic feet would have $\frac{1916.065}{393.438} = 4.87$ grains per cubic foot. But air at 55° F. is saturated when it contains 4.87 grains per cubic foot. The relative humidity of the contained air would therefore be 100. It is clear under such circumstances that any additional air supply would not only diminish the respiratory CO_2 and the organic matter of which it is the index, but also the moisture present. Such cool close damp occupied spaces have a peculiar pungent odor, and seem to render the occupants much more susceptible to follicular tonsillitis, diphtheria, pneumonia, or cerebrospinal meningitis when the micro-organisms are available for introduction and propagation.

But a net air space of 200 feet in barracks dependent upon natural ventilation differs very materially, when results are considered, from the same space on a ship under artificial ventilation. On a modern ship, under ordinary circumstances, including the use of minimum amount of water on decks for cleanliness, the water from the skins and lungs of the men is incapable of preventing the internal heat from *lowering* the relative humidity of incoming air. This circumstance, without regard to a number of others, shows the futility and harmfulness of considering barracks as ships, and demonstrates the necessity for a larger air space (at least 600 cubic feet) and better ventilation (at least 2,400 cubic feet an hour without disagreeable drafts under all circumstances) in all buildings on shore used for men in the naval service. It also demonstrates the powerful action of heat in lowering relative humidity of air and consequently in increasing its drying power, but it illustrates the well-known fact that steam heat strongly tends to cause an irritatingly low relative humidity which can be obviated by controlling the heat, increasing ventilation or adding water to incoming or contained air. The situation is declared in the solution of the following problem:

Twenty men occupy a compartment at 9 P. M. and leave it at 5 A. M., each having had 200 feet of air space to which air has been supplied at the rate of 1,500 cubic feet per man per hour at 60° F. and 70 R. H. During occupation the temperature of compartment was maintained at 72° F., and each man added to the air water at the rate of 42 ounces daily (lungs and skin). What should the relative humidity be at the end of occupation and what the proportion of carbon dioxide, each man having excreted 0.7 of a cubic foot of CO_2 per hour measured at 32° F.?

Without making the solution too direct, and seeking to utilize the steps to suggest additional considerations, the work may be done as follows: As air at 60° F. holds 5.77 grains of water per cubic foot at saturation, it holds $5.77 \times .70 = 4.039$ grains per cubic foot at 70 R. H., or as delivered. As to each of the twenty men 1,500 cubic feet of air were delivered per hour for eight hours, the total air delivered was $1500 \times 20 \times 8 = 240000$ cubic feet at 60° F. and 70 R. H., or with 4.039 grains of water vapor in each cubic foot. Therefore the total amount of water in the air delivered during the eight hours was $240000 \times 4.039 = 969360$ grains.

But the 240,000 cubic feet of air delivered at 60° F. was expanded by the heat of the space to 72° F., and therefore became

$\frac{240000\,[1+(.0020361)\;40]}{1+(.0020361)\;28}=245547.6897$ cubic feet, yet still containing the 969,360 grains of water or $\frac{969360}{245547.6897}=3.9477$ grains per cubic foot at 72° F.

As there were in the space at the time of occupation $200\times 20=4000$ cubic feet of air at 72° F., the total available air at 72° F. was $245547.6897+4000=249547.6897$ cubic feet, and as there were 3.9477 grains of water in each cubic foot, it held $249547.6897\times 3.9477=985150.8$ grains (969,360 in air delivered and 15790.8 in air of space at time of occupation). As air at 72° F. holds 8.54 grains of water per cubic foot at saturation, it should be noted that the relative humidity of the space at time of occupation was $\frac{394.77}{8.54}=46.225$, a condition that would have continued during the 8 hours without occupation if the internal heat remained the same.

But the men were adding water to the contained air, each at the rate of 42 ounces daily or 1.75 ounces an hour or 14 ounces during the 8 hours. The 20 men added during the 8 hours, $14\times 20=280$ ounces, or $280\times 437.5=122500$ grains. However, it has been shown that the total air available contained 985150.8 grains of water by virtue of the initial relative humidity at 60° F. Therefore, the total water available was $985150.8+122500=1{,}107{,}650.8$ grains. As that total amount was held by 249547.6897 cubic feet of air at 72° F., the total available air during the 8 hours, it follows that the air in the space at end of occupation had $\frac{1107650.8}{249547.6897}=4.438633$ grains of water per cubic foot. As air at 72° F., is saturated when it has 8.54 grains of water in each cubic foot, the relative humidity or R. H. at end of occupation was $\frac{443.8633}{8.54}=51.97$, a fall from the R. H. of the air at time of admission of $70-51.97=18.03$, and a rise of relative humidity incident to occupation of $51.97-46.225=5.745$.

If each man excreted 0.7 of a cubic foot of CO_2 per hour measured at 32° F., the 20 men in 8 hours excreted $.7\times 20\times 8=112$ cubic feet at 32° F. The 249547.6897 cubic feet of available air at 72° F. would become at 32° F., $\frac{249547.6897}{1+(.0020361)\;40}=230754.148$ cubic feet, and as $p=\frac{112}{230754.148}=.0004853$, the respiratory impurity would be 4.853 per 10,000. If the atmospheric air supplied contained 4 parts of CO_2 in 10,000 the CO_2 observation made in the space at end of occupation should show, with perfect distribution of air supply, $4.853+4=8.853$ per 10,000. If there were not perfect distribution, multiple CO_2 observation would show by their variations the degree of fault and declare the degree of advisability for additional inlets and exits, but the average of such observations should be about the 8.853 per 10,000 of contained air.

It appears from this that in the practical work of testing the efficiency of a ventilating system the distribution of air in space should be determined by the CO_2 observation or a direct knowledge of the condition of the contained air in different parts of the space, but it is well to check results by calculations based upon direct knowledge of amount of air supply derived from the use of the anemometer. In all ventilation the purity of the air supplied and its amount are not of greater importance than its perfect distribution, as it is through distribution that the rebreathing of air is reduced to a minimum, the claim of each occupant to his share of the air supply is allowed, and drafts are avoided or, for any given air supply at any given temperature, limited as much as possible.

For some years entries were made in the medical journals of our ships of the readings of wet and dry bulb thermometers and, at least once each week, the carbonic acid was determined in the air of the berth deck at night. Such work was of great educational value as it kept in the front rank the necessity for the abolition of the routine wetting of decks and for better ventilation, and by expressing that necessity in mathematical form declared the wide departure from standards and made a more direct appeal to those minds influenced by demonstration rather than by statements based upon opinion derived from the exercise of the sense of smell and observations of condition of health.

When with the shellacked deck and the introduction of artificial ventilation the quality of the air between decks was greatly improved, such observations were discontinued. But, while those observations have undoubtedly lost much of their value as routine work continued during a cruise, they have gained in value in other directions, the thermometer, dry and wet, in relation to amount of wild heat and its removal by ventilation and to reduction of humidity by steam heat; and the carbonic acid observation in relation to distribution of the air supplied, or to the number and situation of inlets and exits in relation to each other and to size and shape of space and amount of air.

As a rule, naval specifications prescribe a maximum velocity at louvers (1,000 feet a minute) and the number of changes of contained air in a given number of minutes. There are type plans of ventilation system, but the changes of contained air are apt to be based too much upon the mere relation of amount of air supplied to size of space, and too little upon distribution which depends, for the same amount of air, more upon situation and number of inlets and outlets. As a general rule, it is better to increase number of inlets as much as practicable rather than depend too much upon reducing velocities on admission by use of cone-shaped terminals, however important the latter may become in reducing draft to obtain the maximum practicable air supply with the maximum practicable number of inlets. It is also unwise to place an inlet near a natural outlet or in such relation to an exit, when supply and exhaust are used on the same space, that the air is not diffused or distributed, going into the space merely to go out of it. It is to declare such lack of proper adjustments that the carbonic observation is now of chief value. It becomes, therefore, not so much a routine observation during the cruise as at the beginning of the commission to declare defects in distribution and the necessity, if there be one, for change in position and number of inlets and, incidently in connection with the anemometer, to compare actual delivery of air with specification delivery at commencement of cruise and later, as plants deteriorate by use of motors and accumulation of dust in pipes.

In making a carbonic acid observation the analysis depends on the relative alkalinity of lime-water (or baryta water) before and after it has absorbed the carbonic acid in the sample of air examined.

If 2.25 grams of crystallized oxalic acid are dissolved in sufficient distilled water to make 1 liter, 1 c.c. of this solution exactly neutralizes 1 milligram of lime.

For: Oxalic acid (crystal) $= C_2H_2O_4.2H_2O = 126 =$ molecular wt.

Lime $= CaO = 56 =$ molecular weight.

$$\underset{(126)}{C_2H_2O_4.2H_2O} + \underset{(56)}{CaO} = CaC_2O_4 + 3H_2O, \text{ or}$$

126 grams of oxalic acid neutralize 56 grams of lime, or

$\frac{126}{56} = 2.25$ grams of oxalic acid neutralize 1 gram of lime.

Therefore, if 2.25 grams of crystallized oxalic acid be dissolved in sufficient distilled water to make 1 liter, 1 c.c. of the solution exactly neutralizes 1 milligram of lime and hence the amount of lime in a given quantity of lime-water can be determined by adding the solution of oxalic acid until the point of neutralization is reached, the number of c.c. of the solution required being also the number of milligrams of lime in the volume of lime-water titrated. The amount of oxalic acid required for neutralization expresses the alkalinity of the lime-water. If the alkalinity of the lime-water be known before and after it has absorbed the carbonic acid in the air contained in a glass jar, the difference will give the amount of lime in milligrams which has united with the carbonic acid in the air so confined. Knowing the *amount of lime* that has combined with carbonic acid in the air under examination, the *amount of carbonic acid so combined* may be determined as follows:

Lime $=$ CaO $= 56 =$ molecular weight.

Carbonic acid gas $= CO_2 = 44 =$ molecular weight.

$CaO + CO_2 = CaCO_3$.
(56) (44)

Fifty-six milligrams of lime combine with 44 milligrams of CO_2. Thus, 1 milligram of lime combines with $\frac{44}{56} = .785714$ milligrams of CO_2. Therefore, in the difference of alkalinity each c.c. of the acid solution indicates 0.785714 milligram of CO_2 (that amount of CO_2 having combined with 1 milligram of lime and each c.c. of the acid solution corresponding with that amount of lime).

Now the weight of 1 c.c. of CO_2 at 32° F. and 29.92 inches' pressure (0° C. and 760 mm.) is 1.965 milligrams.

$1 : 1.965 :: X : .785714$.

$X = \frac{.785714}{1.965} = .399854 =$ c.c. of CO_2 weighing .785714 milligrams at 32° F. and 29.92 inches' pressure.

Therefore, the number of c.c. of the acid solution, shown in the difference of alkalinity, multiplied by 0.3998 will give the number of c.c. of CO_2 at 32° F. and 29.92 inches' pressure absorbed by the lime-water in the jar (contained in the air under examination).

Apparatus required: Glass jar, cubic capacity at standard temperature and pressure, marked in c.c.

Rubber stopper and sheet rubber to tie over neck of jar.

Burette graduated into tenths of c.c.

Glass measure graduated to 60 c.c.

Glass rods.

Bottle of 1 liter capacity, containing solution of crystallized oxalic acid (2.25 grams in sufficient distilled water to make 1 liter).

Litmus or turmeric paper, or, what is much better, a bottle of neutral solution of phenolphthalein.

A small bellows (or even a Davidson's syringe).

Clear lime water in stock-bottle.

Practical Work.—Note the temperature of the compartment and the height of barometer. Have the glass jar clean and dry, and place it on a table or on the deck in a location where the air seems to be a fair sample of that utilized by occupants, or, better, use a number of jars, making simultaneous observations. Force air into the jar with bellows or syringe, having nozzle near bottom of jar, until air in jar is like that of air in compartment. Then put into the jar 60 c.c. of clear lime-water from stock, close with stopper covered with sheet rubber. Then shake the jar that the lime-water may thoroughly wash the contained air and put it aside for at least eight hours (not more than 24 hours). At the end of that time pour into the graduated glass 30 c.c. of the clear lime-water from stock bottle and using the solution of oxalic acid with burette determine its alkalinity (noting the No. of c.c. of oxalic acid solution required and using litmus-paper, or, better, a few drops of the neutral phenolphthalein solution to indicate the point of neutralization). Then take 30 c.c. from the glass jar and determine its alkalinity in the same way. Take the difference in alkalinity (the difference in the number of c.c. of oxalic acid solution required for neutralization in each case) and multiply it by 2 as the alkalinity of only one-half (30 c.c.) of the lime-water (60 c.c.) put into the glass jar has been determined. This product gives the number of milligrams of lime which has combined with the CO_2 in the sample of air that was contained in the jar, and if multiplied by 0.39985 will give the number of c.c. of CO_2 at 32° F. and 29.92 inches' pressure in the amount of air in the jar. (Instead of multiplying the difference in alkalinity by 2 and then by 0.39985, it can be multiplied at once by 0.7997.)

Having determined the number of c.c. of CO_2 contained in the amount of air collected in the jar, it remains to express the amount in parts per 10,000 of air at standard temperature and pressure (32° F. and 29.92 inches).

The formula for the correction of pressure is as follows: 29.92 : observed height of barometer : : net capacity : Z

$$Z = \frac{\text{observed height of bar.} \times \text{net capacity}}{29.92}$$

The result expressed by Z is substituted for the *net capacity of the jar* (the capacity marked on the jar less the 60 c.c. of lime-water placed in it).

Z then is the volume of air in the jar brought to the standard pressure (29.92 inches). To bring the volume Z to standard temperature (32° F.): Air expands (or contracts) 0.0020361 of its volume for each degree F. above (or below) 32° F. Thus, each c.c. of air at 32° F. becomes $1 + .0020361$ at 33° F., and $1 + 2(.0020361)$ at 34° F. Therefore, the formula for the correction of temperature (t) above 32° F. is as follows:

$$V : Z : : 1 : 1 + (.0020361(t-32)).$$

$$V = \frac{Z}{1 + (.0020361(t-32))}$$

It is therefore evident that the correction for temperature above 32° F. and for pressure can be made at once by use of the following formula:

$$V = \frac{\text{observed height of bar.} \times \text{net capacity}}{29.92(1 + (.0020361(t-32)))}$$

Then if *A* represent the number of c.c. of CO_2 determined and *X* the desired parts per 10,000:

$$V : A :: 10{,}000 : X$$

$$X = \frac{A \times 10000}{V} = \text{parts of } CO_2 \text{ in } 10{,}000 \text{ of air.}$$

Example.—At time air was collected: Barometer 29.80; thermometer (in compartment) 72° F.; capacity of jar (at 32° F. and 29.92 inches) 4,460 c.c.; sixty c.c. of lime-water placed in jar.

Examination and calculation at end of twelve hours: 30 c.c. of clear lime-water from stock require 40 c.c. of the acid solution to neutralize. Thirty c.c. from the jar require 34 c.c. of the acid solution to neutralize. Then $40 - 34 = 6$ milligrams of lime that have combined with CO_2. $6 \times .7997 = 4.7982 =$ c.c. of CO_2 (in air of jar) at 32° F. and 29.92 inches' pressure. Now capacity of jar is 4,460 c.c. at that temperature and pressure. Its net capacity is, therefore, $4460 - 60 = 4400$. Correcting this for temperature and pressure by use of formula (that is, bringing the amount of air actually collected in the jar at 29.80 and 72° F., to 29.92 and 32° F.):

$$V = \frac{29.80 \times 4400}{29.92(1 + 40(.0020361))} = 4052.31 = \text{c.c. of air in jar when}$$

brought to standard temperature and pressure.

As there have been found 4.7982 c.c. of CO_2 in 4052.31 c.c. of air, the number of parts in 10,000 of air will be

$$\frac{4.7982 \times 10000}{4052.31} = 11.8 = \text{parts } CO_2 \text{ in } 10{,}000.$$

While the CO_2 observation shows the condition of the contained air as judged by the respiratory CO_2 present or the difference between the total CO_2 present and that in the air supplied, and by a number of such observations enables one to pass judgment on the degree of distribution or the amount of air supplied to any part of a space, and working with the average, to approximately calculate the total air supplied or available, the anemometer is the instrument in general use for direct calculation of the amount of air supplied by any inlet, and thus all inlets, or the amount leaving by any outlet. It is, however, an instrument that like a clinical thermometer always has an error which in this case the maker endeavors to eliminate by indicating in the form of a curve, the amount to be added or subtracted from the readings or various speeds registered. Unfortunately even after such corrections are made the results are merely approximations and often rather coarse ones when considered for scientific experimental work such as the movement of air in pipes under varying conditions. The instrument also requires careful handling to avoid injury causing inaccurate registration and frequent returns to maker for adjustment and new correction curve, and good judgment in placing it so that the average speed of air going through any opening may be obtained.

From a hygienic point of view, the results obtained from a carefully made CO_2 observation are of greater value than conclusions drawn from use of the anemometer. To determine the condition of the contained air is of more importance than to determine, certainly with coarse approximation, the amount of air supplied. On a ship it is more important to have blowers run continuously at designed speed than to determine how much air they can deliver or extract at an exceptional speed. The amount of air supplied is often misleading as it is the amount of air distributed that counts. However, to the designer of a ventilating plant the amount of air made to pass through the space is an important measure of the degree of success, and it is clear to the medical mind that without a proper air supply a proper amount cannot be distributed. Therefore, in arriving at definite conclusions as to the efficiency of a ventilating system the anemometer may be considered to have its place, although the experimental data upon which the plant was calculated were probably determined by use of Pitot tube and the manometer.

The anemometer measures the velocity of air or the number of linear feet traveled by air in a given time. A gas meter measures *quantity* or *amount* in cubic feet, but the anemometer or air-meter measures only *velocity*. Its face looks somewhat like a gas meter, but the readings mean something very different; it is all the difference between linear feet and cubic feet. It consists of a little propeller of perhaps 8 plane blades to be turned to the wind or moving air. The shaft of the propeller passes under the horizontal face and terminates in an endless screw which as the propeller revolves imparts motion to a number of wheels that in turn move the hands on the face each at a different rate much as the wheels of a clock move its hands. Each of the hands, but one, perhaps six in number in all, has a circular part of the face allotted to it, as is the case in a gas meter, and each hand, within its circle, registers its record by means of the 10 divisions on the circumference of its circle, as in a gas meter. There is one hand, however, that is geared for the quickest motion and to register single feet by using the circumference of the entire face which is divided into one hundred divisions for that purpose. When that hand has completed one revolution on its axis or registered one hundred linear feet, the hand geared to the next quickest motion has registered *one* in its circle and will register *two* when the first hand has completed another revolution. When the hand registering each hundred has registered ten of them the hand in the thousand circle registers 1 and so on, the hand in the ten thousand circle registering *one* when that in the thousand circle has completed one revolution and the hand in the 100 thousand circle registering *one* by the time that in the 10 thousand circle has registered *ten*. Each instrument is fitted with a stop or disconnector by which the movement of all hands can be stopped, on the same principle as that of a stop watch where, however, the movement of only one hand is stopped.

The following is an illustration of the instrument in question.

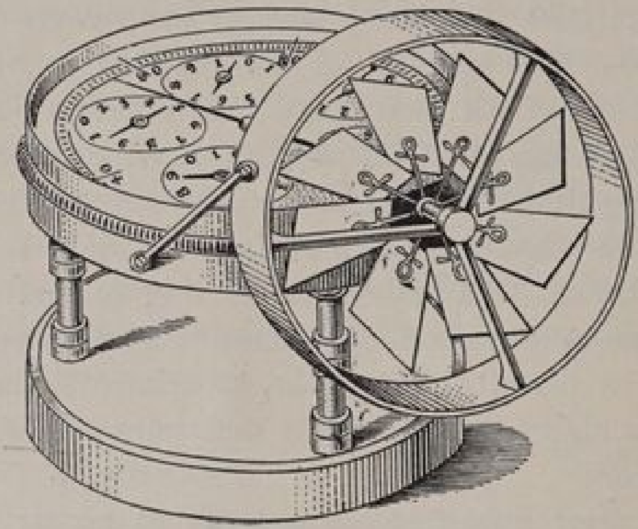

FIG. 6.—The Anemometer or Air-Meter.

In using this instrument the first thing is to make a careful record of its reading at the time, as it is the difference between the two readings, one made before the movement is started and the other after it is stopped, that gives the number of linear feet traveled by the air during the time the movement was recorded. The diagram on the next page represents the face of an anemometer giving 36,220 feet as the reading.

The reading having been made and recorded, the instrument is held with its blades or propeller to the current of air the velocity of which is to be measured. In order to get it away from the influence of the body on the air movement and well into a louver, a stick-holder with a screw at one end is employed, which, being screwed into the under surface of the instrument, enables it to be held above or at arm's length away, diagonally with the body. When stick-holders are long they may be supplied with cord and lever for starting and disconnecting at distance.

In the case of a tube, such as a terminal in artificial ventilation, the instrument should be put well in, but with propeller carefully in the plane having the area of the tube to be employed in completing the calculation of supply or exhaust Such areas on ships are almost invariably circles, but, whatever the shape, it should be recognized that it is the average velocity that is desired and therefore the anemometer should not make its record at the center or mid-point where the velocity is greatest A distance about two-fifths from the sides will give about the mean velocity, but, in terminals over 4 inches in diameter, it is customary to obtain the record by shifting the position of the instrument every 30 seconds until it has occupied five different locations during the run of two and a half minutes as is shown in the following diagram.

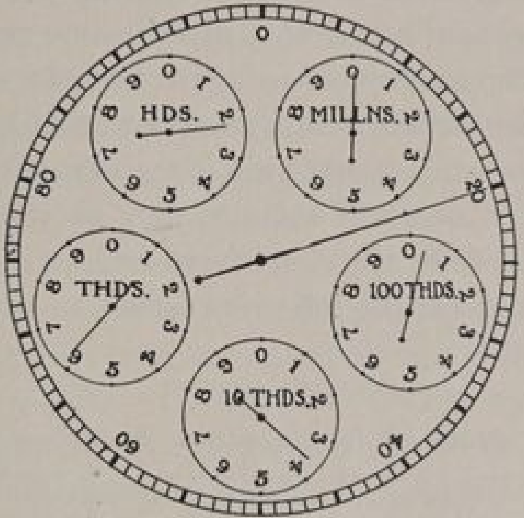

FIG. 7.—Diagram of face of anemometer.

In this method, the reading having been made at the end of two and one-half minutes, the difference between the readings taken before and after the run is multiplied by two-fifths to get the mean velocity per minute.

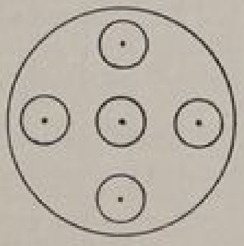

FIG. 8.—Varying positions of Anemometer in Louver.

When a larger opening, such as a hatch, is in question it is well to consider the opening divided into square feet and to take a record in each space, the average being regarded as the desired reading. When air is being forced into a ship's space, hatches are exits, often even for the air supply of the deck below, but, in natural ventilation, a large opening may be acting in one part as an inlet and in another as an outlet, thus giving readings of air moving in different directions. The blades of the anemometer should always be put against the current and readings for one direction considered plus and for the other minus, the difference in averages deciding whether as a whole the opening is acting as an inlet or an outlet and such difference is the velocity for the entire space.

When the instrument has been placed in the current the propeller is moving, but there is no record until connection is made by reversing the stop. The start should be made at the word of an assistant who, watch in hand, also gives the word for shifting position of instrument and for disconnection at the end of a certain time, say two or two and one-half minutes. The instrument is then removed and a careful reading made. The difference between that reading and the one made before the starting is the distance in feet the air is travelling through the opening in the two or two and one-half minutes plus or minus the error to be applied as determined from the chart furnished.

Such a chart may be in the following form:

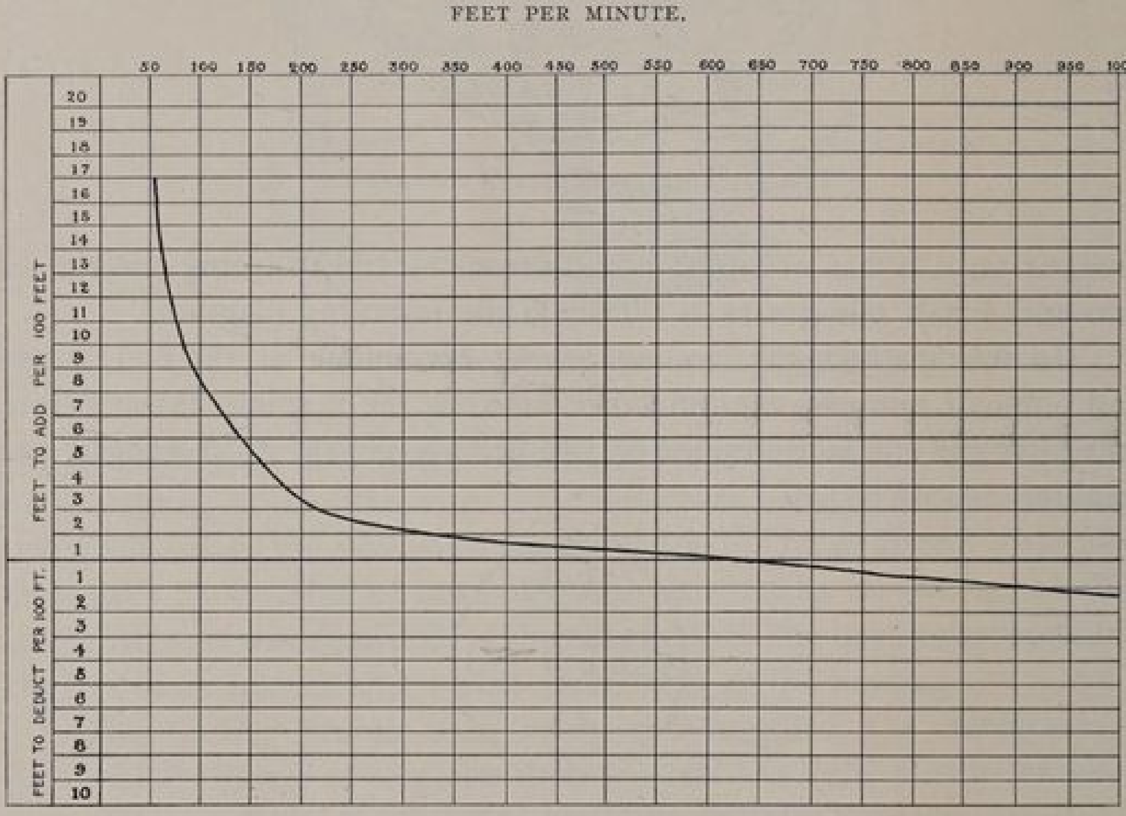

FIG. 9.—Form of correction curve for an anemometer (determined by experiment).

The curved line shows the number of feet to be added or deducted per 100 feet at varying rates of speed. Suppose the anemometer indicates before the observation 36,220 feet and after running 2 minutes 38,020. The distance traveled as shown by instrument is 38020 − 36220 = 1800 feet in 2 minutes or 900 feet in 1 minute. But by reference to the type chart it appears that 1 foot would be deducted for each 100 feet or 9 for the 900 feet. The corrected result would therefore be 900 − 9 = 891 feet per minute, and if the linear discharge is multiplied by the sectional area of the tube at the place where the run was made the cubic discharge is obtained per minute. The area is of course expressed in square feet that the discharge may appear in cubic feet.

It is evident that, although the air begins its distribution immediately on leaving the opening or the end of the pipe, the amount of discharge will be represented by a figure having an altitude equal to the velocity and a uniform cross section equal to that of the opening or of the pipe at the place where the run was made. Of course air may come in or go out of openings of any size and shape, and the accuracy of results will depend upon exactness with which the area of such openings are determined.

In comparing amounts determined at different observations it will also be theoretically necessary to reduce them not only to a common standard of temperature and atmospheric pressure, but also of relative humidity. In our service the standard selected seems to be 70° F., 30 inches and 70 relative humidity in designing a plant. It is the calculated delivery of air at that standard upon which number of renewals of contained air in a given time is based. But in view of the amount of probable error in anemometer records it will ordinarily be unnecessary to make such corrections, but at most it would suffice in practice to obtain temperature of the air at inlets and, bringing the calculated delivery to 70° F., estimate the renewals accordingly for comparison with specifications. However, in connection with the CO_2 observation it is of course advisable, having taken the temperature at each inlet and made a barometer reading, to bring the delivery to the same standard as that of the CO_2 observation (32° F. and 29.92 inches).

The amount of air reduced to standard going into a space—an occupied space—may be considered in anemometer work as equal to the amount at standard going out of the space, or the amount of air at an ascertained temperature going into a space may be regarded as the amount going out expanded (or contracted) as indicated by temperature at outlets. This is not strictly true in an occupied space or in any space supplying water to contained air, but, in view of approximate results obtained by use of anemometer, may be so regarded in an attempt to check calculated air supply by calculation of amount of air leaving a space.

A general idea of the foregoing may be obtained from the solution of the following illustrative problem: A ship's compartment is receiving its air supply from six inlets or louvers. The three starboard louvers (Nos. 1, 3, and 5) are circles, each having a diameter of 15 inches, and the three port louvers (Nos. 2, 4, and 6) are rectangles, each 16 inches by 11 inches. The anemometer shows the following movement at each louver on runs of two minutes: Nos. 1 and 2, 1,200 feet; Nos. 3 and 4, 1,000 feet, and Nos. 5 and 6, 900 feet. The temperature within each louver is 60° F. The air is leaving the compartment by only one outlet—a hatch 4 feet by 3 feet—where the temperature is 75° F. How many cubic feet of air is each louver delivering per hour and what is the total supply; how many cubic feet of air are leaving the compartment per hour, and what average movement should an anemometer show in the hatch on a run of two minutes?

The starboard louvers (Nos. 1, 3, and 5), being 15-inch circles, have each an area of $\pi R^2 = 3.1416 \times (\frac{5}{8})^2 = \frac{9.8175}{8}$ square feet.

The port louvers (Nos. 2, 4, and 6), being rectangles 16 inches by 11, have an area of $16 \times 11 = 176$ square inches $= \frac{11}{9}$ square feet. The deliveries per hour in cubic feet will therefore be as follows:

$$\text{No. 1.}\ \frac{9.8175 \times 1200 \times 30}{8} = 44178.750$$

$$\text{No. 2.}\ \frac{11 \times 1200 \times 30}{9} = 44000.000$$

$$\text{No. 3.}\ \frac{9.8175 \times 1000 \times 30}{8} = 36815.625$$

$$\text{No. 4.}\ \frac{11 \times 1000 \times 30}{9} = 36666.666$$

$$\text{No. 5.}\ \frac{9.8175 \times 900 \times 30}{8} = 33134.063$$

$$\text{No. 6.}\ \frac{11 \times 900 \times 30}{9} = 33000.000$$

Total supply $= 227795.104$ cubic feet per hour at 60° F.

$$\frac{227795.104\ (1 + (.0020361)\ 43)}{1 + (.0020361)\ 28} = 234377.065$$ cubic feet at 75° F., or the amount leaving compartment by hatch. As the hatch has an area of 12 square feet and 234,377 cubic feet of air pass through it an hour the average anemometer record for a run of two minutes should be about $\frac{234377}{12 \times 30} = 651$ feet.

Should it be required to consider change in volume due to change in relative humidity it would be advisable for its better elucidation to first ascertain how to find the weight of a given volume of air at a given temperature, pressure, and relative humidity, although volume will be merely inversely as pressure. Suppose it is desired to find the weight of a cubic foot of air at 70° F. and the ordinary standard pressure, the relative humidity being 70. It has already been shown that the cubic foot of moist air may be considered to be a cubic foot of dry air under the given pressure *minus* the tension of the vapor in it, and of a cubic foot of vapor at 70° F. at a tension corresponding with its relative humidity. Referring to the Table of Maximum Tension, it appears that the maximum tension of vapor at 70 is 0.733 inches of mercury. It has been shown elsewhere that relative humidity $= \frac{\text{Tension actually present} \times 100}{\text{Maximum tension that could be present}}$, then in this case the tension actually present $= \frac{\text{Relative humidity} \times 0.733}{100}$. But in this case the relative humidity is 70. Therefore the tension actually present $= \frac{70 \times 0.733}{100} = 0.5131$ inches. The cubic foot of air considered dry in this cubic foot of moist air will then be at 70° F., and at a pressure $= 29.922 - 0.5131 = 29.4089$. Its weight therefore will be $= 566.85 \times \frac{29.4089}{29.922} \times \frac{491}{491 + (70 - 32)} = 517.11$ grains. And the weight of the cubic foot of vapor at 70° F. and at a tension corresponding with its relative humidity will be:

$566.85 \times \frac{0.5131}{29.922} \times \frac{491}{491 + (70 - 32)} \times 0.622 = 5.61$ grains. Therefore, the weight of one cubic foot of air at 70° F. and 70 relative humidity is, at standard pressure, $517.11 + 5.61 = 522.72$ grains.

If it is assumed that air is delivered at 60° F., and 60 R. H., and standard pressure, a similar calculation would show the weight to be 534.15 grains per cubic foot. A cubic foot of dry air at 60° F. will weigh at standard pressure $\frac{566.85 \times 491}{519} = 536.27$, the cubic foot of dry air at 32° F. weighing 566.85 grains at standard pressure.

These calculations show that as air obtains water it expands and weighs less per cubic foot and that the expansion incident to moisture is that due to the difference of pressure as declared by the barometer reading minus the elastic tension incident to the relative humidity. If, then, it is desired to know, as might be the case in the anemometer problem already given, what a cubic foot of air delivered at 60° F., and 60 R. H. and standard pressure would become at 70° F. and 70 R. H. at same pressure, it appears that the difference of pressure at the higher temperature and humidity is $29.922 - 0.5131 = 29.4089$ and at the lower $29.922 - \frac{60 \times 0.518}{100} = 29.6112$. Therefore, each cubic foot of air as delivered would become at the higher *temperature* and *humidity*, $\frac{29.6112}{29.4089} \times \frac{529}{519} =$

1.026. But the first factor shows how small is the change incident to humidity alone. Of course, the same method would be employed when the barometer reading at time of delivery of air was above or below standard, using that reading instead of standard in relation to air delivered.

However, the important conclusion to be drawn from such calculations is that the more water air acquires the lighter it becomes per cubic foot. The fact is of great importance on account of its influence on natural ventilation in which the most important force is the difference of weight between the air without and the air within. The heavier the outside air, in relation to that inside, the greater the force causing air to enter a space where inlets are available, and the greater the supply. The dominating factor in this difference of weight is ordinarily difference of temperature without and within. But as the temperature outside approaches that within, the relative humidity becomes a larger factor in questions of air supply. It is a damp early spring or fall or some unusually warm but damp days of winter that cause the overcrowding in barracks to be most apparent as, with inlets arranged for cold weather and with less difference of temperature within and without, the light moist air is unable to enter with the usual rapidity. It is also generally at such periods that certain epidemics become prominent.

In natural ventilation the movement of air into and out of a space is caused by Nature's own forces—diffusion, wind, and difference of weight of air due chiefly to differences of temperature. In artificial ventilation man, taking advantage of the natural properties of air, brings additional force to bear upon that fluid and causes it to flow in a desired direction by application of mechanical energy within ducts.

As has been stated elsewhere, diffusion is much too feeble to give appreciable results in the ventilation of a ship and it is very inadequate for that purpose everywhere.

Wind is a powerful agent in ventilation, but it is too uncertain being very variable in direction and in force, and often absent or neutralized by the movement of the ship itself. When the power of rapid wind is exerted upon a ship, enormous quantities of air find admission at available openings whose plane is directed toward the movement and, at the same time, the value of exits is greatly increased by its aspirating effect or perflating power, the contained air seeking to fill the partial vacuum moving air creates on all sides of its path. The total result is very striking, the draft through the furnace fires is markedly increased as the movement up the smoke pipe is stimulated; the supply of air down fireroom ventilators, their cowls being turned to the wind, is strikingly increased by direct action of wind upon them and the perflating power at the top of the stack; hatches open to the air and having the wind for the most part moving parallel to the plane of opening exhibit its perflating power and discharge more rapidly the contained air, while those into which deflected wind passes deliver air to spaces in large volume; open ports and other openings on the windward side deliver large quantities of air, while those on the leeward side have their function as outlets greatly increased, being under the influence of perflation; any ventilators on the windward side with cowls turned to the wind deliver air under the most favoring circumstances and all ventilators on the leeward side with cowls turned away from the wind discharge air to the best advantage.

A covered deck across which wind is moving through ports or doors even at the low rate of 2 miles an hour will have its air renewed in a remarkably short time perhaps two or three hundred times an hour. Such cross ventilation is very difficult to control, and on the upper decks of all ships there are a number of openings through which cold winds are apt to find their way, the undistributed air causing disagreeable drafts responsible for much of the sickness of ships north in the winter months. In fact, all natural ventilation of ships in view of the small space and the varying power and direction of wind is most uneven. A degree of opening suitable at one moment becomes unsuitable the next, owing to change of direction or power of wind or change of course of the ship, and this applies also to the use of tubes with cowls as ventilators, the difficulty being, when there is wind, to distribute the air so that it will not cause drafts and to secure such careful supervision that the cowls will be properly turned, but, when there is little or no wind, there is of course insufficient ventilation from that source.

Considering a ship as a hollow spindle-shaped body partially submerged and divided by horizontal partitions or decks and by partial vertical partitions or bulkheads into spaces, it is obvious that the large submerged portion containing boilers, machinery, coal bunkers, and stores can have no side openings, that the nearest side openings to the water, circular air ports of the berth deck, while very valuable at times must be capable of quick closure and become useless for ventilation, though valuable for light, whenever there is rough water, and that openings in connection with guns, while capable as in case of gun ports of being considered almost windows or outside doors, are, like all outside doors in cold or rain, difficult to arrange with a view to ventilation without draft and frequently closed to keep out water and cold wind. Even then, unless unusual care is exercised, the closure is liable to be too incomplete in the case of openings about larger deck guns unless such guns are secured as if for a gale at sea.

The superstructure has its doors and ports which, like all such openings in a ship, are invaluable to a crowded deck in warm weather, but difficult to arrange in cold weather for proper distribution of air.

In the vertical partitions or water-tight bulkheads of a ship there is communication from one berth deck compartment to another by means of water-tight doors, but while such openings influence ventilation or currents of air, especially where air is abstracted by mechanical means allowing heated and vitiated air to travel from one compartment to another, they should not be regarded as openings in relation to fresh air. However, turret doors when open determine a movement of air through turret, and an open door from gun deck into evaporator-room will also determine an outlet for air from the deck in view of the rapid ascent of heated air in that room seeking its outlet. In the latter case the radiation of heat into the deck may, especially in warm weather, more than offset the advantage derived from the movement of air in that part of the deck. The advantage will depend upon the presence of a pocket of foul air liable at sea in bad weather to be found on a gun deck which is the berthing part of a ship usually depending upon natural ventilation. The internal arrangements of ships vary greatly, but under such circumstances a gun deck about an engine-room trunk, if unprovided with sufficient outlet, may show marked accumulation of foul air. An additional outlet frequently does not affect the amount of the air supply, but it generally causes a more complete distribution, thus enabling men who would otherwise be in a pocket of foul air to obtain a larger proportion of the air supply of the deck.

In the horizontal divisions or decks of a ship are numerous openings. Such openings are chiefly concerned directly with vertical exchanges of air, and not with cross ventilation. All decks communicate with other decks by means of hatches. The hatches are large openings, and where they communicate directly with the external air, or are even situated directly under others that do, contribute to the ventilation of the ship. Circumstances decide whether they act as outlets or inlets. The hatches leading from a berth deck to the decks above act as outlets when air is forced into berth deck spaces by mechanical means and as inlets when air is abstracted. When air, forced into the lower parts of a ship, passes through a line of hatches one above the other, in its haste to reach the atmosphere, it can have some appreciable effect on the air of the decks through which it passes, especially if adjacent spaces are small and without definite air supply; and, if the adjacent space is connected for exhaust, some of the air from storerooms or other lower parts of the ship will, with perhaps objectionable odors, be diverted to form part of the air supply of that space.

Hatches, communicating directly with the outside air, while not usually causing the extensive drafts in cold weather common in cross ventilation, are not free at times from objection, as they have to be more or less covered with hoods in wet weather, and in cold windy weather, especially when the air forced into the lower parts of the ship has been intentionally reduced to a minimum on account of lack of means of heating air supply, and with objects on the deck above to deflect the wind, they may deliver large quantities of cold air. Any deck hatches on the open main deck often have to be battened down in bad weather, but those on the upper deck, while they have to be more or less hooded in wet weather, can be left open as a rule. Engine- and fireroom hatches are very important openings in relation to the overheated air of those spaces. A fireroom hatch may be an inlet dominated by the fires and the ascent of hot air by uptake space and jacket of stack, but the engine-room hatch is always an outlet, especially as it is dominated by the engine-room supply from artificial ventilation.

Through any of these hatches a windsail may be used, thus, when wind is available, converting part of the hatch area into a very positive inlet and conveying the incoming air to a desired locality. The windsail appears to have been the earliest means employed for the ventilation of ships, but on the introduction of artificial ventilation it practically disappeared and is now very seldom seen. Yet a few should be among the stores of every ship, as they furnish means of giving a measure of relief in time of stress, such as a break in ventilating motor or insufficient provision for moving overheated air in some locality in exceptional weather. They then furnish means at times of lessening the effects of localized error in a ventilating system made apparent under exceptional conditions.

A windsail is a canvas tube or hollow cylinder, say 3 feet in diameter, of considerable length as when in use it must have one end well up into the atmosphere to catch the wind, while the other end is down in the ship near the deck of the space to be ventilated. The lower end is open and the upper end is closed and fitted at its center with loop for attachment of rope by which it is hoisted. The wind gains admission by a large rectangular opening left in cylinder near its upper end. To each vertical side of the opening is attached a wing, at the tip of which a guy is attached for trimming, the two wings thus holding the opening up to the wind and themselves adding to the delivery by deflecting the current. There were a great many forms of this ventilating device in the old days of wooden ships, but of course all forms are useless if there is no wind, and the form described is of little value unless kept trimmed to the wind. Under the best conditions it can deliver a large quantity of air but, being a single inlet, the air is not apt to be well distributed, especially if there be another hatch near at hand to act as the one outlet.

Through the decks of a ship there also pass a number of hollow metal cylinders terminating on open decks in cowls. Many of these cylinders connect with fan casings, thus forming part of the artificial system of ventilation, but some merely terminate below in open ends, as in boiler-rooms. When the cowls are turned to wind the ventilators act as powerful downtakes. They are trimmed by hand and receive the air on the upper or superstructure deck. They are apt to be kept trimmed, as the fireroom force depends largely upon their operation for air supply when the ship is under natural draft. However, their effectiveness may be considerably diminished by lack of suitable height of cowls above deck and the consequent interference with the access of wind by boats and other obstructions.

In view of the uncertain action of the wind and the difficulty in its control, it is fortunate that Nature has provided a more constant force by currents of air established as the result of difference of weight between inside and outside air due chiefly to difference of temperature. That force is amply sufficient to ventilate any space when suitable provision has been made in the form of proper inlets and outlets. Openings on the sides of ships do not require wind to be effective, provided they are sufficiently numerous or have sufficient area. Wind adds greatly to the delivery, often too greatly, not allowing the air to become properly distributed, a fault, however, that may even be present when there is no wind, but a low outside temperature. No ship would require artificial ventilation in any part if suitable inlets and outlets could be secured for the operation of this force, but, in view of the degree of submersion of a ship and thus the limitation in number and position of openings that are also often made inoperative by closure to keep out wind, rain, or sea, it cannot be depended upon for sufficient ventilation, though at all times of importance on every ship. It is this force that makes every air port of value even in the most marked calm, that determines the natural circulation in a space by fall of cooler air and ascent of warmer air, that determines the value of such channels for the discharge of overheated air as the uptake space and the space within the jacket of boiler uptake and of smoke pipe, and that permits a ship's mast to be utilized as a ventilator.

If colder outside air can find an opening it must enter and the warmer inside air must ascend and seek an outlet; and the lower the inlet, the warmer the contained air, and the higher the outlet, the more rapid the movement in a living space. It is a too great interference with this force that permits a high content of CO_2 in barracks in winter, and it is a utilization of the force that obtains air by direct inlets delivering under radiators of barracks. It is the study of the operation of this force that, as in the burning of a taper in a closed space, discloses the necessity for both inlet and outlet in all ventilation—a fact not always remembered in devising methods of ventilating, the outlet being as important as the inlet in securing circulation of air, air in natural ventilation not being able to enter except by the slowly acting force of diffusion unless there is provision for its discharge, as otherwise the pressure within would accumulate and there would be a relative vacuum outside. And air cannot leave a space unless there is also an inlet, as otherwise there would be an increasing degree of vacuum within. In artificial ventilation an exhaust fan merely diminishes the available air unless provision is made for an inlet, and a supply fan merely continues to compress air or increase pressure up to its limit unless there is an outlet.

Air enters a vacuum at the rate of 1,303 feet a second, or at the same velocity a falling body would acquire in a descent of five miles, the depth of the air if it were all of uniform standard density. Bodies from rest fall through the same space in the same time, and the distance varies as the square of the time. This is expressed in the formula $V^2 = 2\,g\,h$, in which V = velocity in feet per second, g = acceleration of velocity in each second of time (about 32.18 feet), and h = height fallen in feet (in this case 5 miles, or 26,400 feet). Then $V = 8.02\sqrt{26400} = 1303$ feet per second, the velocity of air into a vacuum.

But it is apparent that in ventilation air does not enter a vacuum, and that in natural ventilation this force under consideration results from merely the difference of pressure or weight within and without, the heated air within weighing less than the colder air without. As the air entering all the time is tending to equalize the pressure, the difference cannot usually be directly observed. Nevertheless, it is calculable as (the difference of level of inlet and outlet) × (the difference of temperature multiplied by the coefficient of expansion), the result representing height fallen or h in the formula.

For instance, the temperature within a ship's compartment is 70° F. and of the outside air 50° F.; what is the theoretical delivery of air in cubic feet per hour of a 12-inch circular air port if its center is 3 feet above the deck and the exit into the air, a hatch, is 8 feet above the deck? The difference in level of inlet and outlet is 5 feet and expansion of contained air due to 20° difference of temperature is $\frac{20}{491}$; therefore, $h = \frac{5 \times 20}{491}$ $= 0.2036$ feet, or height of fall to give required velocity. Then considering $V = 8\sqrt{h}$ and substituting 0.2036 for h, $V = 8\sqrt{0.2036} = 8 \times 0.45 = 3.6$ feet per second, the rate of flow of air through port. As the port has an area of 0.7854 square feet, the theoretical delivery per hour would be $0.7854 \times 3.6 \times 60 \times 60 = 10{,}178$ cubic feet. But the theoretical delivery is greatly in excess of actual delivery as the result of friction, which would vary very much according to such circumstances as character of finish of surfaces of compartment, distance of inlet from outlet, or degree of distribution of air in space, relation of size of outlet to inlet, and presence of beams. It is customary to deduct from 25 to 50 per cent. for friction. If in this case 1/3 be deducted, the delivery would be 6,785 cubic feet, or about sufficient under the standard for two men. If the space was small or an occupant near the port, there would be some draft that in cool weather would lead to partial closure of port, and if the delivery were increased by wind, as is often the case, the port would have to be more nearly closed.

The calculation is, however, made to exhibit the power of the force under consideration, and to make evident the fact that the lower the inlets in relation to outlets in natural ventilation the greater the air supply, and, with delivery of cold air, the more marked the drafts, especially about the feet, and to give some idea of the powerful action of the movement of hot air in uptake space, and within jacket of smoke pipe in relieving boiler-rooms of heat. In the last case such spaces act as chimneys, the inlet being within the boiler-room and the outlet many feet above where the spaces terminate, sometimes at the top of the pipe. The great height or difference in level between inlet and outlet and the marked difference of temperature between the outside air and the air of boiler-room and that within the jacket heated by conduction of the pipe itself would be very favorable to a rapid flow but for the dominating influence of the fires. Of course, the more air the jacket obtains from other sources, such as from its utilization as natural outlet from coal bunkers, the less will be the aspirating effect on boiler-room.

In natural ventilation of a living space it is generally assumed that about 24 square inches per head for inlet and at least as much for outlet are necessary under average conditions of weather. In barracks such openings should be provided in the construction of the building without regard to doors and windows which are often necessarily closed in cold weather to avoid drafts. In order to secure distribution of air the inlets should be increased in number rather than size, a single inlet delivering air for about 3 persons only and the outlet withdrawing the air of about 6. All inlets should be placed to avoid drafts. Some should be placed very low if made to open under radiators, but not otherwise unless air supply is heated, and all should be controlled by valves to regulate flow as altered by wind or change in outside temperature. If part of the air is unwarmed it should be admitted about 6 feet from the floor, but there should be terminals so controllable as to permit a deflection of current toward the ceiling. In any barracks there should be provision for heating at least a part of the air supply to the point of avoiding draft, and under such circumstances those inlets should be low, but it is best not to depend upon a heated air supply to heat the space, but merely to abolish perceptible drafts, unless such a system of indirect heating is very elaborate involving the delivery of large quantities of air that have never been overheated or scorched, and to which the requisite amount of water-vapor has been added.

Inlets should not be placed near outlets or there will be great loss in distribution of air. Under ordinary circumstances outlets should be high, as ordinarily the air at the top of a room is warmest and its natural outlet would be high. In construction of a barracks it is well to provide for outlets by built-in shafts situated in *inner* walls as may be practicable that the air may continue relatively warm, or to use artificial heat for that purpose, as under those circumstances the discharge is more certain and constant.

On ships there is little or no opportunity to fix inlets or outlets in accordance with requirements for natural ventilation except to a certain degree in relation to ventilators. Openings on the sides of ships result from such circumstances as position of guns and considerations of strength of structure and control in relation to the sea. The principal outlets are naturally high, as hatches utilized for communication from one deck to another. In building barracks there are many devices of inlets and outlets, such as double windows, perforated or air bricks, drawer ventilators, Sheringham valves, Tobin tubes, and the like, but in ships the openings available for natural ventilation are those incident to the ship as a fighting machine, or permissible under considerations of safety of vessel at sea. In building barracks there are many devices for heating air supply, such as direct, direct-indirect, or indirect methods of heating, but on ships all air obtained by natural ventilation is air at outside temperature and therein is found the cause of not a little of the sickness in cold weather in a naval service where the air space per man on ships is necessarily small, and any cold air whether admitted by natural or artificial means readily reaches occupants in the form of dangerous draft.

In naval parlance the term artificial ventilation is confined to the renewal of air of spaces by use of ventilating fans and pipes. Of course, any ventilation secured by heat intentionally utilized for that purpose might be regarded as artificial, and if steam jets, or pumps, were employed to produce movement of air the ventilation secured would be artificial. But on modern ships the agent in artificial ventilation is a fan operated by an electric motor in connection with a system of air ducts or metal pipes. Such a fan is confined in a casing which is connected with two pipes, one to supply air to the casing or fan, and the other to conduct air from the casing or fan. The opening in the casing through which air passes from the fan is the first or discharge outlet, or fan outlet, while the opening in the casing through which air passes to the fan is the fan inlet. An opening or louver through which air passes into a space is an inlet with reference to the space, but an outlet with reference to the system of ventilation, and an opening through which air may be leaving a compartment on its way to a fan is an outlet with reference to the space but an inlet with reference to ventilation system. Unless this be kept in mind there will be confusion, as it is necessary when the words outlet and inlet are used in connection with artificial ventilation to know whether the reference is to the fan or the space it ventilates. The designer of the system generally refers to the fan.

The runner or wheel now employed in the ventilation of ships is not shaped like a propeller. It has a peripheral discharge or discharge perpendicularly away from the axis, while a disk or propeller wheel fan forces the air through or beyond the wheel in lines parallel to the shaft. A disk-wheel can therefore be used for moving air in opposite directions by simply changing direction of rotation, but when connected with piping, in view of the resistance, it cannot accomplish the amount of work done by the peripheral discharge type of fan.

Just as the utilization on ships of to-day of the space between smoke pipe and jacket for the removal of the heated air of a boiler-room is a revival of Sutton's idea, expressed in 1742, of changing the air of ships by aspirating effect of heat secured by closing the fireplace and ashpit of the ship's coppers with tight iron doors and leading into the ashpit a pipe of sufficient capacity having branches from lower decks, so the present ventilating fan is practically a revival of Desagulier's wheel exhibited in 1734. That machine is described as "consisting of a wheel 7 feet in diameter and 1 foot wide divided into 12 cavities by partitions directed from circumference toward the center, but wanting 9 inches of reaching the center, open toward the circumference and center, and closed at the circumference only by the case in which the wheel turns." The aspirating pipe was attached to the center of the case, while an outlet pipe communicated with the circumference. On turning the wheel by a crank, air was driven toward the circumference by centrifugal force, and drawn in through the aspirating pipe which communicated with the space to be ventilated. The action was to be reversed by changing the connections.

As such a wheel had a circumference of $7 \times 3.1416 = 21.99$ feet, the tips of the blade would travel $21.99 \times 60 = 1319.4$ feet per minute on 60 revolutions a minute. As the effective velocity under such circumstances was usually taken as about 75 per cent., $\frac{3\times1319.4}{4}=989.55$ feet per minute would be the rate of movement of air through fan outlet. Supposing the outlet to be a 12-inch circle or to have area of 0.7854 square foot, the delivery would be 777.2 cubic feet per minute, or 46,632 cubic feet per hour on 60 revolutions per minute, a standard supply for over 13 men, and a supply of 1,500 cubic feet per man for 31 men. However, the revolutions probably did not exceed 30. The wheel was worked by hand and seems to have been an innovation of short duration on a few ships, though said to be somewhat similar in design to the magazine ventilators in use in the navy as late as fifty years ago.

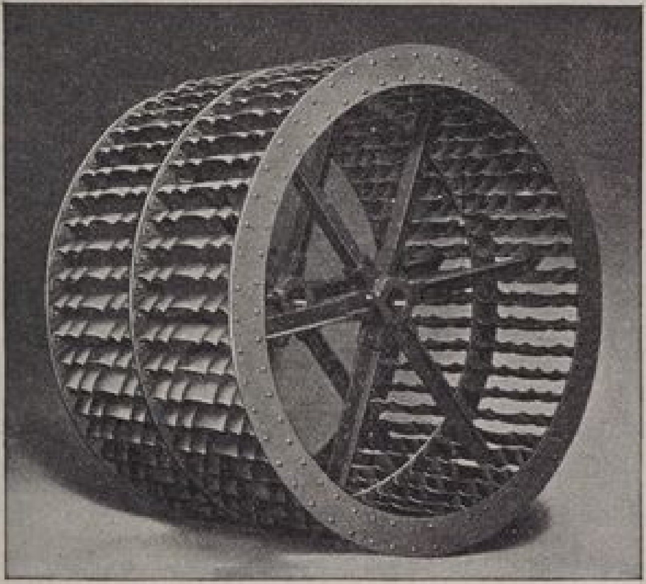

FIG. 10.—A Type of Sturtevant Multivane Runner.

The fan wheel in use on ships to-day is essentially of much the same design as that of the Desagulier wheel, as may be seen in the above illustration in which a type of the new ventilating wheel of the B. F. Sturtevant Co. is shown without casing.

Wheels or runners vary in angle, number and character of blades and in size in accordance with the work required, but the best angle and number and design of blades are still undetermined by makers, as under ship conditions the practical or stated efficiency of the best design, or the one given in the illustration, which was primarily developed for naval vessels, seems to be about 50 or 60 per cent. of the theoretical efficiency under the advanced method of testing recently devised. There is also in this connection considerable discussion as to the most efficient forms of casing, but, however much the appliances may be improved in the search for better results on a given number of revolutions, they are readily designed for any required delivery and have effected a revolution in ship ventilation, and the multivane runner has added greatly to results formerly secured.

It appears from the illustration that both sides of the wheel are open. In the runner of a naval vessel only one side may be open, depending upon construction of casing, and it is there that air gains admission to the wheel, passing thus from center to periphery by centrifugal force as the wheel revolves. When such a wheel is placed within its casing the revolving fan receiving air at its center causes a marked pressure between its periphery and the casing which compels the air to seek the fan or case outlet, and rapidly fills the discharge pipe with which it is connected. This discharge pipe, if used for delivery of air to a space, is called the main, and from it at intervals proceed branches, each terminating in the space, such terminals becoming inlets for the space. Such a fan working for ventilation against the usual best pressure of about 5 pounds to the square foot is essentially a centrifugal pump. The fan within the casing is placed between decks either upon the deck or, as at times, suspended from the deck above, a pipe conducting the air into the casing at the center of the wheel and a pipe conducting the air from the casing at some point near the periphery of the wheel.

It is evident that as the wheel throws air from its periphery it creates a vacuum at its center which causes a movement of air into the casing at the center of the wheel, and that as much air must pass into the wheel as passes out of it. It therefore follows that these wheels can be used either to pump or force air into a space or to extract air from a space. In the former case the air passing into the wheel is conducted to it by pipe starting in the air to be supplied, and usually at a cowl on an upper deck, and ending at the wheel; while in the latter case the air for the wheel is obtained from the space by branches leading to a main that terminates opposite to and near the center of the wheel, such branches acting as outlets for the space and inlets for the system, and the air from the wheel is conducted by pipe extending from the casing on the periphery of the wheel and ending on the upper deck in a cowl which may be made to facilitate the discharge by turning away from the wind.

There is here declared the two systems of artificial ventilation—the plenum or supply system and the vacuum or exhaust system; but a peripheral discharge fan must work in one or the other system in accordance with its connections, not being capable of working alternately by change of direction of rotation as in a disk-wheel. A fan used to deliver air to a space may be called a blower and a fan used to exhaust air from a space an exhauster, but, in the navy, blower is often used to designate either. It is evident that any fan may be situated within the space it ventilates or elsewhere as it operates through its ducts which may be led to or from any location desired.

Fans and fan casings are made of metal, the fan usually of steel and the casing of iron or steel. Casings vary in design, but are usually coated inside with asphaltum and frequently provided with a closely fitting door for inspection of interior and cleaning. Motors are either enclosed to keep them free from dust and moisture or screened, and provided with controlling panel giving speed regulation, usually to about 20 per cent. below full speed.

It is evident that casings may differ considerably in appearance as in design. There are various types of discharge as the air may be made to leave the casing at top or bottom or at various angles. Such variations have given rise to such terms as bottom horizontal discharge, up-blast discharge, etc. A fan may also be right-hand or left-hand, as the motor is on the right or left hand as one faces the outlet, but in each case the fan inlet is concentric with the shaft on the side opposite the motor. However, convertible fans are now beginning to be installed. These have water-tight motors, but in any case instead of having the feet of the blower support the motor a foundation is made for the motor and the shell supported, so that direction of discharge or hand can be changed at will at time of installation.

The illustrations on pages 230, 231 and 232 show a number of Sturtevant electric fans, one giving an excellent idea of details of casing, runner, pedestal and bearings.

As an exhibition of the *interior* of a type of casing containing its runner, the illustration on page 233 furnished by Constructor D. W. Taylor, U. S. N., and made in connection with his important experiments with ventilating fans and pipes may be examined with profit.

These fan wheels as installed on ships can be run at speeds varying for different sizes of fans from 400 to 2,000 or even more revolutions per minute, with capacity varying from 500 to over 10,000 cubic feet per minute, as in engine-rooms, but the multivane runner on account of increased efficiency has permitted a reduction in size and weight of fans for a specified delivery and in power required to drive them. It is evident that, with such means, considerable pressure or rapid movement of air can be secured within pipes, and consequently at terminals where, in designing a system, the maximum permissible velocity for those in crew spaces is generally taken as 1,000 feet per minute. The problem for the designer therefore may be stated to be to lay out a proper system of piping, consisting essentially of a main of requisite size to furnish a sufficient number of branches whose terminals are to supply (or extract) the required quantity of air at about the same terminal velocities not to exceed 1,000 feet per minute in crew spaces, the movement of air to be produced by a blower (or exhauster), maintaining the necessary pressure at its outlet on a minimum expenditure of power or coal.

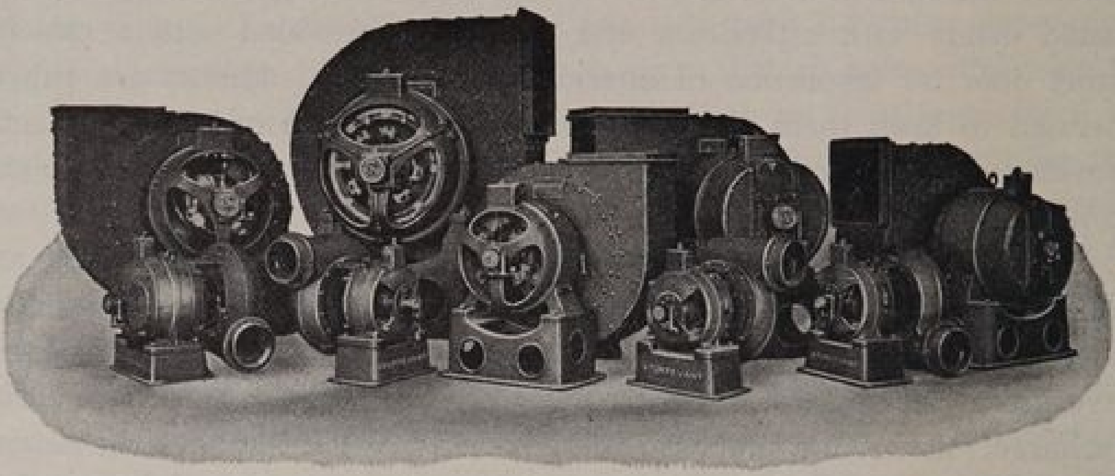

FIG. 11.—Sturtevant Electric Ventilating Sets with enclosed and semi-enclosed motors.

Such a problem belongs essentially to the designer, the sanitarian being chiefly concerned in results as exhibited by the secured renewal of air. But, as the problem is stated, there may be some differences in regard to what constitutes a satisfactory result, as there is no definition of what is a sufficient number of branches or terminals, it being understood that each duct from a main duct is to have no branch.

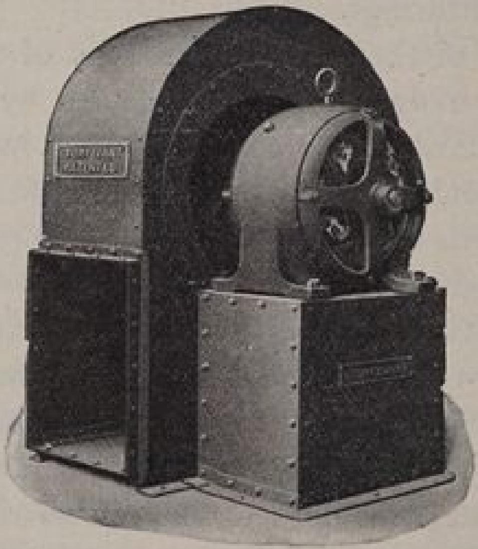

FIG. 12.—Sturtevant Ventilating Fan. Multivane Type.

The question of number and distribution of terminals is important because with a given renewal of air it is concerned with its proper distribution. If air leaves a terminal at 1,000 feet a minute, the volume will depend upon area, a large terminal delivering more air than a small one; it follows, then, that the same volume of air may be delivered by a small number of large terminals as by a larger number of small terminals, but that in the former case there would be less distribution than in the latter, with, however, less friction and less expenditure of power. *There is need, therefore, on the part of the designer of recognition of the advisability of the greatest practicable multiplication of well-distributed terminals.*

In natural ventilation of buildings it is calculated that each occupant should be allowed 24 square inches of inlet and that the area of each inlet should not exceed 72 square inches, or enough for 3 persons, the object being to secure a proper distribution of air. In the artificial ventilation of ships there seems to have been no corresponding limitation.

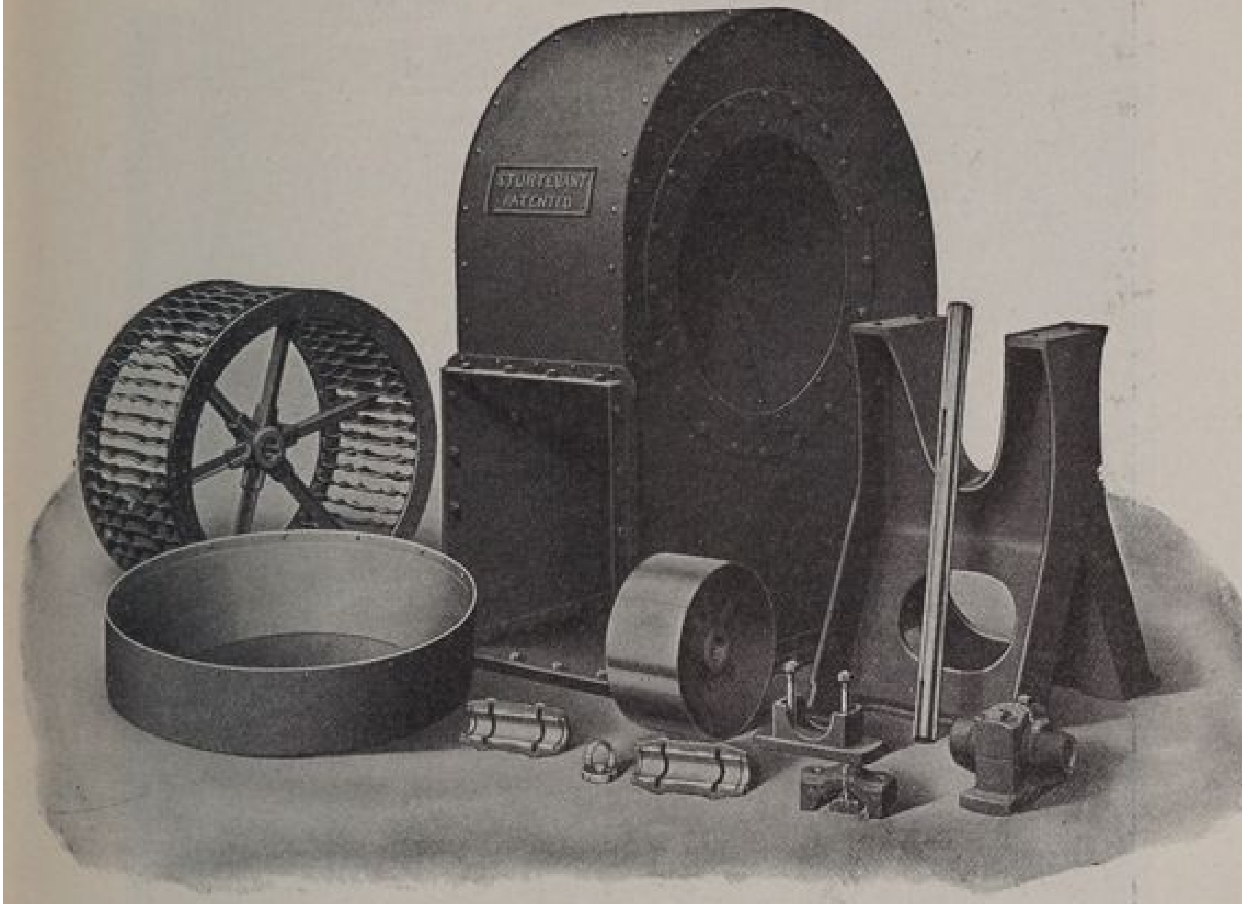

FIG. 13.—Sturtevant Multivane Fan. Details of Casing, Runner, Pedestal, and Bearings.

On naval vessels the specification air renewal is based upon the gross capacity of compartments, their contents in men or furnishings not entering into such calculations. The air supply in relation to available air space is therefore more liberal than would appear at first sight. The specification renewal of a crew space outside of armor bulkheads is commonly in from ten to twelve minutes, and inside of such bulkheads, as there are no air ports or other means of supplying air naturally, in about four to four and one-half minutes. If the gross capacity be considered as 210 cubic feet per man, there would be in the first an artificial supply of about 1,050 to 1,260 cubic feet per man per hour and in the second of about 3,000 to 3,150 cubic feet. These are maximum working approximately calculated deliveries under the supposition of all available space used for berthing purposes.

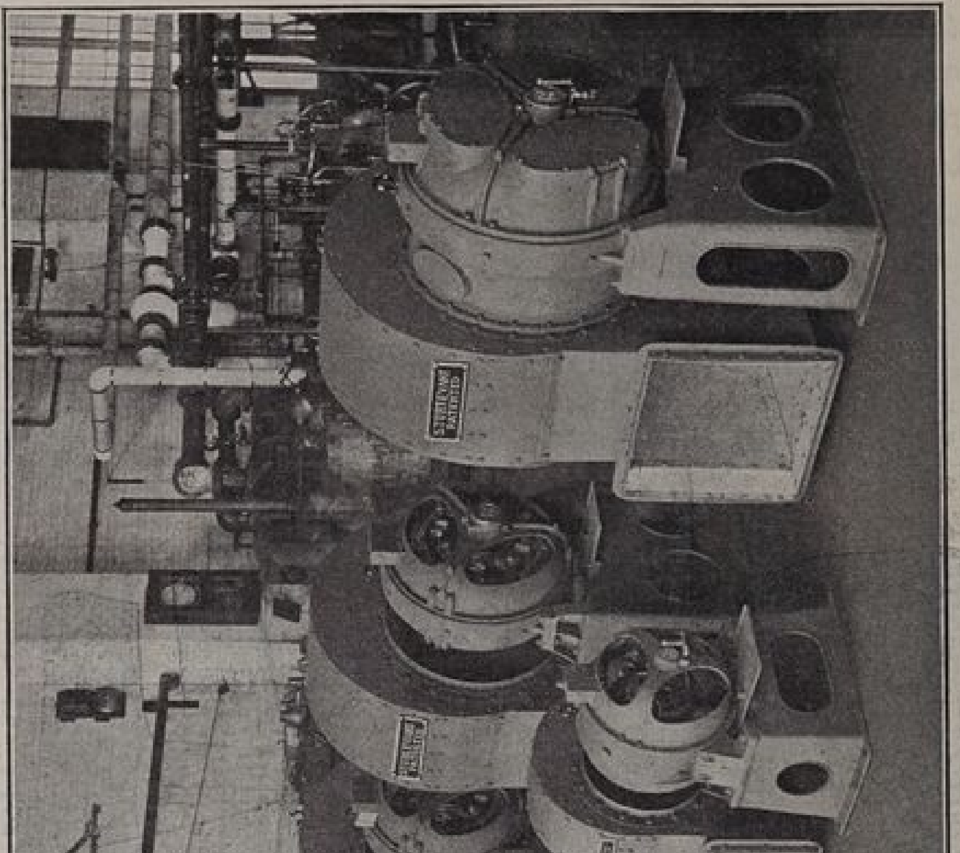
FIG. 14.—A group of Sturtevant multivane fans designed for naval vessels.

At a speed of 1,000 feet a minute, 1,260 cubic feet per hour, would be delivered by a sectional area of 0.021 square foot or 3.024 square inches, and 3,150 cubic feet per hour would be delivered by a sectional area of 0.0525 square foot or 7.56 square inches. If with these allowances a similar degree of distribution be sought as in natural ventilation by having one inlet for each three men, the inlet outside of armor bulkheads would be 9.072 square inches and inside 22.68 square inches, in the one case a 3.4-inch circle and in the other a 5.37-inch circle for each three men, any increase in area, provided each louver be limited to the supply for three, being advisable, as thus the velocity for a fixed delivery is diminished.

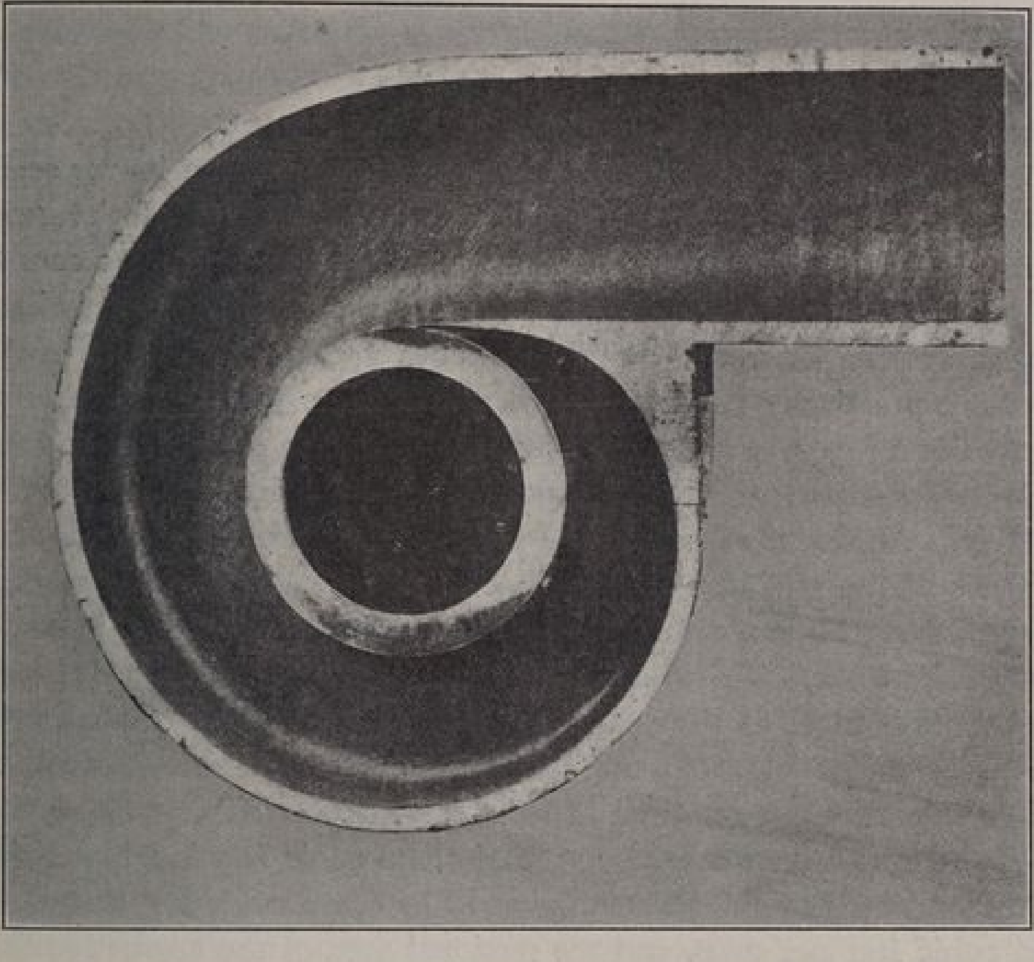

FIG. 15.—Interior of a type of casing showing a runner of the old type with straight blades. (*Taylor.*)

Of course the multiplication of terminals is of chief importance in actual berthing spaces or in spaces where men are crowded. The term berth deck on a modern ship is usually somewhat misleading, as often only a small part of it is used by the crew for berthing purposes and that is chiefly or entirely outside of armor bulkheads, the large majority of a crew berthing on the gun deck and under the superstructure or upper deck with no artificial ventilation usually provided for either space. Within the armor bulkheads there is therefore generally a large air supply and few men, a situation lessening the importance of complete general distribution and leading to more or less increase of sectional area of louvers for removal of heated air in particular localities, such as dynamo-room or around engine- and fireroom trunks.

The living space on the berth deck aft of armor bulkhead is, except in very modern ships, taken up chiefly by officers' quarters where there must be departure from any such plan as the association of three occupants with one louver, as *it is essential for any room, however small, to have its louver.* The specification change of air in a wardroom officer's stateroom is about once in 8 minutes by its one louver, in the wardroom country in 12 minutes by several louvers, and in the bathrooms in 6 minutes. Each water-closet, however small, must also have its louver, connected in such cases with an exhaust system, and therefore acting as an outlet for the space.

The question of the allotment of three men to one louver seems, therefore, to be pretty much confined to crew spaces on berth deck forward of armor bulkhead, including frequently the sick-bay. In that case the calculation of a 3.4-inch circle as a minimum for each louver is based upon an assumption which on analysis does not hold, inasmuch as all billets are practically never occupied at the same time. In port there is generally a liberty party of greater or less size, and it is in port that a considerable degree of natural ventilation is practically nearly always available. At sea there is always a large watch on deck and about one-third of the engineer force below. It may therefore be reasonably assumed that the space technically allotted to five men is in reality occupied by three. This would permit the allotment of one louver to five men instead of to three, thus permitting a larger area per louver, less piping and friction in the system, and less interference with the multitudinous fittings required in ships' spaces.

If three men have a gross space of 1,050 cubic feet in which the air is changed in ten minutes the supply will be 6,300 cubic feet an hour, or 2,100 cubic feet per man, and the sectional area of the louver required, at a velocity of 1,000 feet a minute, will be represented by a circle about 4.4 inches in diameter. The conclusion, therefore, from a sanitary point of view, is that in a crew's berthing space outside of armor bulkheads, having the contained air changed in ten minutes, there should be under ordinary conditions of crowding a louver for about each 1,000 cubic feet of gross space, with a diameter not less than 4.4 inches, and if practicable 5 inches, such a terminal giving a supply for about five billets when delivered at standard velocity (1,000 feet a minute). The greater the number of louvers, the larger the number of branches and the greater the friction and space occupied. The idea here is to indicate hygienic requirements or to show the direction in which the designer ought to move, a multiplication of louvers being strongly advisable, and not a decrease.

In a sick-bay proper there should be berths for about 1.75 per cent. of the crew where an isolation space is provided, and for 2.125 per cent. if such a ward is not provided. Then on a ship having a crew of 800 men there should ordinarily be accommodations for 14 people in the sick-bay proper. In seeking the requirements of a sick-bay for air, all berths should be considered occupied, and the required amount of air should be estimated without regard for natural ventilation, as it is common at sea for the space to be deprived of all natural openings into outside air. Under such circumstances it is therefore desirable to have a louver for each three cots with the area of each calculated to effect the desired number of renewals per hour.

While standards are found for floor space and cubic space per bed in hospitals on shore, it is not practicable to consider the question from quite the same point of view in relation to the sick-bays of ships. A battleship is maintained as a fighting machine and not as a hospital, and it is a question in every ship as to how much space can be spared for the accommodation of the sick. The cells for the confinement of prisoners will probably each have a cubic capacity of from 300 to 350 cubic feet, and should have an air port and a supply louver in each—or a louver per man. It has been seen that in a crew's berthing space, on the principle of three men occupying the space allotted to five, there is maximum gross space of about 350 cubic feet per man, though on not a few ships that estimate would be in excess. If for a sick-bay no more than 350 cubic feet per cot can be allotted there should be means available to renew the air in 6 minutes with adjustable terminals fitted with valves and one supply terminal for each three cots. Making the calculation on that basis, it will be found that each louver should be a circle of at least five and two-thirds inches in diameter and that there should be one such louver for about 1,000 cubic feet of gross space.

In sick-bays the only dependable outlets are usually doors, and therefore ordinarily the inlets should be placed to secure distribution under the idea that the air supplied will find its exit in that way. Then under those circumstances the branches should be led into the space under the general idea of delivering air in a direction away from doors and should be brought into the space overhead a sufficient distance (say from 1/3 to 1/2 that from doors to opposite bulkhead) and distributed across the space to secure equal distribution in all its parts. But it may be that the use of doors as exits would force the air of a particular sick-bay into a crew's sleeping-quarters. The probability of such a result can usually be predicated by reference to position of ultimate exit into the open air, and *all sleeping-quarters should themselves be ventilated by supply*, but the ultimate exit of a sick-bay should not require passage of its air through such quarters, and, if in view of the plan of the ship such a result would naturally obtain, exits should be provided by connection with an exhaust system generally required anyhow in that part of a ship for removing air from paint and oil rooms. It is to that system that a sick-bay lavatory should be connected, thus making under any circumstances an additional exit for the air of the sick-bay proper.

When air is supplied to a sick-bay proper, from which air is also taken in large quantity by extraction, the position of inlets and outlets requires consideration in order to secure distribution. As a rule, there should be one outlet for every six cots, each having at least twice the area of an inlet. Such outlets should in general be spaced at the bulkhead behind inlets. The operating-room should be on both systems—supply and exhaust—and in that case it seems better to have two adjustable and valved inlets, by branches to enter so as to be out of the way, but low and near one end of the space and one large outlet placed high at the other end with air renewal calculated for 6 minutes. An isolation ward should have its artificial ventilation entirely by exhaust with controlled air renewal every 6 minutes. *The air supply should be provided for by a natural inlet secured by a more or less straight tube having a large cone-shaped terminal* at the space and with intake at some point above in the open air, say, just forward of hammock berthing when practicable. Such an inlet in the space should be fitted with valve as a register and discharge its air well down against or between the coils of a rather large radiator. The outlet of space should be placed high at the greatest distance from inlet and controlled by valve. There should be air port and water-tight door. A convenient place for such a room can often be found in one of the pockets just outside of armor bulkhead, which opening within such bulkhead is at times fairly well away from probable influence on a crowded berthing space. Probably a large modern ship has thirty or more fans of various types and sizes, and more than 300 louvers in all situations, of which more than 60 per cent. are 6 inches or less in diameter.

The distribution or location of louvers is as important as their number. On shore people sleep rather close to the floor, but on a ship a crew swinging in hammocks sleeps rather close to the ceiling or deck above and the same spaces are used in the daytime for serving meals and as living quarters. It is obvious that inlets should not be placed low, especially in the absence of a heated air supply, as drafts on the feet would accentuate the already great objection to delivery at standard velocity in cool weather. Dependable outlets are generally large in area, small in number, and situated high, being hatches in the deck above. If a louver is near a hatch, especially if it is not adjustable or devised to deliver air in any desired direction, the hatch is capable of receiving much of the air as an outlet before there has been distribution. If in connection with a plenum system of ventilation there is also an exhaust, a situation generally inadvisable except for the rapid removal of the effluvia of the sick, or of heated air in spaces unprovided with direct natural outlets, as in a dynamo-room or steering-engine room, it is possible to have an inlet so directly under the control of an outlet that the air passes through the space practically undistributed. As a general rule, louvers delivering air to a ship's living space should be placed high, fitted with valves, be capable of adjustment to supply air in many directions and located with the general view of direction toward those parts of spaces away from hatches or other fixed outlets, the ventilation of corners being especially desirable.

It is a result of experience that where too much area has been given to one outlet, dependence being placed upon air velocity and direction for distribution, pockets of foul air are generally found in locations far from outlets. A plenum system can be depended upon to furnish to a ship's living space a much better air supply than can be secured by extraction, but it requires a nice adjustment and much consideration of each space, as they differ greatly in shape and in position of natural outlets.

The navy began its experience in artificial ventilation by use of the vacuum or exhaust system with fans driven by steam, thus adding greatly to the wild heat. It has gradually diminished the amount of exhaust ventilation in sleeping-quarters and adopted the plenum system, until now the prevailing idea seems to be to utilize direct supply whenever practicable. The change has been due chiefly to hot ships and increased amount of tropical cruising, a ship ventilated by exhaust necessarily having a contained air of higher temperature as well as of doubtful quality in crew spaces.

As the change from exhaust to direct supply was gradual, there was a period when the two systems were in large measure on the same ship, and even at the present time there are a number of ships giving evidence of plans of ventilation arranged to accord with many different ideas in this connection. It is evident that on each ship there must be both exhaust and supply systems, but it is becoming more evident each year that *the berthing spaces of all vessels should be ventilated by direct supply.* On the other hand, for special purposes, such as water-closets from which odors would be disseminated, the exhaust system is necessary, and in connection with certain overheated spaces without direct natural outlets to outside air, such as dynamo-room and steering-engine room, both systems must be fitted—a direct supply on account of its cooling effect and an exhaust to form a positive outlet for heated air, and also to prevent the movement of hot air to other parts of the ship.

If an attempt be made to ventilate any living space by exhaust, the air removed will immediately have its place occupied by such air as is naturally available, and it would often arrive from various other parts of the ship in very unsatisfactory condition in regard to oxygen or CO_2 or temperature or odor—*it would not generally be fresh air.* On the other hand, a plenum system is *positive* in character, always delivering fresh air, and, what is perhaps of even equal importance in hot climates, air in sufficiently rapid motion to produce agreeable cooling currents, thus greatly limiting the debilitating effects of the heat of ships.

To anyone who has lived on ships in tropical waters the advantages of the plenum system of ventilation for living-quarters have been plainly evident, but in cold weather its disadvantages are equally apparent, as, with no method of heating the air supplied, the drafts are not only very disagreeable, but dangerous, and there is not only a marked tendency to greatly limit the amount of air supplied, but also even to close valves or dampers in terminals and thus shut it off entirely. In cold weather men billeted near such terminals will, when there is lack of valvular control, tend to utilize clothing to prevent draft either by stuffing articles into louvers, where they are not protected by wire mesh, or tying articles over them. The condition is accentuated when there is diminished distribution incident to too few louvers and men have been known to attempt to secure better distribution, and therefore less draft, by fastening the waistband of trousers about louvers, thus causing the trouser legs to act as ducts, dividing the current and substituting two terminals for one.

As the situation is in marked contrast with that on the same ship in the tropics, where like movement of air secures a relatively cool and comfortable vessel, it seems evident that, the disadvantages being clearly resident in low temperature of supply, the remedy is found in heating the air to the point of least perceptible draft—a difficult undertaking on ships of war in view of limited space, objection to increased weight and power required, and trouble in control, including humidity and also the relation to the arrangement that a single blower may perform the double duty of ventilating at the same time living and other spaces, such as certain storerooms in which heated air is objectionable in causing deterioration of food supplies. Yet, if it be considered that in view of the very large percentage of cruising in hot weather or climates, and of the necessity for unvitiated air supply, the plenum system must be fitted to berthing spaces, the importance of the proper solution of the problem resulting from cold weather is apparent. Indeed, much of the sickness on ships is directly attributable to drafts of cold air in quarters during the comparatively short time passed in cold weather. It should, however, be recognized that heating the air supplied by artificial ventilation would simply decrease the damage, inasmuch as such ventilation is not extended to spaces above the berth deck where the large majority of the crew is quartered and where the difficulty is chiefly associated with the undistributed air from natural ventilation.

Nevertheless, on the berth deck will ordinarily at this time be found wardroom, junior officers' quarters, warrant officers' quarters, sick-bay, and at least one berthing space for crew, perhaps for chief petty officers, and if the air supply for those quarters were properly heated there would be a great advance, from a sanitary point of view, in the ventilation of vessels of the navy.

Considering the question in relation to manner in which other advances have been made it seems probable that a satisfactory solution of the problem will result from experimental installations, changes being made to overcome objections thus declared. In fact, such an installation was made on the U. S. S. Vermont, and it is safe to say that others will be made with improvements in design, as it is clear that the next distinctive advance must be along that line. It is understood that in some foreign navies considerable work has been done in the same direction.

It appears that on the Vermont the installation is essentially for *heating* purposes and not for *ventilation*. It is an indirect system of heating, the total air supply being warmed for the purpose of heating the space and not merely to the temperature advisable for the greatest reduction of draft. That means in cold weather the raising of air many additional degrees of temperature, thus causing, especially without means of adding water, a much greater lowering of relative humidity at louvers, and, in the air streams, greater dryness and, perhaps in very cold weather, some scorching of particulate bodies with resulting odor. Another objection, but one in relation to the former, is the absence of proper individual control in officers' quarters where, with a number of staterooms perhaps losing heat in different degrees or at any rate having occupants of different susceptibility to heat or cold or with different thickness of underclothing of different material or on different food intakes, all must depend for heat upon air supplied at the same temperature, the actual heat control being central, and any diminution incident to control in a particular room involving a diminution in the amount of air or loss in ventilation.

While, in a cold climate, a proper system of ventilation cannot be successfully separated from a proper system of heating, the two cannot be combined advantageously in the same system under conditions found in naval ships where there is crowding with, at times, in the spaces under consideration, an absence of natural ventilation. In crowding, or a small air space, at least some occupants are under direct influence of undistributed air from louvers. If the total air supplied for ventilation is heated to the temperature necessary for heating the space, it will have to leave the louvers warmer than the contained air which is losing heat by conduction. This warmer air, by virtue of greater expansion due to the additional heat, and of the fact that it has not, as the contained air, been able to even acquire the water of excretion from occupants, will have a lower relative humidity than the contained air of lower temperature. It will, therefore, have a greater drying power than the contained air which, in the absence of means of adding water, will itself be much too dry. Besides, such air will not only unduly dry the mucous surfaces near louvers, but also subject the body to the debilitating effect of undistributed air of too high temperature. The conclusion, from all considerations, seems to be unavoidable that, in warming the air supplies of the berthing spaces of ships, the first essential is the supply of air in proper condition for the *ventilation* of small air spaces and not primarily for their *heating*. *The plant should be designed for ventilation and not for heating*, and even then with means of adding water vapor as required, and with *easy*, and, if possible, automatic control of heating area.

On the Vermont it is an indirect system of *heating* confined to officers' quarters and sick-bay. Aft of the quarters on the berth deck is a blower from which the discharge pipe or main is at once led to the deck space below where it divides into two branches, one for each side, port and starboard. Each main branch conducts air into a closed heating chamber or thermo-tank and thence proceeds forward under its line of staterooms, giving off a branch for each room that obtains entrance by passing up through the deck.

In the heating chamber are three sets of steam pipes each with heat control by hand valve, that one, two, or all may be used as required by the varying temperature of outside air. The heating area within the two heating chambers is designed to be sufficient to maintain the temperature of contained air of berthing space at 70° F., on the cold day at sea. There are no radiators within the berthing space, dependence being placed upon heated air supply for heating space.

This experimental design therefore seems to be lacking in an essential, having been made for heating and not primarily for ventilation. The heat control, if it can be regarded as sufficiently divided, does not appear to be sufficiently direct or easy, as it is not readily accessible and yet requires much personal supervision, and there is no method provided for adding water to air that must at times be delivered at very low relative humidity. If the design had been solely for ventilation a smaller heating area would have been required in the heating chamber or thermo-tank, and some heating area in each stateroom and in wardroom country, but, of course, much less than is necessary when air is not warmed for ventilation, as the supply would be delivered at the required temperature of space or in view of its movement a little higher, say at 70° F. and 50 to 55 relative humidity, or with about 4 grains of water in each cubic foot.

The regulation of relative humidity is one of the problems to be solved in perfecting the design of such a plant. Addition of water by steam from the radiating pipes of chamber would be the simplest method, but might be expected to give the air odor; yet that might be overcome by the use of a small evaporator. There could be addition of water by fine spray or evaporation of water within the heating chamber from pan or from a regulated dropping of water on pipes or on certain pipes installed for that purpose.

In regulation of temperature of air supplied for ventilation it would seem necessary on ships to regulate the temperature or area of heating surface, as a hot and cold system or double duct with mixing damper seems to be outside of discussion. Such a system is employed on shore in combined heating and ventilation, as incoming air can be passed by separate duct or by-pass without coming in contact with steam pipes, and by mixing damper at base of each flue the desired temperature in each room obtained, volumes of cold air being mixed with volumes of warm air in any desired proportion. But, in delivering air to wardroom for ventilation only, a constant temperature at delivery is desired in all rooms, any difference of temperature required being secured by varying heating area within the spaces.

In calculating the heating surface required within the heating chamber to deliver a given quantity of air at 70° F., it is necessary to estimate the heat units required to raise a certain volume of air from an assumed minimum outdoor temperature and then to provide the area necessary to furnish those units under the steam pressure that will be employed. Into this problem the character and arrangement of heating surface enter as well as initial temperature. The initial minimum temperature could be safely assumed to be 0° F., or even some degrees higher. As air at that temperature, even when saturated, only contains 0.55 grain of water-vapor per cubic foot, it may, for practical purposes be considered dry as it passes into the heating chamber, and, therefore, the *maximum* amount of water to be added by the plant would be about 4,000 grains, or 0.57 pound of water for each 1,000 cubic feet delivered at 70° F., and 50 relative humidity.

One thousand cubic feet of air at 70° F. are $\frac{1000 \times 459}{529} = 867$ cubic feet at 0° F. at fan suction, an approximate calculation eliminating change of volume due to humidity alone. The maximum number of heat units required for each 1,000 cubic feet of air delivered would, therefore, seem to be that necessary to heat 867 cubic feet of expanding air from 0° F. to 70° F. under the datum that a heat unit, or the amount of heat necessary to raise 1 pound of water 1° F., will raise 4.2034 pounds of air the same increment. The weight of 867 cubic feet of dry air at 0° F. is about $867 \times .0864 = 74.9$ pounds. Therefore, the maximum number of thermal units required for each 1,000 cubic feet of air delivered dry at 70° F. would be $\frac{74.9}{4.2034} \times 70 = 1247.3$, or about what would be obtained from the condensation of 1.4 pounds of steam at 86 pounds' pressure. The heating area will depend primarily upon steam condensing power, as it is the latent heat of steam set free by such condensation that is utilizable in such calculations, and having ascertained the number of heat units required in a given time for each 1,000 cubic feet delivered, the designer determines the character of heating surface and then its amount under the working pressure (say 50 pounds) that will be supplied, and under experimental data as to power of given character and arrangement of heating surface to condense the stream supplied under minimum average temperature of circulating air, say, in this case, 35° F.

As water is to be added in the heating chamber to the maximum amount of 0.57 pound for every 1,000 cubic feet delivered, the amount of heat necessary to accomplish that result or at least the method of accomplishment, as by spray, steam jet, or otherwise, enters into the problem, and if by evaporation the area of evaporating surface.

Of course the amount of resistance to the movement of air by the fan is greatly increased by the coils in thermo-tank. This increase of resistance probably amounts to 20 or 25 per cent. The expansion of the air incident to heating would also lead to an increase in the sectional area of the discharge pipe from the tank or the tank outlet. The coils themselves would have to be made of brass, as are the radiators in the spaces of the modern ship.

All of this is merely intended to give some idea of the general character of the problem, the solution resting entirely with the designer, as the sanitarian should under the circumstances be required only to state the results desired and to show the necessity therefor. The practicability is variable and should depend in this case upon questions of weight and space. On a ship any design has limitations prescribed by space available and weight that can be allowed. Everything that is to go into a ship has relation to the ship as a whole, but it is gratifying to the naval sanitarian that there is space on the U. S. S. Vermont for such an installation even for purpose of heating, and that changes in naval architecture during recent years toward higher free-board and increased size of vessels and difference in size and arrangement of guns, are tending to increase space in relation to men and to make practicable many things that were impracticable on smaller vessels. At any rate, it is always well to keep standards to the front and to realize that in the long run what ought to be done is done, at least to the extent constituting improvement.

The large number of fans on a modern ship is necessitated by water-tight bulkheads. The safety of ship in action or collision requires such bulkheads and that their integrity shall not be placed in question by openings for air ducts. In the early days of artificial ventilation of ships, fans were placed near mid-ship section with long horizontal mains leading forward from one set of fans and aft from another. Such mains necessarily pierced thwart ship partitions and thus lessened the efficiency of transverse water-tight bulkheads. Such an arrangement was also opposed to good ventilation, as the longer the main the greater the friction to be overcome by the fan, and also the more difficult it is to so apportion the system that the movement of air at different louvers shall be about the same. With central fans it was the rule for those louvers farthest away to show little air movement, while those nearest the fan delivered or extracted most of the air. As a result the ventilation of distant compartments was, as a rule, very inadequate, while those near the fans were receiving air intended for all.

Under the present plan of carefully respecting the integrity of transverse and longitudinal water-tight bulkheads whenever practicable, each part of a ship, divided off by such bulkheads has its own independent system of ventilation. A modern ship is therefore said to be ventilated by *independent systems*, an expression that carries with it an assurance of a large and better apportioned supply. It does not mean, however, that each portion of the ship so defined is necessarily under the operation of a single fan, as there may be, and often is, more than one fan operating on exhaust or supply or in combination of the two systems of ventilation.

It should be recognized that a space between transverse water-tight bulkheads is divided into a number of spaces by decks and longitudinal water-tight or other bulkheads, and that also the influence of a fan will be exerted in accordance with the lead of its ducts on spaces on different decks. For instance, a fan may be situated on a gun deck and exhaust air from the head and chief petty officers' water-closets on that deck and also from the sick-bay lavatory, the isolation ward and the paint and oil rooms on the berth deck below; and two blowers, one on the port side of the ship and the other on the starboard side, may be located on a berth deck and operate on quarters and storerooms on that deck, and on communication room and switch-board room below the protective deck. A blower perhaps situated on a berth deck may supply air to a sick-bay and also to storerooms below. Operating on a dynamo-room may be four fans, two supply and two exhaust situated on the berth deck, but the supply blowers may also operate on the bakeries on the gun deck. It is obvious that under any circumstances special outlets should be provided in bakeries. But fans are located with a view to relatively short ducts and to ventilate spaces without piercing the principal longitudinal or transverse water-tight bulkheads. Should ducts pierce such bulkheads they are made water-tight and are fitted with valves.

The men's berthing space on a gun deck is not provided with artificial ventilation. It has a large measure of natural ventilation, but the air supply is so variable that at times at sea, or in bad weather generally, it is not unusual to find foul air on that deck in connection with small air space per man, a large portion of the crew living and berthing there. Water-closets on that deck are under an exhaust system of ventilation *with fan intakes over urinals and water-closets* and air renewal in 6 minutes or less, and sometimes bakeries in order to lessen heat are provided with supply by fan located on the deck below.

In view of the installation on modern ships of blowers utilized in connection with spaces not occupied by men it would seem practicable at times to extend a measure of artificial ventilation to the gun deck without additional blowers. Perhaps among such spaces may be designated the steering-engine room and the air casing below protective deck covering the entire area over the boiler-rooms which is connected with the ship's ventilation system for supply and to the funnel casings for natural exhaust. The supply blower for a steering-engine room is generally located in the room itself and supplies that room and perhaps certain storerooms. It generally gets its air through a cowl located on the center line of the main deck aft. In view of the situation of the cowl it is often made portable that it may be unshipped in very bad weather. If an alternative lead controlled by valve were made, the supply, or any portion of it, could be obtained from within the ship, say from the gun deck aft, when desirable. Such air, while not as a rule as cool as that outside, would in hot weather be sufficiently near it in temperature for the purpose for which it is needed. A supply blower for the steering-engine room of a large ship may have a stated capacity of 3,000 cubic feet per minute. The air casing in boiler-room has a 24-inch air space in which the air may be renewed in about one-half to one minute. The air is generally supplied from some adjacent system which, if not associated with spaces occupied by men, could be made, by an alternative lead controlled by valve, to take its air from the gun deck when and to the extent desired. In hot weather and at sea with ports closed such fan intakes on the gun deck could be utilized to any degree desired in place of usual intakes in the open air, and they could be so placed as to increase the action of natural intakes or inlets of the deck, thus causing a circulation down hatches without overcoming the partial vacuum created in water-closets by their exhaust systems. At any rate, the unsatisfactory condition of the contained air of gun decks has been attracting much attention of late, and, as it is there that the concentration of men is greatest, it is evident that the ventilation should be much improved. Possibly the introduction of the multivane runner will lead to the extension of some artificial ventilation to that deck at sea.

In engine-rooms the air may be changed 23 or 24 times an hour by numerous supply ducts at various levels, and natural exhaust or outlet through engine-room hatches. This is generally accomplished by two large blowers which are perhaps situated on the gun deck level. Each blower has two outlets with ducts going to both engine-rooms, thus securing some supply of cool air for each in the event of one of the blowers or motors being in need of repairs. Engine-room air casings are generally included in this system as also may be certain adjacent spaces.

Coal bunkers are not ventilated by fans, but are provided with natural inlets and outlets. Their outlets generally lead into smoke pipe air casings, which also carry heated air from boiler-rooms, and into dynamo-room trunks, and supply ducts are carried down to the different bunkers from the upper deck, dependence for movement, being therefore chiefly placed on the induced draft in air casings around smoke pipes.

In boiler-rooms there are large natural intakes by ventilators, or ash-hoist trunks, large hatches and natural uptakes in heated spaces previously described. In times of stress, from accumulation of heat incident to peculiar outside conditions it is practicable to reduce temperature of firerooms by assisted draft or by a degree of forced draft for which a large number of steam blowers is provided. Such fans generally obtain their air from ash-hoist trunks, and in forced draft the firerooms are closed to enable the fans to produce a degree of air pressure within the rooms, the maintenance of which involves the supply of large quantities of air in view of the rapid natural outlets by way of the fires. Hatches in boiler hatch casings at gun deck, coaling scuttles, bottoms of ash-hoist trunks and a number of dampers, even those in coal bunker ducts, are closed. Such a course involves greater expenditure of coal and more work in moving coal and in firing. When utilized in a particular fireroom at any time for the purpose of lowering temperature it would seem to indicate the advisability of steps for the increase of the ordinary or natural means by which overheated air in such spaces is generally removed or the routine use of assisted draft. Turrets may be ventilated by placing the handling rooms under a plenum system.

It has at least become apparent that the ventilation of a large ship is a very complicated problem. There are also always a number of details, even where much care has been taken in design and installation, that require attention after a ship has been placed in commission. In the large number of details some things of a very fundamental character are at times overlooked, such as is illustrated in a provision for the extraction of air from a space without an inlet for the space. An isolation ward is under such circumstances useless, and in an officers' water-closet it is possible to produce such a vacuum that the door can only be opened with difficulty. At times a degree of local management is also necessary in order to obtain the advantages for which provision has been made. In a sick-bay under supply, and in a case with doors as the only outlet at sea, it is practicable to have little or no circulation of air, but considerable condensation or pressure within the space by closure of doors. *In every case of supply or exhaust it is necessary to consider provision for corresponding outlet or inlet.*

The natural exhaust, or outlet, through the funnel-jacket space by junction somewhere above protective deck may be very disappointing owing to more or less down draft at times, as in the case of a smoking chimney or fireplace incident to changes in weather. The ventilation that may be provided in that manner for a blacksmith shop, for instance, may lead at times to the room being filled with gas from the forge or jacket. Cowls acting as intakes or exhausts on main deck, especially forward, may have to be unshipped in bad weather, thus necessitating the stoppage of blowers when they are most needed, natural openings being closed. It is best to go to the upper deck for fresh air intakes whenever possible. The ventilation of a laundry is important on account of tendency to accumulation of overheated air and necessity for movement of air in drying-room. The top of the drying-room may be connected with boiler hatch casing and the laundry with a fan for supply capable of renewing air in 4 1/2 minutes by adjustable louvers permitting control of the direction of the flow of air. Washrooms are ventilated by exhaust. The evaporator-room being a heated space should be well ventilated by supply with air renewal in about two and one-half minutes, and, unless there is a good natural outlet, connection should be made with exhaust fan to remove heated air from top of room. In all heated spaces in which men work there should be at least some adjustable supply terminals that the cooling effect of the air supplied may be secured to the extent desired. In a large space, such as that on the berth deck between transverse armor bulkheads, supply blowers with general arrangement of fan outlets near both ends and exhausters with space outlets about amidship will secure a good arrangement for circulation and distribution.

The following is the approximate air renewal in various spaces, based on gross capacity:

Officers' quarters and crew space, berth deck, outside of armor bulkheads, in from ten to twelve minutes, and inside such bulkheads in about four minutes.

Water-closets and crew's head in about six minutes.

Storerooms and passages in eight to twelve minutes.

Magazines in from six to eight minutes.

Engine-rooms and steering compartments in about two minutes.

Evaporator-rooms in about two and one-half minutes.

Dynamo-rooms in about three-fourths of a minute.

In securing those renewals it is evident that method of piping is as important as fan and casing. That question belongs more particularly to the designer, but in relation to it there seem to have been a number of misconceptions that find expression from time to time in sanitary reports. In natural ventilation it is generally considered that bends in pipes or flues have a very marked influence in diminishing rapidity of flow. In calculating the effect of friction in such cases it has generally been obtained for smooth surfaces by use of the formula $\frac{1}{1+\sin.^2\theta}$. θ being the angle of bend, and for general application from the formula $\frac{1+\cos.\theta}{2}$. A bend of 90° would therefore reduce the flow to 1/2 and 45° to 2/3.

But in artificial ventilation as obtained on ships such formulæ are of no value. Stove pipe bends are of course never employed in changing the direction of a branch, as all bends are made as parts of circles, the center line of pipe making a right-angled bend, being one-quarter of a circle. The change of direction is made with as generous a curve as possible, but on a radius not less than one and one-half diameters of pipe. The actual pressure in the main at the fan outlet is about 5 lbs. to the square foot, and velocity at fan outlet is 2,000 feet a minute. Under such circumstances it has been determined that a properly made right-angled bend in a branch causes an increase in friction equivalent to only 3 feet additional length of the branch, and two bends to only 7 additional feet, and that for bends of less degree the equivalent length of pipe is in proportion.

In regard to angles of branches from mains it was formerly assumed that it was necessary to obtain the smallest workable angle and fifteen degrees were generally taken, but it has now been determined that for the general run of branches anything less than 45°, say 30°, gives equally good results and that the angles should be increased toward the end of the main, where the velocity is reduced, the last branch, which should be at most 1/2 the final diameter of main, coming off at 90°.

As round pipes give the greatest sectional area with least frictional resistance they should be employed, and all expansions or contractions should be made at the rate of 1 1/2 inches to the foot. Contractions are made in mains to obtain the original fan outlet velocity when the flow has been reduced by effect of branches to between 1,200 and 1,500 feet. Expansions are made at terminals to secure standard velocity of 1,000 feet. By such cone-shaped terminals or louvers a greater velocity within the branch pipe is reduced to standard velocity by increasing to the extent necessary the sectional area of the discharge opening.

These conclusions resulted from certain important experiments and calculations made by Constructor D. W. Taylor, U. S. N., in 1905 at the Experimental Model Basin, Navy Yard, Washington, on ventilating fans and pipes in actual systems set up to duplicate ship conditions. They were undertaken for the purpose of obtaining information needed to calculate deliveries of ventilation systems on board ship. The results and a description of the work formed a report that was in all essentials subsequently published in the proceedings of the Society of Naval Architects and Marine Engineers. Additional conclusions were that the coefficient of friction does not change with the velocity of the air or with size of pipe used on ships, the friction varies as the square of the velocity of air through the pipe, and the coefficient may be as low as 0.00008, but is increased by comparatively small internal roughnesses, or errors of shape or alignment to 0.0001 or more.

In general terms the volume of air delivered by a fan varies with speed, the air pressure changes as the square of number of revolutions and the power to drive the wheel varies as the cube of speed. Doubling speed doubles delivery, increases pressure four times, and requires eight times the power. The larger the fan the less the required speed, and the less the losses due to excessive friction in pipes due to moving air at high pressure. Even small internal roughnesses greatly increase friction, and deposits of coal dust and other material in pipes lessen delivery. Such deposits are very much in evidence on ships, but especially about louvers protected with wire mesh which on board ship is not less than 1/2 inch in adjustable louvers and 1/4 inch in fixed terminals. To avoid accumulation of dust in terminals requires careful supervision and frequent cleaning unless there is provision for washing air.

All ducts are made as straight as possible and number of bends reduced to a minimum. No branches or openings are fitted in any bends of ducts or in any ends of main ducts or in any ends of branches from which more than one terminal is taken. In all such cases the ends of ducts and branches are blanked and the terminals taken off the sides of the pipe at an angle increasing from 30° toward end of pipe.

FIG. 16.—A McCreery Adjustable Elbow or Terminal with wire screen.

Terminals in living spaces and quarters, including sick-bay and also in dynamo-room, are cone-shaped or bell-mouthed, often to double the area of their branches, and fitted with butterfly dampers or with slides or cut-off attachments for regulation of delivery with regard to temperature or draft, and are also adjustable for control of direction of flow of air with regard to same conditions. The McCreery elbow is commonly taken as a type of such adjustable terminals. It consists of a number of pieces of metal to form an elbow similar to a right-angled bend in a round ventilating pipe, but with bell- or cone-shaped mouth and with no rivets at joints of pieces, all joints being arranged to be movable. Any section of the elbow can therefore be turned on any other section, and thus not only can the bend as a whole be turned at the branch junction but the curve can be reversed in part or in whole, or, by reversing alternate pieces, can be converted into a straight pipe. The following are cuts of such a terminal, showing the many different angles at which the air can be delivered, and below them is a cut of the McCreery "shutter-gate" that may be used for a similar purpose when, from lack of space, it is necessary to avoid projections.

The attention of the Navy Department has been attracted for some time to the McCreery device for cooling and cleansing air. The McCreery elbows have been used for years and with much success in our service, but there has been little or no experience with the other device under naval conditions, though it is utilized on a number of merchant vessels. However, as that device is to be installed experimentally on the Alabama it is advisable to give some consideration to the principles and methods involved.

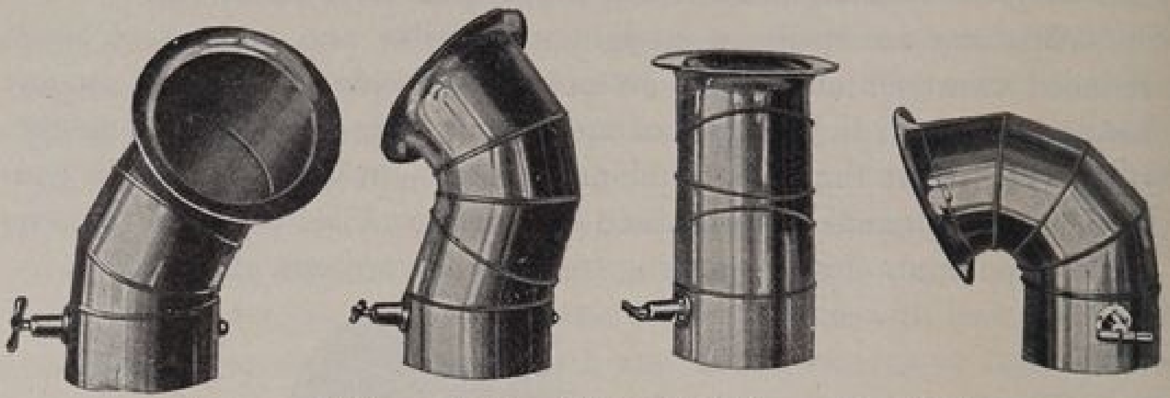

FIG. 17.—McCreery Sectional Adjustable Elbow or Terminal.

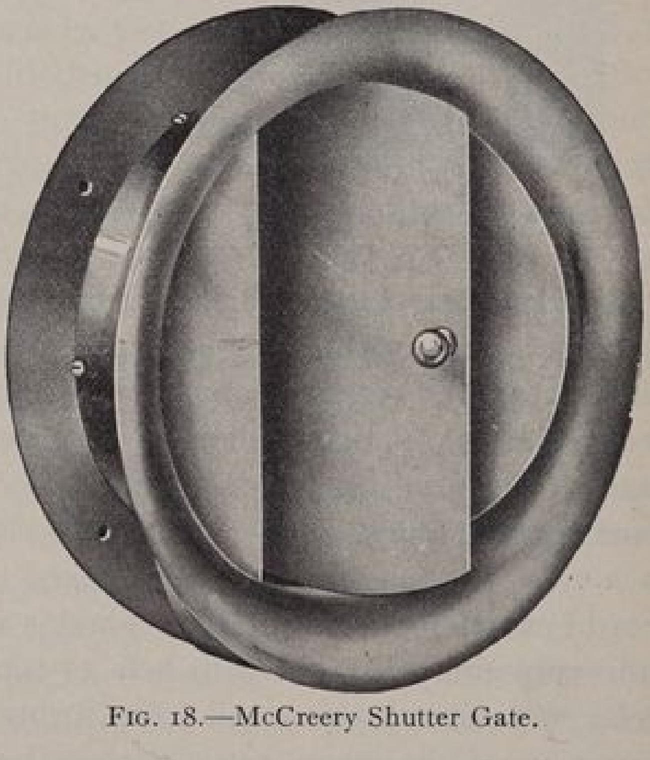

FIG. 18.—McCreery Shutter Gate.

The apparatus is attached to a blower and consists essentially of a container to which a pump delivers water from over the side. This container is known as the air washer and cooler, and the following is its cross-sectional view; showing casing, spray, and water-tank.

The air is *drawn through the cooler* by the fan. In other words, the fan is exhausting air from the cooler and delivering it to the space ventilated. The air enters the cooler from the downtake duct at the upper left-hand edge, as shown in the cut. The character of this inlet as a whole is shown in another cut which gives an external view of the air cooler.

The air entering the cooler is drawn in long sweeping curves through two complete reversals of direction and in its course passes four successive curtains of spray. The spray results from the operation of certain heads upon the water delivered to them by pump. The thorough mixture of the air with the colder spray for an appreciable time is the effective cause of the alteration of temperature. In other words, the change of air temperature depends upon the difference of temperature between the air and the water.

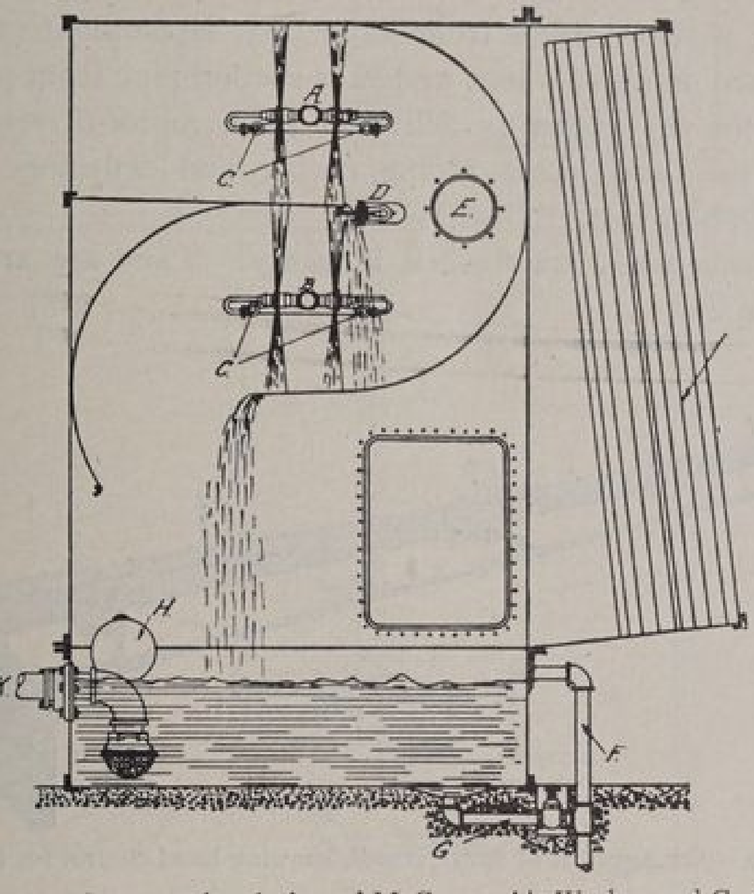

Fig. 19.—Cross sectional view of McCreery Air Washer and Cooler.

Solid impurities in the air are either blown upon the curved walls of the spray chamber, over which constantly flows a film of water, or are caught in the water from the spray heads. In either case they pass with the water into the water-tray located below as shown in the cut.

Gaseous impurities in the air are also largely absorbed by the fine mist which results from the splash from the spray heads.

The air passes from the container or spray chamber through the eliminators designated by the arrow at the extreme right of the cut. The eliminators are a series of metal troughs arranged more or less vertically and staggered. They abstract the free moisture or mist from the air.

In the cut, A is the top spray pipe with two series of spray heads, B is the lower spray pipe, C are pressure pipes to spray-control, D is an electric light set in a water-proof globe at the end of the casing opposite to E which is a dead light for observation of the spray thrown from the heads, F is the overflow from water tray, H the float valve to maintain a constant depth of water, and K is suction pipe from pump.

Water for the cooler is delivered by a motor-driven centrifugal pump, and the spray heads, piping, casing, and deflectors are made of brass and copper.

The spray heads are flushed in gangs. They are arranged as in the following cut:

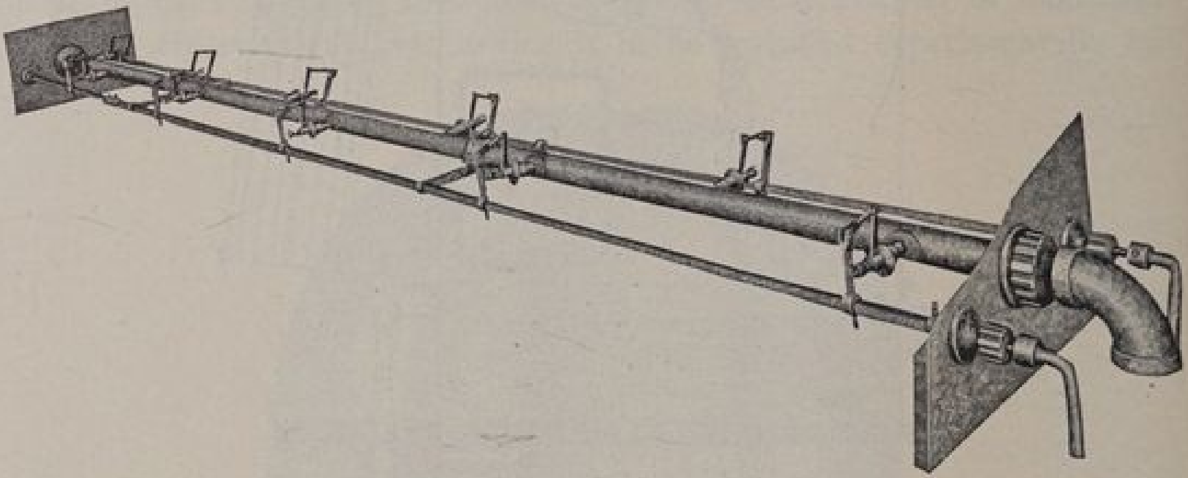

FIG. 20.—Arrangement of Spray Heads, showing hand control for flushing.

To the right are seen the two levers, each employed to actuate a rocker arm which in turn controls the spray heads near it. It is this flushing feature that insures a continuous operation of an effective spray.

The apparatus is intended, under normal conditions, to utilize water from over the side to cool air delivered to a ship's spaces. But in recognition of the fact that in certain locations there is but little difference between air and water temperature, provision is also made for the pump to draw its suction from a separate receiver in order that brine cooled by coils connected with the ice machine may be circulated and recirculated in place of water taken from over the side. It is claimed that spray water may be reused for long periods as air will be cleansed with water which itself is far from pure.

When water from over the side is used directly, the expression "natural cooling" is employed to designate the process, and when a refrigerating coil is used to cool the fluid that is sprayed, the expression "artificial refrigeration" is used. To accomplish artificial refrigeration the piping is cross-connected as shown in the above cut where it

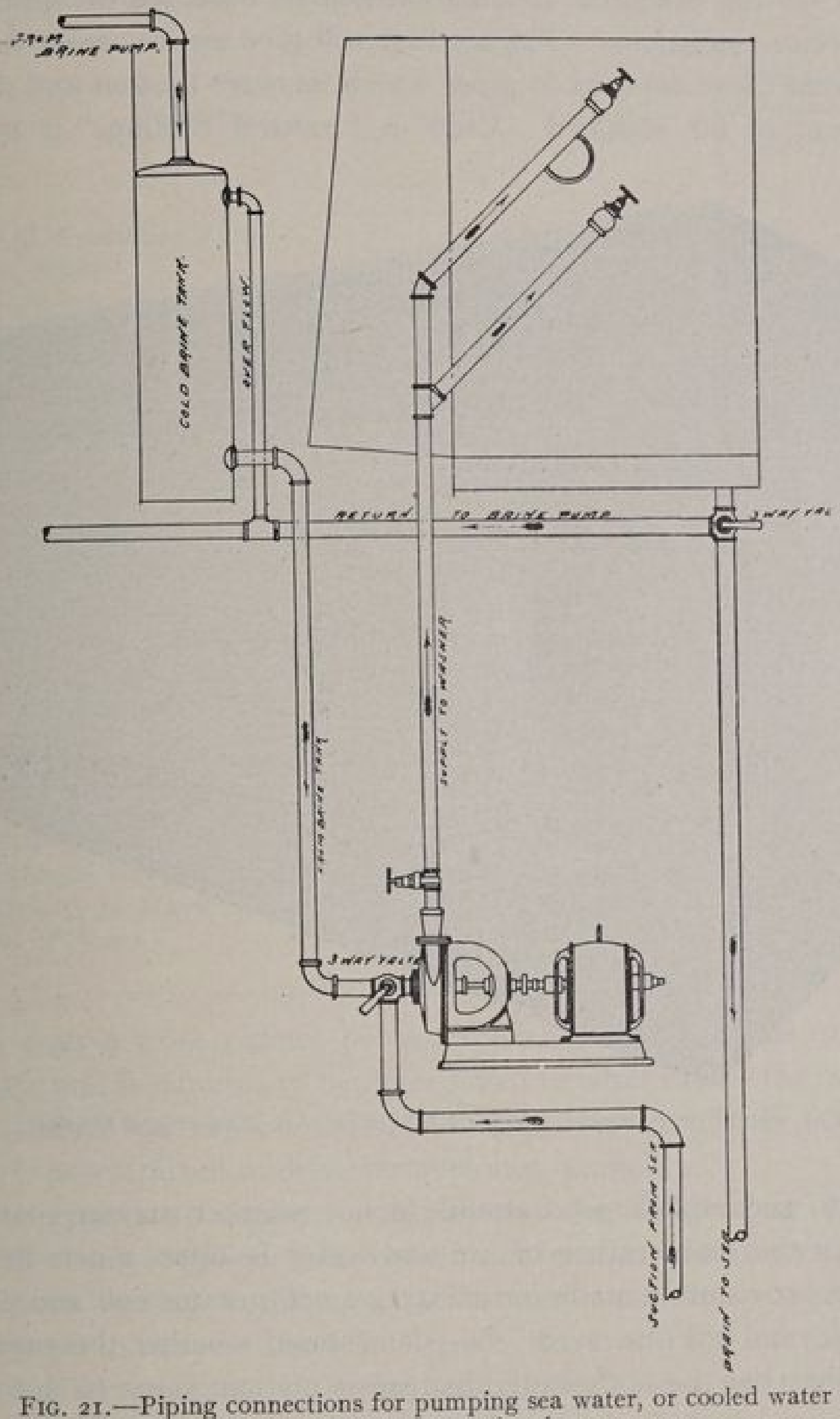

FIG. 21.—Piping connections for pumping sea water, or cooled water or brine to spray heads.

appears that by a pair of three-way valves sea-water is replaced by recirculated water or brine.

This apparatus is very ingenious and interesting, and from the installation on the Alabama information will be obtained of applicability under service conditions. The method will give air free from dust, and thus prevent those deposits in pipes which increase friction and diminish the amount of air supplied. Used in "natural cooling," it might be expected to accomplish good results in hot weather on our coasts. In the tropics the temperature of air and water is often much the same, and, while provision is made for utilizing a refrigerator coil and circulating brine, it will have to be determined whether the capacity of ice machines can be sufficiently increased on our ships to accomplish the desired result and whether the opposition to increased consumption of coal will not be too great to be overcome. The question of coal consumption also comes into the necessity for power to keep sufficient spray water to accomplish the desired result, especially when the temperature of water and of the air tend to approach.

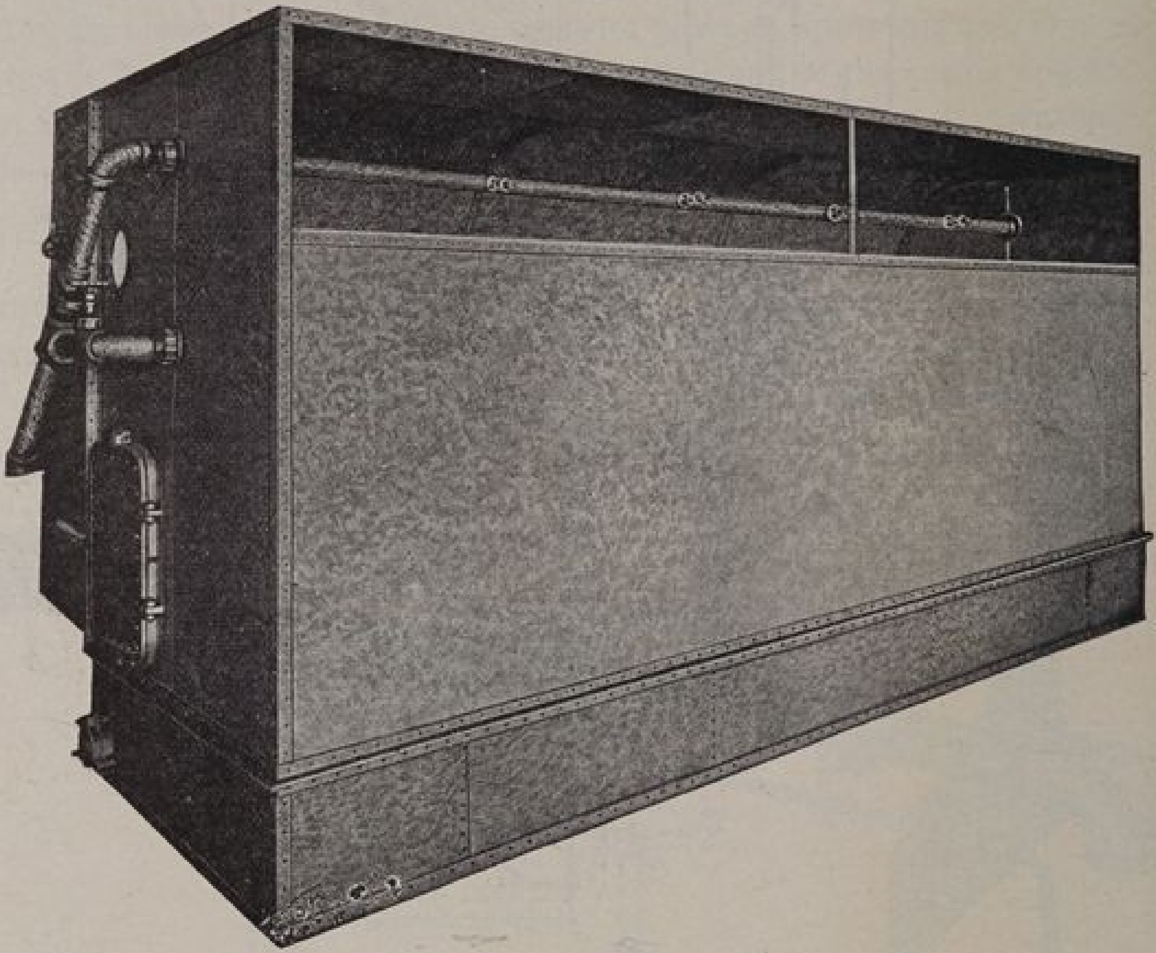

FIG. 22.—Front view of a type of McCreery Air Washer and Cooler.

The following table has been furnished by the McCreery Engineering Company, showing the temperature of air and water at noon, at different points on the Atlantic coast, from the Kennebec River to Cuba; days selected being clear and pleasant. When taken in harbors, the average for several days was taken.

Location	Date	Temperature of	
		Air	Water
Mouth of Kennebec River	July 29, 1898	72	66
Boston, Mass.	Sept. 3, 1898	85	66
Provincetown, Mass.	Sept. 1, 1898	71	66
Provincetown, Mass., 4 P. M.	Sept. 1, 1898	75	66
Newport, R. I.	July, 1899	75	65
New York, N. Y.	Aug. 24, 1899	74	73
Delaware River, a few miles below Philadelphia, Pa	July 8, 1899	82	77
Fort Monroe, Va.		81	77
Charlestown, S. C., Quarantine Grounds	Aug. 25, 1898	84	83
350 miles from Old Point, Va., south	May 6, 1898	79	75
Key West Harbor, 4 P.M.	May 9, 1898	78	74
Midway between Key West and Tampa.	May 26, 1898	82	80
Key West, Florida	June 5, 1898	85	81
Key West, Florida	July 25, 1898	89	83
Lat. 23° 20′ N., Long. 80° 00′ W.	June 11, 1898	88	81
Lat. 23° 52′ N., Long. 80° 49′ W.	June 16, 1898	90	82
Lat. 20° 05′ N., Long. 74° 02′ W.	June 19, 1898	85	81
Off Ætares, Cuba	June 22, 1898	87	83
Guantanamo Bay, Cuba	June 24, 1898	87	83
Off entrance to Havana	July 3, 1898	84	82
Off Isle of Pines	July 28, 1898	85	83

Of course work cannot be accomplished without the expenditure of energy, and it remains to be determined to what extent the coal supply on a vessel of war can be utilized to secure results in this case. However, it is now utilized to drive blowers and pumps.

The apparatus suggests consideration from the point of view of humidity of air supplied. As the air leaves the eliminators it may be regarded as having a relative humidity of 100. In passing through the main on its way to the ship's space, there is some increase in temperature and consequently a corresponding decrease in relative humidity. There is a further decrease within the warm space, but that will be less apparent in air in the neighborhood of a louver. In a report made by Naval Constructor H. G. Smith, U. S. Navy, on July 29, 1902, in which he expresses the opinion that the system possesses decided merit and is worthy of trial, the following occurs in relation to humidity: "Regardless of the relative humidity of the air at point of entrance to the cooler, the relative humidity at point of discharge from the fan is practically 100; that is, the air is fully saturated. This requires some comment. The humidity of the air at time of trial was approximately 50 per cent. and the reduction in temperature about 8°, which is near the dew-point for air of the above humidity at 82° temperature. Therefore, although the relative humidity of the air at discharge is greater than at entrance to the system, the absolute quantity of vapor in the air has been slightly affected. With extremely dry air it is probable that the dew-point would be below the temperature to what air is finally reduced, as a result of which, additional moisture would be taken up by the air in passing through the spray. If, on the other hand, the relative humidity of the air at entrance to the system is high, the dew-point would undoubtedly be above the temperature to which the air is finally reduced, resulting therefore in a deposition of water, and as the relative humidity cannot exceed 100, the condition of air on discharge would be better than on entrance to the system. As the difference in temperature of sea-water and the temperature of air will in most cases nearly equal and probably exceed that given in the test, it is reasonable to assume that the relative humidity of the air can be improved by passing it through the system."

The naval sanitarian is not only interested in the designer's work and method of installation through which sanitary perfection and imperfections are declared in use, but also in the management of the various systems on the ship in commission. A blower may be designed to accomplish certain work on a prescribed number of revolutions, but of course it will not do the work on a smaller number of revolutions. *If the maximum work is desired, the blowers must be run at maximum speed*, and, in view of hard service, motors should be specially designed under the idea that maximum speed is not exceptional. A controlling panel gives speed regulation down to about 20 per cent. below full speed, and such control is very important, but the longer a ship is in commission the greater the friction in pipes due to coal dust and the like, and also, after much use, the less capable the motors tend to become, especially perhaps open motors on ships. In connection with accumulations about fans, the drainage of bearings is important to prevent oil from working into fans, and hand-holes in shells are valuable.

With adjustable terminals much personal supervision is required to secure the best distribution practicable and intelligent supervision can only be exercised in that direction from knowledge acquired by careful study of the space, especially during visits at night when billets are occupied and particularly when high temperature tends to increase the advantages of cooling currents and when low outside temperature, without means of heating air supply, necessitates avoidance of drafts within spaces. Even with proper means, relatively poor results will follow without a zealous intelligent supervision both on the part of those responsible for the integrity of the plant and of those responsible for its best sanitary use. With means of warming air supply the necessity for supervision in cold weather will be greatly increased in the required regulation of temperature and humidity.

In connection with supervision, when, owing to exceptional atmospheric conditions or to inadequacy of plant or to lack of adjustment, it is strongly advisable to increase the amount of air supply in a berthing space under artificial ventilation, it may be of interest to realize that piping on ships is at times so fitted with dampers or valves that it becomes possible to divert air from unoccupied spaces, such as storerooms, to some extent or perhaps to any extent necessary, or to discharge even the entire volume of air from a fan into a living space. In doing this of course the storerooms supplied by that fan are robbed of the amount of air diverted from them, and they consequently do not receive the amount of air intended for them unless through some fault in design they are unduly robbing the living spaces. Such diversion can be done with understanding of leads and only under authority. The condition of the part of the ship to be partially robbed of air should be thoroughly understood as well as the necessities of the living space. The necessity is not likely to arise on a modern ship and the possibility also varies with different ships, scarcely existing unless the main branch going to the particular storerooms is fitted with valve.

By the same method it is also practicable at times to increase amount of air going to particular storerooms that may happen, on account of accumulation of overheated air resulting from steam pipes led through them or of character of stores, to need it. Generally louvers in storerooms are not fitted with dampers, but in the air pipes of ships there are numerous butterfly and other valves which can only be operated at the valves or are fitted to operate automatically only in certain emergencies or by those having the necessary authority specifically delegated. While coaling ship all fans are stopped as a rule to avoid accumulation of coal dust in pipes and to avoid dissemination of such dust throughout the ship. Fans are also stopped at fire quarters.

Before leaving the subject of ventilation it seems advisable to indicate briefly the considerations and methods suggested in relation to the determination of degree of efficiency of a ship's ventilation.

General Considerations.—Systems should be considered in relation to work required from a hygienic point of view—that is, with varying hygienic loads under service conditions, especially maximum and ordinary loads in *different parts* *of the ship.* That is, consider night conditions at *anchor* and *underway*, billets occupied, ports closed and opened, and routine management at night of hatches, including those between decks. Study each independent system, including its leads and the parts of ship under its influence, and consider fans at varying speeds; study location of inlets or outlets of system in relation to hatches and doors and direction of terminals for best results; study gun deck ventilation (natural); use the thermometer freely in sleeping-quarters and in engine- and firerooms, and remember that cruising in tropics and in cold climates may lead to different conclusions in regard to amount of wild heat and efficiency in removal of overheated air; pay attention to radiating bulkheads and decks and loss of heat by conduction of ship's plates, and study arrangements to avoid transmission of heat from engine- and boiler-rooms.

Steps in Making Tests.—1. Calculate in cubic feet the *gross space* of compartment to be examined. 2. Calculate *air space* by deducting from gross space the space occupied by contents (accurate results are important not only in relation to ventilation, but also to disinfection and should, therefore, be obtained early in the commission). 3. Ascertain number of occupants and calculate *net air space per man* allowing 7 cubic feet for man and hammock (3 for the man and 4 for his hammock). This calculation is also important in all berthing spaces in connection with adjustment of billets that the crowding in relation to air supply may be about the same in all spaces. 4. Calculate area of inlets and outlets per man, and consider their number in relation to distribution of air, checking conclusions by results of a number of CO_2 observations made when system is under maximum load. 5. Calculate air supply: (*a*) Directly (anemometer work); (*b*) Indirectly: (1) Loss of oxygen (not usually necessary); (2) Multiple CO_2 observations (important as direct indication of condition of contained air and degree of distribution); (3) Sense of smell; (4) Relative humidity (psychrometer work, but giving only a rough approximation as regards amount of air supply; important in regard to quality of contained air in relation to health, to heating, and to ventilation in a true sense); (5) (Estimation of living and dead organic matter in air by bacteriological and chemical methods. Not usually an available method on ships and so far generally unsatisfactory as routine work, but offering a desirable field for investigation in naval life.)

The question of meeting the respiratory requirements of crews of submarines is a special one. Considering that the submarine has now obtained a permanent place in navies, it follows that its special requirements from a hygienic point of view will appeal more strongly each year to the naval sanitarian. It may also be considered that just as that type of vessel is in a peculiar stage of evolution, so its hygienic problems are in a great degree in the process of development. It may be said, however, that there will be no new principles involved, but new applications. Inasmuch as the amount of nitrogen in contained air is not affected by respiration, it would seem at least theoretically that, while totally submerged, the best result would be obtained by the use of oxygen liberated at the rate that gas is taken from the air by occupants, and by the use of chemicals for the removal of the carbon dioxide excreted. But in practice it is not clear that such a course has as yet been made satisfactory, as at least in one foreign navy there is complaint of the cumbersome apparatus required.

It is said, however, that in France an invention has been made in which so-called solid oxygen is employed to meet the respiratory requirements of the crews of submarines. The solid oxygen is probably a peroxide, perhaps fused sodium peroxide yielding oxygen on contact with water. The trade terms oxone and oxylith are used for some of the substances so employed. As in liberating the oxygen from a peroxide the hydroxide remaining can be utilized for removing the CO_2 from the contained air, the method indicated may be based upon that association, as in some French and other boats it seems that foul air has been passed through a solution of caustic soda for that purpose. Tabloids of the peroxide have also been employed, such tabloids yielding oxygen when dropped into water. In that connection the rate of liberation is an essential factor which may form an objection to tanks of compressed oxygen from which leaks might cause a very undesirable condition of contained air from a hygienic point of view and also an unsafe condition in view of gasoline vapors.

In a submarine, submersion is a more or less temporary condition, barring accidents. Ten or twelve hours may be regarded at this time as a long submersion except perhaps in an endurance trial. During those periods the situation is theoretically much like that of an animal in a corked bottle or of tapers burning in an hermetically sealed space. Under such circumstances the withdrawal of oxygen is associated with a production of CO_2 which being a heavy gas settles and extinguishes first the taper on the lowest level. The loss of heat by conduction through the plates of a submarine would, especially in connection with the small air space in relation to conducting surface, facilitate the fall of CO_2 to the lowest parts of the vessel and define its line of asphyxiation or upper level in spite of diffusion. As a result, a lighted candle placed low would be extinguished before individuals with heads on a much higher level would show marked signs of distress. It appears that a crew has remained submerged about an hour for each 25 or 30 cubic feet of initial air per man, perhaps with faculties more or less blunted toward the end, but still performing duties. A man within a submarine may be considered to have 500 cubic feet of air, and therefore a submersion of 16 or more hours has been practicable on the initial air supply under additional influence to be stated.

Considering the excretion of CO_2 to be only 0.7 of a cubic foot per hour per man, the amount of CO_2 at the end of 16 hours with 500 cubic feet of air would be about 228 parts in 10,000, but the occupants *with heads up* would not be subjected to that concentration. It is this situation which would make the liberation of oxygen of value even without the withdrawal of CO_2, for, at the same time there is settling of the heavier gas, each individual is withdrawing oxygen from the air surrounding him. If settling pits are provided it also indicates the place where the CO_2 could be most rapidly absorbed by chemicals or removed by pump, but in the latter event the withdrawal should at least from a theoretical point of view be made good by liberation of compressed air, *a system in vogue on some submarines.* But the use of electricity to work a pump will be dangerous if there is concentration of gasoline vapor.

The withdrawal of oxygen by occupants is in excess of the production of CO_2, and in time the poverty of the air in oxygen would cause symptoms even if the carbon dioxide were withdrawn. The time of onset of such symptoms varies with individuals but is usually expected when the oxygen is reduced to 12 per cent. by volume. Five hundred cubic feet of sea air usually contains about 103.3 cubic feet of oxygen. When reduced to 12 per cent. the oxygen is 60 cubic feet, a loss of 43.3 cubic feet per man required before there are symptoms of oxygen poverty, *provided the suffocating effect of CO_2 is not present.* If an adult be considered to withdraw from the air about 0.8 of a cubic foot of oxygen per hour the result would tend to show a possible submergence of even 54 hours on 500 cubic feet of net air space, if the CO_2 were removed. Such calculations are only approximate, but they serve to illustrate the fact that at least from the emergency point of view it is much more important to remove the contamination than to supply oxygen.

Such appears to be the outline picture from a theoretical and to no small extent from a practical point of view when air vitiation by occupants during submergence is considered, but in practice there is an important factor in favor of the crew. In theory the air pressure within the submerged boat might be expected not to vary greatly. The men themselves are diminishing the volume of air calculated dry at standard, and, although they are adding heat and moisture, there is also loss of heat by conduction and some tendency to sweating of plates which is more or less controlled by cork paint. But as a matter of fact, the air pressure increases often to the point of some recognized pressure on ear drums. On coming to the surface the opening is made more or less gradually as by sudden release of pressure the singing of ears is more apparent. The chief factor in producing this pressure is leakage in the compressed air system. From a mechanical point of view this may be a defect, but from a hygienic point of view it is a decided safeguard, and is probably the cause of the relatively small effect of submergence on the general health of crews.

The pressure at which compressed air is carried in tanks in some submarines is very great, perhaps 2,250 lbs. to the square inch. Sixty or more cubic feet of such air represent a large volume of atmosphere, and a large power utilized for blowing out tanks and charging and firing torpedoes; but, under such extreme pressure, there is unavoidable leakage which dilutes vitiated air, greatly diminishes danger of asphyxiation during long submergence and at the same time lessens the theoretical urgency under ordinary circumstances for addition of oxygen by chemical means, while pointing to the great improvement to be accomplished by the simple withdrawal of a large part of the CO_2 from settling pit by pump or chemical means. It should be recognized that compressed air is carried as a stock of mechanical energy and not primarily as an air supply for occupants. It is regarded, however, as a reserve supply of air for breathing purposes under recognized contingencies, and as capable of being so employed in connection with the use of pump with suction in settling pit for corresponding withdrawal of the more foul parts of contained air. By mere leakage there is no true air circulation or renewal of air as in ventilation, but merely a measure of dilution, and a submarine must come to surface for a proper renewal of contained air. It is when under surface propulsion that the gasoline engine can also be used to furnish power for refilling air reservoirs and recharging the electric batteries that give power for movement when entirely submerged.

It is in storage batteries and in the presence and in the actual use of gasoline as fuel that are found additional dangers to crews through character of contained air on submarines. Storage batteries are charged at the surface, but during the process, and in overcharging, large volumes of hydrogen gas are evolved. A mixture of hydrogen and air is a powerful explosive. It does not appear that the danger is altogether confined to the period of charging, but that *a boat should be also carefully ventilated after the accumulators have been charged.* Neither is it altogether clear that bubbles of hydrogen gas subsequently freed from plates during bad weather may not be a source of danger in view of the history of the Fulton in 1902. In many submarines there is a use of fans, suction and supply, when charging these batteries that the hydrogen may find its way out rapidly and with little concentration.

Another danger from such batteries is present under the most disadvantageous circumstances and that is where bouyancy is lost from the admission of salt water from any cause. It is stated that in the British submarine A 8 which was raised in 48 hours the men were not killed by explosion, or even drowned, but died of chlorine poisoning. It is stated "that with the enormous electrical energy stored up in submarine boats, if you admit salt water, not necessarily into the battery, but if it merely comes to the terminals of any large circuit, with a difference of 160 volts, chlorine gas will be given off, which will preclude almost any chance of saving life unless you resort to something in the nature of the 'Fleuss' or other apparatus for giving men fresh air in a vitiated atmosphere." The same trouble was experienced in the British submarine No. 4 in original trials due to a defect in the caulking of main ballast tank adjacent to battery tanks, salt water having been forced into accumulators when tank was blown. And the crew of the French boat "Narval" was troubled by sulphuric acid fumes from accumulators during a submerged test. It is noticeable, however, that the British submarine A 4 in 1905 sank through water entering one of the ventilators and returned to surface from a depth of 90 feet without injury to her crew. The submersion was, however, not long.

In gasoline there seems to be two dangers—the gasoline fumes incident to storage and the formation of carbon monoxide incident chiefly to occasional back explosions when the gasoline is burned as fuel, though there is probably some from piston leakage. In some submarines (the Lake boats) the main gasoline tanks are carried outside, that is, in a superstructure. Such tanks are made of galvanized steel and tested to 100 pounds' water pressure per square inch. They are connected with small copper service tanks within, provided with automatic shut-offs and seamless brass tubing connections. It would seem that this carrying of the main supply or almost the entire supply exteriorly would provide a distinct measure of safety. It might be claimed, however, that the more common, and indeed the usual source of danger is in connections which have to be provided under any circumstances, but, nevertheless, it would seem that such connections can be made to better advantage by direct gravity leads from main tanks outside.

That the storage of gasoline constitutes a danger appears in the history of the French boat Anguille in 1905 and in that of the British boats A 2 in 1903 and A 5 in 1905. Such accidents are apt to occur from ignition by electric sparks when there are marked accumulations of the gas and the electric motor is started, say even for ventilation purposes. The vapor of gasoline is heavier than air, as is CO_2, and therefore tends to seek with the carbon dioxide the lower spaces. It is quite conceivable in view of the blunting of the sense of smell, when under the prolonged influence of an odor, that an unsuspected concentration of gasoline vapor can occur in the lower parts of a submarine until an explosive mixture with air has been formed which only awaits an electric spark or an open light of any kind in that locality to cause disaster. In view of the marked tendency of gasoline to get outside of a container in which it is stored in bulk, it might seem advisable to keep as much of the liquid outside of the submarine as is practicable, as tank leakage would there dissipate itself in the open. In view of the tendency of the vapor to settle, it can be removed in considerable quantity together with some CO_2 from a settling pit provided for that purpose, when engine is running under gasoline, by leading an induction pipe from the pit so that it may be under the influence of the suction caused by the engine intake. Thus automatically those gases would be expelled with the engine exhaust. It is usual to enclose the whole of the crank chamber and lead into the enclosure various induction pipes, one being also from the carburetor where the liquid fuel is vaporized.

It was in the Lake boat Argonaut, designed to use her main engine for propulsion on surface or under water, that serious trouble was experienced from carbon monoxide after immersion of only two hours. The gas was found to result from the occasional back explosions and to find its way into the contained air by back flow through the induction pipe fitted to operate in connection with settling pit. This was perhaps in 1897, and showed the necessity for the lead of induction pipes into a tank, as that about crank chamber, such induction tank being connected with the induction pipe of engine. The induction tank is fitted with check valve to prevent back flows, when combustion gases back up into it, without interfering with its suction influence except for the moment during which such gases are taken out by engine induction.

A modern submarine utilizes its main engine when cruising, when awash and at all times except where totally submerged, but there is a type of boat that can make short submergences under gasoline propulsion. When running under liquid fuel large quantities of air enter the boat to support the combustion through such openings as the degree of submergence and weather permit, hatches, high ventilators, conning tower, and sight-hood, if one be fitted.

In the sight-hood of the Lake boats there is an automatic arrangement which admits air without water in spite of wave action, even when one-half or more of the hood is awash, the conning tower being entirely submerged, and under those circumstances the use of the gasoline engine has been continued. In the Holland boat it has been the rule to utilize fans in connection with a ventilator, such fans exhausting air and discharging it through the ventilator. One such fan would be above gasoline engine to carry off any poisonous gases in that locality, another forward of the engine, and others abaft the engine room partial bulkhead where there is marked tendency to collection of foul air. A measure of distribution of incoming air is secured by the induction pipes under the influence of engine exhaust and operating on settling pit. But, in view of the increasing size of submarines and greater radius of action, it seems probable that there will be a more extensive use and better arrangement of fans for surface work.

One improvement of contained air will probably result from the substitution of heavy oil engines for gasoline engines. Gasoline causes a well recognized danger. The present internal combustion engine does not appear to greatly increase the temperature of contained air, but the heavy vapor of gasoline has always necessitated the greatest caution, and exhaust fans, at least as they have been employed, may leave the air of a submarine in undesirable condition in view of the weight of some of the gases that may be present. And, considering the character of the gases that may be present, no satisfactory tests have been put forward for the determination of the condition of the contained air.

However, so far as surface work is concerned the carbonic acid observation will indicate the degree of ventilation as well in a submarine as in a battleship, and a simple apparatus can readily be devised with which approximate determination may be quickly made on the vessel itself under any conditions. But it would not indicate defects in the induction tank surrounding crank chamber through which carbonic oxide may be passing into the contained air, or gasoline leak in tanks or connections causing poisonous as well as explosive vapors.

In testing efficiency of arrangements the danger from presence of carbon monoxide (carbonic oxide) may be determined, as has been at least suggested in the British service, by hanging a cage of white mice over the gasoline engine. It is a practicable plan to utilize such pets on a submarine, as they are much more susceptible than men and therefore give early and timely warning, the urgency represented by their symptoms being in direct proportion to that for coming to surface, and their collapsed state showing necessity for immediate full surface condition with every available opening and a renewal of air by use of compressed air tanks and other means provided.

Doubtless as the construction of this type of vessel progresses its defects from a hygienic point of view will be lessened, especially as not a few of them are associated with certain recognized dangers, the elimination of which will go far to inspire that confidence in the boat directly conducive to its successful employment. As its size increases, there will also be more opportunity to consider the comfort of crews on surface as well as when submerged. And that comfort may also have some relation to type of boat as it may be evolved. Fortunately the use of electricity in lighting and, as in some Russian boats, in heating does not tend to vitiate contained air and the tendency to larger conning towers and more superstructure makes for increased comfort, especially in surface work. Use develops weaknesses, including those from a hygienic point of view.

Returning to the contained air of ships in general, it has been indicated that quality of air expressed by temperature is of very great importance. It has been shown how the ship itself, as well as occupants, tends to modify the temperature of contained air, and how important to maintenance of health is equability of temperature in any living space. Experience of occupants is itself sufficient to declare the necessity for not only a proper distribution of air, and thus the avoidance of disagreeable drafts, but also for the maintenance of a more or less constant and comfortable temperature of air at a suitable relative humidity. In hot weather the tendency of a ship, as has been seen, is to greatly overheat many of its occupied spaces, and the problem is to greatly limit the wild heat for, in living quarters and to no small extent in working quarters, the health of a crew depends largely upon heat control; but in cold weather, while health in living spaces depends as greatly upon the control of temperature of contained air, it is in the direction of ability to *add* heat to the extent that is desirable, and thus to secure the comfort and well-being of crews which would be lost by low temperature.

Man is to a great extent a creature dependent upon averages, being more or less intolerant of extremes. In food, clothing, and regulation of habits he thrives best when avoiding extremes. It is moderation as well as avoidance that tend to long and useful life. Excessive heat and excessive cold are alike inimical to his well-being, especially when he is unassisted by proper food and clothing and exercise and habits. Now, all men have practically a fixed temperature which is maintained primarily by a regulated control belonging to the body as a part of its design. This regulation is through the nervous system and, at least in civilized or clothes-wearing man, is readily disturbed outside of recognized limits.

The method of control may be divided into two interdependent varieties—the chemical regulation of temperature or the variations in the production of heat incident to variations in metabolism produced chiefly in normal man by variations in the external temperature to which the body is subjected, and the physical regulation of temperature through amount of blood circulating near the surface of the body, thus varying heat loss by radiation, convection, and conduction, and through amount of sweat, thus varying heat loss by evaporation.

The former method is quite similar to variations in the consumption of fuel under a boiler, the body increasing, though involuntarily, its metabolism to produce more heat to maintain its temperature in cold weather. Of course that metabolism is much more greatly increased by work or exercise, and the increase in mechanical energy is associated with an enormous increase in the production of heat, which in turn warms the cells of the body, making their metabolic changes more rapid. While in work or exercise man is not seeking, as a rule, to increase production of heat, which is often embarrassing and requires the marked intervention of the physical method of heat control to keep the body temperature down near its average, it is evident that, when the increase of heat incident to chemical control in cold weather is not sufficient, he can and does resort to muscular effort to make up the deficiency, thus voluntarily causing the body to consume more fuel. But work is necessarily followed by rest and man in his living quarters is at rest. Then a temperature of contained air too low for the body to maintain its heat by chemical regulation, especially when the cold air is at the same time unduly robbing the body of heat and overtaxing its method of physical control enervated perhaps by civilized habits of dress, demands either more clothing or some external source of heat, if the physical method is not to be allowed to shut off the supply of warm blood to which the skin is accustomed, lowering too greatly the temperature of nerve endings even to the point of producing that shivering which is not only very uncomfortable, but often indicative of danger.

Excitants depend largely upon contrasts and man's sensations are therefore derived from changes of warmth. Maintaining the warmth of the body by additional clothing is required in the open to avoid an undue appreciation of change of temperature of skin. Man seeks by clothing to maintain an even skin temperature, a tropical condition of the air immediately surrounding 80 or more per cent. of the surface of his body. He can maintain that condition in quarters in cold weather by regulation of external sources of heat and he can continue to more or less maintain it in the open by additional clothing combined with more or less muscular effort as may be required. Besides, it is not practicable in a state of rest and in the clothes of daily wear to properly maintain body temperature in a cold living space by additional clothing. Many fur-covered animals change their coats to accord more or less with season, and man, lacking in fur, does practicably the same thing, but in addition being a house-dweller he changes the weight of clothing in cold weather to accord with his position inside or out. He has learned from experience that in indoor life in cold weather an additional source of heat is required, for it is impracticable to so carefully vary the total amount of clothing and its distribution, as on feet, in hours of leisure or at meals, as to secure with varying temperature of contained air the desired skin temperature, and, if through any excess, the body seeks by perspiration to diminish the body heat, reduction of clothing, or exposure in the open without much additional clothing, becomes dangerous on account of a too rapid and chilling loss of heat.

The normal body at rest is intolerant of sensible perspiration. Its health at rest lies in the maintenance of its uniform temperature with a so-called dry skin, especially in cold weather, a fact opposed to too much clothing or too much external heat. When at rest in bed the body is more evenly and completely covered, as a rule, and the circulation in a recumbent position is more readily and uniformly carried on. Under such circumstances the feet chilled by low temperature of contained air or by cold undistributed air become warm; the production of heat, which is ordinarily increased by the simplest muscular movement, is more uniform and the air imprisoned by clothing is more readily and evenly kept in confinement, thus enabling the individual to more satisfactorily adjust clothing to meet surrounding conditions, the even distribution of the covering and the uniformity of heat production lending their aid to increase the limit of low temperature at which the covering provided becomes insufficient, and to diminish the objection to additional covering as required or desired. The discomfort and danger of too much or too little bed-clothing is, however, generally recognized. The danger of exposing even parts of the body wet with perspiration to surrounding moving cold air is present, but a person who, having slept cold, returns to bed, after having momentarily exposed his body to the cold air, often has the advantage of the reaction incident to the cold bath and will thus find clothing warm that was formerly insufficient.

All navies recognize the necessity for controlled sources of heat within living quarters in cold weather. This has been ordinarily secured entirely by use of steam in radiators—a direct system of heating, as it is entirely separated from warming air supply. The use of steam for heating purposes depends upon the amount of latent heat it contains and which is set free and transmitted by the radiating surfaces as it is condensed into water. The heating plant is generally arranged to work at the apparently high pressure of about 50 pounds and the radiators have areas in relation to cubic feet of space to be heated that vary in different parts of the ship from 50 to 125 cubic feet per square foot of heating surface. Ordinarily in crews' spaces of ships having non-conducting sheathing applied to outside plates, it is about 125 cubic feet per square foot, in wardroom country and rooms 100, and in sick-bay 60. The use of such non-conducting sheathing has increased the space heated by each foot of heating surface.

These figures seem to have been fixed by experience rather than by calculations as it does not appear that any coefficient has been determined for loss of heat through ships' sides, and, in view of the extensive use of non-conducting sheathing on the modern ship, such a coefficient would have been greatly modified by present conditions, including limitation of wild heat as well as of loss through ship's plates. It is, however, generally accepted to be better to have too much heating surface than too little, as, by proper control, it can always be reduced to the extent desired. Such control is obtained by valves at radiators; by division of heating area, coils or standing radiators being divided into two or more parts when exceeding an area of 10 square feet; and by use of circuits so connected that each can be operated independently of the others.

The use of steam on ships for heating purposes does not appear to have been a subject for much controversy as it does not seem to have been considered that its rival, hot water, is suitable for a ship, and especially perhaps for a fighting ship. The controversy has not been in regard to steam, but in relation to its use in connection with the air supplied in artificial ventilation. It is evident that when all the heat is utilized for the purpose of heating contained air, the air supplied by a plenum system of ventilation will create very disagreeable drafts, prevent equability of temperature, and, if admitted in proper amount, cause much sickness. It is therefore evident that the attempt to heat the space without heating the air supply results in failure, if considered, as it must be, in connection with ventilation. The result secured is generally an overheated inadequately ventilated space containing air of an irritatingly low humidity, or a space warm near the heaters but cold in other localities and full of drafts.

An appreciation of that situation has developed a tendency to go to the extreme of expending all the heat in warming the air supply to the point of warming the space. That means the complete removal of radiators from space and placing them within thermo-tanks that the entire heating area may be employed in heating the air forced over it by fans and conducted to the tanks, and from the tanks to the spaces, by pipes. That is a forced system of ventilation and heating in combination—an indirect system of heating combined with a plenum system of mechanical ventilation.

The objections to that method have been stated, although, all things considered, it may be regarded as an improvement upon an unheated air supply and a direct system of heating. But, for reasons already given, the opinion is here again expressed that less objection will be found to hold against a division of heating area—one portion being placed in thermo-tank for the purpose of warming air entirely for ventilation and another portion placed within the space to make up the loss of heat by transmission. In that case the air supplied is not overheated or scorched, and, being delivered at much lower temperature than necessary for heating the space, does not in seeking distribution cause as much appreciation of draft or come in contact with bodies at such low relative humidity, even when water is not added as required, as it should be.

All radiator coils, radiator pipes and circuit steam and drain pipes should be made of brass and all radiator coils or pipes should be led along the deck at the bottom. Naval necessities require them to be placed out of the way in location not interfering with ship work and usually near bulkheads. The lead of circuit, steam, and drain pipes presents many difficulties, and this is often especially true of steam and drain pipes not forming part of the heating plant, but connected with auxiliary engines, such as anchor engine. As an anchor engine is used, though intermittently, in warm as well as cold weather, and an ice machine especially in warm weather, and a steering engine constantly when under way, their steam pipes serve in spite of non-conductors to liberate more or less heat which tends to act on any space through which they may lead as if more or less steam were being utilized for heating purposes.

These conditions are apt to make certain hot storerooms in which some stores, perhaps food or medicines deteriorate, and, in accordance with the lead, may affect living spaces, including a stateroom or a sick-bay. Steam pipes are also liable to leaks which have caused considerable damage. If a steam pipe is too near a fresh-water pipe, or if a fresh-water pipe passes through a greatly overheated space, it may also lead to an objectionable situation, especially if water so warmed is to be used for drinking or even bathing purposes. If such water goes into a scuttle butt its state unfits it for use, at least until the cooling coil has been able to overcome the objection. The uncontrolled heat of a ship is also capable of rendering quarters practically uninhabitable. The case might be cited of certain warrant officers' quarters situated on the gun deck of a big ship and even connected with the artificial ventilating system. In 1906 the temperature in those particular quarters was said to average 98° F. in port and 105° F. at sea, as they are over the evaporator-room and the fresh-air ducts, passing through the evaporator-room, delivered air at from 90° to 95° F. It was not only a case for the use of ventilated non-conducting sheathing, but also for a change in the lead of ventilating pipes. It was also a case of deficient ventilation of an evaporator-room with its after end situated over the high-pressure cylinders of the main engines. At sea the temperature in evaporator-room was 130° to 140° F. and in port about 120° F.

Heat, controlled or uncontrolled, on a ship presents some of the most difficult problems in naval hygiene, and the attempt has been made here to show how, while general principles may be stated, each ship requires more or less study from a hygienic point of view in the design and building, and, in spite of any attention that may be given during those periods, will still require such changes as are indicated by experience during the period of commission. The health problem is never completely solved as the data are always insufficient. It is a progressive problem that should accumulate data in any progressive and growing navy.

In addition to heat, electricity is, as has been seen, another force which, though acting indirectly, has had marked effect on the contained air of the modern ship. That has appeared in its use to operate fans in artificial or mechanical ventilation, to which may be now added the many bracket fans (60 or more on a battleship) in sick-bay, staterooms, and officers' quarters; the various portable ventilating sets (probably 10 or more on a big ship); and the practical abolition of candles and oil for lighting purposes by the substitution of the electric light for them. The bracket fans are 1/6 and 1/12 horsepower and the ventilating sets 1/4 horsepower. Ventilating sets are used for renewing air in double bottoms when visited for inspection or work, and in connection with any part of the ship below the extension of the pipes of the ship's ventilation system. These are in addition to a compressed-air system, including gun-gas-expelling devices in turrets and are shown in their most recent form in the following illustration:

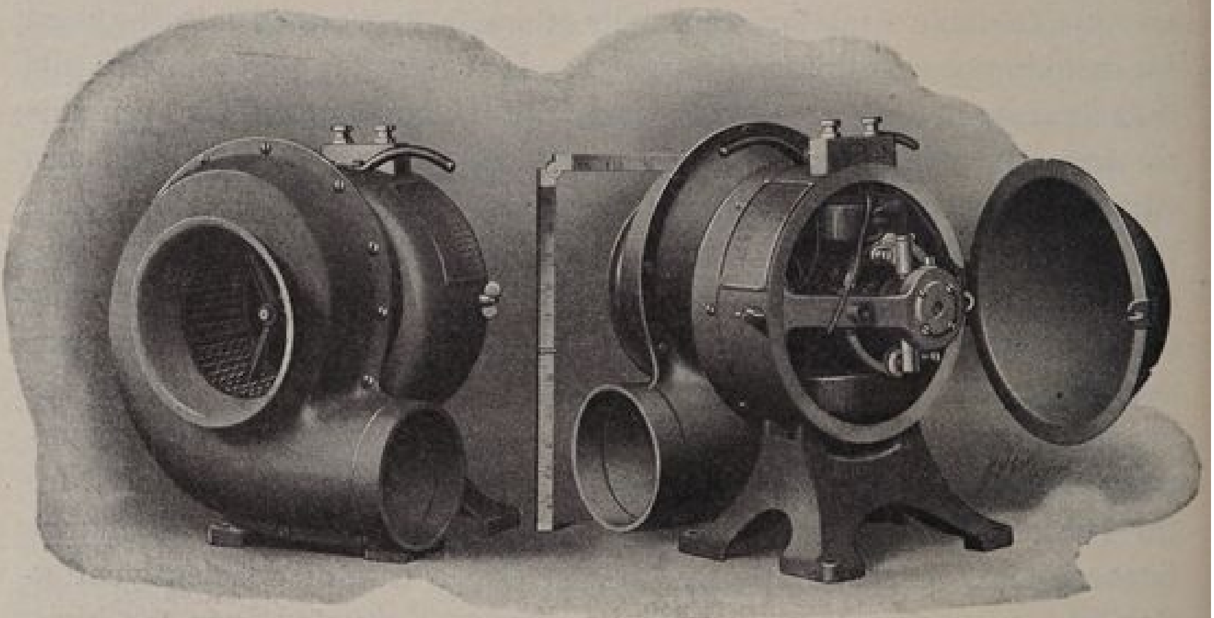

FIG. 23.—Sturtevant Portable Electric Ventilating Set. Weighs 50 lbs. 400 cu. ft. per minute.

A bracket fan does not ordinarily change the air of a room, though, by the currents it produces, it can be made to greatly aid in the distribution of the air supply or, by movement of contained air, can be utilized in hot weather or in an overheated space to create acceptable cooling drafts which, however, are capable under recognized circumstances of acting injuriously when received directly, not a few cases of neuralgia and myalgia being traceable to that source and occasionally even more serious conditions. A bracket fan placed in an air port can also be made to act as a ventilating agent, either drawing air into a room through the port or expelling air from the room in accordance with the direction in which it is operated.

In hot weather air-scoops, temporarily fitted to such ports, can also often be used to advantage when ship, at anchor, is swinging to the wind. Such thin metal scoops, projecting beyond the ship's sides, catch the wind and divert it into the space, often in large volumes which can be, however, readily controlled by changing the angle of the scoop in relation to direction of wind. Such scoops, when turned with concave surface to the water and with slight outboard inclination, may also at times permit a port to remain open during rain.

Electricity in substituting the electric lamp for candles and oil has, as already shown, effected a marked change in contained air. Of course the combustion products of candles and oil are not in some important respects like the vitiation from human sources. This subject has already received consideration and it has become evident that the chief objections to combustion within spaces are found in heat and carbon dioxide, and, under certain circumstances, in the water added. Other substances are in insignificant amounts, and there is absence of the organic matter of bad odor evolved by lungs, skin, and intestinal tract of man. Nevertheless, in view of the small air space per man on ships, the electric lamp has made a marked and perceptible change for the better in contained air, and especially when cruising in hot climates. In electric lighting there is absence of odor and of carbon dioxide and there is relatively little heat. It takes the combustion of only 12 grains of carbon to produce 44 grains of CO_2, and if an oil contains 85 per cent. carbon it would require a consumption by a lamp of only about 186 grains of such oil per hour to equal the CO_2 excretion of a man at rest. In barracks a cubic foot of gas when burned takes the oxygen in more than 6 cubic feet of air and forms about 0.82 cubic foot of CO_2 and 1.15 cubic feet of water-vapor. An open-flame gas burner will consume from 5 to 6 cubic feet of gas per hour, and a Welsbach, giving 3 times the light, will consume 3.5 cubic feet. In all ships electric lighting is employed and also in all hospitals and barracks, but there with combination fixtures—electricity and gas—as a rule, while on ships candles and oil lamps are provided for emergencies, the latter being also regularly used in the running-boats.

Air is the common medium of sound in which it has a velocity of about 1,090 feet per second at 32 degrees F., increasing as temperature rises. A noise is caused either by a single impulse or by a series of impulses at irregular intervals. The term is generally applied to an annoying or disagreeable sound. Sound, including of course noise, differs in intensity or loudness and diminishes with the square of the distance from the sounding body, but sounds may, like light-rays, be reflected from an opposing surface, and thus concentrated or intensified.

The effect of sound on the health of men is as little understood as that of light. Immediate disturbing effects seem to depend primarily upon contrasts, as is often the case with light. Darkening a room ordinarily conduces to sleep, but many men can become accustomed to continuing the morning sleep in a room into which the gradually increasing light ultimately streams with considerable brilliancy. In the same way sounds recurring at regular periods very often soon cease to disturb, and the same is true of continued sounds, while an unusual or unexpected sound, as an unusual or unexpected light, will frequently cause immediate disturbance, depending in no small degree upon its intensity. Man is to a great extent a creature of habit and within wide limits becomes accustomed to or even dependent upon conditions that to others would be more or less intolerable. Men have lived for months on ships where a gun is fired every morning at a certain early hour without hearing the noise more than once or twice and at sea the constant churn of the propeller and the consequent ship vibration may permit sleep when the cessation causes immediate wakefulness.

Enlisted men as a class do not seem to be disturbed by the routine noises of a ship, and others, being for most of the time less exposed, acquire a degree of immunity that may not be so complete. But in all cases there are limits, depending chiefly upon quality, intensity, or concentration, or unexpectedness. The unusual whisper will disturb more than the accustomed voice, the hammering of squilgee handles on the deck more than holystoning, the unexpected noise of the ash hoist more than the continuous noise of machinery or propeller, and in many sick-bays the rush of chain in hawse-pipe is even more startling to a patient than the firing of a salute overhead.

In general terms the absence of unnecessary noise suggests efficiency when things are being done. A well-constructed machine is supposed to run smoothly and a well-constructed ship and a well-run ship is supposed to furnish the minimum amount of noise in its daily routine. There are very noisy and moderately noisy ash hoists and there are ash ejectors. There is a noisy morning watch and a relatively quiet one, and in wardrooms as elsewhere there are well-trained attendants and others not so well trained. And in wardrooms, especially at sea, there are officers who have the mid-watch and others who have no watch. Noise that interferes with sleep is not conducive to good health or efficiency, and in the construction as well as in the routine of ships its limitation is in the interest of the common welfare.

Whatever may be the wear and tear of body tissue directly or indirectly incident to noise, waves of sound, as in the case of waves of light, are capable of causing injury when in sufficient intensity. There are not only the sunburn and the X-ray burn, the retinal exhaustion common from too much illumination and the more slowly appearing amblyopia from exposure of the retina to intense light, but also the deafness or greatly impaired hearing of the boiler-maker, the temporary deafness on the battlefield, and in the use of secondary batteries and great guns of ships, the ruptured tympanic membrane from the blast concussion of gun firing, the occasional permanent deafness from more deep-seated effects of concussion, as, on the nerve endings in the labyrinth itself, and the tongue bites, and general shock from vibrations of the gun itself transmitted through surrounding surfaces or structures. So far as effects on the ear itself are concerned the blast or muzzle concussion is by far the more potent factor.

As installed, the guns of a ship may be divided into the main and secondary batteries, the former being the larger, or the big guns in turrets or casemate, and the latter the smaller or more rapidly fired guns chiefly on the upper or open decks. The larger guns use heavier charges of powder and projectiles of greater weight and consequently the blast discharge has much more volume, but such guns are mounted within protection in the form of steel walls, and the muzzle is also at greater distance from the breech. Thus the men at those guns are afforded much protection from the effects of the blast, and so far as one's own gun in turret is concerned it is generally considered that the secondary battery with its rapid and open fire and the more intimate general relation of a particular gun's crew to the blast of another gun is more trying to the integrity of the auditory apparatus. However, the turret itself is often in intimate relation to the blasts of other than its own gun fired over it or in its general direction. Each turret has a sighting head from which its occupant makes observations and directs the gun fire and where he is liable to be placed very strongly within the influence of the blast of some gun other than his own. The same thing is true of an individual near an open air port, especially when guns are fired in direction more or less fore or aft, the danger being greatly increased as one tends to occupy a position in advance of the plane at the muzzle vertical to the line of fire, and that position may be occupied in relation to an opening on any deck when a gun is fired in direction along the sides of a ship more or less fore or aft. The force of concussion is at times seen in such results as broken crockery or sky lights, doors torn from hinges and even iron stanchions thrown out of line.

The chemical reactions incident to the combustion of the powder cause the evolution of an enormous volume of mixed gases of which carbon monoxide and hydrogen are more than 50 per cent. The total volume of gas gives an enormous pressure within the piece which is relieved at the muzzle and which with the projectile causes primarily a marked compression of the atmosphere in the vicinity. This leads to a rapidly increased pressure on the body surface of anyone near its influence, but is followed, as in any rapidly moving wind or in the case of any rapidly moving body through a fluid medium, by a partial vacuum in its wake and a marked movement of the fluid to equalize pressure or to regain a state of equilibrium. Therefore, the increased pressure on the body is followed by a period of vacuum or suction. The blast therefore acts directly and indirectly. The ear-drums and the abdominal walls are forced in as by a blow and are then nearly as rapidly subjected to a minus pressure or suction under which they momentarily tend to bulge as if under increased internal tension. Thus with the general violent agitation or shaking there may be nausea with or without a ruptured drum, loose articles of clothing, such as a cap, may be blown or drawn from the body and even cotton wool placed in the external auditory canal for protection of the drum may be displaced under the suction and lost.

The bombardment of tympanic membranes with sound waves during rapid firing tends to produce more or less tinnitus and deafness even when the auditory apparatus itself remains intact. This may be considered comparable to the discomfort and temporary blindness incident to marked glare or very brilliant illumination, and when noise is continued from day to day, as in the work of a boiler-maker, or of persons daily subjected to long-continued rapid firing, the deafness ultimately becomes permanent. As, however, in the case of the permanent blindness sometimes following a relatively short exposure of the retina to very intense light, permanent deafness can follow exposure to the shaking or agitation produced by a single explosion, the ear drum being intact. In these cases it appears that all the bones of the head and face act together with the ossicles in the transmission of vibrations to the inner ear, and that the shaking of the body as a whole is also a factor in causing injury to the terminals of the auditory nerve. These cases have seemed to have some relation to body tension about the breeches of guns during the period of rigidity associated with expectancy of noise, gun recoil, and vibration of platform. The rigid body is conducive to the maximum injury of internal ear, and during that period the condition of the *tensor* *tympani* and *stapedius* and the more or less closed *Eustachian tube* incident to mouth closure may contribute to results, though in relation to the inner ear such factors are disputed.

Tightening of the *membrana tympani* conduces to rupture, and when the tube is closed the vibrations of the membrane are transferred to the ossicles less diminished than when the tube is open, as then a part of the vibrating air is forced through the tube, but also tightening of the membrane diminishes conduction. It is under such circumstances that the blast is more effective in producing drum-rupture, but at the breech the influence of the blast is lessened, yet there is considerable general shaking of the body and bone conduction that when often repeated has a tendency to injure terminals in the inner ear.

Drum-ruptures vary greatly in extent, and it is evidently not unusual for them to attract little notice when unassociated with perceptible bleeding. It does not take long for general firing to cause more or less tinnitus and deafness followed by some headache, and men are accustomed to make light of such things. It is this spirit that tends to limit the use of cotton wool in ears. Perhaps a ruptured drum may not appear at sick-call until there is more or less median otitis or pain following swimming over the ship's side. When cases are taken promptly repair under cleanliness and boric acid is the rule. It is, however, undoubtedly true that absorbent cotton placed or packed loosely in external auditory canals, not in contact with the drum, and that the slightly open mouth greatly diminish the number of ruptures. The interference with hearing is not so much of a factor as it appears in view of the natural diminution of hearing incident to gun fire, and, all things considered, the use of cotton wool by the majority at secondary battery and in casemates and sight-hoods should be advocated at target practice or in action in default of something better. It was used rather extensively but not generally during the Spanish-American War. In the battle of Manilla a number utilized this method of ear protection with good results. There were some cases of rupture, but they do not appear to have occurred among those so protected. It also limits the subsequent headache, though that is also one of the effects of powder fumes, and the tinnitus and deafness which nearly everyone notices in himself and others in varying degree.

Cotton wool was also utilized generally for this purpose by the Japanese navy during the war with Russia, and although the protection was evidently not absolute the results are stated to have been relatively satisfactory—that is very much better than no protection at all. Possibly a material somewhat similar to wax will be found more serviceable than cotton wool, as the velocity of sound is relatively small in such inelastic substances and yet they would interfere with hearing somewhat less, especially with the appreciation of high-pitched notes. Paraffine of low melting-point in thin sheets has been employed for this purpose. A piece about the area of the thumb nail is taken for each ear, held for a few moments between the thumb and index-finger until softened, and then fitted snuggly over the external auditory meatus.

There is also an artists' modeling material known as *plasticine* which has received some official recognition in the British navy as a protection for ear drums at target practice or in action. It has the consistence of dough or putty, which is maintained probably by a percentage of glycerine. Its cost is small—about 20 or 25 cents a pound. A piece about the size of a walnut is sufficient for both ears. It is customary in order to increase the tenacity of this dough to knead it together with cotton wool. A piece of the dough about the size indicated is pressed flat between finger and thumb and then about 50 grains of cotton wool are spread lightly over and the two substances thoroughly kneaded until the incorporation is complete. The mass is then halved and a piece is fitted into the meatus of each ear. This dough is said to contain considerable sulphur and to be an antiseptic prohibiting the growth of ordinary bacteria. It is also claimed to permit a larger degree of hearing than cotton wool, while affording better protection. It is under trial in our service.

The interference with hearing is a recognized drawback in the use of all material used to plug the meatus. It is admitted that the noise or concussion itself produces more or less deafness, but it has been considered possible to preserve the undoubted advantage of readily hearing orders that may be of vital importance and at the same time to give ear drums the protection they undoubtedly deserve. In the attempt to accomplish these results Elliott's ear protector has been devised. It consists of a celluloid ball and wing. The ball fits into the meatus and the wing extends backward within the concha against the antihelix. Through the apparatus there runs a tortuous canal which permits hearing, but at the same time prevents access to the drum of vibrations with the directness and intensity to cause rupture. It is an ingenious device of much merit. The pinna naturally serves to collect the sound waves and reflect them into the meatus, and from the lower wall of the canal they are thrown perpendicularly upon the drum set at the proper angle to so receive them. It makes a marked difference in results whether the face or the unprotected ear is turned toward the blast of a gun, and there would be a much smaller number of ruptures if faces could be kept in that direction. This device prevents that concentration of waves by the pinna so capable of causing rupture and at the same time permits the passage of a sufficient volume of regular vibrations to produce hearing.

The chief difficulty so far found in the use of this apparatus is incident to the difference in sizes of external ears and the necessity for an exact fit, as otherwise there may be considerable local irritation, headache, and even lack of protection. It appears that this protector is made in a number of sizes and that, although not a little attention has to be given to fitting, a result of much value can be obtained. It cannot be denied, however, that at present the subject of the best protection is, from a service point of view, in a more or less experimental stage, and that not a few officers and men who have tried the Elliott device prefer cotton wool. However, a considerable majority of those who have tried both are in favor of the former, and it seems likely that, if a good fit is secured in each case, division officers at least would do well to provide themselves with this means of ear protection which, while insuring the drum from rupture, provides for that degree of hearing necessary for an understanding of orders transmitted by voice.

There is no effeminacy in providing for such protection. The damage without protection is too real and at times too serious. To spend years in acquiring the knowledge necessary to practise one's profession with success and then to deliberately permit mere noise to take away one's usefulness is surely not commendable. In fact, a naval service protects gun crews as well as guns with inches of armor, and should, it may be believed, not only ascertain the best means to protect its personnel from a necessary yet useless and damaging noise, but also provide the means and insist upon the use. And doubtless every service would so act not only in this but also in other directions if the solution of questions in hygiene in the corresponding directions were as simple under service conditions as they might seem at first sight. It is doubtless more clearly known than ever that the recognition of the importance of questions relating to health is essential for service efficiency and it appears that such recognition may not always be readily obtained, though more readily now than ever, but on the other hand medical as other minds are apt to grasp ideas from their own special direction and not to turn them around to be viewed from every side. Naval advances bring about new conditions or accentuate old ones and no problem in hygiene can be properly considered as something apart from essential service conditions.

With a device like the Elliott it is not easy to obtain general use in view of the necessity for fitting. Target practice is not part of the daily routine, and if such devices were fitted and served out they would in many cases not be with the men at the guns, and if kept at the guns there would be delay in each man finding his own especially with changes in the make-up of gun's crew. Cotton wool, plasticine, or like mixtures can be made free from such objections and always available, and such articles once used are not reused. If the Elliott device is kept in the canteen its use immediately becomes optional and the first cost is deterring. It seems from a practical point of view that individuals specially associated with gun pointing could be required to use such a device, but that in a general way cotton wool or a substance similar to plasticine has more chance of general adoption. This is increased by the facility with which at target practice between runs men remove cotton from the meatus and retain it for the time being in the upper inner part of the concha or about the fossa of the antihelix. If the Elliott device were removed during the same period it might be stowed in a pocket from which in stooping it could readily be lost, or, as a rule, in the absence of a pocket mislaid upon some ledge. The main point is that some protection is necessary and should be required, but that no material so employed should ever be in contact with the drum or remain in place after the necessity has passed. A subordinate use for such device is when decks are being caulked. One who has had the night's rest disturbed by a watch or from other causes or who is keeping his room on account of sickness can avoid such very disturbing and almost deafening noises by employing the device indicated.

In connection with gun vibrations there are also a few face injuries from telescopic sights, especially those of smaller pieces, and following the firing of guns there are injuries at times from "flare backs" which have occasionally occurred with even disastrous results. These back explosions are made possible by a limited mixture of atmospheric air with the combustion gases rich in carbon monoxide and hydrogen remaining within the gun. The flash is of very short duration and usually has relatively little effect upon sweating skins. The circumstances under which "flare backs" occur, their prevention and the avoidance of disastrous results through powder ignition belong to the domain of ordnance where the entire subject has received and is receiving careful attention.

This study of the air without and within the ship has been necessarily rather more suggestive than conclusive in view of the extensiveness of the subject and the numerous ramifications even from a purely hygienic point of view. There has been some detail in certain directions that have seemed of direct importance, but the subject as a whole is one inviting investigation along many lines, and even original research. Air is the substance of more immediate importance to man than any other, and in the history of navies the direct relation of disease and death to the condition of the contained air of vessels is apparent in a most pathetic way in view of the unlimited supply of pure air always in actual outside contact with the vessels themselves.

The history of such a subject is of great interest, as when complete it enables one to follow the changes from year to year or from one decade to another, and to arrive at the present with a better understanding of conditions prevailing and their effects upon the health of crews. The necessity for an adequate renewal of the contained air of ships has now come to be generally recognized, and, through the period of steam blowers to the present use of the electric blower, the method has been evolved to supply air in any desired volume. But this particular phase of the subject has had its importance so terribly emphasized by the history of navies that there has been danger of too much concentration upon that one idea.

Man's necessity for air is urgent and his welfare is intimately associated with amount received and its purity; but that welfare is as intimately associated with the manner in which the air is received and upon its temperature and humidity. It is not merely a question of separating man from his excretions, but also of effecting that separation with safety. For air not only furnishes the oxygen required at each moment and receives the gaseous and other air-borne excretions entrusted to it for transportation and dilution, but also, by its temperature, humidity, and movement on the body surface, affects metabolism and regulates body temperature. It is not only a question of clean air as secured by purity of air supplied, rapid renewal, and cleanliness of person, clothing, and surroundings, but also of such distribution and such regulation of temperature and humidity that the renewal may be effected with safety, without dangerous drafts, without chilling of body surfaces.

The question of condition of contained air as shown by humidity occupies as prominent a place in the history of this whole subject as the amount of air supplied, and singularly enough, it also was associated with the most commendable conception of the necessity for cleanliness, but unfortunately with misdirected effort. That was the long period during which decks were flooded and during a part of which the mixture of water and excretions was run into bilges. It finally became a maxim that a dry ship is a healthy ship, for eventually after very many years it came to be recognized that a part truth is often worse than no truth at all.

There are dangers along the same line to-day, for all navies are not only paying too high a price in ill health for cleanliness secured by the methods employed, but also suffering more or less from the means used to secure dryness in quarters. For from a practical point of view the maxim itself is only part of a very important truth in relation to ships, as the apparently dry ship must also be one that does not retain man's excretions, and considering the length of time linoleum has been in general use as a covering for decks it is acquiring notoriety in providing a means for the retention of man's excretions, collections occurring under it from time to time that have causative relation to such serious diseases as diphtheria and cerebrospinal meningitis. There is an increasing tendency in the service to spread hammocks on decks rather than swing them, and there is also an increasing tendency on the part of medical officers to view linoleum with suspicion and to use their influence against the practice of deck sleeping. There may be a better moral atmosphere in the billets provided and there is certainly better air in view of the position of louvers. But the contrast of methods is notable and of value. Formerly excessive humidity between decks was the rule with accumulation of filth in bilges, and even in concealed pockets near quarters due to leakage from flooded decks into such spaces as may have been formed by rotting of timbers or may have been left as an incident of ship construction. The excessive humidity was a prominent cause of rheumatism and general ill health, while occasionally the filth accumulations would attract attention by the appearance in epidemic form of some fever of known or unknown character. *Now* the spaces of ships are water-tight. Any collection of water used in cleaning has to be mopped up as carefully as on the floor of a house on shore. Humidity of contained air is avoided as much as possible, and the decks have a permanent covering of shellac and linoleum. Yet the concentration of men remains great and the mouth and other excretions probably reach the deck in as large quantities as ever, for the purity of the deck was at least as much considered in old times as to-day. The application of shellac mixture is of distinct advantage on account of its disinfecting qualities and the smooth finish it tends to secure, but, as the linoleum is a fixture subjected to hard usage, defects in laying or loss of integrity from wear and tear permits accumulation of filth beneath it that in view of the higher temperatures possible on modern vessels may become even more productive of evil than the accumulations in older times.

No material normally going within a man or coming usually in contact with him affects him so vitally or profoundly as air. The air surrounding him is his climate. A few degrees difference in its temperature is the difference between comfort and discomfort, and a high temperature with high relative humidity goes far to diminish activity of mind and body, to lessen utilization of food, to drive away sleep, and to diminish the pleasure of life. It is thus during the hot week in our own climate, perhaps even in May, that we recognize some of the effects of tropical conditions which we forget during the next cool week, perhaps in June, when the sun is practically of the same height and brightness. It is under such circumstances that one knowing the tropics realizes it is the condition of the air, its continued heat and high humidity, which causes the climatic anæmia, depression, and loss of weight, and not chiefly, at any rate, the light with chemical rays.

But whatever the cause within the tropics the results induce the belief that the general good health of a navy can readily find marked deterioration in a custom of keeping ships more or less continuously in hot climates. It is also apparent that if the air surrounding a man may be considered in any sense his climate, slight changes in the location on the ship of the body may make marked differences in the degree of comfort and welfare. Such changes become of great value to men where employment keeps them much of the time below decks, and emphasize the importance of regulations facilitating their access to the upper decks. This question relates chiefly to members of the engineer force off duty and to such storeroom keepers as tend to use storerooms for working- or living-rooms. In one case results are made to depend in no small degree upon the disinclination of tired men to repeatedly change uniform during the day in order to be presentable under the regulation of visible uniformity in dress, and in the other case the anæmia and general deterioration of health are incident to a bad habit of life that should find correction in ship administration.

Here is again evolved a contrast of the present with the past. In the old days of yards and sails the conflict between man and the elements was fought in the open air. It was a struggle to make the sweeping head-wind carry in the desired direction, to make the gain on one tack exceed the loss on another. It was a fight in caps without gromets and of wide-legged trousers streaming in the wind out on the yards or at the braces. They were the days of wind-tanned skins and rolling gaits. But they were also days of foul contained air.

The lives of the men themselves paralleled the course of the ship. The watch on deck was the time of battle in which they gained in health and strength by victories won. It was the tack in which distance was gained on the sea of life, but the watch below was the losing tack, the drifting tack, in which the air was less favorable. Legs that had been wearied on the shrouds, arms that had tired at the ropes, lungs that for hours had gladly inflated themselves to the utmost with the sweeping air of unlimited space were crowded together to lose in sleep much that had been gained in open struggle and perhaps at times more.

But now the inflated lungs are not so much on deck as below. The contained air of chests is not pressed out on yards of ships, but on the handles of shovels; the apices of lungs are not inflated by air salt from the foam of the sea, but laden with the dust of the mine; and skins are not tanned by wind, but whitened by darkness and sweat though grimed with powdered coal. The struggle is no longer comparable to the tack of gain, but to the tack of loss, and the body depressed by labor in overheated dust-laden air lays itself down at times in the tropics still grimed to gather strength for the next struggle with heat and coal.

And the men on deck, the followers of those of the old school of reefers and bracers, of knotters and splicers, of handlers of tar. They are as of old adapted to the work of their time. There are no longer sails to handle and braces to man. Ships no longer tack, but plow their way through the water and the engine-room bell has been substituted for the cry "All hands shorten sail." It has for them ceased to be a story of sail and has become largely a complicated story of guns. It is a day of machines and therefore of engineers or mechanics. It is no longer a day of blocks and tackles, but of screws and levers, and the ram has taken the place of the rammer and the turret of the gun-port. But with sails, the sail was watched and tended from anchorage to anchorage, and even at anchor, where each rain was followed by loose sails, and every afternoon it was "Down top-gallant and royal yards." Now the handling of guns is a routine drill, not even in the open with certain guns, and not to-day, but to-morrow or next day for perhaps an hour. Guns are secured for sea while sails were loosed.

The times are so changed, the life on ships so revolutionized, that one may read as rollows: "It is apparent that a large proportion of the enlisted men of the service housed on large ships with numerous decks and compartments do not get enough exercise or work in the open air and sunshine to keep them in as good physical condition as they should be. This is clearly shown in the large number of sallow and anæmic-looking individuals seen at general muster. On our ships with so much covered deck space the men can so readily stow themselves away that there seems to be a disinclination to take advantage of leisure hours in following health-giving pursuits. Quarters, 'setting-up drill,' routine exercises, and other duties force them out for a time, but after these are over there is again a general stowing away. The games indulged in on shore by the men are not of a character to bring about an improvement of the physical training of the crew as a whole. In the first place only a limited number can engage at one time in such games as football and baseball, and, as far as can be seen, the selection of men to make up the teams is from those who are already of good development, and necessarily they must be so in order to stand the physical exertion required."[1]

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[1] Surgeon I. W. Kite, U. S. N., Report of the Surgeon-General, U. S. N., 1907.

We are living in a new age and are facing new problems in the hygiene of the navy from which the study of air cannot be separated. Advances in the construction and design of ships are being rapidly made. Each ship is a better fighting machine than its predecessor, but of all the most indispensable mechanical instruments are the men themselves, and they also must be developed and improved. It must be a powerful ship—a ship able to give and to take—manned by a vigorous crew—a well developed, willing, and enduring crew.

It does not seem advisable to close this chapter without some reference to the contained air of the diver's helmet, though such an addition may be regarded more in the nature of an appendix than having relation to the contained air of ships.

The diver does important work that is frequently performed to meet some emergency, and it is true that the helmet can even be utilized during fires or in bunkers or whenever there may be an accumulation of noxious gases. But of late the required range of diving operations has increased with possibilities of service at considerable depths, even in relation to submarines. At any rate navies, and especially the British navy, have recently regarded the subject of deep-diving as well worthy of special investigation in view of the increasing importance of such work, and the dissatisfaction caused by former methods in relation to depth of submergence considered practicable under them, and the small amount of work that could be accomplished at the depth attempted because of the untoward effects upon the diver of the condition of the contained air of his helmet.

Those effects may be considered to result chiefly from two causes: an insufficient air supply and an improper method of decompression, under which bubbles of nitrogen gas form within the body after return to the surface, causing "divers' palsy" or caisson disease in its various forms and degrees.

The primary requirement of the properly dressed diver is a sufficient circulation of air through his helmet, as he descends, to prevent an undue accumulation of carbon dioxide within it and at the same time a sufficient accumulation of air within the compressible part of the dress to keep that part over the chest inflated. If the amount of air supplied is at all times that calculated to be sufficient to meet the requirement in relation to carbon dioxide the required inflation of dress can always be secured.

A diver's dress is essentially an incompressible helmet joined below to a rubber or compressible dress provided with rubber wrist rings. The air inlet and the air outlet are in the helmet. The former is supplied by tube connecting with the helmet, and, at the surface, with the pump or pumps, and the latter is an escape-valve merely, the air leaving the helmet against the pressure of water. This valve is so arranged that the spring pressure against the check can be regulated by the diver while under water and it is also so fitted with a button on the inside of the helmet that the diver can open the valve by placing his head against the button. It is therefore quite obvious that with an air supply the diver by regulation of outlet valve can increase the pressure of air within his dress, and with an adequate air supply for his depth can at all times, without danger from accumulation of CO_2, have an elastic layer of air between his chest and his compressible dress which the water pressure is seeking to bring in contact with him.

The pressure of air over the chest is provided for by having the escape valve work only when the pressure within the helmet is about 1/2 pound greater than that of the water on the outside of the helmet. This is necessary because while the diver is upright under water, the pressure of the water at the level of his chest is about 1/2 pound greater than the pressure on the helmet. This becomes apparent when it is considered that while a mercurial barometer is standing at 30 inches, a sea-water barometer would stand at 33 feet. In other words 33 feet of sea-water exerts the pressure of an atmosphere or approximately 15 pounds to the square inch. Therefore, if a man 6 feet tall is standing under water the difference between the pressures on the top of his head and at his feet, being that of 6 feet of water, is $\frac{6}{33} \times 15 = 2.73$ pounds per square inch. However, the escape-valve is not at the top of helmet, but at its back almost on the level of the ears, and therefore by difference of water-depths the pressure on the chest is about 1/2 pound per square inch greater than at the level of the valve, and it is the proper pressure at the chest level that is required within the dress.

But by the manipulation or regulation of the valve the diver can regulate the degree of inflation. This is important for if the inflation becomes too great the diver becomes too buoyant and if very excessive, as when working for too long at one time in a bending position without a well-opened valve, in crawling or lying down, he may be blown up to the surface, an accident not free from danger if he is at much depth. On the other hand, if the inflation is insufficient there is excessive pressure on the chest with difficulty in breathing. This may be very excessive with air supply inadequate for the depth, and the condition is thus emphasized when a diver goes down more rapidly than his air supply is correspondingly increased. Should a diver fall several fathoms without a correspondingly rapid increase in air supply he would be subjected to a squeeze that could readily be fatal. The proper degree of inflation is when the helmet and attached weights are about lifted off the shoulders and thus the diver no longer breathes into a space having rigid walls or into one of too small capacity for comfort or has to expand his lungs filled with air at helmet pressure against a greater pressure.

A recognition of the fact that the air leaves the diver's helmet by reason of greater pressure within is of extreme importance in the calculation of his required air supply at varying depths, for it is apparent that if the volume of air necessary at the surface be determined *at least the same volume should enter the helmet under whatever pressure the diver is working.*

According to Boyle's law, the volume of a gas varies inversely as the pressure and consequently a given volume of air at one atmosphere becomes 1/2 that volume under a pressure of two atmospheres, 1/3 of the original volume under three atmospheres and so on. Consequently if at each turn of the fly-wheels of a pump 1/10 of a cubic foot of air is being delivered within the diver's helmet at the surface only 1/20 of a cubic foot would be delivered at the helmet if it were at a depth of 33 feet, and thus under the pressure of an additional atmosphere, and only 1/30 of a cubic foot at a depth of 66 feet of water.

Air goes on accumulating within the diver's dress until the outlet valve operates, but, as that valve does not operate until the air pressure within somewhat exceeds the water pressure without, the volume of air entering the pump at the surface is, when it enters the helmet, only that volume as it has been reduced by the pressure the diver is under. Of course, if under an inadequate air supply a diver goes down to his work *with sufficient slowness* air will accumulate within his dress, but it will be stagnant air until the pressure within exceeds the pressure without to the extent necessary to operate the outlet valve, but even then the circulation of air through the helmet will be insufficient to prevent that increase in the CO_2 content capable of causing labored breathing and unconsciousness.

The maxim in relation to a diver's air supply is that the necessary air supply measured at the surface must increase in direct proportion to his absolute pressure. For instance, a diver in 33 feet of water must receive double the supply of air required at the surface, as he is under an absolute pressure of two atmospheres, and at 198 feet must receive 7 times the volume required at surface, as he is under 6 atmospheres excess pressure or 7 atmospheres absolute pressure. Non-recognition of this fact will defeat all attempts at deep diving, as unless the CO_2 is kept below 4 per cent. at atmospheric pressure there will be labored breathing, at 6 per cent. very great distress, and above 10 per cent. an increasing tendency to loss of consciousness; and the effects of the CO_2 in deep diving depend upon its pressure or tension at the depth, as, for instance, if 4 per cent.

at atmospheric pressure cause labored breathing and 6 per cent. very great distress, then at 198 feet, or 7 atmospheres absolute pressure, $\frac{4}{7} = .57$ per cent. would also cause labored breathing, and $\frac{6}{7} = .857$ per cent. would cause great distress. It is thus quite evident that the air supply must increase in direct proportion to absolute pressure.

In determining the amount of air necessary for the diver at the surface in order that the corresponding amounts at varying depths may be calculated it should be recognized that the situation of the diver within his dress is not an ordinary condition of life, and that the standards are therefore not those considered necessary for the preservation of health under continuous circumstances. A man remains in his diving dress a limited time and gives up a better and necessary environment from the point of view of continued good health to undertake work of short duration under conditions not conducive to good health. It appears that a man at complete rest in a diver's suit excretes about 0.84 cubic feet of CO_2 in an hour measured at standard pressure (1 atmosphere) and about 2.7 cubic feet when at work. The fact that a diver does not feel respiratory discomfort from the pressure of CO_2 when it is not in excess of 3 per cent. at the surface has caused that percentage to be taken as the standard in calculating the minimum supply of air required at the surface.

Using the formula $D = \frac{e}{p}$, it appears that, considering $e = 2.7$ and $p = .03$, the amount of air in cubic feet per hour necessary to keep the respiratory CO_2 content at 3 parts per hundred is 90. It may therefore be considered that the minimum air supply for the diver at the surface is 1.5 cubic feet per minute. Then, as the air supply measured at the surface must increase in direct proportion to the diver's absolute pressure, the coefficient becomes $\frac{1}{33} = .0303$ for each foot from the surface. Therefore, the *minimum* air supply in cubic feet per minute for any given depth may be computed by the following formula: $S = 1.5(1 + F(.0303))$. In which S is the required air supply in cubic feet per minute measured at the surface, and F is the number of feet the diver's helmet is below the surface. For example, what should be the *minimum* air supply in cubic feet per minute measured at the surface for a diver at 25 1/2 fathoms? As 25 1/2 fathoms = 153 feet, the formula becomes: $S = 1.5(1 + 153(.0303)) = 1.5 \times 5.636 = 8.454$ cubic feet per minute. In other words, as a diver at 25 1/2 fathoms is under an absolute pressure of 5.636 atmospheres the air received per minute within the helmet must have 5.636 times the volume required at the surface in order to have the same volume on delivery.

It should be recognized that the standard of 1.5 cubic feet per minute at the surface is a *minimum* standard based upon an excretion of 2.7

cubic feet of CO_2 per hour when at work and upon the requirement that the CO_2 percentage shall not exceed 3. But during *hard* work, that CO_2 excretion would be increased while the percentage increase in the contained air required to produce distress is relatively small. Nevertheless, the standard, 1.5 cubic feet per minute at the surface, prevents, at all depths that have been attempted, the severe distress leading to unconsciousness, and adherence to the requirement that the air supply measured at the surface must increase in direct proportion to absolute pressure abolishes that oppression which formerly increased as the depths increased and which was invariably and erroneously ascribed to the increasing pressure. In the British navy a depth of 35 fathoms or 210 feet has been obtained with comfort on an air supply of about 11 or 12 cubic feet per minute measured at the surface. Yet, considering all the circumstances the pump capacity employed for the depth should be sufficient to increase the air supply 1/3 if necessary.

By using the formula that has been given, a table showing the required air supply at varying depths can be readily constructed. The delivery of the amount required depends of course upon capacity of pump and rate of pumping. Each cylinder of a pump has a certain capacity, and if with each revolution of fly-wheel the piston completes two strokes, it is evident that, barring leakage, there is a fixed relation between the required air supply and the number of revolutions of the wheel. For instance, suppose with each turn of the wheel or each two strokes of the piston 0.1 cubic foot of air is delivered against atmospheric pressure. Then with 15 revolutions per minute the 1.5 cubic feet per minute would be delivered at the surface. But with the diver at the depth of 33 feet or an absolute pressure of 2 atmospheres the 1.5 cubic feet at the surface would be only 0.75 cubic feet at the helmet. It therefore follows that as the air at the surface must be 3 cubic feet for the delivery at the helmet to be 1.5 cubic feet, the revolutions of the wheel must be 30 per minute for that depth. And so the number of revolutions can be calculated for each depth.

The pump in our service and probably in all services has two double-action cylinders and is fitted with gages to denote the air pressure, and thus the depth of the diver. The cylinders are surrounded with copper cistern and water apparatus to keep them cool. These cylinders may be connected or disconnected so that one or both may be in use. Thus with both cylinders in use the air supply on each revolution is doubled. Consequently, if 15 revolutions with one cylinder give the requisite air supply at the surface, the same number of revolutions with two cylinders would give the required amount at a depth of 33 feet. As a general proposition it is not easy to maintain 30 revolutions per minute against much pressure, and so as the depths increase the number of cylinders (or pumps) have to be increased that the calculated air supply may be delivered on from 20 to 25 revolutions after making allowance for leakage.

The air hose is constructed to withstand 500 pounds hydraulic pressure for ten minutes and sections of hose are coupled with gun metal couplings. If the apparatus is well set up the leakage is chiefly in the pump itself and is principally a piston leakage. The integrity of all the apparatus is a prime consideration and a pump may readily leak sufficiently to bring down the supply of air delivered to a point where asphyxia results. On the other hand, no pump is without some leakage, but if in good condition a well-constructed pump should not show a greater loss than 25 per cent. in 200 feet of water with proportionate loss for varying depths, for instance, 12.5 per cent. in 100 feet. A pump is, however, regarded as efficient when the leakage does not exceed 20 to 25 per cent. at a depth of 132 feet or 60 lbs. excess pressure. The British navy provides for the testing of these pumps at least once a quarter, and requires "a Whitehead reservoir, torpedo air chamber, or other strong vessel whose capacity is accurately known" to be utilized for this purpose.

Assuming a leakage of 25 per cent. at a depth of 132 feet, or 60 pounds' excess pressure, to secure the calculated air supply the number of revolutions of pump has to be increased accordingly. For instance, the air supply required at a depth of 132 feet is 7.5 cubic feet per minute measured at the surface. Two pumps or four cylinders would deliver that amount on about 18.87 revolutions per minute, as each revolution is assumed to deliver 1/10 of a cubic foot from each cylinder. But as the leakage is 25 per cent., the number of revolutions would have to be 25.16 per minute to accomplish the desired result as in the equation $x - \frac{x}{4} = 18.87$, $x = 25.16$. If the leakage at 132 feet is 25 per cent. then it may be considered to be about 37 1/2 per cent. at 33 fathoms or 198 feet. The calculated air supply at 33 fathoms is 10.5 cubic feet per minute. Three pumps or 6 cylinders would deliver that amount on 17 1/2 revolutions per minute, but as the leakage is assumed to be 37 1/2 per cent., the revolutions would have to be increased to 27 per minute.

In going down the diver should not be ahead of his air supply for the depth, and should avoid ear-pains by opening his Eustachian tubes by repeated swallowing or by going through the motion of yawning. The object is to go down to the required depth as rapidly as is practicable, and the more rapid the revolutions of pump the more quickly this can be accomplished. If the dress contains the requisite amount of air the descent may readily be made at the rate of 60 feet per minute. But if the air supply is insufficient, with a valve not sufficiently closed, the squeeze will stop the descent until the air supply is sufficient. As will be seen, the more quickly the diver can descend in deep water and complete his work the more rapidly he can be returned to the surface without danger.

It is interesting to note that in the ventilation of the diver's helmet the standard has relation to the CO_2 content, as is the case in ventilation elsewhere, the diminution in oxygen not being a factor, and the question of organic matter not receiving consideration. The asphyxia resulting from a too greatly limited air supply is regarded as purely a suffocation from carbon dioxide. However, as has been stated, the standard of ventilation in relation to the diver is evolved merely from consideration of conditions that can be secured in practice, and under which it is practicable for the required work to be done, and has no relation to those conditions required by men in daily life for the continuance of good health. A diver is selected to undergo an ordeal. He must pass a special medical examination and be considered fit to stand the strain. A steady man of good physique and free from obesity should always be selected for such work, an excess in fat being especially undesirable for reasons relating to danger in decompression. He must have good heart and lungs, and no derangement or disease of the kidneys or degeneration of the arteries, or any constitutional disease. The drinker is barred and also the user of tobacco in excess. And, in view of the necessity for equalization of pressure within and without the tympanic membrane, there must be no middle ear disease or catarral condition that can interfere with the patulousness of the Eustachian tubes. He must not go down soon after a full meal and must be in good health at the time of descent. In deep diving the diver should not be older than 45.

But such requirements have relation not merely to questions of air supply but also to the second question involved—the proper decompression to avoid caisson disease. For while it is true that the troubles experienced by divers in descending have been erroneously attributed to pressure, it is true that their troubles after reaching the surface are attributable to conditions resulting from subjection to excessive air pressure during which they have absorbed a considerable quantity of nitrogen that, when the pressure is lowered too rapidly, forms bubbles within the body and produces the condition known as caisson disease.

The atmosphere is composed chiefly of two gases, nitrogen and oxygen (roughly in the proportion of 4 vols. N. to 1 vol. O). Nitrogen is remarkable for its chemical inactivity, and as it goes into the lungs during respiration is merely obedient to the law of gases in saturating the blood to the extent practicable under its alveolar tension or pressure.

The blood as it passes through the lungs is thus kept normally saturated with nitrogen at its partial pressure in the alveolar air, and is also the medium through which each tissue of the body acquires nitrogen. The body may therefore be considered as always normally fully saturated with nitrogen under the atmospheric pressure.

It is calculated that the amount of nitrogen contained by the body is about one liter measured at standard. But as in diving the pressure of air to which the body is subjected is increased, the actual amount of nitrogen absorbed will directly increase with the pressure, *provided the increased pressure is sufficiently prolonged* to permit the body to be completely saturated at that pressure. For instance, considering the body to normally contain one liter of nitrogen, it will when subjected to additional pressure immediately take up an additional amount of the gas, and will in about four hours become fully saturated for that pressure, but the *volume of the gas will remain the same.* Therefore, for each additional pressure of one atmosphere the body, when fully saturated at that pressure, will have acquired an additional liter of nitrogen measured at standard, but will continue to hold only one liter of nitrogen measured at that pressure to which the body is then subjected. In other words, the body holds about one liter of nitrogen when saturated at any pressure, but, for instance, if that liter be within the diver at a depth of 198 feet, or 7 atmospheres' absolute pressure, it would tend to become 7 liters at the surface. Thus at the surface such a diver might be roughly compared to a bottle of soda water which uncorked is liberating its gas in the form of bubbles.

It has, however, been shown experimentally that the body requires at least four hours to become *fully* saturated at any designated pressure. The absorption of nitrogen begins at once and the actual amount absorbed increases as the depth of the diver increases, but the *rate of absorption and the amount absorbed* vary with each variety of tissue, and the diver who gets down most quickly and returns to the surface with the least practicable delay will have acquired the smallest additional amount of the gas.

It is considered that during a uniform rate of descent a diver absorbs about 1/2 as much nitrogen as is absorbed during the same period on the bottom. Consequently all delay in descending in deep diving as well as all delay at the bottom is time expended in acquiring additional nitrogen and in making the return to the surface more hazardous. Formerly a slow descent was required, but now that the labored breathing in diving is found to be due to inadequate air supply it is clearly demonstrated that the descent should be as rapid as the pressure on the drums and the inflation of dress will permit. In the diving experiments in the

British navy descents of 35 fathoms were made by experienced divers in two minutes without inconvenience, the air supply being adequate.

It is also apparent that the more limited the time of exposure to high pressure the less will be the amount of nitrogen absorbed and consequently the further the body will be from saturation and the less will be the tendency to formation of bubbles during the decompression. It is also evident that, as the tension of the gas within the body must be considered in relation to the tension in the atmosphere, the greater the depth the shorter should be the time of exposure to pressure.

A diver descending rapidly in 22 fathoms of water and starting to return to the surface in 12 minutes may be decompressed or brought to the surface in 16 minutes without danger if the time be properly utilized, but if he were to remain down an hour the ascent would require careful management and an hour and three-quarters to be entirely free from danger. At 30 fathoms and 12 minutes before the start to return, the decompression is accomplished in 30 minutes, but if the time were over an hour instead of the 12 minutes the decompression would require more than three hours. It is thus quite evident, in view of the special situation of the diver that it is essential to greatly limit the time of exposure to high pressure, say in depths exceeding 10 fathoms. In practice it should be considered proper to limit the time on the bottom to such time that the decompression can be safely accomplished in 30 minutes.

It has been declared that the different tissues of the body saturate at different rates and at saturation hold different amounts of nitrogen. Parts of the body well supplied with blood take up nitrogen rapidly under excess pressure, and those having a limited blood supply saturate more slowly. Adipose tissue therefore acquires nitrogen more slowly, but fat ultimately acquires a large proportion of the gas, and the fatty nature of nerve tissue also permits it to acquire large amounts.

Tissues that acquire nitrogen rapidly part with it or desaturate rapidly, while those that acquire nitrogen slowly part with it slowly. Consequently divers decompressed too rapidly may well arrive at the surface in what seems to be excellent condition and then at some time after the removal of dress develop caisson disease in more or less marked degree. It is thus common for bubbles to be found in adipose tissue and in the spinal cord in such cases. But in all fatal cases bubbles may be expected in the blood and in rapidly fatal cases bubbles distend the right side of heart and block the pulmonary vessels. Pulmonary air embolism is thus the common cause of death and also of the preceding dyspnœa.

Now, the most important consideration in relation to decompression is that bubbles do not form within the body unless the internal nitrogen tension is more than twice the tension on the outside of the body. For instance, it is common experience that a diver receiving a proper air supply can remain at the bottom in 33 feet of water, or even at somewhat greater depth indefinitely, and return to the surface at once without danger from caisson disease. This common experience is in accord with the ascertained fact that bubbles do not form within the body when the ratio of nitrogen pressure within to nitrogen pressure without does not exceed 2 : 1, *whatever the actual tensions may be.* Thus a diver at 33 feet is under an absolute pressure of two atmospheres, and consequently can return to the surface at once without danger, even when fully saturated as he is there under an absolute pressure of one atmosphere or 1/2 the pressure at which the additional nitrogen was acquired.

The same principle is applicable to deep diving. A diver who has descended 30 fathoms or 180 feet is under an excess pressure of 5.46 atmospheres and an absolute pressure of 6.46 atmospheres. He can therefore ascend without danger, even when fully saturated, to an absolute pressure of one-half or 3.23 atmospheres, which is equivalent to a depth of about 73 feet and, depending upon degree of saturation as calculated by time from beginning of descent, can be allowed to come up further, even to 50 feet from surface, before being required to stop if the time from beginning of descent is less than 13 minutes. However, for other reasons a diver should not ascend to that depth faster than one foot per second.

The calculations by which degree of saturation is deduced are somewhat complicated. They extend not only to a determination of the first and subsequent stopping places at various depths during the decompression, but also to the times or stoppages in minutes at each place. The method of making these calculations can be found in the report of the Diving Committee of the British Admiralty made in 1907, and in a very comprehensive article on "Prevention of Compressed Air Illness," by Boycott, Damant, and Haldane, that appeared in the *London Journal of Hygiene* in June, 1908. The material of those papers has been freely utilized here, and the papers themselves are most interesting to those making a special study of deep-water diving. It, however, seems sufficient in relation to the method of decompression evolved therein to give the tables that follow on pages 294–298, as showing in its own practical form the conclusion of the Admiralty Committee on deep-water diving. The particular method is known as stage decompression and is put forward in opposition to slow and uniform decompression.

It is manifestly true that as a diver at one absolute pressure can come at once without danger to a depth giving one-half that pressure, he is then placed without delay under the condition that facilitates to the greatest degree his desaturation with safety. It will be noticed that the tables are constructed to secure safety—"to leave a clear margin beyond everything which either human experience or experience on animals, or calculation, has shown to be risky"—and that the time under the higher pressure is always to be the *time from surface to beginning of ascent.* It should also be recognized that the time of stoppages at the different depths are given under the supposition that the diver has made only the one descent. There is increasing danger as dives are repeated, diminishing as the length of time between them increases. When the interval is short the tissues desaturating most slowly have not had time in which to free themselves of all their surplus nitrogen. When the interval is short it is therefore safest to consider the two dives as one and decompress from that point of view in accord with the tables, applying the extra time only to the second half of the stoppages. If, however, the interval has been two or three hours that precaution is unnecessary, and if an hour the additional time might be halved.

By way of assisting the decompression, the diver should increase his rate of breathing. This he can do by continuing to move his arms and legs at the stops. He should also be assisted in that direction by diminution of air supply as the ascent progresses. The exercising of limbs during stoppages is essential. It also diminishes the tendency to "bends" which may tend to appear under any practicable rate of decompression *after long exposures* at high pressures. The diminution in air supply by diminishing number of cylinders increases respiration by permitting a slight excess of CO_2. It is thus customary to stop all but one pump *after* the first stop or stage.

TABLE I.

Stoppages during the Ascent of a Diver after Ordinary Limits of Time from Surface.

Depth		Pressure,	Time from surface to beginning of ascent	Approximate time to first stop	Stoppages in minutes at different depths*						Total time for ascent in minutes
Feet	Fathoms	Pounds per square inch			60 Ft.	50 Ft.	40 Ft.	30 Ft.	20 Ft.	10 Ft.	
0–33	0–5½	0–15	No limit								0–1
33–42	5½–7	15 to 18½	Over 3 hours	1						5	6
42–48	7–8	18½ to 21	Up to 1 hour								1½
			1 to 3 hours	1½						5	6½
			Over 3 hours	1½						10	11½
48–54	8–9	21 to 24	Up to ½ hour								2
			½ to 1½ hours	2						5	7
			1½ to 3 hours	2						10	12
			Over 3 hours	2						20	22
54–60	9–10	24 to 26½	Up to 20 mins.								2
			20 to 45 mins.	2						5	7
			¾ to 1½ hours	2						10	12
			1½ to 3 hours	2					5	15	22
			Over 3 hours	2					10	20	32
60–66	10–11	26½ to 29½	Up to ¼ hour	2							2
			¼ to ½ hour	2						5	7
			½ to 1 hour	2					3	10	15
			1 to 2 hours	2					5	15	22
			2 to 3 hours	2					10	20	32

* During each stoppage the diver should continue to move his arms and legs.

(This table is from the Report of the Admiralty Committee on Deep-Water Diving).

TABLE I—Continued.

Stoppages during the Ascent of a Diver after Ordinary Limits of Time from Surface.

Depth		Pressure, Pounds per square inch	Time from surface to beginning of ascent	Approximate time to first stop	Stoppages in minutes at different depths*						Total time for ascent in minutes
Feet	Fathoms				60 Ft.	50 Ft.	40 Ft.	30 Ft.	20 Ft.	10 Ft.	
66–72	11–12	29½ to 32 . . .	Up to ¼ hour .	2	. . .	. . .	. . .	. . .	. . .	2	4
			¼ to ½ hour . .	2	. . .	. . .	. . .	. . .	3	5	10
			½ to 1 hour . .	2	. . .	. . .	. . .	. . .	5	12	19
			1 to 2 hours .	2	. . .	. . .	. . .	. . .	10	20	32
72–78	12–13	32 to 34½ . . .	Up to 20 mins .	2	. . .	. . .	. . .	. . .	. . .	5	7
			20 to 45 mins .	2	. . .	. . .	. . .	. . .	5	15	22
			¾ to 1½ hours. .	2	. . .	. . .	. . .	. . .	10	20	32
78–84	13–14	34½ to 37 . . .	Up to 20 mins .	2	. . .	. . .	. . .	. . .	. . .	5	7
			20 to 45 mins .	2	. . .	. . .	. . .	. . .	5	15	22
			¾ to 1¼ hours. .	2	. . .	. . .	. . .	. . .	10	20	32
84–90	14–15	37 to 40 . . .	Up to 20 mins .	2	. . .	. . .	. . .	. . .	3	5	10
			20 to 40 mins .	2	. . .	. . .	. . .	. . .	5	15	22
			40 to 60 mins .	2	. . .	. . .	. . .	3	10	15	30
90–96	15–16	40 to 42½ . . .	Up to 20 mins .	2	. . .	. . .	. . .	. . .	3	5	10
			20 to 35 mins .	2	. . .	. . .	. . .	. . .	5	15	22
			35 to 55 mins .	2	. . .	. . .	. . .	5	10	15	32
96–108	16–18	42½ to 48 . . .	Up to 15 mins .	3	. . .	. . .	. . .	. . .	3	5	11
			15 to 30 mins .	3	. . .	. . .	. . .	3	7	10	23
			30 to 40 mins .	3	. . .	. . .	. . .	5	10	15	33

* During each stoppage the diver should continue to move his arms and legs.

(This table is from the Report of the Admiralty Committee on Deep-Water Diving).

TABLE 1—Continued.

STOPPAGES DURING THE ASCENT OF A DIVER AFTER ORDINARY LIMITS OF TIME FROM SURFACE.

Depth		Pressure, Pounds per square inch	Time from surface to beginning of ascent	Approximate time to first stop	Stoppages in minutes at different depths*						Total time for ascent in minutes
Feet	Fathoms				60 Ft.	50 Ft.	40 Ft.	30 Ft.	20 Ft.	10 Ft.	
108–120	18–20	48 to 53½	Up to 15 mins	3	. . .	. . .	. . .	2	3	7	15
			15 to 25 mins	3				5	5	10	23
			25 to 35 mins	3	. . .	. . .	. . .	5	10	15	33
120–132	20–22	53½ to 59	Up to 15 mins	3	. . .	. . .	. . .	2	5	7	17
			15 to 30 mins	3	. . .	. . .	. . .	5	10	15	33
132–144	22–24	59 to 64½	Up to 12 mins	3	. . .	. . .	. . .	3	5	5	16
			12 to 25 mins	3	. . .	. . .	2	5	10	12	32
144–156	24–26	64½ to 70	Up to 10 mins	3	.	. . .	. . .	3	5	5	16
			10 to 20 mins	3	. . .	2	3	5	8	10	31
156–168	26–28	70 to 75	Up to 10 mins	3	. . .	. . .	2	3	5	5	18
			10 to 16 mins	3	. . .	2	3	5	7	10	30
168–180	28–30	75 to 80½	Up to 9 mins	3	. . .	. . .	2	3	5	5	18
			9 to 14 mins	3	. . .	2	3	5	7	10	30
180–192	30–32	80½ to 86	Up to 13 mins	3	. . .	2	3	5	7	10	30
192–204	32–34	86 to 91½	Up to 12 mins	3	2	2	3	5	7	10	32

* During each stoppage the diver should continue to move his arms and legs.

(**This table is from the Report of the Admiralty Committee on Deep-Water Diving**)

TABLE II.

STOPPAGE DURING THE ASCENT OF A DIVER AFTER DELAY BEYOND THE ORDINARY LIMITS OF TIME FROM SURFACE.

Depth		Pressure, Pounds per square inch	Time from surface to beginning of ascent	Approximate time to first stop	Stoppages in minutes at different depths								Total time for ascent in minutes
Feet	Fathoms				80 Ft.	70 Ft.	60 Ft.	50 Ft.	40 Ft.	30 Ft.	20 Ft.	10 Ft.	
60–66	10–11	26½ to 29½	Over 3 hours	2	. .	. .	. .	. .	. .	. .	10	30	42
66–72	11–12	29½ to 32	2 to 3 hours	2	. .	. .	. .	. .	. .	. .	10	30	42
			Over 3 hours	2	. .	. .	. .	. .	. .	. .	20	30	52
72–78	12–13	32 to 34½	1½ to 2½ hours	2	. .	. .	. .	. .	. .	. .	20	25	47
			Over 2½ hours	2	. .	. .	. .	. .	. .	. .	30	30	62
78–84	13–14	34½ to 37	1¼ to 2 hours	2	. .	. .	. .	. .	. .	. .	15	30	47
			2 to 3 hours	2	. .	. .	. .	. .	. .	5	30	30	67
			Over 3 hours	2	. .	. .	. .	. .	. .	10	30	35	77
84–90	14–15	37 to 40	1 to 1½ hours	2	. .	. .	. .	. .	. .	5	15	25	47
			1½ to 2½ hours	2	. .	. .	. .	. .	. .	5	30	35	72
			Over 2½ hours	2	. .	. .	. .	. .	. .	20	35	35	92
90–96	15–16	40 to 42½	1 to 1½ hours	2	. .	. .	. .	. .	. .	5	15	30	52
			1½ to 2½ hours	2	. .	. .	. .	. .	. .	10	30	35	77
			Over 2½ hours	2	. .	. .	. .	. .	. .	30	35	35	102
96–108	16–18	42½ to 48	40 to 60 mins	2	. .	. .	. .	. .	. .	10	15	20	47
			1 to 2 hours	2	. .	. .	. .	. .	5	15	25	35	82
			Over 2 hours	2	. .	. .	. .	. .	15	30	35	40	122
108–120	18–20	48 to 53½	35 to 60 mins	2	. .	. .	. .	. .	5	10	15	25	57
			1 to 2 hours	2	. .	. .	. .	. .	10	20	30	35	97
			Over 2 hours	2	. .	. .	. .	. .	30	35	35	40	142
120–132	20–22	53½ to 59	½ to ¾ hours	3	. .	. .	. .	. .	5	10	15	20	53
			¾ to 1½ hours	3	. .	. .	. .	5	10	20	30	30	98
			Over 1½ hours	3	. .	. .	. .	15	30	35	40	40	163

(This table is from Report of Admiralty Committee on Deep-Water Diving).

TABLE II—Continued.

STOPPAGE DURING THE ASCENT OF A DIVER AFTER DELAY BEYOND THE ORDINARY LIMITS OF TIME FROM SURFACE.

Depth		Pressure, Pounds per square inch	Time from surface to beginning of ascent	Approximate time to first stop	Stoppages in minutes at different depths								Total time for ascent in minutes
Feet	Fathoms				80 Ft.	70 Ft.	60 Ft.	50 Ft.	40 Ft.	30 Ft.	20 Ft.	10 Ft.	
132–144	22–24	59 to 64½	25 to 45 mins	3	. .	. .	. .	3	5	10	15	25	61
			¾ to 1½ hours.	3	. .	. .	. .	10	10	20	30	35	108
			Over 1½ hours	3	. .	. .	. .	30	30	35	40	40	178
144–156	24–26	64½ to 70	20 to 35 mins	3	. .	. .	. .	3	5	10	15	20	56
			35 to 60 mins	3	. .	. .	. .	7	10	15	30	30	95
			Over 1 hour	3			20	25	30	35	40	40	193
156–168	26–28	70 to 75	16 to 30 mins	3	. .	. .	. .	3	5	10	15	20	56
			½ to 1 hour	3	. .	. .	3	10	10	15	30	30	101
			Over 1 hour	3	. .	5	25	25	30	35	40	40	203
168–182	28–30	75 to 80½	14 to 20 mins	3	. .	. .	. .	3	3	7	10	15	41
			20 to 30 mins	3	. .	. .	2	2	3	10	15	25	60
			½ to 1 hour	3	. .	3	3	7	10	20	30	35	111
			Over 1 hour	3	. .	15	25	30	30	35	40	40	218
182–194	30–32	80½ to 86	13 to 20 mins	3	. .	. .	. .	3	3	7	15	15	46
			20 to 30 mins.	3	. .	. .	3	3	5	10	15	25	64
			½ to 1 hour	3	. .	3	5	10	12	20	30	35	118
			Over 1 hour	3	5	20	25	30	30	35	40	40	228
194–206	32–34	86 to 91½	12 to 20 mins	3	. .	. .	3	3	5	7	10	20	51
			20 to 30 mins	3	. .	3	3	3	5	10	20	20	67
			½ to 1 hour	3	3	3	5	10	15	20	30	35	124
			Over 1 hour	3	15	20	25	30	30	35	40	40	238

(This table is from the Report of the Admiralty Committee on Deep-Water Diving).

Considering the object of the tables it is evident that when a diver is blown up from deep water he arrives at the surface in a condition most favorable to the development of caisson disease, and that his danger is in proportion to the time he has been exposed to the high pressure. A diver can blow himself up in shallow water, perhaps up to 7 fathoms, without danger but coming to the surface in that way from deeper water is decidedly dangerous. It is most apt to occur from accident when the diver is crawling with head down. With head down the water pressure on the helmet is increased and consequently the escape of air by outlet valve is checked. The tendency, therefore, is for air to accumulate in the back of the dress and if that continues the diver soon finds himself helpless with a dress so distended that he is unable to move his arms. He may even be capsized head down if much air gets into legs of trousers. As he leaves the bottom the air expands under the diminished pressure and his movement to the surface is accentuated. He should there be hauled in promptly, relieved of the excess air by holding up the head and opening the valve and then immediately sent down again to be decompressed in accordance with the table given. The British Admiralty Committee recommended the adoption of the plan of lacing up the legs or of winding cord round the legs of the dress to prevent their distention with air.

The sending down of the diver, who has been blown up, in order to prevent the development of caisson disease is also the method to be employed without delay when owing to improper decompression the disease is developing. The most serious symptoms of that disease are apt to appear in a few minutes after the diver reaches the surface. The dyspnœa appears as a symptom of the presence of bubbles in the pulmonary vessels, and the time is short before unconsciousness supervenes. The distress generally begins with stomach pains, as is also often the case in the paralytic form. In that type the paralysis is preceded by the sensation of pins and needles. The latter form appears later than the former, probably in from 10 to 30 minutes. Nothing of value can be done for these cases at atmospheric pressure. In the first cases death will usually quickly follow unless they are rapidly subjected to pressure. Recompression is thus demanded in both types with the least delay. In the first type even unconsciousness should not prevent resubmergence in from 60 to 90 feet of water with outlet valve open and with air supply for that depth.

The third type is characterized by "bends" or severe pains in or about the joints. Such pains are immediately relieved by recompression. They are well known by all divers, and experience shows will disappear in time. But if the tables given be carefully utilized in the decompression of divers, caisson disease in any form will be very rare, and in any severe form should be unknown, in spite of the fact that susceptibility to the disease varies in different individuals, and, if the calculated air supply be delivered, asphyxia from suffocation by CO_2 cannot occur.

Hemorrhage resulting from excessive pressure on drums as the result of closure of Eustachian tubes stops at the surface. The serious hemorrhage is that resulting from the squeeze due to rapid increase in depth, as when a diver through lack of proper attendance is allowed to fall with too slack breast rope and pipe, perhaps from a stage used in work on a ship's bottom.

The squeeze is also practicable during the management of ascent. Of course, the diver is dependent upon signals for knowledge of when to stop during the stages of decompression and when to leave one stage for another. The depth of the diver is deduced from the pressure shown by the gauge, but so long as the pump is working the gauge pressure exceeds the water pressure. Therefore, as the diver is ascending at about the rate of one foot a second, there is danger that he will come up too high before he is stopped. To avoid that situation it is customary to stop the diver when the gauge appears to indicate a depth of 4 or 5 fathoms *below the first stopping-place.* The pump is then stopped a little time, there being quite sufficient air within the dress to make that practicable, the gauge tapped to make it more lively and the true water pressure ascertained. At the same time the diver is signalled to come up slowly, and then stopped at the right depth, *when the pump is immediately restarted.* If in this procedure the diver has been allowed to get above the stopping-place he is sent back to the right depth, but *unless the pump is started before he begins the descent there is liability to squeeze.*

It is interesting to note the following recommendations made by the Deep-water Diving Committee to which reference has been made:

"1. That it be made a routine practice to supply divers with the amounts of air which the Committee's investigations have shown to be required at different depths; and that a printed table showing the rate of pumping and the number of cylinders required at different depths be supplied with each diving pump.

"2. That arrangements be made for regular and thorough testing of the diving pumps belonging to each ship, together with the air pipes, pressure gauges, and helmet valves, and for the making good of any serious defects; also that all new pumps and other diving apparatus be thoroughly tested on delivery.

"3. That all new diving dresses be provided with an arrangement for lacing up the legs, as described in the Report, and that the issue and use of the 'crinoline' be abandoned.

"4. That a metal junction-piece for connecting together the air supply from three pumps be supplied with each pump.

"5. That a printed table (combined with that referred to in recommendation 1) showing the precautions recommended by the committee as regards limits of time in deep water at different depths, and stoppages during the ascent, be supplied with each diving pump.

"6. That a new edition of the Diving Manual be prepared, containing, in addition to other information and instructions, a clear account of the physics and physiology of diving, and describing in detail the methods of carrying into practical effect the results of the Committee's investigations; also that corresponding practical instructions be given in connection with the diving courses for officers and men.

"7. That, with a view of simplifying future investigation into this subject, any cases of illness caused by diving may be fully reported, with a statement of the depth of the dive, time on the bottom, and rate of descent and ascent, so far as known, and the report forwarded to the Admiralty for the Medical Director-General and embodied in the Annual Report on the Health of the Navy.

"8. That investigation on the means of avoiding the difficulties and dangers met with in diving be continued."

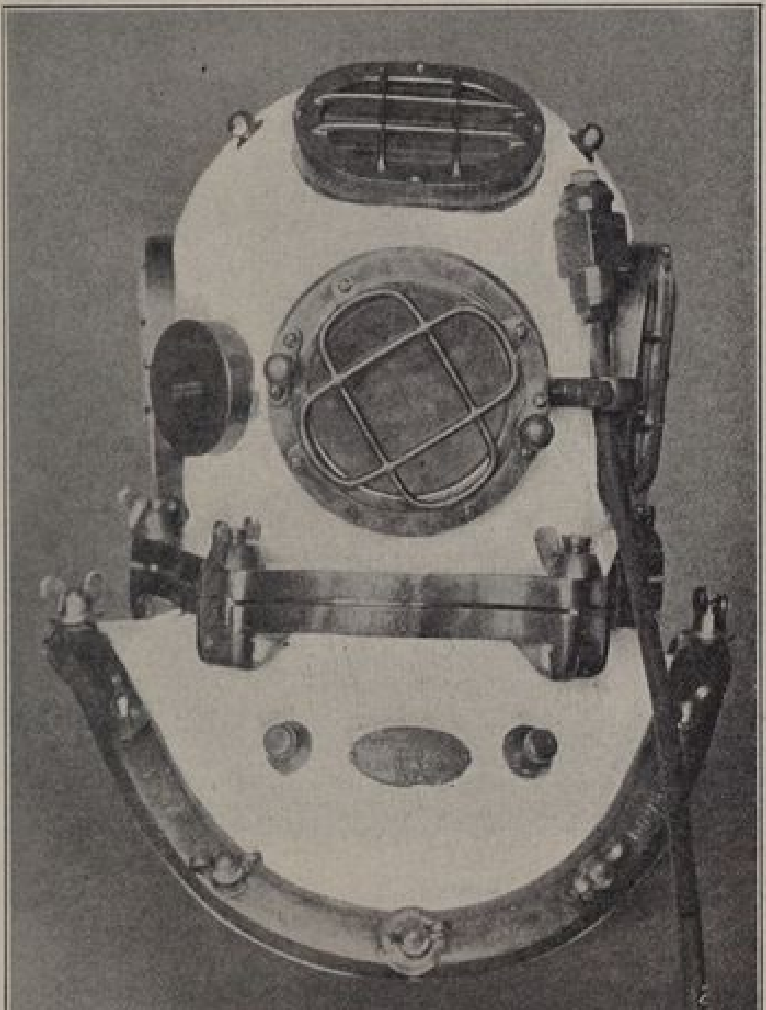

FIG. 24.—Standard Diver's Helmet, U. S. Navy. (Front view.)

The illustrations of the diver's helmet included here will be of service in connection with the text and may stimulate interest in the many problems involved which present peculiar difficulties, especially if the range of the diver's work is to be extended. There are many very interesting problems in physiology and hygiene in the possibilities of very deep diving. Ultimately the oxygen tension comes into question as well as a number of factors that are, up to this time, either in a subordinate position or in an unrecognized relation.

It should be noted that in all the calculations given above of revolutions of pumps to obtain the required delivery of air, it has been assumed that on each revolution each cylinder delivers $\frac{1}{10}$ of a cubic foot of air at the surface. That capacity would seem to be the most convenient standard under naval conditions. But in our service each cylinder has a diameter of $3\frac{7}{8}$ inches and a piston stroke of 6 inches. Therefore, on each stroke the piston would deliver about 0.04 cubic foot at atmospheric pressure, or $\frac{8}{100}$ instead of $\frac{1}{10}$ on each revolution.

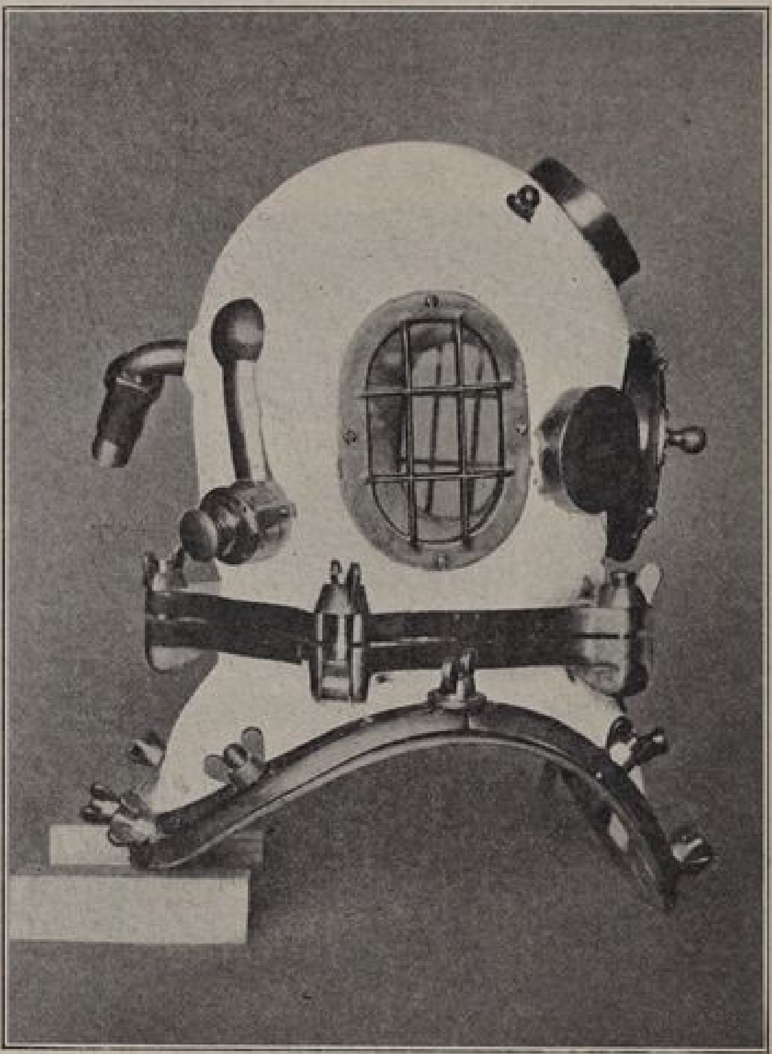

Fig. 25.—Standard Diver's Helmet, U. S. Navy. (Side view.)

It would therefore appear that at the surface one cylinder would deliver the 1.5 cubic feet of air per minute or 18.75 revolutions instead of 15, and that with a diver at the depth of 66 feet, the required amount of air (4.5 cubic feet per minute) would be obtained on about 28.12 revolutions, using both cylinders and making no allowance for leakage. If the leakage be regarded as 10 per cent. at that depth the required number of revolutions per minute would seem to be about 31.24, or a number it would be difficult to maintain. Therefore, under a standard air supply of 1.5 cubic feet per minute at the surface it seems that our present service pump, even if in fair condition, would not ordinarily give the standard supply for one diver at 66 feet on 30 revolutions per minute.

CHAPTER III.

LIGHT WITHOUT AND LIGHT WITHIN THE SHIP.

The so-called chemical elements are the simple substances which resist analysis by any known chemical means. They have, therefore, been regarded as representing so many elementary varieties of matter from which all other forms have been derived by chemical combinations, so many atoms of two or more elements being held in chemical combination or by the force of chemical attraction to form a chemical compound of which the smallest particle is the molecule. The total chemical attraction or chemical affinity in any particular molecule may be expressed in terms of other forces, such as mechanical work, heat, or electricity, necessary to disassociate the atoms, or rather break the molecule into its constituent elements, and the weight of the molecule or its molecular weight is exactly equal to the sum of the weights of all the atoms of which it is composed. The molecule, therefore, becomes the smallest mass of any substance capable of existing in separate form, hence the molecule is taken as the physical unit.

Sir William Thomson stated that if a drop of water (H_2O) were magnified to the size of the earth, the molecules or granules would each occupy spaces greater than those filled by small shot and smaller than those occupied by cricket-balls. In this connection it should, however, be recognized that some of the so-called elements themselves appear in different forms. For instance, oxygen has ozone as an allotropic form, and the element carbon exists nearly pure in three totally distinct forms—the diamond, graphite, and charcoal. The elements themselves do not exist as a rule as atoms, but as molecules; for instance, oxygen is ordinarily a two-atom molecule, while ozone, an unstable form, is a three-atom molecule. It then appears that molecules formed by varying numbers of the atoms of a single so-called element have varying qualities or exhibit differences as matter.

As atoms of the same element combined in varying numbers or ways may give rise to varying substances, so the so-called elements themselves may be the result simply of the varying combinations of the atoms of a single substance. In other words, it is getting to be generally believed that there is only one element, the so-called chemical elements being regarded as elements merely because they have so far resisted chemical analysis, and that all the so-called atoms are merely molecules of electron, the only element, having molecular weights identical with their so-called atomic weights. If the size of the molecule of water be as indicated, the size of the electron, very much smaller even than any atom composing the molecule, must be too minute to be within any true comprehension, and its weight equally so. Yet, if all the various forms of matter are so many varying expressions of a single element, the transformation of any one of the so-called elements into another becomes a recognized possibility and the dream of the alchemist ceases to be a dream in the eyes of the scientific world of to-day. In fact, it appears that the transmutation of copper into lithium has actually been effected if spectroscopic analysis be worthy of the confidence so generally accorded it.

The idea of one elementary substance finds a parallel in the behavior of the forces which, being energy, have no expression except through their action on matter or substance. The close relationship between all forces appears in the rapid and constant transformation of any one into others with a certain fixed quantity of one having an exact equivalent in terms of each of the others. As a force is measured by its effect on matter and as all matter may be expressed in terms of electrons, it appears that from the behavior of the electrons may be evolved the consideration of a single force, perhaps electricity, from which all other forces may be regarded as having originated, or of which all other forces may be considered as natural transformations.

While from the ordinary practical point of view the various forces, as judged by their actions, readily assume different names, yet in certain directions there has been much confusion, and there is still much difficulty in making distinctions. For instance, the sun, in spite of the great distance intervening, exercises control over the earth not only in the maintenance of orbit, but also in life history, in the latter case by the rays or waves caused to be transmitted. The sun illuminates the earth and heats it, and it has been common to speak of heat and light as separate forces. For many years the solar spectrum was considered to be merely the color display caused by the separation of sunlight into its component parts through the action of a prism, the various rays together causing the sensation of white light, but causing separately different colors and each differing from the others in refrangibility. It was found that each of those rays had a different wave length and that the colors followed in sequence in accordance with length of wave, the degrees of refrangibility varying in that relation, the violet having the shortest wave and the greatest refrangibility, being at one end, and the red, having the longest wave and the least refrangibility, being at the other.

But then it began to be appreciated that the whole spectrum is not visible, that there are waves of greater length than the red and consequently of smaller refrangibility, and waves shorter than the violet and consequently of greater refrangibility. Thus the visible spectrum came to be known as only a part of a spectrum which extends, though invisible, below the red (infra-red) and beyond the violet (ultra-violet).

It is as in sound where there are notes too low in pitch to be appreciated by the human ear and notes too high. In music the low note of an octave has twice the wave length of its high note and, as the wave length of the extreme red bears about that relation to the wave length of the extreme violet, the visible spectrum is often spoken of as including rays separated by one octave. It may aid to arrive at some understanding of the length of the spectrum as a whole to realize that from the extreme ultra-violet to the longest wave recognized in the infra-red are more than seven octaves.

With an appreciation of the spectrum as made up of invisible and visible portions, there was a tendency to divide it into three parts—the invisible heat rays, the luminous rays, and the so-called chemical or actinic rays. But such a division is largely erroneous since all the rays of the spectrum are heat rays if they are received upon an absorbing surface, such as lamp black, and chemical changes in general are more facilitated by what is commonly called heat than by the violet or ultra-violet rays; though such are more potent in effecting those particular changes necessary in photographic work. The fact that certain rays cause a certain effect when transmitted to the retina cannot be taken as showing any real difference in kind from the other rays incapable of producing the sensation of light, for all the rays differ intrinsically in wave length only, and the difference of effect is incident for the most part *to the character of the surface upon which they act.*

Such rays, one or all, are neither heat nor light, but a form of wave motion or strain which when transferred to substance causes a molecular motion; the so-called radiant heat thus becomes heat proper which is resident in a body. Without substance there is no heat. The entire spectrum may thus perhaps be considered a heat spectrum, including both the luminous and invisible parts, with intensity everywhere proportional to its heating power, or at any rate merely a spectrum of radiant energy.

In the transferrence or action of such energy there is the phenomenon of absorption which may be considered to be the taking up of vibrations by the molecules of a body. It may be in part that the molecules of each substance are more susceptible to vibrations within certain lengths than to others. This may perhaps find a partial parallel in the relation of substances to sound waves which proceed from bodies as a result of certain vibrations or disturbances of their molecules communicated to the atmosphere; but those from one substance not causing vibrations in the molecules of another unless they have tones in sympathy or are in sympathetic resonance. Thus, if two musical strings are stretched over the same sounding-board and one of them is struck, the other will vibrate also if tuned to the same note or if tuned to give the octave; a single note on a piano will cause a bell swung near the instrument to vibrate when other notes are powerless in that respect.

Thus, when the rays of the spectrum impinge upon substance they may each seek to act upon the molecules of the material in their path in accordance with wave length and by action are absorbed, but with results more or less differing in accordance with material, waves of certain length having a more direct effect upon the integrity of the molecule itself of some material, and thus producing direct chemical changes; while in other cases, or with other character of material, the molecules may take chiefly that length of vibration which is manifested as heat with or without subsequent chemical changes incident thereto, breaking up molecules and perhaps forming other compounds. Then, in order to produce any effect on substance, the rays must be absorbed, rays that have passed through the substance or have been reflected from it being without effect, but rays that are absorbed, differing essentially only in wave length, may in accordance with resistance or property of material ultimately undergo change so that a luminous ray may become lengthened, and thus invisible or certain invisible rays may have their wave length shortened and thus capable of producing the sensation of light.

Reflection depends upon character of surface. A surface that reflects more of the rays than another leaves less to be absorbed, and therefore less to effect changes in the condition of the substance itself. A light surface reflects much of the spectrum readily, while a dark surface reflects little. The result is that in the sun's rays the coat of light color manifests much less heat than the dark coat, the difference being very marked to the hand. Under the same circumstances the thermometer with a whitened bulb stands much lower than one with a blackened bulb. In this manifestation of heat the luminous rays have also contributed but in different degrees.

White surfaces also part with heat or prevent its radiation less readily than dark surfaces. Water boils less quickly in a white kettle and when taken from the fire cools much less rapidly than in the case of a dark kettle, and a white coat permits the body to part with its heat less rapidly than a black one, other things being equal. Consequently in the sun opaque clothing of light color diminishes the effect of the sun's rays on the body as expressed by heat, but in the shade diminishes the loss of heat by the body when contrasted with dark clothing in other respects the same.

A material is said to be opaque when it is impervious to luminous rays. This property, however, depends not only upon character of substance, but also upon quantity, for the most opaque metal if thin enough permits some luminous rays to pass through, and with colorless glass, or any other transparent substance, the amount of the luminous rays absorbed has relation to its thickness. Ten per cent. is about the degree of absorption in the case of an ordinary thick plain glass shade.

This power of rays to penetrate substances may have a certain relation to character of wave. Of this the X-ray is an example, but if the physics of that ray of very short wave length be the subject of inquiry it will be found to be too disorderly or inharmonious to be present among the sun's rays. In fact, the solar spectrum is not even rich in any ultra-violet rays when compared with certain spectra such as that from an arc lamp in which zinc or aluminum is one of the terminals. A substance may be opaque and at the same time permit certain rays to pass, but, as in the case of luminous rays, the result will depend upon character and thickness of material and concentration of rays on the substance.

The effect of material on both penetration and absorption is seen in the cases of rock-salt and carbon disulphide, on one hand, and of water and alum on the other, the former absorbing or stopping radiant heat but little, and the latter arresting a large portion of it; the former being nearly diathermanous and the later comparatively athermanous. The absorption of light independent of surface may be seen in colored glass, the light passing through green glass giving the sensation of green because the glass has absorbed other rays of the visible spectrum, while the leaf looks green because it also absorbs the other luminous rays but reflects the green.

In view of the lack of concentration of ultra-violet rays in the sun's spectrum and the more marked direct chemical action in certain directions which has given the name actinic especially to those rays and to the violet and blue parts of the spectrum, it appears that the effect of any substances in limiting the passage of all such rays of the sun may be measured with sufficient accuracy for practical purposes by their visible effect upon the luminous rays concerned. For instance, a *pure* or entirely yellow, orange, or red glass may be considered to absorb all the other luminous rays of the spectrum and thus prevent the passage of violet and blue rays, and with them any such orderly ultra-violet rays as the solar spectrum contains; and surfaces of opaque bodies of the same color may be considered to entirely absorb all other luminous rays and reflect only that ray corresponding to its color.

The material or substance of which clothing is ordinarily composed is itself more or less opaque, and its transmission of rays of the sun will depend principally upon color and closeness of texture. A white shade at a window while it reflects much more of the spectrum than a dark shade of same texture permits more luminous rays to enter the room by virtue of the very power of reflection. The white shade will become much less warm than the dark shade because its absorption is less, but its threads are each reflecting much more than dark threads and in changing direction of rays give many more an opportunity to pass through the interstices. In other words, there is incident to the color a greater concentration of rays in spaces where there is only air, through which they can readily pass into the compartment, provided their direction, as determined by angle of reflection, permits. Even a white mosquito netting will thus permit very much more light to pass than a black one.

It follows, therefore, that, other things being equal, white clothing in the sunlight, while itself becoming less heated and therefore radiating less heat to the body, will as a single garment permit the passage of much of the unmodified spectrum, including rays of the shorter wave length; whereas, if the color of the material were yellow or orange, all additional light passing as the result of reflection would be from that part of the spectrum having the longer wave length, and at the same time, the total absorption in the sun rays being much less that in the case of black, the excess of heat proper manifested by the garment itself in comparison with the body temperature would be much less. Thus a man wearing a white shirt in the sun will not only receive on his body more light than if the garment were composed of clothing material of any other color, but the light will be less modified and consequently in its effects more nearly those of the luminous rays as a whole, and the thinner the material and the more open the texture the more marked the effects, as under such circumstances the individual may be even severely sunburned in summer or a tropical climate when he would have remained free from such disturbance under an orange shirt or under a black one, but in the latter case the garment would itself become so very greatly heated as to cause great discomfort or even prostration, especially if it fitted closely, thus parting with its heat more directly and without much interference by enclosed air which is a poor conductor of heat.

It is, then, apparent that while in cold weather the question of clothing depends largely upon its power to limit movement of the air in contact with the body, in hot weather or in a tropical climate it has a marked relation to color in its effect on *amount of heat and character of light* reaching the body, and upon its facility in permitting movement or renewal of air in contact with the body surface. This is of course without regard to moisture which is an important additional factor.

But the idea at this time is not so much to consider the question of clothing as the question of light in direct relation to the health of a navy's personnel. A large part of the contained air of a ship is away from natural light. The atmosphere absorbs some of the radiant energy of the sun, and whatever change of quality may thus be directly incident to the absorption of luminous rays, it is greatly limited within ships by the relatively small amount of natural light in their spaces and may be regarded as absent in the many spaces having no natural illumination.

Whether a cubic foot of the substance called air gathered in the sun does undergo any change whatever when transferred to darkness is largely conjectural. The fact that the "wireless" in touch with the distant station at night is unable to remain in touch during daylight may not be regarded as indicating a change in the air itself, as the long Hertz waves are not propagated by air any more than luminous rays are. It may, however, be taken to indicate some difference in the immediate surroundings of man when he goes from light to darkness, or the reverse, irrespective of the light itself; but what relation any or all of such changes may have to man's well-being is in the realm of pure speculation.

However, light, or the luminous rays, does have a practical effect upon air as it is breathed by man in the daily destruction of the lives of myriads of the particulate bodies it carries. It then becomes a factor in the prevention of microscopical life from taking possession of the earth. The absence of sunlight from a ship's spaces may therefore be regarded as having some direct relation to their condition as habitations, but the spaces in which there is least natural light have, all things considered, the more rapid renewal of air, and consequently the more rapid removal of air-borne particles. Such movement of air also makes for dryness of surfaces, and thus tends to limit the life period of many microscopic forms. Yet, the absence of light at least enjoins greater care in the preservation of cleanliness and in the frequent removal and exposure to light of articles having such intimate relation to occupants as clothing and bedding.

The effect of light upon the lives of microscopic forms, which may be regarded as exposed protoplasm, has accentuated the importance of the inquiry of the direct effect of light upon the life of man himself. Regarding natural light as radiant energy from the sun having such tremendous influence upon the life-history of the earth, it seems entirely reasonable to hold that the life of man is under its influence. Yet even at this time it cannot be said that work directed to arrive at some definite answer to the question is much more than in an experimental stage, such conclusions as have been put forward being quite tentative and more the outcome of empiricism than of laboratory work. Reasoning from analogy is often rather dangerous, and the direct effect of light in many of its connections is so intimately blended with the effects of heat, of humidity, of exercise with increased food consumption, and of fresh air that it is difficult to separate the influence of light from total results.

Yet the luminous rays of the sun are a form of energy and, if not capable of acting either as a benign influence or as an injury according to circumstances, form a notable exception. The man who tumbles from the mast-head is obedient to the law of falling bodies and is destroyed by a force that has made his independent and continued existence possible, and he who is burned is injured by a force without which there could be no life and with which life is readily destroyed. The latter cannot be put aside as lacking in analogy under the view that the entire spectrum is a heat spectrum, because the rays of the sun are repeatedly causing "burns" that may not be accounted for by temperature. A fireman stripped to the waist may remain for a long period with a surface exposed to an amount of radiant heat from a boiler that sends the thermometer higher than the temperature in the sunlight. His skin remains undisturbed, but if the same man were to expose his surface to the sun there would soon be redness and ultimately considerable inflammation with blistering. It would therefore seem that from certain practical points of view the old distinction between light and heat as forces may be still considered to hold.

The reddening of the skin on exposure to the sun's rays is not *necessarily* Nature's attempt to protect the body from light, for such reddening occurs in inflammation unassociated with questions of light. It is noticeable, however, that the members of the engineer force of a ship, necessarily working away from sunlight, exhibit a degree of pallor when compared with the bronzed or tanned exposed surfaces of the deck force, and the same seems to be true of miners or underground workers who also often labor in very high temperatures. The radiant heat, therefore, does not seem to be capable of producing a tanned skin. On the contrary, the integument seems to tend, in the absence of light, to a pallor or diminution of pigment which is also a condition of surface diminishing absorption of rays, chiefly causing the sensation of heat, as in the case of any light on white surface. The darkening of the skin incident to sunlight would therefore seem to have no relation under those circumstances to heat, but to be Nature's protection against light, or at least against those rays capable of causing the particular skin disturbance in sunburn, for as the change of color becomes more marked the liability to such burns diminishes in proportion. The X-ray is absent from the solar spectrum, but its delayed, yet often extensive, destruction of tissue is an example of the effect of wave energy on the body apart from the effects of heat.

If the amount of tan is, in general terms, a measure of the degree of exposure to sunlight, then the Navy's clothing in the tropics, when worn, may be considered to give the covered portion of the body adequate protection, though there is considerable room for doubt as to whether the result is accomplished in the best or perhaps in a very reasonable way in the tropics. In a member of the deck force a sharp line of tan or demarcation, between the areas that have acquired pigmentation and those which have not, will be found to coincide with the limit of clothing. It may not be stated with certainty that the double-covered area has undergone no change whatever with tropical cruising, but there seems to be no perceptible change, the very fair skin remaining very fair, while the integument of the face, neck, and upper part of chest in front has acquired, with the hands, a very marked tan.

In the tropics the naval personnel has white cotton drill as external clothing and the underclothing is white. The material has considerable body in all cases, in view of rough usage and frequent scrubbing. There is, however, in warm climates a marked tendency to cut off from undershirts every vestige of sleeve and, at work, to roll jumper sleeves, leaving arms exposed, or, as when coaling ship, to remove the jumper entirely. Some men have a liking for going around, whenever practicable, with arms exposed, and it is not rare to see men working in the sun with chest covered only by the sleeveless undershirts. Sunburns are not rare at first and occasionally are quite marked. In seine hauling there is at times direct exposure of not a little of the skin areas of some individuals to the sun's rays, and occasionally men have sought enjoyment on the beach by going in swimming during the heat of the day, and even running along the beach with body entirely exposed.

Penalties are often paid in the way of sunburns with more or less constitutional disturbances as in other burns, but, among deck crews, sunstroke, regarded either as diarthermasia or phœbism, is rare *on* or *about* ships, at least in any form associated with unconsciousness. Cases of simple continued fever and ephemeral fever may not be regarded as uncommon, but they have not increased in our service with the more intimate association with the tropics. But ships tend to come out of the tropics during summer months and find on our eastern coast conditions often as favorable to the production of such affections as in the tropics themselves. However, the statistics have been influenced more by the water on which ships float and by the general care taken of the men. But in the total results it is not practicable, under service conditions, to determine whether the hygienic precautions have had relation as much to light as to heat.

In common parlance it is recognized in a navy that men must be protected from the extreme direct *heat of the sun* in hot weather and from their own heat as increased by exercise. This is especially true at anchor when, in the open, air movement is not under the influence of ship movement. Heavy drills afloat are limited to morning hours, rarely beyond 10.30 or 11, and at times omitted, and there is a light drill of short duration toward the latter part of the afternoon. Most drills on the exposed decks of a ship at anchor, and often even at sea, are under awnings, and boats, down or under oars, are generally provided with awnings. Boatkeepers are under awning as a rule, and during the hottest and lightest part of the day many men are found in crew spaces.

It is axiomatic that a crew exercised by drills in the extreme heat and light of the tropical day will not have good health, and awnings in sunlight of warm climate very greatly contribute to the welfare of officers and crew. It is, however, good policy to furl or trice up ship's awnings for a time late and early in the day to facilitate movement of air within the ship, but in tropical countries they should be spread always at night to protect those men from dew or rain who are either on deck duty or may be sleeping on the open deck in the desire to get away from any heated space below. Awnings interfere considerably with the natural movement of air between decks and accentuate the advantage of open ports in warm weather, but they diminish greatly the amount of heat absorbed by a ship during the day, give more or less protection from light and heat to persons on the deck during that time, and furnish necessary protection at night.

A ship's awning is a tent, side curtains making the walls, though such curtains are not so extensively employed as in army life. This ship's tent is peculiar in having large openings in its flooring, or the deck, by which it may be deserted at any time. These openings or hatches lead by ladders into spaces of greatly diminished light and often at midday of diminished heat. The crew having access to the tent is therefore not dependent in such great measure upon its proper construction for comfort. Yet, practically at all times there are some men under its influence, and at all times when spread it is influencing the ship as a whole.

The discomforts under the awning in a tropical climate are due to heat and glare in the production of which the two main factors are the passage of light through the canvas and, more extensively, the reflection of the sun's rays from water and deck, and thus also from the undersurface of the awning itself. This ship's tent is without fly and is of heavy canvas more or less white, which, however, by virtue of its color, permits in the sun the passage of some light, though not of course absorbing and subsequently radiating heat to the extent a dark canvas would. It may be often without ridge, extends continuously above the deck, and the fore and aft mid-line is a rope sewed to the surface of the canvas. This line is called the head of the awning and the rope is the head roping. At the ends of the rope are thimbles and it is taughtened into postion by hauling out a fore and aft tackle. To prevent sagging there may be a block of wood called a euphroe above the awning and through it the crow foot is rove, the ropes fastening to eyelets along a middle section of the head roping. Then by use of crow foot halliards the euphroe is hauled up and thus the remaining slack of the head-roping taken up. The awning or roof of the tent is then stopped out to the ridge rope, which is the name given to the wire rope running outboard around the deck through the ends or eyes of stanchions provided for that purpose.

Side curtains of less heavy white canvas are stopped to the ridge rope when they are to be employed, but they are often not in place or are in use only temporarily as the slanting rays of the sun tend to invade the deck. Thus they may be down on one side and rolled up on the other. With the large area of deck covered, shade can generally be found until the sun is quite low, and the use of side curtains on hot days is generally made to depend upon amount of interference with air movement, the general tendency being to take the glare rather than diminish the cooling effect of a breeze upon the body in the shade. Such curtains are not employed at night for obvious reasons, among which is the marked interference with movement of air between decks. The same objection obtains against housing awnings or increasing the slant by stopping them to the railing, an expedient, commonly resorted to during rain, by which the water reaches the deck and the tendency to accumulation on top of awning is obviated. However, the deck under an awning generally becomes an uncomfortable place during a tropical rain.

In stopping out there is more or less space left between awning and ridge rope or railing, and thus the drainage is not always into waterways, awnings themselves are inclined to develop leaks, and turrets, other surfaces, and flush decks facilitate access of water. Yet the awning permits hatch covers to be left off and then under such circumstances facilitates the natural ventilation of crew spaces.

It has been rather extensively recognized in navies that a double awning or a tent with a fly would add to comfort by diminishing both heat and glare on the deck in a tropical sun. Such awnings are, however, uncommon. But considering the glare to depend in no small degree upon water and deck reflection and subsequent reflection from the under surface of the awning itself, it would seem advisable for the main awnings not only to be double, but also for the under awning to be of a darker color. As it is a question of eye effect during daylight, the blue canvas on the market is probably as good as any under all the circumstances. The darker color of the under awning would increase the necessity for an open space between them that air circulation might prevent accumulation of heated air, and this would necessitate two ridge ropes, one at least a foot below the other. Stops could be provided, on one awning along head roping, to be made fast to eyelets at the head roping of the other. The heat should, however, be also diminished by making the under awning incomplete at the mid fore and aft line except toward either end. The open space should be two feet or more across with rope boundaries and the awning could be held in position by the use of eyelets and double stops from the awning above, by reaving a line or lacing through eyelets in both awnings, thus in the process forming a single lacing across the open space in the lower awning, or by some other simple means. The general idea is much the same as that of the Munson tent which has been found to greatly improve the comfort of men in the field. In view, however, of the facilities afforded by the deck spaces of ships, it seems likely that a navy would be slow to make the change indicated in view of increased stowage required and seeming difficulties in handling. Yet the advance would be greater than appears at first sight in view of diminished heat and the tendency of men to seek the open, especially when there is a breeze, and to engage in reading or writing or games in the glare of the deck.

Keepers of boats at swinging booms or even astern should always be under awnings in hot weather. Such persons are even then frequently subjected for hours to marked glare from water and from sides of ships especially when the paint is white, though in steam-cutters the protection is generally better. The white outside color which has been so often given to ships may have resulted from æsthetic considerations, but it is also claimed that it causes in the sun a large reflection of radiant energy which the metal beneath would otherwise tend to conduct in the form of heat to crew spaces. In this case the opacity of metal makes a condition differing from that of white clothing in the sun or intense light, but the color in both cases causes glare and thus increases the tendency to eye troubles. Each person wearing white in the sun is often adding to the discomfort of his neighbor, and any white surface about a deck is open to the same objection. The liberal use of non-conducting sheathing or ceiling in more recent ships has greatly diminished the influence of side plates on contained air and the condition seems to be more favorable to abandonment of the practice of painting so many surfaces a brilliant white.

It used to be very common to paint houses white, but for some years now the practice has been very generally abandoned to the comfort of all concerned. Apart from the glare the claim has even been made that white lead exhibits some of the conducting property of metal, and that the reflecting properties of its color are to no small extent offset by its property as a conductor, thus rendering it an unsuitable covering when used to avoid absorption of radiant energy as heat. There is room for experimentation along this line, for if by chance white lead is a hot paint there is not so much limitation of heat absorption by its use as a prominent component of the mixture employed, and there is less objection to having custom give way to the strong advisability of tinting; even in ships' space where under the influence of incandescent lamps the glare is much greater than is necessary, and where all walls or bulkheads should be a light buff.

The discomfort experienced through the eyes under glare is sufficient evidence of its harmfulness, and the marked iris accommodation required in going on deck in the tropics more than suggests the advisability of a navy undertaking to remove objection along that line to any extent that is practicable not only in softening the colors of ships, but also that of the white clothing so universal on the water in hot climates.

The effect of light on the eye may find a parallel in very general terms in the effect on the body as a whole. For instance, it may be conceded that the eye has been evolved as an organ of sight in connection with light. It requires light in the performance of its function, and the continued absence of light would lead to its disuse and eventually in generations to change of structure; yet, its troubles are very frequently associated with either too little or too much light. With too little light there is eye-strain, and with too much light there is overstimulation followed even by sudden blindness or exhaustion if the intensity is extreme. The eye depends primarily upon the sun for its integrity, but unprotected is incapable of gazing at the source of its well-being, and when in trouble often has to be excluded from its stimulating or exciting or irritating influences.

The body of man as a whole has also been evolved as the results of its surrounding or environment of which light is a natural part. It may therefore be considered to require a certain amount of light in the continued performance of its general functions in the best way, in the maintenance of its natural integrity or nutrition, yet its troubles may be associated with either too little or too much light. With too little light there is a pallor, and it is said a light-hunger that makes a search for light as apparent as that of the geranium with every leaf toward the port. The body depends upon the sun for its existence, but unprotected is incapable of receiving the rays without irritation, and if too intense without inflammation, or it has even seemed at times, without loss of consciousness, though there is much room for dispute whether Nature's spectrum contains rays capable of passing, at least with such intensity or effect, behind the barriers formed by some pigment and by red blood, and by the bone about nerve centers.

Man is naturally half the time in darkness, and civilized man, though his clothing has intentional relation to heat and moisture and not to light, keeps most of his surface in relative darkness or in very subdued light nearly all the rest of the time. This condition would tend to diminish the power of the surface to stand light or even to utilize it in amounts that were perhaps primarily of advantage. The same is undoubtedly true of varying degrees of heat, the natural capacity of the body to protect istelf against cold having been greatly lowered by the continued tropical temperature of the air sought to be maintained around it. Heat has a profound effect upon nutrition and light may be considered to have been, primarily at least, a factor in the chemical control of metabolism. Both are employed in the treatment of certain conditions characterized by disturbances of nutrition. Many men are advised to be out more in the light, but at the same time they have the advantage of better air and often of more exercise. It is also common advice to avoid the sun in hot weather, or to seek protection by following the shade or by producing shade, as in the use of the umbrella, awnings, and the like. But in all such attempts heat is much more considered than light, though the facial expression in intense sunlight shows discomfort from glare.

Extensive reflexes through the eyes under the influence of light are well known as in the involuntary muscular actions under sudden flash of intense light and the sneezing from transition into sunlight. Irritating substances applied to the nasal membrane affect distant parts, as the heart in the treatment of syncope, and the body may be normally affected by light-reflexes, though the blind have lived to old age. But in eye trouble, involving strain or disturbances of focus, are headaches and even vertigo, and glasses can be constructed to cause a condition similar to seasickness; while a bright button or point is an important factor in that situation contributing to the force of hypnotic suggestion.

Inhabitants of hot countries are shade lovers, but as most living things in such countries are colored, aside from protective influences, for at least the more rapid radiation of their own heat, it would seem that the withdrawal into shade has certainly a marked relation to ridding the body of its own heat in temperatures higher than are comfortable. However, the avoidance of glare is a factor recognized by man, as well as that subdued light contributes to sleep and rest, while mechanical work is the most potent method of normally increasing the production of body heat. The habits, including relation to clothing, of individuals accustomed or indigenous to tropical life would therefore seem to be chiefly and primarily an expression of the tendency of man everywhere to facilitate that regulation of body heat through which he finds comfort.

If a thousand men are transported to the tropics they are strongly under the influence of certain habits, many of which are not in accord with the requirements of changed conditions, and, in separation from home, some exhibit a tendency to acquire habits commonly regarded as pernicious even in their old surroundings. But the tendency is to diminish the amount of clothing for the purpose of limiting the sensation of heat, and, while at the same time the average amount of light reaching the body surface may be considered to be increased, glare; humidity; the attempt to maintain the old standard of work; disturbance of the skin showing as prickly heat under the woolen undershirts retained in accordance with a home or official creed; insufficient sleep incident to tendency to enjoy the late cooler hours which facilitate companionship in a climate requiring more sleep; increased body temperature which may have some relation to light irritation, but is more apt to be chiefly due to irritation by waste products of excessive exogenous metabolism and to disturbance of cell metabolism incident to cell warming and found in members of a fireroom force who are away from light, but subjected to high temperature and unable to rid the body of heat with sufficient rapidity; excessive use of alcohol with direct drug action, autoinfection or abnormal sleep; malarial and other parasites; lack of exercise in some cases incident to heat discomfort, and other factors can not be excluded, and light on body surfaces or sun's rays affecting nerve centers regarded as in greatest measure responsible for breakdowns manifested as anæmia, neurasthenia, loss of weight, diminished strength and energy, liver engorgements, neuritis, and in some other ways.

Men affecting the storerooms of ships, away from natural light, are apt to become anæmic, to lose weight, and to furnish a larger percentage of cases of tuberculosis. They generally have a large measure of air but diminished exercise, yet, it must be noted, are at the same time often subjected to much less heat than others. Such anæmic individuals have their nutrition improved by deck-work and conditions. And in some navies the engineer force has attracted attention by the larger percentage number of cases of tuberculosis furnished.

In both, the diminished light is favorable to the life of the tubercle bacillus and enjoins greater care in the disposal of sputa. Sputum in dark corners is not so readily detected, and pathogenic organisms flourish in such locations. Small-stores should not be served out at storerooms but taken upon the gun-deck at least, and better on the deck above. To utilize a storeroom for serving out results in a deposition of sputa in that part of the ship, as men standing in line will not lose their places for the purpose of finding a spitkid and some, not being under observation, will expectorate on the deck. All such parts of a ship are not under the practically continuous observation to which other parts of a ship are subjected, and storekeepers are often more concerned in having things made ready for Sunday morning inspection than in keeping the deck free from sputa at all times. A sailmaker's mate should have a spitkid in his storeroom, use it only when necessary and keep it in proper condition. He should be required to do most of his work elsewhere.

In engine- and fireroom there is the additional danger incident to drying power of heat and passage of sputum as dust into the air. This effect of heat should also be recognized about the galley, and in both localities the regulations against spitting on the deck plates, or concrete, or in corners should be very strictly enforced. The interest displayed in the habits of the men in this respect in all those parts of a ship will be of value and will conduce to adequate supervision. The lethal temperature of the tubercle bacillus seems to be about 137° F., and consequently, in warm parts of ships, the heat, apart from any debilitating effect it may have on the men, is often favorable to the dissemination of a micro-organism that under ordinary circumstances may be injured by light or localized by moisture.

The gang of men engaged in cleaning any parts of the bilges that are ordinarily dry have opportunities, in view of the limited illumination, to deposit sputa that may endanger subsequent workers. Men engaged in such work should be under responsible supervision, as in breaking out storerooms, not allowed to chew tobacco during its performance, and warned to avoid expectoration or any nuisance.

Every brig should have its port as a source of light and of air, and the influence of side plates should be limited by non-conducting sheathing. A person in darkness is from many points of view an additional nuisance, and it is much better for brigs to be so constructed that occupants can be under constant observation. Each brig should have its spitkid which should be subjected daily to the treatment accorded other spitkids, and the bedding of men in confinement should be repeatedly placed in the air and sunlight. No brig should be occupied by another prisoner until its interior surfaces have been wiped over with corrosive sublimate solution and allowed to dry, and cleanliness of person and locality should be required at all times. A man in confinement requires much more frequent inspection of person and locality and more constant observation for the sake of the man himself as well as of the ship's crew as a whole, than a man on duty. Brigs should not be hot spaces, but well ventilated, lighted, and heated.

It is obvious that whatever may be the effects on men of too much light, the spaces of a naval ship should receive all the natural illumination that her construction as a vessel of war permits, as the tendency between decks is toward that degree of diminished illumination opposed to cleanliness, cheerfulness, and the use of eyes without strain. The row of circular glass air ports on berth and gun decks are constant sources of daylight, hatches are usual additional sources, and gun ports or other openings practicable in connection with gun installation are available in warm weather, but the standard on shore of window area as one-fifth of floor area, or at least one-tenth, cannot be secured, especially as there are large spaces within the citadel. Even in a stateroom the relation of only one to ten would require a circular air port having a diameter of about three feet, an area too great for safety and opposed to strength of structure of the ship as a whole.

Deck lights are fitted in decks and in hatch covers as may be necessary to give light in rooms and passages on the gun and main decks. Deck lights are often of considerable importance as they may represent the only means that can be provided for the admission of natural light, and they should be fitted under such circumstances whenever practicable and made as efficient as possible. In order to secure the necessary diffusion of the relatively small amount of light so admitted it is not sufficient to employ bull's eyes, but it is advisable to secure the diffusive action of the prism and to install glass of good quality and surfaces. The greatest amount of light will be obtained when the rays strike the glass vertically as under a hatch, but when the light reaches the deck light at an angle, the amount of light will decrease with the angle of obliquity from the aperture to the upper surface of the glass which is fitted so as to be flush with the deck. Other things being equal, the amount of light admitted will increase with the area of glass at the deck, and its intensity may be considered to vary inversely as the square of the distance of the deck light from the source of light, whether hatch or port.

In view of the necessary and marked diminution in degree of natural illumination on ships when compared with properly constructed habitations on shore, even in connection with those spaces most advantageously located, and of the number of spaces deprived of daylight, the proper artificial illumination of ships is of special importance, not only in relation to securing light without vitiation of contained air, but also in relation to utilization of the light itself to the best advantage with the least injury to eyes. It is in this connection that the variation of intensity of light in accordance with distance from light source is of chief importance. In the discussion of the electric lighting of ships the proof of the well-known proposition that the intensity of light varies inversely as the square of the distance from the light is not regarded as necessary, but merely advisable to preserve continuity in the discussion in which it necessarily has an important place. The proof is short and can be deduced geometrically from the following figure:

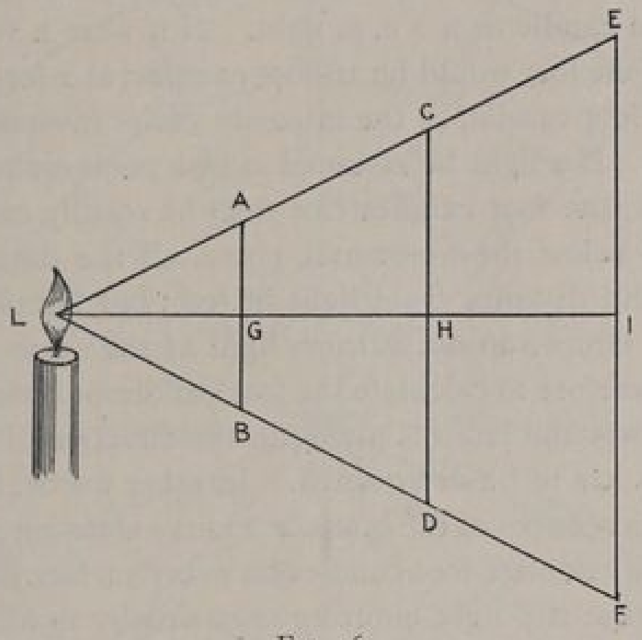

FIG. 26.

If L be the light and AB the side of a square at a distance of one foot, the square receives the same *number* of rays as the square of which CD is the side. But if the square represented by CD is two feet away or twice the distance of AB, its side is twice the length, and therefore the area four times as great. Then, as the same number of rays falls on a surface four times as large the intensity is only one-fourth, or the inversion of the square of the distance. In the same way the square represented by EF, if three feet away from the light, is illuminated with only one-ninth the intensity of the square AB only one foot away, or one-third the distance.

If the light L were from a standard candle, that is, a sperm candle burning one hundred and twenty grains an hour, it would be said to have an intensity of one candle-power or to be a one c. p. light. Such a candle contains 80 per cent. carbon, 13 per cent. hydrogen, and 6 per cent. oxygen. This is known as the British candle, but is not a very satisfactory standard as it may have values differing by 5 per cent. or more. It is, however, the unit of luminous intensity in the United States, but in the photometry of electric lamps it is common to take the Hefner lamp as the primary standard and to express the result in British candles using the ratio, 1 Hefner = 0.88 British candle. Different countries use different standards. The Carcel lamp used in France has an intensity equal to 10.69 Hefner candles and the Harcourt lamp to 10.95 Hefner.

The illumination or the amount of light on a surface is expressed as foot candles. For instance, in the illustration employed to show that the intensity varies inversely as the square of the distance from the light, the illumination of the point *G* is one foot candle, as it is one foot distant from a standard candle or a 1 c. p. light. If it were a 16 c. p. light, the illumination at one foot would be 16-foot candles; at 2 feet, 4-foot candles, and at 4 feet 1-foot candle, as the intensity varies inversely as the square of the distance. If a light be assumed to be a point emitting rays equally in all directions, the foot candles can then be readily calculated for any point above or below the horizontal plane, all the data required being candle-power and distance from light in feet; but lights, such as, for instance, electric lamps, do not furnish light of the same power in all directions, and therefore to calculate the foot candles it is necessary to know what candle-power the lamp is giving in the direction of the point where the foot candles are to be determined. In other words, it is necessary to have a distribution curve of the lamp or a curve showing its candle-power at every angle to calculate foot candles on every surface illuminated by it.

It is clear that if a light emitting rays equally in all directions is at the center of a hollow globe the interior surface of the globe will be equally illuminated. In other words, its distribution curve in any plane will be a circle; and if the radius of the circle be considered to indicate candle-power by length, the higher the candle-power the larger will be the circle. The distribution curves of a number of such lights varying only in candle-power would then be represented by an equal number of concentric circles arranged in order of candle-power, the smaller circle corresponding to the smaller candle-power and the difference between radii corresponding to the difference in candle-power. This is shown in the diagram on page 323 of distribution curves of different lights emitting rays equally in all directions and varying in regular progression by one candle-power.

It therefore follows that if a lamp is not emitting rays equally, but has a different candle-power for each direction, its distribution curve in any plane will not be a circle, but the line joining the ends of right lines proceeding from the lamp at every angle and having lengths in proportion to candle-power. For instance, on page 324 there will be found the distribution curve in a vertical plane of a bare 50 watt "Gem Metallized" vertical incandescent lamp in accordance with candle-power given by manufacturer and as determined by photometer for varying angles in that plane.

It will be noted that this curve on page 324 is plotted in connection with concentric circles, each one of which would be the distribution curve of a light emitting rays equally and having the indicated candle-power.

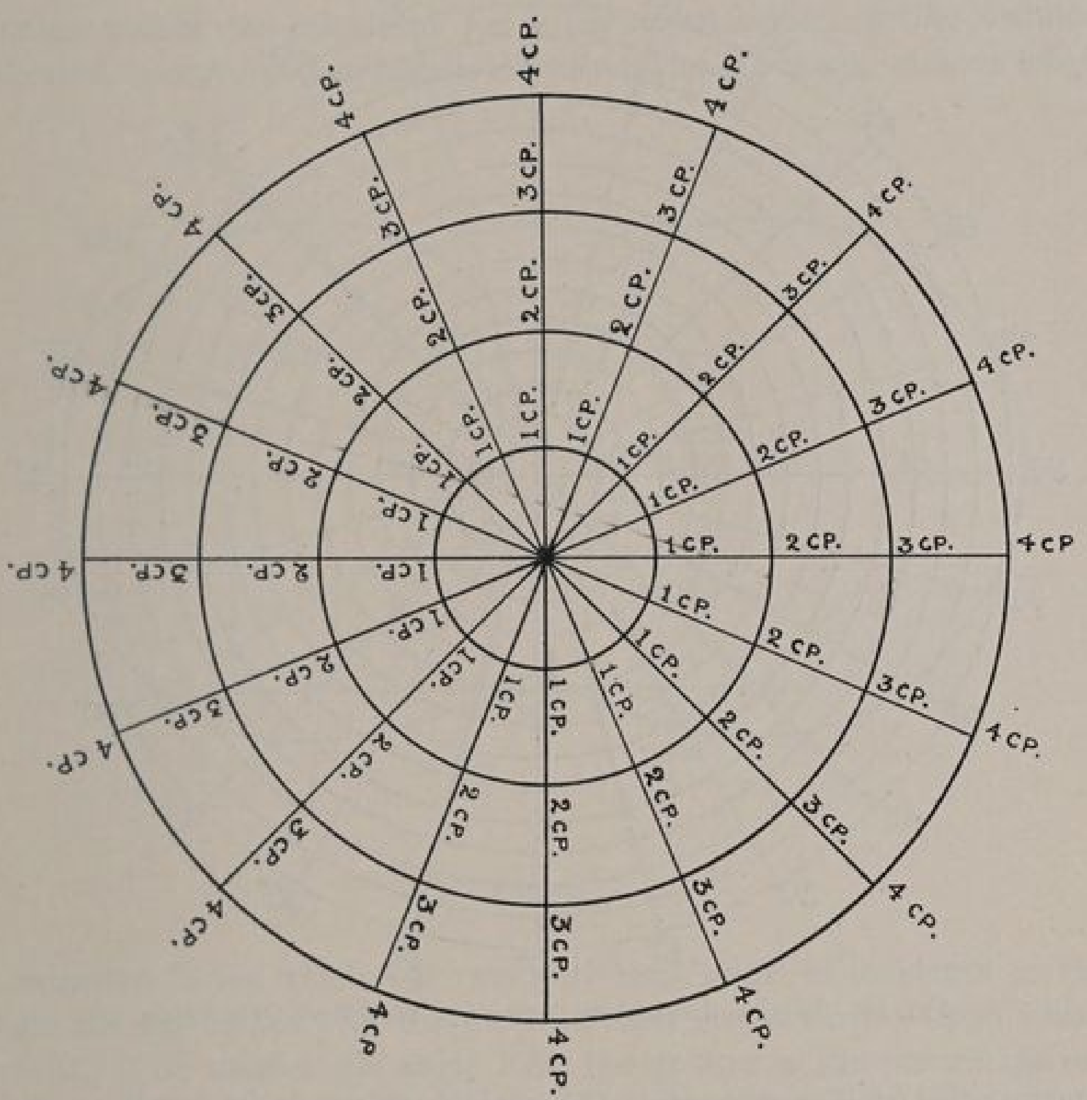

FIG. 27.

From that illustration it appears that the horizontal candle-power in that particular vertical plane is about 19 or 20, while the vertical candle-power or that in a direction immediately under the lamp is less than 9, and at an angle of 45 degrees from the vertical about 15.

Suppose, then, it were desired to calculate the foot candles at a point *P* in the plane *t s*, eight feet below such a lamp and eight feet from the foot of the perpendicular through the lamp. From diagram on page 325 it will be seen that the distance of such a point from the lamp is the hypotenuse of a triangle of which the vertical side is the distance under the lamp and the horizontal the distance from the foot of the vertical.

As the length of the hypotenuse is equal to the square root of the sum of the squares of the other two sides, the distance of the point *P* from the light *L* will be equal to the square root of 128. As the angle at *L* is 45°, and the candle-power of the lamp in that direction is 15, the foot candles at *P*, representing the *normal* surface in its locality, will be equal to 15 divided by the square of that distance, or $\frac{15}{128}=0.117$. Thus, in all such calculations it is necessary, in default of direct determination by photometer, to have the distribution curve of the lamp as it has been determined by photometer, and then, having determined the distance from the light of the point to be illuminated and the value of angle at *L*, to pick out from the curve the candle-power corresponding to the angle and divide it by the *square of the distance*, which in all cases is the sum of the squares of the other two sides of the right-angled triangle.

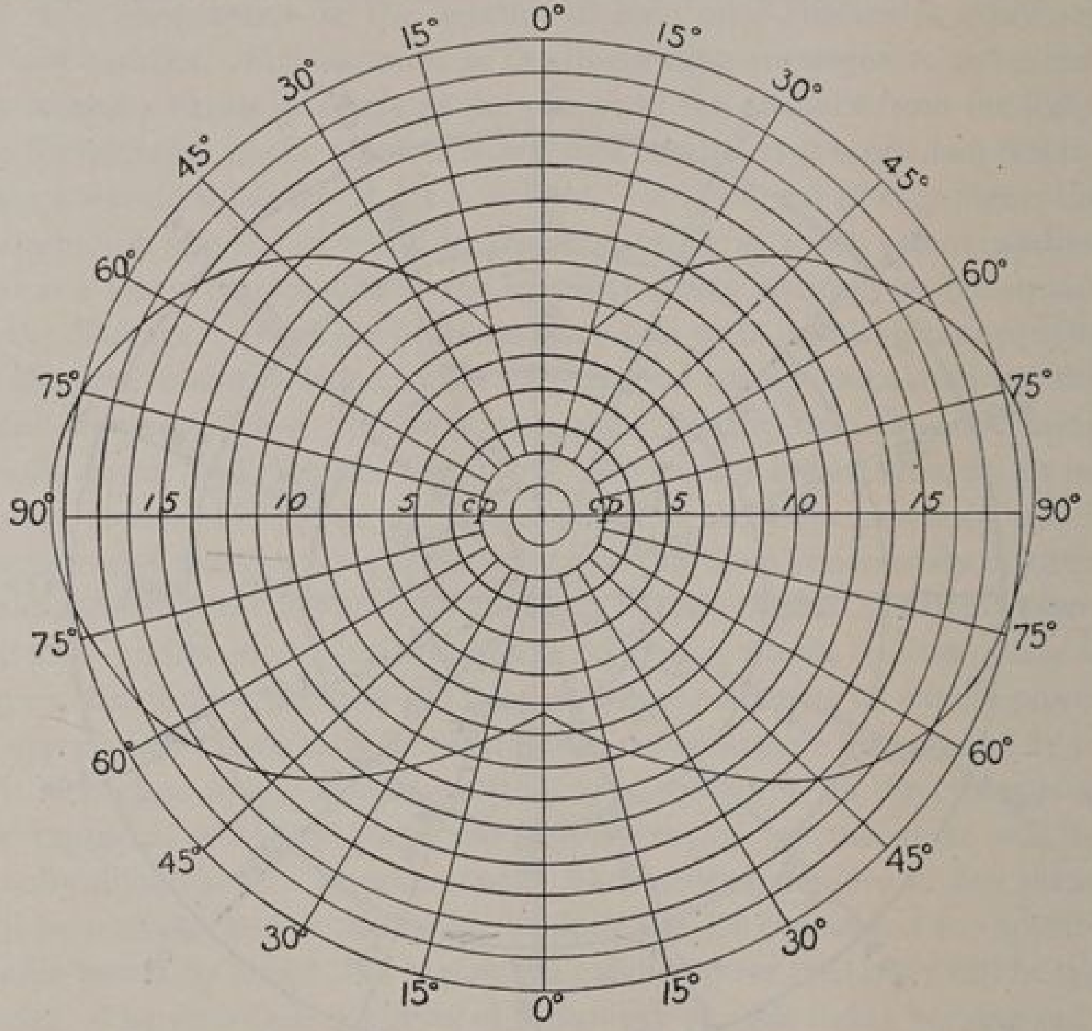

FIG. 28.—Vertical distribution curve of 50 Watt Bare Gem Lamp.

But this does not take into consideration the value of the illumination obtained on a given surface unless it is a plane *normal* to ray or perpendicular to its direction, as in the dotted line *ts* in the diagram; for all points except *F* in the horizontal plane under the lamp, or the surface *F P*, are losing available light by reflection, such light for instance finding the walls of a room and being available for the illumination of the horizontal surface as appreciated by the eye only to the extent to which it is reflected thence and finds the eye from the surface. Consequently the available foot candles cannot be calculated for a horizontal surface in the manner indicated, except for that surface directly under the lamp, without using a reduction factor which will vary with each angle of incidence or the angle the ray makes with the perpendicular to the surface upon which it falls. The smaller the angle *FPL*, the greater is the percentage reduction, as the greater is the relative amount of light reflected, and the larger that angle the less the percentage reduction until when the angle is 90°, or the point is immediately under the light, the reduction becomes zero.

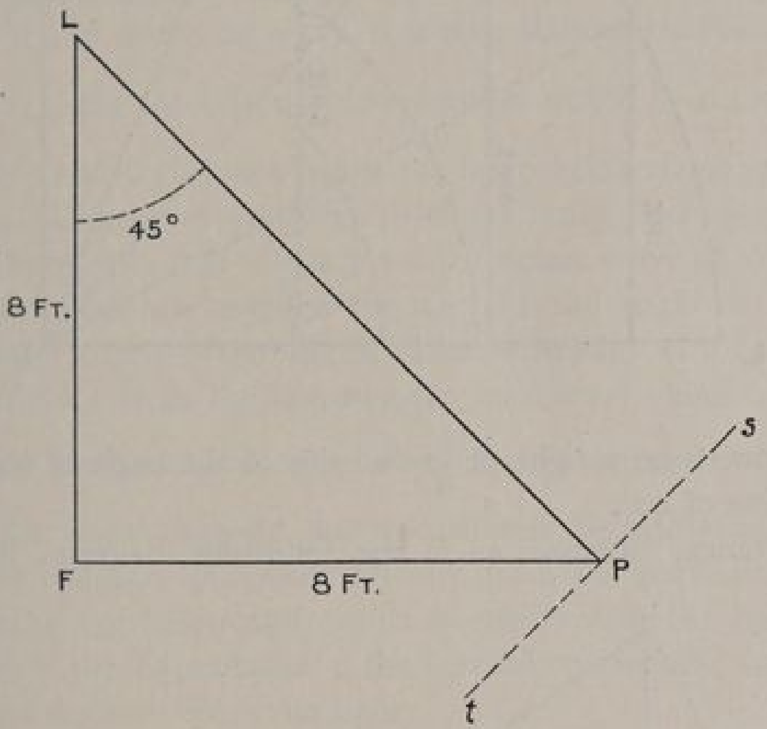

FIG. 29.

If in the first diagram on the next page *L* is a point of light of one candle-power and *P* the part of the horizontal plane illuminated by it, it is obvious that if *L* be moved about *P* with *P L* as a radius it will remain at the same distance from *P* during the revolution.

But as *L*, the light, moves on the circumference toward *L′*, the loss in foot candles at *P* increases as the sine of the angle of obliquity diminishes, the angle of obliquity being the angle the ray makes with the horizontal (*L′P*), and the foot candles at *P* under an oblique ray will be to the foot candles under the vertical ray as the vertical distance below the light is to the distance from a light, or as the sine of the angle of obliquity is to unity, the sine of 90°.

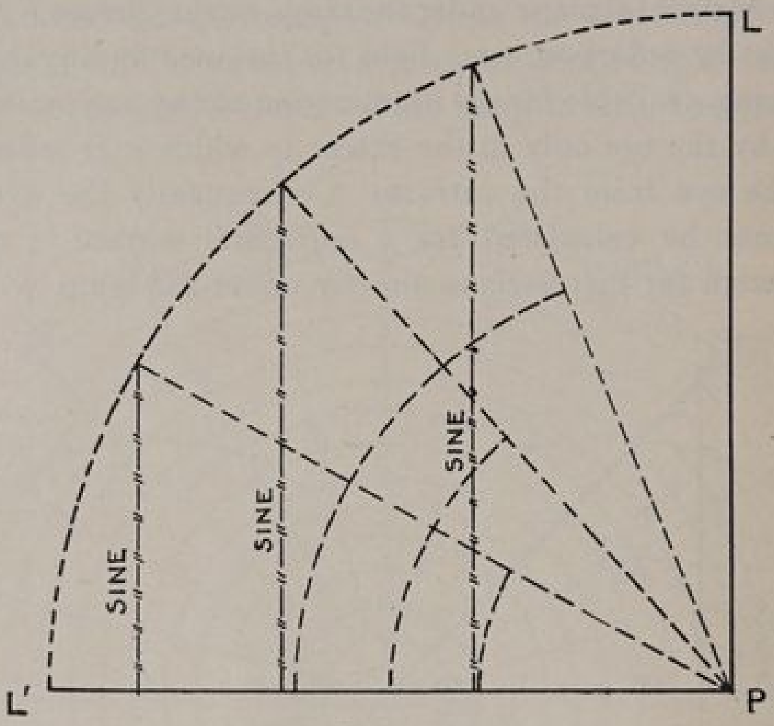

FIG. 30.

For instance, suppose, as in the following diagram, it is desired to find the foot candles on a horizonal plane *H P* at a point *P*, 8 feet below a 1-candle-power light *L* and 12 feet from the point *H* directly under the lamp.

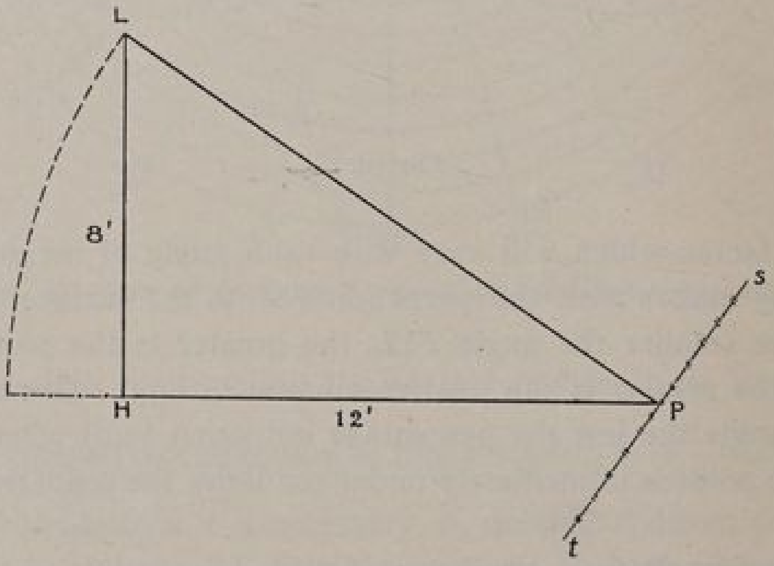

FIG. 31.

The distance *PL* from the light is equal to $\sqrt{64+144}=14.42$

feet, and the foot candles at P *on the plane is normal to the ray* are $\frac{1}{(14.42)^2}=.0048$. But eight feet is the vertical distance below the light, and, that distance is $\frac{800}{14.42}=55.48$ per cent. of $P\,L$, or the distance from the light. Therefore, the foot candles on *the horizontal plane* at P, from a single candle-power at L will be $.0048\times.5548=.00266$; or $x : .0048 :: 8 : 14.42$.

Returning to the distribution curve given and to the calculation showing that at a point 8 feet below such a lamp and eight feet from the foot of the perpendicular through the lamp the foot candles on a plane normal to the ray would be 0.117, it is now obvious that on a horizontal plane at that point the effective foot candles would be $0.117\times\frac{8}{\sqrt{128}}=.0828$, or, the vertical distance below the lamp being about 70.73 per cent. of the actual distance of the point from the lamp, $0.117\times.7073=.0828$.

It has been seen that to use the distribution curve of any lamp it is an essential to have the angle at the lamp or the angle the hypotenuse of the triangle, which is the line of distance, makes with the vertical or the perpendicular from the lamp to the horizontal plane. This should be calculated by the formula *Sine* $A=\frac{b}{h}$, but in the absence of a table of sines may be approximately derived, though probably with sufficient accuracy for ordinary purposes, directly from the parts of the triangle itself, by using the following formula in which A is the required angle at the light, h the hypotenuse, v the vertical or altitude, and b the base or horizontal distance from the light:

$$A=\frac{90\quad\sqrt{h-v}}{\sqrt{h-v}+\sqrt{h-b}}$$

For convenience the following table has been prepared, for use in determining foot candles at points within ship's spaces at varying distances below lights and varying horizontal distances from lights. In this table the angle A, or the angle at the light, has been obtained from Sine $A,=\frac{b}{h}$ and the foot candles have been ascertained in the manner already indicated, under the assumption of a *one-candle-power* light emitting rays equally in all directions.

TABLE OF EFFECTIVE ILLUMINATION IN FOOT CANDLES AT VARYING POINTS ON HORIZONTAL PLANES BELOW A ONE-CANDLE-POWER LIGHT AND OF CORRESPONDING ANGLES AT THE LIGHT.

Height of Light (Feet) above Horizontal Plane	Horizontal Distance (Feet) from Point for which Foot Candles are to be Calculated to Foot of Perpendicular from Light.															
	0		2		3		4		5		6		7		8	
Feet	Angle	Foot Candles	Angle	Foot Candles	Angle	Foot Candles	Angle	Foot Candles	Angle	Foot Candles	Angle	Foot Candles	Angle	Foot Candles	Angle	Foot Candles
2	0	.25000	45.0	.0883	56.3	.04265	63.4	.02240	68.2	.01280	71.6	.0079	74.1	.00518	76.0	.00355
3	0	.11111	33.6	.06397	45.0	.03927	53.0	.02400	59.0	.01513	63.4	.00993	66.8	.00679	69.4	.00480
4	0	.06250	26.6	.0447	36.8	.03200	45.0	.02206	51.3	.01523	56.3	.01064	60.2	.00763	63.4	.00560
5	0	.04000	21.8	.03198	31.0	.02522	38.6	.01904	45.0	.01414	50.2	.01049	54.5	.00785	58.0	.00595
6	0	.02775	18.4	.02365	26.6	.01987	33.6	.01600	39.8	.01259	45.0	.0098	49.4	.00764	53.1	.00602
7	0	.02041	16.0	.01814	23.2	.01584	29.7	.01335	35.6	.01090	40.7	.00893	45.0	.00708	48.8	.00582
8	0	.01563	14.0	.01428	20.6	.01282	26.6	.01119	32.0	.00952	36.8	.00801	41.1	.00665	45.0	.00552
9	0	.01235	12.5	.01147	18.4	.01054	24.0	.0094	29.1	.00824	33.6	.00711	37.9	.00607	41.7	.00515

A table of this character greatly facilitates the determination of the illumination (foot candles) at any point on a desk, table or deck below any light of which there is an available distribution curve. For instance, considering the distribution curve already given, suppose it is desired to know the foot candles at a point on a desk seven feet below the light and three feet from where the perpendicular from the lamp meets the plane of the desk. From the table it appears that the corresponding angle at the light is 23.2 degrees and from inspection of the distribution curve it is evident that the candle-power of the lamp in that direction is about 10.42. As it appears from the table that one candle-power would give 0.01584 foot candle at the point designated, it is evident that 10.42 candles would furnish $.01584 \times 10.42 = .165$ foot candles.

It is apparent from the distribution curve given that a very large percentage of the light from a bare lamp is in and above the horizontal plane through the lamp and is therefore lost for the direct illumination of any surface below. Such light goes to walls and ceiling where a varying percentage is absorbed in accordance with their color, and therefore entirely lost, and the remainder is reflected into the room to add to the general illumination given directly by the lamp. While the effective illumination of a room depends very greatly upon the color of the room and of all objects within it, and this is a factor of prime importance in any room, especially where there is near work, it is very uneconomical and otherwise undesirable to depend upon such reflected light to make up required desk illumination, as not only must high candle-power be employed but, if the light is exposed, the eyes are subjected to the more or less blinding glare found in all systems of direct lighting without means of softening or diffusing direct rays. As a result, a bare lamp should have no place in the illumination of any occupied space, but in all direct lighting reflectors should be used to diminish loss of light and either globes should be employed or shades, which are not opaque, but on the contrary constructed to permit the passage of the largest percentage of light with the requisite degree of softening or diffusion. It should be the object to always secure a good general illumination which should not be much less than that of the desk itself if the space is to be used for near work.

There are two systems of artificial illumination, direct and indirect. In complete indirect or cove lighting the total light is first reflected upon surroundings, say ceiling and perhaps upper parts of walls, and thence to the lower portion of a room. Thus the concentration of direct light near the lamp is received by the reflector and diffused by being thrown upon the large surface of the upper part of the room, whence it is still further scattered by reflection to the lower parts of the room. In complete direct lighting opaque shades are placed above the lamp and the light reflected at once downward. In many cases both systems are really combined in varying degree. In indirect lighting there are no bright points to come into the field of vision and no disconcerting shadows, but an indirect light causes insufficient illumination for reading purposes unless the amount of light or candle-power of the lamp is about 65 per cent. greater than that of a direct light giving adequate illumination for that purpose, as even with ceiling and walls of the best color for reflection such a large percentage of light is lost by absorption. An indirect system of lighting is suitable for the general illumination of a hospital ward, the electric lamps being inside of whitened spun glass bowls on fixtures from ceiling along center line of ward. Such bowls should be covered with a thin sheet of plain glass to keep out dust. As in such a system there is so much loss of light at ceiling and walls, a socket between beds is required that an individual lamp, provided with frosted bulb and reflector can be used for examination of patient as required. But on a ship the illumination lost for power expended would be too great in indirect lighting, and also in any space where there is reading and writing or clerical work that system would not secure the *somewhat* increased illumination on the page over that of surrounding objects which experience shows is advisable for comfort.

On the other hand, in direct lighting the opaque shade is highly objectionable, as it floods the page with light, often with too much light, and leaves most of the room in such comparative darkness that the eye looking up from a brilliant surface, and therefore with a small pupil, is in much the same situation as if the individual had come suddenly into a dark room from a well-illuminated one. This is reversed when the work is renewed and then the eyes suffer for a time from the access of too much light through a dilated pupil. Thus opaque shades cause marked iris accommodations and repeated shocks that are opposed to the continuance of good sight. Those shocks are so frequent and damaging that they are sufficient to condemn any system causing them.

Such considerations and many others lead to the conclusion that while the artificial illumination of ships must be in great part by the direct system, the method employed should at least combine both systems as it should also include means of obtaining general illumination by diffused light or by shades or globes so constructed as to hide the filament and yet permit the passage of light, at the same time softening it to the point of abolishing glare. Such shades should be constructed of prismatic glass and should really be diffusing prismatic reflectors. As constructed on the Holophane system, they give as wide diffusion as opal with very much less loss of light by absorption, only about 12 per cent., and are made in many different forms to meet varying requirements appearing as globes and as shades or reflectors.

When a globe or shade reflector is used in connection with a lamp, the distribution curve is of course greatly modified, and consequently the curve of the bare lamp then becomes valueless in all calculations of foot candles. It is necessary to have photometric or distribution curve of the lamp in connection with its globe or reflector, the distribution curve of the bare lamp merely affording an interesting comparison with the modified curve as showing the effect of the globe or reflector employed. But the *method* of calculating the foot candles from the modified curve remains of course the same.

The following is an illustration of a Tungsten lamp with one variety of the bowl Holophane reflector, and on the next page is the vertical distribution curve of such a lamp and reflector, as furnished by the National Electric Lamp Association through the Columbia Incandescent Lamp Co., manufacturers of the Gem Metallized, the Tantalum, and the Tungsten lamps, which are all filament lamps recognized as high-efficiency or low-watt incandescent lamps.

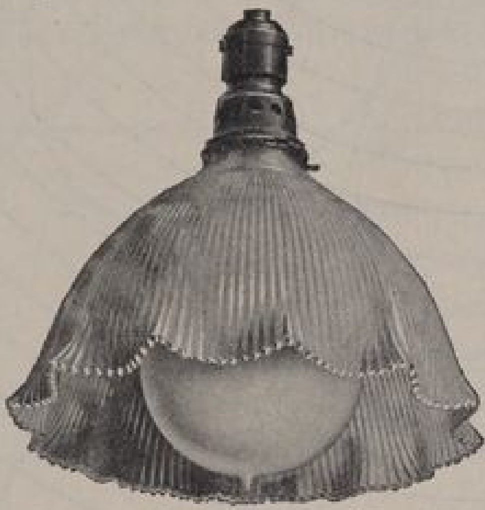

FIG. 32.—Tungsten Lamp with one variety of Bowl Holophane Reflector.

These Tungsten lamps are made in two sizes and are rated by total wattage as 40 and 60 watts. They are operated at a stated efficiency of 1.25 watts per candle, and therefore the distribution curve given may be considered to be that of a 48-candle-power lamp as modified by the particular Holophane clear bowl reflector employed. It will be noted that in a direction perpendicular to the horizontal plane the candle-power is about 34, and that the maximum candle-power, about 69, is with an angle at the light of about 36 degrees. It is evident that the light is fairly well brought down as at an angle of 90 degrees, where with the bare lamp the candle-power is greatest, this prismatic shade reduces the

48 candle-power to about 27, thus, unlike an opaque shade, allowing a large percentage of the light to pass through for general illumination, while diffusing it and hiding the filament as such.

Applying to this distribution curve the method previously employed it can be demonstrated that at about 3 feet $4\frac{1}{3}$ inches immediately below such a fixture the illumination is 3 foot candles. For if x be the required distance immediately below the fixture at which the illumination is to be 3 foot candles, then, as the candle power in that direction is 34, $\frac{34}{x^2}=3$, or $x^2=11.33$, or $x=3.366$ feet.

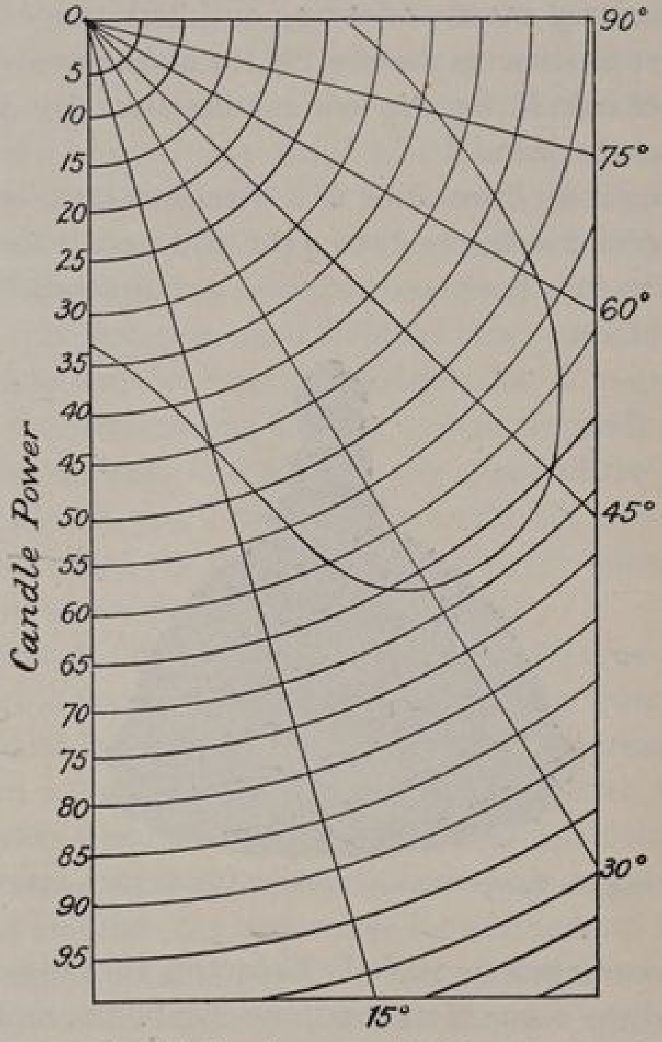

FIG. 33.—The corresponding distribution curve (60 Watt Tungsten Lamp Clear Bowl).

But in view of shadow on work, it is never advisable to have a lamp immediately overhead when using a desk, and therefore in utilizing such a fixture at a desk it is first necessary to decide just where the perpendicular from the lamp should meet the desk and then locate the fixture at an elevation over that point which will give the foot candles desired at the work. In the case of this fixture, suppose it is desired to have 3-foot candles at any given point on the desk, the perpendicular from the lamp to meet the desk at a distance of 2 feet, say on a line making an angle of 45 degrees with the desk front, as in the following diagram in which *P* is the point to be illuminated and *V* the point immediately under the lamp.

From inspection of the distribution curve it appears that at about an angle of 26.6° the candle-power is 65. That angle corresponds to a height of 4 feet above the desk if the horizontal distance from the perpendicular is 2 feet, as will be seen by reference to the table given where it also appears that the reducing factor is 0.0447. As $65 \times .0447 = 2.9$, the height of the center of the lamp above the desk should be almost exactly 4 feet to secure an illumination of 3-foot candles at the point indicated. With the 40-watt or 32-candle Tungsten lamp in the same position and with the same reflector the foot candles at the same point would be about 2. And when two or more lamps are in question the effective illumination at a given point is the sum of the foot candles from each.

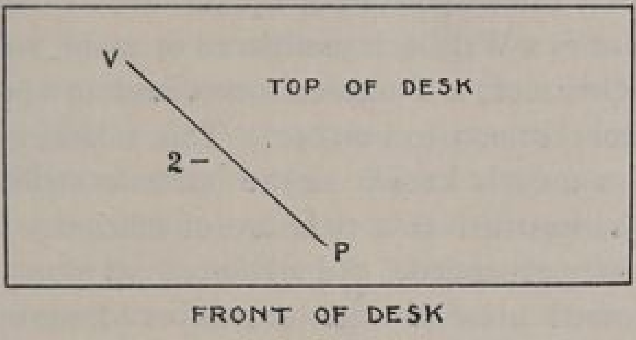

FIG. 34.

Such calculations are of much importance as they emphasize the fact that it is not only practicable to have certain standards of illumination, but also to have standard fixtures, selected with reference to the requirements of different parts of the ship, which can be located to accomplish or secure the desired or standard illuminations. In other words, there should be no haphazard illumination of ships, as the subject can be taken up in the careful and systematic way its importance deserves. Each part of a ship must be considered in accordance with the demands upon the eyes in that locality; for instance, while in every occupied part of a ship adequate general illumination without glare is essential, in staterooms and offices there should be in addition a standard desk illumination for near work, and for mess and other tables around which persons gather there should also be a specified number of foot candles, in all cases secured by fixtures of known qualities knowingly located to accomplish the results required.

In the selection of fixtures there are general and specific requirements, as all lights in living spaces should be so shaded and placed as not to present points of great brilliancy in the field of vision, at least without deliberate attempt to gaze at light source, and in near work the fixture or fixtures should not only give the required general illumination as well as the foot candles on the work, but also the location of work should be *evenly* illuminated. This last consideration is of very great importance, for if the illuminated field has bands varying in foot candles the retina is rapidly receiving light of varying intensity, and the iris is unable to respond with sufficient rapidity. Such contrasts cause rapidly repeated shocks, are often worse than glare, and produce marked eye-strain with ultimately permanent defects. This situation is a fruitful source of eye troubles, and is apt to occur when reflectors have a polished white interior surface and at the same time the lamp has a clear bulb.

The necessity, as measured by retinal fatigue or exhaustion, for removing the light source from the field of vision increases with its intensity expressed in candle-power per unit of its surface. An ordinary candle has about 3 candle-power per square inch of flame surface, a gas flame perhaps 5 or 6, a Welsbach mantle 20 or more, an ordinary carbon filament 400, a Gem 600, a Tungsten 1,000, and an open arc light in its various parts from 10,000 to 200,000. This relation of candle-power to area of light source is known as the intrinsic brilliancy, which in a filament lamp is regarded as a measure of efficiency when considered in relation to power expended. An advantage of glow or vacuum lights is in the increased area of light-source or diminution of intrinsic brilliancy.

From the figures just given it is obvious that with the introduction of electric lighting the necessity for taking the light source out of the field of vision was very greatly increased, and this became especially important in crew spaces in view of the relatively large number of bulkhead or side lights. But at this time in the crew spaces of naval vessels the bare lamp is the rule, any additional glassware being plain and employed solely for the protection of the lamp. Frosted bulbs were issued originally in considerable number, but the issue has been greatly reduced in view of the important fact that a frosted carbon incandescent lamp falls to 80 per cent. of its initial candle-power in about one-half of the time taken by a corresponding plain-bulb lamp, although the total life of the lamps is the same. This lowering of the efficiency of the frosted bulb makes its use very uneconomical and in other respects undesirable as such lamps are more apt to be continued in use in fixed locations after the illumination has become insufficient. The initial intrinsic brilliancy of the frosted bulb is usually less than 5 candle-power per square inch, and the use at bulkheads greatly diminishes glare as well as the direct effect of the glowing filament. But the total loss of light is always greater than with clear prismatic glass.

Up to the present time the illumination of crew spaces with artificial light has not been accomplished with satisfaction, and the trouble and much of the damage are from bare filaments and uneven illumination. The eye does not resent an intrinsic brilliancy at or below 5 or even 6 candle-power per square inch in the light-sources of a space, but at present such sources have 400 candle-power and one such source is in plain view in about each 500 cubic feet of space. An exhausting picture of the filament is thus repeatedly formed on the retina, and the various objects about the space seem relatively dim. The result is an expenditure of light disadvantageously and harmfully.

It should be recognized that there is much difficulty in placing lamps to the best advantage in crew spaces, and that the location of a fixture is perhaps as important as the character of the fixture. The sun has an intrinsic brilliancy, varying with angle, of from 2,000 to 600,000, and it is fortunate that as its brilliancy increases it is further from probable line of vision and at all times, as a single light-source in a vast hemisphere, is not in position to surprise the wandering eye. On a ship, the deck overhead is cut up by beams and occupied in no small degree by piping, mess tables, benches, and other things. There are, however, a number of overhead lights and in certain locations where that arrangement is practicable the fixtures should be selected to give the requisite foot candles on mess tables that may be allowed on the deck at certain hours for reading, writing, and games.

For the space as a whole, the difficulty or impossibility of placing a sufficient number of lamps overhead has led to the location of many lights on bulkheads where decided projections have to be avoided, as if a lamp is given much prominence it is liable to be injured. Such lamps are therefore placed vertically to keep them out of the way and in spring sockets, as are all ships' lamps, to take up concussion and ordinary vibrations. In addition they are protected by elongated more or less cylindrical coverings of rather thick plain glass. The fixture is completed by an outside metal cage swung like a door to give access for cleaning and renewals.

As the distribution curve of a bare lamp placed vertically shows maximum candle-power in the horizontal plane through its center, a lamp placed with its long axis close to and parallel with a surface, such as a bulkhead or deck overhead, is in the best position to lose efficiency due to the large amount of light going at once to the surface where much is absorbed and whence much that is reflected has to pass back, a part through at least two thicknesses of glass and a part again and again reflected to take its chance of ever finding the space to add to the general illumination. It is very common on ships to find lamps so placed, as it has been almost the rule with bulkhead lamps and quite generally with overhead lamps which are often provided with *flattened* plain hemispherical globes to give them less prominence and lessen chance of injury.

The number of lamps on naval vessels has rapidly increased. At first there was one 16-candle-power lamp to about each 1,000 cubic feet in crew spaces. The tendency now is to place one such lamp in each 500 cubic feet. This, while increasing general illumination, has added greatly to the difficulties of eyes in relation to bare filaments and uneven reflection about fixtures. The results would be more apparent, even in statistics, but for the routine life on a ship under which a man is either in his hammock early or on watch, and the general illumination about the decks reduced to a minimum.

To remove the difficulties, the first essential is to soften the lights and remove the filaments from view, and, under the circumstances, it is not clear that any more acceptable means will be found than in the use of prismatic glass. It is true that in softening or diffusing light there is in general terms a greater loss than where plain glass is used, but with prismatic glass the result is accomplished at the smallest loss, and as it is practicable, even with bulkhead lights, to secure reflection within the glass of rays that would otherwise go to ship surfaces almost in contact with the fixture, there would be a degree of gain in that direction to offset in part the loss in others. Besides, the limits of instrinsic brilliancy of filaments are set by capacity of dynamos. It is a question of power of plant. At present the old-fashioned carbon filament lamps are employed on naval vessels. Such lamps operate at best at an efficiency of 3.1 watts per candle. The stated efficiency of the Tungsten lamp is about 1.25 watts, of the Tantalum 2, and of the Gem Metallized filament 2.5. A 16 c. p. carbon filament lamp may therefore be rated in total wattage, as, at best, about 50 watts and often about 55, while that of a Tungsten lamp of 32 c. p. would be only about 40, thus giving double the candle-power on less wattage. The Gem Metallized 50-watt lamp operated at an efficiency of 2.5 watts per candle is a 20-candle-power lamp. It would seem, then, to be practicable to make up any possible loss from use of prismatic glass by increasing the candle-power of the lamps themselves without increasing consumption or coal expenditure or size of plant. It would only add to existing troubles to use any of these low-watt or high-efficiency lamps with present fixtures, for their intrinsic brilliancy is very high, but the increase in candle-power without increasing load on dynamo eminently fits them for use within prismatic glass under the circumstances.

They also possess additional qualities of value in quality and relative steadiness of light. Flickering or varying brilliancy in a lamp is to be deplored. Steadiness is a very desirable quality in a light. Fluctuation of voltage is rather common on ships, and in a carbon filament the resistance decreases as the temperature increases. In a Tungsten lamp the resistance increases with rise of temperature, and therefore the candle-power is less effected by change in voltage. A carbon filament lamp is also apt to be in use when its efficiency is below 80 per cent., while the Tungsten is said to have a life of 800 or more hours with burn-outs, as a rule, before the candle-power has dropped 20 per cent. All these lamps give a much whiter light than the carbon filament, but operate at much higher temperatures.

There are, however, conditions on ships that keep all apparent improvements in doubt until they have been tried. Service conditions are something apart from conditions on shore. It is believed that the carbon lamp is no longer the best form of filament lamp for the illumination of buildings on shore, but it is not safe to assume that the new lamps are suitable for general use on naval vessels. There seems to be in some of these new lamps a greater difference in life as the result either, of difficulties in manufacture and changes incident to high operating temperature, or of inherent brittleness of filament especially in cold weather. They therefore require more care in handling, and are more susceptible to injury from accidental contact or perhaps from concussion of gun fire.

The filaments of a Tantalum lamp are supported above and below and are started slack between supports because under heat they change structure and shorten, thus acquiring tension by contraction. This strained condition of filaments tends to rupture or to increased susceptibility to jars. This lamp in its older form had one trial on a naval vessel and received an adverse report. The Tungsten is the most economical in operation, gives a brilliant white light and operates with equal satisfaction on direct or alternating current. But it is advisable to handle Tungsten lamps with care since when cold the filaments are brittle. This is, in a measure, overcome by increasing thickness of filament as in the Tungsten lamp adapted to street lighting. The Gem lamp can be used equally well on any current or at any angle. It gives a whiter light than the ordinary carbon filament and saves 20 per cent. in current. It is a carbon filament that has been subjected to very high temperature in manufacture and is then said to have been "metallized." It gives a steadier light than the ordinary carbon filament on change in voltage, varying only 7/10 as much in candle-power for each volt variation. The initial cost is low compared with that of the other two lamps, and it is believed it can be used wherever an ordinary carbon filament can. But its frosted bulb acquires the deposits common to all carbon filament lamps.

These three lamps seem to be the most prominent representatives at this time of the high-efficiency or low-watt incandescent lamps, but they do not express a finality as the indications are that the whole system of lamps may be on the eve of radical change from which the electric lighting of ships will probably be greatly improved. At any rate, anything that may be advanced in favor of special lamps to-day may become obsolete to-morrow. Changes have already been made in electric lighting as marked as in lighting with gas in which the mantle adds greatly to steadiness and brilliancy, but at the expense of length of life of fixtures, an ordinary gas burner lasting almost indefinitely, while a mantle has to be renewed repeatedly. As yet in electric lighting such a very small per cent. of the energy used is ever converted into light that there is room along that line for vast improvement, and it may be that something better than a filament lamp will be found, even for general use on ships, resulting from experiments in vapor lighting. The Cooper-Hewitt light, a system of mercury vapor lighting, can never be used afloat, at least in its present form, on account of its green color, green or red being dangerous for the general lighting of a ship, if for no other reason on account of the confinement of those colors to the side or running lights. The green shades not uncommon on desk lamps of ships should be discarded for a number of reasons, and especially as most of them have a polished white interior surface causing, without a frosted bulb, a streaked or uneven illumination very trying to eyes.

The Moore light represents a development in vapor lighting that is promising in a number of directions. Up to the present time it has caused much improvement at the operating-table at night on shore. It is said to be the best light for that purpose, as it abolishes shadows and resembles daylight both in diffusion and effect on colors, the tissues of the body having much the same appearance as if viewed by the light of day. It is also under good control as it can be regulated or made to vary from a mere glow to a brilliancy of 20 candles per foot of tubing. It then has a low intrinsic brilliancy as the tubing is one and three-quarters inches in diameter. It appears as a continuous glass tubing and is operated by an ordinary alternating current acting on a partial air or CO_2 vacuum, a very much smaller degree of vacuum than is obtained in the ordinary incandescent lamp. The air is exhausted only to that degree necessary to cause it to acquire the desired conductivity for currents of ordinary pressure, a small transformer being employed to secure the electromotive force required. The degree of vacuum is maintained automatically by the lamp, a carbon cone admitting air when its point is automatically uncovered by mercury with which it is ordinarily hermetically sealed. There is very little heat from this light, and the effect on the eye is agreeable. There are no reflectors employed, but the continuous glass tube is supported on the walls of the operating-room near ceiling, and thus out of direct line of vision. Such a light avoids shadows and would seem ideal for the operating-rooms of hospitals on shore, but its availability in connection with surgical work of a ship is at least doubtful in view of the probable effect on the tubing of concussion from gunfire. CO_2 is now generally used instead of air in this lamp.

At the present time it appears that only a filament lamp is clearly suitable for the general illumination of a ship's spaces at night, and for the more or less constant illumination of such spaces as are either inadequately supplied with daylight or entirely deprived of it, unless arc lamps at coaling stations in firerooms may be regarded as an exception.

In staterooms and offices and on mess tables it is best for the light to be received from above the ordinary line of vision. This is at least always practicable in the case of officers' mess tables and often the percentage of overhead lights in crew spaces can be increased. In staterooms and offices desk-lamps should be abolished, as they leave too much to the discretion of users, and are unsuitable anyhow as they cause marked contrasts, vary illumination from time to time from changes in position of lamp, do not lend themselves to general illumination and multiply the necessity for rapid iris accommodations. It is also not uncommon to see these desk-lamps utilized to make up by increased illumination for defects of accommodation. If a person cannot see well when the work has the standard number of foot candles, a conclusion is at once declared requiring examination of eyes and probable use of glasses. Too much light on work leads to iris fatigue with ultimately undesirable dilation of pupil and consequent admission of more light than the retina can bear without injury. It is, perhaps, as objectionable as too little light.

A lamp utilized for desk work should always be operated from one position located by calculations with reference to the desk. The lamp need not be regarded as always necessarily in that position, as it would be practicable to provide means for locating it elsewhere in the room if desired, but the second location should have reference to its own part of the room, the bunk for instance, and require the first position if the desk is to be used. A fixed position for lamp in all desk work is important because the worker at the desk is then able to locate the page or the work with confidence, or without experimentation at all times, such adjustments of his own position as he may have found desirable being the same and therefore made automatically, including the shifting of desk chair to bring the light somewhat behind and over the shoulder in newspaper or book reading at leisure. It is opposed to the hygiene of this subject to bring the light low and thus secure sufficient illumination by bringing the light near, especially with bulb exposed, and thus perhaps with points of great brilliancy within the field of vision. It is also unhygienic to have the lamp so placed that the reflected light brings out the gloss or glare from paper; that is, it should be to the left rather than directly in front.

In locating a lamp above the plane of a desk the height should not be *less* than three feet four inches. As the top of the desk is about two feet six inches from the deck this would place the center of the lamp at least five feet ten inches from the deck. The distance between decks is probably not much more than six feet three inches in the clear as the beams may be considered to have a depth of eight or nine inches. It would therefore seem that the natural point of suspension would be from the deck above, although some variety of the many wall brackets could be employed if necessary, the desk being against the bulkhead.

With the *minimum* as three feet four inches above the desk, the most important consideration is the required candle-power or the distribution curve of lamp and proper prismatic diffusive reflector to give the standard number of foot candles at that elevation or as much above it as may be practicable.

It has been decided experimentally that for ordinary reading and writing and desk work the foot candles should not be below two or above three. In much written work with paper ruled for columns such as is done by ships' writers it should be about three. In staterooms a standard desk illumination of 2.6 would be acceptable, while in ships' offices from 3 to perhaps 3.2 might be better, both having been considered in connection with drop in candle-power incident to life of lamp.

The candle-power need not be received from a single lamp, and in offices, especially where there is more than one worker, it can be more advantageously obtained from two lamps, as difficulties from shadows can thus be minimized. In the case of more than one lamp operated in relation to desk or desks, the location of each should also be fixed with relation to work, the required number of foot candles for the place or places of work being obtained as the sum of the foot candles from each lamp, and the most economical and effective relation of the lamps and reflectors to each other depending upon character of their distribution curves.

In view of the required removal of the bare filament from field of vision, even in location designated, and of the advisability of a somewhat greater illumination of work than of surroundings, it appears that in staterooms and offices the best result at desks on ships will be obtained from a prismatic reflector of the bowl variety. Bowl reflectors vary in shape and construction within their type, and these variations cause corresponding changes in distribution curves.

These bowls may also have their interior surfaces uniformly etched, thus giving greater desk illumination with some decrease in general illumination but with less glare. Lamps may also be frosted in whole or in part or at tips. But each change in bulb of lamp or in shade causes a change in distribution curve and thus in the illumination secured. However, considering even a clear bulb in the general location designated, there should be in a state-room for desk illumination at least a 32 c. p. lamp within a bowl reflector, perhaps differing somewhat from the one previously illustrated and more like the one below.

It seems probable that with a 32 c. p. lamp so arranged a sufficient illumination on the desk could be obtained, provided the general illumination were assisted by an additional light and by proper coloring of room. But in default of more candle-power additional desk illumination required could be secured by etching or whitening the inner surface of reflector. Yet if such a lamp were a Tungsten its operating efficiency would be only 40 watts, and either a 60-watt (48-c. p.) lamp could be used over the desk at somewhat greater elevation, or, better, in connection with the 32 c. p. lamp an additional lamp employed within a prismatic globe for general illumination, the foot candles at the desk being calculated under those conditions.


FIG. 35.—Gem Regular Bowl Type Reflector.

The result sought to be accomplished is of very great value, and the problem could be sufficiently solved in all its details by experimentation with a few varieties of shades and lamps and by photometric work in a typical properly colored stateroom. Such an investigation would greatly lessen the number of complaints and go far to relieve the eye-strain which is now not unknown as an incident of lack of a proper lighting system or of the research work necessary for the acquisition of knowledge to overcome recognized objections or to diminish recognized damage.

In the solution of this problem the coloring of room and of objects within it demands consideration as an important factor in ultimate results. Eyes looking up from work should not gaze into comparative darkness. In other words, there should be a sufficient general illumination without glare in any properly lighted room. The color of bulkheads, decks, and furniture of a stateroom has a marked effect on degree of general illumination, as it has everywhere, and thus is in important relation to eye-strain. A room on shore with white ceiling and chrome-yellow walls will have more than double the effective illumination on the same number of candles of a similar room with emerald-green, dark brown, vermillion, blue-green, cobalt-blue, or deep chocolate paper. White walls give the largest amount of total illumination, but they so reflect the light as to cause glare, yet most ships are finished inside in white paint.

It is strongly advisable for all interior surfaces of living spaces to have a very light color not only for economy in reflection of light, but also to avoid marked contrasts during near work between the page, having the eye most of the time and the surroundings having the eye more often than is supposed. The walls or sides of a room, office, or crew space should be in a light buff or what might be called a white stone yellow. No furniture in a room or office of a ship should be *dark*, and, in view of the relatively large area of side wall it covers, at least the natural hue of the lighter woods should be obtained. Light or yellow-colored shellac on linoleum is to be preferred. In a work room on shore receiving much sun or light a light grey green for side walls may be desirable, but darker rooms should be in light buff, and under no circumstances should dark walls or wood work be permitted in such rooms.

In connection with effective illumination it should also be recognized that while there is often very great loss from use of unsuitable globes or shades, there is also much loss unless they are kept clean. In softening light with the smallest reduction of illumination the Holophane system offers very apparent advantages. Ordinary glass causes a loss of perhaps 10 per cent. and an opal globe of 60 to 70 per cent. It is on opal and ground-glass globes that dust is apt to remain unnoticed, and thus to cause an additional serious loss of light.

It is important for all mess rooms to be well illuminated, especially at and over tables. Gloomy surroundings are not conducive to the intellectual pursuit of swapping ideas and do not lend themselves to the maintenance of that high tide of cheerfulness which contributes to good digestion, general well-being, and efficiency. A gloomy mess room is opposed to general companionship, as it tends too much to cause separation of members after meals, and thus does not facilitate amusements in common. Lamps should always be placed *vertically*, as there is much loss of light with horizontal bulb, and *over* tables not only with regard to illumination at meal, but also with reference to position of tables when the mess table has been cleared and secured. The prismatic pendant ball may be considered a suitable design for the globe, within which there should always be a reflector, as it facilitates the general distribution of light. The stalactites are a good form of the modified prismatic globe to throw much of the light directly downward, and they may be placed with reference to tables when cleared. It is not *essential* for the globes to be uniform, but advisable for them to be harmonious. All such globes should be from the deck above and arranged in a line corresponding with the mid-length of the table when set, and at distance from each other determined by distribution curves to secure a fairly uniform table surface illumination of at least 1.5-foot candles.

In the wardroom country, especially of large ships, there are often additional tables that may be denominated side tables. On such tables the illumination should be as good as on stateroom desks as, with sufficient illumination, they are utilized for reading as well as for other purposes, and it is about such tables that members of a mess tend to gather. This result can be accomplished with a bowl reflector over each table. Officers' quarters and the offices of a ship are good locations in which to determine the usefulness from a service point of view of the Tungsten, as the relatively small number employed would permit more or less loss from brittle filaments without greatly increasing money expenditure, and the improvement in illumination secured would be marked. The 60-watt Tungsten lamp and a bowl reflector with "satin finish" over side tables would give excellent illumination. However, the Gem promises to be more or less suitable for a naval service, as it is a low watt lamp that can be used wherever the ordinary carbon filament is used.

The only tables available on a ship for the use of a crew in playing checkers or other games and in reading or writing after dark are the mess tables which, folded, are carried overhead when not in use. There are locations on large ships in which a few such tables can be made available for the purpose indicated, and on some ships cargo lights without the wire protection are being utilized overhead for that purpose—four 16 c. p. lights under a large metal reflector having its inner surface painted white. Such a fixture has the advantage of overhead filaments, but the glare, also in connection at times with the exposed filaments of side lights common on ships, is objectionable and the light requires softening, especially with 64 candle-power and lamps placed under an opaque reflector at an angle of perhaps 45 degrees to the vertical. With suitable globes for bulkhead lamps the amount of diffused light about the deck would be increased, but, as a mess table provides room at meals for 16 to 20 men, the light from a single overhead cluster, if brought down too much, will not illuminate a sufficient area. There is also in crew spaces more danger of breakage of special glassware placed overhead, and thus the tendency is to use metal reflectors for the purpose indicated.

The four 16 c. p. lamps now employed, having carbon filaments, consume at least 200 watts. If two 100-watt Gem lamps, six feet apart and each under a bowl type reflector, were used over each table a more even illumination would be obtained. The diameter of shade would only be 6¾ inches and the over-all length of lamp and socket about 8 inches. The fixture would therefore be fairly well out of the way of injury if a limited part of the deck were selected for reading purposes and the fixtures given a fair clearance with reference to stowing of mess tables. The effect of concussion from gun-fire on such a shade would probably necessitate its removal before target practice, but with a suitable shade holder that could be done, especially as there would be only a few such shades to be removed.

The arrangement of a limited number of tables for reading, writing, and games should be made as much a part of the routine, at least in port, as the placing of lights for a band.

In sick-bays, glare under artificial light is, as elsewhere, an objectionable feature, but in that location there is more control as with men in cots the degree of general illumination can be diminished as required and with side lights from any direction that may be desirable. Shapes of sick-bays and the relative positions of cots vary on different ships, but as a general rule cots are placed fore and aft and are occupied with the head forward. Lamps on a forward thwart-ship bulkhead are thus entirely out of the field of vision in the majority of cases. But a number of overhead lights in the care of the sick are as valuable here as elsewhere and they should never have exposed filaments to meet the gaze of men lying on their backs. The same is true of lamps on an after thwart-ship bulkhead or in any position that would cause the brilliant filament to be in the line of vision of patients. The prismatic pendant ball with reflector is a suitable globe for overhead lamps in sick-bays and, at least on after bulkheads, frosted lamps are desirable in the absence of special covering of prismatic glass. White paint for side walls, as elsewhere, should be abolished and even the deck overhead tinted with yellow. The general effect, should, however, be decidedly light.

In every sick-bay at least one movable lamp is essential and it should be usable at any cot. It should be provided with shade and reflector and utilized also as a desk lamp or as a night lamp when desired, at which time the illumination may be made especially dim by using an outside paper shade. The small degree of illumination in a sick-bay at night necessitates a greatly softened light in the sick-bay lavatory to avoid shock in going from one space to the other. The lamp in the lavatory should at least have its bulb frosted and be overhead. In operating rooms a good working light over the table is required. In recent years the Frinck reflector containing five 16 c. p. lamps has been reported as furnishing a suitable light for that purpose.

It appears from the foregoing that to avoid eye-strain in any system of lighting the following must be given careful consideration: 1. Insufficient illumination: On all ships the load on the dynamos as represented by consumption in watts is generally jealously watched. In a stateroom one 16 c. p. lamp has been allowed, but the tendency at present is to allow two such lamps—one a desk lamp and the other overhead for general illumination. The tendency shown by occupants to subsitute a 32 for the one 16 heretofore allowed is at least *prima facie* evidence of insufficient general illumination. 2. Too much illumination: There is natural tendency to exaggerate in quantity of illumination and this is facilitated by the desk lamp which can be located almost on the work. Under such circumstances heat may also become a factor. Both are eliminated by having a standard and locating the lamp well above. 3. Steady light: The lamp selected should not deteriorate rapidly, and should be considered in relation to varying candle power with varying voltage. Force in dynamo-room should be well trained in that management necessary to secure even voltage. Wide variations on ships are not uncommon. 4. Lamps should be so shaded and so placed as to avoid brilliant points in line of vision and shadows on work: In securing this result elevation of lamps is most important, and then the use of a shade with such diffusive properties that the shade itself appears as the source of light, thus substituting a large area of low intrinsic brilliancy for a small area of high intrinsic brilliancy. Every effort should be made to remove light sources of high intrinsic brilliancy from the field of vision. 5. The general illumination should be by diffused light, and only somewhat less than that of the work itself to avoid marked iris accommodations and retinal shocks: This can be secured by diffusive shades, increased number of separated lamps, at least two, and proper coloring of room and contents, a light buff for walls and no dark woodwork. 6. The light reaching the eye should not result from regular reflection, thereby bringing out the sheen or glare incident to gloss of paper: This requires the lamp, though placed above, to be somewhat to one side—the left, as a rule. It is also very important to abolish desk glare by covering desk with woolen cloth without gloss, tinted green. 7. The illuminated field should be free from streaks: This requirement causes the abolition of *polished* interior surface of shades, unless the lamp has a frosted bulb. An uneven illumination of this character is a fruitful source of eye troubles. 8. Quality of light: Troubles, as a rule, result more from quantity than quality, except as regards softening of light. A large light surface or low intrinsic brilliancy and good general illumination are more important than color of light, except for special work. Colored shades of much intensity are uneconomical, and are apt to be associated with too much iris accommodation incident to loss in general illumination. Any colored shade is, however, much better than a bare filament. The ordinary carbon filament light is much like that from kerosene oil, but its high intrinsic brilliancy makes it a dangerous light in comparison unless it is properly shaded. The higher brilliancy of the new low-watt lamps makes them still more dangerous without shades. They give a much whiter light, and tend to accomplish much good by forcing prismatic glass into general use. It is said that the green light of the Cooper-Hewitt lamp is easy on the eyes, but it is natural to suppose that a longer experience may develop objection in some direction.

In considering the artificial illumination of ships electricity has been regarded as the sole source of light, and the incandescent lamp, so far, as its sole means of expression. While the introduction of electric lighting has greatly improved the condition of the contained air of ships it has not been free from objection in other directions. There are quite a number of men in the service to-day who trace eye troubles to the electric lighting not only at sea, but also on shore as at the Naval Academy where it is believed there is at least five per cent. of acquired myopia. The fact that eye-glasses are more generally worn in the Navy to-day than in old times cannot be ascribed altogether to service conditions, as they are more common on shore where a larger percentage of the people are engaged in near work than ever before, and consequently there are not only more defects acquired, but also more defects declared. There has also been a growing disposition to provide glasses along with increased facilities for detecting defects and increased tendency to ascribe constitutional states to eye reflexes or strains. It does not appear, however, that eye troubles have decreased among the class that in the history of the country always engaged in the pursuit of book-knowledge and burned the midnight candle. At any rate, there is a growing disposition to believe that there is much room for improvement in the character of illumination found in naval services, both afloat and ashore, and that it is a time for the establishment of standards in all navies and for the selection of the best means to secure them. But it should, nevertheless, be clearly recognized that the problem of successful artificial illumination for near work is not merely difficult of solution, but even at this time solvable only in a relative sense. Such illumination might be relatively good or the best obtainable, but there would always be some complaints.

Our service has had relatively little experience with other form of electric lighting than the incandescent lamp, but it is about to enlarge its knowledge, as arc lights, which have been heretofore exclusively used as search lights, are installed on recent ships in engine- and firerooms—two lamps in each engine-room, one for each firing position in boiler-rooms, and a number, 12 or more on a big ship, in coaling-rooms. It seems likely in view of experience in other navies that these lamps will be the cause of trouble from time to time. As a rule, in other navies the accidents have followed attempts to vary or rectify the distance of terminals in search lights while current is on, and it seems that in the French navy goggles of a very deep blue color or almost black glass are provided for such work, although the light itself is very rich in blue and violet rays. Cases have occurred of electric amblyopia associated with a number of symptoms, including marked photophobia, conjunctivitis, and cephalalgia in men who have neglected to utilize the goggles. As a rule, the trouble becomes manifest some hours after the work has been completed. Generally such cases end in recovery, but not always, and even from testing or long exposure to bare filament lamps, incurable cases of amblyopia have apparently resulted. Arc lamps used for general illumination are swung well overhead and provided with opal globes.

In our service considerable attention has been attracted of late to complaints of dimness of vision among men working in dynamo-rooms. It appears that the trouble results from continuous exposure to practically the same conditions that are present in crew spaces. In view of the length of time men working in dynamo-rooms are exposed to electric lights, it seems very advisable to greatly soften the illumination in such spaces. This can be accomplished by the use of prismatic glass in the form of globes. A sufficient number of globes should be used to obtain an even general illumination, but the candle-power of the lamps employed within the globes should be sufficient to secure only a rather low general illumination. This would require the use of local lights for special illumination in localities where work might be required from time to time. A suitable local or portable light may be obtained by the use of a Gem lamp in connection with a metal Holophane reflector having a matt interior surface. Such a fixture is only intended for use while work is in progress, the eyes being commonly under the influence of only the very greatly softened light of the general illumination.

In concluding this chapter, it seems to be advisable to note the rapidly growing disposition to believe that artificial illumination in the naval service, afloat or ashore, can be greatly improved. To those who live on ships it is quite apparent that the subject is well worthy of exhaustive investigation.

CHAPTER IV.

THE SHIP'S WATER SUPPLY AND DRAINAGE.

A ship is literally a floating habitation, and thus is in contact with an unlimited amount of water. The fact that the water is ordinarily salt and, as in harbors, otherwise unfitted for drinking or cooking, does not prevent it from forming an important part of the water supply, inasmuch as it is suitable for flushing and fire purposes, is ordinarily used with sand for washing open decks, gratings, and the like, and is employed to clean outside paint work and to a certain extent in scrubbing hammocks and even, at times, clothing in connection with salt-water soap. Salt-water baths, especially shower baths and swimming, are common, and by the use of special apparatus this water from over the side is distilled, made free from salt and other impurities, and stored in metal tanks for drinking and cooking and all other purposes for which it is not suitable in its raw or natural state. It is thus made to complete the water supply.

It serves not only all the requirements of the ship as a floating mechanism, but also all the requirements for water of the men as living machines, carrying away from them all their solid and liquid excreta properly committed to its charge, taking away from the surface of their bodies and from their clothing the accumulation of excretions from their skins, and supplying the body with the liquid necessary in its multitudinous chemical processes, in ridding itself of its incompletely oxidized waste products, and in regulating temperature by evaporation of perspiration. Air and water are the two greatest friends and the two greatest enemies of naval life.

This water from over the side if considered as sea water has a composition that varies more or less and, if considered as harbor water, that varies very greatly, especially as it is the harbor which receives the solid and liquid excreta of the population on its shores and the water and refuse of the river that may empty into it. The analysis of sea water may be considered as no more fixed than that of river, well, or spring water. It not only varies in different seas and oceans, but also at different depths and in different parts of the same ocean and at different seasons. In accordance with chemical composition, drinking water may be divided into pure, usable, suspicious, and impure, and, from the point of view of domestic and boiler economy, into hard and soft. But such divisions cannot be made in the case of sea water, as it is never potable and always an example of an extremely hard water. Consequently, from a hygienic point of view, variations in its chemical analysis are, as a rule, of little importance, its relation to the water supply as a whole depending upon certain general characteristics always present in marked degree except in the neighborhood of such great rivers as the Amazon and Mississippi.

Its chief distinction is its well-known saline character. The inorganic salts in the water over the side of a ship on the Atlantic may be considered to average 35,900 parts per million, or about 2,096 grains per U. S. gallon, on the Mediterranean 39,200 per million, on the Pacific 34,700, in the Black Sea only about 17,650, and in the Baltic even less. In contrast with this enormous saline content, sea-water frequently contains less organic matter than potable waters, but in connection with it the hardness is very high, being on the Atlantic about 6,652 parts per million, of which the permanent hardness is 6,157. Multiplying these figures by 0.0584, they are found to correspond to 388.5 and 359.5 grains, respectively, of calcium carbonate per U. S. gallon, or multiplying by 0.07 to 465.6 and 431 degrees, respectively, on the Clark scale. It is generally considered that a total hardness in excess of 300 parts per million unfits water for domestic purposes, and the total hardness of sea water is 6,652. A water to be considered soft should not exceed 150 parts.

As the carbonates of sea water are only in small amounts and free carbonic acid perhaps the exception rather than the rule, the permanent hardness is a very large percentage of the total hardness. This shows that the water is dominated by chlorides and sulphates which especially as chloride of magnesium and sulphate of calcium render a water very unsuitable for use in a boiler. The higher the permanent hardness, the more objectionable is the water. Yet it is a matter of common knowledge that a water may be too pure for steaming purposes. A pure water, especially when rich in dissolved oxygen and free carbon dioxide, has a corrosive action on iron which is increased by the presence of chlorides. This corrosive action is manifested in greatest degree where the gases are longest in contact with the plates, that is, at the water level and in the neighborhood of the feed. In view of the effect of the heat in driving off gases, it is also quite conceivable that such corrosion might be most marked in cold boilers in which the water is kept and thus in boilers not in constant use. But a really good steaming water should not come within the class of hard waters and if practicable should have a permanent hardness perhaps not much above 50 parts per million, or 3.5 degrees of Clark's scale, while sea water declares its marked unfitness for such purposes in a permanent hardness of 6,157 per million or 431 degrees Clark.

This lack of fitness for steaming purposes is, from a practical point of view, the most serious characteristic of sea water, for the amount of fresh water available for issue to the personnel of a ship depends chiefly upon the demand for feed water or make up feed in the boiler-rooms. This demand varies greatly, but it is not unknown, especially if there are some leaking tubes, for the boilers of a big ship to take away from the men perhaps one-half of the output of the distilling plant. The unfitness of sea water for drinking and cooking has been overcome by the distiller, but its unfitness for steaming purposes throws a burden on the fresh-water plant that deprives it of much of its usefulness from a hygienic point of view, as it diminishes the issue for washing clothing, persons, and mess-gear.

It is, then, in its saline content that the hygienic objection to sea water is found directly and indirectly. Of the 35,900 parts per million in the water of the Atlantic about 28,032 are sodium chloride, 791 potassium chloride, 3,341 magnesium chloride, 2,191 magnesium sulphate, 1,412 calcium sulphate, 75 magnesium bromide, 50 calcium carbonate, 5 ferrous carbonate, 2 magnesium nitrate, and the very small remainder, chiefly ammonium chloride, with traces of magnesium carbonate, lithium chloride, and silica.

This analysis declares the sources of difficulty in using sea water in boilers or for washing the bodies and clothing of men or for general cleaning purposes. The hardness of water removed by boiling is its temporary hardness. This temporary hardness is due to the carbonates of calcium and magnesium which, probably present in the water as bicarbonates, and therefore is soluble form, are precipitated by heat. In sea water there is practically no carbonate of magnesium, and consequently the deposition on simple boiling is almost entirely carbonate of calcium. But as the amount of carbonate of calcium in sea water is relatively small the temporary hardness is small. In other words, the hardness that is not removed by simple boiling, or the permanent hardness, is not much less than the total hardness which is the sum of the temporary and permanent hardness.

Permanent hardness is caused, as a rule, by the salts of magnesium and calcium other than the carbonates, such as the chlorides and sulphates, which are soluble as such in water and are, therefore, not thrown out by simple boiling. As the amounts of magnesium chloride and sulphate and of calcium sulphate in sea water are large, the permanent hardness is high. There are waters in which the total hardness is three times the permanent hardness. Such waters are of course greatly softened by boiling and thus often made applicable to household uses. But, as has been shown, there can be but little change made in the hardness of sea water by boiling. Permanent hardness can, however, be reduced by chemicals, such, for instance, as washing soda or sodium carbonate, for both the sulphates of calcium and magnesium are decomposed by it, insoluble carbonates of calcium and magnesium being formed and sodium sulphate taking the place of the original sulphates in solution:

$$CaSO_4 + Na_2CO_3 = Na_2SO_4 + CaCO_3$$

It is in part some such reaction as this that occurs when the special soap known as marine or *salt-water soap* is used on ships in connection with salt water or harbor water in washing clothes or hammocks. *Salt-water soap* is made of palm- or cocoanut-oil and soda. It is then a hard soap, as in a soft soap potassium is the base in combination with the fatty acid. If any particular sample of marine soap is made from palm-oil it is then, so far as the genuine soap in it is concerned, chiefly sodium palmitate, and if made from cocoanut oil, a mixture of the sodium salts of a large number of fatty acids, including cocinic and oleic. Usually, after the saponification, sodium silicate is mixed in with the product. But a cocoanut-oil soda soap has the power of forming a firm mass even when mixed with a rather large percentage of water, especially in the presence of various alkali salts. It thus happens that a salt-water soap may contain only 15 to 20 per cent. of soap, 80 to 85 per cent. of the mass being water, silicate of sodium, and extra alkalies.

In our service such soap is made from pure cocoanut-oil. It is entirely soluble in both sea water and fresh water, makes a fairly good lather and is free from fillers. The bars weigh three pounds each and must contain the following: Carbonated alkali (equivalent to Na_2CO_3), between two and three per cent.; free alkali (equivalent to NaOH), not more than 0.50 per cent.; salt (NaCl), not more than three per cent.; mineral matters, including silicate of soda, sulphate of soda, etc., not more than 0.05 per cent.; water, not more than 55 per cent.; and the remainder, cocoanut-oil combined with the proper amount of alkali to form a neutral soap. The alkalies soften the sea water as washing soda. In some *salt-water soaps* the silicate or water-glass has been added for its well-known detergent properties.

There are two other soaps used on our ships, one a soap powder for use in dish-washing machines and the other a fresh-water laundry soap. The powder is a uniform mixture of soap and soda-ash. It is freely soluble in luke-warm water, and shows on analysis not less than 25 per cent. of anhydrous soap, not less than 45 per cent. of dry sodium carbonate (Na_2CO_3) and not more than 20 per cent. of moisture. It is free from rosin, caustic alkali, and all inert fillers. The original package is a carton containing not more than four pounds of the powder. The laundry soap contains not more than 25 per cent. of rosin, not more than one-half of one per cent. of free alkali (NaOH), not more than one-half of one per cent. of mineral matter, not more than one-half of one per cent. of carbonated alkali (Na_2CO_3) and not more than 28 per cent. of water, the remainder being strictly neutral hard tallow soap with the necessary alkalies to neutralize the rosin. This laundry soap is in 12-ounce cakes. Toilet soaps are not issued on our ships, but are kept in the canteen.

A calcium or magnesium soap is insoluble, and as all calcium and magnesium salts in water undergo double decomposition with either a sodium or potassium soap, the resulting insoluble soaps are useless. The hardness of water for domestic purposes is objectionable chiefly in that way and in the additional work and in the delay required.

This action in the formation of insoluble soaps is utilized in determining the degree of hardness, total, temporary, and permanent, as soap has to be added in varying amounts to different waters until the magnesium, calcium, barium, iron, or aluminum that may be present have been taken up as bases by the fatty acids, and there is then sufficient soluble soap present in solution to form a lather. For this determination of hardness a standardized soap solution is employed. The solution may be made in a number of ways, but its object is to ascertain the amount of soap destroyed by a given volume of water before a lather is obtained, and thus before the detergent properties of the soap become available, and to express that amount in terms of calcium carbonate that dissolved in the same amount of water would destroy the same amount of soap. The method that has seemed most available under ship conditions will be given in sufficient detail when water analysis on ships is considered.

While *salt-water soap* has done much to overcome many of the objections to sea water for such domestic purposes on ships as the individual washing of clothes and hammocks, there is found in the magnesium chloride content an additional and important limitation depending upon its hydroscopic property or its tendency to deliquesce or become damp in moist air. Sea water contains 3,341 parts of magnesium chloride per million, or of the 2,096 grains of salines per U. S. gallon 195 are magnesium chloride. It is chiefly this constituent that keeps a common or unrefined table salt so damp in the tropics that it cannot be used unless put in the oven from time to time to dry, and it is chiefly due to this constituent that clothes wet with sea water may never become entirely dry and remain under the influence of atmospheric humidity.

The health of men depends in no small degree upon dry clothing, and if clothes, however well cleansed by use of *salt-water soap*, are not finally well soaked and rinsed in fresh water instead of sea water before being put on the lines, the hygienic requirements of clothing cannot be maintained. Therefore, while the use of salt-water soap has made it practicable to wash clothing with more or less success in sea water, it has not diminished the necessity for fresh water, at least in the final stage of the operation. This is a subject of considerable importance and its consideration clearly demonstrates the advantage of as large an issue of fresh water on a ship as may be practicable for washing clothes.

In the old days, when tons of sea water were used almost daily between decks in washing down, the wood remained more or less perceptibly wet all the time, especially in locations where the deck was decayed or where the air movement was least. This tendency to continued dampness, while in great part the result of prolonged soaking in water, rotten wood, and deficient ventilation, was also facilitated by the magnesium chloride in the water employed. In the tropics high relative humidity is a constant enemy of health and continued dampness in quarters is objectionable even when not visible as water. Ventilation will apparently dry a deck that has been wet with sea water, but there always remains a greater tendency to dampness, inasmuch as magnesium chloride absorbs water very rapidly from the air itself. When sea water is used for cleaning surfaces between decks there tends to result, though in less degree, a condition which from a practical point of view is not in some respects essentially different from the retention of water by sweating of metal. The influence of one, however, is at its maximum under damp tropical conditions and of the other in cold climates.

The hardness or saline character of sea water makes it unsuitable for cleaning the skins of a crew. Salt-water bathing has its advantages, especially in hot weather, inasmuch as cleaning is only one of the objects of bathing, and, apart from that, sea water has all the advantages of any other slightly cold bath. Cold water, as a short bath, stimulates metabolism, exercises the involuntary muscles of arteries controlling skin circulation by contraction and subsequent relaxation, thus educating the body to protect itself against the effects of variations in air temperature, reduces the sensation of heat in hot climates, and produces a feeling of well-being.

In swimming there is considerable exercise without, in the tropics, the distressing effects of increased production of heat, inasmuch as the cool water abstracts heat from the body. Apart from the movement of arms and legs, there is an increased action of the respiratory muscles directly incident to the pressure of the water upon the thorax which must be counterbalanced by increasing the pressure within the lungs, unless the swimmer is on his back. It is a form of exercise in the open that undoubtedly strengthens the organism and at the same time cultivates an art especially useful to the sea-going class. But it is an exercise not available when a ship is underway and that should not be permitted in dirty water or where the temperature of the water is below 70° F. If a crew has not been indulging in bathing over the side the first swimming exercises should be short, not exceeding ten minutes, and at no time should they exceed twenty minutes.

For bathing, salt water is largely used on ships as shower baths, and crew's lavatories are provided with salt water only, but in the lavatory for firemen there are, on large recent ships, both salt and fresh water. Each shower-bath inclosure for enlisted men is fitted with an 8½-inch tubular shower with removable top and universal joint for ¾-inch inlet connection supplied direct with salt water from a brass heater as shown in the plate on page 355.

The heater consists of a polished brass outer tube with copper inner tube, composition head castings arranged for steam connection and water inlet, and composition bottom castings arranged for outlet connection and drain. It is designed to stand a pressure of 100 pounds per square inch and to be capable of raising the temperature of water from 45° F. to 105° F. at the rate of not less than five gallons per minute with a steam pressure of not more than 25 pounds per square inch. In officers' quarters there is also such a heater in each bathroom, with controlling cock when supplied with fresh and salt water (page 356). There is also a distributing cock for distributing water from heater to the different fixtures, such as lavatory, shower, or bath and shower.

The flooring in shower-bath inclosures is tiling laid in cement with slope to prevent standing water, and there is a drain for each group of not more than four shower baths. *A tiled, or a stone and cement, floor is found also in crew's heads, all water-closet spaces, bathrooms,* and *washrooms* and also in *galleys, bakery, laundry, operating-room* and *at scuttle butts.*

On a ship the shower bath is to be greatly commended from a sanitary point of view and the tub bath condemned. The same is true at all training stations. The shower bath permits a much larger number of men to bathe, as it requires less time, takes less room, and therefore in an equal space allows a greater number of fixtures, carries soiled water directly from the bather and thus leaves none of his products to influence the health of his successor. It requires less water and greatly diminishes or avoids the danger of communicating skin or other diseases. If it be true that at each bath millions of micro-organisms are removed from the skin, the increased advantage of the shower bath, wherever there is concentration of men, becomes quite apparent.

The concentration on ships is, however, so great that even the number of showers is insufficient, and the supply of fresh water is so

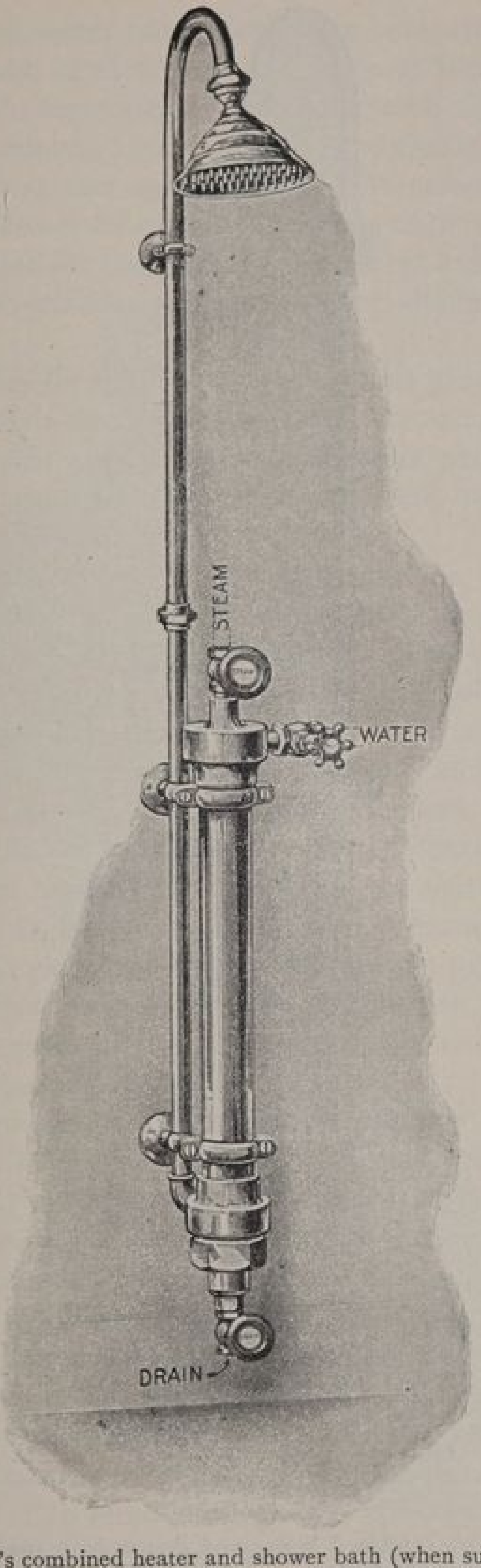

FIG. 36.—A ship's combined heater and shower bath (when supplied with one kind of water only). (Jenkins Manufacturing Co.)

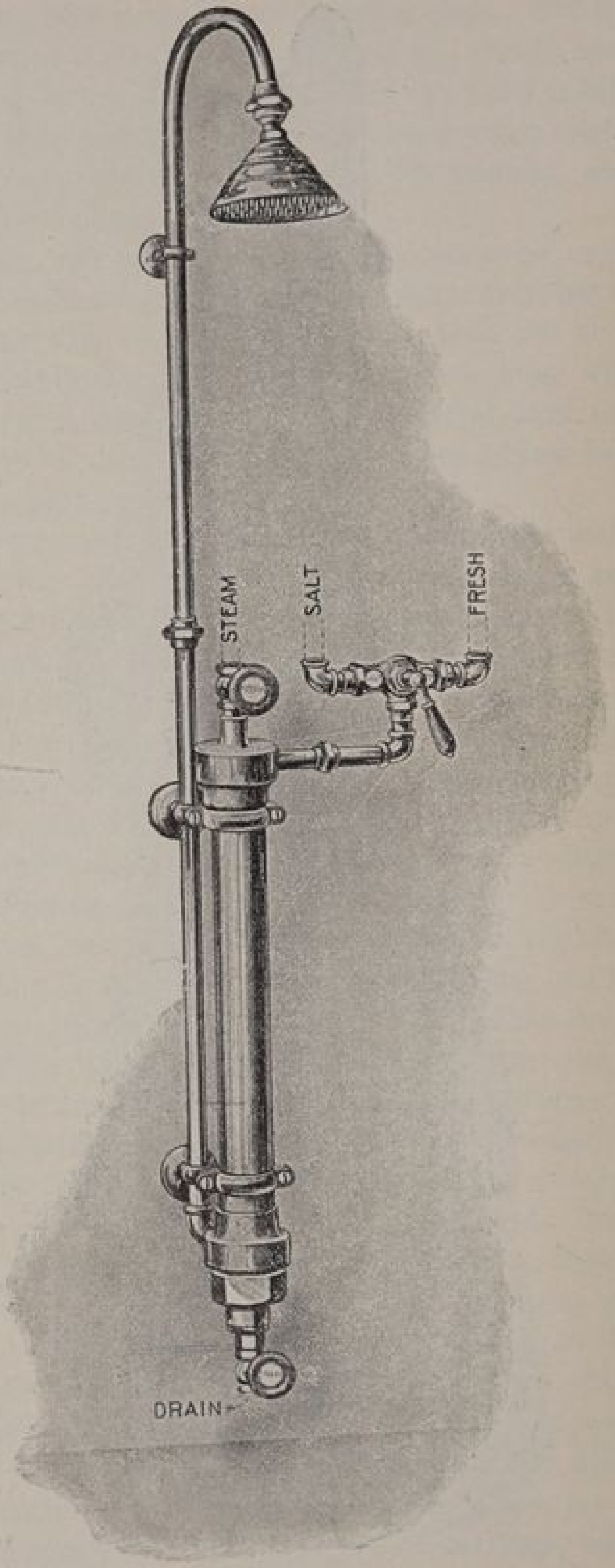

FIG. 37.—A ship's combined heater and shower bath (when supplied with fresh and salt water). (Jenkins Manufacturing Co)

limited that only salt-water connections have been available for crews. From a sanitary point of view there should be at least one shower for every 20 men, and in lavatories one basin for each eight men. Those numbers should be minima at shore stations and should be approximated on ships to the extent that space permits. At present on large ships there is perhaps a shower for each 40 or 50 men of the enlisted force, but the division into those for deck force, for engineer force, for chief petty officers, and for mess attendants, while necessary, diminishes the facilities somewhat.

In the lavatories for firemen and crew there are cast-iron roll-rim tip up basins, porcelain-lined inside and over the rim, and painted exteriorly. These basins are 13 inches in diameter and 6½ inches deep, and have 3/4-inch trunnions, with stops to prevent basin from tipping backward, as shown in plates on the next page.

These basins are arranged over a trough, the trunnions resting upon composition bearings secured to the sides of trough and arranged with stops for holding the basin in position. The basins are spaced about 22½ inches center to center. A 3/4-inch polished brass self-closing faucet is provided for each basin. Each trough is made of galvanized steel plate and is about 18 inches wide and 8¾ inches deep, at high end, with slope of about 1/4 inch to the foot toward the drain opening. The basins are arranged to tip in the direction of the length of the trough. The longest trough contains not more than six basins, and all rivet heads on inside of trough are countersunk. Each trough is fitted with a brass strainer equal in area to drain pipe. A brass S or half S trap is provided, fitted in the manner shown on page 358.

The height of trough from deck is about 30 inches, and the complete lavatory has the appearance given on page 361.

Whenever a lavatory or shower-bath inclosure is situated near the water line, as on a berth deck, it drains into the cylinder of a sewage discharger, generally located in the engine-room, which, as it fills, automatically empties its contents overboard by steam pressure, the steam also acting to sterilize the cylinder. Otherwise the discharge is directly overboard by gravity through scuppers. The trough plan has been found more sanitary in crew's quarters than stationary basins with separate piping.

The men on a ship who are most frequently in need of washing, for the removal of excretions and foreign matter from skins, are members of the engineer force. This receives recognition in the increased permanent facilities provided, the number of basins in their lavatories tending to approximate one to eight men on recent ships, and in the modern large ship there are often both fresh- and salt-water connections controlled by

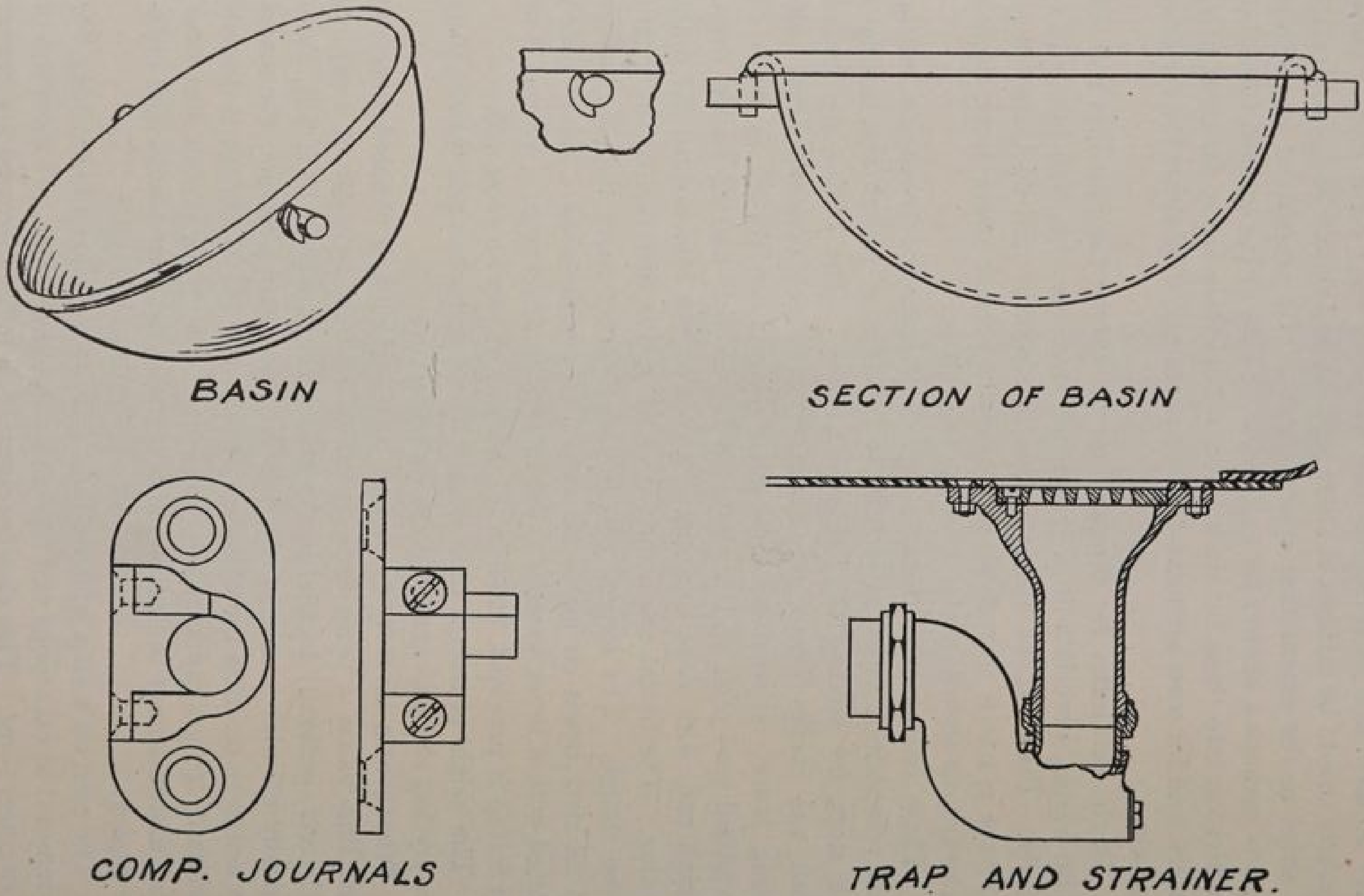

Fig. 38.—(Jenkins Manufacturing Co.)

self-closing brass faucets. The fresh water in these lavatories is frequently from copper gravity tanks with inner surface thoroughly tinned and ordinarily with a direct supply from distiller pumps, thus avoiding the necessity for ripening or aerating water not used for drinking. The same is true of the fresh water supply for chief petty officers' washrooms and for laundry. In a firemen's washroom the capacity of such a tank on a big ship may be about 500 gallons, and in the laundry, when one is provided, not less than 200. All such tanks are fitted with overflow pipe and placed as nearly flush with lower edge of beams as practicable in order not to interfere with head room. Outside of the physical advisability for gravity tanks in the distribution of some of the fresh water on a ship, they also, with known capacity, afford means of grading or limiting the supply for various purposes or to different parts of a ship.

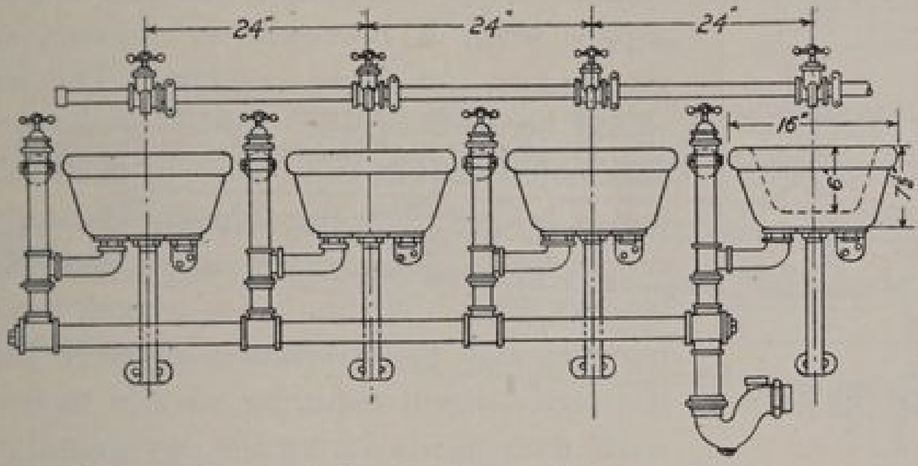

FIG. 39.—Lavatories for Chief Petty Officers. (Front view.)
(Jenkins Manufacturing Co.)

The deck force is not as liberally supplied with fixtures as the engineer force, especially as the latter washes more frequently in watches; and such fixtures as are provided have no fresh-water connections, though in neither case is fresh water supplied to showers which are also limited for each on account of difficulty in providing room.

Crew's lavatories should not be placed in heads, but in separate inclosures. Such a situation not only leads to uncomfortable crowding, as a rule, but places the bather in surroundings sufficient to produce even some sense of disgust. It is also not sanitary. The head is itself, with difficulty, kept often in only moderately good condition and a washroom, if used, is a damp or even a wet place. The combination facilitates the dissemination about the ship of very undesirable material, diminishes the tendency to bathe, and is opposed to the cultivation of habits of cleanliness in general. A head would not be selected as a place for washing clothes and it should not be selected as a place for washing persons except perhaps for ablution of hands.

There is certainly not sufficient washing of hands on ships. There is plenty of soap and a man has his towel, but it is not at hand on leaving the stool. All persons should also wash their hands before meals, but the washing of hands after stool is the A. B. C. of personal cleanliness and decency. And yet, in view of the concentration of men and the general situation on a ship, the difficulties in the way of this apparently simple hygienic measure have never been overcome.

A reasonable cry has been raised by naval sanitarians against the use of drinking cups in common at the scuttle butt, and the same cry would be properly raised against the use of toilet articles in common, especially towels which have been credited with the dissemination of diseases, more often, perhaps, certain forms of conjunctivitis. The service supplies water-closet paper and on a ship it might supply soap, if necessary in fixtures, such as granulators, for hand-washing. The difficulty would be with towels. Roller towels would be most objectionable, and the use of small individual towels belonging to the ship would require large supplies, difficult and close control, and continuous laundry work. A ship is not a hotel, but a floating fort and the innovation of freely supplying the material and requiring all men to frequently wash their hands during the day would probably invoke criticism. Yet men who wash their hands after stool and before meals are none the less manly and might be expected to be more efficient, and fecal matter is commonly regarded as the most concentrated and dangerous of man's excreta. *A ship's laundry could not be better employed than in the constant washing of towels, including dish cloths, if its entire capacity had to be utilized for that purpose.*

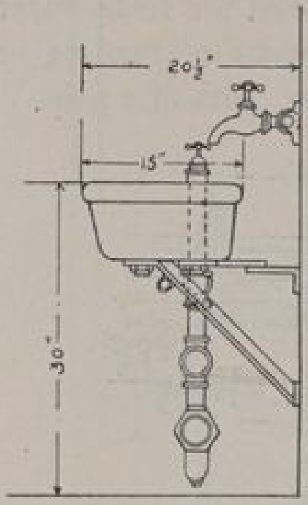

FIG. 40.—Lavatory for Chief Petty Officers. (Side view.)

Apart from the water that has to be furnished for drinking and cooking, the chief object of the ship's fresh-water supply is to separate men from their solid and liquid excreta and thus prevent personal and ship pollution. Salt water carries the fecal matter and urine overboard that is entrusted to it, and fresh water and effort cannot be expended to better advantage than in primarily attacking the filth on board where-ever it may be in most concentrated and dangerous form. The hands of men are those parts of their bodies going to mouths and most apt to contaminate the majority of articles touched, including food, and towels while utilized to remove water from surfaces of bathers are, with clothing, the great retainers of the surface excreta of a crew. Damp dirty towels placed in lockers are directly opposed to the essential requirements of removal of excreta from a ship and, when reapplied to the bodies of men, not only defeat the cleansing office of the bath, but return to the body excreta more dangerous on account of incubation in the locker. Soiled hands at meals, and at scuttle-butts particularly, and dirty towels and dish cloths menace the health of crews. A laundry that did nothing except wash towels would amply pay for the space allotted to it, and ships in which soap and clean towels were as freely available as toilet paper would mark a navy that had cast certain undesirable traditions aside and had made a long voyage in the direction of preserving health in peace and in diminishing the effects of wounds in war.

The lavatories for dispensary, chief petty officers, and mess attendants are installed on a more liberal basis as regards space than in the case of those for crew. The lavatory is all porcelain vitreous-glazed (white) inside and out with roll rim rounded front, and flat back and bottom and with soap cup moulded in right-hand corner and with combined standing waste and overflow at left-hand outside of basin. The basin except in dispensary, is about 15 by 16 inches by 6 inches deep, and spaced about 24 inches center to center. In the dispensary there is a single basin 19 by 20 1/2 inches and 7 inches deep. The cuts on pages 359 and 360 show the arrangement for chief petty officers.

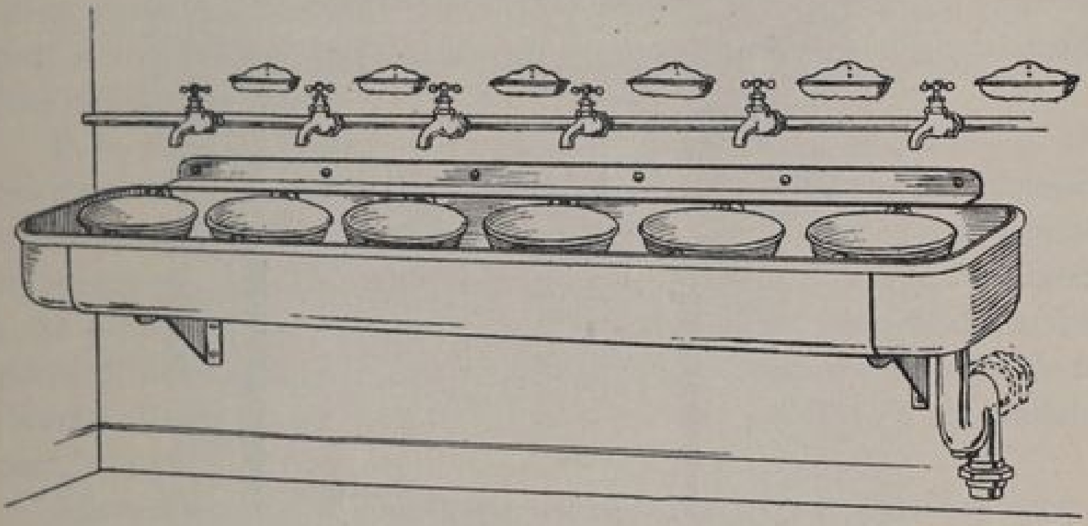

FIG. 41.—Lavatory for firemen and crew. (Jenkins Manufacturing Co.)

The lavatories for officers, sick-bay, sick-bay bath, and operating-rooms are not unlike many found on shore and are sufficiently inidcated by the illustration on the next page.

For each stateroom, stationary basins of whatever type should have no place, in view of the small air space and the chance of air contamination, should there be connection with a fixed discharge pipe. Permanent stands are also undesirable as they are difficult to keep clean. Many such stands have been tried and abandoned for rings with wash bowl, ewer, and waste jar. The wash bowl is, however, provided with plug that it may be emptied without removal from its supporting ring, the waste jar being placed in its ring just below. The ring for wash bowl is also hinged that it may be placed out of the way against bulkhead.

In warm weather there is a good deal of bathing on the open deck during the morning watch or the period devoted to clothes and deck washing. Naked bodies are then very much in evidence and deck buckets are employed to hold the water required. It is at such times that too much limitation in the supply of fresh water leads to very insanitary habits, such as the utilization of the same small amount of water by different men, perhaps not only in washing clothes, but also their own bodies. There are also weather conditions during this period, not only in regard to bathing, but also even more prominently in washing clothes and decks, which produce large sick lists in cool climates and are very detrimental to crews. Under such circumstances there is probably no factor in naval life more productive of general bad health or more

FIG. 42.—Lavatory with integral bowl. (Officers, sick-bay, etc.)
(Jenkins Manufacturing Co.)

powerful in causing that frequent and persistent coughing on the decks at night during cold weather.

So long as the climate is such as to permit this work to be done with comfort in bare feet it ceases to be a detriment and usually is a gain. It is then a period of cleaning clothes and bodies by men in good spirits who are starting the day in a manner to be followed by a sense of well-being, particularly if it has been practicable in clean water to arrange on the upper deck temporary showers under which men may use some soap, and subsequently with a fresh-water allowance free bodies from salt. A hose may also be arranged to take soap from bodies or at least to afford the advantage of a short salt-water bath. But in cold or even cool weather the conditions are changed. The amount of open-air bathing is naturally greatly limited, and in the work of washing clothes and deck those men are well provided who have rubber boots and not a few will probably be found injuring shoes in salt water, which may or may not be kept on after the work is over, and with clothes more or less damp as an incident of conditions under which the work has to be done.

It is along such lines that water is to-day a direct enemy of the general good health of crews. During the period of bare feet the deleterious influence of water on health is least, and during cold or cool weather the benefit of a laundry would be greatest. In warm weather a limitation in the supply of fresh water for bathing leads to the greatest discomfort and in all weather the relatively small amount of fresh water available for a laundry limits its use even if the capacity were not limited by available space.

Salt-water soap is very frequently or perhaps quite generally used in bathing, and under the shower the cleaning power of salt water is increased by heating. But the warm bath should always be followed by the cold shower. Too much of any soap tends to diminish unduly the oily condition of the epidermis, covered as it is by sebaceous secretion, and of course the more free alkali the soap contains the greater the action. To secure the cleansing effect with salt water the tendency is to use a great deal of soap, and some skins, especially if water is not used freely to take off all the soap employed, show signs of irritation.

In recent years there has developed a tendency to utilize the same pump for the flushing system and distiller circulating water, the latter water going into salt-water pipes instead of going overboard from the coils. Such a method may not only possibly cause increased pressure within the distiller coils, and thus increase the chance of leakage of harbor water into the distillate, but also heats the salt-water supply and, as on the Maine and some other ships, furnishes water at the showers perhaps too hot for comfort, especially when cruising in warm waters. This deprives the showers of cold water and leaves the bather without the final cold bath necessary to contract the capillaries and protect him from atmospheric influences. Provision is made at the showers for heating water, and a system that requires the use of only warm or even hot water is to be condemned, *especially as it practically leads to disuse.*

Deck buckets are generally at a premium on a ship as from lack of storage room they cannot be kept out of sight when accumulated in numbers desired by a crew. Certain men assigned to certain parts of a ship or to boats have opportunities of stowing buckets away in odd places when not in use, thus not only relieving the lockers, but also facilitating individual use. There is, however, always considerable indiscriminate use of such wooden buckets, and thus more or less indiscriminate transfer of excretions. It is by deck buckets that fresh water is served out by various petty officers from taps about the decks.

The bath-tub or immersion bath is disappearing from officers' quarters and showers are being substituted. Ships are supplied with portable tubs for officers' rooms—shallow metal tubs frequently stowed in the rooms themselves. The disappearance of stationary tubs except from commanding officers' and other special quarters has not resulted from the sanitary objections which apply to them, but from the desire to limit the consumption of fresh water. A shower bath may expend 5 or 6 gallons of water and a stationary tub 30 or 40, or even more. There is a further tendency to limit consumption of fresh water by having none or only one of the showers in a set of quarters supplied with such water.

This increase in number of salt-water connections only is in contrast with the constant dislike on the part of all hands to using such water in washing persons and even clothes. Many men refrain from using lavatories, preferring to trust entirely to deck buckets and the allowance of fresh water. They are apparently anxious to go overboard into any kind of water however dirty, on account of unusual exercise, demonstration of skill, and the general liveliness naturally displayed, but there is a steady avoidance of the salt-water bath for cleanliness with its subsequent stickiness and the feeling of not being clean. And the term *salt water* as here employed means any water in which the ship is—sea water or harbor water, the one clean and unobjectionable except for saline constituents, and the other frequently a carrier of the filth of large populations.

It is fortunate that the skin is an organ of excretion and only under exceptional circumstances an organ of absorption. It is a living organ that by its nerve connections is readily influenced by temperature, and thus readily influences the body as a whole. It is susceptible to disease, including parasitic disease, and when its integrity is lost either by disease or injury the resulting surface ceases to protect the body and may readily pass material into the circulation. Its protective qualities depend in no small degree upon its sebaceous secretion, and may be overcome in a measure with reference to substances held in solution or suspension by oleaginous excipients, including its own oils, especially when rubbed in. But the living skin even in immersion does not become wet in the true sense as it does not absorb water or watery solutions, and there seems to be no evidence of constitutional disease directly communicated through normal skin during bathing.

However, if a crew indulges in swimming in contaminated harbor water there will ultimately develop a certain percentage of fevers. This is also true at training stations near specially contaminated water. At League Island swimming exercises in the Delaware river have been repeatedly stopped for that reason. In such exercises a certain amount of water gains access to the mouth either directly or in drying the lips. Only some of the men will receive water containing pathogenic microorganisms and of those a number will either be immune or the organisms will be rendered inert by character of stomach contents. Some, however, will not escape, and at times the movement of disease will be quite marked. In July, 1898, the Puritan and Terror, two monitors, were together in the harbor of Ponce. From one ship swimming was frequent during each day, while from the other it was relatively infrequent or absent. The crew that took to the water developed a large number of cases of a continuous fever not influenced by quinine. The evidence is not conclusive, but otherwise the lives of the two crews seemed to be much the same. Under the shower supplied with harbor water there will be a percentage of men whose mouths will receive some of the water employed. As a practical question evidence does not seem to be available of effect on healths of crews, especially as there is a disposition to avoid the showers.

The amount of fresh water available for daily issue on a ship depends upon three factors: 1. Service requirements in regard to fresh water for boilers. 2. Space that has been given to apparatus for making fresh water (number of evaporators and distillers and their actual output). 3. Space that has been given to storage (tank capacity).

The necessity for fresh water in boilers is due to the action, on certain saline constituents of sea-water, of the high temperatures obtained when boiling water is under pressure or much above 212° F. Calcium sulphate requires 500 parts of cold water to dissolve it, but is nearly insoluble in water having a higher temperature than 212° F., as is the case in boilers. It is therefore readily deposited in large quantities from sea-water in a boiler and, with the insoluble products resulting from the decomposition of magnesium chloride at high temperatures, forms a compact incrustation of very low conductivity, and thus, not permitting the heat to pass from the metal over the fires to the contained water, allows the boiler to become red-hot and to collapse at the overheated area. Such a deposit also greatly increases the expenditure of coal, inasmuch as the transfer of heat from the metal to the contained water is limited.

Where magnesium chloride is in water brought to boiler temperatures something like the following reaction occurs:

$$2MgCl_2 + 3H_2O = Mg(OH)_2 + Mg(OH)Cl + 3HCl.$$

The hydrated oxychloride and some oxide formed by further changes set with the calcium sulphate forming a hard boiler scale and the hydrochloric acid, unless an alkali be added, gives the water a corrosive action, some escaping with the steam and ultimately affecting steam pipes, valves, and cylinders. The presence of alkali carbonates would tend to limit this corrosive action, but sea water contains a small amount of carbonates and a large amount of magnesium chloride. Calcium sulphate forms over 70 per cent. of the boiler incrustation from sea water at high pressures, and the magnesium salts perhaps 10 per cent.

The necessity for boiler water causes ships to take on fresh water for that purpose at every opportunity. This water is carried in feed and trimming tanks or double bottoms. The amount of such water that can be carried by ships varies, but a large ship may be allowed to have 100 tons or perhaps more in a designated part of the double bottoms.

There are, therefore, three varieties of water forming a ship's water supply—water from over the side, steaming water,and distilled water. The distilled water may be replaced by water taken on board for drinking and cooking, but the general tendency is strongly against that course except in some emergency, and the steaming water is not infrequently from an evaporator, the water taken on board for that purpose not being sufficient for the voyage.

The sanitary quality of boiler water may not be altogether a matter of indifference. Experience tends to show that fresh water taken on board for one purpose may at times be more or less used for another in view of the concentration of men, their varying duties and opportunities, and the limitation in supply of distilled water. If fresh water in a trimming tank is cooler than that at the scuttle-butt, either from lack of cooling coil or from a break-down in the ice machine, there will be some who will manage to drink it, and also in view of the number of pipes on a ship carrying water and the large number of by-passes or emergency connections and varying pressures, the supply of distilled water may not be, as will be shown, at all times free from adverse influences, although it is the intention to make it so.

The fresh-water system may be in general terms about as follows:

Fresh-water tanks located below the protective deck aft are utilized as ripening tanks, the water coming from the distillers being warm and flat or in need of aeration. Into those tanks the distiller fresh-water pump, or the pump moving the distillate from the distillers, discharges directly and that pump is also connected to the filling pipes for the forward tanks to be used as required. From the ripening tanks water is pumped into tanks under the protective deck forward from which it is distributed into gravity tanks located on the upper deck, and also through the ship's main into various small tanks, and by means of direct connections to all parts of the ship. The fresh-water main may be a 3-inch pipe located under the gun-deck beams. Spaces on or below the berth deck are supplied by direct connection from the main which may be considered to run the length of the ship. The main and tanks are filled by electric-driven pumps, each having a capacity of perhaps 60 or more gallons per minute. One may be located aft with direct connection to the ripening tanks, and another forward with connection to the forward tanks, below the protective deck, and each with a discharge pipe into the main. These discharge pipes have branches which by cut-out valves are operated to fill the gravity tanks. There are numerous relief and cut-out valves and by-passes in the system. Pipes working as a manifold are arranged for filling, through the top, each of the main forward tanks and the after tanks are arranged similarly except that each filling pipe has direct connection to the distiller fresh-water pumps and a by-pass from the main. Suction pipes are also worked as a manifold. The gravity tanks are filled and discharged through a pipe connecting to the bottom of the tanks.

The system is complete in relation to primary and ultimate distribution from distillers, but to take in water from a water-boat a pipe is led across the ship forward under the gun deck and a direct connection is made to the filling pipe manifold to the forward tanks and a by-pass to the ship's main. For boiler water to reserve feed-tanks from a water-boat there are connections from both the port and starboard side by perhaps a 3½-inch pipe, but a *by-pass is often or even generally made to the fresh-water main*, the control being by valve. In all these cases there is of course a hose connection at the side for taking in the water from a boat and, in view of the large amount of boiler water so taken and the pumping pressure, the by-pass to the fresh-water main may be a source of danger, either through carelessness or ignorance or valves becoming inefficient. All these fresh-water systems are more or less complicated with variations on different ships. Each ship is a special study from the point of view of possible water contamination. This by-pass from the filling pipe of reserve feed-tanks to fresh-water main is an emergency connection with little chance of use during an entire cruise, and if it were eliminated and fittings made for hose connections even that emergency could be met.

There might seem to be little chance of contamination of fresh-water supply by harbor water, or water from over the side, in view of separation from flushing system, but such contamination has occurred and may occur more frequently than is supposed. As in the fresh-water system, there is in the flushing system a main, known as the flushing main. It is perhaps a 4-inch pipe and is also fitted under the gun-deck beams and with branches for the salt-water supply of washrooms, shower baths, laundry, pantries, galleys, and other places. There are also branches from this main for flushing all water-closets and urinals. This system is of copper throughout, tinned or sabined, and is supplied by a direct connection from the distiller circulating pump, or the pump sending cold water through the distiller coils for the condensation of steam within the distiller shell, a by-pass from the distiller discharge, and by a by-pass from the fire main. Therefore, not only may water at shower baths be hot, but also the flushing water of the heads, thus causing men, even in warm climates to sit over hot water when at stool. Spaces forward of the forward transverse armor bulkhead may, however, in certain ships be flushed by an independent system supplied by motor-driven centrifugal pumps with direct connection to the forward trimming-tank's sea valve and discharging into a main, supplying all fixtures in the heads, chief petty officers' washroom, and closets, and sick-bay bathroom. That main may, however, be supplied by a by-pass from the fire main, fitted with a cut-out valve. These flushing systems are generally under considerable pressure, which tends to be greater than in the fresh-water system especially at fixtures receiving fresh-water supply from gravity tanks.

This difference of pressure may lead to fresh-water contamination where both supplies find exit at a common nozzle, as for instance at a bath-tub, or perhaps under exceptional circumstances even at a shower bath with both supplies. Under the following circumstances the water served at a wardroom mess table was salt to the taste from contamination by water from over the side. A pantry where the water was taken for the mess was next to a bathroom in which the tub had, as is customary, both a fresh-water and salt-water supply by a common nozzle such as is frequently found on shore for hot and cold water. Either from an inefficient or incompletely closed valve in the fresh-water pipe or from turning on both supplies at once the salt water or harbor water backed from difference of pressure into the fresh-water pipe from which a branch passed through the bulkhead into the pantry. In the mixture, the percentage of harbor-water was in this case so great that the water served at the table gave warning by taste, but it is surely quite conceivable that such contamination may occur without detection, especially as there is no data to show how far salt water may find its way into fresh-water pipes under such circumstances.

The situation in this case is shown in the following diagram:

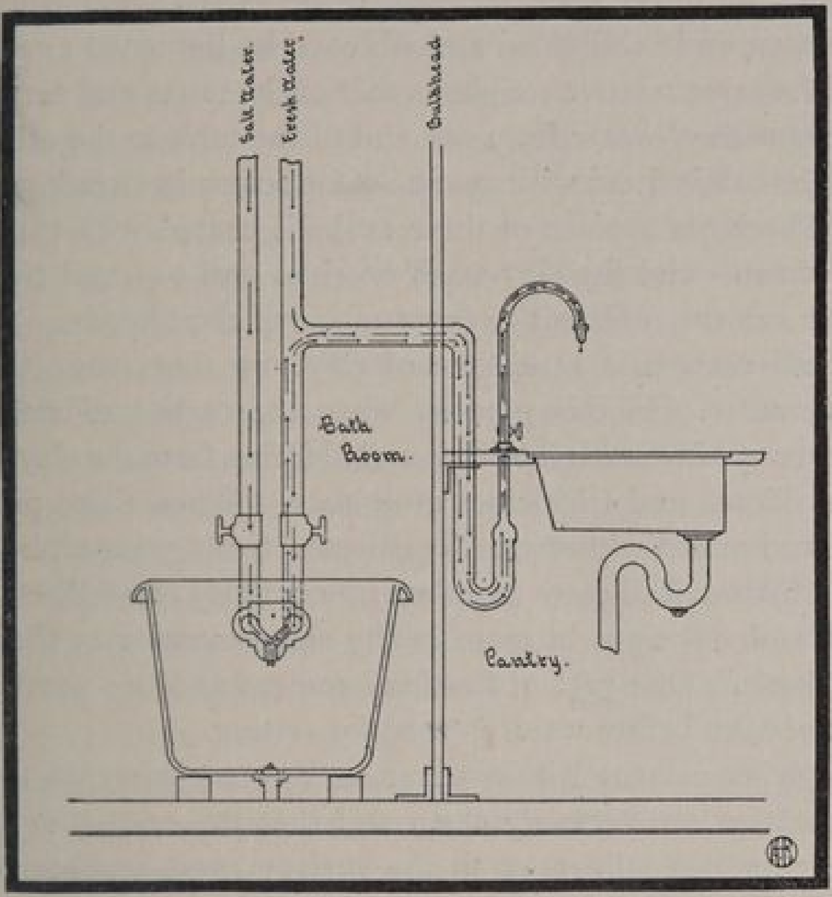

Fig. 43.—Diagram showing method by which distilled water has been mixed with harbor water.

Bath-tubs are in diminished number on recent ships, but they are common in officers' quarters of less recent ships, and are always present in certain quarters and in sick-bays. The tubs should have an independent faucet for each water supply, and *it is safe and best for salt and fresh water never to be delivered through an opening in common.* Tests should be made from time to time on all ships of water drawn from all faucets where drinking water is obtained and comparison made with water in main tanks and as it leaves the distiller. For this purpose the determination of chlorides is sufficient under any ordinary circumstances in view of the very marked saline character of the water supporting the ship.

It is within the distiller, where the circulating water is separated from the distillate by tubes under considerable pressure, that may be increased at times if discharge water goes into flushing system, and at certain fixtures that the fresh and salt water of a ship's supply are nearest, and every reasonable precaution should be taken to prevent contact within pipes. *It is important for the fresh-water system to be free from chance of connection with any other system.*

Fresh-water pipes are made of galvanized wrought iron, and the main tanks, those forward and aft under the protective deck, and also the gravity tanks on upper deck are built of perhaps 12-pound iron plating and angle bars, and subdivided and stiffened by lightened swash plates of plating of the same relative weight as that of the tanks and arranged so as to break the rush of water from one end of the tank to the other in a sea way. Each tank is fitted with manhole for access in cleaning or making repairs. The inner surface of these tanks is coated with three or more layers of cement- and fire-clay-wash on sides and top, and the bottom is coated with cement sufficient to cover taps and rivet heads.

Portland cement is a mixture of clay and limestone calcined at a high temperature. In this process, when the carbon dioxide is driven off, the lime combines with the silica and alumina from the clay to produce tricalcium silicate and tricalcium aluminate. When these products are powdered and mixed with water the silicates, freeing some lime, pass into the soluble hydrated silicates and then immediately crystallize again, thus hardening and setting as a mass in the same manner as the setting of plaster of Paris. One part of Portland cement and two parts of sand is the usual mixture before water is used for setting.

In applying cement within water tanks great care has to be taken that the surfaces are perfectly clean and that the cement is of the best quality as complete adherence to the surface must be obtained if iron rust is to be avoided in the water supply and the water is also to be free from particles of cement. At first such tanks may give the water a slightly peculiar taste and particles of cement may appear later in the cruise if the cement becomes detached to any extent or broken. There is, however, to meet the demand a rather rapid renewal of tank water and the use of cement in avoiding iron rust limits sediment, and with distilled water greatly limits the advisability of cleaning tanks—a process not free from chances of contamination.

These tanks, before cement is applied, are tested to a pressure of 15 pounds per square inch and are required to be absolutely tight under the pressure. The copper fresh-water tanks as in washrooms are tested at 8 pounds, and the fresh-water system of piping is tested to 40 pounds per square inch with fixtures cut off, and to 15 pounds with fixtures in place and small tanks cut out.

The fire main (salt-water fire system), running under the protective deck beams, is tested to 250 pounds with plug caps removed and to 100 pounds with caps on plugs and all valves open, and the flushing or sanitary system is tested to 100 pounds per square inch with fixtures in the various rooms cut off, and 15 pounds with fixtures under pressure. The pressure at the sanitary system terminals is kept down by relief valves set at not more than 15 pounds, this, among other results necessary for the working system, also limiting chance of mixture of waters within pipes at certain fixtures.

The position of manholes on top of tanks has been considered open to criticism. In that position they facilitate tank inspection and access of individuals, especially in view of the small clearances made available, perhaps not more than 18 inches between tanks or bulkheads, but in that position they are considered to facilitate passage of dust or other accumulations into tanks when covers are lifted. From a purely sanitary point of view it is generally regarded as better for manholes to be placed high on the side of fresh-water tanks, and if that be recognized as a sanitary requirement it can doubtless be met. The lock-barred hinged cover, with thumb-screws and gasket, effects a good closure. The cover should stand the test pressure to which the tank is subjected and gaskets should be renewed as the rubber deteriorates. Tops of fresh-water tanks should be respected as much as possible, especially with manholes in that location, *water should never be supplied directly from them*, and *the manhole covers should be kept well in place and never lifted unless necessary.*

The capacity of a ship's fresh-water tanks will vary with the ship, and it is admittedly difficult to state what it should be in view of the innumerable requirements for space in a ship as a fighting machine and the varying output of distillers, representing a varying ability to renew water in a given time. The statement that the capacity should be as great as is practicable, while true, is too general to be of much value.

For the continuance of life a certain amount of fresh water is well known to be necessary, and that daily amount per man is an unquestioned minimum requirement. But it can of course only be regarded as the allowance when circumstances render it absolutely necessary to make it so. It is the water necessary to meet the physiological requirements of the body in its nutritive and heat-regulating processes—to prevent painful thirst and loss of strength, to prevent a death that comes much more quickly than that from lack of food. Its consideration can, however, be scarcely regarded as of practical value under service conditions except perhaps in relation to water-breakers for boats in abandoning ship, or for distant expeditions, or in the supply from the ship of landing parties with water for drinking. The amount will vary with weight of individuals, with work or muscular exertion, with character of food, and with temperature or climate, and with condition or training of individual.

It may be assumed, however, that a member of the deck force requires daily about one-half ounce of water per pound of body and that from 25 to 33 per cent. of it is in his food. Thus a man weighing 150 pounds would require about 75 ounces, or probably in the tropics 100 ounces, of which perhaps from 3 to 4 pints would be drunk in some form. If there be added to this the amount required for cooking the sum will not be less than one gallon, and may be one and a half gallons.

This is recognized in the navy regulations for commanding officer in the statement that he shall not, unless absolutely necessary, limit the daily allowance of fresh water to less than one gallon per man for all purposes, and that he shall also, when practicable, issue fresh water to be used for washing the soiled clothes of the crew. The general disposition is to issue as much fresh water as is practicable, and to insist upon no avoidable waste.

The regulations require men to wash daily, and that when possible supplies of fresh water shall be allowed for that purpose. It is also required that bath- and washrooms shall be supplied with hot and cold water, and kept open during the evening, and that every effort shall be made to encourage cleanly personal habits. At morning inspection division officers are required to carefully observe whether the rules have been followed, and, should it be necessary, any man may be punished for their infraction. Every reasonable opportunity and facility are to be given to the crew to wash their clothing, and at morning inspection, from which no one is to be excused unless positively necessary, a careful examination is required to be made to see that the clothing is clean and neat. There is also at least once each month an inspection of all clothing to ascertain, among other things, whether it is clean. Each man must have two mattress covers, and it is required that he shall change them frequently. Blankets are to be washed as often as necessary and special facilities, if possible, given to firemen, mechanics, and others whose bedding requires frequent inspections and much care. The regulations also require cooking and mess utensils to be kept clean, and that the ship shall be thoroughly clean throughout.

It is evident that these regulations were framed under the view that many of the desired results can be obtained in a reasonable way only with the use of fresh water which is to be issued, when practicable, for washing clothes and, when possible, for washing persons. It may be considered that cooking and mess utensils, in view of their greasy condition, cannot be even roughly cleaned with satisfaction in sea water, and should not come in contact with harbor water. It is more than doubtful, in view of the concentration of men and the facilities at hand on many ships, whether mess utensils are satisfactorily cleaned, even with the use of fresh water and soap. It is a cardinal rule of hygiene to get rid ot even what is useless, much less what is recognized as dangerous, as soon as possible, and mess utensils improperly cleaned are capable of transferring material from one mouth to another. The proper cleaning of mess utensils is a very important part of the hygiene of a ship and of a station on shore, and it cannot be satisfactorily accomplished under the circumstances of crowding without the assistance of material designed for use with water to remove grease, and perhaps without sterilization by heat, and without clean dish cloths. This ordinarily means under the circumstances the use of sufficient fresh water and soap powder in an efficient form of dish-washing machine, and care of dish cloths. On recent large ships the dish-washing machine is electrically operated with capacity of at least 6,000 pieces an hour and with necessary steam, water, and drain connections, and with overhead tracks and trolleys. The machine is installed in a general mess pantry in which the shelves are of wire mesh.

There is generally one attendant or "striker" who has been detailed for each mess of about 20 men. If the mess utensils are washed by hand they cannot be cleaned by piling them up in some receptacle with sufficient warm soap-water to cover them and then wiping them over with a wet cloth and finally wiping them with another that soon becomes nearly as wet. Such water may have been rather warm or even hot when it was brought, but soon cools from the mass of utensils immersed in it and soon becomes overcharged with material derived from them. It is an inefficient method that is greatly improved by more fresh water and receptacles, plenty of clean dish cloths and the expenditure of more time or effort, but at best is lacking in those desirable results secured by a boiling temperature.

Now, the expenditures of fresh water for the various purposes indicated can be made either more or less liberally or on a minimum basis. For instance, if a man is allowed a bucket of water for washing clothes he will probably go in with another man, one bucket being used for washing the clothes of both and the other for rinsing the clothes of both, rather than use salt water for washing and fresh water for rinsing; or as the washing of clothes is easier in fresh water he may even wash them in fresh water and rinse in salt. The general rule, however, will be to do all the washing and rinsing in fresh water, even if still greater concentration is obtained by washing the body or bodies first in the same water. A man will probably have some clothes to wash three times a week if he has an opportunity to use the line that often, and 12 gallons of water a week or an average of 1.7 gallons a day is a very moderate allowance for the purpose. In going over his body daily with fresh water two gallons may be considered as needed, and in washing his cooking and mess utensils, and in cleaning up after him around mess table and in quarters generally, two gallons may be estimated. The total, therefore, considering drinking and cooking water as one gallon, is 6.7 gallons per man per day, which is a low estimate if one is to keep his person and clothing fairly clean without a really satisfactory general bath during the week, and even considering such use of salt water as is at all probable.

This estimate includes no allowance for waste, or undue appropriation, or for additional expenditure of water in sick-bay and officers' quarters. The expenditure in officers' quarters will have relation to stationary tubs, but, considering all the various factors, the minimum working expenditure of fresh water on a ship should be about 7.5 gallons per person per day, and every ship, especially those with laundries, could utilize 15 gallons to great advantage and requires at least 10 gallons in the tropics for a crew to be only reasonably clean and comfortable in view of the appearance of white clothing as a daily feature.

Considering the tendency of the ship to require, even if only at times, distilled water for boilers, the distiller working capacity or ordinary output of potable water should be at least 15 gallons per man per day and considering the condition of water as it leaves the distiller and the necessity for a reserve supply, the total tank capacity ought not to be less than 30 gallons per man. Thus with a complement of 800, the distiller would furnish 12,000 gallons a day, requiring a daily expenditure of perhaps 6 tons of coal for that purpose, and the total distilled water-tank capacity would be 24,000 gallons, including all gravity tanks as well as distilled water tanks below protective deck. The question is complicated by the present struggle for space and reduction of weight on a ship as a vessel of war. But the figures given seem to represent the minimum requirements for health and at the same time such requirements as can be met under service conditions. Yet, in view of the relatively small tank capacity, the idea would be to have the distillers at work about all the time in order to have tanks practically full (once each day) and to give the ship's personnel the available output; that is, the distiller output to balance the daily expenditure of water for that purpose. As much of the distiller output can be utilized without going to ripening tanks, drinking water with multiplication of tanks can be aerated before use, even on maximum expenditure of water.

The system of aeration itself necessitates a separation of tanks below protective deck, but those main tanks forward and aft are in number in each location not only to facilitate trim of ship, but also for control over quality of water supplied by distillers. *Water is not necessarily good as it leaves a distiller*, and multiplication of tanks is a means to avoid injury of entire amount stored. However, increase in number of tanks does not in itself afford sufficient facility for that purpose, but, as a rule, there should be on each ship a tank through which the entire distiller output must pass before distribution. During each watch the simple qualitative test for chlorides should be made several times at each distiller by the man on watch there, and, as the tank is filled, the same test should be made of the water as a whole prior to distribution. If in addition a supervising interest be exhibited, the importance of the subject is emphasized and a sense of responsibility readily instilled, or even rivalry between watches created, which is accentuated by the knowledge that the test at the tank assists in fixing responsibility.

Of the fresh-water tanks of a ship, the scuttle butt excites peculiar interest from a sanitary point of view as it is there the crew obtains drinking water. It is a closed cylindrical iron tank with a net capacity of from 75 to 100 gallons, and is located forward on the gun deck. It contains a refrigerating coil made of copper well tinned on the outside and connected with the ice machine. The tank is installed with metal stand, drip pan, and faucets around its base. The water is received generally from gravity tank on upper deck by a connection at the top of the tank. Not many years ago the scuttle butt was always a butt or cask with a scuttle or opening in one head through which water was dipped for drinking. It is now generally a closed metal tank from which water is drawn by faucets into cups or mess bowls often attached by chains. The scuttle butt is thus the location where there is a mixture of mouth secretions, as the mess bowls are used in common by a large number of men. To this fact has been attributed at times the spread of various diseases, and on many ships attachments have been provided for immersion of drinking cups in formaldehyde solution. Such a provision to be efficient requires an appreciation of its importance on the part of the men, which experience has shown is generally lacking in spite of such assistance as may be given by a sentry.

Various devices have been put forward with a view to the abolition of the cup. These have included individual suction pipes, each man to have a tube device for that purpose, and drinking from a jet of water or from some miniature fountain or bubbling spring. The suction tube is manifestly impracticable for the purpose as it would too frequently pass from man to man, would not be on hand when wanted, and would be dropped or lost or even found about decks and subsequently utilized in a dirty state.

Of the various devices for drinking from running water the one that has been put into more or less successful use in our service is the "bubbling spring" devised by Surgeon Manley F. Gates, U. S. Navy. It is described by him in the Journal of the Association of Military Surgeons of the United States, and in report to the Navy Department:

"The attachment consists of a 'bubbling spring' or fountain for each faucet of the ordinary ship's scuttle butt. Its construction and operation are shown in the accompanying photograph and sectional drawing.

"The fountain is composed of two turned brass funnels arranged concentrically, one within the other, the outer being at the base two and three-fourths inches, the inner two inches in diameter, with its base projecting one-fourth inch above the outer funnel.

"The inner funnel connects at its apex, by a small pipe, with the scuttle butt faucet which is an automatically closing type, preferably the 'rabbit ear' pattern.

"The outer funnel has a shank which fits and screws into the upper arm of a one-inch cross. The lower end of this cross is closed by a brass screw plug.

"This plug is perforated and tapped to receive from above the stem of the inner funnel which passes axially through the shank of the outer funnel and the upper arm and body of the cross, but leaves a clear space about it until it reaches the plug.

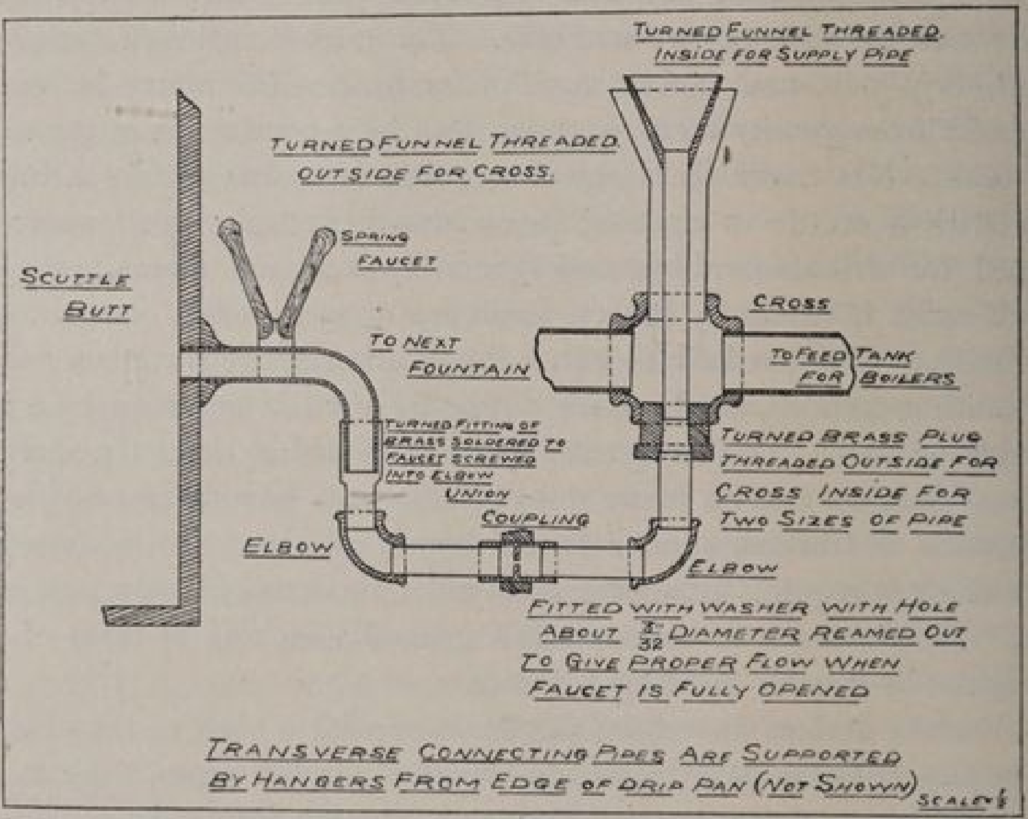

FIG. 44.—The Transverse Section of the Gates Sanitary Scuttle-Butt.

"From below, the plug recives the pipe leading from the faucet, thus forming a union between it and the stem of the inner funnel above, as well as closing the lower arm of the cross.

"The lateral arms of the cross are connected by one-inch piping with the corresponding arms of adjoining fountains and the outer arm of the last fountain with a drain-pipe leading to a feed tank.

"When the spring faucet is opened the water flows through the small pipe into the inner funnel; the excess overflows into, and is caught by, the outer funnel, passes through the cross, around the supply pipe, and is conveyed by the lateral connecting pipes and drain to the feed tanks for boiler use.

"The maximum flow of water with the spring cock fully open, is regulated by a metal washer, flanked by elastic washers to prevent leakage, which is placed in a screw union located in the lower part of the 'U'-shaped tube connecting the faucet with the inner funnel.

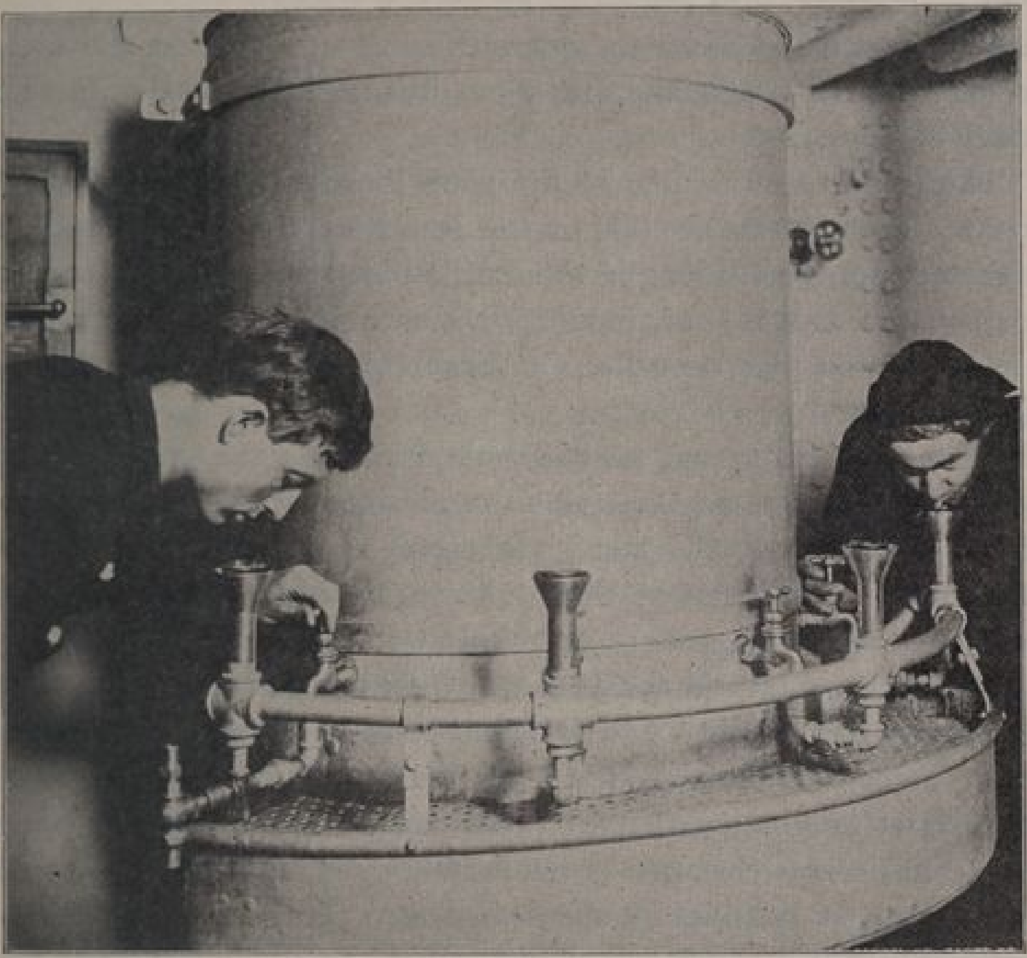

FIG. 45.—The Gates Sanitary Scuttle-Butt.

"This washer is reamed out to give the proper flow with the usual pressure at the faucet. Its aperture would vary somewhat with other examples installed where different pressures were found. In this case the orifice is only about 3/32 inch in diameter, as the scuttle butt usually has considerable pressure from the gravity tank which is located on the upper deck, and from which it is fed.

"When the ship is in dry dock the gravity tank supply is discontinued and at such times the usual washers are replaced by others with an orifice of slightly under 3/16 inch diameter.

"When the faucet is opened a cone of water rises from one-half to three-fourth inch above the level of the inner funnel. In drinking, by slightly protruding the lips all risk of contact of the mouth with the funnel is avoided. If carelessly used only the outer, skin-covered, surfaces of the lips touch the funnel.

"A man about to drink instinctively opens the spring faucet before he approaches his lips to the top of the mound of water, and in this way water that might have touched the lips of a person previously drinking, as well as any dust or foreign substances that may have reached the water, is carried over and discharged with the first gush of the fountain.

> "From observation I am satisfied that less water passes into the outer funnel of this attachment than is wasted by the usual careless and uncleanly rinsing of the ordinary cups, which is a matter of importance on modern ships where all drinking water is distilled and the amount used affects the coal expenditure.
>
> "The only waste in the use of this appliance is the expenditure of energy in cooling the water which is not drunk and which passes into the feed tanks. Its sanitary and esthetic advantages are obvious."

This device has been received with some approbation and has also received a degree of official approval, as it is being installed or fitted on a number of ships.

The scuttle butt is one of the good locations from which to take water for examination as that is the last storage before consumption. Water does not remain long in the scuttle butt as a crew will soon drink 75 to 100 gallons, but that amount is within available cooling capacity of the refrigerating pipe or coil. On large ships there will, however, be two scuttle butts.

Men in the firerooms obtain their drinking water in buckets, and when there is an ice machine, as on large ships, obtain a supply of ice. This consumption of ice-water in firerooms is one of the features of a modern navy. Its effects on the health of men doing work in high temperatures do not appear to have been the subject of investigation. It is one of those natural demands which, like the consumption of ice on shore in very hot weather, has ceased to be regarded as a luxury and has come to be considered a necessity. It is to some extent like the supply of cold water to a man with a fever, for men working in the fireroom soon have a considerable elevation of temperature, depending upon the degree of ventilation or removal of overheated air. Such men on account of their work have an enormous increase in the production of heat which, in view of the high temperature of surrounding air and the large amount of heat received by radiation, even their sweat-covered bodies cannot discharge with sufficient rapidity. Warming the body cells increases body metabolism.

In a hot fireroom the elevation of body temperature will be evident within thirty minutes from the beginning of the watch, will increase to the end of the watch and after relief from duty will gradually diminish during two or more hours. The usual elevation during a four-hour watch in a hot fireroom will be about 2° F., and in particular cases may be nearly 4° F. The profuse perspiration explains in great part the increased desire for water, but the elevation of body temperature accentuates the desire for cold water. Warm drinking water, or water heated within firerooms, also tends to produce nausea, but that tendency was formerly diminished by use of oatmeal in the water.

Under ordinary circumstances work does not raise proteid metabolism. In view of the feverish condition of a fireroom force it might be expected that there would be an increase in proteid metabolism. But it is a physiological and not an infective fever, and it is a question whether such fevers when not above 102° F. have much effect on proteid metabolism. There is marked diminution in amount of urine and, specially on a high protein intake, an increased concentration of purin bases that may in itself not only tend to increase thirst, but also to increase temperature. With the increased work there is requirement for increased carbohydrate ingestion, but it is not clear that the high protein ingestion of our navy is not itself responsible for much unnecessary discomfort in firerooms. The subject is one for investigation in several directions and offers an interesting and important field for scientific experimentation. In the meantime the primary necessity is reduction of fireroom temperatures by limitation of wild heat and by renewal of air.

It will be noticed by reviewing the declared general plan of fresh- and salt-water systems of ships that there are both supplies at the sinks of pantries. In this case there is an independent faucet for each. It is presumed that the salt-water supply is to save fresh-water supply in cleaning and flushing the sink itself. Mess attendants are not, as a rule, conscious of any responsibility entailed by the presence of the two water supplies, and are only restrained from the use of salt water in cleaning mess utensils by the extra work it involves and the difficulty in obtaining an apparently good result. They are also not usually restrained by consideration for fresh-water supply from using that supply in cleaning and flushing the sink.

The advantage of the two supplies from the point of view of economy in fresh water is not clear, while the danger from a hygienic point of view is quite evident. So long as the two supplies are there, the danger of using the water from over the side, as dirty harbor water, to the detriment of health of the mess is present. For instance, lettuce from any locality washed in harbor water is surely dangerous, and plates and forks and knives and cups that have passed through such water are often not fit for use. In certain localities, League Island for instance, the danger is increased by having relatively fresh water over the side, and in many closed harbors the presence at the sink of a salt-water supply is a distinct danger. The fact that concentration is ordinarily not practicable is a saving feature, but a mess attendant who happens to merely rinse a table glass in harbor water before filling it with distilled water may be preparing a mixture that will enshroud subsequent events in mystery.

At the ice machine distilled water is frozen in the ice-making tank. If the distilled water be good the ice is free from objection if the tank was clean. There is, however, always much direct handling of ice and there is an insufficient washing of hands. This subject has received consideration elsewhere, but may take its place among the various ways in which water may become contaminated after it leaves the distiller and as helping to show methods by which disease, such as typhoid fever, may spread on a ship even if the water as it leaves the distiller is free from objection. To avoid additional repetition it is advisable in this connection to refer to prophylaxis in typhoid fever and cholera as given in the chapter on Vital Statistics.

The ice machines on our ships are of the dense air type. That is, they depend for result upon a disappearance of heat, an imperfect gas, such as air, having been compressed or made dense, absorbing heat on expansion. In this process the higher the pressure or the lower the temperature the greater is the absorption of heat on expansion. By storing up the cold produced by the expansion and using it to cool air about to be expended and so obtaining a cumulative effect, the temperature can be carried very low and utilized to freeze water or, in cooling pipes, to make surrounding water cold, as in the scuttle butt, or the surrounding air cold as in a cold-storage room.

The cooling effect of such machines is measured in terms of tons of ice per day, a two-ton machine having the cooling effect necessary to make two tons of ice per day. This rating is based upon ice making as the total or only work performed, and does not designate the amount of ice actually obtained from a machine of that rating under ship conditions, as a large percentage of the power is expended on cold-storage rooms and on the cooling coils in scuttle butts. Valves are provided so that the work may be distributed or concentrated and all the cooling effect may be expended directly on the cold-storage room or only a part as when it operates also on the ice-making tank.

Cold-storage rooms are partitioned off into separate spaces for meats, vegetables, fish, and butter and milk. The inside of those spaces is lined with sheet lead on the bottom and with galvanized iron or zinc on sides and top. This does not give the cold-storage room the brightness suggestive of cleanliness and some better lining is desired. Each compartment is thoroughly insulated. Metal shelves and pipe rods with hooks are fitted in each compartment. So far as water is concerned, it might be supposed that there would be no question in relation to those rooms in view of the low temperature calculated to be maintained there. When everything is in good working order, and ordinarily that means essentially the ice machine, there is of course more or less frosting of surfaces, especially of the cooling pipes themselves as the coldest. This is due to the great lowering of temperature of contained air, the squeezing out of its watery vapor as in the sweating of metal and its subsequent or immediate freezing as a frost. Whenever the rooms are entered some portion of the warmer outside air enters and the frost tends to increase. Subsequent events, so far as water as such is concerned, depends upon the continued integrity of the ice machine.

The life of an ice machine is for practical purposes in its coil. It is the coil that tends to deteriorate rapidly at times, so rapidly occasionally as to suggest an undue galvanic corrosion. At any rate, the breakdown of an ice machine has not been an uncommon occurrence, and, unless repairs can be made quickly or, much better, two such machines have been provided, each with sufficient capacity to safeguard the cold-storage rooms, a very insanitary condition may be expected. Meats in such rooms, perhaps in large quantities, spoil, and the frost collected on pipes melts as a solution of putrid material, gathers on the floor and, especially if there is a slope in any direction, tends to find the joint between the lead lining of floor and the galvanized iron lining of the side of room. If there is a drain from such a corner its use requires considerable caution. It should be under valve control, as the material should not be allowed to make its way into any part of the ship. If there is no drain, the water should be removed, as it forms in quantity, to avoid leakage through joint of lining, but such joint should be placed well above floor, especially at the lower corner. This removal is accomplished with buckets and swabs by men working in rubber boots. The spoiled meat having been condemned and thrown overboard at sea, the spaces can be freed from odor by the use of swabs followed by a liberal employment of soap powder and water, the process to be repeated next day.

In going back over the circulation and uses of salt and fresh water on our ships it will be noticeable that in the consideration the systems have been kept more or less closely together as they are in fact on the ships themselves. It has been thought that in this close association something of value might be found, ultimately if not now.

In the history of navies it is evident that, during a considerable period, extending certainly through the seventeenth and eighteenth centuries into the nineteenth, there was a very long chapter of sickness and death depending not only upon lack of ventilation, but also upon lack of personal cleanliness and of good drinking water and upon damp ships as the result of free use of salt water between decks. Ships are not carrying more men to-day than in the early days, for in the seventeenth century there were ships of 120 guns and 800 men. Prior to 1815 all drinking water was carried in casks. After that date iron tanks, each containing two tons of drinking water, were used as ballast replacing the lower tier of casks and effecting such economy in storage as to make the daily issue of water more liberal. It was also about this time that the use of soap became a feature of naval life. The quality of the drinking water remained in essential respects the same and dysentery continued to be a scourge, but as soap came to be used liberally, the air between decks improved and, with increased cleanliness and better construction of ships, typhus fever greatly diminished.

The sailing ship was, however, the ship of many days between ports, and the daily allowance of water thus remained small at sea. Subsequently steam shortened voyages and thus diminished the necessity for as large reserve supplies of water under ordinary circumstances, and eventually, through the distiller, furnished the means for a daily supply of pure water, though creating a new demand for fresh water. Yet through it all there has been an increasing amount of fresh water for crews, with marked improvement in quality, and probably at no time in history have the men been as clean as they are now and, in view of artificial ventilation, has the contained air been as little contaminated or vitiated by the men themselves.

It may be recalled, however, that for many years after distillers came into use steam was used only as an auxiliary power, and the amount of coal carried was small and hoarded for some ship emergency from the seamanship point of view. To distill water coal is required, and in those days it was not unusual for the supply of fresh water to be too greatly limited through coal economy. In these days coal is handled in very large quantities, and for some time the expenditures necessary in distilling water have seemed to attract little attention. More recently there has been competition between ships in fleet in regard to coal expenditure in general, but so far it is not clear that that has been extended to the making of water. Any extension in that direction leading to a diminution in amount of water available for a crew should be regarded as false economy, inasmuch as improved health and greater contentment are to be sought in an increased fresh-water supply.

The increase in number of salt-water connections, more apparent each year on our ships, may or may not show tendency to a saving of coal. Even with evaporators in single effects, the most uneconomical method of making water, but the method giving the maximum output, an expenditure of a pound of coal for each gallon of distilled water is not greater than the average. The difference, then, between 9 gallons and 10 gallons of water per day per man is 3 pounds of coal per day per man or about a ton for a battleship. This small additional expenditure makes for a greater difference in the cleanliness and comfort of a crew, and space for storage and money for buying could not be expended to better hygienic advantage. In fact, instead of increase in salt-water connections the health of a navy is in the direction of increase in number of fresh-water connections.

With crews going under showers from divisions on different days, the expenditure of fresh water would not be greatly increased. If each man had a fresh-water shower even every five days at a maximum expenditure of 6 gallons, he would use 36 gallons of water a month for that purpose. As on those days he would have had 2 gallons issued to him anyhow for bathing purposes, the additional expenditure would be 24 gallons a month or 8/10 of a gallon per day. With a crew of 800 men the additional expenditure would be 640 gallons per day, or about 640 pounds of coal at a money value of perhaps one and one-half dollars for the whole ship. Twelve men might wash under a shower in an hour or 160 men under 9 showers in an hour and a half. But if on a big ship only 16 showers were supplied with fresh water for even an hour each day the entire expenditure of fresh water at the showers during the hour could not exceed 1,152 gallons and would probably be less, especially under supervision, and the additional expenditure need not be greater than 768 gallons.

It is believed that such an expenditure can be made ordinarily or frequently on ships by utilizing the apparatus for making fresh water to its full extent, and as the question should be primarily one of capacity of plant, storage of water, and bunker capacity—in other words, available space—it seems probable that the tendency to increased tonnage and all-big-gun ships without corresponding increase in complements will afford opportunity for greater distiller and storage capacity, and thus permit more fresh water connections. Our naval service probably has at least as much fresh-water as any other naval service, but the hygienic ideal is unlimited supply without waste. That should be realized at all times at naval barracks and hospitals where if the flushing is by fresh water the source of supply of barracks should furnish daily not less than 35 gallons with 50 gallons per man in hot climates, and in hospitals at least 40 to 50 gallons per bed.

With the increase of salt-water connections on ships it should be noted that much ill health in the old navy was caused by too intimate association with salt water between decks. During that period the effect on health resulted chiefly from dampness. There was an excessive use of water in cleaning decks, but an inadequate use of water in flushing heads. A ship with anchor down swings with wind and tide and in those days the wind frequently caused the whole ship to be pervaded with the odor of fecal matter from the "head" or men's water-closet, where there was no continuous flush, but perhaps an occasional inadequate flushing with hand-pump. To-day each man deposits his fecal matter and urine in troughs of running salt water, and a minimum amount of water is used between decks for cleaning. Yet in view of the increasing number of salt-water connections there is provision for a renewal between decks of that old intimacy with salt water, though in another form.

Then it operated through the skin, thus interfering with the regulation of body temperature and causing rheumatic and pulmonary troubles prominently, and now it is a question whether it is not operating at times by direct contact with alimentary canals, by gaining access to mouths when used in bathing. So far as sea-water is concerned, there is little or no danger from that direction, but harbor-water is often a filthy mixture, and in some harbors the water is regarded as even unfit for washing down the open decks.

It seems clear that no salt-water showers should be used in closed harbors and especially in certain well-known harbors from whose waters even distilled water free from taste and odor cannot be made. If water is too foul for swimming it is too foul for shower baths on the ship. It has not seemed practicable to measure this danger by known results, for, very generally, a case of typhoid fever appearing on a ship is not traced to source. If reference be made to table of prevalence of typhoid fever given under *Vital Statistics* it will appear that the cases have been appearing of late in increasing relative number, but no one may now say to what extent this source of danger has been a factor. It can be said that it does not appear to have been a dominating factor.

In harbor the demand for boiler water is at a minimum, while the amount of such water that can be obtained is often unlimited. The daily amount of distilled water available for issue to the crew can then be at its maximum, and in view of the limited use of salt-water showers those connections can be then cut out by valves without much loss of comfort from the crew's point of view.

The use of the tooth-brush may not be general among crews, but it is becoming more general, and if the water from over the side is at all fresh, as at League Island, there are certain men who will use it in that connection, especially if made readily available as in washrooms. The indications are that all salt water connections for personal cleanliness may be a menace in harbor and that the naval sanitarian can at least view with distrust the growing intimacy between crews and the water from over the side when the ship is not under way. This may assume greater prominence on ships doing river work in locations where cholera is frequent.

The process by which fresh water is made on ships from salt water is in principle the same that nature has employed since it started to provide for the first mist or fog or rain. If distillation may be defined as the conversion of a liquid into a vapor and its re-condensation into the liquid form, then all fresh water wherever found may be considered as having been at some time in its history salt water and as rain to have started its descent upon the earth as distilled water, it having first passed into the atmosphere as water-vapor, the result of natural *evaporation*.

While extensive beds of rock-salt are found in a number of countries and large quantities of common salt are obtained from them, by mining, very much of the common salt of commerce is obtained by the natural or artificial evaporation of water, either of salt springs or of the ocean itself. In cold climates if sea-water is used for this purpose shallow pits are made upon the shore and the water allowed to freeze in them, the ice being nearly free from salt and the solution of salt remaining being sufficiently concentrated to pay for evaporation. In certain hot climates the industry is carried on by running salt water into a number of shallow pits or reservoirs, where it is evaporated by the heat of the sun, becoming thus more and more concentrated by spontaneous evaporation. This process may be allowed to be concluded by nature, but as a large percentage of the common salt is deposited when the specific gravity becomes as great as 1.24 the remaining liquor, called *bittern*, can be utilized to obtain sodium sulphate resulting from decomposition of some of the remaining sodium chloride by the magnesium sulphate, or by additional evaporation and subsequent cooling to obtain potassium chloride.

In all these processes the object is to get rid of the water by evaporation in order to obtain the saline constituents, but Nature herself operates for the main purpose of obtaining the water itself with which to water the earth, to separate the water from its saline constituents for the sake of the water. This is carried out on a tremendous scale directly in relation to salt water in view of the power of the sun exerted over the enormous ocean area and the thirst of the air, kept in constant operation by air movement. It is the wind blowing from the sea that is damp, and the cloud is merely a collection of that aqueous vapor resulting from evaporation which having attained higher levels has been condensed by the lower temperature into watery particles. Thus the process is completed—the first stage being that of *evaporation* and the second that of *condensation*, the first accomplished by *heat* and the second by *cold*.

It is this process that is carried out on ships, the apparatus designed for the first stage being known as the *evaporator* and that for the second being called the *distiller*, although in reality it is simply a condenser, but there are other condensers on a ship and this one has retained its historic and convenient designation. In the first, salt water is rapidly evaporated, sufficient heat being used to convert the water into steam; into the second that steam is received and, by contact with pipes, kept sufficiently cool by constant circulation through them of water from over the side, is condensed into the liquid form as water separated by evaporation from its saline constituents.

The boiler of a ship is itself designed for the conversion of water into steam, and at first sight it would seem unnecessary to interpose a special evaporator between the distiller and boiler, for the former has of course the same power in condensing boiler steam as in condensing steam from the evaporator. But there are two main objections to condensing boiler steam for drinking water. Salt water is not used in boilers and, owing to return steam from main and auxiliary engines, any boiler water becomes very dirty and contains much oil, leading to a large percentage of volatile products in its steam which when condensed appears as water containing much oil and not free from other organic products and disagreeable taste. As salt water is not used in boilers, that alone is an inseparable objection, but if it were used the hygienic objections would be merely emphasized.

Also, if a distiller receives steam directly from a ship's boiler, priming is perhaps more frequent, especially if the boiler also supplies steam for main engine. Priming is the carrying over of hot water with the steam from a boiler. It would therefore transfer to the distiller a dirty boiler water, or water that has not been converted into steam, thus passing into or mixing with the distillate non-volatile products as well as considerable oil. Priming may also occur from an evaporator, especially if the evaporation is too intense or is carried on unevenly as with too much or too rapid variation in water levels. Apart from tending the evaporator with care it is necessary, for the purpose of avoiding priming, *to have the distiller situated as high above the evaporator as is practicable* and to have the steam leave the evaporator by a vertical lead. As it is salt water that is being evaporated, priming will always cause a perceptible or marked increase in the chloride content of the distillate.

An evaporator is a fireless boiler. There is no combustion at the evaporator, but the water within the evaporator shell, or to be evaporated, is boiled by contact with steam pipes, also of course within the shell and covered by the water, which receive their steam, just as a radiator would, from the ship's boiler. Through those horizontal brass seamless pipes steam circulates more or less slowly at considerable pressure, and at its condensation gives up the enormous latent heat its change of state from water originally required when it was formed in the ship's boiler over the furnaces. This heat is conducted by the metal of the pipes to the water, in contact with them and to be evaporated, which by convection is kept boiling.

This primary steam so formed from the evaporator, occupies the water space within the evaporator shell above the water level, and as the pressure accumulates passes, by the steam connection provided, upward into the distiller shell where it comes in contact with cooling seamless pipes made of copper or brass thoroughly tinned on both sides and carrying the distiller circulating water which is kept in rapid movement by the *distiller circulating pump.*

The tubes within an evaporator carry steam, while in our service the tubes within the distiller carry water—the water pumped through them from over the side. In an evaporator the water is outside the tubes and supplied as required by the *evaporator feed pump,* in a distiller the steam is outside the tubes. A leak in an evaporator tube passes boiler steam into the boiling evaporator water, a leak in a distiller tube passes water from over the side—harbor or sea water—into the condensing steam or relatively cool distillate passing out for drinking water.

The tubes of an evaporator are together called the evaporator coil and those of the distiller the distiller coil. Neither is a coil, but rather a battery of seamless straight parallel tubes terminating at each end in a plate known as a tube sheet, and made of composition. Thus each set of evaporator tubes and its tube sheets form a large cartridge, as it were, which can be removed from its position within evaporator shell for cleaning or repairs. The evaporator coil is horizontal and the distiller coil vertical. The evaporator tubes are tested to perhaps 400 pounds per square inch and the distiller tubes usually to 50 pounds.

A leak in an evaporator tube will have somewhat the same general effect upon the distillate as if the distiller were receiving steam directly from the ship's boiler. This will be *manifested chiefly by the appearance of oil on the fresh water supplied.* A leak in a distiller tube will give the distillate the same general characteristics as priming, but from a hygienic point of view there is a very important difference. In priming the water is carried over with the steam, and has therefore been subjected to high temperature, but when distiller circulating water passes into the distillate *the increase in chloride content is the result of a mixture with raw salt water,* which, if harbor water, contaminates the drinking water with whatever micro-organisms such filthy water may contain. Such a leak is not of much importance while actually at sea, provided it is not sufficient to give the water the slightest taste of salt, but in port or at anchor even a very small leak represents a serious loss of integity in the apparatus.

It is the possibility of such a leak that gives the test for chlorides its chief importance, for while a certain increase in chlorides is generally due, especially at sea, to priming from forcing the evaporators, from rough weather, especially on small ships, or from the faulty position of the distiller, or from all, the result may be due, especially in port where water is generally made more quietly, to an exceptional leak in the distiller coil.

For a certain distance, the determination of CO_2 in the contained air of quarters and the estimation of chlorides in distilled water of a ship may be paralleled, but after that there may be a marked departure which should be noted by naval sanitarians. The CO_2 observation is utilized merely as an *index* of degree of ventilation. It is not so much the CO_2 itself that under any ordinary circumstances is cause for alarm, but chiefly the fact that when in excess it indicates a too great loss of available oxygen and, as is generally assumed, more particularly the presence of excessive amounts of organic matter derived from the men. It is merely an *index* of the condition of the contained air, the source of the CO_2 being known. Within any ordinary limits it is not the chlorides in distilled water which *per se* causes objection. The body requires chlorides, and such mineral salts are classed as food being an essential part of the food intake. Salt is not tasted in water when within 1,071 parts per million, or 62 grains per U. S. gallon; and so far as chlorides are directly concerned, the distilled water of a ship containing 70 or even more parts per million, or about 4 grains or more per U. S. gallon, could certainly not interfere in any way whatever with the body's economy.

On shore a natural water classed as pure, even away from the sea coast, may contain 14 parts per million or about 8/10 grain to the gallon and very many usable natural waters in the same situation have 40 parts, or 2.32 grains to the U. S. gallon, while good waters near the seacoast commonly contain much more, and deep well water not infrequently contains large quantities. Now, in the nitrate of silver test, salt in 15 parts per million gives a haze and even 60 parts a marked white turbidity that tends to darken on standing. But in the examination of fresh waters in no case is objection made to chlorides on their own account, but their value is merely that of an index. Their presence in excess is a reason for suspicion because while on shore they may come from strata containing chlorides or from impregnation with sea water, they may also be derived from mixture of the water with sewage or the excreta from man or other animals.

The question is the same on a ship, for it is simply the source of the chlorides. The primary source of the chlorides in the distilled water of a ship must be the water supporting the ship. Their immediate source must be either the evaporator or the distiller or both. If from the evaporator the admixture is the result of priming and is with salt water that has been raised to a high temperature. It does not appear that chlorides derived in that way can be regarded as an index of pollution in the sense of ability to produce specific disease; and if at sea, inasmuch as sea-water would be a potable water, but for salines, the evaporator water is itself free from pollution unless the chance of the pump suction taking in material from heads while underway be worthy of consideration. On the other hand, if the chlorides are derived from the distiller the parallelism with the CO_2 observation holds, inasmuch as they are a true index, the admixture being with raw water from over the side.

A ship at sea is headed for port and, whatever may be thought of the admixture, even in small quantity, of raw sea water with the distillate, a leak in a distiller tube should cause the rejection of water from that distiller and immediate substitution of a new tube for the old one. It is even reasonable to extend the objection further for distiller tubes rarely if ever leak within a number of months from their installation, but acquire leaks with age as the result of the corrosive action of the salt circulating water. When one tube leaks the others are not worthy of trust and the distiller should be retubed and all the other distillers with tubes of the same age. In fact this part of the fresh-water plant is so important from the point of view of the prevention of water pollution that in spite of the frequent nitrate of silver tests at the distiller, especially as all anchorages are not in salt water, League Island for instance, a safe maximum life should be assigned to these tubes and renewals should be made before there is chance for a leak due to corrosion. An entire new set is carried as spare parts, but it is not safe to renew each tube as it is discovered to leak.

Each apparatus for making fresh water has a certain degree of individuality depending upon relation of evaporator and distiller, and upon the way in detail connections have been made. The nitrate of silver test is a very delicate one and a certain increase in chlorides is not uncommon at sea in rough weather or when boiler water is in demand. But it is not safe to have an unusual increase in chlorides passed by in silence, or the standard in port will be in jeopardy, and, therefore, such an increase in chlorides should be proven to result from priming, by comparing the water obtained from bleeding different distillers or by working the evaporator connected with a particular distiller, or the distiller itself, much more slowly for a time and noting change in distillate, or better by testing any water that may collect in the suspected distiller that has been cut out from steam, but is still receiving circulating water; in other words, the engineering authority should investigate distillers, to prove the absence of leak, along any line recognized as proper.

The shell of an evaporator is made of plate steel and is a cylinder placed horizontally, and that of a distiller of cast iron and placed vertically. This difference in material depends upon difference of pressure, steam forming in one and condensing in the other. All bolts in contact with salt water are made of Tobin bronze and, as in an evaporator there is chance of galvanic and other corrosion, a zinc protector is employed. Such a zinc protector is bolted to stays or lugs attached to the shell and has about 1 1/2 square feet of exposed surface for each 100 square feet of heating surface.

An evaporator may have about 275 square feet of tube heating surface and a distiller about 66 square feet or more of tube cooling surface. Such an evaporator might be considered as capable of evaporating about 20 gallons of water per day per square foot of tube surface or about 5,500 gallons, and the distiller as condensing in the same time about 50 1/2 gallons per square foot of cooling surface, or about 3,333 gallons. Of course, calculated outputs are based upon certain standard conditions of steam pressure in evaporator tubes, and temperature of its feed water and temperature of distiller circulating water. The distiller circulating water as it is taken is generally assumed to be 60° F., but of course that is much lower than is found in Gulf Stream, in the tropics, or generally in the summer. The feed water of evaporator may be taken from over the side, that is, at the same temperature as the distiller circulating water, or it may be taken from the distiller circulating pump, after it has passed through the distiller. In the latter case it is fed to the evaporator shell already warm or hot, and thus is more economically and rapidly converted into steam. The calculated output will therefore, even with unencrusted tubes, often vary from the actual output.

As in an evaporator, salt water is boiled under pressure, there is the same tendency to the formation of incrustation, chiefly sulphate of calcium, as in any other boiler using salt water, and, with continuous evaporation, there would also soon be an evaporator water depositing salines in even larger quantity as it reached points of saturation in spite of feed water. The incrustations form chiefly on the tubes and having a low conductivity diminish the efficiency of the evaporator by limiting the passage of heat to the contained water.

To limit the formation of incrustation or scale, each evaporator has a bottom blowpipe, or valve and pipe, of ample size, through which it may be blown off when working under pressure—that is, the pressure of the steam formed within the evaporator can be utilized to force the evaporator water out through the blowpipe, thus emptying the evaporator and tending mechanically to loosen the scale. The evaporator then receives a new supply of water by its feed pump that greatly tends to detach the incrustation which falling in particles to the bottom of the evaporator pass out by the blowpipe when the evaporator is next blown off.

There is also on the outside of the shell of an evaporator a salinometer pot or receptacle into which some evaporator water may be drawn. The salinometer pot is furnished with thermometer and hydrometer or salinometer. The salinometer is graduated to show percentage of salines and thus concentration of evaporator water as an indication for blowing off. An evaporator may be blown off once a watch, or every four hours. There is also a brine pump connected with the bottom of each evaporator by which its water may be pumped out and discharged overboard.

In spite of such measures more or less incrustation will form on tubes, and perhaps once a month a semicircular plate bolted on the lower part of the face, or one end of the evaporator, will have to be removed, connections broken, and the coil run out and supported by overhead trolley until cleaned or scaled. This also leaves the shell accessible in all its parts for scaling.

There are then two pumps connected directly with an evaporator—the evaporator feed pump and a brine pump; and two pumps directly with a distiller—the distiller circulating pump and the distiller fresh-water pump, the last being connected near bottom of distillers and also with drains of low-pressure evaporators and discharging the condensed or distilled water into fresh-water tanks, main feed tanks, or reserve feed-water tanks as may be desired. The distiller circulating pump has its suction pipe from the sea and its discharge to the distiller, the water, having passed through the distiller, either going overboard or into the flushing pipe at will, though some of it, as has been stated, may be taken for evaporator. There is also a direct connection from this pump to the flushing pipe, but there is *a relief valve for distillers* by which it is intended to safeguard the distiller coils from undue pressure. To provide for repairs to distiller circulating pump provision is made for circulating water through the distillers from a discharge pipe from pump supplying fire main.

The diagram on the next page is intended to give a general idea of the relation of evaporator and distiller, and of the construction of an evaporator and of a distiller.

Now a large ship will have several evaporators, perhaps three or even four, and as many distillers. Each evaporator is arranged for its coil to take steam from the ship's auxiliary steam pipe, and its coil drain pipe to lead through a trap and drain into feed tank, main condenser, or auxiliary condenser, the water from the steam within each coil thus ultimately finding its way back to the boiler from which it started as steam. Under such circumstances the steam generated in each evaporator shell from the boiling of evaporator water passes to its own distiller, and each evaporator is said to be run in single effect—that is, each evaporator and its distiller are run together as if there were no other evaporator and distiller on board. Under such circumstances there will be a *maxi-*

mum output of distilled water, but, as will be seen, the tendency to priming will be more marked and there will be less water made per pound of steam utilized in evaporating coils, and consequently less water per pound of coal consumed. There will be more water, but it is not apt to be of such good quality as when evaporators are run in double or multiple effects and it will cost more per gallon.

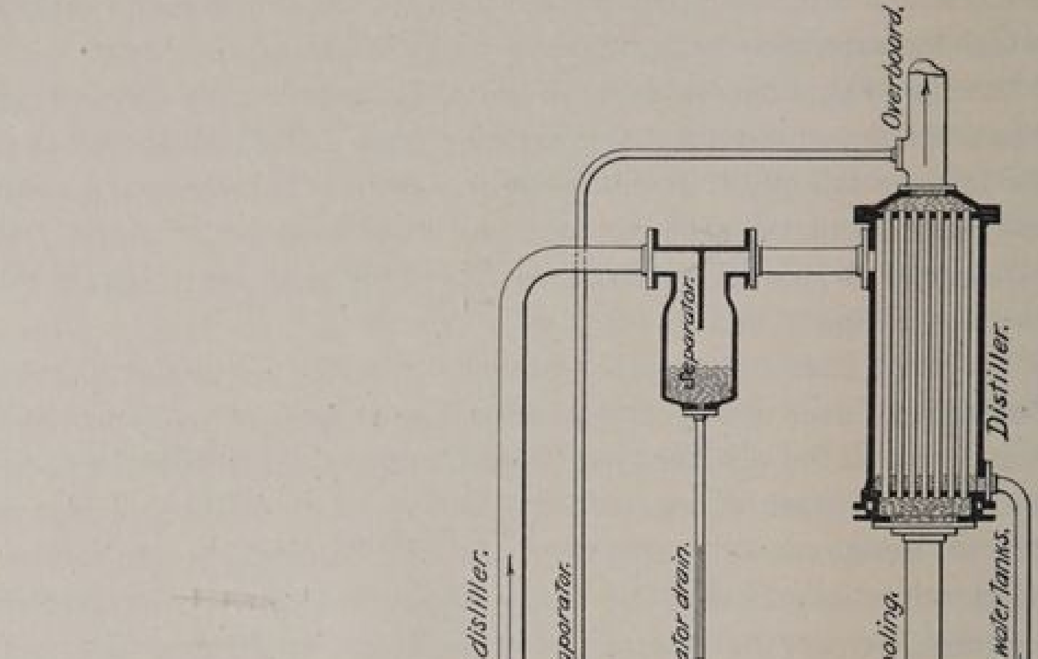

FIG. 46.—Diagram of an evaporator, distiller and connections, (U. S. Navy).

At sea the difference in quality of water will not be of hygienic importance, unless there are leaks in the evaporator coils, as it will be represented almost entirely by some increase in chlorides from priming, but in harbor there are apt to be more volatile products in the output and organic matter carried over with the priming that may interfere in more marked degree with keeping qualities, and, if the harbor is very dirty, will give the distillate a more decided taste and odor.

In addition to the steam connections and drain of evaporator coils indicated above, the evaporators themselves are so connected that the steam generated in the first evaporator can be shut off from its distiller and conducted to the coil of the second or of the third evaporator, or to the coils of both, when desired, or that generated in the second evaporator to the coil of the third evaporator and so on. The first evaporator is called the high-pressure evaporator because its coil receives steam at high or boiler pressure from the auxiliary steam pipe, and the others are called low-pressure evaporators because their coils may receive steam of lower pressure from evaporator shells. There is, then, on the shell of the high-pressure evaporator a connection with the necessary valves and pipes for directing the steam generated by that evaporator into the steam coils of either or all the low-pressure evaporators or into the distillers, or, it may be noted, into the auxiliary exhaust pipe as feed water.

On the shells of the low-pressure evaporators are connections for directing steam into the distillers or into the auxiliary exhaust pipe, or on some ships from the shell of one to the coil of another. When two evaporators are so connected that the coil of one is receiving its steam from the shell of the other working in high pressure, they are said to be operated in double effect, and if then the low-pressure evaporator is itself supplying steam to the coil of a third, the three evaporators are in triple effect.

On the next page is a diagram of two evaporators so connected as to operate in double effect, H P E being the high-pressure evaporator, L P E the low-pressure evaporator, and D the distiller of the low-pressure evaporator.

The diagram has been arranged to trace in theory the course of each pound of steam received from the boiler by the coil of the high-pressure evaporator and to show the result in output of water for purpose of contrast with output from each pound of steam in single effect. In making the calculations the evaporator feed water was taken at 60° F. and no allowance was made for loss of heat by radiation. The result in practice would vary also with steam pressure carried and loss by leakage.

It will be seen that each pound of steam passing into the coil of the high-pressure evaporator ultimately passes back to the boiler as one pound of water. This would happen in any event whether the evaporator were in double or single effect. But in single effect the only additional and all the potable water obtained from that one pound of steam would be from the steam generated by it in its evaporator shell and which would go to its distiller (omitted in diagram) to be condensed into 0.773 pounds of water according to calculation. In other words, if the high-pressure evaporator were operated in single effect its total water from one pound of boiler steam would be 1.773 pounds of which 0.773 pound would be drinking water. But in double effect that 0.773 pound as steam generated in the high-pressure shell, instead of going to its distiller goes to the coil of the next evaporator and makes steam in its shell, the steam so generated representing an additional amount of potable water from the original pound of boiler steam. In this case there would be the one pound of water from boiler steam (not potable), 0.773 pound from high-pressure shell and 0.609 pound from low-pressure shell—a total of 2.382 pounds from one pound of boiler steam in double effect in contrast with 1.773 pounds from one pound of boiler steam in single effect. In the first case there would be 1.382 pounds of water that could ordinarily be used for drinking and in the other only 0.773 pound.

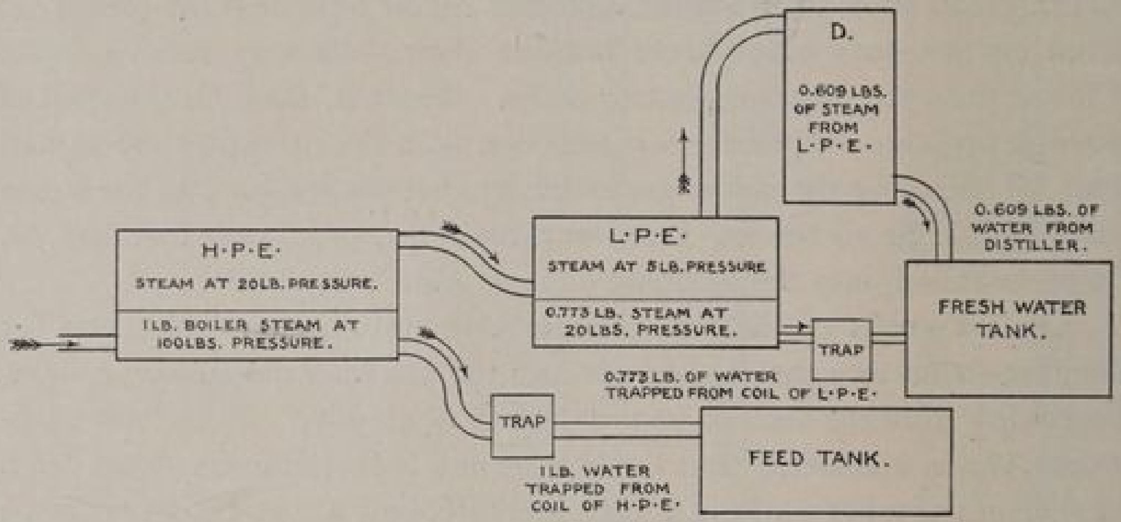

FIG. 47.—Diagram of evaporators connected to operate in double effect. (Bryan, U. S. N.)

In the first case the 0.609 pound from the distiller is the best drinking water because it comes from the evaporator having the least coil pressure, or in which the evaporation is more slow with little or no priming, and chance of coil leakage at its smallest. The 0.773 pound trapped from the coil of the low-pressure evaporator is from steam generated in the high-pressure evaporator and will probably show the effects of priming somewhat more markedly than if it had gone direct to a high placed distiller. It might also show more oil, as there is more chance of leakage in a coil carrying the high pressure.

It is more economical to make water in double effect, and the water coming from distiller is of better quality, but the total output of drinking water in double effect is not as great as if each evaporator were operated singly, because in that case the evaporators would together receive two pounds of boiler steam for each pound used in double effect

Water passing from distillers with evaporators operated in single effect should always at sea be good drinking water, for with apparatus in order, the distillate is only under the influence of priming and that should never be sufficient to cause the appearance of chlorides even in quantities found in very many good waters on shore. In port, evaporators should never be pushed when worked in single effect, and in many harbors whose waters are not unusually rich in volatile matters, good drinking water can at least be obtained by having both the low-pressure evaporator coils take steam from the shell of the high-pressure evaporator and draining all coils into auxiliary exhaust pipe or feed tank.

In a few harbors distilled water free from taste and odor cannot be made on account of volatile products in evaporation. In such cases either fresh water should be taken from shore into feed tanks and used as evaporator feed water or the ship should go to a cleaner anchorage or to sea. The last is best as a rule, if practicable, for such harbor water is not fit for washing down open decks and should not be allowed at sait-water fixtures for bathing.

As has been stated, in any harbor the distillate should be repeatedly tested to secure a fairly slow evaporation and with the main object of detecting a possible leak in distiller coil. The engineering department is the only one on a ship that knows the apparatus for making fresh water and is in charge of it. The medical department is the judge of the quality of the output. Both departments are very anxious to have good water and very willingly cooperate to secure that result. That there may be an efficient cooperation the regulations provide that no water shall be used for drinking purposes unless it shall have been tested and approved.

The question of the merits of various types of evaporators and of distillers is one in engineering, provided the sanitary requirements are met. In many services, and sometimes in our own, incomplete diaphragms are bolted within the shells of evaporators above the water level in order to limit priming. In the diagram given of evaporator, distiller and connections, priming is reduced to a minimum by a dry-pipe, or pipe with saw-cuts on its upper surface, within the evaporator shell and by a separator in steam lead to distiller.

In most other services the steam passes into the coil of the distiller, the circulating water being outside the coil. In our own service, many of the older ships have such distillers, the coil being an actual worm coil. It has been claimed for such distillers (Baird) that the single worm coil takes care of its own expansion and cannot leak unless the metal is actually ruptured, and that having the steam within the coil and the circulating water within the shell there is not so much wild heat or heat radiated into the compartment or room. Straight brass tubes expand more than the iron shell and it is claimed this tends to make a "crawl" with subsequent leaks in the new distillers. However, this is said to be overcome, when straight tubes are used, by having a flanged tube sheet working in a stuffing box. It is an important question because it is just in this part of the apparatus that a defect is most serious from a hygienic point of view. The wild heat is limited by covering shells with hair felt put on in sections, but it is always greater than is desired, yet much of it comes from the evaporator, which would be used whatever the type of the distiller.

With the worm coil distillers (Baird) in service, there is an arrangement by which the steam just before entering the coil sucks in a large quantity of air that goes to aerate the water as the steam is condensed, and there is also a large animal charcoal filter through which the water passes after leaving the distiller. Those measures were certainly of great importance at one time, especially before evaporators were employed, as then the rapid aeration of the steam at condensation helped to oxidize organic matter in boiler steam and by aeration to make it more quickly available for use, and the filter helped to render water from boiler steam clear and free from odor. The use of the evaporator greatly limited the advisability of filtration and on large ships the circulation of water from ripening tanks diminished the necessity for aeration at the distiller.

Aeration and filtration at the distiller belong to the history of distillation on ships. It may be stated briefly that the first practical distilling apparatus on ships of our navy was improvised in 1861 by Eldridge Lawton, the chief engineer of the U. S. S. Mississippi. It probably was intended to meet the emergency of having frequently to leave the blockade during the civil war in order to take on fresh water. It was composed of a worm coil and a whisky barrel. The circulating water entered near the bottom of the barrel and was discharged near the top and boiler steam entered the coil at the top of the barrel, and left the coil as water at the bottom of the barrel. As boiler steam was condensed, the water contained organic matter and oil used in steam cylinder. On exposure to air for a week it lost its flatness and became utilizable for drinking.

Distillers were then regularly designed and placed on all steam ships of our service, but about that time surface condensers came into use. With a jet condenser, such as the Mississippi had, only about one-fortieth part of water was returned to boiler, but with the surface condenser practically all was returned, and the same water passing over and over again to boiler made the boiler steam very dirty. This made the distilled water very objectionable and required it to be kept a longer time before it could be used. It was under such conditions that the Baird distiller was adopted with its aerator and filter. But subsequently, to take much of the work of purification off the distiller, the evaporator was placed between it and the boiler. The evaporator used in connection with the Baird distiller usually gives very good water.

It has been made clear that it is not safe to assume that water is good when it leaves the distiller, or being good on leaving the distiller that it will be good when it reaches the consumer. Even when the integrity of the apparatus is established, certain harbor-waters will furnish a product more or less rich in volatile matters, or in priming may cause the distillate to contain some lifeless organic matter. Such matter may undergo change in tanks or may directly act as a chemical substance causing intestinal disorders. Such results are rare, but the distilled water of a ship should be clear, colorless, and free from any taste or odor not generally recognized as incident to all recent distillation, such as the flat warm steamy qualities freshly distilled water possesses.

In the construction of the fresh-water system sufficient care seems to be taken to avoid contamination of distillate by lead or copper, or any of their salts. The effect of lead is cumulative so that minute amounts in water may cause symptoms of poisoning only after many days. A ship's water being a soft water has the reputation of attacking lead rather vigorously, though containing little CO_2, but in the making, storage, and distribution much care is taken to eliminate danger by practically avoiding lead or any of its salts in construction of apparatus.

It is generally stated that many cases of lead poisoning have occurred on board ships from the use of red lead or *minium* in making joints, or from the use in the fresh-water system of zinc pipes containing lead. That is doubtless true, but in a navy such cases must be very rare, as the records of our service would seem to indicate that the question has attracted no medical attention for many years in spite of the fact that in the fresh-water system galvanized wrought-iron piping is employed and that the scuttle butt itself is made of galvanized iron.

Galvanized iron is made by coating clean iron with zinc. Zinc is obtained chiefly from calamine ($ZnCO_3$) or blende (ZnS) or red zinc ore (ZnO). Blende is generally associated with galena or lead sulphide, but that is rather carefully picked out of the ore before smelting. In the distillation of the zinc a small quantity of lead always distills over. The specific gravity of lead is 11.4 and of zinc only 7 so that when the zinc is to be made into sheets, as lead interferes with successful rolling, a further separation from lead is secured by melting the *spelter* in a reverberatory furnace and taking the melted zinc from the top. The *spelter* is also liable to contain some antimony, arsenic, and copper.

Zinc itself is readily dissolved by dilute acids, and is, therefore, unsuitable material for cooking utensils, its soluble salts being poisonous. Zinc chloride is frequently used in soldering the tins of canned food in order to cleanse surface, and has thus been responsible for a number of cases of poisoning, as it is very soluble in water. Solder itself is an alloy of tin and lead. But zinc is not a cumulative poison like lead, and therefore its presence in small quantities is not so objectionable in water, and the compounds usually formed by the action of water are little soluble. On board ship water does not come in contact with zinc in storage tanks, but only in distribution by short contact in relatively short pipes, and water does not remain in a scuttle butt more than a few hours without renewal. A refined zinc used in galvanizing would not contain more than 1.5 per cent. of lead and probably contains less, for in the refining process described, melted zinc (410° C.) does not seem to be able to dissolve more than that percentage of lead.

It is difficult to predicate to what extent any particular water will affect or acquire either lead or zinc. Ordinarily new bright lead is much more rapid in contaminating water than dull lead and a water containing even a trace of free acid, especially a vegetable acid, will take lead into solution, while a neutral or alkaline water is apt to hold the basic carbonate ($PbCO_3$) with variable proportions of lead hydroxide ($Pb(OH)_2$). This carbonate forms on a piece of clean lead if left in distilled water for a few minutes. Shot used in cleaning wine or beer bottles and carelessly left therein may readily cause lead poisoning. Small shot are made of lead to which about two per cent. of arsenic has been added. Lead is readily converted into oxide and chloride by action of air and sea water.

Zinc poisoning from drinking water has been regarded as impracticable by some authorities, but it is nevertheless believed that some waters can take up zinc in dangerous quantities. However, it does not appear that the distilled water of a ship has much effect upon galvanized iron under usual service conditions. If the water were stored in galvanized iron tanks it would doubtless acquire zinc in appreciable amounts and, after a long storage, the amount might be as much as 1.2 grains per U. S. gallon or even more, but as the storage of drinking water is in cemented iron tanks and there is short contact in pipes and scuttle-butt the question of zinc or lead has not had prominence in the service. The temperature of water in scuttle-butt is also lowered by cooling pipe, and warm water has more effect on metals than cold water. It is generally considered that water containing even 1/25 of a grain of lead per U. S. gallon is unfit for drinking, and many authorities condemn water containing 1/5 of a grain of zinc per U. S. gallon. Certainly in regard to lead no water on a ship should be considered suitable for drinking that contains a trace, and the same standard can be maintained in relation to zinc, as its presence in water is distinctly objectionable. Under all circumstances it is best for a ship's fresh-water plant, after a satisfactory inspection of tanks, to be put in operation a sufficient time, before the ship receives her crew, for the pipes and pumps to receive and discharge water repeatedly, and for the distillate to be examined chemically, especially at the scuttle-butt, before is is considered suitable for use.

The tubes of a distiller are made of copper or a brass containing perhaps 70 per cent. copper and 29 per cent. zinc and one per cent. tin, and the cooling coil of scuttle-butt is of about the same material. All such tubes are, however, thoroughly tinned, and are thus able to resist in great measure for a time the action of air or of water at ordinary temperature even when containing acids and saline matters. But distiller tubes are not altogether immune from corrosive action as such tubes are carried as spare parts and require renewal occasionally. However, the changes are slow and without appreciable effect in adding metallic substances to the distillate.

It is probable that the changes in distiller coils are partly mechanical (varying expansion due to heat and pressure and continuous friction of circulating water) and partly chemical. Salt water ultimately corrodes copper by converting it first into oxide and then, by the sodium chloride, into oxychloride of copper. It thus seems probable that the circulating water is ultimately chiefly responsible for chemical changes in distiller tubes, and thus for ultimate leakage at working pressure.

The steam cookers at the galley are also made of copper, but they are tinned on the interior. A perfectly clean surface of metallic copper is not apt to be affected in cooking, but if copper is allowed to remain exposed to air the oxide is formed which ultimately combines with water and CO_2 to form a basic carbonate of copper. This is readily dissolved and has often led to poisoning. The oxide is also more apt to form when air acts in the presence of acids, fats, or common salt and then readily passes into soluble salts of copper. Tin resists the action of air in the presence of such acids and salts, and its use is a hygienic measure of importance. It is also used on the inner surface of the small copper gravity tanks on ships.

Since the use of cement within storage tanks, iron has ceased to be a distinct feature of the distilled water of ships. It does not appear that the mere presence of this metal in water has ever been directly objectionable on ships from the point of view of health. It appeared as the hydrated ferric oxide or rust and was objectionable as a sediment in interfering with the inspection of tanks, in masking or facilitating other sedimentation and by its formation, in causing a roughness of tank surface not conducive to cleanliness. It caused a frequent cleaning or scrubbing of tanks with multiplication of dangers from that direction. At present with the absence of rust, sediment in the drinking water of a ship is a cause for immediate investigation, and in that investigation should be included water-coolers, as well as storage tanks, and ice-making tanks. Often local conditions or lack of care on the part of mess attendants is responsible for objectionable drinking water, but whatever the cause it is always important to trace at once to source.

The foregoing is intended to be a declaration of the normal opportunities the distilled water of a ship has to acquire metals or their salts. In the construction of a ship, workmen, in hastily knocking off work or in the hurry of work, have been known to do rather curious things, and although no lead is used as such in the construction of a fresh-water plant or system, material, such for instance as a can of red lead, might be stowed away and forgotten in certain undesirable locations. Though the chance of such an accident is evidently very remote it is always well anyhow for a medical officer to have in mind at the very beginning of a ship's commission the possibility of contamination of water by metals, and to make the qualitative tests required for determination and given in the notes on water analysis to follow, although the chances seem to be strongly in favor of negative results, at least so far as copper and lead are concerned, and practically so far as zinc is concerned.

The extended use of distilled water on ships has rendered the taking of fresh water from shore for personal use a marked exception rather than a frequent occurrence. This situation represents a great advance in naval hygiene, for the conditions under which shore water was usually taken were such as to preclude the exercise of reasonable caution, and, as a result, it was not very uncommon for water to give trouble after it had been examined and passed by the medical officer. *As a rule, the medical officer did not know that water was to be taken until it was alongside in the water-boat, and then all the circumstances made for hurried examination and a snap diagnosis.*

To ascertain that water is safe for drinking requires a wide knowledge of its source and repeated tests that demand apparatus, suitable surroundings, more or less expert knowledge of the value of tests, and not a little *time.* Nothing more than probabilities can be expressed when an opinion is required in an hour, or even two, as such opinion must rest solely not only upon chemical tests, but also upon a limited number of such tests, in view of ship conditions. Experience during a number of years demonstrated that the tests that were made were not sufficient, at least under the interpretations, to safeguard the ships. This seems to have been more the result of circumstances than the fault of examiners, and therefore it seems wise to depend upon the distillation of water rather than the taking of water which, even if pure at the time it goes into the water-boat, often has many chances for contamination before it reaches a ship's tank.

There is also not a little evidence to show that water of good reputation, as incapable of causing disorders at time of receipt, may acquire the ability to give much trouble after it is stored on board. For instance, in March, 1877, the fresh-water tanks of the sloop of war, Swatara, were filled at Norfolk, Va., with water from Lake Drummond supposed to be suitable for storage on shipboard. In a severe storm off Hatteras, lasting several days, the water was constantly agitated, its changes being also hastened by the heat and confinement of foul air between decks incident to a southern latitude, and the closure of hatches. Sixty cases of intestinal disorders, regarded as dysenteric in character, developed in one day from its use, the disease disappearing rapidly when the distiller was employed. Such marked lessons have in time taught the great value of distilled water for drinking purposes on vessels of war, and have led to appreciation of the necessity for its general use in the preservation of the health of crews. Water from Lake Drummond had been used for years on the receiving ship at Norfolk, and continued to be used for many years without untoward effects. It had a good reputation and still has among the river men, but its history as an innocuous water was of no value under the conditions on the Swatara.

The general regulation now applied to this subject is that ships on the Asiatic station and elsewhere where pure water cannot be obtained from the shore, shall distill all water used for cooking and drinking, and that no water shall be used for drinking purposes unless it shall have been tested and approved. Whenever a supply of water is obtained from shore either for drinking or cooking and before it is taken on board as complete an analysis of it as possible, with the means at hand, is to be initiated and report made at once if any doubt exists as to its purity. These regulations seem to be quite sufficient, except as to time for investigation, especially as any doubt of purity is made a cause for rejection.

But the same regulations in regard to shore water have been in force for many years, and experience has demonstrated that the conditions under which the water was usually found (alongside in a water-boat) and under which the examinations were made, left altogether too much to chance. It is, therefore, fortunate that such examinations of shore water are now rarely made, although if water is rejected strictly under the instructions of any doubt as to its purity, and it is practicable to exclude that water from the ship though probably the only kind of water available in that port, such tests as are practicable on ships have more real importance than they have appeared to have. This is true in spite of the fact that along the seacoast the value to be given the determination of chlorides is often a most perplexing question, making the testimony of an important witness in other localities of little avail and always complicating the inquiry of possible or even probable contamination during transportation in the water-boat, the condition of which in some ports should itself be cause for rejection.

In any chemical examination of water the first question to be answered is whether it is a stable water. Any water that is in a state of change is particularly dangerous in a ship's tanks, for under such circumstances, even if the bacteria feeding on its nitrogenous matter are not pathogenic, the condition in the tanks of agitation, heat, and limited air may produce potent chemical substances that might never have been formed, at least in large quantities or great concentration, during the process of self-purification under normal conditions. It can usually be assumed that water going into a ship's fresh-water tanks, though used rather rapidly, will be consumed during the very active stage of the decay of its nitrogenous organic matter if it holds such matter. It is therefore not merely a question of bacteria but also of toxines, it being recognized that the nitrogenous compound is in a state of change because it is being utilized as food by micro-organisms.

Now, as the result of this change there are certain chemical products—intermediate products and ultimate products. Among the intermediate products are carbon dioxide, ammonia and nitrites, while the ultimate products are regarded as nitrates. Nitrates, therefore, unassociated with nitrites indicate completion of the change, and if in *large amounts* tend to show that the quantity of changing or unstable organic matter was at one time large, but that the water is now stable though rich in material for plant-growth. Such a water was very probably originally from an undesirable source and may at times have more organic matter than it is able to work over before it reaches the consumers. It, therefore, may very well be dangerous in general terms as a continuous water supply, and, having probably contained large numbers of bacteria as is suggested by its large nitrate content, it may not now be quite safe, unless it is free from both the intermediate products, ammonia and nitrites, showing it has been purified. Such water should have no odor.

Nitrates above 0.5 parts per million should immediately attract attention, and if above 1.2 parts should be considered with even additional seriousness in relation to the free ammonia and nitrites that may be present. This consideration is often complicated by question of source. There is an important link missing when the examiner does not know the source of the water, that is, whether surface or ground water, in great or small part, deep or shallow well water, spring or lake water, river or rain or cistern water, and how it has been stored or treated, and what its general or special relations to human habitations have been. All such information and more is required as essential in passing upon a given water as a water supply, but the history of such examinations on ships shows that in the large majority of cases very little or none of this information has been available at the time it was wanted.

Rain carries down a little free ammonia from the atmosphere, and many pure or usable waters contain from 0.02 to 0.05 parts, per million. Rain itself may contain from 0.1 to 0.4 parts, but it takes a very short time for unpolluted soil to oxidize ammonia, and therefore in the absence of pollution the water supply should have less. Cistern water itself is very generally a suspicious water, as it contains material washed from roofs that may have been derived from even rather distant locations. It is therefore necessary to permit the roof to be well washed off before water is admitted to the cistern, and even then to allow the cistern water to stand undisturbed for some time that it may have opportunity for self-purification. Under such circumstances the free ammonia should be less than 0.05 with an absence of nitrites and little or no nitrates, especially if the water is filtered before ultimate storage.

Free ammonia may be regarded as the first product of the decay of nitrogenous organic matter, but as derived from the atmosphere it was obtained separated from source. On the other hand, in sewage it is forming and may be much higher than 20 parts per million and is rarely below 10. With the nitrogenous matter in that stage there has not been time or opportunity for the formation of subsequent products, and the nitrites and nitrates may be in small amounts or even absent.

In the absence of facilities for the determination of free ammonia in water, or as most important supplementary help, bacteriological work finds its marked expression in the detection of sewage contamination. Sewage contains perhaps 60 or 70 parts per million of chlorides, but near the sea that fact may not be of much help, as the normal waters of the locality often contain more, and in very recent sewage contamination of water the amount of the organic matter itself as albuminoid ammonia and the amount of free ammonia, representing its first change, would be the chemical determinations of importance. But such determinations require *time* and *distillation* and would rarely if ever be made with a water-boat alongside even if a still were available. Bacteriological tests require even more time and at least some kind of incubator, but the results permit more or less direct conclusions when sewage forms are found. Yet, if the opinion is to be given hurriedly, such tests are not available.

A sufficient incubator can be extemporized by immersing an electric light and bulb in water around another receptable in which the fermentation tubes of glucose and of lactose broth seeded with varying amounts of the water to be examined are placed and the whole covered with a towel.

In sewage there are gas-forming organisms in large numbers, of which the colon bacillus may be regarded as the type. That bacillus is taken as the direct indication of intestinal contamination, and thus its presence is important as an indicator of animal influence. It is not so much the actual number of bacteria in water as their kind and the number of objectionable forms—sewage forms. It is, therefore, a qualitative bacteriological examination that is primarily of the greatest importance and the number or prevalence of the objectionable forms. Therefore, in connection with fermentation tubes it is necessary to plate out and carry through cultural methods if satisfactory conclusions are to be drawn as to the presence of the colon bacillus. But as such organisms may multiply rapidly in the water of a water-boat, especially in hot weather, such tests become very much complicated under ordinary service conditions. Altogether it is doubtful how much along this line, even with time in which to make the tests, will be done on ships, though as processes are simplified, bacteriological work is rapidly increasing. It, however, forms a special subject that while belonging to *hygiene* is mentioned in naval hygiene chiefly to show connection with sources of information readily available elsewhere.[1]

In our service there are at present the following official notes on the bacteriological examination of water:

> The three principal points to consider are:
>
> 1. Number of bacteria per cubic centimeter.
> 2. Nature of bacteria (whether developing at 37.5°).
> 3. As to the presence of special organisms (*B. coli*, *B. typhosus*, *Streptococci*, *Sp. choleræ asiaticæ*.
>
> In collecting water attend to the following points:
>
> (*a*) Bottles (from 25 to 100 c.c. capacity) should be sterile (either by heat or by rinsing with a little H_2SO_4 and subsequently washing thoroughly with the suspected water before collecting). If to be transferred, pack in ice to prevent bacteriological development. (Frankland states that count of 1,000 per cubic centimeter became 6,000 in 6 hours and 48,000 in 48 hours.)
>
> (*b*) If collecting from city water supply be sure not to take from a cistern; always *direct* from *mains*. Let the water from tap run a few minutes before collecting. If from pond, stream, or cistern, be sure that the water comes from at least 12 inches below surface (avoidance of surface scum, etc.).
>
> (*c*) In relatively pure waters, as from springs, bacteria multiply rapidly during first few days; in impure water, however, multiplication is slow.

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[1] The bacteriological examination of water in the Navy is made a part of the work of the Department of Bacteriology at the Naval Medical School and the methods employed can be found in Practical Bacteriology, Blood Work and Animal Parasitology by Surgeon E. R. Stitt, U. S. Navy—P. Blakiston's Son & Co., 1909.

Quantitative Bacteriological Examination.

1. Deliver definite quantities of the water to be examined into tubes of liquefied gelatin or agar and plate out the same, or into a series of Petri dishes. The water should be deposited in the center of the plate and the melted gelatin or agar poured directly on the water, and then carefully tilting to and fro mix the water and the media. One set of plates should be of gelatin and incubated at room temperature; a similar set should be of lactose litmus agar and incubated at 38° C. If the water is highly contaminated it is necessary to dilute it—thus with river water which may contain from 2,000 to 10,000 bacteria per c.c. a dilution of 1 to 100 would be desirable.

Ordinarily it will be sufficient to deliver from a sterile graduated pipette 0.2 to 0.3 and 0.5 c.c. of the water in each of three sets of plates, one set for gelatin, the other for agar.

When gelatin is not at hand or convenient to work with, the gelatin plates may be replaced by others of lactose litmus agar for incubation at room temperature. After 24 hours at 38° C. or 48 hours at 20° C. the count should be made.

Example.—Forty colonies were counted on the gelatin plate containing 0.2 c.c. of the water. The number of organisms would be 200 per c.c. Ten colonies were counted on the agar plate containing 0.2 c.c. and incubated at 38° C. Number of bacteria developing at body temperature equals 50 per c.c.

There is no strict standard as to the number of bacteria a water should contain per c.c. Koch's standard of 100 colonies per c.c. is generally given. It is by the qualitative rather than the quantitative analysis that one should judge a water.

If there should be very many colonies on a plate the surface can be marked off into segments with a blue pencil. If very numerous cut out of a piece of paper a space equal to 1 square centimeter. By counting the number of colonies inclosed in this space at different parts of the plate we can strike an average for each space of 1 square centimeter. To find the number of such spaces contained in the plate, multiply the square of the radius of the plate by 3.4116. Then multiply this number by the average per square centimeter and we have the total number of colonies on the plate. This is the principle of the Jeffers disk.

The relative proportion between the bacterial count at 20° C. and that at 38° C. is of great importance from a qualitative standpoint, as will be seen later.

2. Deliver into a series of Durham fermentation tubes containing glucose bouillon and into another series containing lactose bouillon varying definite amounts of the water to be examined. In tubes showing the presence of gas in both glucose and lactose bouillon the evidence is presumptive that the colon bacillus is present. For the positive demonstration plates must be made from such tubes as show gas.

It is sufficient to deliver from graduated pipettes in each series quantities of water varying in amount from 0.1 c.c. to 10 c.c. In our laboratory we inoculate with 0.1 c.c., 0.2 c.c., 0.5 c.c., 1 c.c., and 10 c.c. of the suspected water. If the 0.1 c.c. tubes show gas, we have reason to assume that the water contained at least 10 colon bacilli per c.c. If only the 10 c.c. tubes showed gas—those with less amounts not having gas—we would be in a position to state that the water contained the colon bacillus in quantities of 10 c.c. but not in quantities of 1 c.c. or less. Many authorities regard water as suspicious only when the colon bacillus is present in quantities of 10 c.c. or less—waters of good qualities frequently showing the presence of the colon bacillus in quantities of 100 to 500 c.c.

It is generally accepted that if a water shows the presence of the colon bacillus in quantities of 1 c.c. or less it should be regarded as suspicious.

At the present time the medium that gives the least source of error in carrying out the quantitative presumptive tests is the bile lactose. It is made by adding 1 per cent. of lactose to ox bile, and fermentation tubes of the media showing gas may be considered as very probably containing the colon bacillus. The percentage of error with this method is reported to be only 11 per cent., while with glucose fermentation tubes the error is more than 50 per cent. Gas formation is usually shown in 48 hours, but it is advisable to continue the incubation for 72 hours. Even with this method plates should be made.

3. As the colon and sewage streptococci ferment lactose with the production of acid and hence produce pink colonies on lactose litmus agar much information can be obtained from the proportion existing between the number of pink colonies and those not having such a color. Waters of fair degree of purity rarely give any pink colonies.

Qualitative Bacteriological Examination.

General considerations.—In some countries the proportion of liquefying to non-liquefying colonies on gelatin plates is considered of importance. Certain sewage organisms belonging to the proteus and cloaca group liquefy gelatin; consequently if the proportion of liquefying to the non-liquefying be greater than as 1 to 10 the water is considered suspicious. The test is not considered by American authorities as of any particular value.

The American Public Health Association recognizes the importance of the information obtained from a comparison of the number of organisms developing at 38° C. and those developing at 20° C. Bacteria whose normal habitat is the intestinal canal naturally develop well at body temperature, while normal water bacteria prefer the average temperature of the water in rivers and lakes. Consequently when the number of organisms developing at 38° C. at all approximates the number developing at 20° C. there is a strong suspicion that sewage organisms may be present. Normal waters give proportions of 1 to 25 or 1 to 50, while in sewage-contaminated waters the proportion may be as 1 to 4 or less.

In addition, the appearance of pink colonies on the lactose litmus agar is of great assistance in judging of a water. Both sewage streptococci and the colon bacillus give pink colonies—those of the streptococci are smaller and more vermilion in color. Microscopic examination will differentiate the cocci from the bacilli. It is well to bear in mind that the pink colonies after 24 hours may turn blue in 48 hours from the development of ammonia and amines. Consequently the lactose litmus agar plates should be studied after 24 hours.

A good water supply will rarely show a pink colony, while in a sewage-contaminated one the pink colonies will probably predominate.

The diagnostic characteristics considered important by the American authorities in reporting the colon bacillus are:

1. Typical morphology—non-sporing bacillus, relatively small and often quite thick.

2. Motility in young broth cultures. (This is at times unsatisfactory, as some strains of the colon bacillus do not show it even in young bouillon cultures.)

3. Gas formula in dextrose broth. Of about 50 per cent. of gas produced, one-third should be absorbed by a 2 per cent. solution of sodium hydrate (CO_2). The remaining gas is hydrogen. (Later views indicate that the gas formula is exceedingly variable and should not be depended upon. To carry out this test, one fills the bulb of a fermentation tube with the caustic soda solution; then holding the thumb over the opening or with a rubber stopper, the bouillon culture and the soda solution are mixed by tilting the fermentation tube to and fro. The total amount of gas is first recorded and then that remaining after the CO_2 has been absorbed is reported as hydrogen.)

4. Non-liquefaction of gelatin.

5. Fermentation of lactose with gas production.

6. Indol production.
7. Reduction of nitrates to nitrites.

Note.—The reduction of neutral red with a greenish-yellow fluorescence is very striking and has been suggested as a test for the colon bacillus. Many other organisms, especially those of the hog-cholera group, have this power. It is convenient, however, to color glucose bouillon with about 1 per cent. of a one-half per cent. solution of neutral red.

Isolation of the Typhoid Bacillus from Water.

This is probably the most discouraging procedure which can be taken up in a laboratory. Only the most recent reports of such isolation from water supplies, which have been verified by immunity reactions, can be accepted, and of these the number of instances is exceedingly small. Owing to the long period of incubation the typhoid organisms may have died out before the outbreak of an epidemic suggests the examination of the water supply.

There have been various methods proposed for the detection of the *B. typhosus* in water. A method which would offer about as reasonable a chance of success as any other would be to pass 2 or 3 liters of the water through a Berkefeld filter; then to take up in a small quantity of water all the bacteria held back by the filter. Then plate out on lactose litmus agar and examine colonies which do not show any pink coloration. The dysentery bacillus has about the same cultural characteristics as the typhoid one, so that it is important to note motility. If from such a colony you obtain an organism giving the cultural characteristics of *B. typhosus*, carry out agglutination, and preferably bacteriolytic tests as well. Some strains of typhoid, especially when recently isolated from the body, do not show agglutination.

The Conradi Drigalski, the malachite-green, and various caffein-containing plating media have been highly recommended.

Isolation of the Cholera Spirillum from Water.

The method proposed by Koch in 1893 does not seem to have been improved upon by later investigators. To 100 c.c. of the suspected water add 1 per cent. of peptone and 1 per cent. of salt. Incubate at 38° C., and at intervals of 8, 12, and 18 hours examine microscopically loopfuls taken from the surface of the liquid in the flask. So soon as comma-shape organisms are observed, plate out on agar. The colonies showing morphologically characteristic organisms should be tested as to agglutination and bacteriolysis. Inasmuch as the true cholera spirillum shows a marked cholera-red reaction, it is well to inoculate a tube of peptone solution from such a colony and add a drop of concentrated sulphuric acid after incubating for 18 hours. The rose-pink coloration is given by the cholera spirillum with the acid alone, the nitroso factor in the reaction being produced by the organism.

However, ordinarily a water-boat is not filled from a particular well, spring, or cistern, but from some large water supply of a town or city. Under such circumstances its changing organic matter ordinarily has had opportunity to progress further than free ammonia in the presence of decay and to form some nitrites. It has already been made apparent that a water without nitrites may be very impure, but, on the other hand, a water showing nitrites is always suspicious when obtained from a water-boat, and therefore causes at least reasonable doubt of its purity. It is believed to be prudent to avoid for a ship's water supply, a water containing even traces of nitrites, and that conviction is strengthened if there is even a slightly musty or disagreeable odor when heated in a flask, although many good waters have a slightly marshy odor while not a few impure waters are odorless.

This development of a musty odor to be distinguished from an odor of vegetable origin is regarded as often an important indication of sewage pollution of surface water and would create a doubt of purity even when chemical analysis did not give convincing testimony. This odor is something like that of damp stable straw, and is to be distinguished from the swampy or marshy odor of purely vegetable origin. Surface waters not having been to any great extent under the influence of the nitrifying micro-organisms of soil, as have ground waters, very generally contain relatively small amounts of free ammonia, nitrites and nitrates, the products of the decay of the nitrogenous organic matter, but as it has rather recently washed the earth's surface is apt to be rich in the organic matter itself. The musty odor being of animal origin is, therefore, of particular value in the examination of these waters.

To the test for nitrites can be readily added on ships an estimation of oxygen-consuming power. This estimation merely furnishes an additional link in the evidence for or against a water. What is sought in this test is a measure of the organic carbon in the water from the amount of oxygen required to complete its oxidation. As the organic matters in the water are carbon compounds, it has been thought that the amount of oxygen consumed must bear some relation to the amount of such matter. While that is doubtless true in a general way, there are, in a particular way, differences in the organic matter itself, just as there is difference between protein of animal and vegetable origin, and while the oxygen-consuming power may be a measure of the quantity of organic matter then present in the water, it cannot differentiate between that of animal and of vegetable origin or between *nitrogenous* and *non-nitrogenous* matter, for such organic matter contains no nitrogen, and it is the nitrogen cycle that is of chief importance in the chemical examination of water.

Nevertheless, a water having an oxygen-consuming power of about one or more per million is in the class requiring a more careful attention to the other witnessess, nitrates, nitrites, and, whenever practicable, as on shore stations, to the free ammonia and albuminoid ammonia. It is not simply oxidizable substances that are in question but decaying substances. It is not even the amount of albuminoid ammonia, supposed to represent the nitrogenous matter capable of change, but the proof that it is tending to change. Nevertheless, albuminoid ammonia above 0.1 per million should lead to much suspicion. If with that the free ammonia is as high as 0.05 the suspicion may be strengthened, and if nitrites are present one need not hesitate to condemn as too suspicious to be safe, in a ship's tanks at any rate; a condemnation strengthened by a nitrate content of 1.2 or above.

The deduction from estimation of chlorides in water from the sea-coast is very uncertain in many cases. One of course must condemn water well short of a suggestion of brackishness. In this connection it should not be forgotten that the sample obtained from the water-boat is liable not to be a true sample of the water supply from which the boat was filled. *Whenever it is possible it is strongly advisable to obtain a sample at the place where the boat obtained its supply and compare it with the sample from the boat in all tests.* The water-boat is ordinarily floating in a dirty salt water, and an increase in chlorides should be taken as indication of contamination by harbor water.

In certain ports the construction of the water-boat itself or the conditions prevailing on board are ample cause for the rejection of the water. No drinking water should be taken from a wooden water-boat, as such boats, acting as tanks, are subject to leakage and are also very difficult to keep clean. No water should be taken from a boat on which families live or persons not under the strictest control or from a boat showing lack of cleanliness or if possible from a boat whose tanks have not been recently filled. All of this is under the proviso that it is much better not to take in drinking water at all, and that it is best to carry out the present service custom of making all fresh water by distillation.

The sample should be collected in a bottle that has been thoroughly cleaned and then rinsed several times with the water to be examined. Collect the water below the surface and insert the clean cork or stopper in that position. If the water is taken, have the first pumpings wash the hose before water goes to tank and have the hose one that has never been used to carry harbor water.

While each year the examination of water from shore has become a diminishing feature of sanitary duty on ships there has been a certain increase in water analysis at naval stations, especially in the tropics and often in relation to civil population under naval control. At all such stations the problem is one in general hygiene and is more properly treated in works on that subject. But, in dealing with it, the work of first importance is to make a most careful inspection of source of possible pollution and not only consider repeated analyses in that relation but also in relation to the removal of cause of pollution. Yet, in connection with such analyses ashore and afloat, and in view of the material usually at hand, the following notes *official in our service*, have been included here as of value in doing the chemical work required:

The chemical examination that is ordinarily made as an aid in judging the quality of a water for sanitary purposes has for its object not a complete analysis of the water, but simply the determination of the contained quantities of those ingredients which, although common to all natural water, are more or less influenced by contamination with animal or vegetable products. In addition, the physical properties of the water, such as color, odor, turbidity, and sediment, are observed, even though they may not have much bearing on the quality.

Those ingredients, the quantities of which are sought, are the total solids, free and albuminoid ammonia, nitrites, nitrates, and chlorine. In addition to these, the quantity of oxygen consumed, although it is a property rather than an ingredient of the water, is always determined, as it is considered by many analysts to be one of the most valuable guides to the quality. Hardness is of little value hygienically, but its determination is frequently necessary on ships in ralation to boilers.

The results of the examination are variously expressed, the quantities of the ingredients being said to be present as so many parts per million, grains per United States gallon or grains per imperial gallon. Of these the expression "parts per million" is the one now more generally used, although either of the others may be desirable.

To obtain the parts per million, the weight of the substance, in grams, contained in a liter of the water is determined. This weight when divided by 0.001 or multiplied by 1,000 gives the desired result. As obtained by dividing by 0.001 the result is milligrams per liter, a liter being 1,000,000 milligrams, and when multiplying by 1,000 the number of grams in 1,000,000 grams or 1,000 liters, either being parts per million.

If the number of grains per United States gallon is desired it can be obtained by multiplying the number of parts per million by 0.0584. To express the result in grains per imperial gallon multiply the parts per million by 0.07.

Note.—The result as calculated above is not strictly true, for in a liter of ordinary water there is dissolved quite a quantity of solid matter—say, for example, 0.5 gram, or 500 milligrams. A liter of this water would weigh approximately 1,000,500 milligrams instead of 1,000,000. In this case each milligram per liter would be one part in 1,000,500 instead of one part in 1,000,000.

For the waters ordinarily met with the calculation as given above is sufficiently accurate. In a water highly charged with saline matter, as, for example, sea-water, then the quantity of the water used in the various determinations should be by weight and not by volume.

The water must not be filtered before examination, except as noted below, but on the contrary the vessel containing the specimen should be thoroughly shaken before each and every portion is withdrawn. By so doing an analysis representing the composition of the water as it is consumed is obtained.

In the various determinations solutions of exact strength are required. As it would be difficult or impossible to prepare these aboard ship, the Medical Department of the United States Navy issues the reagents in tablet form. Generally these reagents can be added directly to the water under examination, thus in many cases avoiding the necessity of preparing the solutions. The method of using these tablets or "soloids," as they are called, will be described under each process.

Color.—This is determined by observing the color of a column of the water 2 feet in thickness. A tube 2 feet long and closed at both ends by glass plates is used for the purpose, the observation being made through the long axis of the tube, and using a white surface as a back ground. Attempts have been made to fix standards of color, but for ordinary purposes it is sufficient to note the color observed.

The color of a water has but little significance except for appearance, for some very dark waters are of good quality, while many that are clear and colorless are highly polluted.

Turbidity.—This is due to the suspension of very finely divided material. As its estimation is of little importance, it is sufficient to note it as being slight or marked as the case may be.

Sediment.—This is composed of the coarse inorganic and organic matter which separates on standing. The quantity can be determined by simple observation, for it is usual to note it as being small, large, etc.

Odor.—The method of obtaining the odor is to about half fill a flask with the water and bring it to the boiling point. The contents of the flask are then agitated and the odor noted.

Total Solids.—The total solids consist of all substances dissolved and suspended in the water. To determine the quantity, place 100 c.c. of the specimen in a tared dish, preferably one of platinum, evaporate to dryness on the water-bath and then dry in steam or air oven at a temperature not exceeding 120° until the weight becomes constant. The increase in the weight of the dish equals the quantity of solids in 100 c.c. of the specimen. Calculate the quantity in a liter and then express the result in parts per 1,000,000. This determination cannot be made aboard ship.

Loss on Ignition.—This is to be determined by gradually raising the temperature of the dish and its contents to dull redness, cooling in a desiccator and again weighing. The weight lost is the loss on ignition. This, like all other results, should be expressed in parts per 1,000,000.

The changes occurring in the residue during the ignition are of much more importance than the loss of weight, the latter having little if any quantitative value. Should the residue become blackened (which will be due to the carbonization of the organic matter) and it is afterward difficult to discharge the black (carbon) so produced, then the water may be looked upon with suspicion. Exceptions to this, however, are numerous. It should also be borne in mind that residues which do not blacken are not necessarily residues from pure waters.

Free Ammonia.

The free ammonia of water consists of ammonia (NH_3) existing as such, together with that which is present in the form of ammonium salts. This ammonia results either from the decomposition of organic nitrogenous matter, the reduction of nitrates, or is added by accident.

Owing to the exceedingly small quantity of ammonia or ammonium salts that are ordinarily present in the water and also because of the presence, usually, of interfering substances, it is necessary in order to determine its quantity, to use some method by which the ammonia can be concentrated and at the same time freed from impurities. This unfortunately requires elaborate apparatus, and as a consequence the determination, even though important, cannot be carried out aboard ship.

When it is possible to make this determination the following solutions must first be prepared:

Nessler's Reagent.—Dissolve 13 grams of mercuric chloride in 400 c.c. of distilled water. In another 400 c.c. of distilled water dissolve 35 grams of potassium iodide. Add the mercuric chloride solution to that of the potassium iodide until a small quantity of red precipitate remains permanent. To the resulting solution add 160 grams of solid potassium hydrate, and when this is dissolved add about 5 c.c. more of the mercuric chloride and sufficient distilled water to make 1,000 c.c. of solution. Allow to settle and use the clear supernatant solution as required. This reagent improves with time.

Standard Ammonia Solution.—Dissolve 0.0315 gram of pure ammonium chloride in one liter of ammonia free water and thoroughly mix. Each cubic centimeter of this solution will contain 0.00001 gram of ammonia, NH_3.

Sodium Carbonate.—Dissolve 50 grams of pure, dry sodium carbonate in 300 c.c. of distilled water.

Ammonia-free Water.—Add sodium carbonate to water to the extent of about 1 gram to the liter. Distill, and when the distillate ceases to give a reaction with Nessler's reagent collect the remainder of the distillate in a perfectly clean bottle. Several liters of this will be required.

Having prepared the above solutions the estimation is now made in the following manner: In a glass retort of about 1,200 c.c. capacity place 250 c.c. of the ammonia-free water, 10 c.c. of the sodium carbonate solution, and then drop into the retort a small piece of pumice (the pumice should previously have been heated to redness and dropped into the retort while still hot). Make all the connections tight, and be sure that a generous flow of water is passing through the jacket of the condenser. Begin the distillation. Collect the distillate in 50 c.c. Nessler jars and add to each jar 2 c.c. of the Nessler reagent. If the apparatus has been properly prepared, the third portion of distillate will not give a reaction with the Nessler.

The operations so far have been directed toward the removal of that ammonia which might, by accident or otherwise, have remained in the apparatus, and which, if it were allowed to remain, would cause serious error. If the third distillate gives no reaction with the Nessler, the apparatus is properly prepared and the examination of the specimen for free ammonia can be begun.

Note.—The distillates so far collected are to be discarded, for they in no way have any bearing on the examination of the water.

Without disturbing its contents, introduce into the retort 500 c.c. of the water to be examined and distill, adjusting the flame so that 50 c.c. of distillate are obtained in 15 minutes. The distillate is collected in 50 c.c. Nessler jars as before, and to each jar is added 2 c.c. of the Nessler reagent, when there will develop, within 5 minutes, a color ranging, according to the amount of ammonia present, from a very pale yellow to a deep orange or brown. Continue the distillation until a tube of the distillate is obtained which does not give a color on the addition of the reagent. (The lamp is now removed from beneath the retort, but the contents of the latter are not disturbed, as they will be immediately used for the estimation of the albuminoid ammonia, as will be directed in the article describing it).

Standards, each containing a known quantity of ammonia, are now prepared. They are made by adding to a series of 50 c.c. Nessler jars such quantities, for example, as 0.5, 1.0, 1.5, 2.0 c.c. of the standard ammonia solution, filling to the mark with ammonia-free water and then adding to each jar 2 c.c. of the Nessler reagent. Allow them to stand for 10 minutes. These standards would contain, respectively, 0.000005, 0.00001, 0.000015, 0.00002, etc., gram of ammonia, NH_3. Compare each distillate with the standards until one of the latter is found which has the same color. This standard and the distillate contain the same quantity of ammonia. The sum of the quantities of ammonia found in the distillates will be the ammonia in 500 c.c. of the water. Multiply this quantity by 2 and the result will be the quantity of ammonia in a liter. Convert this into parts per 1,000,000.

Example.—Collected four 50 c.c. portions of distillate, added to each portion 2 c.c. of Nessler, and then after 10 minutes compared with the standards. The first distillate was found to contain 0.00002 gram of ammonia, the second 0.00001, the third 0.000005, and the fourth a trace. Then:

0.00002
0.00001
0.000005
0.0000000
0.000035 Quantity of ammonia in 500 c.c. of the water.
2
0.000070 Quantity of ammonia in 1,000 c.c. of the water.
0.001)0.00007(0.07 Free ammonia expressed in parts of 1,000,000 or
0.00007
1000
0.07000 Free ammonia expressed in parts per 1,000,000.

The free ammonia of water consists of the ammonia existing as such and also that which exists in the form of ammonium salts, such as the chlorides, sulphates, etc. The latter are converted by alkalies and alkaline carbonates and heat into ammonia (NH_3) and the corresponding salts of the alkali. Assuming that the chloride and sulphate of ammonium are present, then on the addition of the alkali, which in this case is sodium carbonate, the following reactions occur:

$$2NH_4Cl + Na_2CO_3 = 2NH_3 + CO_2 + H_2O + 2NaCl.$$
$$(NH_4)_2SO_4 + Na_2CO_3 = 2NH_3 + H_2O + Na_2SO_4 + CO_2.$$

The reaction between the Nessler reagent, which is a solution of potassium mercuric iodide ($2KI.HgI_2$) in one of potassium hydrate (KOH), and the ammonia is—

$$2(2KI.HgI_2) + NH_3 + 3KOH = NHg_2IH_2O + 7KI + 2H_2O.$$

The compound NHg_2IH_2O is hydrated dimercuri-ammonium iodide.

Albuminoid Ammonia.

It should be understood that this is not a form of ammonia existing in the water, but is the ammonia which results from the oxidation of the contained organic nitrogenous matter, the oxidation being accomplished by means of an alkaline solution of potassium permanganate.

As its determination is a continuation or a repetition of the process for the estimation of the free ammonia, it is obvious that its determination is impossible aboard ship.

Alkaline Potassium Permanganate.—Dissolve 200 grams of solid potassium hydrate in about 1,400 c.c. of distilled water and add to this solution 8 grams of potassium permanganate. Boil down to 1,000 c.c. Keep in a glass-stoppered bottle.

To the contents of the retort remaining from the estimation of the free ammonia add 50 c.c. of the alkaline permanganate solution, distill, and estimate the ammonia in the distillates just as in the estimation of the free ammonia. The calculation is made in the same manner.

Instead of using the residue from the estimation of the free ammonia a fresh 50 c.c. portion of the water may be taken and the total ammonia determined by adding the potassium permanganate and distilling. The difference between the total ammonia and the free ammonia would be albuminoid ammonia.

As solutions of any strength could readily be obtained whenever it would be possible to estimate the ammonias, the directions for the use of the soloids or tablets in this connection are omitted.

Chlorine.

Chlorine exists in water principally in the form of sodium chloride and is derived normally through the disintegration and alteration of mineral matter, from the air and often near the seacoast from the infiltration of sea-water. Abnormally it is derived from animal excreta.

In the pure waters derived from springs, streams, and shallow wells the quantity is, as a rule, very small, the same being also true of rain water when it is properly collected and stored. In rain water gathered near the seacoast the quantity of chlorine may be considerable. In the water from larger streams and rivers the quantity of chlorine is usually small, unless highly polluted or influenced by the sea. In the distilled water aboard ship it should never be present in any appreciable amount, and if found in abundance it indicates either too rapid distillation or a leak in the apparatus, a condition which may lead to serious results. Small quantities, as stated, have no significance and will be frequently found.

For the estimation of this very important ingredient the following solutions will be required:

Standard Silver Nitrate.—Dissolve 4.802 grams of pure crystallized silver nitrate in sufficient distilled water to make 1,000 c.c. of solution. Each c.c. of this solution will precipitate 0.001 gram of chlorine.

Potassium Chromate.—Dissolve 2 grams of yellow potassium chromate in 100 c.c. of distilled water. To insure freedom from chlorine, add a few drops of the silver solution and filter.

A qualitative test for chlorine should always be made in order to determine the relative amount present. If, on the addition of a few drops of a strong solution of silver nitrate to a little of the water, only a slight haze or a moderate opalescence is produced, it of course indicates that only a small quantity of chlorine is present; but it also indicates that concentration of the water is advisable before an effort is made to estimate the quantity of chlorine. If, on the other hand, a decided milkiness or a precipitate moderate in quantity results, then concentration is not necessary, and the chlorine may be directly estimated. Should, however, a very copious precipitate be obtained, it is probable that dilution with distilled water would be advisable.

When the quantity of chlorine is small, evaporate a large but known quantity of the specimen until its bulk is reduced to 100 c.c., the volume to be evaporated ranging from 500 c.c. to 2 liters, the smaller the quantity of chlorine the larger the volume to be evaporated. (Should the evaporation be carried too far add sufficient distilled water to the concentrate to make it measure 100 c.c.) Now add 1 c.c. of the potassium chromate and then from a burette add the standard silver solution until a permanent faint red tint is obtained. From this titration determine the number of c.c. of the silver solution that would be required to precipitate the chlorine in one liter of the water. This result multiplied by 0.001 will give the weight of chlorine, in grams, in a liter. The result is then to be expressed in parts per 1,000,000.

Example.—Evaporated 500 c.c. of the sample to 100 c.c., added the potassium chromate and then from a burette the standard silver solution. Of the latter 7 c.c. were required to produce the desired result. As 500 c.c. of the water required 7 c.c. of the silver solution, then the liter would require $7 \times 2 = 14$ c.c. and $14 \times 0.001 = 0.014 =$ the weight of chlorine, in grams, in a liter. Then $0.014 \div 0.001 = 14$, the chlorine expressed in parts per 1,000,000.

It should be noted that *it is the volume from which* and *not the volume to which* the concentration is made that enters into the calculation.

With those waters which do not require concentration, take 100 c.c., add the potassium chromate and then titrate with the silver solution as above. The calculation is made in the same manner, only substituting the proper figures for those given.

Of those waters which require dilution, take a small weighed portion, add sufficient distilled water to make 100 c.c., and proceed as above.

The estimation of the chlorine by means of the soloids is limited, practically, to those waters which are comparatively rich in this ingredient. When they can be used, proceed as follows: In 100 c.c. of the water dissolve one or two soloids of potassium chromate. Now add a soloid of silver nitrate and stir until dissolved. If a permanent red color is not produced, add another soloid of the silver nitrate and stir until dissolved. If still a permanent red color does not appear, continue to add them, one at a time, until the desired reaction is obtained, keeping account of the number of the soloids added. Then to calculate the quantity of chlorine present let it be supposed that the third soloid did not produce a permanent red color, but that the fourth did. As each soloid of the silver nitrate is equivalent to 0.002 gram of chlorine, then the quantity of the latter present in 100 c.c. of the water would be more than 0.006 but less than 0.008 gram, for it is only when an excess of silver has been added that a permanent red color is produced. Then as 100 c.c. of the water contains between 0.006 and 0.008 gram, a liter will contain between 0.06 and 0.08 gram. The chlorine under such circumstances, expressing it in parts per 1,000,000, would be more than 60 but less than 80 parts.

The soloids can be utilized for waters of low chlorine content either by evaporating large volumes of the water, several liters, to small bulk and proceeding as above, or by converting the soloids into the standard silver solution and then carrying out the estimation in the usual manner. The soloids are converted into the standard silver solution by dissolving each soloid in 2 c.c. of distilled water.

Nitrites.

The nitrites of water result either from the action of bacteria on the nitrogenous organic matter or from the reduction of nitrates by chemical process. When due to the former cause their presence even in the smallest quantity is of the utmost significance and would immediately condemn a water. It should be remembered, however, that frequently in waters which are highly polluted and in which bacterial activity is not yet established nitrites may be and often are absent. It can be said, then, that while the presence of nitrites is a suspicious sign, yet it does not necessarily indicate pollution, and on the contrary their absence is equally far from an assurance that the water is pure.

If nitrites are present, they are usually in such exceedingly small quantity that for their detection it is desirable to use a reagent which will give a pronounced reaction with exceedingly minute quantities.

A number of such reagents have been suggested, but that of Griess, which consists of two solutions, one of sulphanilic acid and one of naphthylamine hydrochloride, is without doubt superior to all others. Although two solutions are required, they are easily and quickly prepared, and any extra trouble which the preparation of the solutions would involve is more than compensated for by the reliability and extreme delicacy of the test.

The solutions required for the detection and estimation of the nitrites are those of sulphanilic acid and naphthylamine hydrochloride and a standard nitrite. The water used in the preparation of these must be free from nitrite.

Sulphanilic Acid.—Dissolve one gram of sulphanilic acid in 100 c.c. of distilled water.

Naphthylamine Hydrochloride.—Heat 0.2 gram of this salt for 10 minutes with 50 c.c. of distilled water and filter while hot. This solution should be prepared as required, as it is not stable.

The dispensary scales are sufficiently accurate for weighing the ingredients of the above solutions.

Standard Nitrite Solution.—Dissolve 0.0986 gram sodium nitrite in 1,000 cc. of water. Dilute 5 c.c. of this to 100 c.c. One c.c. of the resulting solution will contain 0.000001 gram of nitrogen as nitrite.

Owing to the deliquescence and impurity of sodium nitrite it is advisable to use silver nitrite for preparing the standard nitrite solution. This silver salt can readily be obtained by adding a solution of silver nitrate to one of sodium nitrite as long as a precipitate is produced. This precipitate of silver nitrite is collected on a filter and thoroughly washed with cold distilled water. It is then dried in the dark at room temperature. When dry, dissolve 0.22 gram in about 200 c.c. of water. To this add about 0.8 gram of sodium chloride which has previously dissolved in a little water. Finally add enough water to make 1,000 c.c. Mix thoroughly and allow to settle. Dilute 5 c.c. of the clear solution to 100 c.c. One c.c. of the latter will contain 0.000001 gram of nitrogen as nitrite.

To detect the presence of nitrites place 50 c.c. of the water in a Nessler jar and add to it one or two drops of 10 per cent. hydrochloric acid, 1 c.c. of the sulphanilic acid, and 1 c.c. of the naphthylamine solutions, and then thoroughly mix with a glass rod. Allow to stand for half an hour. If a red color, diffused throughout the liquid develops, nitrites are present.

While it is usually sufficient to note that the nitrites are present in traces or more, as will be determined by the intensity of the reaction, yet it is frequently desirable to determine the actual quantity. To do so place in a series of 50 c.c. Nessler jars such quantities, for example, as 0.1, 0.2, 0.3, etc., c.c. of the standard nitrite solution, fill to the mark with water, and then add to each jar the same reagents that were added to the water. Mix thoroughly and allow to stand for half an hour. Such standards would contain 0.0000001, 0.0000002, 0.0000003, etc., gram of nitrogen as nitrite. Then compare the tube of treated water with the standards. The tube of water and the tube of standard having the same color will contain the same quantity of nitrite. This quantity multiplied by 20 will give the quantity of nitrogen as nitrite in a liter of the water. Express the result in parts per 1,000,000.

Example.—To 50 c.c. of the water added the necessary reagents and after the proper time elapsed compared it with the standards. Found that it had the same color as the tube containing 0.0000002 gram of nitrite. Then $0.0000002 \times 20 = 0.000004$ gram of nitrogen as nitrite in a liter of the water; and $0.000004 \div 0.001 = 0.004$ parts per 1,000,000.

The red coloring matter produced in this test is a naphthylamine-azobenzine-sulphonic acid having the formula—

$$C_6H_4(HSO_3)N_2C_{10}H_6NH_2.$$

The reaction which takes place to produce this is—

$$C_6H_4(NH_2)HSO_3 + C_{10}H_7NH_2 + HNO_2 = C_6H_4(HSO_3)N_2C_{10}H_6NH_2 + 2H_2O.$$

The detection and estimation of the nitrites by the soloids is very unsatisfactory, as they frequently fail to give a reaction even in the presence of a very considerable quantity. This is probably due to the deterioration of the metaphenylenediamine, of which they are composed. This reagent when in good condition gives a yellow to brown color with nitrites, and when the latter are present in minute quantities the reaction produced is not nearly so pronounced as that which would be given by the same quantity of nitrite with the Griess reagent.

The method of employing them, however, is to add to 50 c.c. of the water one soloid of the metaphenylenediamine. If a color ranging from a pale yellow to brown develops within 5 minutes, then nitrites are present.

Note.—The color must develop in the time stated, for if it appears later it may be due to the decomposition of the reagent itself.

To estimate the quantity, prepare the standards as above, and then add to each jar one soloid of the metaphenylenediamine instead of the sulphanilic acid and the naphthylamine. After standing for 5 minutes the water is compared with these standards as before. The calculation is made in the same manner.

Nitrates.

The nitrates represent the last change to which nitrogenous organic matter is subject, and consequently the quantity of nitrate present is a measure of the organic matter which has, some time in the past, been added to water. As the nitrogenous organic matter of vegetable origin is subject to the same degree of oxidation as that from animal sources, the presence of nitrates even in quantity does not necessarily indicate pollution.

While a general statement cannot be made yet, it can be said that normally in pure rain, spring, shallow well waters the quantity of nitrate is usually small, while in deep well waters a rather large quantity is the rule.

The method which is generally preferred for the detection and estimation of the nitrates is that by which they are converted into picric acid and the latter into ammonium picrate, a substance which is such a powerful yellow staining agent that that quantity which is produced from an exceedingly small amount of nitrate will, when dissolved in a little water, yield a pronounced yellow-colored solution.

The solutions which will be required for the detection and estimation of the nitrates by this method are:

Phenolsulphonic Acid.—A mixture of 180 grams of pure concentrated sulphuric acid and 15 grams of pure phenol is heated on a water-bath for 6 hours.

Standard Nitrate Solution.—Dissolve 0.722 gram of pure potassium nitrate in 1,000 c.c. of distilled water. Each c.c. of this solution will contain 0.0001 gram of nitrogen as nitrate. In a porcelain dish evaporate 10 c.c. of this solution to dryness on the water-bath and when just dry remove. Moisten the residue with 2 c.c. of the phenolsulphonic acid and then dilute to 100 c.c. with distilled water. Each c.c. of this solution, which is the standard, will contain the equivalent of 0.00001 gram of nitrogen as nitrate.

Standard Sodium Chloride.—Dissolve 1.6497 grams of pure sodium chloride in one liter of distilled water. Each c.c. of this solution will contain 0.001 gram of chlorine.

To detect nitrate add to 50 c.c. of the water one or two drops of a saturated solution of sodium carbonate and then evaporate it to dryness in a porcelain dish on a water-bath. Remove as soon as dry and moisten the residue so obtained with 2 c.c. of the phenolsulphonic acid, then add about 25 c.c. of distilled water, and finally 5 c.c. of strong ammonium hydrate, when, if the nitrate be present, a yellow-colored solution will result. The intensity of the color will be proportional to the quantity of nitrate. Add sufficient water to the contents of the tube to make 50 c.c. and reserve for the estimation.

To estimate the quantity of nitrates prepare a set of standards by adding to a series of 50 c.c. Nessler jars, varying quantities, such as 1, 2, 3, etc., c.c. of the standard nitrate solution, then to each jar an amount of the standard sodium chloride solution which contains the same quantiy of chlorine as 50 c.c. of the water, the chlorine of the water having been previously determined. Now to each jar add about 5 c.c. of strong ammonium hydrate and then enough water to make 50 c.c. Such a set of standards would contain 0.00001, 0.00002, 0.00003, etc., gram of nitrogen as nitrate. Compare the tube of water, which was prepared and used for the qualitative test, with the standards. The tube of water and standard of the same color will contain the same quantity of nitrate. Multiply this quantity by 20 and the result will be the quantity of nitrate in a liter of the specimen. Express the result in parts per 1,000,000.

Example.—Evaporated 50 c.c. of the water to dryness, moistened the residue with 2 c.c. of the phenolsulphonic acid, added about 25 c.c. of water, then 5 c.c. of strong ammonium hydrate, and finally added sufficient water to make the whole measure 50 c.c. The water so treated was found to have the same color at the tube of standard to which 3 c.c. of the standard solution was added. As the quantity of nitrate represented in this tube is 0.00003, then 0.00003 × 20 = 0.0006, quantity of nitrate in a liter of the water. Then 0.0006 ÷ 0.001 = 0.6, nitrate expressed in parts per 1,000,000.

Two reactions are involved in this process, the first being the formation of picric acid by the action of the nitrate on the phenolsulphonic acid, and the second is the conversion of the picric acid into ammonium picrate. The reactions are:

(1) $C_6H_4(OH)HSO_3 + 3HNO_3 = C_6H_2(NO_2)_3OH + H_2SO_4 + 2H_2O.$

(2) $C_6H_2(NO_2)_3OH + NH_4OH = C_6H_2(NO_2)_3ONH_4 + H_2O.$

To detect the presence of nitrates by the soloids add to 50 c.c. of the water one soloid of zinc dust and one of acid sodium sulphate and stir until the latter is dissolved and the former is disintegrated. Allow to stand for 10 minutes. During this period the nascent hydrogen generated by the action of the acid sodium sulphate on the zinc dust will reduce the nitrate to nitrite, the quantity of the latter produced being a measure of the quantity of the nitrate originally present. The solution is now filtered through a well-washed filter until perfectly clear, and to the filtrate add one soloid of metaphenylenediamine. If a dark-brown color is immediately produced, nitrates were present in considerable quantity. Lighter shades and those requiring longer to develop indicate smaller quantities. If nitrites were originally present, a control tube of the water must be used. This is done by adding one soloid of the metaphenylenediamine to 50 c.c. of the untreated water at the same time that one is added to the filtrate from the treated water. If, then, nitrate be present the tube of treated water will have the darker color.

If it is desired to attempt an estimation of the nitrates by this method, prepare a set of standards as directed under Nitrites and proceed accordingly. The standards now required will necessarily be of much greater strength than those mentioned, becaused the nitrogen which normally exists as nitrate, even in the very pure water, is exceedingly large as compared with that quantity of nitrogen which might occur as nitrite. Even when the former is said to be of an average amount and the latter excessive, the nitric nitrogen would still be many times the greater.

Example.—Treated 50 c.c. of the water with the zinc dust and acid sodium sulphate, let stand 10 minutes, filtered and added a soloid of metaphenylenediamine. Prepared standards which contained, respectively, 10, 20, 30, etc., c.c. of the standard nitrite solution and added a soloid of the reagent to each tube. After 5 minutes compared the water with the standards. The water matched the tube containing 30 c.c. of the standard nitrite solution. Then 50 c.c. of the water contained 0.000001 × 30 = 0.00003 gram of nitrogen, as nitrate for *x* quantity of nitrogen as nitrate will, when reduced, yield *x* quantity of nitrogen as nitrite. Then 0.00003 x 20 = 0.0006 gram of nitrogen, as nitrate in 1 liter of the water; and 0.0006 ÷ 0.001 = 0.6 nitrogen as nitrate in parts per 1,000,000.

This method is not recommended because of the unreliability of the metaphenylenediamine, the exceedingly strong and necessarily highly colored standards required, the color being too deep for accurate comparison, and the uncertainty of the reduction of all of the nitrate present. It is for the two latter reasons that this reduction method was not recommended with the Griess reagent for the detection and estimation of the nitrates.

Oxygen-consuming Power.

Practically all waters contain organic matter, and as this is readily oxidizable the quantity of oxygen which is required for the purpose is considered by many analysts to be a most valuable guide to the quality. It must not be forgotten that vegetable as well as animal, and non-nitrogenous as well as nitrogenous substances, are equally oxidizable, and consequently a high oxygen-consuming power may be possessed by a water that is perfectly wholesome; and equally important is it to remember that waters which previously contained large quantities of organic substances have been subjected to natural oxidizing agencies, with the result that little additional oxygen will be required to completely dispose of such matter, so that a low oxygen-consuming power does not always indicate a water that is above suspicion.

The most available source of oxygen is potassium permanganate in connection with dilute acids or alkalies, the former being best suited for the purpose under consideration. The permanganate yields oxygen according to the following equation:

$$K_2Mn_2O_8 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 3H_2O + O_5.$$

As oxidization takes place more readily at high temperatures, the organic matter of water is more quickly and uniformly oxidized when carried out at the boiling-point.

The best method to determine the quantity of oxygen consumed is Kubel's modification of the old Forchammer process and is described in the following paragraphs:

The following solutions must first be prepared and tested as directed:

Standard Potassium Permanganate.—Dissolve 0.3925 gram of pure crystallized potassium permanganate in a liter of distilled water. One c.c. of this solution contains 0.0001 gram of oxygen available for oxidation purposes.

Standard Oxalic Acid.—Dissolve 0.7875 gram of pure crystallized oxalic acid in a liter of water. One c.c. of this solution should exactly decolorize 1 c.c. of the permanganate solution.

Dilute Sulphuric Acid.—Pour one part by volume of pure concentrated sulphuric acid into four parts of distilled water. Bring to the boiling-point and then add enough of the permanganate to impart a permanent faint pink color. The addition of the permanganate is necessary because the sulphuric acid at times contains substances which consume considerable quantities of the permanganate. If this were not guarded against a serious error would result.

The first step necessary in this process is to find the relation between the permanganate and the oxalic acid, for even though these solutions were so made that they should correspond—that is, that 1 c.c. of the oxalic acid will exactly decolorize 1 c.c. of the permanganate, it is necessary to be sure that they do. To determine this relation proceed as follows: In a beaker place exactly 10 c.c. (measured with a pipette) of the oxalic acid, then 190 c.c. of distilled water, and finally add about 10 c.c. of the dilute sulphuric acid. Bring nearly to the boiling-point, and then from a burette add the permanagante solution until a permanent faint pink color is obtained. Repeat the experiment and find the average quantity required. Make careful note of this quantity, for it is an important factor in the final calculation.

The oxygen-consuming power can now be determined. Proceed as follows: In a suitable beaker place 200 c.c. of the water, add about 10 c.c. of the sulphuric acid and then from a burette, which should have previously been filled to the zero mark, add sufficient of the permanganate solution to impart rather a deep red color to the water, this usually requiring about 15 c.c. Bring the contents of the beaker to the boiling-point and allow to boil gently for 10 minutes, adding more of the permanganate if the color shows a tendency to fade. Then remove the lamp and add enough and more of the oxalic acid, noting accurately the quantity used, to decolorize the solution and to dissolve all suspended matter, thus producing a solution of the appearance of distilled water. Then from a burette continue the addition of the permanganate until a permanent faint pink color is produced. From the total quantity of the permanganate used, subtract the equivalent of the oxalic acid that has been added. This difference is the number of c.c. of the permanganate consumed by 200 c.c. of the water. Multiply this by 5 and this result will be the number of c.c. required for a liter of water. This last figure multiplied by 0.0001 will be the quantity, in grams, of oxygen consumed by a liter of the water. Express the results in parts per million.

Example.—Found that 10 c.c. of the oxalic acid required 10.4 c.c. of the permanganate to produce a faint pink color. To 200 c.c. of the water added the sulphuric acid, and then 18 c.c. of the permanganate and boiled for 10 minutes. Then added exactly 20 c.c. of the oxalic acid. Continued the addition of the permanganate and found that 7 c.c. more of it were required to produce a faint color, or what is the same, that altogether 25 c.c. of the permanganate were used. Subtracting from this the equivalent of the oxalic acid added—which in this case was $10.4 \times 2 = 20.8$ c.c.—the result will be $25 - 20.8 = 4.2$, which is the number of c.c. of the permanganate required for 200 c.c. of the water. Then $4.2 \times 5 = 21.0$ c.c. will be required for a liter. Then $21 \times 0.0001 = 0.0021$ gram, this being the quantity of oxygen consumed by a liter of the water. Then $0.0021 \div 0.001 = 2.10$ parts of oxygen consumed expressed in parts per 1,000,000.

Certain substances which frequently occur in water, and while not organic in nature, consume large quantities of oxygen and if not removed would lead to an erroneous idea of the quantity of organic matter. These substances are the nitrites, the ferrous salts, and hydrogen sulphide. They are removed or rendered inactive by boiling the water for 10 or 15 minutes after the addition of the dilute sulphuric acid, but before the addition of any of the potassium permanganate. After such boiling the permanganate is added and the boiling continued for 10 minutes in the usual way.

To use the soloids for the oxygen-consuming power, proceed as follows: To 100 c.c. of the water add a soloid of the acid sodium sulphate and dissolve; then add one soloid of the potassium permanganate which contains 0.001 gram of available oxygen. Bring to the boiling-point and allow to simmer for 15 minutes. If during the heating the red color should fade out, add another soloid of the permanganate of the same strength. Then for each soloid of the permanganate added, add one of the oxalic acid containing 0.0079 of the acid (and which exactly decolorizes one soloid of the permanganate so far used). Now add soloids, one at a time, of the permanganate which contain 0.0001 gram of available oxygen, until a permanent pink color is produced. The number of these weaker soloids multiplied by 10 will be the number required for a liter of the water. This number multiplied by 0.0001 will give the quantity, in grams, of oxygen consumed by a liter of the water. Express the result in parts per 1,000,000.

Example.—To 100 c.c. of the water added one soloid of the acid sodium sulphate and one of the strong (0.001) potassium permanganate and boiled. As the boiling progressed the red color considerably faded, so added another of the strong permanganate soloids. Then, after boiling was completed, added two soloids of the oxalic acid (for it is directed that one of the oxalic acid must be added for each one of the strong permanganate used). The solution of course was decolorized. Then began the addition of the weaker permanganate soloids. Found that it required six of them to produce a permanent pink color. If the 100 c.c. of the water required six, then the liter would require $6 \times 10 = 60$. This number multiplied by 0.0001 will give the quantity of oxygen in grams consumed, as $60 \times 0.0001 = 0.0060$. Then $0.006 \div 0.001 = 6.0$, oxygen consumed expressed in parts per 1,000,000.

Hardness.

Hardness as it is usually understood is the quantity of soap that must be added to water before any part of it becomes available for its detergent properties. The quantity of soap required depends almost entirely upon the quantity of calcium and magnesium salts present, and as a consequence it is expressed, not as the quantity of soap required, but as so much calcium carbonate.

It is of two varieties, the temporary and the permanent, the former being due chiefly to calcium and magnesium carbonates, compounds which are readily removed by heat and filtration, while the permanent is caused by those salts, the sulphates, chlorides, etc., of the same metals which are not precipitated when the water is heated. Although it is of more importance from a commercial than a sanitary aspect, the determination of hardness is frequently included in a sanitary examination.

The easiest and most convenient method for its estimation is that in which a standard soap solution is added until a permanent lather is produced. While this, the so-called "Clark method," may be scientific in principle, but not in results, yet it conveys information that is sufficiently accurate for most purposes. The principle of the method is that sufficient soap must be added to water to completely precipitate the calcium and magnesium present before a lather can be formed.

The following solutions are required for the determination of the hardness by this method:

Standard Calcium Carbonate.—Dissolve 1 gram of pure calcium carbonate in a little hydrochloric acid, evaporate to dryness on the water-bath, then dissolve the residue in a liter of distilled water. Each c.c. of this solution contains the equivalent of 0.001 gram of calcium carbonate.

Standard Soap Solution.—Dissolve 10 grams of pure castile soap in a liter of 70 per cent. alcohol and filter. This solution must be standardized by titrating against it a known volume of the calcium carbonate solution. This is done as follows: In a flask of about 200 c.c. capacity place 100 c.c. of distilled water. Then from a burette add soap solution, 0.1 c.c. at a time, shaking vigorously between each addition, until a permanent lather forms. The lather should persist for 5 minutes. Note the quantity of soap required. Repeat the experiment and take the average quantity of soap used. This will be the quantity of soap required to produced a lather in 100 c.c. of distilled water, a figure that is important. Now clean out the flask and place in it 10 c.c. of the standard calcium carbonate solution and 90 c.c. of distilled water. Then from a burette add the soap solution, 0.25 c.c. at a time, shaking vigorously between each addition, until a permanent lather is produced. Note the quantity of soap required. Repeat the experiment and find the average quantity of soap used.

Note.—It is important that in repeating the experiment both in standardizing the solution and in the examination of the water that even though it is known to be within 0.1 of a c.c. the quantity of soap that will be required, it is absolutely necessary that it be added in quantities not exceeding 0.25 of a c.c. at a time and shaking between each addition.

From the quantity of soap required for the 10 c.c. of calcium carbonate plus the 90 c.c. of distilled water subtract the quantity required for 100 c.c. of distilled water. This will be the number of c.c. of soap solution used by 0.01 gram of calcium carbonate.

Example.—One hundred c.c. of distilled water required 0.6 c.c. of the soap to produce a lather; 10 c.c. of the calcium carbonate plus 90 c.c. of the distilled water required 11.7 c.c. of the soap. Then 11.7 − 0.6 = 11.1 c.c. of the soap required for 0.01 gram of calcium carbonate. Hence 0.0100 ÷ 11.1 = 0.0009—that is, each c.c. of the soap solution will represent 0.0009 gram of calcium carbonate. The soap solution is not stable so it should be frequently standardized.

To Estimate the Hardness of Water.—Place 100 c.c. of the water in the flask and add soap solution from a burette, 0.25 c.c. at a time, shaking vigorously between each addition, until a permanent lather forms. Note the number of c.c. of the soap solution required; repeat the experiment and take the average quantity of soap used. From this quantity deduct the quantity of soap required to produce a lather with 100 c.c. of distilled water. This difference multiplied by the value of the soap solution will give the quantity of calcium carbonate represented in 100 c.c. of the water. The quantity so found multiplied by 10 will be the quantity in a liter. Express the results in parts per 1,000,000.

Example.—One hundred c.c. of the water required 14.6 c.c. of the soap solution so produce a lather; 100 c.c. of distilled water required 0.6 c.c. Each c.c. of the soap = 0.0009 gram of calcium carbonate. Then: 14.6 − 0.6 = 14 c.c., the quantity of soap required by the calcium carbonate in 100 c.c. of the water; 14 × 0.0009 = 0.0126 gram, the quantity of calcium carbonate represented in 100 c.c. of the water, and 0.0126 × 10 = 0.126 gram of calcium carbonate represented in 1 liter of the water; 0.126 ÷ 0.001 = 126, hardness expressed in parts per 1,000,000.

The reactions involved in estimating the hardness by this method may be represented:

$$CaCO_3 + 2((CH_3)(CH_2)_{16}COONa) = Ca((CH_3)(CH_2)_{16}COO)_2 + Na_2CO_3.$$
$$MgCO_3 + 2((CH_3)(CH_2)_{16}COONa) = Mg((CH_3)(CH_2)_{16}COO)_2 + Na_2CO_3.$$

The method of using the soloids for estimating the hardness is to dissolve each soloid of soap in 4 c.c. of 70 per cent. alcohol. Each c.c. of the resulting solution would, approximately, equal 0.001 gram of calcium carbonate. Then proceed as in the usual process. The reactions, calculations, etc., are the same.

Especially for the nitrites, nitrates, and chlorine it is at times necessary to clarify the water before their detection or estimation can be accomplished. To obtain the necessary clarification, add to the water a little freshly prepared aluminum hydrate, shake, and allow to stand for twenty-four hours, at the end of that time decanting the clear supernatant liquid.

The aluminum hydrate is prepared by adding to a solution of sodium carbonate one of potash alum, filtering, and then thoroughly washing the precipitate.

It is not possible to state definitely the quantity of any particular ingredient that should be present in a potable water, but in order that a fair idea may be had of what one might reasonably expect to find, the following table, compiled from various sources, is given, the quantities being expressed in parts per million.

	Rain water	Spring water	Deep well water	River water
Free ammonia	Usually high.	0 to 0.10	Usually high.	0 to 0.06
Albuminoid ammonia	Trace to 0.10	Trace to 0.10	Trace to 0.10	Trace to 0.10
Chlorine	Trace to 8	Trace to 10	Usually high, from 15 up.	3 to 10
Nitrite	. . . . . .	Slight trace.	Trace.	Slight trace.
Nitrate	Trace to 0.5	Trace to 2	5 to 7	1 to 4
Required oxygen	. . . . . .	1 to 2	. . . . . .	5 to 7

In the above table traces of nitrites are stated to be a normal ingredient of spring, river, and deep well waters. This is true only in limited sense; therefore it would be better to consider the presence of nitrites, even in traces, as a suspicious sign.

Poisonous Metals.

The question of poisonous metals—especially lead, copper, and zinc—is of such importance that the plan of applying the so-called quick and simple tests should be condemned, for, like many tests of the kind, experience has proved that they are about worthless.

Still, keeping in view the necessity for methods which are not too involved, the following tests are given for the detection of these metals when occurring alone. Should the presence of two or more be suspected in the same sample then recourse must be had to those methods which are to be found in complete works on qualitative analysis.

Lead.—To a half-liter or more of the water add 4 to 5 drops of sulphuric acid and then evaporate until the volume has been reduced to about 10 c.c. Now add a little tartaric acid and then enough ammonium hydrate to make alkaline and boil for a few moments and filter. Cool the filtrate and add sufficient acetic acid to make acid. Add now a few drops of potassium chromate and allow to stand for some time. A yellow precipitate proves the presence of lead.

As lead occurs only in small quantities it is important to remember that the larger the volume of the water concentrated the more positive and reliable will be the test. Three or four liters would give better results than half a liter. It is equally important to keep the volume of solution as small as possible after concentration has been completed.

Copper.—Concentrate as under Lead and filter. To the filtrate, which should not be too strongly acid, add a few drops of a freshly prepared solution of potassium ferrocyanide. If a chocolate-red or brown precipitate is obtained, copper is present. The precipitate disappears on the addition of an excess of ammonia, and a blue solution will result. Should the precipitate produced be white, lead or zinc and not copper is present.

Zinc.—Concentrate as under Lead and filter. To the filtrate, which should not be strongly acid, add a few drops of a freshly prepared solution of potassium ferrocyanide. A white precipitate proves the presence of zinc. The precipitate disappears on the addition of an excess of ammonium hydrate.

Lead and zinc give exactly the same reaction with this test—that is, a white precipitate. It is necessary to prove the absence of lead before the test can be applied for zinc.

Drinking water considered to require purification is not taken on board, but, in a harbor where the ship has to remain and the water from over the side is unfit for distillation on account of volatile products, it may be necessary to utilize water-boats furnishing a more or less questionable supply. Under those circumstances the best means of purification is at hand as the water can be passed into the reserve feed tanks and utilized as feed water for the evaporators. As then the evaporator feed water is fresh, the distillate should give no trace of salt.

However, the general question of purification of water supplies is not outside of the interest of the naval sanitarian in view of the intimate relation of crews to conditions on shore incident to liberty and the number of landing parties placing naval forces under the conditions of an army in the field. In the former case the water supply of every port visited by a ship should attract attention not only on account of its bearing at the time upon the health of the crew, but also in connection with the visits of other ships.

In connection with the sanitary report made yearly from each ship information of the sanitary conditions of various ports visited on foreign stations or beyond the continental limits of the United States is required. In that information is included the water supply with special reference to source, processes used for purification, quality supplied, and diseases attributable to use. It also includes drainage and sewerage. In fact, to carry out the instructions the writer of such reports must be familiar with *Municipal Hygiene.*

In the latter case (landing parties), naval forces being under army conditions in the field, a knowledge of *Military Hygiene* is essential. However, often in such cases the ship itself is used as a base, and distilled water is supplied for drinking. When that is impracticable sterilization by boiling for five minutes is the method of purification contemplated by regulations in which it is considered that water collected from streams and wells is always suspicious under the *conditions* surrounding such parties—in and about towns, often in the tropics. It is also provided that cooking utensils and dishes used to contain food should be washed in water that has been boiled.

In the Japanese army during the war with Russia, it is not clear that filtration was greatly depended upon in purification of water supply in the field, as it appears that boiling was practically the chief method employed. For that purpose, there was the water-boiler-cart drawn by one horse, and the water-cart drawn by four horses, but such outfits are not practicable in the case of a navy's landing party. Water stations for the supply of boiled water were established during the march and at these stations the soldier had to fill his canteen. When the canteen was exhausted it was filled from the one-horse carts that always accompanied the troops. The soldier also carried his individual pan which could be used for boiling water when necessary. When water was obtained from a stream, the orders were to get the drinking water from the middle in order to avoid impurities from the bank, and then boil before consumption. They avoided old wells, ponds or marshes, considering the water even when boiled as dangerous, thus, perhaps, recognizing the fact that some waters are apt to contain material that as chemical poisons are not rendered inert by boiling. A water that is to be both filtered and boiled should for reasons of that character be filtered first and then boiled.

They made a point of *immediately placing a guard over a source of water supply* whenever troops were halting or going into camp. This was for the purpose of preventing the consumption of the water when considered by the medical officer as unfit for use, or to prevent its pollution when regarded as potable. A suspected or infected source was posted, and thus following troops had advantage of knowing what water had or had not been used by the others, but water that had been regularly used was boiled when possible. Any well water in a district newly captured was regarded with suspicion.

On the march a camping party, consisting of line and medical officers, was sent ahead to see if the camping place were suitable from a sanitary as well as a strategic point of view. Medical officers had then also to inspect the source of water supply as well as the condition of the houses that might be found, and it is stated, as far as practicable, of the people living within. If the water was considered unfit to drink, a notice was put up cautioning the troops not to take it.

Special difficulties in regard to water sources were encountered during night marches, and there was very much trouble from flies during the campaign, as it is said that the army "was practically overwhelmed by their incursions," but some diminution was eventually obtained by burning manure as quickly as possible, as well as other refuse. In camps refuse was either *burned* or *buried* daily and excrements were treated in the same way, and where latrines could not be made in time, each soldier was cautioned to dig a hole and after use to fill in with the soil in order to prevent flies from coming in contact with excrement. Such a course requires a designation of locality, even when latrines are not established, and such a location should always be selected with special care to avoid chance of pollution of water supply.

The Navy regulations state that latrines should be placed to leeward and below the camp and as far as practicable from the water supply and also from the kitchen, with due regard, however, to the fact that if too distant the men will be tempted to pollute the soil at more convenient points. Straw or paper, saturated with kerosene if practicable, should be burned in such sinks twice daily. Dry earth, kerosene, and quicklime should all be used when possible. Such sinks should be located so as not to fill during rains, should be screened by bushes and kept as dark as possible, *each man should be required to immediately cover his own excrement*, and on breaking camp they should be refilled with earth.

Two sinks can be more conveniently managed than a single large one, but additional multiplication is undesirable. Screening sinks tends also to prevent the dissemination of paper or other material over the camp-site by winds. It should be the duty of a sanitary squad to keep the camp clear of all such material.

In a camp as on a ship the fundamental problem is to avoid pollution of locality. Unless the strictest measures are taken to keep men away from the influence of their own excreta no one can be safe in relation either to food or water. It is through food or water or fingers or flies that typhoid fever chiefly exerts its influence on a camp, and no one can be safe unless the material that is taken by the mouth has remained free from the influence of the solid and liquid excretions of man and especially of the very men then in camp. But the danger from others should also be recognized and a site that has been previously used for a camp should be avoided whenever possible. The source of the water supply at an old camp site should also be carefully considered, and it is better to get water further up stream than lower down. A well under those circumstances is suspicious and also one in unfavorable relation to houses. A well under the influence of a dirty harbor may be almost as dangerous as one under the influence of a cesspool, and such wells have caused lamentable conditions in camps.

Boiling destroys the germs of specific disease, but it should be recognized that men are apt to prefer the taste of water that has not been boiled and, therefore, with two available water supplies of which one is more doubtful than the other, a guard should be placed over that not to be used as well as over that which is to be used, where there should be intelligent supervision and the approach protected by boards, rails or logs even in temporary camps. There should be no drinking cups at the source of supply, but water should be obtained by designated individuals and then boiled for the use of the camping party and carefully stored and protected until used. Lip drinking should be practised by all where cups are not disinfected.

If the water obtainable is muddy it should be cleared by filtration before boiling. It should not be considered that any filtration practicable in a naval camp can be depended upon to take all pathogenic organisms from water. It is surface water that is muddy and such water is liable to contain excrement washed from surfaces of earth upon which men live. The danger increases directly as the habitations of man along the banks or water shed increase. Muddy water from uninhabited sources may be innocuous, but all muddy water should be considered to contain substances that even if subjected to boiling may give the water the power to cause intestinal disorders.

To filter such water a barrel or double barrel or box in which the filtering media are sand and pebbles can be employed. All such filtering media should be thoroughly washed and then heated to a high temperature before use. The sand may be placed in the barrel or box above the gravel, with charcoal between if obtainable, when a single barrel filter is used, and the filtered water allowed to leave by opening in the bottom of the barrel or by a spout provided for that purpose near the bottom of the barrel. When a double barrel or box is used a layer of sand may be placed at the bottom of the larger and, the smaller with perforations in bottom having been well imbedded in the sand, the interspace can be partially filled with charcoal and coarse gravel. The water admitted on top of the media between the barrels rises within the smaller and can be removed for boiling. The media should be renewed frequently.

The Japanese army has been reported to have had during recent war an admission rate for typhoid fever of 9.26 per thousand, but as the death rate is given as 5.16 per thousand it has been thought that the admission rate as stated may ultimately be found to have been about 19.26 per thousand in contrast with 37.14 cases and 10.98 deaths per thousand of force in the Japan-China War. But whatever the admission figures, this more recent war declares that typhoid fever remains the great producer of deaths from disease during military operations, and that precautions in camp and on the march have not yet attained in any army the degree of perfection that is necessary.

One great defect in the naval service afloat and ashore seems to be the lack of diffusion, or application, of an elementary knowledge of hygiene. The acquisition of this knowledge should begin in the public schools of the country and be continued in the service. In this very question of boiled water the chances are that at least those directly charged with the work may have little appreciation of its importance, especially if they have other duties to perform, and are liable, without special apparatus and a special detail, not to do the work unless carefully watched, and that those for whom the water is boiled are not impressed with necessity for using it, especially as they do not like it, and will fill their canteens at farm-houses or elsewhere as opportunity occurs.

The same lack of appreciation may be exhibited in pollution of soil with urine. In connection with every camp there should be conveniently located urinals that should be quicklimed daily when practicable, and at least covered with dry earth twice daily to protect from flies, but in bad weather or at night there is a tendency to utilize the ground between tents.

Fortunately, a naval camping party from a cruising ship does not ordinarily occupy the same site long, frequently returning to the ship after a brief occupation, and therefore night-tubs for the reception of urine so necessary in a standing camp will rarely be required, especially as the men coming from the ship are ordinarily free from infection. But however short the occupation, and one cannot always know just how temporary a camp may be, urination other than in the places designated should be prohibited and the infraction punished. Such a camp site should be changed at the end of a week anyhow, even if the removal is merely to entirely clear the old ground.

The prevention of typhoid fever during military operations has so far been a problem without a satisfactory solution in practice. This may be due to the chronic carrier of the bacillus, the mild or unrecognized case, the typhoid fever convalescent returned to duty as well, yet not free from the exciting cause of the disease, and to flies acting as carriers from which no military force in the field has been able to sufficiently protect itself. The character of water at its source may therefore in particular instances have no place as a causative factor, or may cause infection even after having been boiled as in the use of the drinking cup in common or of infected hands in dipping water.

There are so many important factors in causation that no prophylactic measures in time of war have been sufficient. Even those who have been in attendance on cases and remain in apparently good health may often be chronic carriers, and with flies abundant in urinals and latrines and with recently excreted urine and fæces most highly infective, water may well at times hold a subordinate place in propagation.

The channels of invasion being so numerous there seems to be no hope of satisfactory general prevention unless *all the usual sanitary measures be combined with means for the marked diminution of number of susceptible individuals.* The time seems at hand when each recruit of a navy or of an army will be required to submit to inoculation of serum for the prevention of typhoid fever just as he is now required to submit to vaccination for the prevention of small-pox, and to repetition of such inoculations during service as is now the case in vaccination for the prevention of small-pox. Every person rendered immune ceases to be a probable focus of infection, and the wide dissemination of the typhoid bacillus is an indication of some means of dissemination practically outside of ordinary means of control in military life.

A marked diminution in number of cases means in general terms a marked diminution in dissemination of the bacilli, and a great increase in number of immunes lessens the far-reaching consequences of lack of control of the typhoid bacilli leaving even the bodies of unsuspected men. But if every man in a naval service were immune to typhoid fever, every precaution to secure an innocuous water and to maintain an unpolluted camp site would be required in view of the methods by which diarrhœa, dysentery, and cholera are propagated.

Some reliable method of readily and acceptably purifying a camp's drinking water by chemical means would be of great value in a navy's landing party, but the use of chemicals for that purpose does not seem to have been sufficiently developed to permit its unlimited advocacy at this time when boiling is available. Tablets of sodium bisulphate (a 30-grain tablet to the quart of water) have been advocated in connection with refilling canteens on the march whenever boiling is not practicable. The water becomes sterile in 20 minutes, and if the tablet has been sweetened (saccharin) and flavored (oil of lemon), an acceptable drink is obtained (Notter and Firth). In the camp itself the Japanese army used chemical precipitants at times in connection with filtration to clarify water. The filter was a canvas cone capable of holding perhaps 25 gallons of water, and constructed with canvas funnels or arms normal to the cone surface and at about a third of the distance from the apex. In each of these funnels was placed a sponge and granulated charcoal. The cone having been suspended base up and nearly filled with water, two powders, each a mixture, were added in fixed amounts to act chiefly as precipitants, and thus aid the filtering media in the funnels to purify the water. It is stated by Notter and Firth that one powder is a mixture of potassium permanganate with potash alum and china clay, and the other a mixture of china clay with chloride of aluminum, a little carbon, and a small quantity of some vegetable extract. Four ounces of the first and two ounces of the second were needed in the treatment of each 25 gallons of water, and the filter removed 90 per cent. of the bacteria from 50 gallons of water an hour.

Such a filter could be readily constructed on a ship, occupies very little room in the equipment of a landing party, has little weight, is readily cleaned or sterilized, and seems to be an ingenious method of rapidly clarifying and, to a considerable extent, purifying water when compared with the improvised barrel filter. It does not sterilize water, but evidently greatly limits danger of trouble when through intention, carelessness, or lack of opportunity, the requirement of subsequent boiling is not complied with.

The chemicals employed in connection with this filter can be utilized to advantage to illustrate certain principles in the purification of water by chemical means and especially by chemical precipitants. China clay is *kaolin* or the hydrated silicate of aluminum ($Al_2O_3.2SiO_2.2H_2O$) which is also the chief part of fuller's earth. Its office in the powders employed may be regarded as very important, but purely mechanical. It furnishes a ready means of rapidly distributing the alum with which it is mixed and thus mechanically quickens the formation of the aluminum hydroxide from the chemical reaction of alum with the carbonates of the water. The aluminum hydroxide would otherwise be produced rather slowly and therefore its method of purification by sedimentation would be delayed. Ordinarily when alum is used to clarify water stirring and prolonged sedimentation are necessary. As the hydroxide is forming, the china clay also adds weight and bulk to that gelatinous material, and thus gives to the more rapidly settling mass a much greater power to carry down with it the material including the bacteria that the water to be purified holds in suspension.

Aluminum hydroxide, $Al_2(OH)_6$, is a gelatinous material that clarifies water by its action as a precipitant and decolorizes also by its great attraction for most coloring matters with which it forms insoluble compounds called *lakes*. It is formed by the action of calcium carbonate in the water upon the alum, $AlK(SO_4)_2$. added:

$$2AlK(SO_4)_2 + 4CaCO_3 + 3H_2O = Al_2(OH)_6 + 4CaSO_4 + K_2CO_3 + 3CO_2.$$

Additional weight and bulk is given to the gelatinous mass of the hydroxide by the china clay in the second powder which also acts to secure the rapid distribution of the relatively small amount of the aluminum chloride and the vegetable extract. The charcoal in that powder is probably depended upon to prevent the chloride salt from deliquescing, and thus in the presence of moisture from forming an albuminate with the albuminous material in the extract. Aluminum chloride is very soluble, and has disinfecting properties depending upon its formation of albuminates in the presence of nitrogenous organic matter after the manner of corrosive sublimate. By rapid action on a vegetable extract to form an albuminate, it may perhaps, be supposed to supply in part a substance that may have a catalytic action in hastening the separation of the hydroxide formed in the manner shown in the above equation.

The permanganate of potassium in the first powder is probably in rather small amounts. It is well known as an oxidizing agent. Charcoal, which however does not now have the good reputation it once had as a filtering medium, takes up the waste manganese from decomposition of the permanganate whose oxygen has been expended in the oxidizing of the available organic matter and mineral substances. The chemical treatment of water with permanganate is sometimes called "pinking," as it is commonly added in amounts sufficient to *maintain* a very slight pink tint for perhaps an hour. The amount will vary with each water, as it depends upon oxygen-consuming power and its action as a disinfectant depends upon the liberation of nascent oxygen. This method has been used extensively in certain countries for purifying water in limited quantities, as in wells suspected of being infected with the cholera germ or even that of typhoid fever or dysentery. Very satisfactory results have been reported from India during cholera epidemics; and while its action cannot be compared in efficiency with boiling, it has great value where circumstances practically preclude the use of heat.

Some reports have been made that a 1 per cent. solution of potassium permanganate to which one per cent. solution of hydrochloric acid has been added becomes a disinfectant of remarkable power, killing anthrax spores in two minutes. When the relatively small amount of aluminum chloride contained in the second powder comes in contact with the water, it is partly decomposed into Al_2O_3 and HCl. The little hydrochloric acid thus formed becomes available to act with the permanganate to increase its disinfectant power. This canvas filter, therefore, offers a number of interesting features for study and investigation which might well lead to improvements rendering it still more applicable to the treatment of the water supply of camps, especially as the purification of water by chemicals may be regarded as still in its infancy.

Alum is more largely used in this country for the purification of water supplies than any other chemical. In such municipalities as New Orleans it is regularly used, as the water of the Mississippi contains a very fine silt that is not sufficiently deposited in the sedimentation basins and tends to overcrowd the filter-beds. When a municipality undertakes to purify the water supply the purification is said to be central, but when the purification is undertaken in the homes of the people or at the places of consumption it is said to be peripheral. In the peripheral purification of water, *distillation or boiling are regarded as the only reliable methods in the presence of cholera or typhoid fever.*

For domestic use there are, however, a great many filters employed. Some of these are merely gravity filters or those without direct connection with the water-supply pipes, and the others are connected with such pipes at taps to filter under the city pressure only the amount of water required for drinking, as in the case of such bougie filters as the Berkefeld or, better, the Pasteur-Chamberland or the Columbia; or with the service pipe to filter the entire house supply, as in mechanical filtration by such filters as the Loomis-Manning, Bouden, and others in which the filtering media are sand or animal charcoal, magnetic carbide of iron, spongy iron, etc.

In such mechanical filtration, as all the house supply passes through the filter, the filtration is necessarily more rapid than in the case of any of the usually accepted tap filters which should be removed from the tap every third or fourth day and cleaned with brush and water and sterilized with boiling water.

In mechanical filtration for all domestic purposes the filtering media are roughly cleansed by a reversed current which, lifting and separating such material, washes it, carrying the collected dirt into a drain provided for that purpose. These mechanical filters are very generally so constructed that by a controlled by-pass alum is automatically added to the water before filtration, thus combining chemical treatment with filtration. This requires some adjustment, as otherwise surplus alum will be carried through the filter, the amount added being in excess of the calcium carbonate present in the water and required to form the hydroxide which appears as a gelatinous layer on top of the filtering medium, greatly increasing its efficiency and at the same time removing coloring matter from the water, thus both brightening and clarifying the filtrate.

But no method of domestic filtration can be accepted as altogether satisfactory as none of them can be depended upon to continue to furnish water free from micro-organisms. In mechanical filtration many of the filtering media ordinarily employed are objectionable, as they add material which during subsequent storage of the water serves as food for the multiplication of germs that have passed the filter in rapid filtration or may subsequently gain admission to the filtrate. That is the objection to charcoal in spite of its desirable primary action as a deodorant.

The very large amount of water passing through such filters tends to overcrowd the filtering media whose weight and bulk may be limited by space available and by the lifting power of the water of the reverse current required to clean them. After reversal, when the filter is again put into use, the filtrate may be especially dangerous for some time at least, until the water becomes clear and sparkling. But the mere washing of the media, especially with unfiltered cold water under small pressure, does not tend to satisfy the hygienic requirements. Any filtering medium acting mechanically tends by its very filtering action to become a highly infected mass, that is liable, without very careful management, to furnish at some time a sample of water crowded with the bacteria it has for some days succeeded in straining from the large volume of water that has passed.

This is even true of the fine bougie or tube filters made of diatomaceous earth or of clay and attached to the water taps. Such filters have also been used in the field, the water pressure being obtained with pump. The Berkefeld, made of diatomaceous earth, was found to be too fragile, and also when dropped into boiling water was liable to crack. Repeated boiling also lessens the efficiency. The yield is also greatly lessened whenever the water happens to be muddy, thus necessitating for field use provision for prior filtration or clarification by a sponge chamber and for domestic use the frequent removal of filter for cleaning with brush. The fine clay-porcelain tube is, however, less fragile, and more readily cleaned, and much more susceptible of sterilization by boiling without breakage. If the integrity of the apparatus is complete, those filters give a sterile water for a few days; but in a week, more or less, bacteria may find their way even through these tubes under the water pressure required to secure filtration. This requires the sterilization of the tubes every three or four days, which, however, is readily and quickly accomplished even in military service, as the number of such tubes is small and arranged in batteries, a square inch of tube surface filtering at the rate of perhaps 5 1/2 gallons a day at 40 pounds' pressure.

In the United States Army there seems to be a disposition to regard with distrust any system of filtration for the sterilization of water under the conditions of active service, and to place confidence in sterilization by heat. For that purpose, instead of a wheeled water tank fitted with filters, there is a water wagon fitted with the Waterhouse-Forbes sterilizer and all necessary accessories, including pump, coarse filter, kerosene furnace, and storage tank. This Forbes sterilizer, consisting of a varying number of cylinder units, can be made in varying sizes, the smallest being portable by hand and the largest being mounted on wheels. In its smaller size it forms part of the field hospital equipment of the Army, and, being an interesting apparatus from a sanitary point of view, should be studied from some of the descriptions that have appeared from Army sources. In this apparatus only a small amount of water is boiling at any given instant, and being boiled for only a short time there is less change in taste; and the heat of the boiled water is used to warm the water to be boiled, thus economizing in fuel and at the same time cooling the output.

Municipalities obtaining water from questionable sources, such as most of the large rivers of this country whose waters are becoming more polluted as population along their banks or on the water sheds increase, tend to combine sedimentation with natural filtration as the means of purification. There was a theory of self-purification of streams. It was said that "running water purifies itself." Experience has demonstrated that such purification is only partial and very unreliable. In fact, the more rapid the stream the more capable it is of bringing contaminated water to the consumer. Water in reservoirs tends to purify itself, for quiescence is the first requirement in the purification of surface water.

That is the function of the large settling reservoirs of cities. Purification by storage may be sufficient in itself when the reservoirs are sufficiently large and in sufficient number to permit prolonged quiescence. Sedimentation exerts a powerful influence in the purification of water. At some time of the year temperature may assist in killing some bacteria, light may kill others, unfavorable environment at the bottom others, and ultimate lack of food others.

Ordinarily a city does not have sufficient storage capacity to permit the reservoirs to act as more than settling basins for clearing the water in a measure of the mud. However, such settling lessens in no small degree the number of bacteria in the water. If sedimentation is allowed for even 24 hours it is an important preliminary to filtration. In some cities the character of the material in the river water is such that it cannot be cleared sufficiently in this manner, and then from the settling reservoir the water passes into a mixing basin where alum is added prior to filtration. Under such circumstances the amount of calcium carbonate in the water is estimated, and thus the amount of alum to be added becomes known. It varies generally from one to six grains per gallon for different waters.

Other waters are so hard that they have to be softened before distribution in order that they may be used economically and efficiently for domestic purposes. Clark's process of softening water is to add lime in the mixing basin in order to effect combination with CO_2 in the water, and thus cause a precipitation of the carbonates of the water, just as occurs when the CO_2 is driven off by boiling. To know how much lime to add it is necessary to know at least the degree of temporary hardness. Ordinarily an ounce of lime per 100 gallons for each degree of such hardness is added. In the settling of the carbonates, originally in the water and of the carbonates formed by the lime and CO_2 of the water, considerable organic matter is also carried down. Thus the process is not only one of softening, but also to some extent of purification. The Porter-Clark process is similar except that to make the water more quickly available it is strained or filtered without waiting for the sedimentation of the carbonates.

From the settling reservoirs the water needing further purification passes to the sand filters, where it undergoes the process of natural filtration, so called because the filters are constructed to purify in the manner in which Nature furnishes pure ground water, either for springs obtaining water from great depths, or for deep wells, including artesian wells. This is not merely a process of filtration, but also, and characteristically, a subjection to the action of numberless nitrifying bacteria which as a gelatinous living mass forms on and below the surface of the sand, acting itself not only as a filtering medium, but also as a living organism feeding on the organic material in the water.

These filtering beds have molded concrete bottoms to provide for under-drainage by pipes. Upon this bottom is placed coarse and then fine gravel and over the top of the gravel from 2 to 4 feet of good white, fine, sharp-grained washed sand. The sides of the filter are made like a wedge to secure unbroken contact with the sand, and the water is admitted first into a shallow well to avoid scouring. Before the water to be filtered is admitted, the filter is flooded by backing up filtered water through the under-drains.

Eventually, of course, those filters have to be cleaned, and that is done by scraping off some of the sand which can thus be reduced in thickness of layer to between 12 and 16 inches before renewal is required. Such a filter removes at least 98 per cent. of the bacteria, but daily bacteriological and chemical examinations of both filtered and unfiltered water are necessary to test continued efficiency. Each sand filter is generally made to cover an acre, and in cold climates they are constructed covered to prevent formation of ice by which their efficiency would otherwise be greatly diminished. A depth of water of from 3 to 4 feet is maintained, and 2 million gallons per acre per day is a moderate output. With some waters even 5 or 6 million can be obtained with safety. A study of the management of these filters in detail is interesting and is advised.

Sand or natural filtration has provoked criticism on account of high first cost, expense of keeping, and loss of use incident to cleaning and, in some cases, to aeration. There are strong advocates of mechanical filtration as opposed to natural filtration in the central purification of water; and certain mechanical filters at central stations have given very good results in connection with alum. However, the questions involved are within the province of the sanitary engineer and the sanitarians of civil communities, and should not be discussed here where the subject is taken up simply because it is one of great general interest to a navy whose health depends so intimately upon conditions on shore.

On our more recent ships there is neither purification of water by filtration nor by chemical means, and it is not clear at this time that either can be advised as necessary. On a number of older ships, fitted with the Baird distiller, the water, as has been explained, passes through animal charcoal before reaching the tanks. As a general proposition it does not appear that distilled water should require purification. If the distiller maintains its integrity the distillate is germ-free, and to accomplish that result is the main object of all attempts at purification of water supply. A charcoal filter renders the water that passes more capable of sustaining bacterial life, and a bougie filter would endeavor to remove germs from water that is already free from them. Alum is barred by the absence of the calcium carbonate necessary to form with it the hydroxide upon which its action depends.

It is true that in certain harbors the distillate is objectionable on account of volatile products. In their diminution or removal a charcoal filter would be of value in view of its power to absorb into its pores large quantities of such gases as are easily absorbed by water. This action is primarily purely mechanical, but eventually the offensive gases absorbed by the charcoal from the water are chemically acted upon by the oxygen of the air in its pores and converted into inodorous products. In this way sulphureted hydrogen (H_2S), for instance, is converted slowly into sulphuric acid (H_2SO_4). But unless the distiller is provided with an aerator, such as the Baird distiller has, the distillate as it leaves the distiller is practically free from air and therefore incapable of renewing the oxygen the charcoal originally contained. Such filters therefore require rest.

A cubic inch of wood charcoal that has been heated to redness and allowed to cool in a closed vessel will absorb at least 50 cubic inches of sulphureted hydrogen. The same amount of charcoal absorbs nearly 10 cubic inches of oxygen. Recently calcined charcoal has this power in greater degree than when it has been allowed to acquire water from the atmosphere, and charcoal that has lost its power of absorption of gases will regain it in great measure after it has been heated to redness. Animal charcoal has much more deodorizing power than charcoal made from wood. This may be due in part to the fact that in bone-charcoal nine-tenths of the weight is phosphate of calcium which separates the carbon into finer particles, thus making it more available to remove many liquid and solid substances from their solution in water. Animal charcoal contains much less carbon than wood charcoal, but the decolorizing power of the latter is very feeble in comparison. But water that has passed through charcoal not only gives up certain substances, but also acquires others, such as phosphates that diminish its keeping qualities, inasmuch as they furnish food for bacterial life. It is in this respect that spongy iron or a "metallic sponge" has the advantage over charcoal which acts as a "carbon sponge."

The action of a filter on a naval vessel would, therefore, be directed against volatile products, as a rule, but of course in the event of a leak in the distiller tubes a filter such as the Pasteur-Chamberland would be a satisfactory safeguard, while a charcoal filter such as has been used would be of little or no value in the prevention of infection. But under a proper system of tests at the distiller and a test of the water as a whole in tank before distribution, as has been described, contamination of water by distiller leaks can be avoided, and such leaks under proper construction and renewals should be at least as rare as those incident to imperfect bougies in filtration. If the service continued to take on board water from shore for drinking, filters of the Pasteur-Chamberland type would be necessary, and even the chemical treatment of water would probably have a place.

The problem of the removal of the water supplied a community is as important as questions relating to the character of the supply itself. Wherever there is concentration of individuals, whether it be in a city, at a training station, or on a ship, drainage is imperative not only for the removal of the water *per se*, but also for the removal with it of the burden of man's excretions it carries. The water supplied in pipes to a community is comparable in a way to the air supplied by pipes in artificial ventilation, while the rainfall in any locality may in a sense be compared to natural ventilation. In all ventilation there must be a more or less systematic renewal of air, for which purpose the exit, as has been shown, is as essential as the inlet. To provide openings for the admission of air without providing openings for its exit would surely defeat any plan of ventilation. The renewal of air is not only for the purpose of supplying the body with oxygen, but also of separating man from his air-borne excretions. As water is one of those excretions, and as water is also employed to some extent in securing cleanliness of the surface of man's environment, movement of air not only removes the air-borne carbon compounds thrown off by man, but, also in view of its thirst, makes for dryness of locality within its water-bearing capacity.

In comparison, water is supplied a community not only to furnish the liquid the body requires in its metabolic processes, but also as a solvent and as a mechanical carrier to take from him, as in the laundry and in bathing, the exfoliations and solid excretions of his skin, and solid adventitious material his surface may have acquired, and to receive for transportation the liquid and solid excreta leaving the body as urine and feces. As in ventilation it is necessary to remove contained air that man may be separated from his air-borne excreta, so in supplying water it is necessary to remove immediately all that has once been utilized in order that he may be rapidly made free from the influence of his solid and liquid, or water-borne, excreta. Lack of drainage necessarily causes the surrounding air to be damp and dangerous in its interference with the regulation of the body temperature and it also leads to pollution of locality by which individuals are kept in dangerous proximity to their own waste material. In that danger the mosquito and the fly play a prominent part. Standing fresh water is the breeding-place of the mosquito and filth is the breeding place of the fly and is its preferred resort.

A drain is the channel, whether closed or open, by which the drainage or material to be drained off is conducted from a locality. A surface drain is such an open channel, and as found on ships is called a "waterway." These waterways are constructed of metal and extend around an open deck to receive the rainfall or the water used in washing down. They discharge into scuppers.

Scuppers are the closed drains or pipes that carry overboard the drainage of whatever character from all decks and fixtures above the berth deck. They are made of composition and discharge near the water line or above cofferdams where they are provided with extensive lips to throw water clear of the ship's side. They are located more or less vertically wherever a closed drain is required, and the flow is entirely by gravity and is very rapid. Not only are all open decks, bridges, hammock-berthing on weather decks, military tops, search light platforms, boat cranes, top of chart house and the like drained by scuppers, but also the floors of such spaces as washrooms, shower baths, crew's head, galleys, their separate drains discharging into a main scupper *at an angle not exceeding 20 degrees.*

Scuppers are also fitted for special purposes, such as discharges from water-closets and urinals and crew's head. There are all the advantages in this arrangement of short piping and rapid flow and, in water-closets, heads, and urinals, of unlimited supply of salt water for flushing. Yet, in spite of all these advantages the plumbing should be entirely exposed and also even more carefully constructed, ventilated, and safeguarded against return than in the case of houses discharging into the sewers of a city. Not only is the concentration of men on a ship so great that even short pipes are liable to slowly forming accumulations of filth, but the flushing water itself by its hardness, lack of solvent power, and roughening of pipes by chemical action facilitates much clogging by slow deposits. An attempt has been made to increase its cleaning power by ultilizing the hot water discharge of the distiller, but that has now been abandoned on more recent ships in view of the personal discomfort involved.

Besides, *a ship at sea, especially in rough weather, is constantly and greatly changing its water line, thus tending to the backing of water up drains and the forcing of their contained air into spaces*, and even of water itself if drainage of a fixture, too close to water line, is attempted by gravity. In limiting this action the discharge opening of a scupper is protected by a flap valve when the end of the scupper is buried. *Drains are also provided with air vents* and are also fitted with strainers, traps, and cleaning plugs. Floor drains are often of the stop-valve type and *the drain pipes of ships are or should be fitted with a steam connection for blowing out.*

As a general rule, the water-closet for crew is at present a tinned heavy copper trough usually about 17 inches at top and 9 inches wide at bottom. The upper edge is flanged about 1 1/2 inches and the back of the trough is vertical. The bottom is inclined to the drain opening which is about the middle. It is supported by the waste connection and suitable saddles and is provided with a connection for end flushes. There are also one-inch diameter perforated flush pipes fitted high at back and front and extending the full length of the trough. The flush is continuous and the supply is controlled by key valve. The discharge is by special scupper as in the case of all discharges from sinks, urinals, and water closets *which should never connect with floor drains or discharges from other fixtures.*

The seats are made of ash about 1 1/2 inches in thickness by about 18 inches wide, arranged with openings about 9 inches wide by 12 inches long, shaped as in seats for individual closets. They are usually made of four pieces, the grain of the wood running from side to side for the front and back pieces and from front to back for the side pieces. The seats are spaced about 24 inches center to center and are hinged. Each is within a stall not less than 24 inches in width, extending to 5 feet 6 inches above the deck, with frame of galvanized piping and sides of galvanized sheet steel.

It appears that the trough might be improved by increasing width at top, say to 22 inches, in order to more certainly protect the flushing pipes which although capable of flushing the troughs cannot completely cleanse themselves. There is also a tendency in the completed oval seat-opening to fouling both in front and behind that might be obviated in a crew's head by leaving the oval and the seat incomplete or entirely open anteriorly and posteriorly.

With the very frequent use on ships, wooden seats in the head tend to develop cracks and even to start at hinges and not being removable are difficult to keep clean and at times, it has seemed, even free from the *pediculus pubis.* All such seats should be made of thoroughly seasoned wood, carefully put together for durability and smoothness, and of sufficient thickness to stand very rough usage. Two-inch ash would perhaps not be too heavy and would permit more substantial hinges. Cracked or broken seats cannot be kept clean even by the daily washing with soap and water to which they should always be subjected. All seats should be examined daily by some member of the carpenter's gang detailed for that purpose, and kept in constant repair. The seats should also be specially treated, before they are fitted, to limit their power of absorption and to facilitate cleaning. This may be done by covering with grated paraffine and melting it into the wood by using a hot iron. Subsequently, any surplus paraffine having been removed, a solution of wax and paraffine in turpentine should be applied and then monthly or as required. The solution would fill small cracks, give a smooth surface capable of polish, and free the seats of any vermin that happen to be present.

A number of naval medical officers are not in favor of any woodwork at all in a head and are especially opposed to any that cannot be removed daily and scrubbed with water and sand during the morning watch. They contend that a trough is objectionable and the stalls, having no doors, secure only a limited measure of privacy that is not so greatly desired by a crew as to prevent a recognized cleanliness of seat from being welcomed in exchange. Stalls limit the mixing of odors, but also diminish the general movement of air. On some of the old-time ships, without stalls, substantial and well separated wooden back and front pieces were fitted on the ship as seats, which, by using spare parts, could be removed and scrubbed daily. Objectionable heads containing troughs have been greatly improved in that way. A head is the location where the results of carelessness or bad habits are most observable, as there is tendency to retain, within the ship, excreta, the immediate removal of which is of very great importance. The construction should facilitate cleanliness and offer opportunity for efficient supervision, inspection and policing.

The trough water-closet has certain advantages as installed for use by large bodies of men, but it has disadvantages that will probably lead to its exclusion from ships, at least for a time, and the trial of individual closets. One objection is the splashing accentuated in a shallow trough by a continuous flush that is apt at times to be excessive. In that way individuals may receive on their persons, including hands, water contaminated by the discharge of others. It would then be quite possible for such a disease as typhoid to find a method of extension in this way, the fecal matter of a typhoid case being carried under the seat occupied by another individual and splashed upon his person. In connection with the attempt to do away with the trough a closet has been devised with integrant seat, thus doing away entirely with woodwork. This form of closet is shown in the illustration on the next page.

It is an extra heavy all-porcelain, vitreous glazed oval flushing-rim seat hopper with flange and extension to let into trap with a 1 1/4-inch inlet flush connection. The hopper is secured to a heavy cast-brass 4-inch deep seal 3/4-S trap with flange to suit bottom of hopper and extension, and flange 8 3/4 inches in diameter, for connection to waste pipe. The trap has a pedestal body and is flanged outward for securing to deck stool. The hopper is provided with a heavy rubber concussion washer and secured to trap by brass cap nuts with concussion washer.

A 3-inch clean-out cap is arranged at the top of trap. This closet is flushed by a brass slow-closing flush valve with cast-iron weighted handle with support.

While such a closet will be free from certain objectionable features inseparable from the trough closet, it will be found in practice to have serious defects of its own, as it will be frequently used as a urinal and the seat and deck will then become contaminated with material that is very often infected. There will be an absence of woodwork, but a clean seat will not be secured. Also in a large ship there would be about 20 such closets in each head and the discharge piping will present difficulties in the way of air compression, especially if heads are continued on the gun deck. With so many closets on one level, the more or less horizontal discharge piping should be liberally air-vented at *each end*, the vertical discharge being continued upward undiminished in caliber well above an open deck and a similar air vent being fitted to the other end of the piping into which closets empty directly. This is a variety of circular venting that in this case would greatly diminish the effect of air compression on water seals. On ships, as in houses, the gases from

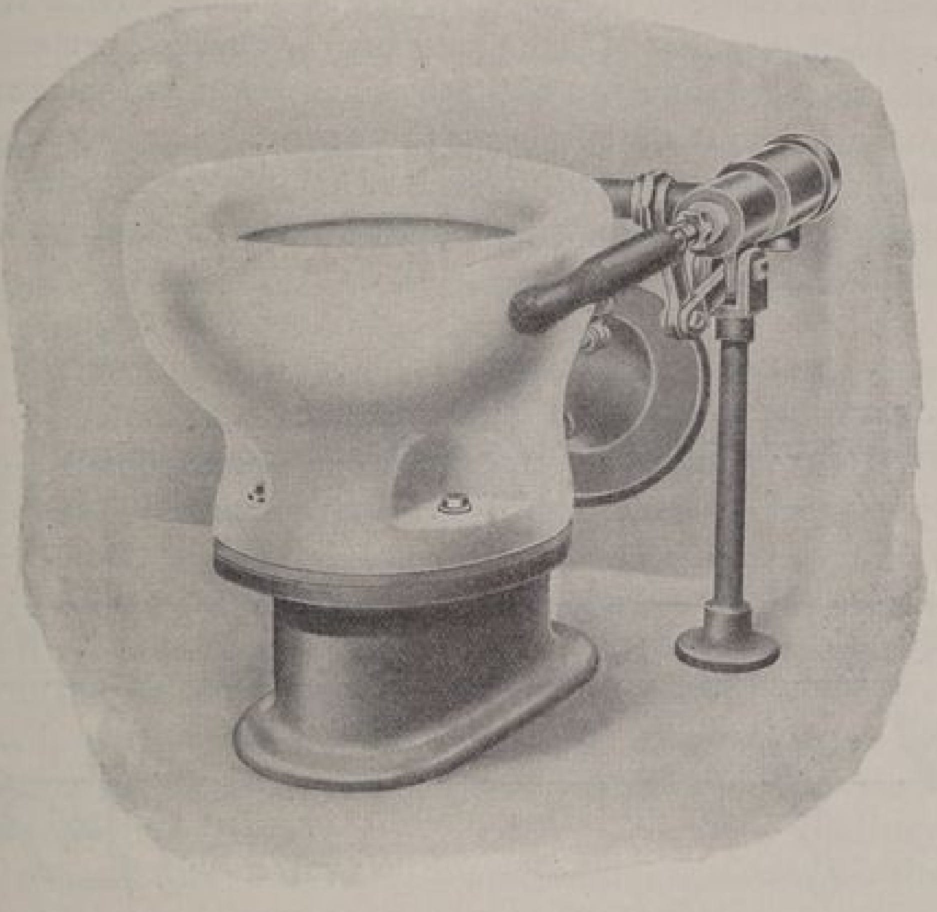


FIG. 48.—Water-closet for crew (when not the ordinary type of trough). (Jenkins Manufacturing Co.)

decomposition of material in piping directly connected with closets are those against which the water seal is chiefly designated. The absence of sewers in connection with ships does not therefore abolish the necessity for such seals.

The crew's urinals are each made of cast-iron porcelain lined. It is a rolled-rim lipped-trough with integral or detachable back of the same material. The back is about 8 or 9 inches high and the trough 8 inches wide at the top, 6 inches deep and 4 inches wide at the bottom. The lips extend 3 1/2 inches beyond the front line of trough and are spaced about 24 inches from center to center. The lengths of these troughs are 4 and 8 feet. There is across the back a perforated 3/4-inch copper wash-down pipe with key valve and also a one-inch end flush with key valve arranged at opposite end to drain opening. The drain opening or waste outlet is fitted with strainer and a cast-brass S or half-S trap with straight inlet, vent capped and clean-out plug, is provided. The arrangement is shown in the following plate:

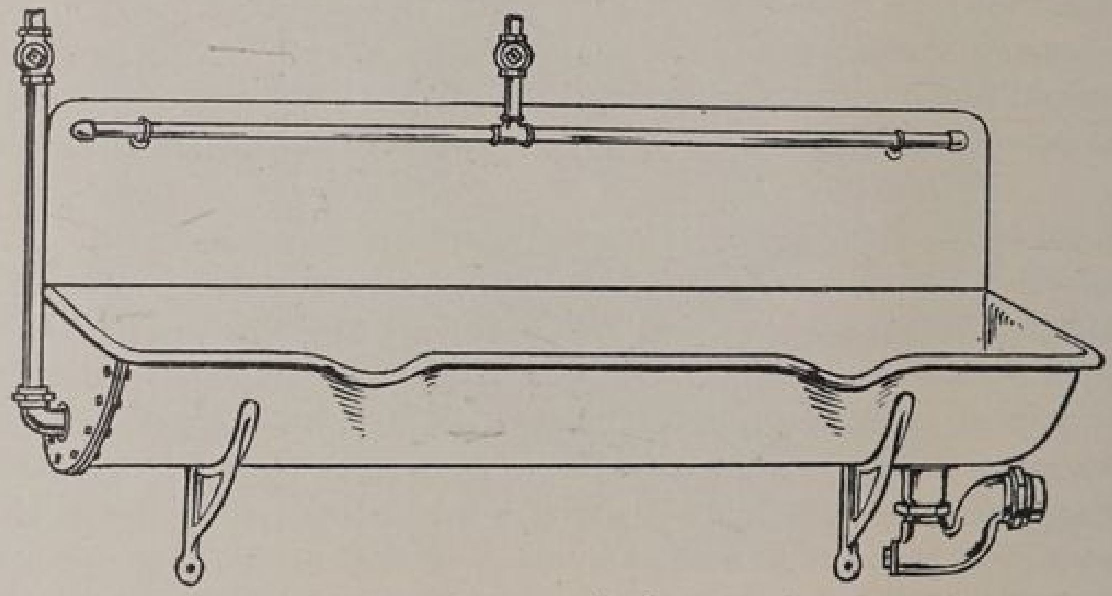


FIG. 49.—The Trough Urinal. (Jenkins Manufacturing Co.)

The trough urinal, while not free from objection, appears to be the most suitable for a crew's head. All parts of the trough in front are not flushed and, as in all urinals used by many, there is more or less contamination of the deck. During recent years urine has been more generally recognized as frequently infected and its deposit outside of the running water may be assumed on a ship to constitute a danger. A ship in a seaway may not always be conducive to the use of urinals with precision, but under any circumstances there is more or less dropping. Considerable limitation can be secured by a projection from the deck about two inches in height and 12 inches in width with slight slope toward the trough and so located that it must be occupied to use the urinal. This arrangement, while greatly limiting deck contamination, also limits the area contaminated and diminishes chance of tracking or dissemination about the ship.

The degree of flush, whether of water-closet or urinal, requires close supervision. With the relatively high pressure in the flushing main, the tendency is toward an excessive flow from which there results a damp head from contaminated water reaching decks and seats, and unnecessary and undesirable splashing of individuals. As there are two heads, one on each side of the forward gun deck, there is opportunity for careful cleaning which with good construction should obviate or greatly lessen the necessity for the use of disinfectants and deodorants. As a general rule, the use of deodorants in such places is considered to indicate faulty construction or bad management or both. But on a crowded ship there are many difficulties, especially in hot weather. Carelessness in the use of a ship's head is punishable, and a degree of cleanliness can be maintained by the captain of the head and his assistants if it is greatly desired. But the dry and clean deck that is very desirable cannot be secured if a head is also used as a general lavatory.

In the French navy there has recently been a general movement to utilize electrolyzed sea water, prepared after the manner of Hermitte, to render urinal and water-closet traps unobjectionable. Only a current of 70 to 80 volts is used, and the carbons employed are similar to those in the search-light. Considerable success is reported as by a substitution of such water for the regular flush during an hour or two daily, the troughs are kept free from odor. The apparatus is said to be regarded in that service as simple, easily installed, and of great advantage.

But in electrolyzing sea water by the Hermitte process, products are formed that have a more or less corrosive action on pipes, and unless the process is modified in some way or carried out only in relatively small degree, as in the French Navy, the action is distinctly destructive to trough, traps, and scuppers. The water and the sodium and magnesium chlorides are more or less resolved into their constituent elements as the current overcomes the chemical attraction by which the elements are held together. Thus the water itself will be decomposed to some extent into hydrogen and oxygen, some of the latter being evolved as ozone. Oxygen is in a negatively electric condition, and is therefore attracted by the anode or positive pole, and the same is true of the chlorine evolved from the chlorides. Both of these gases being highly electro-negative have very little or no direct attraction for each other, but, as a mixture, have a powerful decomposing effect upon carbon compounds, the chlorine tending to combine with the hydrogen in such compounds and the oxygen with the remainder of the molecule containing the carbon and perhaps nitrogen. Chlorine even has the power to slowly decompose water itself, so strong is its affinity for hydrogen. Among the products of the putrefaction of animal matter in water-closets and urinals are ammonia, sulphureted hydrogen and the like. Chlorine breaks up these hydrogen compounds, forming inodorous substances. For example: $4NH_3 + Cl_3 = 3NH_4Cl + N$. Its bleaching action is along the same line.

Nearly all vegetable and animal coloring matters contain carbon, hydrogen, nitrogen, and oxygen, and are converted by chlorine in the presence of water into products that are more or less colorless, some of the chlorine, however, generally ultimately combining with hydrogen to form hydrochloric acid, and the remainder forming a part of the carbon, nitrogen, oxygen, and hydrogen molecule. All such actions are greatly hastened in the presence of free oxygen, as organic matter is itself readily oxidizable, and therefore oxygen greatly hastens a readjustment of molecules when hydrogen and chlorine are also strongly seeking each other to form hydrochloric acid. But during the process the attraction of hydrogen and oxygen also finds a certain degree of momentary expression in the form of hypochlorous acid ($HClO$), but that acid has never been obtained in the separate state, being so readily decomposed into HCl and O. However, its very instability makes it a powerful oxidizing and bleaching agent, and the effect of electrolyzed sea water as a disinfectant probably depends to a certain extent upon the instantaneous formation and decomposition of this agent, as also does some of the effect upon metals, iron seizing upon the oxygen while liberating chlorine and copper taking both the oxygen and chlorine. But the attraction of chlorine for the metals is usually much superior to that of oxygen and, with the tendency in the completed action of electrolyzed water to the formation of hydrochloric acid, there will be, the more rapidly formed on account of those very intermediate changes, ferrous or zinc chlorides as well as the oxychloride of copper, metal pipes, and troughs showing the results of such action quite soon, even when the water contains only 0.06 per cent. by weight of chlorine.

Possibly in using electrolyzed sea water for an hour or two daily in heads, a disabling corrosive action would not result if the process were carried out under a small voltage for a short time. If experience proves that to be true it would be of value in the treatment of malodorous deposits commonly formed in the head scuppers in spite of the continuous flush. It might also be made of value in the treatment of the slop chute or the galley slop waste, which is often an ash chute utilized to take the galley slop. These chutes have a circular section of not less than 12 inches diameter and discharge overboard. They are fitted with flap valve at the lower end and have at the top a hopper with a 24 x 18-inch hinged, water-tight door. A portable grating is fitted in hopper. Either the forward ash chutes are utilized as galley slop wastes or similar chutes are installed especially for that purpose.

The water-closets for all officers, including those for chief petty officers, are with few exceptions single-valve ship water-closets when situated above the berth deck and pump water-closets when on that deck. On the large very recently designed ships a siphon closet may be found located in officers' quarters above the gun deck, and as on those ships there are no water-closets below the gun deck the pump closet does not appear. All water-closets, except the pump closet, discharge their flush by gravity. The pump closet has generally been utilized on ships only when the situation near or below the water line did not permit the installation of a gravity closet. The bowls of all water-closets, whatever the manner of discharge, are all-porcelain, vitreous glazed (vitro-adamant), flushing rim, and have a uniform thickness of not less than 5/8 inch.

In the pump closet the flush is by a 3/4-inch connection from the flushing system controlled by a foot tread. In other words, a pressure of the foot on the tread flushes the bowl and then its contents have to be discharged by a hand pump, the suction of the pump being on the bowl, and its forced discharge outboard. The cylinder of the pump is about 3 1/2 inches in diameter and its length sufficient to enable the full bowl to be emptied by about 10 strokes. Suitable valves are provided to prevent the return of water and sea water into hopper, and the suction valve is located close to discharge opening in bowl. The discharge opening in bowl and the discharge from pump are each about 2 1/2 inches in diameter. It is evident that such an arrangement is troublesome to each user, is generally not sufficiently flushed, as considerable work is involved even when the pump is in perfect order, and is very liable to be out of repair and then to become a great insanitary nuisance. The opposition to such closets is general not only from a sanitary point of view, but also from the inconvenience their use involves. They are makeshifts as water-closets and have only appeared because near the water line no better arrangement has been regarded as feasible. But as will be seen, a sewage discharger, such as the Hermes, furnishes opportunity for the installation of a closet of general approved type in any location that permits the discharge pipe of the closet on the way to the sewage discharger to be given sufficient fall.

The sewage discharger is always much below the water line, but, situated in the engine-room, is not far from the mid-section of the ship, and in utilizing it in connection with water-closets the difficulty is, unless additional dischargers are located for the purpose, to obtain a sufficiently short or vertical lead for the discharge pipe of a closet placed well forward or aft.

The valve closet, so general on ships, has for a long time been discarded on shore. The pull has a stirrup handle and when the handle is raised, the swinging valve in the heavy cast-brass valve box upon which the short hopper rests is opened downward, and at the same time the flush valve is opened to admit water under pressure from the flushing system which by a flushing rim washes the bowl and carries its contents by the force of gravity down through the valve box into a 4-inch straight untrapped waste connection. When the handle or pull lowers, the discharge and flushing valves are closed and the flushing ceases, but sufficient water drains into the bowl to leave an ample water seal. The following plates give a general idea of this type of closet:

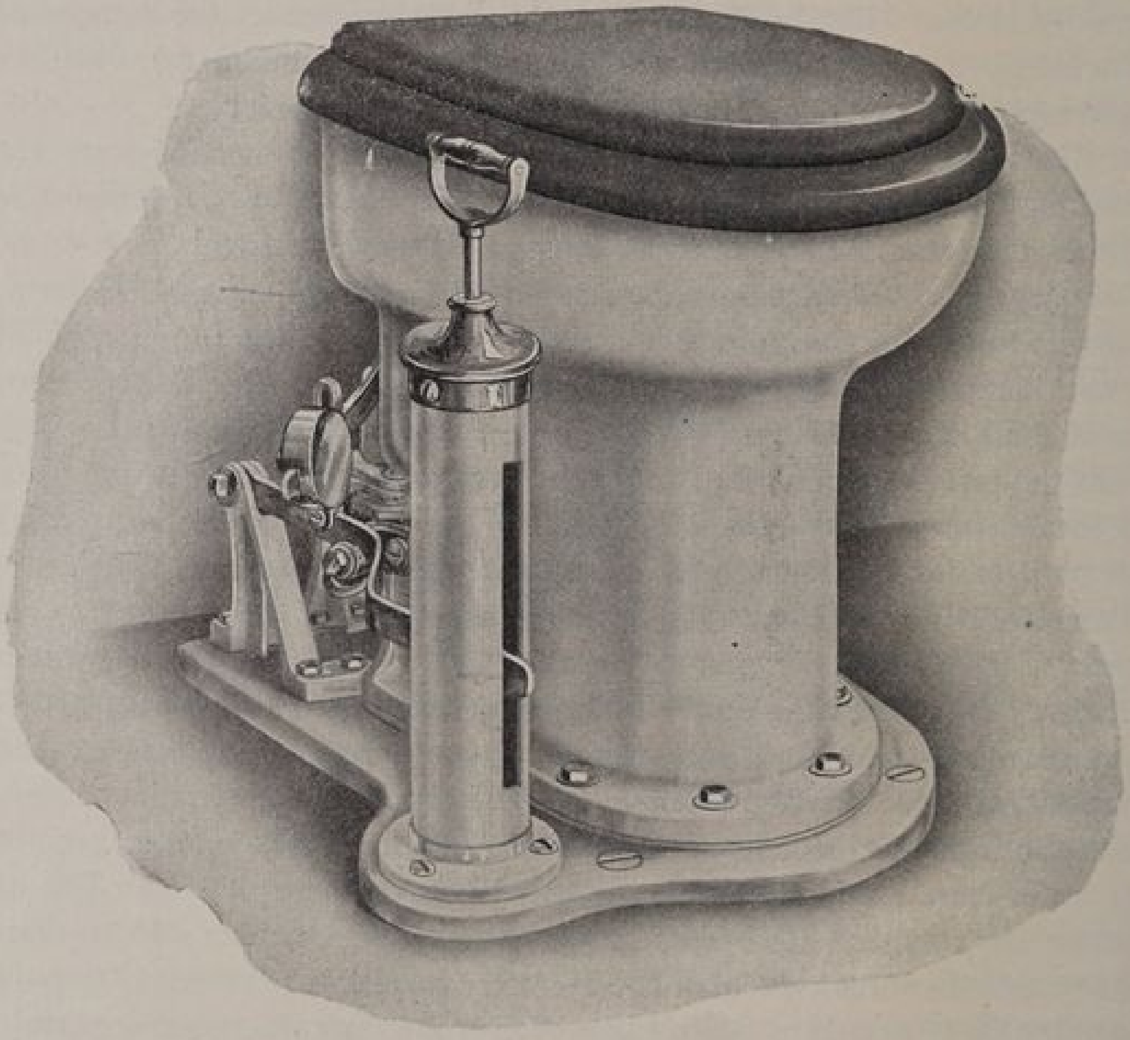


FIG. 50.—Single valve water-closet with pedestal bowl.
(Jenkins Manufacturing Co.)

In using this closet the handle has to be lifted to the full extent of the pull or the flushing of bowl will not be sufficient, much less that of the valve and valve box. It is also quite evident, without going into the construction in detail, that there are a number of parts to get out of order and that unless the material in the valve mechanism is sufficiently heavy and of the very best quality there will be frequent breakdowns with either a full bowl or lack of water seal. In the first case the deck may even be flooded, although there is a trapped bowl-overflow which usually prevents that, and in the second the odor from discharge pipe will be objectionable.

Experience has clearly demonstrated that these closets do not meet the sanitary requirements, because the flushing has been generally too uneven and uncertain; the water seal, depending upon tightness of valve, has been subject to loss, while integrity of that valve and leakage at flooding valve leads to too much water in bowl, and in general the mechanism has been liable to derangement requiring frequent repairs, sometimes after there has been pollution of decks. Doubtless not a few of those objections have now been overcome in a measure by better construction, but a valve closet can never meet sanitary requirements, the very valve box itself constituting an obstacle to successful flushing. It should be clearly understood, however, that the valve closet has been retained on ships not through any lack of appreciation of the sanitary advantages of the various wash-down closets with vertical backs and the siphon-jet closets of approved shapes, but on account of the very valve itself as a protection to the water seal at sea against the plunging of the ship in rough weather.

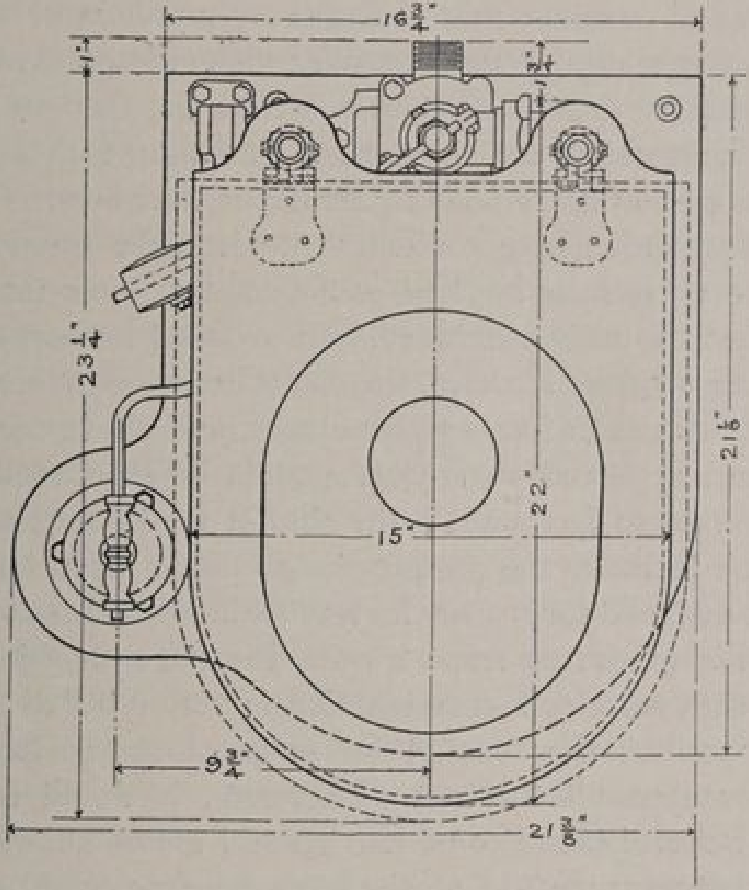


Fig. 51.—Plan of Single valve water-closet.
(Jenkins Manufacturing Co.)

All the discharge pipes of those fixtures have air vents except those of the pump water-closets, but nevertheless it is considered that with an open seal, not only would the movement of the ship directly tend to loss of the water but, in plunging, rolling, and squatting, the ship would force water up the main scupper and thus by air compression in pipes project the exposed seal up on to the person or even clear of the bowl. Such action is apparent at times to some extent even in a valve closet, the flap check valve at the discharge of its scupper having been surprised during some sudden and irregular movement of the ship. Some persons seem to see their way to consider that the sanitary problems of a navy have been solved. But a ship presents peculiar difficulties, and not only have many of its sanitary problems not been solved, but they are surrounded with as much uncertainty and have been associated with as many mistakes as in the case of corresponding problems elsewhere.

There is presented here a distinct problem, the solution of which does not, however, seem as hopeless as did some of those that have been more or less satisfactorily concluded. In a closed harbor, or wherever a ship is resting upon quiet water, the direct drainage by scuppers offers no peculiar difficulties and many advantages, and above the berth deck any of the most approved water-closets could be successfully operated. The difficulty is entirely found in the ship at sea or anchored in open roadsteads, and is due to the compression of air in pipes. A ship must necessarily be designed for sea service and while with high freeboard and large air vents on pipes near traps, a wash-down or siphon-jet closet may be employed with more or less satisfaction in very elevated locations, as a general proposition they cannot be so employed so long as direct discharge by scuppers is utilized. Therefore, it would seem that if sanitary water-closets are to come into general use on ships, either some other and satisfactory method of discharge must be found or some additional change in the individual water-closets themselves must be developed.

The present direct discharge by scuppers offers so many advantages that it should not be lightly discarded. A ship, resting in harbor with her flushing pump operating on an unlimited supply of water and scuppers as short vertical pipes discharging directly overboard, would seem to make a most satisfactory exhibition of a sanitary system. But, as has been seen, many of the fixtures are themselves inadequate and are so because often at sea the objections from a sanitary point of view include advantages from an operative point of view that may not be eliminated.

Now, a certain part of the drainage of ships has never been practicable by scuppers—that from the berth deck. This drainage has been from water-closets on that deck and from washrooms on the same deck. To make provisions for the waste from that level pump closets were installed and a sanitary tank located in or about engine-room for water from the lavatories and shower-bath inclosures. The pump closets have continued to be a nuisance and the so-called sanitary tanks never gave satisfaction although receiving only wash water. The tank water was discharged overboard on different ships by varying types of pumps, but the sediment became very offensive and was a general witness of the disadvantages of an interrupted discharge as compared with the direct scupper discharge from other decks.

This situation has recently developed two tendencies in naval construction. One is to locate all water-closets and washrooms above the berth deck, and the other is, in connection with ships of older design, to substitute what is known as a "sewage discharger" for the sanitary tank. In the large ships as now designed all water-closets and washrooms are on or above the gun decks, commanding and wardroom officers' quarters being considerably forward on or above the main deck level, and the quarters of junior and warrant officers being aft on the gun deck with sick-bay on the same level. Thus pump closets will be eliminated and all washrooms will discharge waste by scuppers.

The higher water-closets are placed the less frequent would be the display of the effect of compressed air in discharge pipes upon an unprotected water seal, and, what is of more importance, the larger and heavier the ship the less will be her change of water line at sea and therefore the less the air in discharge pipes will be compressed. Therefore, on the new ships a certain number of siphon closets will probably appear, connected for scupper discharge, but with very large air vents. However, a large number of valve closets will still be found and at times the siphon closets may give trouble. On those ships there will be no "sewage discharger" for wash water, but it is a question that can only be answered by trial whether such a discharger if very carefully constructed may not be advantageously employed in connection with a number of, if not all, individual water-closets, thus permitting at least a partial substitution of a closet with few and uncomplicated working parts for the unsatisfactory and complicated valve closet.

At present a "sewage discharger," is fitted on a number of our ships merely to take the place of a sanitary tank in connection with wash water from berth deck. The illustration given on the next page shows how the "discharger" has been fitted on certain yachts, in connection with water-closets, and it will be at once apparent that if the discharger is in engine-room and water-closets are aft there will be long and undesirable leads for discharge pipes, but that if, as in the new ships, a number of quarters are placed nearer amidships the leads would be much more nearly vertical than the one shown in illustration. It is not clear, however, that a steam lead could not be obtained for a discharger located aft, perhaps in steering-engine room.

There are at least two automatic sewer dischargers on the market that have been designed for ships. One is known as the "Hermes," which began to displace the "sanitary tank" on our ships in 1904. Such a discharger must have four fundamental characteristics: It must be sanitary, it must be of trustworthy construction or not liable to get out of order, it must be entirely automatic, and its action must be instantaneous. Such a discharger must be quite independent of every attention except that given from time to time to every machine to insure proper maintenance, and its action of discharge must be so frequent that there shall never be any accumulation of sewage in quantity. One of the troubles with the "sanitary tank" was accumulation of sewage, permitting formation of deposits and development of odors. A satisfactory sewage discharger must have small barrel or cylinder capacity, and be capable of very frequent discharges in order to reduce deposits to the minimum. And it must be so designed as to be self-cleaning and self-sterilizing at each discharge, results best accomplished by live steam in the barrel at each discharge and by the sewage inlet and outlet of the mechanism being both at the bottom and in the same line of piping.

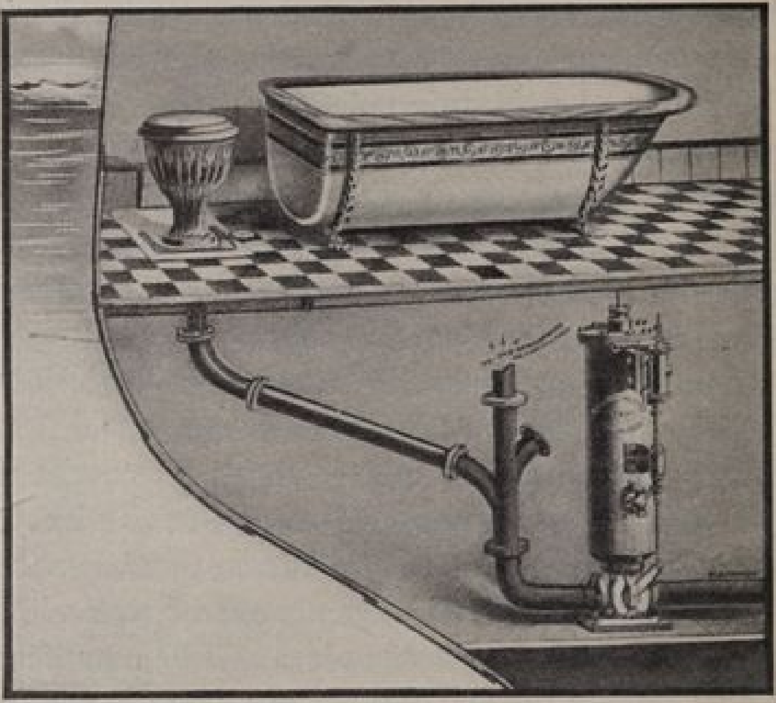


FIG. 52.—The Hermes Sewage Discharger connected with bath-room.

The Hermes discharger is a form of pump. In general terms, it

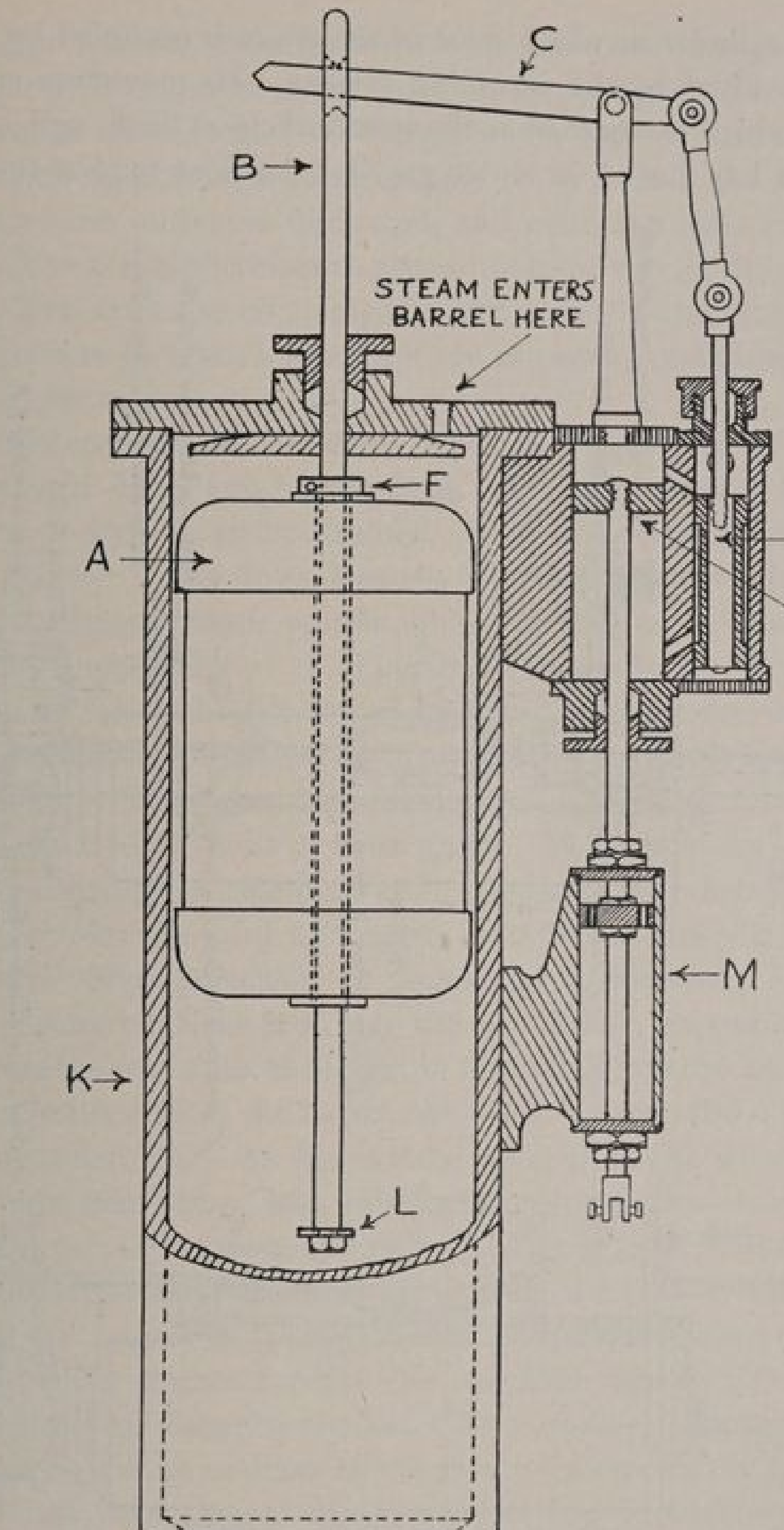


Fig. 53.—Diagrammatic section of Hermes Sewage Discharger.

is a vertical cylinder in which most of the space is occupied by a copper float that is lifted by the incoming sewage. Its maximum capacity is five gallons which is regarded as the standard closet flush, and, as soon as that amount has flowed in under gravity, the float trips a steam valve which simultaneously closes the inlet and opens the outboard discharge. Live steam then enters above the float which moves very loosely in the cylinder and on the float-rod. The steam may act partially on the float as it would on a piston, but designedly by direct pressure on the surface of the sewage. The expanding steam drives the water or waste out of

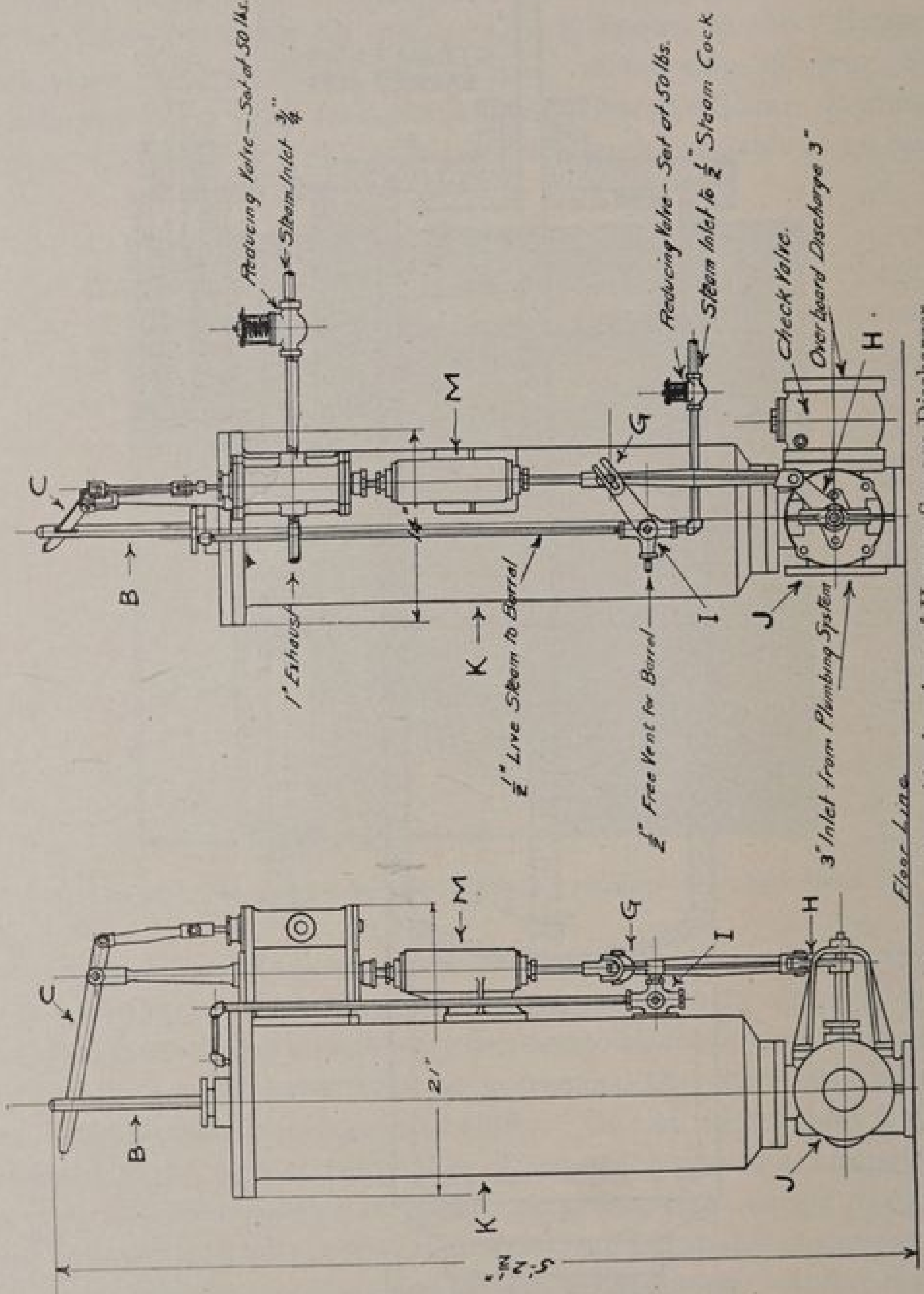


FIG. 54.—Assembly drawings of Hermes Sewage Discharger.

the barrel or cylinder and overboard. As the water in cylinder falls, the float drops with it until moving down on the float-rod it rests its weight upon a collar on that rod. This gives the rod a vertical downward motion which operates the steam supply so as to shut the steam off the barrel, close the outboard discharge, and open the inlet for additional sewage. The action therefore depends upon the receipt of five gallons of sewage. The action is completed in two seconds and therefore it can and will operate 30 times a minute if the sewage is available, discharging 150 gallons per minute.

By reference to the drawings given, a better idea of the method of operation in detail can be obtained. The apparatus is placed *below* the spaces or fixtures to be drained, so that the sewage reaches it by gravity. As the water flows into the barrel in the direction indicated by arrow in diagrammatic section, the copper float, A, rises. When it reaches the "upper collar" F, it begins to lift the float-rod or spindle, B. As B rises it raises the left end of the arm C, thus depressing the other end and lowering the piston-valve, D, until it admits steam above the piston, E. By forcing E downward, the arms G and H, seen in the assembly drawings, reach lower limit of their travel. H controls the sewage-cock, J, while G controls the steam cock, I. Accordingly, when H goes down, it closes the inlet side of J and opens its outlet or sea side that sewage can emerge. Simultaneously G opens the steam cock, I, permitting steam to pass through the pipe, into the barrel, K. Expanding there, the steam drives the water out of the barrel through J into the sea.

As the water falls in the barrel, the float, A, drops also until it touches the "lower collar," L. As this is fixed upon B, it also drops. The left end of C now goes down, and, raising the piston-valve, D, admits steam *below* E which is thus driven upward. As E goes up it pulls up G and H, shutting the steam off I and opening the inlet side of J once more. Thus the discharger is again in its original state ready to refill when water comes. When the water comes rapidly the machine has to correspondingly lessen the interval between strokes. The rapidity during each stroke is regulated by the oil cushion M which acts in exactly the same manner as an ordinary door check. It governs the speed and keeps the action silent.

On a ship two dischargers are installed, one to serve as a spare, as a rule, but with valves so placed that either or both machines may be run. The dischargers are so piped as to act as the main receptacles for waste water from berth deck, all drains from that deck being led to them just as the drains in a building on shore are led to the "house trap."

Considering a modern naval vessel from within, the bilge as a whole is the lower part of the concavity formed by the inner bottom. Within the ship it appears as the bottom and therefore is nearly flat amidships but as it extends forward or aft becomes wedge-shaped. So far as the structural strength of the ship is concerned, the bilge is unencumbered and may therefore be regarded as a smooth concave surface, which, incident to the installation of engines, boilers, shaft alleys, storerooms, and the like, has been modified by saddles or other structural devices to form foundations, and by supports for floor plates which make the platform or flooring for men working in engine-rooms and firerooms to stand upon.

The bilge is divided into starboard and port bilges by the longitudinal water-tight bulkhead, which is continuous at least through engine- and boiler-rooms. These bilges are also further divided by thwartship water-tight bulkheads. The bilges are thus designated, in accordance with location, as engine-room bilges, fireroom bilges, forward bilges, after bilges, etc., and more particularly as starboard or port engine-room bilges, starboard or port fireroom bilges, etc. In addition, one can speak of the shaft-alley bilges, starboard and port in a double-screw ship, which also, as in engine- and firerooms, are covered with metal floor plates.

The shaft alley is a continuous structure made of plating and within which the shaft passes. It is more or less rectangular in cross section and perhaps of sufficient size to permit a man within to walk upright. Access is obtained by man-holes or even water-tight doors. It extends nearly the length of the shaft, but near the stern-bearing is continued merely as the shaft tube. Water gains access to the shaft alley by way of the stern-bearing. Provision is made for a flow of water over that bearing as by abstraction of heat and limitation of friction it contributes to integrity. Such water is the bilge water in that part of the ship, but it is modified by oil from shaft bearings and even by other influences.

But many bilges remain dry or perhaps contain a little water from time to time due to sweating of metal. Yet certain bilges may be regarded as always receiving water. The fireroom bilges receive more or less fresh water from leaking tubes and connections, and, may be, water from wetting down ashes. In the engine-room bilges may be found water used on hot bearings and always much oil.

Bilge water is therefore variable in its composition not only as it has been affected by the other substances the bilges receive, such as oil or ashes, but also by variations depending upon mixtures of fresh and salt water.

In a bilge there is either advantage taken of natural slope to secure drainage by pump-suction, or depressions or wells are provided into which the water gravitates and from which it is removed by bilge pump.

In a shaft-alley bilge the slope is marked and the water collects in the forward part whence it is discharged overboard by pump. In fireroom bilges the bottom is nearly flat and water is taken from depressions or wells. The drainage in that part of the ship is apt to be more or less incomplete, even when the pump-suction is placed as low as may be practicable, and it may be necessary to use more or less cement to secure the slope required for drainage.

It is customary and necessary to thoroughly clean bilges once each week. No ship is properly constructed from a hygienic point of view unless care has been taken to have the bilges accessible for cleaning. And in some ships, if ballast be required it should be so located as not to interfere with access to the bilge.

With care the bilges of the modern ship will not menace the health of crews, although in the wooden ship they were generally a nuisance and undoubtedly very frequently the cause of lowered vitality and disease in the form of fevers of unknown type, especially in men identified with the poorly ventilated orlop deck over shaft alleys and near storerooms. This gave rise in our service to the expression "orlop deck disease," a disease having some of the symptoms of both typhus and relapsing fever.

Even to-day it should be recognized that being the lowest parts of a ship the bilges tend as the result of gravity to be under the influence of the ship as a whole and of the crew. This seems to be especially true in relation to storerooms from which material subject to decay can in time cause the bilge to become a menace to health.

The structures resting upon the bilge and the locations of certain storerooms tend to the formation of pockets not readily accessible for cleaning. Each ship requires special study in that direction and care that some of those dark spaces may not become receptacles for filth and ultimately, under the influence of heat and moisture, a serious menace to health. Close supervision is also required to have each man, engaged in cleaning bilges, respect the proprieties and also strictly refrain from deposition of sputa.

After cleaning, bilges should be carefully inspected by the medical officer, who should also consider them in relation to possible contamination from such sources as cold-storage and other rooms. The bilge is a part of a ship that requires strict sanitary care at all times.

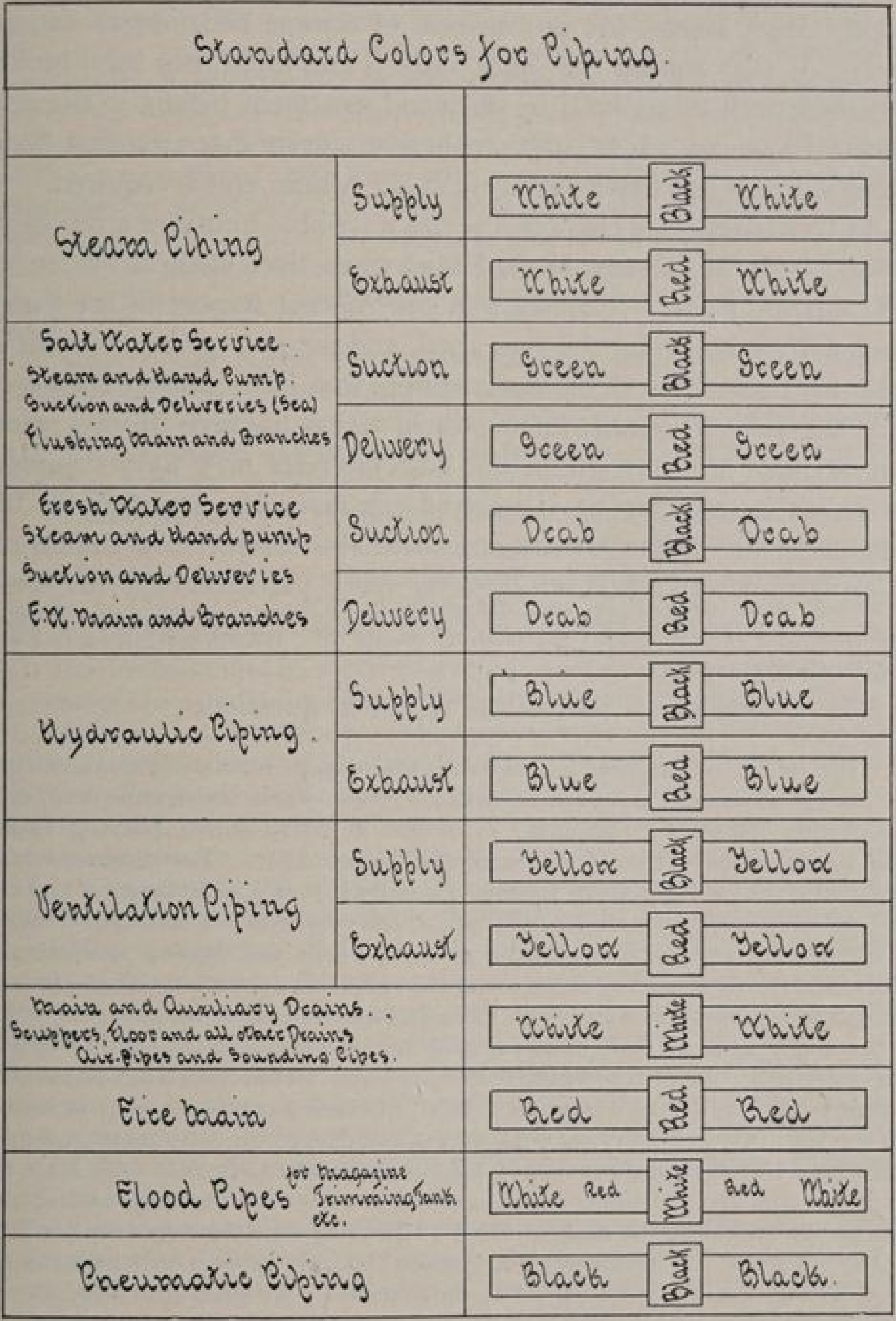
The results of examination of bilge water from modern naval vessels on which there is routine cleaning do not indicate the necessity for routine general disinfection of bilges. The use of disinfectants or deodorants may, however, become advisable in certain bilge locations, where from some fault in construction there may be difficulty of access. It is, however, necessary to make such pockets accessible not only for the integrity of the ship itself, but also to do away with conditions that cause dependence upon chemicals throughout a cruise to safeguard the health of a crew. Solutions of sulphate of iron or of "impure carbolic acid" have been employed in this connection from time to time. In the general disinfection of bilges corrosive sublimate solution is employed.

In regard to ship's piping as a whole, leakage is of much importance, whether from water or steam pipes, suction or delivery, supply or exhaust. The array of pipes seen on a ship is impressive, and, in order to quickly ascertain the character or function of a particular pipe among so many, a scheme of standard colors for piping has been adopted.

A medical officer should have a good general idea of the piping of a ship, and in certain parts of the ship it is very advisable to have that knowledge in detail. This is advisable in all quarters, but especially so in regard to pipes coming into or passing through that part of the ship allotted to the medical department, such as the sick-bay, operating-room, dispensary, and medical storeroom, as he is required as soon as possible after reporting for duty on a ship that is fitting out to examine those spaces directly in his charge, and to make a written report of any defects or deficiences discovered. Subsequently he is to take charge of those parts designated and see that they are kept dry, clean, sufficiently warm, and in good order. One of the essential things in securing such results is to pay attention to piping. Even a small leak at a scupper flange, passing through sick-bay or operating-room from the head, means the admission into sick quarters of water containing urine and fecal matter; a steam pipe, supply or exhaust, passing through a medical storeroom may well lead to the deterioration of many stores, and steam pipes connected with an anchor engine may, after use, heat sick quarters for hours in the tropics or hot weather as if the heating plant itself were in operation. A leak in a drain passing from a heater on the deck above, leaks in flushing pipes, leaks around pipes passing through the deck, leaks from water-ways, and all leaks are worthy of immediate notice and will be stopped without delay if the attention of those having such matters in charge is called to them.

On the next page is the scheme of standard colors for piping now employed in our service, mid-color being on the piping at the flanges or junction of sections.

In view of duty at various shore stations, at home and abroad, and in connection with the naval hospitals and barracks, the general subject of sewage and of refuse disposal becomes of direct interest to the naval medical officer just as the plan and construction of such buildings also become of interest. But as, except in minor particulars, a naval hospital should not differ essentially from other hospitals and naval barracks from other barracks of good design, so the principles and details of sewage and of sewage and refuse disposal at shore stations do not differ from those recognized as applicable to other locations of communities on shore. There is knowledge in that direction of great importance to the naval sanitarian, but the sources of information are so abundant



Standard Colors for Piping.

Steam Piping	Supply	White	Black	White
	Exhaust	White	Red	White
Salt Water Service Steam and Hand Pump. Suction and Deliveries (Sea) Flushing Main and Branches	Suction	Green	Black	Green
	Delivery	Green	Red	Green
Fresh Water Service Steam and Hand pump Suction and Deliveries F.W. Main and Branches	Suction	Drab	Black	Drab
	Delivery	Drab	Red	Drab
Hydraulic Piping.	Supply	Blue	Black	Blue
	Exhaust	Blue	Red	Blue
Ventilation Piping	Supply	Yellow	Black	Yellow
	Exhaust	Yellow	Red	Yellow
Main and Auxiliary Drains. Scuppers, Floor and all Water Drains Air Pipes and Sounding Pipes.		White	White	White
Fire Main		Red	Red	Red
Flood Pipes for Magazine Trimming Tank etc.		White Red	White	Red White
Pneumatic Piping		Black	Black	Black.

FIG. 55.

and obvious that it is unnecessary to include the material here. As naval stations are generally in close proximity to bodies of water, flushing water is generally unlimited. The method of disposal of sewage is usually similar to that of the city near at hand. Occasionally, as at the Naval Station, Great Lakes, the purification of sewage becomes an important factor. At that station the septic tank is employed, but such biological methods as well as methods by chemical treatment belong to the general subject of hygiene. It is sufficient here to advise that attention be given to such subjects as knowledge of them is essential and is required.

In concluding this chapter it seems advisable to utilize a report made by Surgeon L. W. Curtis, U. S. Navy, when fleet medical officer of the U. S. Atlantic Fleet. It appears in the Annual Report of the Surgeon-General, U. S. Navy, for the year 1908, and not only gives a view of some of the features of the ship's water supply that have already been emphasized, but also of certain influences in naval life that from a sanitary point of view are opposed to the best interests of a navy's personnel. The report is stated to have received the favorable indorsement of the Commander-in-Chief who recommended the absolute prohibition of the use of harbor-water aboard ships at navy yards, except for flushing closets, and that the free use of fresh water from hydrants be allowed for all other purposes.

The following is a part of the report in question:

> "The health of the fleet has been normal except for an outbreak of typhoid fever on the Connecticut. The records at hand, which are incomplete, show 78 cases of this disease for the year; 13 of the 16 battleships reporting cases; 38 of the total having occurred on board the Connecticut. The disease, while not of first importance in relation to fleet morbidity, is of special interest and significance in its bearing on ship sanitation at navy-yards. Each ship in the fleet has spent from one to five months at navy-yards undergoing alterations and repairs, and it was following these visits that typhoid appeared. At the four yards visited, namely, Boston, New York, Philadelphia, and Norfolk, general conditions are favorable and, in fact, most inviting for invasions by typhoid as well as all other maladies (including venereal diseases and alcoholism) that have afflicted the fleet personnel during the year. At all of these yards ships float in water foul with sewage; yet, generally, or with occasional exceptions, the method employed for cleaning the ships and personnel is the same as when afloat in pure sea-water—that is, pumps are operated, crews use the showers for bathing, and ships and crews are put through the daily routine of cleaning with fluid fit only for flushing the ship's sewers. But this is by no means the only respect in which sanitation suffers during these periods spent at navy-yards. At such times the ship loses its distinctive feature as such, and is practically reduced in character to a tenement, a crowded tenement, into which daily enters an army of yard laborers bringing with them no end of dirt and disorder incident to their work. The ship as a habitation then takes on the added features of boiler shop and foundry. The two elements of population crowd and embarrass each other at every point; repair work is impeded on the one hand and all systematic drill and instruction are suspended on the other; personnel and ship lapse into a condition of dirtiness and

disorder, and the ship in its character as a home, so far as relates to health and comfort, becomes on a par with that class of tenements generally characterized as 'rookeries.' The futility of all effort to maintain even the superficial appearance of cleanliness is generally recognized, but the attempt is not abandoned; and as water, however foul, has some detergent quality, its routine use is persisted in, supplemented, it is true, by a modicum of fresh water from the yard hydrants. That provision has not long ago been made for the exclusive and free use of hydrant water for all and every purpose on board ships at navy-yards, with crews on board, except flushing water-closets and heads, has been in flagrant disregard of elemental principles of hygienic rule and regulation. The supply of a sufficient quantity of clean water with proper facilities for use as baths and arrangements for scrubbing clothes and bedding are fundamental sanitary necessities at these times, as at all other; the amount having a direct bearing on the health of the personnel through its relation to personal cleanliness, and the quality in its relation as a medium for the introduction of disease-producing organisms.

"To what extent health and general physical efficiency suffer from the various causes referred to is not sufficiently appreciated. All know that at these times the sick list grows, that the wards of our general hospitals are chiefly recruited, and infectious and contagious diseases are most rife. But it is not understood as it should be, that none escapes some impairment of health at these times. At these periods, too, venereal exposure is greatest and alcoholic excesses most indulged in; as, there being little employment on board ship for the enlisted men, liberty is freely given, and with no resources for pastime and entertainment other than the city affords, the saloon and brothel become, more than usual, agencies in depleting health. It would be difficult, indeed, in my opinion, to exaggerate the adverse influences affecting physical efficiency throughout the fleet, not to mention the squalid discomfort incident to these visits, amounting to one-fourth of the year in the aggregate. No phase of the service within my experience or knowledge is fraught with so many influences harmful to health. The daily sick does not adequately show this, but represents only those temporarily or permanently disabled; and it is within bounds to say that for each man borne on the sick list as many as six report for treatment daily for ailments that do not require their admission to the sick list. The best index is the slackness and lack of smartness shown throughout the ship's company, and I believe executive officers will agree that a good deal of this spirit, or lack of spirit, attends and follows these visits to navy-yards. To what extent discipline suffers by reason of liquor smuggled on board by yard employees, and through other incidental agencies, is chiefly within the cognizance of commanding and executive officers.

"As a rule, ships leave the yards with disease infection that always threatens epidemic extension; cases of typhoid, erysipelas, scarlet fever, diphtheria, and the like are on board as constant morbid elements following these visits; and the assumption that they are other than the fruits of our own sanitary shortcomings is wholly untenable.

"The bearing of this matter on desertion also merits consideration, for there is no denying that influences that impair the sense of physical comfort and well-being are prejudicial to contentment, and it well may be that desertions, which are, I believe, most numerous at these times, are to some extent the result of these influences.

"If the case as here stated is substantially correct, as it is believed to be, then it becomes obvious that there is urgent need of reform in this matter.

"The necessity of maintaining the mechanism of the fleet in the highest state of efficiency through alteration and repair is evident, as shown by routine visits to navy yards where on an average three months of each year are spent; but it has not been officially recognized as yet that this routine under the present system entails incidently a very extensive impairment of efficiency in the fleet personnel. It should not be that, while the ships are undergoing betterment, the crews should be lapsing in physical and professional fitness and efficiency, as is certainly the case under the present system of keeping the crews on board. These periods spent at navy-yards are very properly times of respite and relaxation from the arduous and monotonous duties incident to service at sea; but they could, and well might, be made profitable in promoting physical well-being, contentment, and satisfaction with the service which at best proves too often to be essentially lacking in these elements for many enlisted men, as is shown by the large number of desertions.

"As the ships at these times pass into the hands of the yard personnel for all practical purposes, and serve the crews for housing only—housing of a kind devoid of all common comfort and conveniences that pertain ordinarily even to a ship—it would seem to be in the interests of the service to provide other quarters for the crews at such times.

"The opinion is therefore respectfully submitted that at each of the 'home yards' of the individual ships of the fleet home quarters should be provided for their crews; that is, barrack buildings possessing every essential of comfortable and sanitary construction, with ample grounds for drill exercises and athletic sports, and with such adjuncts as reading-room, gymnasium, canteen, etc., so that when vessels make their annual visits for repairs the men will be able to enjoy an agreeable change from the close and irksome environment of the ship (at these times, more than ever, felt to be such), and in this change find a feature of the service of added attraction and therein increased inducements to remain in the navy and the foundation for a permanent attachment to the service. It would, of course, be necessary to keep a detail on board at such times, but that is incidental. At New York and Boston it would be necessary to locate these home quarters elsewhere than in the yard on account of lack of room and suitable environment. But there should be no difficulty in this respect at Norfolk and Philadelphia, where there is probably ample room within the yard limits. At Boston the extensive lands belonging to the hospital might profitably be utilized for this purpose. This scheme would also enable the ship to be put through a thorough cleaning and sanitary renovation before reembarking the crew, whereby disease germs and vermin would be destroyed, and the ship as a habitation would enjoy the benefits of an annual 'house cleaning' such as common experience has proved to be so essential in the maintenance of health in habitations on shore, and which is not possible with the crew on board.

"It is hoped that this matter (which has been dealt with more or less fully in several former sanitary reports) will be regarded as worthy of consideration and investigation, as it is firmly believed the reform herein recommended would be of great practical benefit to the service."

Providing suitable barracks for the crews of all vessels that, while in commission, may be undergoing repairs at navy yards would entail the expenditure of very large sums of money, and it is, therefore, very doubtful whether at this time it may be regarded as within the domain of the practicable from a purely naval point of view, at least until the long recognized needs of the training stations in that respect have been supplied. Recruits at Norfolk are now living in tents, and a building formerly used for ordnance purposes has been converted into a mess hall with seating capacity for 600 men, but at times there are as many as

1,800 men or more, so that when the station is crowded meals must be served in three shifts. During the fiscal year ending June 30, 1908, the percentage of desertion, based on 55,956, the whole number of enlisted men in the naval service during the year, was 9, but less than the prior year.

CHAPTER V.

THE NAVY'S FOOD.

Beef, mutton, pork, poultry, fish, eggs, butter, cheese, milk, cornmeal, oatmeal, rice, wheat flour, beans, potatoes, onions, and tomatoes are examples of food materials used by man. They are food-stuffs as bought in the market, whether fresh, salted, canned, dried, or preserved in any way, and as eaten either cooked or uncooked. They are not food in its fundamental forms, but the essential food-stuffs or the materials *containing* food or the substances called nutrients or proximate principles which, as food, go to the growth or repair of the body or to the production of the body's energy.

This is a fundamental distinction of importance. A man buying a pound of fresh tomatoes is not buying a pound of food, but only a pound of food-stuff that contains an ounce of food, and in buying a pound of beef loin of good quality, a food-stuff that contains about 5 1/2 ounces of food. In the former case 15 ounces of the pound were water and in the latter about 8 1/2 ounces were water and about 2 ounces were refuse, chiefly bone. The same is true of eggs, the refuse being the shells.

A food-stuff, therefore, is made up of an edible portion and of refuse. The edible portion is composed of water and nutrients, and the refuse is the bone, shells, bran, and the like that are rejected as unsuitable for consumption or ingestion. Refuse should not be confounded with waste. Waste is edible and it is the part that is lost through carelessness or intention as in leaving the pulp of the potato with the skin in peeling, in dropping material on the deck while eating, or in leaving material on plates at table from lack of appetite or from excessive supply.

Water forms a varying percentage of food-stuffs, but man probably obtains from that source from 25 to 30 per cent. of all the water he ingests. It is not usually considered a nutrient any more than the oxygen of the air is. Coal is the fuel under a boiler, but while it will not burn without air and its burning or combustion would be useless or even destructive without water in the boiler, neither the air nor the water is classed with the coal as fuel. The fires go out unless there is a supply of air and the life ceases without breath. The boiler cracks and is worthless without water and the body loses its integrity unless the same fluid is circulated through its tubes and is intimately associated with and makes possible the metabolism of its parts. A man dies very quickly when deprived of air and more slowly when separated from a supply of water, but in either case very much more rapidly than when deprived of food. All are necessary for the continuance of his chemical changes or metabolism. Yet, the distinctions made between air, food, and water are understandable.

The general composition of a food-stuff may therefore be expressed by the following equation:

Food-stuff = refuse + edible portion = refuse + water + nutrients.

Each nutritive ingredient or nutrient is a food, but as food has two great functions—to build or repair the tissues and to yield energy—these nutrients have different functions or the same functions in different degrees.

The fuel in a ship's furnaces is utilized for one purpose only—to yield energy in the form of heat. The boilers and machinery are the means by which a percentage of the heat is converted into mechanical energy. The sole object is energy, and day after day the same fuel is used as being best adapted without variation to secure the desired result. But during all that time the boilers and machinery were deteriorating, the boilers in spite of the protection given by the water it holds and regulation of pressure, and the machinery in spite of the free use of oil on bearings. The plant has lost material and the material itself has also undergone deterioration in structure. It cannot protect itself from wear and tear, furnish itself with new material, or even supply from its fuel the lubricant necessary for its joints. Its fuel does not even contain the material of its structure, and the material of its structure cannot be used for its fuel.

Man is a living machine. He requires not only food or fuel from which to obtain heat and mechanical energy, but also food from which to obtain the material of his structure and the lubricants of his joints and bearings. He has to build as well as perform, and therefore has to consume different varieties of food, and not a single food having merely a single function. In fact, his food from a chemical point of view is much like the material of his own structure. It is so nearly so that one can speak of the different nutrients as proximate principles, inasmuch as they are proximate to, or have nearly the same composition as, the principles of the body itself. This is so true that the living machine can and often does use its own material as food when other material is not ingested or digested—its own fat in place of the fat on a steak or the oil from the olive used on a salad or the butter from milk; its own carbohydrates (glycogen) in place of the starch of the potato or of rice, or the sugar of the beat or of cane; and if one or the other of those substances is not available in sufficient quantity to give the energy required by the body, the material of its own tissues, the nitrogenous compounds of which all living matter is essentially made—the protein which as proteid in the form of the material protoplasm is found so largely in the muscle cells of meat or in the grains of peas and beans. So vast, even in this respect of food and fuel, is the difference between a machine of man's devising and the living machine!

The nutrients mentioned—protein, fats, and carbohydrates—are called *organic*. They are well within the realm of organic chemistry, and they are the products of the constructive processes of organized life. It is obvious, however, that from a consideration of the body as a whole, much inorganic material is utilized in its construction, in its digestive processes and in the chemical reactions of its fluids. Its bones are rich in inorganic salts such as calcium phosphate; its stomach secretions contain free hydrochloric acid derived primarily from chlorides ingested, and in general its tissues and fluids contain compounds of calcium, sodium, potassium, magnesium, and iron.

These mineral matters yield little or no energy and yet are indispensable. They form 5 or 6 per cent. of the body weight and are necessary to life either in a mechanical way to give the bones rigidity and the teeth hardness, or to give the fluids certain reactions or material necessary in the preservation of their state, solubility or diffusion through membranes. They are found more or less in all food-stuffs, but the demand of the body for common salt is so great that it is directly utilized as such, being used to give taste and flavor to many food-stuffs, and at the same time to make up deficiencies in the composition of food material. The body contains 6 or 7 ounces of common salt and is losing about 1/2 ounce daily, chiefly by the urine, but also by the skin and intestinal tract. It exists also in a state of combination with proteid bodies, as in the blood plasma; its presence is necessary for the solution of the globulins, it facilitates absorption by promoting endosmotic processes, and it increases tissue metabolism. The carbonates of sodium also occur in the blood plasma, where they are important in carrying CO_2 from tissues to the lungs for excretion. They are, however, derived chiefly as the result of chemical changes of vegetable acids. Iron forms an integral and essential constituent of hemoglobin. From many points of view, mineral matters form a very important part—an essential part—of food-stuffs. When a food-stuff or body material is burned, the mineral constituents are represented by ash.

It appears, then, that the equation of a food-stuff already given may be extended as follows:

Food-stuff = refuse + water + protein + fats + carbohydrates + mineral matters.

But it should be recognized that in the analyses of certain food-stuffs all these terms do not appear. For instance, a steak contains practically no carbohydrates, dried beans and peas and rice furnish no refuse, and refined sugar contains only carbohydrate.

The organic nutrients—protein, fats, and carbohydrates—are primarily divisible into nitrogenous and non-nitrogenous compounds. In the analysis of a food-stuff, the percentage of refuse is determined, and then the term protein is applied to all the organic nitrogenous compounds in the remainder, while its non-nitrogenous organic compounds are classed as fats or carbohydrates. The protein compounds will therefore include all the albuminoids, gelatinoids, and nitrogenous extractives. The term protein is therefore much more comprehensive than proteid, which may be considered to include only the albuminoids and gelatinoids. Thus in general:

Protein = proteid + extractives = albuminoids + gelatinoids + extractives.

But not one of those terms is applied exclusively to any one substance. Protein is applied to practically all the nitrogenous organic substances in a food-stuff or in the body; the term proteid to any animal or vegetable albuminoid or gelatinoid, and the term extractive to any of the animal or vegetable nitrogenous extractives. It is just here that there is marked confusion of terms in different texts, and it is also just here that lack of sharp chemical distinctions in the analysis of food-stuffs has led to the advocacy of certain materials as food materials which are unsuitable for more or less constant use by reason of their protein or fat or carbohydrates, including substances that are more or less harmful to man.

If the value of a substance as a food-stuff is to be determined in a laboratory simply by the amounts of protein, fats, or carbohydrates, it contains, then, the castor-oil bean, barring flavor, would be a suitable article for consumption as food; in fact, a valuable addition to man's dietary. The castor-oil bean or seed contains the highly poisonous toxalbumin *ricin* which under the definition of protein would be so classed in food analysis, and the seed is very rich in an oil that, so far as its chemical expression is concerned, as a fat in food analysis would give it a high fuel value as a food. This is taken as an extreme example of where the ordinary food analysis might lead. But it is nevertheless an exhibition of an important fact that the mere expression of the amount of protein, of fats, and of carbohydrates in a substance that can be ingested does not show its value as a food. And that being the case it may be successfully claimed that the relative value of some of the articles used by man as food cannot be determined from their relative amounts of protein or of fats or of carbohydrates. It would therefore appear that, certainly unless the chemical work be carried further and at the same time combined with experimental work, to determine the physiological action of some of the substances certain food-stuffs contain, man's own experience in the choice of food materials and the frequency of their use will continue to control.

There is an additional consideration of some value in this connection. Undoubtedly when, for instance, castor oil is ingested, *especially, perhaps, in small amounts*, some is absorbed and will be utilized by the body in the production or liberation of energy, as in the case of oils and fats. Yet, no one would consider castor oil as a food on that account, inasmuch as its physiological action as a cathartic is out of proportion to or overrides its value as a food. The fact that its flavor would itself be amply sufficient to exclude it does not affect the discussion, for even if it were agreeable in that respect no one would contend that it could be used as a common food material. Alcohol is also oxidized in small amounts by the body, but, as in the case of castor oil, it should not be considered on that account to be a food, as its physiological action is out of proportion to its nutritive value. They are both drugs, excellent drugs when properly applied to meet indications, and should undoubtedly be regarded as such. It is common knowledge that man consumes alcohol for its action as a drug, and while the argument made in favor of its temperate use as such may be as interesting as that in favor of its non-use, it appears to be outside of reason to advance its claim for general use on the score that it is a food because the normal body is able to and does obtain energy from limited amount ingested.

A food-stuff, therefore, in its proper sense must be a palatable mixture of foods as served and thus capable, when ingested, of being utilized in the quantities and with the frequency employed to maintain the body in an equilibrium of substance or to maintain it in a desirable condition of substance.

In a food analysis, outside of the question of adulterants, the object is to determine the percentages by weight of the nutritive ingredients or nutrients the edible part of the food-stuff contains, the nutrients being expressed as protein, fats, carbohydrates, and ash or mineral matter, and the water and refuse being called non-nutrients as well as the salt of salted meat and fish. But in actual work it has been common usage to consider the protein to include all the nitrogenous substances the food-stuff contains, the fats to be represented by the total ether extract, the mineral matter to be represented by the ash as produced by incineration, and the carbohydrates to be usually determinable by difference but recognized in vegetable food-stuffs to often include fiber or substances allied to carbohydrates but insoluble in dilute acid and alkali.

In estimating the protein, the total nitrogen is obtained and the protein is considered to be the product of the total nitrogen by the empirical factor 6.25. That factor is considered, as the result of long observation, to be evolved from the percentage of nitrogen in protein as a class. Concerning the constitution of many of these nitrogenous compounds very little seems to be known, as the proteids are neither crystalline nor volatile and the molecular formulæ of many may therefore be considered as not definitely determined, as they can not be converted into vapor and do not form well-defined compounds with other bodies. However, many of these nitrogenous products of animal and vegetable life seem to resemble each other very closely in percentage composition, and taking protein as representing the entire class it seems fair to consider, from many points of view, that in an ordinary mixed diet it averages 16 per cent. nitrogen. Sixteen per cent. of anything may be obtained by multiplying by 16/100 or dividing by 100/16 or 6.25, and, therefore, if the amount of total nitrogen is determined in a given weight of any food-stuff, the amount of protein corresponding would be ordinarily obtained with sufficient accuracy by multiplying that amount by 6.25. For instance, if a pound of porterhouse steak as purchased is found to contain 12.7 per cent. refuse, 52.4 per cent. water, and the total nitrogen in the edible portion is 3.056 per cent. of the total weight, then the available protein will be $3.056 \times 6.25 = 19.1$ per cent. of the steak.

Protein thus determined not only includes such proteids as the albuminoids, of which ovalbumin, serum albumin, vegetable albumin, globulin, fibrin, casein, legumin, gluten, and their derivatives, such as syntonin, albumose, peptone, and the so-called combined and compound proteids are examples, and such proteids as the gelatinoids, of which gelatin and chrondrin are examples, but also the non-proteids or nitrogenous animal and vegetable compounds of simpler constitution than the proteids, being cleavage products, such as the animal nitrogenous extractives, of which creatin, creatinin, xanthin, sarcine or hypoxanthin, adenin and carnine are examples, and the vegetable nitrogenous extractives, of which asparagin or its derivative, aspartic acid, are examples. It also evidently includes the alkaloids, which are compounds possessing much more interest in relation to food-stuffs than has been commonly accorded them.

The xanthin-alkaloids represented by theobromin and caffein are familiar, and also the pyridin-alkaloids, such as the piperin of pepper, and nicotin of tobacco, and solanin of potato, the last causing the tubers that during growth have been partially exposed above ground and old potatoes that are sprouting during storage to produce toxic symptoms at times. The potato contains normally a very small amount of solanin, but samples under the circumstances mentioned have been found to contain many times as much of the poison, as the result of the action of certain bacteria. It is found especially in the skin and shoots, and consequently much is removed in pealing. A large part of the remainder is lost in boiling. Yet, this normally valuable food-stuff has an alkaloidal association that is not declared in an ordinary food analysis and which, if sprouted potatoes are eaten, has been known to cause chills, fever, headache, vomiting, diarrhœa, colic, jaundice and great prostration. The stem and leaves of the potato plant are very poisonous.

A number of food-stuffs are closely associated with poisonous substances. The arrowroot used so frequently as a bland article of food for invalids, if made from the root of the cassava, has been carefully separated from a juice present in the root and very poisonous. Yet starch from that source is used as food by very many people in tropical countries. The term lupinosis or lathyrism is applied to a condition resulting from the use of meal made from the chick-pea. It is used in Italy, Algiers, and India, mixed with barley and wheat. When in proportion exceeding 1 to 12 it is very liable to cause a spastic paraplegia, with tremor, involving the legs, and this may proceed to complete paraplegia. The arms are rarely, if ever, affected. It appears to be a slow sclerosis said to be induced by the presence in the pea or grain of certain varieties of vetches, *Lathyrus sativus* and *Lathyrus cicera*, of an alkaloid more or less similar to lupinin found in the seeds of the *Lupinus luteus* and *Lupinus albus*.

The *Lathyrus* is a genus of leguminous plants agreeing in the structure of the flowers quite closely with *Pisum*, or the true pea, and its seed, rich in protein, would, from its chemical analysis as usually expressed, be regarded as a rich available source of protein. It is not clear that the peas and beans, commonly used as food, which also belong to the *Leguminosæ*, and are advanced above other vegetable foods on account of their very large store of protein, chiefly in the form of a proteid called legumin, are altogether free from an alkaloid that may limit their use as food materials. It is true that added to rice they form a staple food of large populations in India, and that in Mexico the cultivated bean of that country forms with certain classes an important food staple. Yet, in the Navy a bean-day that comes more frequently than twice a week does not excite favorable comment, and there are a large number of people who find digestive troubles to follow their frequent use, even when then not relied upon as the sole source of protein, but served as pork and beans or in other ways. There is often a tolerance established in the use of alkaloids, but as the bean is employed in this country it does not appear likely that it will take the place of animal food as the chief source of protein.

At any rate the method of analysis of food-stuffs must involve quantitive determinations of the amounts of each of the nitrogenous compounds classed as protein, and the ultimate conclusion of value must then be based upon a better knowledge of the qualities of such compounds in relation to the health and well-being of man before the dictum of the laboratory in regard to the value of a food material can be accepted in opposition to the accumulated experience of man so placed as to have opportunity of selection and thus of variety.

It sometimes seems that man's desire for variety is not always merely evolved from a relation of appetite to varying appreciation of flavor, but that the desire for change may be the expression at times of the constitutional effects of certain substances in different food materials, the variety thus having a protective influence. It will thus probably be found that where selection has been practicable, as is the rule with the people of progressive nations, the various standard food materials, the relative importance of which is declared by amounts used, and frequency of use, will be found to be great staples not only because they are palatable, and experience has shown that they furnish substances as required for the growth and repair of the body and the production of energy, but also because as served they are the ones that are commonly relatively free from those other substances found in many food materials that, less used, disturb the stomach or intestines and have other more or less toxic properties irrespective of mere questions of digestibility.

As applied to those staples, the crude division of nutrients into protein, fats, carbohydrates, and mineral matters may be regarded as least objectionable. And it is certainly from protein, fats, carbohydrates, and mineral matters that the body makes its material of structure and secures its energy. Its protoplasmic material or living cells can only be built up from certain of the nitrogenous compounds in food material—the albuminoids or simple proteids in contrast with the gelatinoids which characterize connective tissue. It therefore takes substances such as albumin, glutin, casein, myosin, and the like as food to make muscle or nerve cells, the animal basis of bone and other tissues. The body makes its gelatinoids from the albuminoids. The gelatinoids in food material cannot be utilized by the body for building purposes and the same is true of all the animal and vegetable extractives. It is therefore only a certain variety of protein—the albuminoids—that can be utilized by the body for the growth and repair of its living cells.

This maintenance of the body material furnishes the key to a general understanding of the functions of all the nutrients, for they are all intimately associated with the growth and repair of body substance, in spite of the fact that only the albuminoids can supply the nitrogen required for that purpose. The living machine must exhibit energy in the form of heat and internal and external work. When it ceases to liberate energy, that is to oxidize food, and thus, as in the combustion of fuel, to cause its potential energy to become kinetic, there is death. If it cannot get the energy from any other source it will oxidize or consume its own material for that purpose. Fats and carbohydrates are normally consumed by the body to furnish the required energy. They are completely oxidized into water and carbon dioxide—two waste products readily eliminated by the body. Therefore, the fats and carbohydrates, acting as fuel, not only by their oxidation furnish or liberate energy, but also, if in sufficient quantity, furnish all the energy required and thus protect the body substance from consumption for the purpose of making up any deficiency. *They are sparers of the body protein.*

In the body economy this is of such importance that provision is made in two directions in the way of self-protection during the absence of external sources of food. These are found in the storage of glycogen in the liver and of fat in the form of adipose tissue, and in the storage of a soluble and immediately available nitrogenous compound in the fluid that constantly bathes the body cells and which has been previously evolved by working over the albuminoids of the food-stuffs into the form required by the cells for conversion into protoplasm, each cell having those fundamental physiological properties of protoplasm known as receptivity and assimilation. The starving body gets its energy chiefly from its own fats and maintains its essential integrity from its stored nitrogenous compounds. An individual on a full fat and carbohydrate diet does not suffer from nitrogen starvation for a number of days, as his body has or should have a large reserve supply of nitrogen.

It is around this reserve supply of nitrogen that much of the recent controversy in regard to amount of nitrogenous food required in the daily diet seems to have been waged. A man having a small reserve supply may be considered to be on a low plane of nutrition, and one with a large reserve on a high plane of nutrition. The body seeks to maintain a reserve supply of nitrogenous food for its cells. Man by control of his nitrogen intake in connection with a sufficient fat and carbohydrate supply can keep the reserve supply small or large.

When one considers the manner in which interchanges through living membranes is accomplished, it may be assumed that a small reserve is maintained much more economically by the body from a relatively small nitrogen intake than a large reserve from a relatively large nitrogen intake. Osmotic force depends more upon the specific nature of the membrane than upon its porosity, and a larger percentage of a small nitrogen intake will be utilized by the body in keeping a reserve than of a large nitrogen intake. The body as a whole may be said to have a certain economical rate of metabolism for its efforts in all directions that is in a very crude way comparable to the expenditure of coal on a ship. It takes much more than double the coal consumed at 10 knots to drive a ship 20 knots. And under the pressure of the body's needs it will more economically utilize a relatively small supply, its primary digestive processes being more complete, its waste products less inhibitory or disturbing and its reserve fluids more capable of being enriched by the osmotic force of its own membranes. It therefore follows that a *mathematically* ideal daily ration is a mixture of food-stuffs in such amounts as to meet all requirements with the minimum expenditure of labor on the part of the organism.

Yet, considering a reserve supply of nitrogen as one of the requirements, the question of amount of nitrogen intake required becomes chiefly dependent in the long run upon the question of the amount of reserve required. Now, in this connection it is necessary to realize that when fats and carbohydrates are consumed or oxidized in the body the products are water and carbon dioxide. Such products may be roughly compared to the gases that from a furnace find a ready exit by the way of the smoke pipe. But, on the other hand, the nitrogenous compounds ingested by the body are never completely oxidized.

It has been argued by some that if the fats and carbohydrates are in amounts to furnish all the energy required, the living machine may be said to be embarrassed when it has also to use the nitrogenous compounds in that connection, and if those compounds are in excess of the amount required for the reserve supply of nitrogen or, as gelatinoids or extractives, are unsuitable for that purpose, the portion not utilizable for material of structure is regarded as if it were a foreign body and reduced to such compounds as urea and uric acid for elimination. Such substances can only be eliminated by the kidneys when in solution and thus make greater demands upon the body for water, increasing thirst. Their antecedents are substances which in their reduction to urea and uric acid not only increase the labor thrown upon the body, but are themselves, at least in some cases, toxic. The ultimate products may be roughly compared to the ashes that accumulate in the furnace and that impose the frequent labor of cleaning fires to prevent an undue interference with the essential process of oxidation or combustion.

But is it altogether reasonable to assume that the body has no use whatever for such intermediate products formed during the oxidation of the nitrogenous compounds commonly found in food-stuffs? While it is admitted that the nitrogenous waste products may readily be in excess and thus even or often cause such troubles as myalgia, megrim, rhinitis, or bronchitis, it can be as strongly asserted that the living machine has been constructed to utilize the material it uses as food and that just as its organs may be overburdened or its tissues adversely affected by nitrogenous waste products in excess they may also by relative disuse, or otherwise, suffer in structure and function.

A man who is receiving no food will even at the end of three weeks eliminate urea and uric acid, though, it is true, in relatively small amounts, and a man receiving only protein will oxidize it very readily, form little or no new tissue, and eliminate large quantities of urea and uric acid. For it is diet and not work that controls the total nitrogen output. If a man is to consume meat at all, the animal extractives, which are the substances in meat that greatly influence the uric acid output, are a necessary ingredient as they give the meat its flavor and thus stimulate the flow of the digestive fluids. They also have a stimulating effect upon the body after the manner of tea or coffee which also by virtue of their alkaloid, caffeine, increase the output of purin bases. In fact, the desire for meat depends greatly upon the presence of these extractives which furnish little or no energy and are incapable of forming tissue. Yet, while they are entirely incapable of supporting life, meat without them would be insipid and thus not available as an article of diet, and it is not by any means clear that life without them would be as useful, as progressive, as originative, or as agreeable. The argument against them applies with equal force to tea and coffee, while the argument in their favor is much stronger than that for tea or coffee. The disadvantages of all in excess are well known.

It does not seem at all probable that in relation to such an essential as food the living machine during all the long period of human life has been left without automatic control in general or has failed to acquire such control. Its breathing is automatic and commensurate and the same is true, as a rule, of its desire for water. The character of the waste products from a mixed diet is as fixed in relation to the kidneys as in relation to the lungs. The lungs have structure adapted to function which usually becomes impaired from insufficient use and *insufficient nourishment*. Their well-being is not maintained by limiting their usual work. The kidneys have structure adapted to function, and there is no conclusive evidence that their best interests are subserved by reducing their work to a minimum.

Blowing on wind instruments and glass blowing as well as occupations requiring excessive muscular strain and the lifting of excessive weights have been assigned as causes of emphysema, and it seems very likely that the kidneys may also be injured by certain kinds of excessive work. Alcohol has been held responsible for not a few cases of chronic parenchymatous nephritis, and it has always been assigned an important rôle in the production of chronic interstitial nephritis. It is true that in the latter case it is very often associated with the excessive use of protein food and that gout is thus often an expression of a strongly predisposing cause. Those who have had their lives hampered by anxiety or excessive mental strain often resort to stimulants and a relatively large protein consumption. The cause of chronic nephritis is, however, very often undiscoverable, but there is undoubtedly a large class of relatively inactive people who not only consume protein food greatly in excess of possible requirements, thus throwing much work on the kidneys, but also by their inactivity limit their consumption of water and therefore its renewal and its office in the body. On the other hand, tubercular disease of the lungs is an undoubted cause of not a few cases of chronic parenchymatous nephritis, and tuberculosis is most apt to appear in those living on a low plane of nutrition.

The question of minimum nitrogen reserve is also associated with the question of the condition of the body to withstand the attacks of an acute infectious disease, such as typhoid fever or pneumonia. There is a constant waste of body substance in such diseases due to the high temperature itself as well as to the toxic destruction or impairment of the body cells. It does not appear that the loss can be prevented by diet, though there is some evidence to show that there is a reduction secured by a relatively large purin-free protein intake in easily assimilable form in conjunction with soluble carbohydrates. Carbohydrates are normally the greatest proteid sparers, but it is a question whether by themselves they can greatly diminish loss of body nitrogen in these cases. However, it seems remarkable that knowledge of such an important subject is more or less indefinite and inconclusive.

If protein is advisable in such cases, and albumin water, which is free from the purin bases, is quite extensively employed for that purpose, the nitrogen reserve may be of very great importance. The fact that the convalescent begins at once to build new tissue and rapidly make good his losses is not sufficient if it should be shown that a fatal termination is more frequent among those having a low nitrogen reserve. But such a statement may not be made, as evidence is lacking. There is a belief that tuberculosis is more common among those living on a low plane of nutrition, and forced feeding forms an important part of the treatment.

That very many people eat too much is not a new doctrine, and that many of the unprovided eat too little is also a general belief. An excessive nitrogen intake may be considered to be as disadvantageous as one based on the mathematical basis of the smallest intake to balance the output—a nitrogen balance with the smallest reserve. Too much meat in early life paves the way to many of the ills of later life, and especially to that great enemy of longevity known as arteriosclerosis. An excessive meat diet causes an abnormally high arterial tension. This effect seems to have a close relationship to some of the animal extractives which meat contains as purin bases. These purin bases or precursors of uric acid are chiefly hypoxanthin, xanthin, and adenin.

Hypoxanthin is one of the products of muscular waste, and is therefore found in extract of meat, amounting to 0.6 per cent. When regularly ingested it will produce continuous high tension. In earlier life, this tendency is controlled by the secretion of the thyroid gland where activity is stimulated by the meat intake. In later life the undue activity of the gland is followed by more or less atrophy and diminution of power with consequent rise of arterial pressure. Excessive arterial tension mechanically interferes with the nutrition of the coats of the arteries, and this rise of pressure in later years thus shortens many lives. Carnine is also found in meat extract and much resembles xanthin and hypoxanthin or sarcine. Adenin is not only found in animal life, but also in tea, and caffein is a xanthin-alkaloid. The coffee bean contains 1.5 per cent. of caffeine and tea leaves from 2 to 4 per cent. The kolanut contains about 2 per cent.

It seems probable that nuclein, the proteid which is the chief constituent of the cell nuclei, and which is characterized by containing about 2 per cent. of phosphorus in actual organic combination, is an antecedent of the purin bases, the latter resulting as waste products of that part of the cell renewal or of its essential endogenous metabolism in that respect. The brain and nerves are especially rich in nuclein as well as in nitrogenous phosphorized fat called lecithin. The body thus by its own endogenous metabolism produces some purin bases that appear in the urine chiefly as uric acid, but most largely from the hypoxanthin as a waste product of muscular tissue.

But the larger part of man's uric acid output is derived from the purin bases in his food, hypoxanthin ingested increasing the uric acid in urine. This formation of uric acid is called exogenous, as it is not due to the breaking down, or does not result from the waste products, of the body cells. It is interesting to observe that while alcohol does not affect the amount of endogenous uric acid, it markedly increases the proportion of purin bases ingested that appear as uric acid in the urine.

However, of all the animal extractives, creatin is the one that is in largest amount in any extract of meat, such as beef tea or beef extract. An ordinary meat broth consists almost wholly of water, extractives, and salts, and while useful as a stimulant has little or no actual nutritive value as neither building tissue nor yielding energy. Creatin is neither an antecedent of uric acid nor of urea. When ingested it practically all appears in the urine as creatinin, but when creatin is absent from the food intake, the body still excretes small quantities of creatinin in the urine. Creatin and not urea is found in the muscles, and while the amount of urea in the urine is very markedly diminished on a protein-free diet, the amount of creatinin tends to change but little from day to day on any diet free from creatin. This has carried an expression of belief that creatin, as a constant product of endogenous metabolism, corresponds to the essential loss of body proteid.

This loss of body proteid seems to have little relation to work, and consequently while a man engaged in manual labor can more readily dispose of a larger protein intake, he does not appear to require more than during days of rest, provided he has sufficient fats and carbohydrates, inasmuch as the breaking down of his living cells does not depend upon work, but upon the cell itself as a living thing having its own life period. The body proteid is comparatively stable, each cell under normal conditions apparently requiring a relatively fixed amount of proteid to be metabolized for its own purposes during its life period, but this body proteid is itself a living mechanism for metabolizing or effecting chemical changes in all nutrients for the production of energy, such nutrients not becoming a part of the cells. The rate of this exogenous metabolism has relation to the energy requirement as determined by varying demand for heat production or work, but while cold or heat or humidity or work affect rate, there is a certain power or tendency of the cells to metabolize that belong to them as living mechanisms.

But adults indulging in greater muscular work grow as well as minors. The more greatly used muscle increases in size and hardness. The growth of new tissue requires a larger proteid intake than the preservation of old tissue. And greater muscular work is an expression of more mechanical energy and is invariably associated with an enormous increase in heat production. The lives of seafaring men are rarely so regular that they can utilize from day to day the same intake of protein, fats, and carbohydrates. There is also the inherent tendency of the living machine to provide for exigencies by keeping a reserve within the body, and more manual work is associated with a greater appetite for food. Besides, the manual laborer is not a student of metabolism but, on the other hand, is a follower of nature, and thus lays great stress upon the meal hour. He is not contented unless he has fully respected the appetite and the cry of the stomach to be more less distended. Contentment in the naval service in relation to food and water makes for good discipline, and contentment without work is impossible.

It is not as easy to overfeed a working man as an inactive one, mechanical work facilitating the utilization of food and the disposal of waste products by the body. Contentment facilitates voluntary enlistment and a service that supplied protein food in amounts to exactly meet the requirements of the body as evolved from the mathematics of nitrogenous equilibrium would not secure contentment. That is the basis of the daily amounts of food in the Navy ration, the amounts depending essentially not upon what it is thought men ought to eat, but upon what experience has demonstrated they desire to eat.

From the beginning man has taken the food he wanted from that available, his wants being limited by appetite. If his appetite has not been secured by artificial means, but is the natural dictate of an active life, it may be regarded as nature's method of automatic control in the long run. If in a normal working man the dictates of appetite control, there will be excesses from time to time, but the continuance of such excesses requires a forcing that will be lacking. Excessive ingestion of meat, under much exercise or work, even when induced by too highly flavored cooking, as is not the case in connection with a ship's crew, is followed by a reduced desire for meat, a jaded appetite that as a warning or automatic signal may be disregarded for a time by the non-worker whose stomach may be under the influence of preprandial stimulation. But what a man may do under the influence of a drug does not affect the question.

It is remarkable, to say the least, that if the body ought not to burn any protein for the production of energy but should utilize it solely for the growth and repair of tissue, while mechanical work does not increase proteid metabolism even in starvation when there is merely an increased consumption of fat, such work increases the appetite for all food, especially protein food. On the other hand, it is undoubtedly true that if the increased appetite for protein food be disregarded, and the increased demand be met by increased supply of fats and carbohydrates, the protein intake remaining the same as that determined to be the smallest amount necessary to secure a nitrogen balance—the total nitrogen in urine and feces to balance the total nitrogen in the food ingested—bodily vigor is maintained for months and even the total strength increased.

Sylvester Graham, in 1829, practically advocated such a diet, and his followers claimed the abolition of colds, headaches, rheumatism, and low spirits. Recently Chittenden, of Yale University, has demonstrated in a scientific way not only the feasibility of such a diet, but apparently its advisability. It is a question of the science of to-day, which admittedly has not investigated the subject in all essential directions, against the nature of man as declared by his habits in relation to one of his essential requirements. However, it is interesting to observe that Voit's dietary for a man at moderate work—118 grams of protein, 56 of fat, and 500 of carbohydrates—and his dietary for a man at hard work—145 grams of protein, 100 of fat, and 450 of carbohydrates—were fixed with the knowledge that nitrogenous equilibrium can be maintained on one-half or less, of the protein he advised. Certainly the ingestion of abundant protein quickly increases heat production on account of its high specific dynamic action, and in cold weather such an ingestion makes for greater comfort in reducing the sensation of chilliness. But for the same reason, a large protein intake makes for discomfort in warm weather or climate.

But the foregoing was undertaken to show in a form not too concise, the general functions of the nutrients and some of the questions involved in the choice of various food-stuffs to make a ration, food-stuffs varying in their chemical composition. It has been stated that the body readily burns all the organic nutrients for the production of energy and especially protein, but that it can make tissue or cell substance only from certain nitrogenous compounds. It has also appeared that, if the living machine secures its energy largely from protein, products are formed in excess which are themselves detrimental. It follows, therefore, that a normal diet must contain both the nitrogenous and the non-nitrogenous organic compounds. It also follows that at least much the larger part of the body's energy should be obtained from the non-nitrogenous compounds. That is also undoubtedly the natural preference of the living machine; and by such preference it not only secures energy much more economically, but also best protects its material of structure.

But it has been proven experimentally that the carbohydrates protect the body substances more readily than the fats and that they are more easily or economically utilized for fuel. It would therefore seem that the fats in a diet in combination with carbohydrates have relation very largely to the ability of the intestines to prepare and absorb the amounts required, an ability greatly increased by work or exercise. A certain amount of fat avoids digestive disturbances resulting from excessive carbohydrate ingestion, and a limitation of the fat intake is itself prescribed by a limited ability on the part of the alimentary canal to take care of it without distress. These seem to be at least the chief limitations and requirements in regard to amounts of each in relation to each other, but such a conclusion may not be regarded as final.

Now, the energy required by the body is commonly all expressed in terms of heat. That standard is convenient because most of the energy finally finds expression as heat, and the potential energy of food as of other fuel is more readily measured in that form, which, however, in accordance with the law of the conservation of energy can be readily expressed in terms of mechanical work. Heat and work are forms of energy. Energy is latent or potential in food and is developed or becomes kinetic as the food is consumed or oxidized in the body. In the furnace under the boilers of a ship the coal contains latent or potential energy which is developed or becomes kinetic during the combustion or oxidation. This kinetic energy is displayed as heat, very much of which is lost by way of smoke pipe, and in each movement of engine as heat transformed into mechanical work. If those two forms be regarded as the total, then the heat and mechanical work expressed in terms of heat exactly equal the latent energy of the fuel expended. It is the same way with the living machine, its heat and mechanical work or output of energy exactly equalling the latent energy of its food utilized or burned.

There are ways of measuring the energy latent in food as well as that in coal or wood, or any other material used as fuel. This is ordinarily done by employing an apparatus called the bomb calorimeter. This bomb is made of gun-steel lined with a thin sheet of platinum. Within the bomb is a platinum capsule to hold the food to be consumed. The bomb is mounted standing in water which is contained in a calorimeter cylinder that is made of indurated fiber covered with vulcanized rubber. This cylinder, to prevent loss of heat during the combustion of the food, is enclosed in another cylinder. The apparatus is closed with an elaborate cover through which two platinum wires proceed to the platinum capsule that the combustion may be started by electricity. Means are also provided in the cover for charging the bomb with oxygen and a thermometer passes into the water of the calorimeter cylinder to give information of the amount of heat evolved.

The amount of heat given off in the oxidation of a given quantity of any material is called its "heat of combustion" and is taken as a measure of its total latent or potential energy. This amount of heat is measured by the amount of water it can heat, and the unit used is the calorie which is the amount of heat required to raise the temperature of one kilogram of water 1° C. or what is nearly the same thing, one pound of water 4° F. The unit of mechanical energy is the foot-ton which represents the force required to raise one ton through a distance of one foot. One calorie may be considered to very nearly equal 1.54 foot-tons. That is to say, one calorie when completely transformed into mechanical power would suffice to lift one ton a distance of 1.54 feet.

The "heat of combustion" represents the total latent energy. The heat of combustion of food-stuffs ingested exceeds the energy derived from them by the body, for to assume an equality would imply complete absorption from the alimentary canal and ultimate complete oxidation after absorption, a complete utilization, an assumption manifestly untrue in the case of protein. It is essential to know what goes into the body to determine what the body does with it after it receives it. But such a determination involves very much additional investigation in which the respiration calorimeter or a specially and elaborately constructed chamber in which a man can live with comfort, has had an important place. A number of additional calorimetric determinations have also been made along independent lines involving calculations based chiefly upon the heat of combustion of urinary constituents and of feces in tracing the calories utilized by the body from protein ingested and made under the assumption that the utilizable fuel values of fat and carbohydrates are the same as those determined in the bomb calorimeter, the end products being the same—carbon dioxide and water. But only material digested and oxidized furnishes energy available to the body, and in a mixed diet there are amounts of fats and carbohydrates that escape oxidation.

Atwater made practical application of the principle of the conservation of energy in the body in measuring the actual value of food as fuel to the body, determining heat of combustion by the bomb calorimeter and utilizable fuel value by observation in respiration calorimeters. This involved a consideration of the chemical composition of the food materials in the average ordinary mixed diet, the proportions of the nutrients actually digested and oxidized in the body and the proportion of the whole latent energy of each which becomes active and useful to the body for warmth and work.

Taking our common food materials as they appear in an ordinary diet, he made the following general estimate of the energy furnished the body by one gram of each of the organic nutrients swallowed or ingested: Protein, 4 calories per gram; fats 8.9 calories per gram; carbohydrates, 4 calories per gram. Other figures slightly in excess of these have come into common use but in computing the utilizable fuel value of the Navy ration the results given have been accepted as expressing the energy available to the body on the average from each gram of the nutrients contained in the food-stuffs as swallowed. It thus appears that a pound or a gram of protein as derived from both animal and vegetable sources in the proportion in which they usually appear in a mixed diet has the same utilizable fuel value as a pound or a gram of carbohydrate (starch and sugar) as found mixed in such a diet, and that it requires about 2 1/4 pounds of either protein or carbohydrate to equal in utilizable fuel value a pound of fat as found in such a diet. This explains the body economy in storing fat as a reserve supply of fuel, fat being the most concentrated form of body fuel. Less proteid is burned in starvation when the body is fat, and while carbohydrates ingested diminish proteid metabolism more markedly than when fat is ingested, and the body does store some of its excess sugar as glycogen to be quickly available for that purpose, it uses its spaces more economically by converting the larger part of its sugar in excess of its requirement for energy into fat.

From this determination of the fuel value of each of the organic nutrients it follows that while each of the food-stuffs has its own utilizable fuel value, that value will be the sum of the utilizable fuel values of all the nutrients it contains. Its fuel value will therefore vary with its chemical composition, as shown in the amounts of protein, fat, and carbohydrate it contains. For instance, wheat flour contains 11.4 per cent. protein, 1 per cent. fat, and 75.1 per cent. carbohydrate. It is thus very largely a starch or carbohydrate food material. Five hundred grams of such flour will contain: $500 \times 0.114 = 57$ grams of protein; $500 \times 0.01 = 5$ grams of fat; $500 \times 0.751 = 375.5$ grams of carbohydrate. As each gram of protein has a utilizable fuel value of 4 calories, 57 grams will have a fuel value $= 57 \times 4 = 228$; as each gram of fat has a utilizable fuel value of 8.9 calories, 5 grams will have a fuel value $= 5 \times 8.9 = 44.5$ calories; and as each gram of carbohydrate has a utilizable fuel value of 4 calories, 375.5 grams will have a fuel value $= 375.5 \times 4 = 1{,}502$ calories. Therefore, the utilizable fuel value of 500 grams of wheat flour is $228 + 44.5 + 1{,}502 = 1774.5$ calories. On the other hand, butter is mostly fat and without carbohydrate, as is shown by the following chemical composition: Protein 1 per cent., fat 85 per cent. The fuel value of 500 grams is therefore 3,802.5 calories, the calculation being made as before.

It may be considered for practical purposes that, as a rule, carbohydrates are not found in the animal food-stuffs, milk and liver being prominent among the exceptions, the former containing 5 per cent. and the latter 2.5 per cent. Protein and fat are found chiefly in the animal food-stuffs and carbohydrates in the vegetable food stuffs. To the former are several notable exceptions: dried beans containing 22.5 per cent. protein, dried peas 24.6 per cent., and the olive 20 per cent. fat. A number of nuts are rich in both protein and fat. The almond has 21 per cent. protein and 54.9 fat, and the peanut (really a species of pea) 25.8 and 38.6 per cent., respectively. Walnuts, hickory-nuts, Brazil nuts, pecans, and peanuts have been put forward with beans and peas as most available general sources of protein, but such advice has been taken with much limitation probably because in satisfying amounts as staples they are apt to cause digestive disturbances too frequently. Peanuts as eaten contain 25.8 per cent. protein and a beef steak only about 19 per cent. In spite of the difference in cost, relatively few people attempt with any regularity to obtain their protein from the former or from other nuts, and the general conduct may be considered to depend upon causes not disclosed by the food analysis as ordinarily made. Habits in such essentials are very apt to include the habit of self-protection.

Refined sugar is 100 per cent. carbohydrate, and therefore 500 grams has an averaged utilizable fuel value in dietary calculations of 2,000 calories. Cane sugar ($C_{12}H_{22}O_{11}$) is a disaccharid and is converted in the intestinal tract by hydrolysis under the action of ferments into two molecules of the glucoses—dextrose and lævulose and galactose. Starch ($(C_6H_{10}O_5)_n$) has a more complex and stable molecule than sugar. It is insoluble in cold water and does not form crystals, but has an organized structure. It is an invariable constituent of all plants or vegetables used as food. Ptyalin and diastase convert it into maltose and dextrose and it is ultimately utilized by the body in the same manner as cane sugar, but after more changes and often more labor or work in primary digestion from a purely chemical point of view. This increased labor is, however, not utilized by vegetarians as an argument against its regular use and in favor of sugar. In fact, the intestinal tract is more able to regularly dispose of the granulose of the starch grain without distress than of an amount of cane sugar having the same fuel value. The starch granules are composed externally of starch cellulose and internally of granulose. When starch is heated with water the cell walls of cellulose burst and the granulose appears as a viscous liquid becoming a jelly on cooling and a gummy mass when dried.

Unless this change as a result of cooking is thoroughly effected, starch is often quite difficult of digestion, as thus the granulose freed from its capsule of indigestible cellulose becomes not only available for the action of digestive ferments, but also by increased solubility more suitable. Yet man can obtain energy more quickly from sugar than from starch, and this can be utilized to meet emergency requirement for energy. This increased capacity for doing mechanical work under the influence of sugar begins to be apparent in less than an hour after ingestion. The result cannot be considered to be due to alcoholic fermentation.

Alcohol is usually made by the fermentation of glucose or grape sugar through the action of yeast. When yeast acts upon cane sugar the first change is the production of glucose, $C_{12}H_{22}O_{11} + H_2O = 2C_6H_{12}O_6$. The glucose is then converted into alcohol and carbon dioxide, $C_6H_{12}O_6 = 2C_2H_6O + 2CO_2$. But after the ingestion of cane sugar the effect on the body in relation to energy differs in at least one important essential from that resulting from the ingestion of alcohol. Within 40 minutes after the ingestion of alcohol there is a decrease in power that becomes apparent as a depression lasting perhaps two hours which shows that alcohol is disadvantageous when a sustained increase in work is desired. No such depression occurs after the ingestion of sugar. It furnishes power for mechanical work by quickly supplying material readily and normally utilized by the muscle cells, thus as available food for the production of energy greatly increasing their ability to contract.

All starch and sugar digested are absorbed from the intestines as sugar in some form and utilized by the body as sugar in some form or stored as glycogen and fat. That stored as glycogen or animal starch is ultimately utilized as sugar. Mechanical energy is secured by the body more economically from the carbohydrates ingested than from other foods. A much larger quantity of work can be done on a pound of rice than on a pound of beef, and when the carbohydrates cannot be fully utilized, as in diabetes, capacity for work is very greatly reduced.

It has not been shown that fat is converted largely into sugar before it is available for mechanical work, but it appears that proteid when utilized for energy is split into a nitrogenous molecule and a non-nitrogenous molecule that may be either a fat or a sugar. Protein can thus be the sole source of energy. The non-nitrogenous molecule seems to be chiefly sugar, and the carbohydrates thus formed may be as much as 50 per cent. or more of the proteid metabolized and may be stored as glycogen or fat if in excess. This power of the body to store carbohydrates as glycogen or by conversion into fat is a marked characteristic, as the living machine thus exhibits a remarkable adjustment in obtaining energy from that source, available carbohydrate not in itself increasing heat production, the utilizing being apparently almost strictly in accordance with needs. This is in marked contrast with a protein intake and even with a fat intake, though in much less degree.

Man does not live on all the food ingested, but only on that which is digested or metabolized. Metabolism is a term applied, as a rule, to the collective chemical changes in living matter. These changes begin in the alimentary canal and are completed in the formation of the end-products that leave the body, carbon dioxide, water, urea, uric acid, and creatinin being examples. It is usual to regard all that part of the food-stuffs which leaves the alimentary canal, to be utilized by the body, as the part metabolized. For instance, in a mixed diet containing 118 grams of protein, 56 of fat, and 500 of carbohydrates the body utilizes as an average about 108.58 grams of the protein, or 92 per cent., 53.2 grams of fat, or 95 per cent., and 485 grams of carbohydrates, or 97 per cent.

Those amounts are said to be metabolized and the percentages are called the *coefficients of digestibility*. Therefore, given the amounts of each food-stuff swallowed, their chemical analyses are utilized to calculate the total amounts of protein, of fats, and of carbohydrates they contain, and the coefficient of digestibility of each nutrient is applied to determine the amount of each metabolized. If the amount of each metabolized is known, the amount of nitrogen metabolized is their total contained nitrogen, and the amount of carbon is the total contained carbon. Thus, in the dietary given, if the protein be assumed to contain 16 per cent. of nitrogen and 54 per cent. of carbon, the fats 76.5 per cent. carbon and the carbohydrates 43.44 per cent. carbon, the amount of nitrogen metabolized will be 17.37 grams (most of which will appear as the total nitrogen of urine), and of carbon 310 grams (much of which will appear as carbon in the CO_2 excreted by the lungs, but some in the compounds not the product of complete oxidation as in the urea and uric acid excreted by the kidneys). Of course, if the body is gaining weight the formation of total end-products will be delayed, and if losing weight the end-products will be in excess. It is when there is neither gain nor loss that the body is in equilibrium.

The coefficients of digestibility as given can be applied with any approach to accuracy only when an ordinary mixed diet is under consideration. When the protein is obtained in greater degree from vegetable sources its coefficient of digestibility is lower, for vegetable protein is not in as digestible form as animal protein, and the same is true, as a rule, of the vegetable fats as they are generally available. A vegetable diet thus ordinarily requires more work with less result in primary digestion.

In the cereals only 85 per cent. of the protein and 90 per cent. of the fat are digested, while in vegetables and fruits only 80 per cent. of the protein, 90 of the fat, and 95 of the carbohydrates are absorbed on the average from the alimentary canal. Besides, in view of the relatively small amount of protein in many vegetable food-stuffs, it seems evident that digestive disturbances are not unlikely to appear in a haphazard attempt to obtain the necessary amount from that source. The requisite amount may be so obtained, but such a course increases the work of the alimentary canal and requires not a little knowledge of chemical composition upon which to base selection. Under ordinary methods of life abnormal fermentative changes might be expected to be more common unless there was a more careful supervision than is usual under an ordinary mixed diet.

The nutrients in animal food-stuffs are more nearly like the compounds making up our own bodies and require less change before assimilation. It is a question of the capacity of man to conveniently work over the material he receives as food, for the horse and the ox are familiar examples of an enormous growth of muscular tissue on a vegetable diet, and admittedly man should avail himself of vegetable sources for a very large part of his energy.

The metabolism that concerns the structure of the cells of the body is endogenous. All such metabolism is nitrogenous. The growth of a cell is limited by a continuous breaking down of its own material. The metabolism concerned in renewing its material or in building new cells is anabolic or constructive, while the chemical changes leading to the formation of waste products from the breaking down of the cell structure are katabolic or destructive. The one is anabolism and the other endogenous katabolism. The metabolism incident to the utilization of food for the production of energy is exogenous and being destructive is katabolic. As protein, as well as fats and carbohydrates, can be so utilized, this exogenous metabolism may be either nitrogenous or non-nitrogenous. Thus anabolism and katabolism together constitute metabolism which is divisible into endogenous metabolism and exogenous metabolism. Anabolism is always endogenous and nitrogenous. Katabolism, as it relates to cell structure, is also always endogenous and nitrogenous, but as it relates to the production of energy, is always exogenous and is both nitrogenous and non-nitrogenous.

There is a nitrogen balance when the total nitrogen in the food-stuffs ingested equals the total nitrogen in the material cast off by the body, the nitrogen intake balancing the nitrogen output. In making the calculation the urine and fæces are together usually considered to contain all the nitrogen output. The body is unable to free nitrogen and consequently no free nitrogen leaving the body, as in respiration, has been derived from the body, but entirely from the atmosphere. It is also unable to fix nitrogen, and consequently none of the nitrogen in its structure or waste products has been derived from any other source than the nitrogenous compounds ingested.

It is evident, however, that the urine and fæces do not contain quite all the nitrogen output; however, the nitrogen leaving the body from day to day through loss of hair, shedding of epidermis, cutting of nails, and by the perspiration is usually regarded as negligible. The daily growth of hair contains 0.03 gram of nitrogen and of the nails 0.0007 gram. The amount of nitrogen in the perspiration varies with work from 0.07 to 1.8 per day, but may be considered to average 0.5 gram in moderate work. The epidermal waste does not seem to have been definitely determined and the loss by the genital organs has usually been neglected. The average total loss from all these sources is probably not less than three grams of proteid metabolized daily, and therefore in such close calculations as have been made of late to determine the *smallest* nitrogen intake to balance the nitrogen output the additional sources of loss designated may not be considered as entirely negligible.

It is obvious that if the condition of the body practically remains the same from day to day, there will practically always be a nitrogen balance, however large the nitrogen intake, for, if the body is not adding or losing material of structure and is keeping the same nitrogen reserve, any additional nitrogen in the intake, however large it may be, must appear in the output. The fact, then, that men do metabolize large quantities of protein with a balance between nitrogen intake and output is of little value in deciding their requirements. The fact that the bicycle racers, reported by Atwater, consumed 182 grams of protein daily does not declare that they required that amount, but only that having ingested that amount the body was able to convert it into such compounds as were necessary for ridding the organism of the excess as waste products. Therefore, a true nitrogenous equilibrium cannot be considered to be declared by a nitrogen balance unless the balance is maintained under the *smallest* nitrogen intake

It is along that line that Chittenden made his investigations and he found that with uncontrolled appetite for fats and carbohydrates there was nitrogenous equilibrium on little more than one-half of Voit's dietary containing 118 grams of protein. There was of course under such a small nitrogen intake a marked reduction in total nitrogen in the urine when compared with that usually found when man's appetite for meat is also uncontrolled. To this reduction of waste products as representing a reduction of undesirable nitrogenous compounds in the fluids of the body he attributed the greater sense of well-being exhibited and the very large increase in total strength secured.

From these results he deduced the conclusion that man not only has no need for the larger protein intake prescribed in the so-called standard dietaries of which Voit's is an example, but also derives injury from it, that the smallest nitrogen intake required to maintain a nitrogen balance in an adult meets all the requirements of the body for nitrogen, imposes the least burden, and is in accordance with the best interests of man. He also claims that a man, when work is mainly mental, has no real need for high fuel value in his daily ration, that for such a man a high potential energy in the daily intake of food is an incubus, not a gain, that the body equilibrium can be maintained on far less than 3,000 calories per day by the brain worker, that even a man called upon to perform considerable physical work has no apparent need for a fuel value in his food of 3,000 calories per day. It is obvious that a man who works at hard labor will require a larger intake of fats and carbohydrates than is represented by 3,000 calories, but he contends that this is not true of the moderate worker nor of the average man whose work is in large measure mental rather than physical. His contention therefore is that the total consumption of food by the average individual, non-nitrogenous as well as nitrogenous, is considerably greater than the real needs of the body demand, but that this contention has its greatest force in relation to the nitrogenous material of food-stuffs.

It cannot be granted, however, that an increased exhibition of strength and a feeling of elation are more than *prima facie* evidence of improvement in diet, even when long-continued. The factors that make for longevity and the perpetuation of a well-developed race are many and are not well understood. A man in the highest state of physical training exhibits increased strength and endurance and has an increased sense of well-being, but no man undertakes to keep in full training indefinitely. Nature does not seem to contemplate a continuous maximum efficiency, but imposes penalties upon such attempts. Everywhere there is provision for waste, and that is nowhere more in evidence than in the provision for reproduction of kind.

It is not man's nature to live on the smallest amount of food, and it has not been proven that his nature in that respect is not an assurance that mankind will continue to live efficiently in the largest sense. It is true that man pays penalties for natural excesses, but he also pays penalties for unnatural economies. Temperance is a recognized virtue, and the man who eats too much is as much an object of commiseration as the man who eats too little. The differentiation of labor has undoubtedly varied somewhat the requirements of men, and there is a recognized tendency in very many walks of life to eat meat in excess. That tendency is considered to be apparent in the wardroom and certain other parts of ships, and should be discouraged, but one should also discourage those who in keeping away from meat overload the alimentary canal with such vegetable foods as leave large indigestible residues. The work of Chittenden emphasizes the value of temperance, but it is a moderation that cannot be imposed generally upon men even in naval life, as such a course would be distinctly in opposition to a naval policy that necessarily involves the encouragement of enlistments and the discouragement of desertions.

An average fasting man will obtain about 13 per cent. of his total energy from proteid and 87 per cent. from fat. It appears that if such a man does light work he will metabolize sufficient material to furnish about 32 calories for each kilogram of his weight. He will then obtain 4.16 calories per kilogram from his own proteid and 27.84 from his own fat. It would seem that not only should at least that amount of energy be supplied him from his food, but also some additional calories, as it appears from experimentation that to *maintain* an equilibrium an ordinary diet should furnish on the average about 12.75 per cent. more calories than furnished by the material burned during starvation.

This apparently indicates that on a mixed diet the intake should, in light mechanical work, have a utilizable fuel value of about 36.18 calories per kilogram of body weight. In other words, a man in average condition, weighing 70 kilograms, or about 154 pounds, and doing light work should at least receive a daily mixed diet having a utilizable fuel value of $70 \times 36.18 = 2,532$ calories. Such a diet would be calculated as suitable for the man whose work is chiefly mental, the mechanical energy being represented chiefly by exercise. If of this amount 13 per cent. is derived from protein ingested, about 329 calories would be from that source and 2,203 from fats and carbohydrates. As one gram of protein ingested furnishes 4 calories to the body, 329 calories would be derived from about 82 grams of protein, and the 2,203 from 550 grams of carbohydrates, some of which would be replaced by fats to facilitate intestinal digestion and to accord with appetite. This also makes no allowance for personal idiosyncrasy, on account of which conclusions drawn from weight alone are only rough approximations. There are also losses of body structure incident to loss of sleep, irregularities of life, worries as result of unusual responsibilities, and a number of conditions not unusual in life.

In mechanical work there is an enormous increase in heat production of which about 25 per cent. is utilizable as mechanical energy, the percentage varying, however, with kind of work and training of individual in doing the particular work. The required protein intake will also have relation to training and habit of work, as in the case of recruits.

It seems to have been fairly well established that work has little direct relation to amount of protein intake required. But it is admitted that growth has, and in relation to a navy ration it should be recognized that there are many *minors* in the naval service. There is also a growth not incident to age, but the result of work—the growth of muscular tissue incident to mechanical work. A man who is increasing his muscular tissue requires additional material for that purpose. It would also seem to be evident that a man having a well-developed muscular system has more muscle cells than a man of poor development, and consequently requires more protein food to maintain the integrity of a larger number of cells. A man who is already physically up to the work required of him probably does not require more protein on a work day than on a rest day, but if he is growing or making new tissues he requires relatively more than when he is trained up to his work. It is common to furnish a hard-working man with a larger protein intake than one usually employed in light work.

It also appears that what might be calculated as an excessive protein intake in mechanical work is not as capable of causing the damage the same intake, if continued, would be liable to cause in the moderate worker or the physically inert individual. That is the common experience, and would seem to indicate that the greatly increased process of oxidation in the former case and the more rapid circulation of body fluids with increased power of the glands to exert their function vary chemical changes in the transition of protein compounds within the body, though perhaps not greatly varying end-products, and at the same time facilitate excretion. There are men who perform too much mechanical work, especially at times, and the number may be much larger than is commonly supposed, but on the other hand there are a very large number who suffer even more from lack of proper mechanical work or exercise than from excessive food intake, although the latter often accentuates. The right kind of sleep that follows the right kind of work is more potent for good than excessive food is potent for evil. Work the feeder systematically and many of his ills will disappear, but if he does not work a smaller food intake is very advisable.

Assuming that a fuel value of 2,600 calories is sufficient for the average man with light work, the requirement for increased calories will depend upon the increase in amount of work he performs. It is estimated that the external mechanical energy of a man doing light work is about 150 foot-tons and that 300 to 350 foot-tons is a good day's work, 400 to 500 foot-tons is hard work, and 500 to 600 foot-tons is very hard work. If a calorie is equivalent to 1.54 foot-tons, 100 foot-tons will be equivalent to about 65 calories, and if man can utilize about 25 per cent. of his increased heat production as mechanical work he would require 260 additional calories for about each additional 100 foot-tons. If, then, an average man doing light work requires 2,600 calories, he would require from 3,000 to 3,150 for an average or good day's work, for hard work about 3,400 or 3,500, and for very hard work at least 3,800 and probably more.

Many different methods have been advanced for determining the calories required based upon experimental data of various kinds, but any result by any method is only a rough approximation, and the general conclusion is now in the direction of belief in a more economical body in the utilization of energy than has been supposed. A mere foot-ton measurement of work is also often very misleading, as character of work and rapidity or speed are often most important factors in the body economy. The fuel values given are advanced merely to give a fair general idea of the calories ordinarily considered to be sufficient, although Atwater gives 5,500 for very hard work and his estimates generally are above those of others. Theoretically, the question is, first, the resting requirement, and then the addition of sufficient calories to do the work, but as a machine the body has its economical limits, and in very hard or exhausting work there are losses difficult to estimate on a mechanical basis and having relation not merely to energy, but also to construction or repair processes and renewal of reserve supplies.

Men have been known to metabolize for periods of several days food furnishing more than 9,000 calories daily, but there are relatively few men whose total energy, internal and external, can be advantageously made from day to day to exceed, on a working basis of very hard continuous labor, 7,000 foot-tons or 4,545 calories when under any ordinary environment. It is estimated that the average fireman or coal passer metabolizes 5,174 calories at sea, and that the deck force ordinarily consumes food having a utilizable fuel value of 4,256 calories. It is admitted that an environment of very high temperature itself increases body metabolism even without relation to work, but it is at least doubtful whether the service as a whole is not receiving more food than it ordinarily can utilize to advantage, a fuel value in excess of requirements being an incubus and not a gain.

Assuming that an average laboring man weighing 150 pounds and doing an average day's work requires 3,150 calories and that, all things considered, 13 per cent. should be represented by protein food, his protein intake should have a utilizable fuel value of about 410 calories and, therefore, be 102.5 grams. This does not mean that he *could not* do his work very well on less, but that as a living machine seeking a degree of comfort in life in cold as well as warm weather and desirous of maintaining his initiative, he would not *willingly* continue his work on *less*. As the total calories are 3,150, 2,740 or 87 per cent. would be derived from fats and carbohydrates. The ration would therefore be 102.5 grams of protein and 685 grams of carbohydrates, expressing the fat in terms of carbohydrates. The *nutritive ratio* of such a ration would therefore be about 1 : 7 and the relation of nitrogen to carbon in the food ingested 1 : 21.5 and in the food metabolized 1 : 22.5, the amounts of nitrogen and carbon ingested being 16.4 and 353 grams, respectively, and the amounts in the food metabolized being 15 and 340 grams.

So far as the body economy apart from primary digestion is concerned, half the calories may be given in fat and half in carbohydrates. Experience appears to indicate that the average adult alimentary canal cannot readily digest more than 500 grams of the carbohydrates as they appear in the ordinary mixed diet of a working man, and that, in the progress of nations, as a class passes into easy circumstances the tendency to increased protein consumption and to replace carbohydrates with fat increases. If 500 grams be regarded as the usual maximum allowance of carbohydrates, then 185 grams of the 685 grams of carbohydrates previously estimated would have to be replaced by an equivalent amount of fats. The 185 grams have a utilizable fuel value of 740 calories, an amount furnished by 83.1 grams of fat. Therefore the diet as completed would be 102 grams of protein, 83 of fat, and 500 of carbohydrates. Voit's dietary, which is usually accepted as a standard for a man doing a good day's work, is 118 grams of protein, 56 of fat, and 500 of carbohydrates, a utilizable fuel value of 2,965 calories and nutritive ratio 1 : 5.5.

But there is very good reason to believe that, if 2,740 calories in fats and carbohydrates be furnished a laborer doing the ordinary day's work, a nitrogen balance will be maintained on even much less than 102 grams of protein. It is said that the German soldier enjoys good health and does his drills in garrison on 98 grams of protein. The American farmer has about 97 with 130 grams of fat and 467 of carbohydrates, the fuel value being 3,415 and the nutritive ratio 1 : 8.2. The mechanic in the United States has about 103 grams of protein, 150 of fat, and 402 of carbohydrates, but if his circumstances permit, tends to ingest 120 grams of protein. The professional man in the United States takes about 104 grams of protein, 125 of fat, and 423 of carbohydrates, a fuel value of 3,220 and nutritive ratio 1 : 7, thus declaring the tendency to excessive food intake. Rowing clubs in New England were found by Atwater to consume 155 grams of protein in a ration having 3,955 calories, and lumbermen in Maine in very active work were found to consume 164 *grams* in a ration of 8,000 *calories*. The usual Navy ration is 142 grams of protein, 192 of fat, and 492 of carbohydrates, a fuel value of 4,256 and a nutritive ratio of 1 : 6.7.

The "nutritive ratio" is the ratio in any diet between the amount of *digestible* protein on one hand and the amount of digestible fats and carbohydrates on the other, a gram of fat being considered equivalent to 2 1/4 grams of carbohydrates and the fats being expressed in terms of carbohydrates. For instance, taking Voit's standard dietary, 118 grams of protein, 56 of fat and 500 of carbohydrates, and applying the coefficients of digestibility, the digestible protein is $118 \times .92 = 108.56$ grams; the fats $56 \times .95 = 53.20$; and the carbohydrates $500 \times .97 = 485$. Allowing the fats to count as carbohydrates by multiplying their amounts by 2 1/4, the equivalent is $53.20 \times 2.25 = 119.7$. Then $119.7 + 485 = 604.7$ = total carbohydrates. As the digestible protein is 108.56 grams and the total carbohydrates 604.7, the nutritive ratio is 108.56 : 604.7 or 1 : 5.5. It is usually considered that in a well-balanced ration this ratio should not be below 5 or above 7, in other words the nitrogenous food should be at least in sufficient quantity to make a ratio with the non-nitrogenous organic compounds of 1 : 7, and at the same time the ration should furnish the required number of calories. When the ratio is below 1 : 5 it is narrow, and when above 1 : 7 it is wide. As the ratio widens a greater percentage of the energy is derived from fats and carbohydrates, and the tendency of late has been toward a wider ratio. Among fruitarians the ratio is 1 : 10.

To *determine* or *find the value* of a ration in terms of protein, fats, and carbohydrates is an analytical process, while to *construct* a ration is a synthetical process and consequently one of much more difficulty, involving judgment and a large measure of knowledge in many directions. The one is destructive or critical and the other constructive. The bases of such work have been declared in the foregoing, and as in a naval service the consideration of the ration is of much importance and to arrange a proper dietary is of much practical value, it is advisable at this time to give some attention to the methods involved.

To construct a navy ration it is first necessary to prepare a list of all the articles or food-stuffs *available* to form a part of it. Availability depends upon a number of factors, including *sources of supply* and *cost*, for in arranging a ration for a group of individuals there is invariably a limit prescribed by the funds that can be set apart for that purpose. In our Navy the maximum limit is practically set at 30 cents per day per man in the markets of the United States. The cost price thus becomes the first practical factor in availability and is a known quantity that in the primary work is assumed to be a fixed maximum and only susceptible of change by legal act under demonstrations of insufficiency in relation to other essentials.

The sources of supply have to be considered in relation to the condition of naval life. For instance, for people who live on a cruising ship it would be idle to endeavor to obtain animal protein solely from fresh meat, for fresh meat cannot be regarded as always obtainable and must be regarded as often not obtainable. It is, however, just as important to realize that it is often obtainable and that its availability is increased by cold storage. On the other hand, salt, preserved, and smoked meats can be stored on board and carried for long periods and thus may be regarded as practically always available. The same reasoning is applicable to fresh bread as such, while hard tack and flour are in the class that is always available as a source of carbohydrates and of a certain percentage of vegetable protein. The same is also true of fresh vegetables in contrast with canned vegetables, dried beans and peas, rice, and macaroni. There is thus at once evolved a division in the list of available articles selected to form the ration, some being always available and others being available at times. This is a fundamental division in a navy ration as it is the basis of the division of the ration itself into a *sea ration* composed of articles always available, and *the ration of fresh provisions* composed in the main of articles commonly available in port.

This division of availability has relation to *keeping qualities*, *methods of packing*, and *questions of storage*, the general question of availability having relation to *nutritive qualities* and *acceptability;* while the combination of articles to form an *issue table* of each day's ration has a close regard for *variety*, and the inclusion of a sufficient quantity of each food-stuff to give the required *bulk and to furnish as a whole the requisite amount of each of the nutrients.* There are, then, practically two navy rations—a sea ration and a ration of fresh provisions—in both of which there must be each day and from day to day *acceptability*, *variety* and *bulk*, and the *requisite amount of each nutrient*, the whole not to exceed a fixed limit in cost per day.

A knowledge of acceptability depends upon a knowledge of the inclinations of the class for which the ration is intended. No man should attempt to construct a ration without knowledge of the likes and dislikes of the class as a whole for which the ration is devised. The construction of a navy ration is a naval duty, as it involves a knowledge of naval life, and it is not a duty solely of the medical officer, inasmuch as it involves a number of questions having also important non-medical relations, such as storage, packing, facilities for cooking and handling, and acceptability of particular articles as evolved from observation of amounts issued in relation to amounts consumed.

As an example of the last, a ration may be well balanced in amounts of nutrients and to a student of nutrition may seem to be without objection, but the experience of a pay officer or commissary may show that one or more articles, such, for instance, as macaroni, is in excess in each authorized issue of that article, inasmuch as a considerable percentage of the amount is never desired or consumed. In other words, the article has been included in amounts *beyond its acceptability* and the nutrients in the percentage not consumed should be provided for by an increase in the issue of another article or of other articles, then included in the ration in amounts *below acceptability*. A ration should not only be well balanced in amounts of nutrients, but also in amounts of food-stuffs in relation to the desires of the individuals. A man can be kept in nitrogenous and calorific equilibrium on 1,500 grams of good bread daily, but a man practically cannot live on bread alone.

There is thus declared an important relation to *waste*, a consideration in connection with a ration that is far from being a purely medical one. A ration must be constructed primarily for *issue*, a *certain amount* of each article in the day's ration must leave the storeroom or be accounted for as underissued or overissued. That is an essential practical basis of any ration, the amounts *issued* and not the amounts *consumed*, the food available appearing on the tables and the food consumed being that which is actually swallowed. It is evident that there is waste not only in the preparation of food, but also at the tables. The waste is partly avoidable and partly unavoidable, but a ration cannot be figured on the mathematical basis of unavoidable waste, as such a course would place the majority who do not prepare food at the mercy of those who do.

Besides a considerable percentage of waste that is mathematically avoidable is practically unavoidable when time and place and individuals are considered. All will agree that the waste on our ships, as among Americans generally, is remarkably large. Anyone who has even gone so far as to watch the peeling of potatoes on our ships or who has watched the bread floating by after a meal is aware that waste is a large and practical question in naval life. Yet a ration must be calculated as issued, and the man who eats all his bread must not suffer because another man eats only a part of his, and the men must have a sufficient amount of potatoes even if messmen habitually are hurried or careless in depriving the tubers of their skins.

The point is that there is a large waste of food, as there always has been in naval life, and that if the ration is calculated on the basis of no loss from storeroom to ingestion and of a mathematical division at tables, it will be insufficient, and each day there will be men at the mast complaining because they are not satisfied, a condition subversive of discipline and an influence against which no purely theoretical ration could last. No man in practical life should ever study a question to the point of losing sight of its practical side. A number of independent investigations into the amounts of protein, fats, and carbohydrates actually consumed by various messes of the different classes on a ship is much desired, but in the absence of such investigations it is advisable, all things considered, to calculate the amounts *consumed* as about 75 per cent. of the amount as *issued*.

In connection with variety and waste there is a very important feature, known as elasticity, that should be secured in the construction of every ration. *The lack of elasticity or of automatic adaptability or of adjustment in the ration as devised has been a common cause of failure in work of construction.* To provide the required elasticity in a ration is to provide a method by which the *varying* preferences of the men may be satisfied. This necessitates not only a sufficient number of articles to give a very good general variety, but also a way by which that variety may be utilized to the best advantage or the greatest extent to suit the men.

For instance, every ration must be arranged in its construction in the form of a dietary. Such an arrangement, having variety as its basis, may provide, for instance, in a sea ration preserved meats at one issue, salt meats at another, and smoked meats at another; canned vegetables at one issue, beans at another, and rice at another; canned fruit at one issue, dried fruit at another, and preserved fruit at another; hard-tack at one issue, wheat flour at another, and cornmeal and oatmeal at another; pickles on one day, sauerkraut on another; coffee, tea, or cocoa every day; sugar, butter, and evaporated milk every day; macaroni, once or twice a week, and so on for additional articles. Now, if all the articles and no others prescribed for issue on a particular day have to be issued on that day and in prescribed amounts or are issued in less amounts without substitution, because not consumed, the ration has no elasticity; if in a day's issue so much of one article not desired can be obtained in an increased amount of other articles or articles to be issued on that day and desired, the ration has a degree of elasticity, and if at any issue any amount of an article not desired can be obtained in additional amounts of any article or articles in the ration as a whole that is desired, the substitution being made on the basis of money value, the ration has its full practicable elasticity.

Every ration should have full elasticity, and this is provided for where any article comprised in the ration may be issued in excess of the authorized quantity, provided there be an underissue of the same value in some other article or articles. Thus, if a mess does not use all the hard-tack authorized, it can get flour or any other article in the ration in an amount having the same money value as the amount of hard-tack not used, it can obtain more fruit or more breakfast foods and tea, coffee, and so on. This also makes for less waste or a more economical use of articles of food, as a saving in any article leads to a larger *desired issue* in another. The men themselves become interested in economy, as things thrown away as not wanted deprive them of things that are wanted. It then follows that while there should be a standard ration with each article at an invoiced price, the men should be practically allowed to make every desired variation within the limit of cost. The men are then fed as economically as the ration on paper would indicate, and at the same time there is the *maximum variety the ration as a whole permits.*

Having carefully made the full list of articles to comprise the ration and made the division into those suitable for the sea ration, those suitable for the fresh provision ration, and those common to all rations, such as butter, coffee, pepper, mustard, salt, vinegar, sauces, spices and pickles, the next step in construction is to arrange the articles so as to make the *sea ration* in the form of a daily dietary as the basis of issue to secure *variety* and on the basis of meat, bread or flour, fruit and vegetables in each day's issue with butter and sugar, tea, coffee, or cocoa and the accessory foods every day.

The work is confined to the sea ration at first that fresh provisions may be more conveniently considered as substitutes. To do this, a table should be made in a tentative way showing the days of the week in the left-hand column, and, above the other columns and placed horizontally, the articles largely arranged for convenience as sub-headings under appropriate headings—"Bread" as a heading and biscuit, wheat flour, cornmeal, and oatmeal as its subheadings; "Ingredients" as a heading over lard, extract, and yeast; "Meats" over preserved, salt, and smoked; "Vegetables" over canned, beans, peas, rice, flour (when not issued as bread); "Fruit" over canned, dried, preserved; "Beverages" over coffee, cocoa, and tea; "Milk" over condensed and evaporated; and "Butter," "Sugar," "Mustard," "Pepper," "Salt," "Tomatoes," "Macaroni," Cheese," "Sauce," "Vinegar," "Sauerkraut," "Pickles," "Molasses," and "Spices" as individual headings.

On the next page is found a fragment of such a tentative table:

It will be at once recognized that for convenience a large number of articles have been classed under such general headings as preserved meats, salt meats, smoked meats, canned vegetables, canned fruit, dried fruit, and preserved fruit. For instance, preserved meats should comprise tinned bacon, tinned corned beef, tinned roast beef, tinned ham, tinned salmon, and pickled or salt fish. Salt meats should include salt beef, salt pork, and fresh corned beef; and smoked meats should include ham, shoulder, tongue, bacon, and all kinds of smoked sausage. All these articles appear on the original list and are utilized in making out the menu or bill of fare under the issues. Dried fruits are dried applies, peaches, raisins, currants, prunes, figs, dates, or any other dried fruit, and canned fruit may be peaches, apricots, pears, or any canned fruit. Thus in making out the daily bills of fare there is room for much ingenuity on the ship itself, while amounts specified to be issued under the general headings should provide the nutrients required.

In arranging for daily issues it has been seen that the basis of bread or flour, meat, fruit, and vegetables in each day's issue with butter and sugar and the accessory foods is recognition that the general practice of mankind is in accord with the general chemical composition of foodstuffs, the protein largely from meat, the fats chiefly from meats or as butter and the carbohydrates, considering also the vegetable acids as important substances conveniently classed under carbohydrates, chiefly from bread, vegetables, sugar, fruits and vegetable sources in general. A fat such as salt pork and the bean rich in protein go together in theory and in practice, but are limited in number of issues per week for reasons given.

The making of a list of articles to be included in the ration and the formation of a table to show how those articles may be arranged in daily issues to make up meals and secure variety, being the great primary essential steps in the formation or wording of a ration, demand much

Days of the week	Bread				Ingredients			Meats			Vegetables					Fruit			Beverages			Milk	
	Biscuit	Wheat flour	Cornmeal	Oatmeal	Lard	Extract	Yeast	Preserved	Salt	Smoked	Canned	Beans	Pease	Rice	Flour	Canned	Dried	Preserved	Coffee	Cocoa	Tea	Condensed	Evaporated
Sunday		×			×	×	×	×			×					×			×			×	
Monday		×			×					×				×			×			×		×	
Tuesday		×			×				×			×				×					×	×	
Wednesday			×	×				×					×					×	×				×
Thursday		×			×					×		×				×				×		×	
Friday		×			×				×						×		×				×	×	
Saturday	×									×	×						×		×			×	

careful thought and some experience involving even a knowledge of what materials are required in preparation and cooking, as the articles issued must be complete as a whole in every way to permit the appearance of the food-stuffs on the table in acceptable and varying forms. For instance, when flour is to be issued in place of bread it is not only necessary to know what should be used with it in order that good bread can be made, but also what would be required to make from time to time different varieties of bread, or what additional amount would be required to make pastry, as the rest of the issue such as fruit might suggest. It is, therefore, necessary to consider the articles in the form of varying meals or how they may be profitably combined in varying forms and what additional material will be required to make them acceptable in those forms.

After such consideration it is possible to make the wording of the ration in rough or without specifying amounts. For instance, the sea ration could be stated in the following way: The navy ration shall consist of the following daily provisions issued for each person: Salt or smoked meat, with dried or canned or preserved fruit, and beans or pease or flour; or preserved meat, with dried or canned or preserved fruit and rice or canned vegetables or desiccated vegetables; together with biscuit, butter, sugar, coffee or cocoa or tea and condensed milk or evaporated cream, and a weekly allowance of macaroni, cheese, tomatoes, vinegar, pickles, molasses, salt, pepper, spices, and mustard. For biscuit, flour may be issued as bread when lard is also to be issued, and yeast and flavoring extracts as may be necessary.

To complete the wording the amounts of the different articles have to be specified. Guides for work in that direction have already been declared. All the articles in each day's issue should together contain each of the nutrients in sufficient amounts to agree, after allowance for waste, with a standard accepted as suitable for the men who are to consume the articles and no one article should be issued in amount beyond its acceptability as shown by observation of the men in question. The latter consideration has generally necessitated several preliminary rations before one according fairly well with the average taste has been evolved. It is also a paramount consideration in regard to certain articles specified that are either practically without nutrients or, in amounts used, not usually regarded as containing them, such as coffee, tea, mustard, vinegar, and spices. Salt, while an important nutrient, can also be added to the list of articles issued in amounts to accord with the habits of men in seasoning food to taste.

Pickles (and sauerkraut) contain such small percentages of nutrients that they also may be issued in amounts determined merely by their ordinary use as relishes. One-half pint of vinegar, one-quarter pint of pickles, four ounces of salt, one-half ounce of pepper, one-eighth ounce of spices, one-half ounce of dry mustard per week per man, and two ounces of coffee or cocoa or one-half ounce of tea per day are the service allowances, but ordinarily the pickles, vinegar, and spices are underissued on those allowances. One-quarter pint of molasses per week is also about as much as, or more than, the average sea-going man is willing to consume if he has a variety of other articles, while four ounces of cheese per week, the service allowance, is less than is usually desired. Four ounces of sugar and two ounces of butter per day seem to be the average consumption.

So far materials mentioned with allowances are, with the exception of cheese, almost entirely sources of the non-nitrogenous nutrients, when they can properly be regarded as sources of nutrients at all, and from that point of view it seems that their adaptability as measured by average desired consumption may be tentatively accepted without much objection as the amounts in which they should appear in the ration. The same may be said of condensed or evaporated cream, as used with coffee, tea, or cocoa, only one ounce of which is issued per man per day, but of which an overissue is often desired, and of macaroni which experience has shown is adaptable only to the average extent of one-quarter of a pound per week.

Canned vegetables as a class are largely water (87.6 per cent.), canned tomatoes having 94 per cent. The amount of protein in such food-stuffs is well under 2 per cent. and of fat much less than 1. The preserved fruits contain much less protein and even less fat, but have more than 80 per cent. carbohydrates. The adaptability of canned vegetables in a day's issue is about 12 ounces. Dried fruit contains about 1.6 per cent. protein, 2.2 fat and 66.1 carbohydrates, and canned fruit 84.6 per cent. water, practically no protein or fat, and about 14.4 carbohydrates. It would seem that the allowance of those substances might be safely gauged in a tentative way by their average desired consumption in a ration in which there is a large variety of articles, such as the present navy ration, especially when considered in connection with fresh provisions. Their amounts as measured by adaptability seem to be three ounces of dried or six ounces of canned or preserved fruit, with the issue of preserved fruit limited to once a week, as a rule.

In view of the fact that in general the meats may be considered as furnishing no carbohydrates and much protein, *it is better to primarily fix the amounts of vegetable foods* in order to secure the amount of the carbohydrates desired, to then calculate the protein and fat they contain and make up the difference in protein and in fat by recourse to animal sources. It will, however, be apparent that the dried vegetables such as beans, peas and rice, and the canned fruits, contain a larger percentage of carbohydrates than fresh vegetables; potatoes, for instance, containing 62.6 per cent. water and 14.7 per cent. carbohydrates, while dried beans contain 12.6 and 59.6 per cent., and rice 12.3 per cent. and 79 per cent., respectively.

As the two rations will be utilized together whenever practicable, the sea ration usually three times a week and the fresh provision ration four times a week with fresh vegetables nearly every day, if they can be obtained, it is desirable also for the *average* carbohydrates *consumed* in the two rations to be about 500 grams. It seems likely, therefore, the sea ration will ordinarily tend to contain more carbohydrates than the fresh provision ration. The question of excess fat, if incident to obtaining protein, is not of such practical importance from a hygienic point of view, because as appearing in such large quantities in salt meats, such as salt pork, and as butter, the consumer is in a position to regulate consumption by appetite.

Arranging in a form of a list the articles containing nutrients and their allowances as they have been stated so far, dividing the weekly allowances by seven to obtain equivalent daily allowances, and applying their percentage chemical compositions as given in Table I, found on page 509, the following is obtained:

Articles	Daily issue (in ounces)	Protein (in ounces)	Fat (in ounces)	Carbohydrates (in ounces)
Fruit, dried	3	.048	.066	1.983
Fruit, canned	6	.030	.012	.864
Fruit, preserved . .	6	.036	.006	5.070
Vegetables, canned .	12	.192	.048	1.152
Butter	2	.020	1.700	. .
Sugar	4	. .	. .	4.000
Milk, condensed . .	1	.088	.083	.541
Macaroni	0.57	.076	.005	.422
Cheese	0.57	.164	.205	.002
Molasses	0.57	.014	. .	.395

Considering the last six as issued daily, it is found by addition that they contain 0.362 ounce of protein, 1.993 ounces of fat and 5.36 ounces of carbohydrates. But the total carbohydrates tentatively desired is 666.66 grams, as 25 per cent. is to be allowed for waste and 500 grams are to be calculated as consumed. As 666.66 grams are equivalent to about 23.5 ounces and the daily issues so far calculated contain 5.36

ounces, the remainder, about 18.2 ounces, is to be supplied from the additional issues. By referring to the rough draft of the ration as already presented, it will be seen that those additional issues are biscuit or flour every day and fruit with beans or peas or flour, or fruit with rice or canned vegetables. The question now is to fix the amounts of those additional articles.

In the tentative *issue table* as given it will be observed, for instance, that on Saturday, biscuit, canned vegetables and dried fruit are the additional articles. By referring to the list just given it will appear that the canned vegetables contain 1.152 ounces of carbohydrates and the dried fruit 1.983, a total of 3.135. As $18.2 - 3.135 = 15.065$ ounces, that amount of carbohydrates would have to be supplied by biscuit, the remaining article. Now biscuit is 72.8 per cent. carbohydrate and therefore it would take $\frac{1506.5}{72.8} = 20.6$ ounces of biscuit to furnish the 15 ounces of carbohydrates desired. As a matter of fact, 1 1/4 pounds of biscuit is ordinarily above its acceptability and the issue would fall to one pound; or flour, being more desired, would be issued for bread in its place. Flour is 75.1 per cent. carbohydrate and therefore as $\frac{1506.5}{75.1} = 20$ ounces, that amount is equivalent in carbohydrates to 20.6 ounces of biscuit. But as carbohydrates are replaceable to some extent by fats, those amounts would have to be accepted only tentatively until the total fats were determined with an understanding of probable reduction of carbohydrates in view of the considerable percentage of fats the meats in a sea ration contain. As a matter of fact, 18 ounces of flour have been found even more than sufficient under ordinary circumstances.

Referring again to the ration and issue table given in rough, it appears that an issue of dried beans, peas, or flour is made quite frequently instead of canned vegetables when salt or smoked meat is issued. As 12 ounces of canned vegetables contain 1.152 ounces of carbohydrates and as dried beans contain 59.6 per cent. of carbohydrates, it would require $\frac{115.2}{59.6} = 1.93$ ounces of beans to furnish the same amount of carbohydrates. But the acceptability of beans is greater, perhaps 12 ounces, but probably less, and they also assist in making up the lack of protein in salt pork which contains only 1.9 per cent. The additional 10 ounces of beans contain 5.96 ounces of carbohydrates and would permit an equivalent reduction in flour equal to 7.9 ounces, thus bringing the calculated flour issue on those days from 20 ounces to at most 12.1 ounces, less than the amount actually issued. The same is practically true of pease, and, as beans or pease are designated in the issue table three days in the week of sea ration, the required issue of flour for bread on those days may be taken as less than the 18 ounces actually issued unless beans are underissued.

In the same issue table, rice is indicated for one day of the week, and on another flour as a vegetable food. Considering the bread as 18 ounces of flour and that 12 ounces of dried beans contain 7.152 ounces of carbohydrates, the equivalent in rice, which contains 79 per cent., would be $\frac{715.2}{79}=9$ ounces, which is somewhat in excess of the actual issue of 8 ounces that if actually consumed would also reduce the issue of flour as bread to 12.1 ounces, and, as a matter of fact, if the actual Navy ration in its complete form as subsequently given be examined and the analysis of the sea ration, Table II, be considered, it will be seen that the carbohydrates it contains are in excess by at least 75 grams, allowing 25 per cent. for waste.

That amount is equivalent to $\frac{7500}{75.1}$ or nearly 100 grams of flour per day per man, and its equivalent in some form is very probably discarded or remains in storerooms when a crew is strictly on a sea ration which is seldom. This is not of as much importance as it seems because the flour issue of 18 ounces as bread has its balance fairly well maintained, as a rule, by the frequent issues of fresh vegetables, chiefly potatoes and onions, in lieu of the articles usually issued with salt, smoked, or preserved meat. The fresh-vegetable issue may be considered to contain only 13.25 per cent. of carbohydrates, and consequently the issue, 28 ounces, contains 3.71 ounces of carbohydrates, leaving $18.2-3.71=14.49$ ounces to be supplied by bread as bread or flour. As $\frac{1449}{75.1}=19.2$ ounces of flour the general issue of 18 ounces of flour at sea would ordinarily be about correct to complete the amount of carbohydrates regarded as maximum.

The amounts of meat to be issued depend theoretically entirely upon the protein standard and practically upon demand as limited by cost. Preserved meats average 22.84 per cent. protein, and consequently 16 ounces would contain 3.6544 ounces of protein or about 103.6 grams. From the analysis of the sea ration, Table II, it appears that on the average it contains *without meat* 119.43 grams of protein and that the ration as a whole supplies on the average only 64.75 grams of protein from meats, or about 35 per cent. of its total protein. As, allowing 25 per cent. for waste, the 119.43 grams without meat would correspond to 89.57 grams consumed, the Navy sea ration *without any meat at all* exceeds in protein the amount declared by Chittenden to be necessary.

In the fresh-provision ration, Table III, the protein without meat is 90.1 grams per man daily, and the protein from meat is 103.7 grams.

Applying the percentage for waste, the protein without meat is 67.57 grams, or quite as much as, or more than, Chittenden claims is necessary. *In other words, if the amount of carbohydrates is to be maintained with the articles in the amounts either ration includes, his standard would be exceeded on a ration containing no meat.* It is noticeable that in the fresh-provision ration that standard is exceeded without either beans or peas and on an allowance of cheese that does not exceed 4 ounces per man per week. *And it is believed that the Navy would not hold together under a deliberate total deprivation of meat.* It is, however, important to realize that as the ration is now constructed a medical officer can safely advise any individual considered to be suffering from an excessive protein intake to abstain from the ingestion of meat even for long periods and to depend entirely upon the other articles daily available. But in the construction of the ration as a whole some regard should be given to the fact that in the eyes of an enlisted man the degree of acceptability of a ration depends to a considerable extent upon the amount of meats and potatoes it contains.

Salt beef contains 11.2 per cent. protein and fresh beef 15.25 per cent. A pound and a quarter of salt beef therefore contains 2.24 ounces of protein. Its equivalent in fresh beef is therefore $\frac{224}{15.25} = 14.68$ ounces. However, they should not be issued in equivalent amounts because with fresh meats fresh vegetables are issued, and such vegetables contain less protein than dried vegetables, such as beans and peas.

It has been seen that on the average the sea ration without meat contains 119.43 grams of protein and the fresh-provision ration without meat 90.1 grams. Therefore, if a pound and a quarter of salt meat be added in the case of the sea ration the protein will be $119.43 + 63.5 = 182.93$ grams, which become 137.2 grams, allowing for waste. If the fresh-provision ration is to average as much, 92.83 grams of protein will have to be added, or about 3.27 ounces. To obtain 3.27 ounces from fresh beef, $\frac{327}{15.25} = 21.44$ ounces are required, or a little more than a pound and a quarter. The service did issue about that amount, but has found that one and three-quarter pounds, its present issue, can, in accordance with availability, be issued under the average maximum limit of cost of the ration as a whole, and that the increased amount contributes to its policy of making its reputation attractive. This is continued in the absence of proof from its statistics that the increase is detrimental to health, and with the knowledge that under the usual ration containing, as eaten, 142 grams of protein, 192 grams of fats, and 492 of carbohydrates (fuel value 4,256), there has been rather a reduction in rheumatic troubles than an increase, though not attributing the decrease to diet. (*See* Vital Statistics.)

The method used in calculating the general amounts of the meat issues in relation to the average protein in the other issues of the ration should be associated with a similar method in relation to the daily combinations as shown by the issue table, the protein in all other issues for that day being calculated and the meats added in amounts to make the required protein.

In that method it will be noticed that when salt pork is issued with beans the protein is from the beans in very much larger quantity than from the pork which is 86.2 per cent. fat and only 1.9 protein. In that case the pork is the source of fat, the dried beans having only 1.8 per cent., and also of the flavor desired. If the pork is issued in the same amounts as other salt meats or smoked meats, as it is, it is apt to appear as an under issue and thus take part in facilitating elasticity, adding perhaps to the amount of hominy, breakfast foods, and other cereals utilized during the week and included in the list of articles as arranged originally under the head of vegetables.

Salt beef has never been popular in the naval service and in the utilization of both the sea and fresh-provision ration the number of times it is issued is apt to be much reduced and thus it tends to remain on hand longer than its usefulness continues, becoming hard or losing its brine and thus unfit for use. Such experience ultimately leads to elimination from a ration. Fresh corned beef obtained in the market as required should ultimately still further diminish the use of salt beef as found in the service.

The above are among the most obviously essential methods of construction. It is not a work of short duration, inasmuch as the method as a whole, and as finding expression on paper, is one involving selection of many different and suitable food materials, arranging them in dietaries to accord with the food habits of man, fixing amounts by *trial* in connection with standards and a table of chemical composition, and by knowledge of the average man's inclinations in relation to individual articles, and finally by keeping the average cost within the maximum amount allowed.

But, after all the work of construction appears to have been completed it must stand the test of analysis, or the amounts of individual articles must be altered here and there in accordance with their chemical composition until the work as a whole and in each calculated daily issue gives the standard results as derived by the analytical method. In other words, the protein, fats, and carbohydrates taken originally as the standard in construction must be proven to be in the daily ration as devised.

To make clear the *method of analysis* or the work by which a ration is "*determined*" or analyzed, the following simple ration having been constructed is now submitted to analysis under the belief that if the computation is carefully followed the method as subsequently applied to the Navy ration will be thoroughly understood without further explanation:

The issues three times a week for each member of a crew are: One pound and a quarter of smoked ham, one pound of biscuit (hard-tack), four ounces of beans, three ounces of dried fruit and four ounces of sugar; and four times a week: one and three-quarter pounds of fresh beef, one and one-quarter pounds of fresh bread, one and three-quarter pounds of potatoes, nine ounces of oranges, four ounces of sugar, three ounces of coffee, and one-half ounce of salt.

Find per man the average daily:[1]

1. *Issue* in grams of (*a*) protein, (*b*) fats, (*c*) carbohydrates, (*d*) nitrogen, carbon and ratio of nitrogen to carbon.

2. Allowing 25 per cent. for waste, *consumption* in grams of (*e*) protein, (*f*) fats, (*g*) carbohydrates; amount in grams *metabolized* or *digested* of (*h*) protein, (*i*) fats, (*j*) carbohydrates; (*k*) untilizable *fuel value;* (*l*) nutritive ratio; (*m*) total nitrogen output.

The work is as follows:

Total quantities of food materials *issued* to each man during three days (in pounds):

Smoked ham	1.25	×	3	=	3.75
Biscuit	1.00	×	3	=	3.00
Beans	0.25	×	3	=	0.75
Fruit, dried	0.1875	×	3	=	0.5625
Sugar	0.25	×	3	=	0.75

Protein contained in each of those quantities and their total protein in pounds:

Smoked ham	3.75	×	.142	=	0.53250
Biscuit	3.00	×	.144	=	0.43200
Beans	0.75	×	.225	=	0.16875
Fruit, dried	0.5625	×	.016	=	0.00900
Sugar	0.75		. . .	=	. . . .
			Total		1.14225

Fats contained in each of those quantities and their total fat in pounds:

Smoked ham	3.75	×	.334	=	1.252500
Biscuit	3.00	×	.013	=	.039000
Beans	0.75	×	.018	=	.013500
Fruit, dried	0.5625	×	.022	=	.012375
Sugar	0.75		. . .	=	. . . .
			Total		1.317375

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[1] Table I.—Chemical Composition of Articles of the U. S. Navy Ration, on page 509. (The table was compiled from the Atwater tables.)
One pound = 453.59 grams.

Carbohydrates contained in each of those quantities and their total carbohydrates in pounds:

Smoked ham	3.75		. . .	=	. . . .
Biscuit	3.00	×	.728	=	2.1840000
Beans	0.75	×	.596	=	.4470000
Fruit, dried	0.5625	×	.661	=	.3718125
Sugar	0.75	×	1.00	=	.7500000
			Total		3.7528125

Total quantities of the food materials *issued* to each man during 4 days (in pounds).

Beef, fresh	1.75	×	4	=	7.00
Bread, fresh	1.25	×	4	=	5.00
Potatoes	1.75	×	4	=	7.00
Oranges	0.5625	×	4	=	2.25
Sugar	0.25	×	4	=	1.00

Protein contained in each of those quantities and their total protein in pounds:

Beef, fresh	7.00	×	.1525	=	1.0675
Bread, fresh	5.00	×	.092	=	.4600
Potatoes	7.00	×	.018	=	.1260
Oranges	2.25	×	.006	=	.0135
Sugar	1.00		. . .	=	. . . .
			Total		1.6670

Fat contained in each of those quantities and their total fat in pounds:

Beef, fresh	7.00	×	.1525	=	1.06750
Bread, fresh	5.00	×	.013	=	.06500
Potatoes	7.00	×	.001	=	.00700
Oranges	2.25	×	.001	=	.00225
Sugar	1.00		. . .	=	. . . .
			Total		1.14175

Carbohydrates contained in each of those quantities and their total carbohydrates in pounds:

Beef, fresh	7.00		. . .	=	. . . .
Bread, fresh	5.00	×	.531	=	2.65500
Potatoes	7.00	×	.147	=	1.02900
Oranges	2.25	×	.085	=	.19125
Sugar	1.00	×	1.00	=	1.00000
			Total		4.87525

Total organic nutrients (protein, fats, and carbohydrates) *issued* during the week in pounds (recapitulation):

	Protein	Fats	Carbohydrates.
During 3 days	1.14225	1.317375	3.7528125
During 4 days	1.66700	1.141750	4.8752500
Total pounds	2.80925	2.459125	8.6280625

Daily average in pounds. . . .	0.40132	0.351303	1.2325803
Daily average issue in grams	182.0353	159.3477	559.0861
	(*a*)	(*b*)	(*c*)

Total grams of nitrogen and of carbon in the organic nutrients issued daily and ratio of nitrogen to carbon (*d*):

		Nitrogen	Carbon
Protein	182.0353 × .16 =	29.1256	. . . .
Protein	182.0353 × .54 =	. . . .	98.2991
Fats	159.3477 × .765 =	. . . .	121.9010
Carbohydrates.	559.0861 × .4344 =	. . . .	242.8670
	Total.	29.1256	463.0671

$$\text{Ratio} = \frac{29.1256}{463.0671} = \frac{1}{15.89}$$

Consumption in grams of each of the organic nutrients, allowing 25 per cent. for waste (*e*, *f*, and *g*.)

Protein.............. 182.0353 × .75 = 136.527
Fats .... 159.3477 × .75 = 119.511
Carbohydrates ....559.0861 × .75 = 419.315

Average amount in grams of each organic nutrient *digested* or *metabolized* daily (*h*, *i*, and *j*):

Protein.............. 136.527 × .92 = 125.6
Fats .... 119.511 × .95 = 113.5
Carbohydrates........ 419.315 × .97 = 406.7

Average daily *utilizable fuel value* of the ration *consumed* (*k*).

Calories from protein .... 136.527 ×4 = 546.10
Calories from fats .... 119.511 ×8.9 = 1063.65
Calories from carbohydrates...... 419.315 ×4 = 1677.26
Total calories 3287.01

Nutritive ratio of ration consumed (*l*):
Digested fat in terms of carbohydrates = 113.5 × 2.25 = 255.45
Digested carbohydrates........................ 406.73
Total calculated carbohydrates .... = 662.18
Digested protein.............................. = 125.60

$$\text{Nutritive ratio} = \frac{125.6}{662.18} = \frac{1}{5.27}$$

Total Nitrogen Output (m).—Nitrogen output (fæces and urine) = 16 per cent. of protein intake (136.5 grams) or the protein intake divided by 6.25. Therefore,

$$\frac{136.5}{6.25} = 21.84 \text{ grams, the total nitrogen output.}$$

Considering the coefficients of digestibility, the dried fæces would average about 33 grams daily, and considering normal fæces when dried to contain about 8.65 per cent. nitrogen, the nitrogen in fæces would be about 2.85 grams daily, the remainder about 19 grams appearing chiefly as the total nitrogen in urine.

This method of analysis can now be applied to the much more complicated Navy ration. The Navy ration is prescribed by law and therefore cannot be changed on a ship. But while the amounts prescribed to be issued cannot be changed except as such changes result automatically from the large degree of elasticity recently provided, it is within the province of commanding authority to control lawful variations. For instance, it can decide under the law (Sec. 1581 R. S. as amended by Naval Act, June 29, 1906) whether the men shall have fresh provisions two, three, or four times or more a week. Such a question may, therefore, properly come within the advisory capacity of the medical officer.

The following is the wording of the Navy ration and its analysis in such form as has seemed most advisable:

Naval Act, June 29, 1906.—*Provided*, That sections fifteen hundred and eighty and fifteen hundred and eighty-one, Revised Statutes, be amended to read as follows:

"SEC. 1580.—The Navy ration shall consist of the following daily allowance of provisions to each person: One pound and a quarter of salt or smoked meat, with three ounces of dried or six ounces of canned or preserved fruit, and three gills of beans or pease, or twelve ounces of flour; or one pound of preserved meat, with three ounces of dried or six ounces of canned or preserved fruit and eight ounces of rice or twelve ounces of canned vegetables, or six ounces of desiccated vegetables; together with one pound of biscuit, two ounces of butter, four ounces of sugar, two ounces of coffee or cocoa, or one-half ounce of tea and one ounce of condensed milk or evaporated cream; and a weekly allowance of one-quarter pound of macaroni, four ounces of cheese, four ounces of tomatoes, one-half pint of vinegar or sauce, one-quarter pint of pickles, one-quarter pint of molasses, four ounces of salt, one-half ounce of pepper, one-eighth ounce of spices, and one-half ounce of dry mustard. Seven pounds of lard, or a suitable substitute, shall be allowed for every hundred pounds of flour issued as bread, and such quantities of yeast and flavoring extracts as may be necessary.

"SEC. 1581.—The following substitution for the components of the ration may be made when deemed necessary by the senior officer present in command: 'For one and one-quarter pounds of salt or smoked meat or one pound of preserved meat, one and three-quarter pounds of fresh meat or fresh fish, or eight eggs; in lieu of the articles usually issued with salt, smoked or preserved meat, one and three-quarter pounds of fresh vegetables; for one pound of biscuit, one and one-quarter pounds of soft bread or eighteen ounces of flour; for three gills of beans or pease, twelve ounces of flour or eight ounces of rice or other starch food, or twelve ounces of canned vegetables; for one pound of condensed milk or evaporated cream, one quart of fresh milk; for three ounces of dried or six ounces of canned or preserved fruit, nine ounces of fresh fruit; and for twelve ounces of flour or eight ounces of rice or other starch food, or twelve ounces of canned vegetables, three gills of beans or pease; in lieu of the weekly allowance of one-quarter pound of macaroni, four ounces of cheese, one-half pint of vinegar or sauce, one-quarter pint of pickles, one-quarter pint of molasses, and one-eighth ounce of spices, three pounds of sugar, or one and a half pounds of condensed milk, or one pound of coffee, or one and a half pounds of canned fruit, or four pounds of fresh vegetables, or four pounds of flour.

" 'An extra allowance of one ounce of coffee or cocoa, two ounces of sugar, four ounces of hard bread or its equivalent, and four ounces of preserved meat or its equivalent shall be allowed to enlisted men of the engineer and dynamo force who stand night watches between eight o'clock postmeridian and eight o'clock antemeridian, under steam.' "

Naval Act, March 2, 1907.—"Any article comprised in the Navy ration may be issued in excess of the authorized quantity, provided there be an underissue of the same value in some other article or articles."

TABLE I.

CHEMICAL COMPOSITION OF ARTICLES OF THE U. S. NAVY RATION (ATWATER).

Food materials	Refuse, per cent.	Water, per cent.	Protein, per cent.	Fats, per cent.	Carbo-hydrates, per cent.	Ash, per cent.
Apples, fresh	25.0	63.3	.3	.3	10.8	0.3
Bacon, canned	....	19.9	10.5	64.8	....	4.8
Bacon, smoked	8.7	18.4	9.0	59.4	....	4.5
Bananas	35.0	48.9	.8	0.4	14.3	0.6
Beans, dried	....	12.6	22.5	1.8	59.6	3.5
Beef, corned, canned	....	51.0	26.3	18.7	....	4.0
Beef, fresh	18.35	50.45	15.25	15.25	....	0.7
Beef, roast, canned	....	58.0	25.9	14.8	....	1.3
Beef, salt	10.5	33.0	11.2	39.9	....	5.4
Biscuit (hard-tack)	....	9.2	14.4	1.3	72.8	2.3
Bread, wheat, fresh	....	35.3	9.2	1.3	53.1	1.1
Butter	....	11.0	1.0	85.0	....	3.0
Cheese	....	31.6	28.8	35.9	.3	3.4
Cocoa	....	4.6	21.6	28.9	37.7	7.2
Cod, salt	24.9	40.2	16.0	.4	....	18.5
Corn-meal	....	12.5	9.2	1.9	75.4	1.0
Cream, evaporated	....	68.2	9.6	9.3	11.2	1.7
Eggs	11.2	65.5	13.1	9.3	....	.9
Flour, wheat	....	12.0	11.4	1.0	75.1	0.5
Fowls	25.9	47.1	14.0	12.3	....	.7
Fruit, canned	....	84.6	0.5	0.2	14.4	0.3
Fruit, dried	....	28.1	1.6	2.2	66.1	2.0
Fruit, preserved	....	14.5	.6	.1	84.5	.3
Grapes	25.0	58.0	1.0	1.2	14.4	.4
Ham, canned	....	43.6	19.0	34.1	....	3.3
Ham, smoked	13.6	34.6	14.2	33.4	....	4.2
Hominy	....	11.8	8.3	.6	79.0	.3
Lard	....	....	....	100.0	....	....
Liver, beef, fresh	7.3	65.6	20.2	3.1	2.5	1.3
Macaroni	....	10.3	13.4	0.9	74.1	1.3
Mackerel, salt	19.7	34.8	13.9	21.2	....	10.4
Milk, condensed	....	26.9	8.8	8.3	54.1	1.9
Milk, fresh	....	87.0	3.3	4.0	5.0	.7
Molasses	....	25.1	2.4	....	69.3	3.2
Mutton, fresh	19.2	43.5	13.0	23.6	....	.7
Oatmeal	....	7.3	16.1	7.2	67.5	1.9
Onions	10.0	78.9	1.4	.3	8.9	.5
Oranges	27.0	63.4	.6	.1	8.5	.4
Peaches, fresh	18.0	73.4	.5	.1	7.7	.3
Pease, dried	....	9.5	24.6	1.0	62.0	2.9
Pickles	....	92.9	0.5	0.3	2.7	3.6
Pork, salt (clear fat)	....	8.0	1.9	86.2	....	3.9
Potatoes	20.0	62.6	1.8	.1	14.7	.8
Rice	....	12.3	8.0	0.3	79.0	0.4

TABLE I.—Continued.

CHEMICAL COMPOSITION OF ARTICLES OF THE U. S. NAVY RATION.

Food materials	Refuse, per cent.	Water, per cent.	Protein, per cent.	Fats, per cent.	Carbo-hydrates, per cent.	Ash, per cent.
Salmon, canned	14.2	56.8	19.5	7.5	. . . .	2.0
Sauerkraut	. . . .	88.8	1.7	.5	3.8	5.2
Sugar	. . . .	. . . .	. . . .	. . . .	100.0	. . . .
Tomatoes, canned	. . . .	94.0	1.2	0.2	4.0	0.6
Vegetables, canned	. . . .	87.6	1.6	.04	9.6	0.8
Watermelons	59.4	37.5	0.2	0.1	2.7	0.1

TABLE II.

SEA RATION.

Quantities of different food materials *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbohydrates (in pounds)
Biscuit	10.000	1.440	.130	7.280
Oatmeal	6.750	1.086	.486	4.556
Cornmeal (Indian)	4.500	.414	.085	3.393
Flour, wheat (for bread)	56.250	6.412	.562	42.243
Lard	4.725	. . . .	4.725	. . . .
Extract	. . . .	. . . .	. . . .	. . . .
Yeast	. . . .	. . . .	. . . .	. . . .
[1]Meats, preserved	20.000	4.568	4.526	. . . .
Beef, salt	12.500	1.400	4.987	. . . .
Pork, salt	25.000	.475	21.550	. . . .
Ham, smoked	25.000	3.550	8.350	. . . .
Vegetables, canned	15.000	.240	.060	1.440
Beans	15.000	3.375	.270	8.940
Pease	7.500	1.845	.075	4.650
Rice	5.000	.400	.015	3.950
Flour, wheat	7.500	.855	.075	5.632
Fruit, canned	11.250	.056	.022	1.620
Fruit, dried	5.625	.090	.123	3.718
Fruit, preserved	3.750	.022	.003	3.168
Coffee	3.750	. . . .	. . . .	. . . .
Cocoa	2.500	.540	.722	.942
Tea	0.625	. . . .	. . . .	. . . .
Cream, evaporated	1.250	.120	.116	.140
Milk, condensed	3.125	.275	.259	1.690

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[1] Preserved meat is considered to comprise canned corned beef, canned salmon, "roast beef," canned ham, and canned bacon, also pickled and salt fish. In issues under this heading preference seems to be given to canned corned beef and to some extent to canned salmon.

TABLE II.—Continued.

SEA RATION.

Quantities of different food materials *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbohydrates (in pounds)
Sugar	17.500	...	..	17.500
Butter	8.750	.087	7.437	...
Mustard	0.312	...	...	...
Pepper	0.312	...	...	...
Salt	2.500	...	...	...
Tomatoes	2.500	.030	.005	.100
Macaroni	2.500	.335	.022	1.852
Cheese	2.500	.720	.897	...
Sauce	2.800	...	...	...
Vinegar	2.200	...	...	...
Sauerkraut	1.100	.018	.005	.041
Pickles	1.400	.015	.005	.056
Molasses	2.500	.060	...	1.732
Spices	0.078	...	...	...
Totals	293.552	28.428	55.512	114.543
One day's ration per man	4.193	0.406	0.793	1.636
Daily ration per man (in grams)	gm. 1902.175	gm. 184.209	gm. 359.709	gm. 742.222

Daily fuel value per man (in calories), 6907.

Total nitrogen, 29.47 gm.; total carbon, 697.07 gm.; nitrogen to carbon, 1:23.65.

TABLE III.

Fresh Meat and Fresh Vegetables Every Day.

(FRESH PROVISIONS).

Quantities of different food materials *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbohydrates (in pounds)
Bread, wheat, fresh	87.500	8.050	1.137	46.462
Meat, fresh	105.000	16.012	16.012	. . . .
Eggs	10.000	1.310	.930	. . . .
Vegetables, fresh	122.500	2.082	.183	16.231
Fruit, fresh	39.375	.263	.117	4.643
Coffee	3.750	. . . .	. . . .	. . . .
Cocoa	2.500	.540	.722	.942
Tea	0.625	. . . .	. . . .	. . . .
[1]Cream, evaporated	1.250	.120	.116	.140
Milk, condensed	3.125	.275	.259	1.690
Sugar	17.500	. . . .	. . . .	17.500
Butter	8.750	.087	7.437	. . . .
Mustard	0.312	. . . .	. . . .	. . . .
Pepper	0.312	. . .	. . . .	. . . .
Salt	2.500	. . . .	. . . .	. . . .
Tomatoes	2.500	.030	.005	.100
Macaroni	2.500	.335	.022	1.852
Cheese	2.500	.720	.897	. . . .
Sauce	2.800	. . . .	. . . .	. . . .
Vinegar	2.200	. . . .	. . . .	. . . .
Sauerkraut	1.100	.018	.005	.041
Pickles	1.400	.015	.005	.056
Molasses	2.500	.060	. . . .	1.732
Spices	0.078	. . . .	. . . .	. . . .
Totals	422.577	29.917	27.847	91.389
Daily ration per man	6.036	.427	.397	1.305
Daily ration per man (in grams)	gm. 2738.238	gm. 193.857	gm. 180.431	gm. 592.187

Daily fuel value per man (in calories), 4750.

Total nitrogen, 31.01 gm.; total carbon, 499.95 gm.; nitrogen to carbon, 1:16.12.

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[1] For one pound of condensed milk or evaporated cream one quart of fresh milk may be issued.

TABLE IV.

FRESH PROVISIONS ONCE A WEEK—SEA RATION SIX TIMES A WEEK.

Quantity of food material *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbohydrates (in pounds)
Total quantity, 10 men 1 week . .	311.984	28.640	51.559	111.235
Daily ration per man	4.456	.409	.736	1.589
Daily ration per man in grams	gm. 2021.611	gm. 185.583	gm. 334.094	gm. 720.786

Daily fuel value per man (in calories), 6599.

Total nitrogen, 29.69 gm.; total carbon, 668.9 gm.; nitrogen to carbon, 1:22.52.

TABLE V.

FRESH PROVISIONS TWICE A WEEK—SEA RATION FIVE TIMES A WEEK.

Quantity of food material *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbohydrates (in pounds)
Total quantity, 10 men 1 week . .	330.415	28.853	47.607	107.927
Daily ration per man	4.720	0.412	0.680	1.541
Daily ration per man (in grams)	gm. 2141.041	gm. 186.963	gm. 308.486	gm. 699.351

Daily fuel value per man (in calories), 6291.

Total nitrogen, 29.91 gm.; total carbon, 640.74 gm.; nitrogen to carbon, 1: 21.42.

TABLE VI.

FRESH PROVISIONS THREE TIMES A WEEK—SEA RATION FOUR TIMES A WEEK.

Quantity of food material *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbohydrates (in pounds)
Total quantity, 10 men 1 week . .	348.848	29.066	43.655	104.619
Daily ration per man	4.983	0.415	0.623	1.494
Daily ration per man (in grams)	2260.478	188.343	282.878	677.916

Daily fuel value per man (in calories), 5983.

Total nitrogen, 30.13 gm.; total carbon, 612.59 gm.; nitrogen to carbon, 1:20.33.

TABLE VII.

[1]Fresh Provisions Four Times a Week—Sea Ration Three Times a Week.

Quantity of food material *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbo-hydrates (in pounds)
Total quantity, 10 men 1 week . .	367.280	29.279	39.703	101.312
Daily ration per man	5.246	0.418	0.567	1.447
Daily ration per man (in grams)	gm. 2379.922	gm. 189.723	gm. 257.269	gm. 656.487

Daily fuel value per man (in calories), 5674.

Total nitrogen, 30.35 gm.; total carbon, 584.43 gm.; nitrogen to carbon, 1:19.22.

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[1] This might be considered the usual ration as *issued*.

TABLE VIII.

Fresh Provisions Five Times a Week—Sea Ration Twice a Week.

Quantity of food material *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbo-hydrates (in pounds)
Total quantity, 10 men 1 week . .	385.712	29.491	35.751	98.004
Daily ration per man	5.510	0.421	0.510	1.400
Daily ration per man (in grams)	gm. 2499.358	gm. 191.097	gm. 231.661	gm. 635.051

Daily fuel value per man (in calories), 5366.

Total nitrogen, 30.57 gm.; total carbon, 556.27 gm.; nitrogen to carbon, 1:18.19.

TABLE IX.

Fresh Provisions Six Times a Week—Sea Ration Once a Week.

Quantity of food material *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbo-hydrates (in pounds)
Total quantity, 10 men 1 week . .	404.144	29.704	31.799	94.696
Daily ration per man	5.773	0.424	0.454	1.352
Daily ration per man (in grams)	gm. 2618.795	gm. 192.477	gm. 206.052	gm. 613.616

Daily fuel value per man (in calories), 5058.

Total nitrogen, 30.79 gm.; total carbon, 528.12 gm.; nitrogen to carbon, 1:17.14.

TABLE X.

EXTRA ALLOWANCE ENGINEER AND DYNAMO FORCE.

(When standing steaming watches between 8 p. m. and 8 a. m.)

Quantities of different food materials *issued* to 10 men during one week (in pounds)		Protein (in pounds)	Fat (in pounds)	Carbohydrates (in pounds)
Coffee	4.375	....	....	....
Sugar	8.750	....	....	8.750
Biscuit	17.500	2.520	.227	12.740
Meat, preserved	17.500	3.997	3.960	....
Totals	48.125	6.517	4.187	21.490
Daily ration per man	.687	.093	.059	.307
Daily ration per man (in grams)	gm. 311.844	gm. 42.229	gm. 27.131	gm. 139.252

Daily fuel value per man (in calories), 966.
Total nitrogen. 6.75 gm.; total carbon, 104.04 gm.

TABLE XI.

[1] FOOD CONSUMPTION. (Tables II, III, IV, V, VI, VII, VIII, IX.)

(Quantities per man per day with allowance of 25 per cent. for galley and table waste.)

	Eaten			Digestible				
TABLES	Protein gm.	Fat gm.	Carbohydrates gm.	Protein gm.	Fat gm.	Carbohydrates gm.	Fuel Value cals.	Nutritive ratio
II	138.156	269.781	556.666	127	256	540	5180	1 : 8.78
III	145.392	135.323	444.140	134	129	431	3563	1 : 5.38
IV	139.187	250.570	540.589	128	238	524	4949	1 : 8.27
V	140.222	231.364	524.513	129	220	509	4718	1 : 7.77
VI	141.257	212.158	508.437	130	202	493	4487	1 : 7.28
[2]VII	142.292	192.951	492.365	131	183	478	4256	1 : 6.79
VIII	143.322	173.745	476.288	132	165	462	4025	1 : 6.31
IX	144.357	154.539	460.212	133	147	446	3794	1 : 5.84

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[1] When ship is under steam the following quantities should be added to determine the daily ration for each man of the engineer force (Table X, allowing 5 per cent. for waste).—Eaten—protein 40.11 grams, fat 25.77 grams, carbohydrates 132.28 grams; digestible—protein 336.90 grams, fat 24.48 grams, carbohydrates 128.31 grams; fuel value, 918 calories.

[2] The usual ration.

TABLE XII.

COMPARISON WITH PROPOSED DIETARY STANDARDS AND WITH SOME TYPICAL DIETARIES.
(Quantities per man per day.)

DIETARIES	Eaten			Digestible			Utilizable fuel value cals.	Nutritive ratio 1:
	Protein gm.	Fat gm.	Carbohydrates gm.	Protein gm.	Fat gm.	Carbohydrates gm.		
STANDARDS (Healthy man weighing 150 pounds)								
1. Very hard muscular work (Atwater)	175	(a)	(a)	161	(a)	(a)	5500	7.2
2. Hard muscular work (Atwater)	150	(a)	(a)	138	(a)	(a)	4150	6.2
3. Hard muscular work (Voit)	145	100	450	133	95	437	3270	4.9
4. Moderate muscular work (Atwater)	125	(a)	(a)	115	(a)	(a)	3400	6.2
5. Moderate muscular work (Voit)	118	56	500	109	53	485	2965	5.5
6. Light to moderate work (Atwater)	112	(a)	(a)	103	(a)	(a)	3050	6.1
7. Sedentary work with exercise (Atwater)	100	(a)	(a)	92	(a)	(a)	2700	6.1
8. Without muscular exercise (Atwater)	90	(a)	(a)	83	(a)	(a)	2450	6.1
9. Active life, plenty of exercise (lawyer, doctor, chemist, etc.), Chittenden, estimated maximum	70	(a)	(a)	60	(a)	(a)	2500	. . .
10. Athletic work, estimated maximum (Chittenden)	82	(a)	(a)	70	(a)	(a)	3000	. . .
TYPICAL DIETARIES.								
11. U. S. Navy (sea ration)	138	269	556	127	256	540	5180	8.7
12. U. S. Navy (fresh provisions)	145	135	444	134	129	431	3563	5.3
13. U. S. Navy (usual)	142	192	492	131	183	478	4256	6.7
14. U. S. Navy, engineer force, (steaming watches)	182	218	624	168	207	606	5174	6.3
15. Bicycle racers (New York, Atwater)	186	186	651	171	177	631	5005	6.0
16. Rowing clubs (New England)	155	177	440	143	168	427	3955	5.6
17. U. S. farmer (Atwater)	97	130	467	89	124	453	3415	8.2
18. U. S. mechanic (Atwater)	103	150	402	95	143	390	3355	7.5
19. U. S. laborer (comfortable circumstances)	120	147	534	110	140	518	3925	7.6
20. U. S. professional men (lawyers, etc.)	104	125	423	96	119	410	3220	7.1
21. Fruitarians (Atwater)	50	102	237	43	92	225	2055	10.0
22. Japanese Navy (usual or average) (b)	126	56	607	116	53	589	3430	6.1
23. French Navy (average) (c)	170	34	524	156	32	508	3078	3.7
24. French Navy, engineer force (c)	184	35	608	169	33	590	3407	3.9
25. British Navy (average) (d)	127	110	601	117	104	583	3891	7.2
26. British Navy, engineer force (d) at sea	175	149	728	161	141	706	4938	6.6

(*a*) Fats and carbohydrates together with the protein to furnish the indicated amount of energy.

(*b*) The average weight of the enlisted man seems to be about 129 pounds. It appears that 10 per cent. of the rations are commuted and the money used in the purchase of food, The ration has been calculated from such information as was at hand, on the basis of no commutation and 10 per cent. allowance for waste.

(*c*) It is not clear that any allowance for waste was included in the data obtainable. Figures seem to be those of the ration in 1906, but it is probably the ration as issued and not as consumed.

(*d*) This service has a standard government ration that seems to have about the following usual value in nutrients as *issued* in time of peace: Protein, 102 grams; fats 88 grams; carbohydrates, 489 grams. The standard ration represents only 60 per cent. of the money value of the ration, 40 per cent. being commuted as a messing allowance which is "available, not only for expenditure on luxuries in the canteen, but also for taking up government provisions on board, in addition to the standard ration." Therefore, if the *entire ration* were computed on the basis of no commutation it would have about the following usual value in nutrients as *issued:* Protein, 170 grams; fats, 146.6 grams; carbohydrates, 815 grams. The canteen is conducted by contractors on the tenant system, and therefore at such loss to the men in nutrients as is equivalent to the contractors' expenses and profits over government charges in relation to the 40 per cent. of the ration commuted. If for comparison the table and galley waste and canteen profits be considered equal to 25 per cent., the percentage that has been assumed for waste in calculating consumption of food in the U. S. Navy, the British ration consumed would be about that given in the table: Protein, 127 grams; fats, 110 grams; carbohydrates, 601 grams. In this estimate the issue of 2 ounces of spirit daily to those over 20 years of age who desire it has been omitted.

In time of war the ration is increased by 1/4 pound fresh meat or 3 ounces preserved meat and at any time to men on duty at night, or doing heavy extra work, such as coaling, an additional but variable ration is issued having the following maximum: Protein 50 grams; fats, 41 grams; carbohydrates, 134. The engineer force is assumed to have that additional ration at sea.

The fuel value of the U. S. Navy ration has been computed from the total nutrients by using the following factors: For each gram of protein 4.0, of fat 8.9, and of carbohydrates 4.0 calories. Those factors have been selected because they seem to be the results of probably the most reliable research and, as applied to food ingested, to give a closer approximation than others to the amount of available or utilizable energy in an ordinary mixed diet. They are, however, regarded as general estimates resulting from approximate averages. Rubner's factors (4.1 calories per gram of protein, 9.3 per gram of fats and 4.1 per gram of carbohydrates) can be readily applied by those who consider them more satisfactory. The total nitrogen and total carbon have been calculated on the basis of 16 per cent. nitrogen and 54 per cent. carbon for protein. 76.5 per cent. carbon for fat and 43.44 per cent. carbon for carbohydrates. The amount of carbon in protein is often, and perhaps properly, considered to be 52.48 per cent. and that in carbohydrates 44.2 per cent. —all the carbohydrates being regarded as starch.

The nutrients actually available have been calculated from the total amounts actually eaten by employing the following percentages of digestibility: Protein 92; fats, 95; carbohydrates, 97. Those are considered to be the average percentages obtained by the body from the food of an ordinary mixed diet.

The amounts actually *eaten* are estimated from the amounts *issued* on the basis of an average loss of 25 per cent. from galley and table waste. This allowance for waste may be too large, but it is not regarded as much, if any, in excess on account of the large number fed at one time, the necessary custom of placing the same amount of food before each person regardless of the individual's weight or peculiarities, the difficulty in utilizing food left over and the lack of economy in preparing food. The 25 per cent. may also be regarded as including a factor of safety made necessary by the varying chemical composition of the food material, the same articles showing more or less wide differences in different purchases. This is especially true of fresh beef, in which the amount of fat varies greatly.

Rations may be commuted or issued in kind. The value of commutation for one ration is 30 cents, but the commutation of rations is a privilege, not a right, which is regulated by the Department or abolished in its general application. The present ration was devised for the purpose of making commutation unnecessary, for, while the object of commutation is to provide greater variety and some degree of adaptation to seasons and variations in climate, there was found a "commutation evil" in the difficulty of carrying out the law that funds received from the commutation of rations cannot be used for any other purpose whatsoever than the purchase of articles of food for the persons concerned.

In the Naval Act of June 29, 1906, the attempt was made with considerable success to provide so much variety that the loss of commutation would not be seriously felt. But later it was found that, although variety had been considered, the ration was lacking in elasticity. For instance, it provides that, if pickles, vinegar, molasses, spices, macaroni, and cheese are under-issued, for each ration of *all those articles* under-issued there may be issued certain quantities of sugar, or coffee, or vegetables, or fruit, or flour, or milk. But experience proved that all of the first-named items were usually under-issued with the single exception of cheese and, less frequently, sauerkraut issued in lieu of pickles. With a small commutation, the excess of cheese and sauerkraut could be paid for, thus allowing the issue of the substitutes, but with no commutation the substitution was impossible under the law. Thus, the wise provision for substitution would usually be of no use without commutation and, at the same time, the men would be deprived of the full value of the ration, as the under-issues reverted to the Government.

Such considerations led to the inclusion in the Naval Act of March 2, 1907, of the proviso that any article comprised in the ration may be issued in excess of the authorized quantity, provided there be an under-issue of the same value in some other article or articles. Under the degree of elasticity provided by that proviso, the Department abolished commutation of rations for enlisted men's messes (except chief petty officers' messes) on board ships and at naval stations. That order went into effect on July 1, 1907. Prior to that date the regulations limited commutation for the general mess to one-fourth the total number of rations.

Undoubtedly the present ration, as modified in 1907, is the only one the Navy has had that permitted the abolition of commutation without hardship. It is doubtful, however, whether, although there has been distinct gain in the method of handling money, there has not been some loss in other directions. When a ration is issued entirely in kind, there is a tendency for the catering to become a rather dull routine, inasmuch as there is less chance for administrative ability to display itself. With a degree of commutation there is, in a way, a competitive spirit between ships, and, as a matter of fact, many articles of food are prepared with more economy, better facility, and with better result ashore than on board ship. The opportunities ashore are better, and the cooks have more experience. This is seen in pies and cakes, for instance, and, on notable days, in ice-cream. It is probable that lack of commutation will practically eliminate those articles, at least in their best expression, and also the various prepared foods, which have value chiefly in the variety they afford. It is, however, true that ice-cream has never been much of a factor and is often of very doubtful purity. Nevertheless, when catering becomes a dull routine, there is a tendency to lethargy and slovenliness which are generally present when there is no competitive spirit.

Commutation of rations also allows entertainment in a small way of parties from other ships' companies. The abolition of commutation does not necessarily do away with such hospitality, but it tends to diminish it, in view of the difficulty of avoiding over-issues under such circumstances.

The trouble with commutation is one of financial administration. It has been suggested that that difficulty could be overcome by the expenditure of commuted ration money only with the approval of commanding officers and after competition in the market, payment to be made on an authorized form and full returns to be made for monthly audit in connection with a general mess cash statement. It is believed that a degree of commutation can provide additional elasticity, greater variety, and a sufficient quantity, and that it can be made to promote economy and general competitive efficiency. It also permits a better adaptation to climatic conditions.

The amount of each nutrient in the present ration is less than in the prior ration. The protein is about 5.9 per cent. less, the fat 5.5 and the carbohydrates 7.8. But, even after the large deduction for waste (Table XI), it is very evident, from comparision with so-called standard dietaries given in Table XII, that the present navy ration is amply *sufficient in* *total amounts of nutrients* to meet requirements of the service without reference to commutation. It is undoubtedly a very liberal ration, and the sufficiency is declared by the gain in weight of recruits and their improvement in physique.

Even with the issue of fresh meat and fresh vegetables every day, which is practically never the case (Dietary 12, Table XII), the ration exceeds that given by Voit for a man with hard muscular work, and approaches the Atwater standard under the same conditions, while the "Usual Navy Ration" (Dietary 13, Table XII) somewhat exceeds the latter standard in calories with but little difference in protein. The ration for the engineer force (Dietary 14, Table XII) contains more protein than the dietary prescribed by Atwater for a man with very hard muscular work, and differs little from it in fuel value; it also is much like that of the bicycle racers in New York, who were engaged for six days in a most exhausting competition representing a very abnormal expenditure of energy.

It may be stated, in passing, that the usual U. S. Navy ration, and the average U. S Army ration by law seem to have practically the same value, but that apparently the Army dietary in some garrisons is somewhat more liberal as the ration by law is supplemented by the products of the kitchen garden and by purchase from the "savings fund" which is made up of the sale of unused rations, and the profits of the "post exchange." In time of war the Navy ration, as might be expected, has distinct advantages in adjustment over that of the Army in the field.

It is difficult to compare the U. S. Navy ration with the navy rations of other countries except in more or less general terms, as often the information is either not available or is not sufficiently explicit. The amounts of nutrients in a ration as issued cannot be considered as all available because they are not all ingested, the question of waste being of much importance on a naval vessel and probably varying with methods of different nations and character of articles. A people obtaining much of its starch from rice will probably have a smaller percentage of waste in preparing food than one that obtains much of its starch from the potato, and calculations based upon average percentage of fat in fresh beef are subject to wider variations than those based upon olive oil or even other vegetable sources. It often is not clear in the published statements of rations, just what allowances have been made and there are often side lights to show marked variations in data of chemical composition and in methods of application.

In general terms, the U. S. Navy ration seems to greatly exceed the ration of any other navy in fats and fuel value. The nutritive ratio in foreign navies is generally much narrower and in not a few there is the expedient, doubtful from a work point of view, of obtaining carbon to some extent from alcohol, even by additional allowance to the engineer force. At any rate, that forms in many cases a characteristic difference in comparing the ration of our service with others.

There is another difficulty in the varying degree of availability of sources of food outside of the ration in sale from canteens. Private purchases from canteens having food for sale may greatly increase daily food supply. In all navies there is more or less addition made by private purchase, but in some navies the percentage from that source is much greater than in others. The bumboat is utilized by the men to increase the supply of fruit in the tropics and from most canteens not a little candy and some cake may be bought and also canned foods.

In our service, the canteen or ship's store was carried on with money donated by the crew and in abolishing commutation it will be of interest to note whether the function is enlarged and sales increased. Should that be the case, it would apparently indicate an increased burden on the men. In the canteens of our service no alcoholics are sold, and the small percentage profits were used to enlarge stock and, when that was sufficient, to defray expenses incident to the getting up of general amusements, such as minstrel shows and the like. The canteen is an influence to be considered in connection with the effect of the abolition of commutation of rations, as it is capable of providing a degree of elasticity in connection with the ration and of lessening the tendency of issue of food in kind to limit hospitality. It is now a government store.

In the Japanese navy marked changes were made in the ration in 1884. Prior to that date the admission rate of beri-beri was about 320 per 1,000 of force. It appears that commutation was general, and the ration as *purchased* is said to have contained about 109 grams of protein, 16 of fat, and 622 of carbohydrates. There seems to have been the usual trouble in supervision of expenditures and it may be regarded as doubtful just how much less food was consumed. In February, 1884, a change in ration and method was made and the material as *issued* contained about 140 grams of protein, 62 of fat, and 674 of carbohydrates, derived in much larger part from other sources than rice. In that year the admission rate from beri-beri was 127.4 per 1,000 of force, during the next year only 5.9, and since then generally less than 1 per 1,000. Their naval administration attributes the change to improvement in the ration, and the evidence, while perhaps not conclusive, is strongly in favor of removal of predisposing cause by that means. The long-continued comparative immunity, dating from a time when the specified change was deliberately made for the purpose of diminishing the admission rate of that one disease, does not appear as a mere coincidence, but strongly suggests the relation of cause and effect—it is immaterial from a service point of view whether it was merely the predisposing cause, as the effect is measure of value, and a crippled service became an effective one.

While the U. S. navy ration may be considered to conform with all requirements of the so-called standard dietaries, it should be recognized that all such standards are based upon insufficient data. The knowledge of nutrition is not sufficiently definite to permit entirely satisfactory conclusions. The standards are based in part upon experimental data and in part upon arbitrary assumptions. They may, therefore, be regarded as subject to revision as knowledge of nutrition accumulates and, in the meantime, the ration will give to each man all in amount that he should eat even from the point of view of degree of comfort from stomach distension. Still, the standards have been based rather too much upon what men consume under different circumstances than upon what they ought to consume.

Yet it should be remembered that a navy ration cannot be strictly based upon the undoubtedly correct principle that "the ideal diet is that combination of foods which, while imposing the least burden on the body, supplies it with exactly sufficient material to meet its wants"; for the navy ration does not relate to any particular individual, but to bodies of men made up of individuals who live under varying conditions and who under the same conditions differ individually in their requirements and in their ability to utilize the food provided. The ration also has relation to artificial standards among men of a similar class on shore, for the ration must tend to produce contentment and it must provide suitable and acceptable articles of sufficient bulk to produce the sensation of satisfaction that a good appetite and a good digestion demand, especially in a service depending upon voluntary enlistments. It is the lack of bulk, as well as of variety, that helps to make most emergency or condensed rations unsatisfactory from a hygienic point of view as well as from the enlisted man's point of view.

The appetite is at least somewhat lessened and the primary digestion weakened in the tropics, especially for fats which tend to interfere with digestion by undergoing acid changes. Thus, there is tendency to diarrhœa and a weakened alimentary tract. Not a little of the fat is in the meat issue, especially in salt pork, ham, and the like, and, if the appetites of men could be always trusted, would more often remain in great part unconsumed, especially in hot climates. Butter also represents fat that at table affords an opportunity to diminish fat consumption in accordance with appetite. But it will be observed from an examination of Table II that each issue of flour instead of bread increases the amount of fat owing to the amount of lard issued with it, some of which would undoubtedly be used in the making of pastry.

In the tropics, more than elsewhere, the supplies of fresh meat and of fresh bread (from shore) are often uncertain, and, as a crew is practically never on an every-day fresh food ration, the fat theoretically, if not practically, consumed will more generally there than elsewhere be far above 135 grams daily and even well above 192 grams, and the calories of the ration so consumed about, or even above, 4,256. It would certainly seem that the value of much of this fat could be expended to better advantage in the tropics in securing additional fresh fruit in which the allowance of the ration is too small for hot climates. The issue of fresh fruit is about 9 ounces, but a single orange will often weigh as much in the tropics and will not satisfy the daily cravings of a working man who subjected to tropical conditions is, or should be, instinctively desirous of diminishing the consumption of fat and of protein as represented by the ration.

It is, however, under such circumstances that the proviso of March 2, 1907, assumes a special value, for with reduction in issues the value of under-issues becomes available for over-issues in fruit or such other articles as may be desired. The change in under-issues in the tropics depends, however, upon the change in appetite and not upon any adjustment upon a scientific basis. Yet in the tropics there is an increased desire for fresh fruits and fresh vegetables with a tendency to lessen the consumption of fats and protein, and thus there is a degree of automatic adjustment. And rapid changes in diet are not well borne, while, with sudden change of climate, the appetite for fresh fruit in hot weather is often too great, with the probable exception of the orange, and in many localities the consumption of uncooked fresh vegetables is decidedly unsafe.

From experimental data it does not appear that carbohydrates when ingested cause a rise in the production of heat, but it seems that, with a high external temperature, even a small quantity of protein causes a considerable rise in metabolism and that the total heat production reaches its maximum rather quickly. During hot weather a diminution in the protein intake makes for more comfort by decreasing heat production, and this also obviates necessity for the corresponding increase in perspiration by the evaporation of which the body seeks to dispose of its surplus production of heat. A low protein intake in winter leads to discomfort from chilliness. The indications seem to be rather plain that the natives of cold climates cannot afford to continue to use quite the same diet in the tropics that they utilize to advantage at home, and if it be conceded that at home the consumption of protein is ordinarily too great, the advisability of its reduction in the tropics becomes still more apparent.

In this connection the relatively negative effect of carbohydrates on heat production becomes of value because they are also the greatest sparers of the proteid of the body, exceeding fat in that respect. Carbohydrates have the greatest effect in diminishing the tendency of the body to use its own proteid and, therefore, the greatest effect in diminishing the wants of the body for protein in its intake. The apparent value of fat in an ordinary mixed diet is to relieve the intestine from excessive carbohydrate digestion, but it is not able to carry that function so far in the tropics as it more readily leads there to digestive disturbances.

In the reduction of protein in the tropical dietary it is comforting also to recognize that the energy of muscular contraction comes preferably from the oxidation not of the nitrogenous or proteid constituents of the muscles, but of the non-nitrogenous components of the tissue. Mechanical work does not increase proteid metabolism. Without going to extremes, that is, giving due weight to the individual claim for an ample diet, it may be considered that Voit's standard (Dietary No. 5, Table XII) is a more suitable one *for the Navy in the tropics* than the usual Navy ration (Dietary No. 13, Table XII). There is certainly no danger of nitrogen hunger from lack of nitrogen in such a diet; on the contrary, there are some reasons for thinking the protein may be in excess of body requirements.

Man's metabolism is undoubtedly influenced by moisture and temperature and in the tropics he tends to approach the minimum requirement of energy from food. Many temporary residents in the tropics suffer from lack of energy that should be derived from food, but that is not due to scarcity of food put before them, but either to lack of appetite or to inability to utilize food ingested, which may be incident in part to the lack of chemical regulation of metabolism. It is not clear just what part the light of the sun or its many non-luminous rays may play in this connection, but constructive metabolism wanes under tropical conditions of unusual heat and moisture and perhaps excessive light, and it certainly cannot be stimulated by imposing the additional burden on the body of food in excess of its requirements or ability to utilize—such a burden may be, in some cases, one of the factors in the production of the anæmic and neurasthenic conditions.

In the search for something to cause improvement in appetite and to increase ability to utilize food, alcoholics have been brought forward and, at times, their liberal use advocated. It is an expression of desire for flavor and stimulation, and introduces a nice question of balance in certain cases. The question has been very much clouded by the fact that the body can utilize a small amount of alcohol daily, about 72 grams, in the production of heat, when taken in divided doses. The food value, while generally considered in theory, is rarely considered by users and the desire for stimulation can readily cause that liberal use which goes beyond the relatively small ability of the body to utilize.

In using alcohol there is a certain consciousness of effect that places the material, as a rule, outside of the sphere of food, and as a drug its usefulness has to be measured in the same manner as in the case of other drugs. It has long been apparent that, where muscular work is to be done, it fails, inasmuch as the primary increase lasting perhaps 40 minutes, though often less, is followed by a decrease during two hours. There is a depression from which the body must recuperate. An additional amount of sugar permits increased work not characterized by subsequent depression. The effects of alcoholics upon the normal stomach must be at most valueless, but when there is lack of acid secretion they improve appetite and, *when the day's work is over*, may tend to more contentment or less worry or more companionship. Under those circumstances, beverages containing small percentages of alcohol and large amounts of water are sufficient, certainly in amounts within the oxidizing power of the body.

But, as a drug, alcohol is capable of producing the varying effects characteristic of other drugs. The itching or other discomfort about the anus, or the stools of unusual odor, or the early awakening, or the feeling of depression, or the interference with sleep, perhaps some hours after ingestion, or the eczema about the hands, which some experience even after the moderate use of alcoholics, are a few of the signs, especially in the tropics, that alcohol is being employed by the wrong person. In some of these cases there seems to be a degree of autointoxication that certainly is not in line with the attempt to improve general condition or to prevent deterioration. And intemperance in the tropics is certainly no better than in other climates, though many consider it to be worse.

A study of the cause of much of the consumption of alcoholics by temporary residents in tropical countries seems to come within the domain of psychology. The total abstainers have been thought by some to develop a larger percentage of cases of nostalgia, or of quiet discontent or moodiness, with tendency to solitude. Along that line may be found at times a nice question of balance which does not seem, however, to apply to the general ration of a naval force, or of workers and early sleepers among whom there is no division of amusement aboard ship associated with difference of habits in this respect.

The experiments of Chittenden and Folin seem to show that the consumption of protein in general is much too great. Dietaries 9 and 10, Table XII, have been estimated as the maximum allowance of protein determined by the former as permissible under the circumstances indicated. It appears that such dietaries cause increased muscular and, perhaps, mental powers, and an increased sense of well-being—a mental state much desired in the tropics subsequent to that first period of residence during which a stimulating climatic effect appears in some. It is claimed on scientific grounds, and as the result of careful work, that such dietaries are even more than sufficient for the establishment of continued nitrogenous equilibrium with a marked and very desirable diminution in nitrogenous waste products and with a state of continued full efficiency.

The amounts of protein given in Dietaries 9 and 10 are in excess of those that were apparently found necessary in the large majority of cases. The claim is that one-half of the protein in Voit's dietary No. 5 is generally sufficient, leaving the appetite practically free in regard to total fuel value (fats and carbohydrates). In this connection it is interesting to make comparison with Dietary No. 21, Table XII. It may be doubtful whether there is sufficient comfort from such dietaries in cold weather, but, to say the least, they tend to emphasize the increased comfort obtainable by the average man from reduction of protein intake in hot weather or climates.

The work of those investigators and of others, considered in relation to the other so-called dietary standards, certainly emphasizes, what has already been stated, that the knowledge of nutrition is not sufficiently definite to permit entirely satisfactory conclusions, and that, as a rule, the standards are based too much upon what men consume and too little upon knowledge of what they ought to consume. Yet, those dietaries very low in protein have been evolved from a system of balances—the lowest nitrogen intake to balance the essential nitrogen output of the body. It may be regarded as book-keeping applied to a business in which the smallest surplus or reserve is allowed, or a limited mathematical application in relation to processes about which much is to be discovered, the essential cause of metabolism, though recognized as resident in the cells of the body, being unknown. There are undoubtedly different planes of nutrition depending upon different amounts of reserve supply of food within the body, and these dietaries low in protein assume that in the long run it pays to keep the nitrogen reserve at a minimum, an assumption not necessarily true, especially as it is recognized from experience that in training it does not pay to attempt to keep the body for a long time in the highest state of efficiency.

Moreover, there are various side lights on this question which throw considerable doubt upon a simple nitrogen balance as the sole measure of the efficiency of a diet in the long run. In the tropics the natives, while not showing the climatic discomfort of temporary residents, are much more prone to certain diseases, including beri-beri. In the Japanese navy tuberculosis has been more common than in other navies, and in that service beri-beri is considered to have been eliminated by a more liberal protein diet—a diet which, in amounts consumed, is much like that of Voit's dietary No. 5. But of course the relation of beri-beri, an infectious disease, to a low protein intake is disputed, and, indeed, the disease has been ascribed to the *character* of the carbohydrate intake which in the form of rice has been influenced by an abnormal condition of that grain. In the treatment of tuberculosis much of the success seems to have been due to increase in protein intake in readily digested forms.

On board ship in the tropics, a *large number maintain* appetites beyond these low protein dietaries and, in the absence of more definite knowledge, it does not appear advisable to introduce discontent for the purpose of satisfying conditions that have been evolved from incomplete data. But, undoubtedly, the disadvantages of overfeeding have been demonstrated and an overfed man in the tropics is especially uncomfortable, more clearly an object of commiseration, and more apt to become a subject for rehabilitation than one who keeps within his physiological limits.

It is common knowledge that monotony should be avoided in a diet. Such monotony by psychical influences affects secretion and digestion. It does not seem to be so much appreciated that thorough mastication and insalivation cause a much more complete utilization of food and tend to satisfy the appetite with less food, especially animal food. In the tropics it is the utilization of food that is often much in question and it is also in that climate that the necessity for variety in diet and for articles readily digested assumes more than usual importance.

The organization and administration of the "general mess" of the Navy, the duties of the commissary, the commissary steward, the cooks and the bakers, the establishment and administration of the ship's store, and the methods of preparing and cooking the Navy ration are found in the "General Mess Manual and Cookbook" issued by the Navy Department. The abolition of commutation of rations has served the very good purpose of emphasizing the necessity for better cooking in the Navy, and, in 1907, a school for cooks and bakers was established at the Newport Training Station. That school promises to be of lasting and increasing benefit to the entire enlisted force, and in time its scope will undoubtedly be enlarged to include a thorough investigation of the possibilities of the Navy ration under ship conditions. The ration includes a large number of articles and the combinations and methods of preparation can be greatly multiplied to advantage. In time every commissary steward and ship's cook of whatever rating will have passed through the school and have been tried out there. The organization of the force at the galley should become in its line as complete and efficient as that of a gun division at its work. Everything done in order and at the proper time should bring about a proper cutting of quarters of beef, proper preparation and cooking, cleanliness, and the service of hot and not merely warm food.

The commissary steward who may be in charge, under the commissary of the general mess, has most important duties to perform, and unless he performs those duties properly it is more than possible, in spite of the liberality of the Government, to have dissatisfaction on any particular ship. He makes out the daily bill of fare, sees that the necessary stores are issued, directs the manner of their preparation, inspects food before it is served, sees that the galley and all galley utensils are kept in proper condition, keeps the commissary advised of the needs of the mess, and in case fresh provisions or any stores are, in his opinion, of inferior quality and unfit for issue, reports the matter to the commissary. The man who has such work to perform on a ship has a close relation to the degree of satisfaction or of dissatisfaction that may prevail on board. And, while work is essential for contentment, proper food is essential for satisfactory work.

In more intimate and practical relation to the every-day duty of the naval sanitarian are questions of quality of food-stuffs rather than their quantity and arrangement as expressed in the ration and evolved from their chemical composition and nutritive value. It is well recognized throughout a naval service that health and discipline are associated with quality of food material, and therefore there is much effort made to secure, in purchases, food-stuffs of good quality and to have a general recognition on ships that the disposition of those in authority is to have only food of good quality consumed.

This desire finds expression in numerous regulations under which a number of individuals, including members of the crew, are made to take part in food inspection. *Commanding officers* are required to see that the *medical officer* frequently inspects the fresh food purchased for the crew, and the fruit and other articles of food or drink offered for sale alongside, and, when possible, to require a *junior officer and one or more petty officers* to be present when rations are served out, who shall report if there is any cause for complaint in quantity or quality. The *executive officer* of a ship is charged with the duty of regulating the bumboats and all traffic alongside or on board, and is required to be watchful that no unauthorized articles for the crew, unwholesome fruit or food, or improper articles are introduced on board. The *medical officer* must, when required, inspect the provisions of the crew and report any that are unsound or liable to cause illness. He must also report any want of care or cleanliness in the preparation of food for the crew or any instance that may come to his knowledge of neglect in regard to it, which may be injurious to health. He must examine the contents of boats, attending the ship with articles of food or drink for sale, and report if the articles are, in his opinion, suitable to be consumed as food or drink. If any of the crew object to the quality of the provisions issued to them, the pay officer is required to request a survey. If, in the judgment of the surveying officer, the provisions are of proper quality they are issued if the captain approves, but if the provisions are not approved by the surveying officer others of better quality, if on board, are at once issued in their stead. Thus with so many persons interested in the subject of food-stuffs and with a generally recognized disposition to avoid any reasonable cause for complaint good results are very generally secured from the medical officer's point of view and the crew's point of view.

It may be said that practically all hands on a ship should be and are interested in having on board no food that is unfit for consumption. It is clear, however, that in view of the conditions incident to storage on the ship's themselves, the duty a ship has to perform in all climates, and the relatively large quantity of provisions necessarily kept on board, there is a considerable percentage of loss from deterioration with chances of injury to health. It is also obvious that there are certain materials that tend to more rapid deterioration than others even among the articles comprising the sea ration, such, for instance, as butter.

The wild heat on the modern ship when operative, as in storerooms containing steam pipes, is opposed to mustiness as a result of dampness, but may facilitate a number of chemical changes and the multiplication of certain forms of life that develop in or live on various forms of vegetable foods, such as beans, flour, and navy biscuit; and dampness is also not lacking in every storeroom. The sea ration also necessitates the keeping on board of meats prepared in special ways, such as tinned salmon, pickled or salt fish, or fresh corned beef and smoked sausage. And among the fresh meats green sausage has a place. There is also much fresh meat received from the cold storage of supply ships and the cold storage plants of the cruising ships themselves have now become a marked feature of naval life. Questions of packing and storage are therefore not infrequently under consideration in relation to the general or routine care of food and in relation also to the use of preservatives, and food inspections are not uncommon.

Meat inspection is a subject of sufficient extent to fill a book. From a sanitarian's point of view, all animals intended for food should be subjected to inspection before slaughter as well as after, and it is not considered possible to arrive at sufficiently satisfactory conclusions for all purposes simply from an inspection of the carcass after it has been dressed. It is dressed fresh meat, generally in the form of quarters, that comes under the observation of those on ships. This question is, however, losing much of its emphasis in view of the precautions taken by a large number of countries and even municipalities to prevent meat unfit for consumption from passing into the possession of consumers.

In our own country, government inspected meat is largely in evidence, and in our service the records do not show trouble from fresh meat as received from supply ships, which, however, should always carry from home ports government inspected meat, and that also should be the aim of contracts. When there has been trouble, it has resulted from changes in the meat subsequent to its receipt and often from lack of protection during the thawing of frozen meat in tropical climates.

Quarters of meat as they are received from supply ships have, as a rule, been subjected to such low temperatures that it is impracticable for a time to divide them into suitable cuts for cooking, and frozen meat may delay meals by the additional time required in cooking. This situation has often led to the exposure of such frozen meat for hours in a warm climate, and if during that period it is not well protected, especially from flies, it may well acquire properties responsible for acute symptoms after ingestion. Frozen meat often shows a diffuse redness when quickly thawed, and it is possible for it to develop areas having a gelatinous appearance.

No fresh meat should be received on supply ships or should be brought on board from cold storage on shore unless it is provided with the usual cloth or clean muslin covering. Meat unprovided with such covering requires very careful handling and should never be allowed to thaw in the open but should be carefully protected by tarpaulin or otherwise. All quarters taken out of a cruising ship's cold storage as an issue can, as a rule, be at once cut, being chilled meat, and subjected to the cooking required; but in case of meat recently received from supply ships, any thawing away from the fires considered necessary after cutting, which is to be done as soon as practicable, should be under water in warm climates in port.

To permit meat to be subjected to the influence of flies is dangerous, and in tropical ports, either from their influence or from atmospheric influences, bacteria may multiply in the meat with great rapidity and generate poisonous substances, as ptomains or as toxalbumins, that have affected a large percentage of a crew, causing toxic symptoms, among which diarrhœa has a marked place. When the cloth is removed from cold storage or chilled meat, there may be a slightly unpleasant odor, but generally it is a surface odor, and when the meat is cut it is found to be good.

A distinction, is made between frozen and chilled meat, as the latter, having been kept a few degrees above the freezing-point, although it also has a bright red color, has its tissues less altered. In frozen meat the tissues are hard and the fat is usually unnaturally white, while in chilled meat the fat is apt to be pinkish from escape of the meat juices.

In tropical countries it is generally difficult to obtain good meat killed in the locality or to preserve it in cold storage for any reasonable time after it is brought on board. Immediately after slaughter all beef is brownish red and flabby and ordinarily in the tropics it has to be brought on board before it has set or is firm. The rigor mortis in an ordinarily cool climate is marked in twelve hours, but in the tropics the death stiffening is delayed and the meat reaches the cold storage of a ship after much exposure to the sun and often to dirt or to the dirty water of a boat and before the heat is out of it. Such meat will probably spoil in cold storage.

In the quarter of a bull the flesh is stringy, darker in color than in the ox, and has little or no exterior covering of fat. The flesh has an odor peculiar to itself and the connective tissues are not distinctively infiltrated or intermixed with fat as to have that well-known marbled appearance always found away from the limbs in a well-fed ox. This lack of fat gives the quarter of a bull a darker and redder appearance as a whole than in the case of an ox. In the forequarter of a bull the neck is large, while in the ox the neck-piece is so very much smaller or thinner that it can be readily grasped without using the whole hand.

In the female hindquarter the udder is present or a triangular space with apex forward has been left by its removal. In the heifer the gland is poorly developed and surrounded by a layer of fat. In an old cow the flesh is stringy and dry. In good meat the connective tissue when exposed should glisten and be rather moist, but there should be no dropping of moisture *or show of mucilaginous fluid or of pus.* The flesh of a calf is always pale and lacking in consistence. It has a distinctive odor and soon becomes sour. The muscular tissue of the ox is firm or slightly elastic and tolerably dry, and it should have a pleasant aroma. The knowledge of good meat is derived, however, from observation rather than from any possible description, inasmuch as terms employed are necessarily more or less relative. The flesh of very young animals tends to produce diarrhœa and should never be purchased.

The following diagrams illustrate the general methods of cutting sides of beef, veal, mutton, and pork, but the terms used for the different cuts vary in different localities and the lines of division vary somewhat in different markets.

In beef the neck-piece is frequently carried further back. The "plate" may also include the brisket, cross ribs and navel, and the terms "brisket end of plate" and "navel end of plate" employed. Those are the parts very frequently appearing as corned beef. The ribs have three cuts, first, second, and third, the last being next the chuck and the least desirable. The loin nearest the ribs makes "short steak" and the other end is the sirloin. Between the "short steak" and the "*sirloin*" is the portion containing the largest amount of tenderloin or muscular tissue lying within the loin. Porterhouse steak is a common term in designating that cut. It is quite common in cutting such steaks to include a large undesirable portion from the flank and thus obtain a higher price for it than it is worth. The flank and rump are also frequently corned. When the meat is cut to include some of the loin the resulting steak is called rump steak. In the round, that on the inner side is the better or more tender. This is called the "top round."

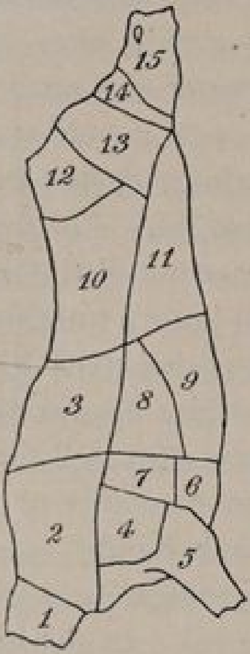


FIG. 56.

U. S. Department of Agriculture.
(Farmers' Bulletin.)

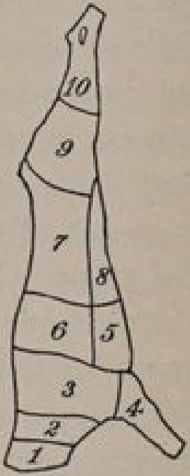


FIG. 57.

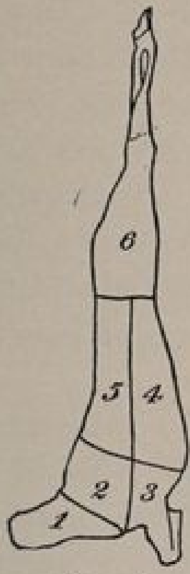
FIG. 56.—Diagram of cuts of beef. 1. Neck. 2. Chuck. 3. Ribs. 4. Shoulder clod. 5. Fore shank. 6. Brisket. 7. Cross ribs. 8. Plate. 9. Navel 10. Loin. 11. Flank. 12. Rump. 13. Round. 14. Second cut round. 15. Hind shank.

FIG. 57.—Diagram of cuts of veal. 1. Neck. 2. Chuck. 3. Shoulder 4. Fore shank. 5. Breast. 6. Ribs. 7. Loin. 8. Flank. 9. Leg. 10. Hind shank.

In the cuts of pork, the back cut is nearly clear fat and is used for salting as in "salt pork." The middle cut is used for bacon and "lean ends" salt pork. The belly often goes into sausage as does also the fat taken from the hams and shoulders. Leaf lard is the kidney fat.

In salting beef there is a strong tendency to use inferior parts or inferior meat that is already showing some putrefactive changes. Salt meat also tends to become extremely hard or tough when it has been in brine too long. The salting is also not always well done, or there may have been leakage of brine leaving the meat unprotected. It then decomposes and becomes moist, slimy, and mouldy on the surface. A skewer or knife may be pushed into the flesh and on withdrawal examined for odor of putrefaction. It is best when salt meat is under suspicion to cut down to the muscles about the bone, as it is there that the evidence is most pronounced.

There has been much discussion of late over the use of borax and boric acid and salicylic acid as preservatives. They have been considered when taken for long periods, even in small amounts, to cause disturbances of appetite and digestion. Such preservatives are no longer used in the Navy's supplies.



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of Agriculture.
(Farmers' Bulletin)

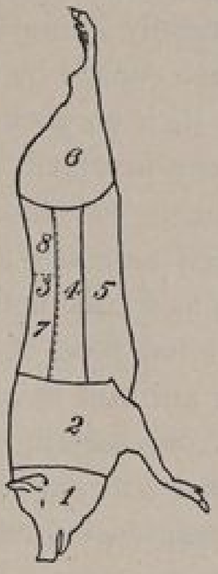


FIG. 58. FIG. 59.

FIG. 58.—Diagram of cuts of lamb and mutton. 1. Neck. 2. Chuck. 3. Shoulder. 4. Flank. 5. Loin. 6. Leg.

FIG. 59.—Diagram of cuts of pork. 1. Head. 2. Shoulder. 3. Back. 4. Middle cut. 5. Belly. 6. Ham. 7. Ribs. 8. Loin.

Many of the evidences of putrefaction are common knowledge. This change in meat is due to microbic action with the formation of products more or less poisonous and having in many cases special odors. Fortunately, those formed in the first stages are not *usually* very poisonous. The substances are, however, more or less variable, but many are destroyed at a continued cooking temperature of 160° F., and therefore toxic symptoms are more apt to be associated with flesh taken raw, as in some sausages or in food not well cooked or not well kept *after cooking*. However, many of the ptomains remain active after having been subjected to a temperature above even the boiling-point of water.

Nevertheless, decomposing flesh is often eaten without apparent disorder, but there is always danger of accident, and it is not safe to have putrefying flesh consumed, and ordinarily only those who have cultivated a certain taste can ingest decomposing meat that has acquired the flavor and odor usual in such cases. Nevertheless, there is often more danger in food that does not give the warning common in ordinary putrefactive changes. Certain conditions under which food has been kept often make the early stages of decomposition, before there is odor or change in appearance, especially dangerous, substances being then formed that may be very poisonous and which later would pass into harmless products.

Undoubtedly cooking destroys many of those products, but some of them are formed under uncertain conditions *after cooking*, and there are some formed at times that are not rendered inert by high temperature. It has seemed that meat kept at a suitable temperature in damp unventilated localities is especially liable to become dangerous. Most of the trouble has generally been caused by sausages, corned beef, potted meats, canned food, and pies, such as pork-pies. In each of these cases some special bacillus is usually involved, and quite often the anaerobic *B. botulinus* in sausage or the *B. enteritidis* of Gærtner. Occasionally the *B. proteus vulgaris* has been assigned as the cause in poisoning from pork. The common factor, as a rule, is the keeping of material under insanitary conditions. In canned food the majority of cases of poisoning are due to mineral poisons and not to ptomains.

In the decomposition of meat a host of substances are formed. The flesh becomes soft and more fluid and paler, tending later to become greenish. A disagreeable odor develops that may be appreciated earlier by pushing into the meat a skewer or a knife and determining its odor. A person who frequently handles meat should be the best judge of its general quality and freedom from the usual signs of decomposition. On a ship the responsible parties should realize that that fact is appreciated when there is reasonable cause for complaint.

Either cooked or raw meat may have a phosphorescent appearance in the dark. It may appear two days after slaughter and may continue for a week. It may even be observed at times in meat that has been kept about the freezing-point, but it is more apt to appear at a temperature of about 65° F. The appearance is caused by harmless bacteria and is not often observed in meat unfit for use on account of decomposition.

Fresh meat showing moulds is very generally unfit for use and, as a rule, will give signs of decomposition. In the case of smoked ham, a mouldy surface is not of much consequence, as scraping and cooking will ordinarily leave the meat fit for use.

There are a large number of animal parasites associated with meat. Of these the *cysticerci* and *trichina spiralis* have attracted most attention, as being directly responsible for trouble in individuals consuming the flesh containing them in a live state. It is interesting to observe that the records of the Navy for a number of years fail to show record of a case

Natural Appearance of Cuts of Healthy Beef

Beef is the most important of any of the meat of flesh foods. To be able to judge of its freshness and freedom from desease is of great practical value. The following colored plates show the appearance of some of the principal cuts of beef in the proper condition for cooking. By comparing the appearance of the beef bought in all markets with these plates it is possible to form a sound judgment of their suitability for consumption.

These seven Plates are
reproduced by courtesy of
Armour & Co., Chicago

Beef Tenderloin

Beef Sirloin

Beef Ribs—Regular Cut

Beef Ribs—Spencer Cut

Sirloin Butts

· Beef Rib

Beef Loin

of trichinosis in the force afloat. During the ten years 1895–1905 there were two cases returned with one death, but they resulted from consumption of pork fattened and slaughtered in some spirit of economy in the direct locality ashore where the disease was contracted. On the other hand, during the same period there were probably 150 cases of tænia, but that is an average admission ratio of only about 0.57 per 1,000 of force per year, and the cases were rarely if ever contracted on the ships, but, as a rule, on shore when on liberty as a result of tendencies most marked in certain nationalities to eat certain varieties of uncooked sausage when it is procurable. These results afloat have not been due simply to special care in the inspection of meat, but also to the fact that the food has been thoroughly cooked.

The condition in animals due to the presence of cysticerci in their organs and flesh is called measles. There are different forms of these parasites, but in meat inspection on a ship the cystic form of the *T. saginata* found in the ox and of the *T. solium* found in the pig are those of interest. When these parasites are present in flesh they vary greatly in number in different cases, and when in large numbers, as throughout the body, the inspection presents few or no difficulties.

The cysts vary in size, but may be considered in general terms to be ordinarily about that of a dried pea or bean. At one point of the cyst will be seen a small nodule that contains the head or scolex. If the cyst is pressed on each side of the nodule, the head can be obtained for microscopic examination. In all cases the diagnosis should be made from examination of the head, and the hooklets should be seen in the parasite of the pig.

In the pig and ox the common sites are the tongue, muscles of mastication, neck, and chest. There may be only a few cysts or even only one or two, and doubtless such cases not infrequently pass unnoticed. This is not considered to be of so much importance in beef as in pork, inasmuch as the *T. solium* may in cystic forms, as the *cysticercus cellulosæ*, invade the muscles of man. This difficulty of inspection, incident to small number of cysts in evidence, accentuates the necessity for thorough cooking of pork. They are even destroyed in a few minutes by a temperature well under 160° F., the true cooking temperature. Pickling destroys the parasites in three weeks, but any pickled or salted meat has to be well cooked.

The *trichinæ* are found in the flesh of the pig, especially in the muscles of the shoulder, loin, tongue, cheeks, and in the intercostal muscles. They are apt to be near the insertion of tendons, and the fat is also often invaded. When calcification of the cysts has occurred they can be readily made out by the naked eye, but then the cysts are several months old, and prior to that the diagnosis generally depends upon chance microscopic examination. The coiled worm has to be seen in all cases for the diagnosis to be made. A magnification of 25 diameters is ample and a smaller magnification is sufficient. The work is generally facilitated by clearing the muscle in a thin slice, by an immersion of a few minutes only in dilute liquor potassa (1:8). If then the worm is not clearly seen as the result of extensive calcification of the cysts, a little dilute acetic acid may be employed. It seems to take two or three months for all the trichinæ in a ham to be killed by salting. In meat that has been thoroughly cured the trichinæ may be considered innocuous. The pork in sausage is, however, rarely properly salted, and it is certainly not uncommon to find on shore sausage served that has not been cooked through and through. In cooking fresh pork there should be no red flesh left in the center, and when hog meat is boiled it should be plunged into boiling water and not less than 20 minutes per pound allowed for the cooking.

In cooking, the texture of food-stuffs is altered. Their appearance and flavor are altered, rendering them more pleasing to the eye and to the palate, and thus with mastication stimulating the glandular secretions so prominently associated with primary digestion. The important rites of cooking were instituted to make food more agreeable, but it is evident that at no time in human history was a greater advance made in sanitation, as the process renders lifeless any parasites or pathogenic organisms the food-stuffs may harbor. Not only is this true of the parasites mentioned above, but also even in relation to water in time of typhoid fever extensions. Outbreaks of typhoid fever resulting from the consumption of raw milk and of raw oysters, and the propagation of cholera by the use of raw vegetables in the ports of countries where human manure is used on the fields are also cases in point.

It has not been uncommon on our ships to consider the appearance of typhoid fever due to fresh milk consumed on board. Formerly such milk was purchased with commuted ration money, but since June, 1906, fresh milk has been a part of the ration, and, considering the conditions under which much of the milk is gathered and transported, it is more than doubtful whether in view of numerous ports visited it has been consistent to carefully distill all the water used as such for drinking and at the same time practically admit milk indiscriminately. Fortunately, the allowance, without regard to under-issues in other articles, is only two ounces per man per day. Infected milk is as difficult to determine as infected water, and the commonest ways of sophisticating milk are the removal of cream and adding water of unknown character.

In our Navy fish is a part of the regular ration. This finds expression chiefly as salt cod, salt mackerel, and canned salmon, but on Fridays there is a tendency to issue one and three-quarter pounds of fresh fish in lieu of that much fresh beef whenever the issue is obtainable. There is also among each crew a certain number who find pleasure in using fishing lines whenever practicable. Since steam became the motive power, trolling at sea has become much less common than in the days of sailing vessels, but when at anchor, especially perhaps in the tropics, the fishing line is much in evidence. A naval vessel is also provided with a seine, and hauling the seine is, in some localities, one of the prominent amusements. It, therefore, appears that the fish occupies a somewhat prominent place in naval life. In this connection it is fortunate that of all the fishes only a small percentage are capable of producing deleterious effects upon man either as poisons when eaten or as producers of poisonous wounds. It, however, becomes important from the point of view of naval hygiene to consider the subject of poisonous fishes, as in all navies, including our own, there have been occasions when considerable numbers of men have suffered severely as a result of the toxic properties of fish consumed and some lives have been lost from this cause. It is also not unknown when hauling seine for one or more men to receive toxic wounds of considerable gravity.

In considering fish as food it becomes quite evident that while cases of poisoning may occur in any locality they are much more common in the tropics. This seems to be due in part to the more frequent appearance of poisonous fishes in tropical waters or warm seas, but undoubtedly many cases of poisoning from eating fish are of the ptomain variety incident to changes that take place after the fish have been taken out of the water. Certain kinds furnish a perfectly harmless food if eaten so soon as they are caught, but if allowed to remain even an hour or two uncooked their flesh spoils.

It also appears that some fish are poisonous only at certain seasons. The spawning season seems to be the one in which such fish are particularly dangerous. This is true, for instance, in the case of the poisonous anchovy found on the coast of Japan, which is especially or only fatal in its effects during the time from July to September. This fact may help to explain why the ovaries and testicles are the parts so often especially poisonous, as seems to be the case in some of the *Tetraodontidæ*. This also seems to explain why some fish poisonous when caught in some localities may be eaten in others without bad results. Yet it is not clear that this may not be frequently associated with the character of food available, or even with pathological changes, as it appears that at times the intestines, and especially the liver, contain the poison in greatest concentration.

While many of the fish that have reputations resulting from their poisonous qualities are more or less revolting in appearance, one cannot judge by general appearance those that are to be avoided, as some which are good-looking are unfit for food, and others which, to say the least, are unappetizing in appearance are harmless and good to eat.

Among the fish that are revolting in appearance and are at the same time very generally poisonous should be included the families *Tetraodontidæ*, or broad-nosed puffers; *Canthigasteridæ*, or sharp-nosed puffers; and *Diodontidæ* or porcupine fishes. All those fishes are generally designated by the enlisted force of the Navy as puff toads, inasmuch as when drawn from the water they are noted for their habit of filling the belly with air. In many of them the degree of inflation is quite remarkable and causes a comical appearance, the fish apparently trying to expand itself to the bursting point. That operation can often be stimulated by irritating their bellies, and, if thrown overboard while inflated, many of the varieties tend to float for quite a time, belly up, on the surface. The skin of those fishes is scaleless, but often more or less prickly, the porcupine fishes being of course noted in that respect. Spinous dorsal and ventral fins are wanting, the fins composed of soft rays; dorsal fin posterior, opposite and similar to anal; no ventral fins, pectoral fins short and broad, and gill openings small, placed close in front of pectorals. No additional description is necessary for their recognition as a class.

While interesting to the observer, they excite disgust, as a rule, when considered from the point of view of food. One should be as willing to eat a toad (frog). Yet they have been responsible for many deaths among sea-faring people, and it is said that in Japan some varieties have been used for suicidal purposes, especially the *fugu*. The flesh of all of them is ill-flavored and of many very poisonous. It appears that the ovaries and testicles are especially poisonous, and that therefore the older fish have much greater toxic properties than the young. This would also seem to indicate a relation to spawning. However that may be, a number of these fish are toxic at all times and all are to be avoided. Two men ate the liver of a Cape Town, South Africa, toad. One died in seventeen minutes and the other in twenty minutes.

Some variety of these toads can be found at almost any open anchorage. They, however, as a class particularly affect warm seas. Many of the most poisonous are only about five or six inches long, but some attain a length of fifteen inches or more. The following may be considered as examples:

Spheroides Spengleri.—A swell toad that inhabits the West Indies, north to Florida. It has been found at Tortugas, Key West, Garden Key, Tampa, Cuba, Martinique, and Porto Rico; also in the East Indies. It is much like *spheroides nephelus* and *spheroides marmoratus* which are also poisonous. In the *spengleri* caudal fin is always barred.

Spheroides Testudineus.—Length, a foot or more. An inhabitant of the West Indies, generally common; ranging north in the Gulf Stream to Woods Hole, common in Porto Rico, and found at Jamaica, Dominica, Puerto Cabello, and Brazil.

Spheroides Maculatum (sometimes called *Geneion maculatum* or *Tetraodon maculatum*).—The Cape Town, South Africa, toad. About six inches long. Has white belly with dirty yellowish spots and a deep brown or blackish back with irregular spots or streaks. It is not confined to Cape Town, having been found in the Indian Ocean, China, and New Caledonia.

Spheroides Sceleratus.—Tahiti; New Guinea; East Indies.

Tetraodon Aerostatus.—Tahiti; Guam; New Guinea; Japan; East Indies. One of the most poisonous in Japan.

Tetraodon Stellatus.—East Indies; Indian Ocean; Red Sea.

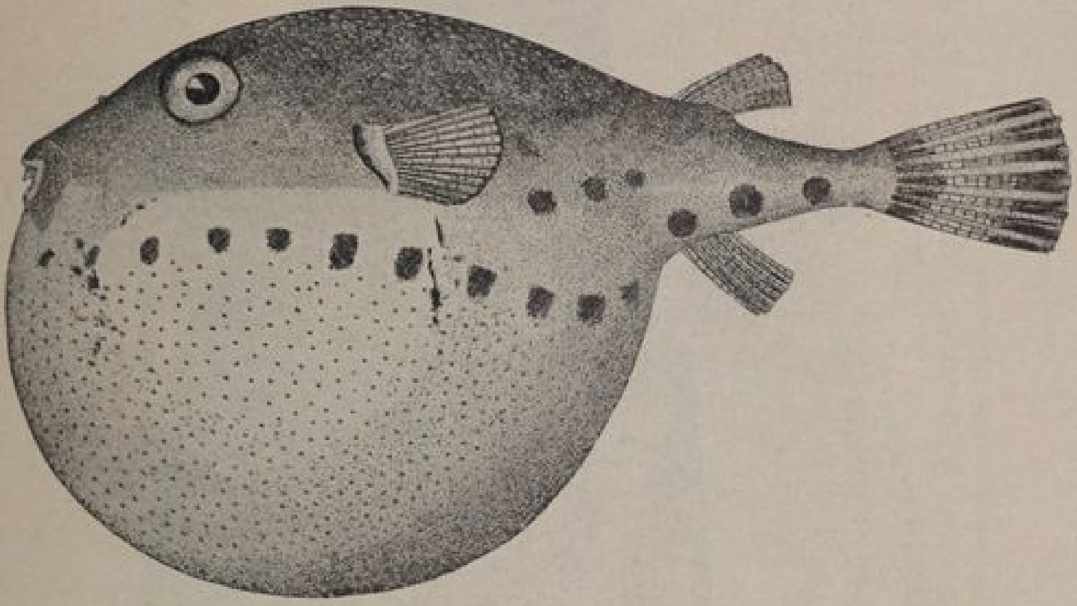


FIG. 60.—Spheroides spengleri. (Bulletin U. S. Fish Commission.)

Tetraodon Hispidus.—Among those noted for its poisonous qualities. Has wide distribution—Hawaii; New Guinea; Samoa; islands of the Pacific Coast of Mexico; Panama; China; Japan; East Indies. In the Hawaiian Islands it is called *Maki Maki*, meaning deadly death. This puffer may reach considerable size—a foot or more in length. The coloring varies greatly.

Tetraodon Nigropunctatus.—New Guinea; Fiji; Samoa; East Indies; Red Sea. Known as *Sui* in Samoa.

Diodon Hystrix.—Tortugas; Key West; Jamaica; Porto Rico; Cuba; Martinique; Brazil; Samoa; Hawaii; Tahiti; Guam; Johnston Island; New Guinea; everywhere common in tropical seas. May attain a length of about 3 feet. Is often stuffed and dried as a curiosity. Covered everywhere except on lips and caudal peduncle with spines. Each jaw is covered with a bony plate like the beak of a bird.

The family *Monacanthidæ*, or file-fishes, should also be avoided as food. They have, as a rule, comparatively little flesh, and that generally has a bitterish taste. Some of these fish have caused serious cases of poisoning, and all should be avoided. As a family, they have very small rough scales forming a velvety covering, and the first dorsal fin is a single

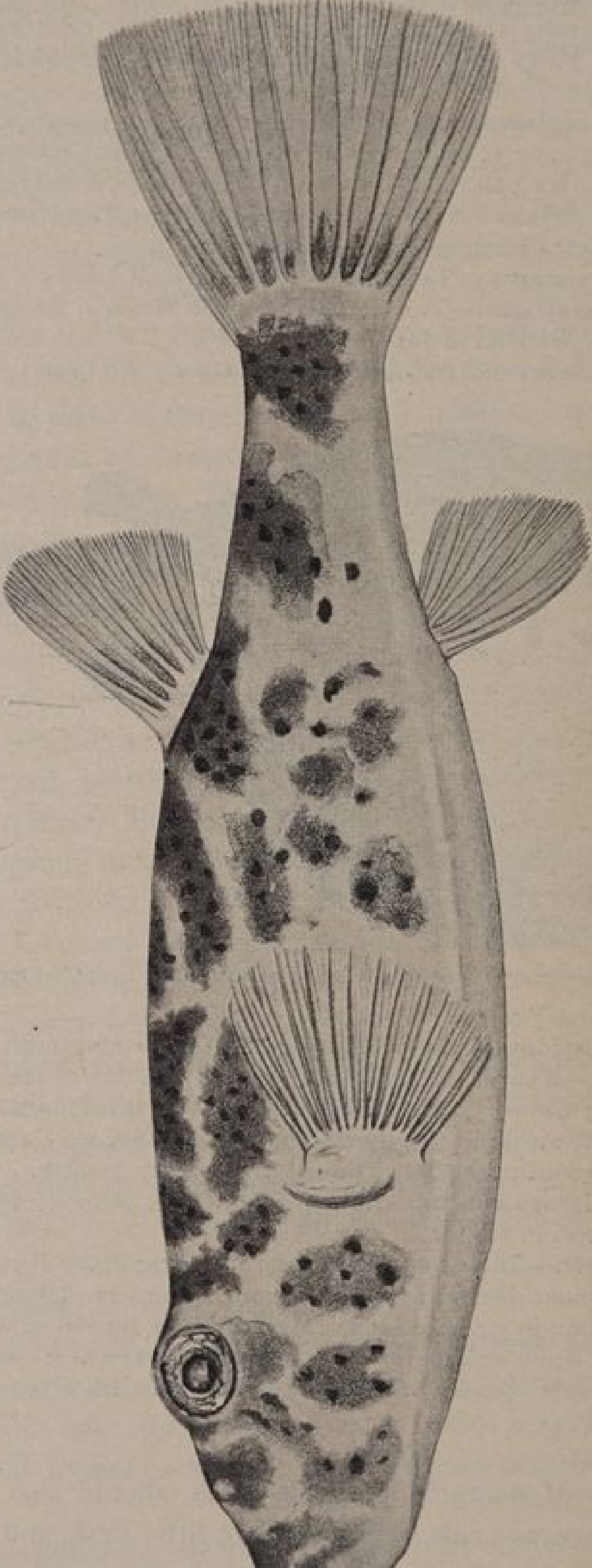


FIG. 61.—SPHEROIDES TESTUDINEUS (LINNÆUS). PUFFER, TAMBORIL.
(Bulletin U. S. Fish Commission.)

FIG. 62.—TETRAODON HISPIDUS LINNÆUS. MAKI-MAKI; OOPUHUE. ABOUT NATURAL SIZE.
(Bulletin U. S. Fish Commission.)

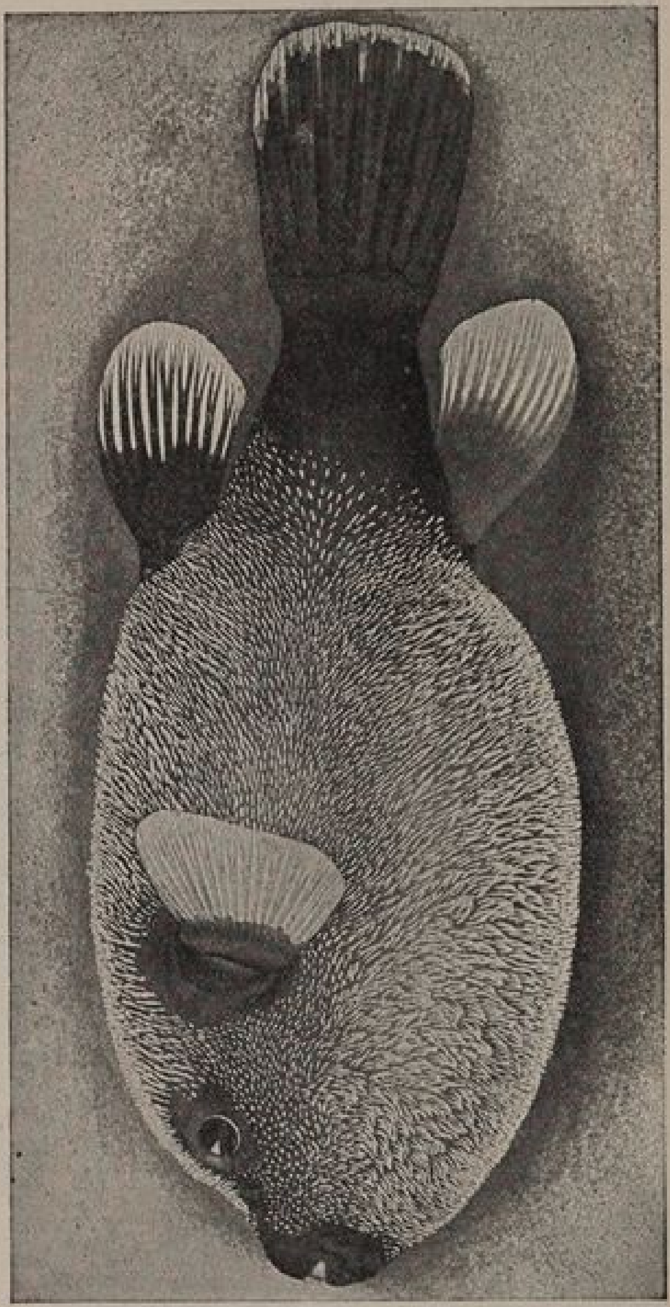


FIG. 63.—*Tetraodon nigropunctatus* (Bloch and Schneider). (Bulletin U. S. Fish Commission.)

spine; the second dorsal is long and similar to anal, and the ventral fin is reduced to a single osseous appendage or is entirely absent.

The *Alutera scripta* or *Balistes scriptus*, commonly called the unicorn fish, may be taken as an example of this family, though it is very much larger than most of them, attaining a length of 2 or 3 feet. It is an inhabitant of tropical seas, common in the West Indies, and has also been found off the west coast of Mexico. Members of the family are, however, found in Hawaii; Samoa; New Guinea; New Caledonia; East Indies; China; Morocco; Brazil.

The family *Balistidæ*, or trigger-fishes, are closely allied to the file-fishes. The first dorsal is composed of 2 or 3 spines: first spine highest, very strong; second locking it in erection; second dorsal of many soft rays; caudal fin rounded or forked; ventral fins wanting, their place occupied by a single thick spine. None of these fish should be used as food, as the flesh in some localities is said to cause very marked toxic symptoms.

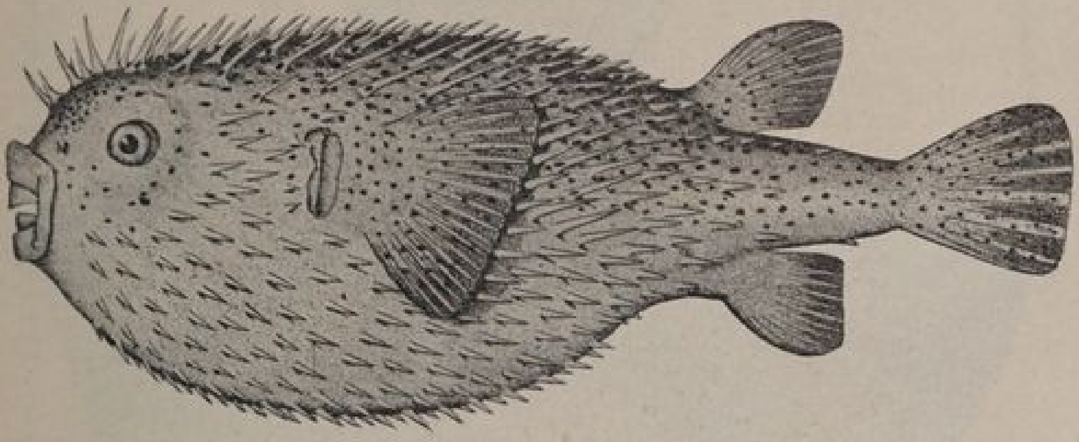


FIG. 64.—*Diodon hystrix* Linnæus; (after Jordan and Evermann). (Bulletin U. S. Fish Commission.)

The *Balistes vetula* may be taken as a sample of this interesting family. It is found throughout the West Indies and is not uncommon at Key West, the Bahamas, and Ascension Island.

The family *Ostraciidæ*, or trunk-fishes, is often regarded as made up of excellent food fishes, the flesh being delicate and of very pleasant flavor. They are rarely seen in the markets, but nevertheless have often been used as food without ill effects. All cases of poisoning from ingesting the flesh of these fishes have been reported from the tropics, especially Jamaica, from the *Lactophrys trigonus*, and it is difficult to decide whether decomposition or putrefactive changes have not always been a causative factor. Some writers regard them as poisonous, and it is said there is gelatinous material near the caudal fin and also near the head that should always be removed in preparing the flesh for cooking as it is capable at times of producing symptoms not unlike those of alcoholic intoxication. Under the circumstances it is perhaps best to regard them as suspicious.

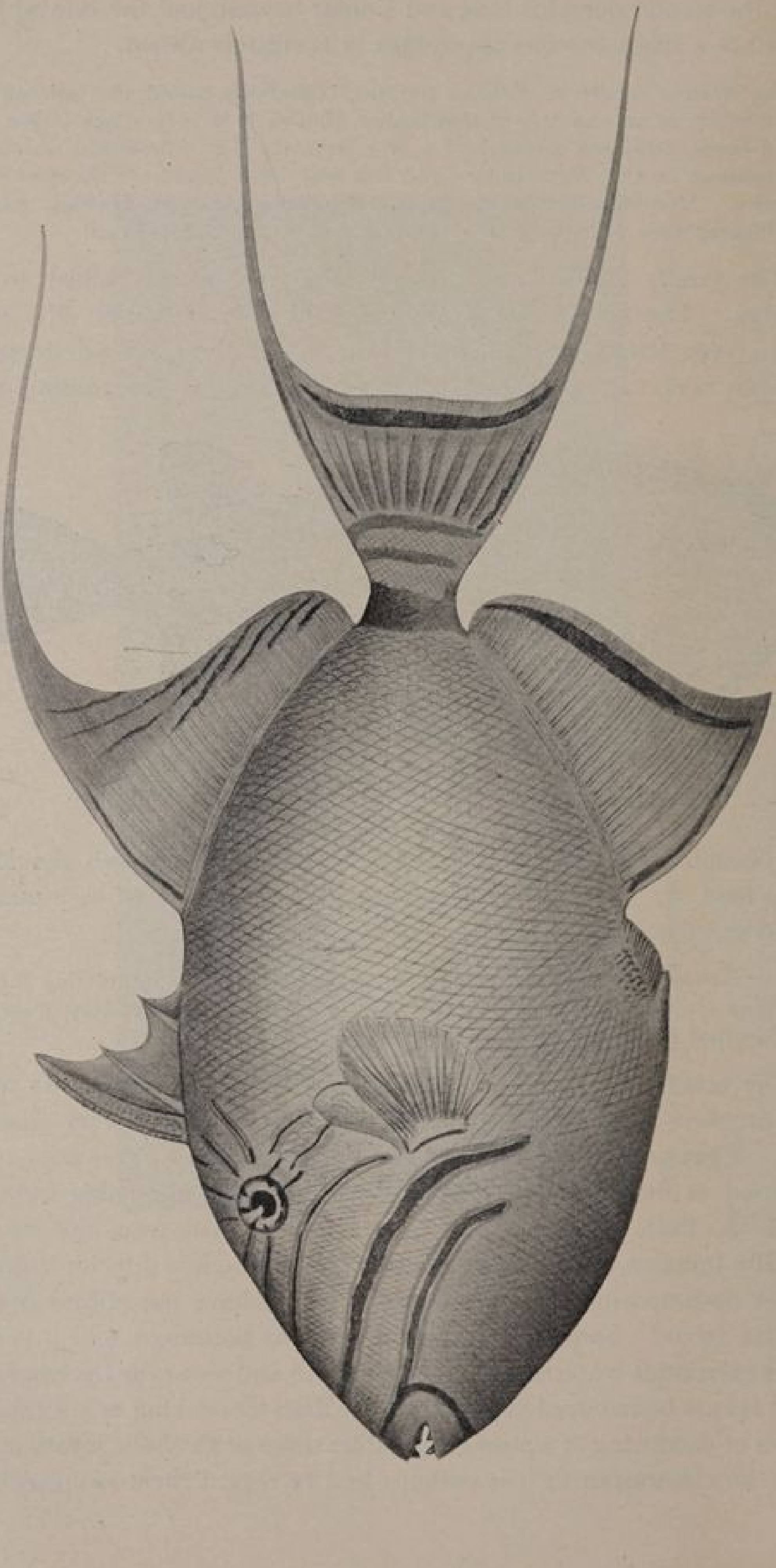


FIG. 65.—Balistes Vetula Linnæus. (Bulletin U. S. Fish Commission.)

They all have a grotesque appearance and do not appeal to one as food. The body is convered by a carapace formed of firmly united polygonal bony patches, the jaws, bases of the fins and the caudal peduncle being the only parts free and covered with smooth skin. The dorsal fin is single, short, and without spine; anal short, similar to dorsal; caudal rounded; no ventral fins. The locomotion is very peculiar, as the force is exerted by the dorsal and anal fins in a half rotary sculling motion, resembling that of a screw propeller, the caudal fin acting usually merely as a rudder. When taken from the water one of these fish will live for hours, all the time fanning it gills to cause a movement of air through them.

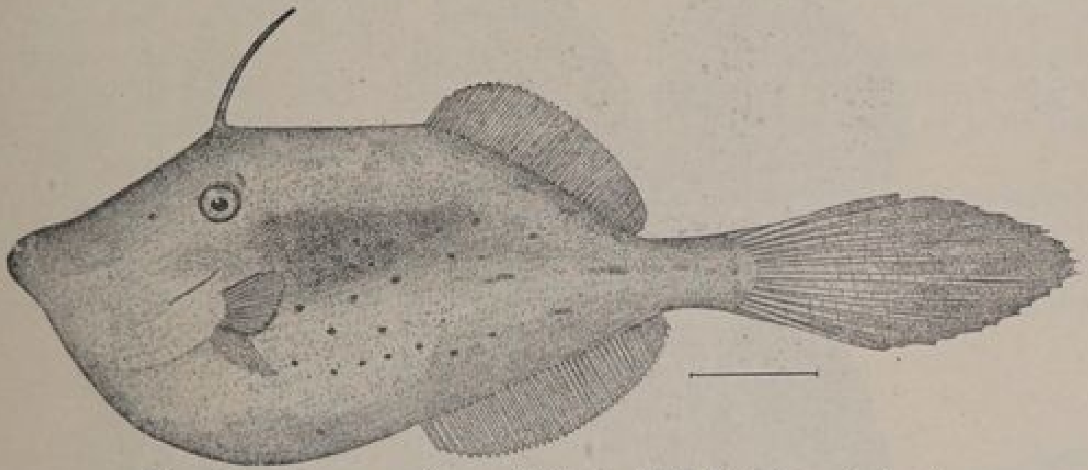


FIG. 66.—Alutera scripta. (Bulletin, U. S. Fish Commission.)

The **Lactophrys bicaudalis,** or spotted trunk-fish, may be taken as an example of this family. It is an inhabitant of the West Indies, generally common from Cuba to Ascension Island. It attains a length of a foot or more.

The *Molidæ,* or head fishes, are another family of freaks, but it is not clear they should be included here. These fish are apparently composed of a huge head to which small fins are attached. The teeth are completely united in each jaw, forming a bony beak, as in the *Diodontidæ,* and the gill openings are small, in front of pectorals. The flesh is coarse and tough, unfit for food, but has been rarely accused of having poisonous qualities. They are fishes of the open seas and many attain very great size. The *Mola Mola* is harpooned, as it invites attack floating for hours at the surface on calm days.

The family *Clupeidæ,* or the herrings, contain some varieties with the reputation of having caused a number of deaths when their flesh has been used as food. Yet many of the species of this family are among the most important food fishes. The *Clupeidæ* comprise about 30 genera and 150 species inhabiting all seas and usually running in immense schools.

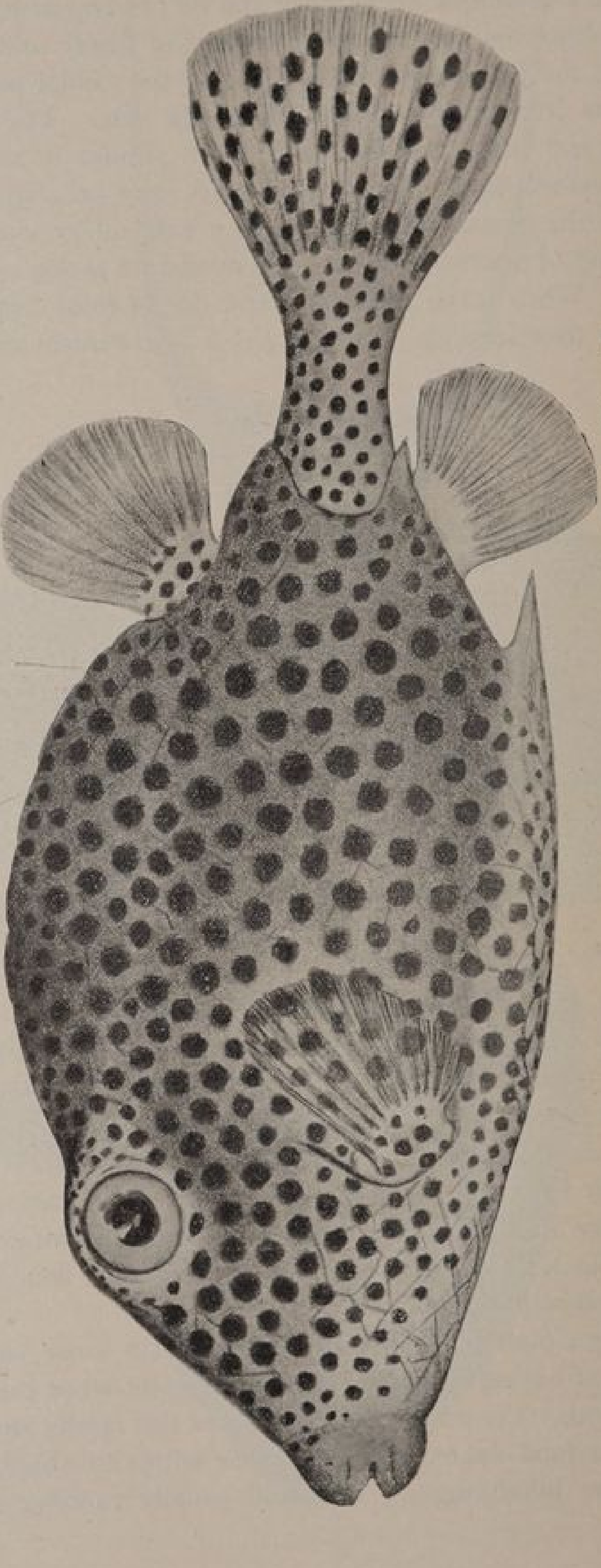


Fig. 67.—Lactophrys Bicaudalis (Linnæus). Spotted Trunk-Fish. (Chapin.)
(Bulletin, U. S. Fish Commission.)

In the East Indian and in Australian waters the poisonous *Meletta* is found in large numbers. It seems to be variously designated as *Clupea sindensis*, *Clupea venenosa*, *Meletta venenosa*. It is a little fish which resembles the sardine, but body is not so elongate. It is about five inches long with a sharp serrated belly, silvery scales and bluish-green back. It has no teeth except a few very small ones on tongue. The snout is black and there is a little black spot at the upper extremity of the first rays of the dorsal fin; lower jaw somewhat projecting; ventral inserted behind front of dorsal. The dorsal fin has from 16 to 18 rays, the pectoral 16, the ventral 8, anal 17 or 18. The caudal fin is forked and each fork composed of 9 rays. It would seem to belong to the scaled sardines which are the small herrings of tropical seas. It is found especially near the Seychelles and near New Caledonia and is always poisonous. It seems to be often confounded with the *Dussumieria acuta* which is said to be not ordinarily poisonous.

The genus *Opisthonema* or thread-herrings or sprats in which the last ray of the dorsal is produced in a long filament, but otherwise much like the *Sardinella*, are very common in the West Indies, on the coast of Brazil and north to the Carolinas. These herrings are considered suspicious, especially during the spawning season, the roe being regarded as the most dangerous part. The toxic quality is certainly very inconstant. *Yet in tropical waters it seems best to avoid any fish of the sardine kind, especially during the spawning season.*

This prohibition may be made in warm waters to include the *Engraulidæ*, or *anchovies*, which are also small fishes swimming in large schools on sandy shores. The mouth is extremely large, usually overlapped by a pointed compressed pig-like snout; eyes large, well forward, without adipose eyelid; dorsal usually short and median; no adipose fin; caudal forked. The principal and perhaps only poisonous variety is, however, found in Japan, where it is known as "Jetareiwasi." It is designated by Schlegel as *Engraulis japonicus*, and is found in large numbers near Nagasaki, but seems much like the *Engraulis ringens* of Jenyns which has a large range in the Pacific. There is also found near Nagasaki another poisonous small fish reported under the name of *Enorantis japonica* which seems much like the *clupea thrissa* or sprat. The *Anchovia bælama* or *Engraulis bælama* in which the dorsal fin is in advance of the anal has also been reported as poisonous. It is found in the Red Sea, on the coast of Zanzibar, and quite generally in the Indian Ocean. A species very similar, *Anchovia evermanni*, is found in Samoan waters. It is about 5 inches long and, though not reported as poisonous, its illustration may be taken in a general way as a type in the *Engraulidæ* which, like the herrings are without objection in most localities, but like the sardines better avoided in warm waters and certain localities on general principles.

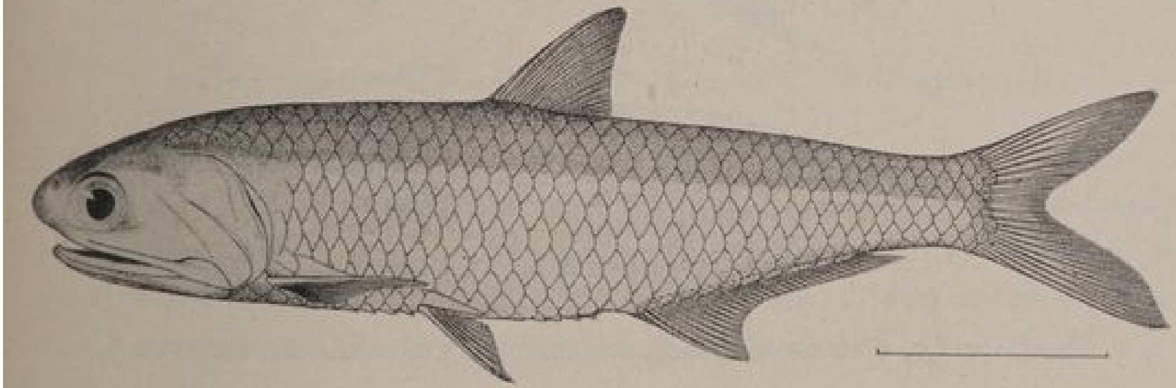


FIG 68.—*Anchovia evermanni*. (Jordan and Seale.)
(Bulletin, U. S. Fish Commission.)

The *Siluridæ*, or catfishes, are characterized in general terms by the presence of abdominal ventral fin and a head with from 4 to 8 long barbels about the mouth and nostrils. The body is scaleless, and there is a single spine in each pectoral and in the dorsal fin. The majority are fresh-water species. Among both the fresh-water and salt-water species are poisonous varieties as food and also in the production of venomous wounds as the result of a poison gland at the base of the pectoral and of the dorsal spine. These poisonous varieties are all small species and, among the fresh water cats, are known as stone-cats or mad-toms, belonging to the genera *Noturus* and *Schilbeodes*, and among the salt water to the genus *Plotosus* chiefly. In all these genera there is a connection of the adipose fin with the caudal.

The *Plotosus anguillaris* or *Plotosus lineatus* is found at Samoa; New Guinea; Solomon Islands; Asia and East Indies. It is occasionally taken in the shallow waters inside the reef at Apia. At Nagasaki, where it is very abundant, it is called "gigioo," and has yellow stripes on the sides which are very faint or wanting in those at Apia where the color is dark olive, mottled, white below; sides with scarcely a trace of pale stripes; fins dusky, especially on the edges. Young individuals are more distinctly marked, with two white stripes. The wound from this fish is very painful, is apt to eventually show gangrenous areas, and is said to tend to the development of tetanus.

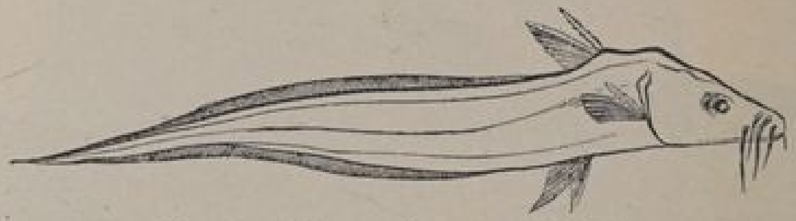


FIG. 69.—*Plotosus lineatus*. (Nielly.)

The *Labridæ*, or wrasse-fishes, contain the genus *Lachnolaimus*.

The *Lachnolaimus maximus* or "capitan" is the single species of that genus, and is often regarded in the West Indies with suspicion, especially the large individuals. It is considered at Key West to be an important food fish and is a favorite in Cuba, though there its sale at one time was forbidden. In Porto Rico the large ones are regarded with doubt. It is found about rocky reefs, and may weigh 10, 15, or even 20 pounds and be 2 or 3 feet in length. It is more generally found in the markets from 10 to 12 inches in Porto Rico and is frequently in the fishermen's boats at Culebra. All things considered, it is very doubtful whether it is ever a poisonous fish unless it has become so temporarily from material in the stomach eaten as food. It feeds chiefly on mollusks and crustaceans and small fish. It is a showy fish, remarkable for the long streamer-like filaments on the dorsal spines. It has a deep and compressed body; elevated back; anterior profile long and steep, nearly straight, slightly concave before eye; 4 strong canines in front of upper jaw, 1 pair in front of lower with 2 smaller conical teeth between them; color brick red with scales edged with reddish-yellow; caudal fin deeply lunate and red with 2 pale brown crossbars and 2 spots of same on each tip; ventral fin purplish-red and pectoral lemon. The large adult male is remarkable on account of a heavy black blotch over the forehead and eyes.

The *Sphyrænidæ,* or the barracudas, which contain a single genus with about 20 species, are carnivorous pike-like fishes, often of large size, active and voracious, inhabiting warm seas. Many of them are valued as food, and yet at times those same varieties have poisoned large numbers of people, as on the French man-of-war Marceau at New Caledonia in 1866, and on the Pallas of the same service at Rio Janeiro in 1862. In those cases it was the *Sphyræna barracuda* or the *Sphyræna becuna* that caused the trouble and yet that fish is generally reported of good food qualities. It is common in the West Indies ranging north to Charleston and the Bermudas and south to Brazil.

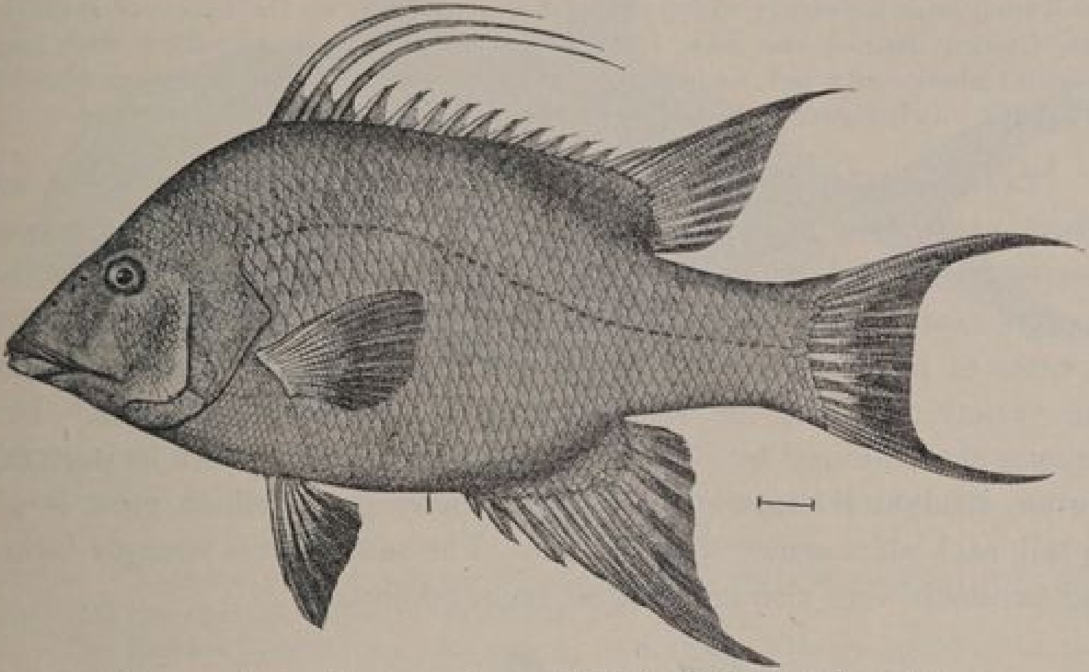


FIG. 70.—*Lachnolaimus maximus.* (Bulletin, U. S. Fish Commission.)

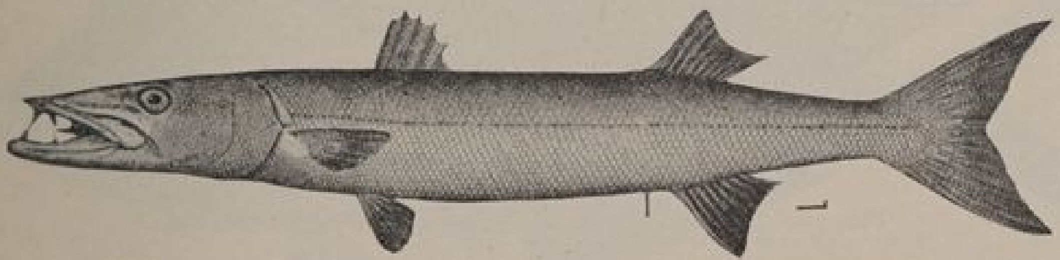


FIG. 71.—*Sphyræna barracuda.* (Bulletin, U. S. Fish Commission.)

The picuda is a fierce and voracious fish and is sometimes very dangerous to bathers. It may attain a length of 6 feet, and the fish consumed on the Marceau was about 3 1/2 feet long and weighed over 20 lbs. The picuda has abdominal ventral fin, straight lateral line, and strong teeth. The first dorsal originates behind the root of ventrals, over last third or fourth of pectoral, and is composed of 5 slender and flexible spines. The second dorsal is soft and similar to anal; caudal well forked, upper lobe slightly the longer. It seems likely that when this fish is poisonous it is in some condition of disease. It is said that under those circumstances when the flesh is cut there is an oozing of whitish sanious fluid. It is also said that the fact of its being poisonous is shown by the teeth being black at the roots.

The family *Gobiidæ*, or the gobies, embraces about 80 genera and 800 species, few of which are large enough to be of much food value.

In the genus *Rhinogobius* is the *Gobius cringer*, Cuvier and Valenciennes, or the *Rhinogobius nebulosus* which is found in Australia; on the coasts of Malabar; New Guinea; Samoa and East Indies. Its color is at times yellow with large irregular black spots, but, as in Samoa, may be olive-green with darker blotches and spots. It is regarded as poisonous, especially the head and intestines.

The *Carangidæ*, or the Pompanos, include 29 genera and about 200 species abounding in warm seas and often moving northward in summer. Nearly all are valued as food, but they seem to undergo putrefactive changes rapidly, and have therefore been responsible for quite a number of cases of poisoning. However, in the genus *Caranx* there is at least one variety that has the reputation of being often poisonous. This genus is characterized by a lateral line anteriorly arched with its posterior portion straight, but armed with strong bony plates which grow larger on tail, each plate armed with a spine. The caudal fin is strongly forked and peduncle very slender; ventral fins abdominal.

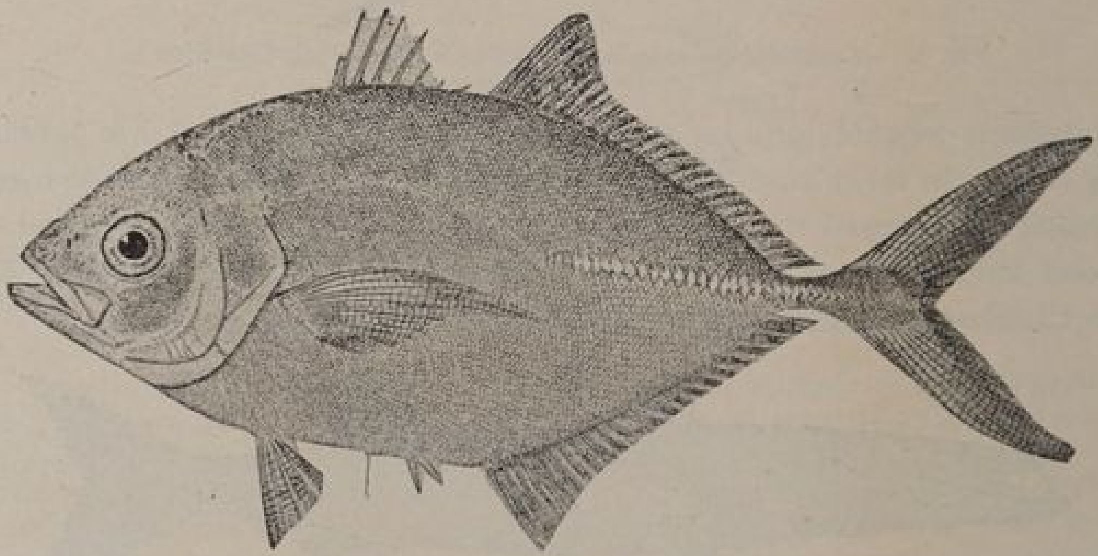


FIG. 72.—*Caranx latus*. (Bulletin, U. S. Fish Commission.)

The *Caranx latus* or *Caranx fallax* or Horse-eye Jack is the very widely distributed species, reported as at times poisonous. It occurs in all tropical seas, and is very abundant in the West Indies and in Brazilian waters. It is often found in the markets of Porto Rico where evidently its reputation as poisonous does not hold. However, as many of the genus *Caranx* are more or less important as food fishes, it is of some consequence to distinguish the objectionable species. In that connection it is safest in the Atlantic to discard any *Caranx* which has not a *well-marked black* spot on the gill-covers. The *Caranx bartholomai* has no black spot on opercle, but its loss under the rule would not be of much consequence. It may, however, be distinguished by its being everywhere strongly washed with golden. In the Atlantic a *Caranx* weighing more than 2 pounds should attract particular attention, as the *Caranx latus* may often greatly exceed that weight while the other species seldom do. It also has its breast scaled, while in the *Caranx crysos* and *Caranx hippos* the breast is bare. The *Caranx latus* has 22 soft rays in the second dorsal, while the other species mentioned have 26, 24, and 20. It is bluish with golden or silvery sides; fins mostly grayish, but caudal yellow. Anterior part of soft dorsal is dusky; no spot on pectoral; no axillary spot and the opercular spot is very small.

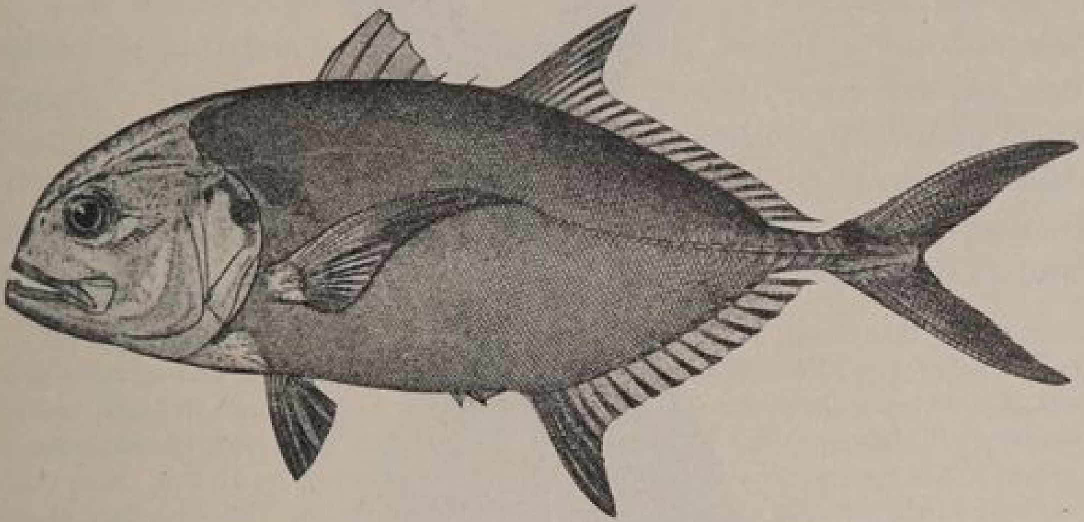


FIG. 73.—*Caranx hippos.* (Bulletin, U. S. Fish Commission.)

The *Caranx lugubris* is a rare species in both the Atlantic and Pacific, but it is generally considered poisonous and excluded from markets. It reaches a length of 18 inches, and is of dark or blackish color, hence its name.

In this same family is the genus *Trachurops* in which is the species *Trachurops crumenophthalmus* or *Scomber plumieri*, Bloch. This variety is bluish above, silvery below, and with a faint dark opercular blotch. It has a more elongate form than a *Caranx*. It attains a length of 2 feet and is found on both coasts of tropical America and in tropical seas generally. It is called Goggler; Big-eyed Scad; Goggle-eye Jack. In the French West Indies it is called "Coulirou" and by the Spaniards "Chicharro" It seems to be a fish that is only poisonous at certain times and in certain localities. It does not seem to be regarded

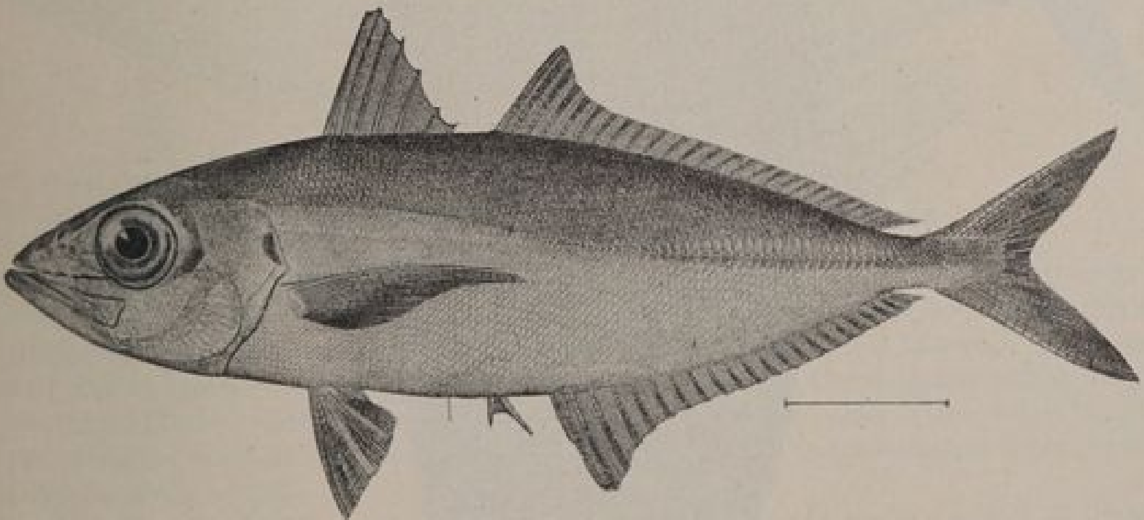


FIG. 74.—*Trachurops crumenophthalmns* (Bulletin, U. S. Fish Commission.)

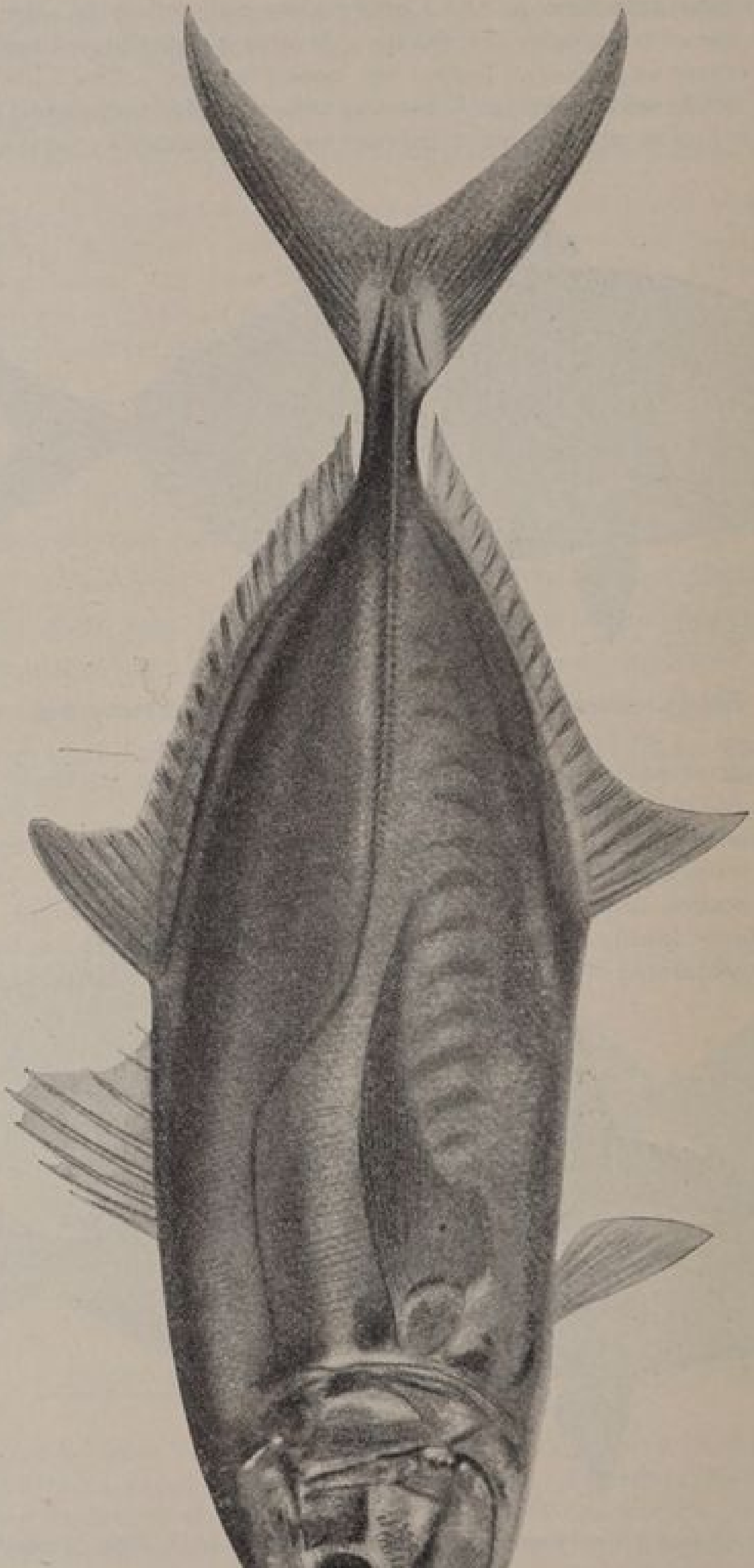


FIG. 75.—Caranx Crysos (Mitchill). Runner. (Bulletin, U. S. Fish Commission.)

as poisonous in Havana, but in Guadeloupe, where it is very common and where it has a fine flavor, it sometimes happens that specimens are caught which are so poisonous that they are used to poison rats. It is said that such specimens are immediately recognizable by the bones being red, all others being harmless.

The family *Scombridæ* or the mackerels, are remarkable for the rapidity of putrefactive changes when taken from the water in warm weather. Therefore, under such circumstances, these fish not infrequently develop toxic properties and are responsible from time to time for many accidents from fish-poisoning. Most of them are highly valued as food fishes, the flesh being firm and oily, but sometimes coarse. The body of this family is elongate fusiform and its lateral line is undulate.

The *Scomberomorus regalis*, found from Cape Cod to Brazil, but common only about Florida and Cuba, and the *Scomberomorus cavalla*, or king-fish, found in the tropical Atlantic, in the open seas, and in immense numbers at the Florida Keys, are remarkably fine food fishes. The *cero* or king-fish weighing forty pounds is not rare, and they sometimes weigh 100, but the average weight is under 15 pounds and probably about 6; and the *sierra* or *pintado* may weigh 20 pounds or more. The common mackerel of the North Atlantic is the *Scomber scombrus*, while the Spanish mackerel is the *Scomberomorus maculatus* (Mitchill). The latter is found on both coasts of North America, appearing in large but very irregular schools in the Gulf of Mexico. It ranges north in the fall as far as Cape Ann, and south to Brazil. It is rare or unknown in Cuba, but is known in Jamaica and Porto Rico. It reaches a weight of 8 or 9 pounds, and is one of the very best food-fishes. But all of these fish require very close observation when being prepared for food, as they are liable to cause trouble in warm weather from rapid putrefactive changes.

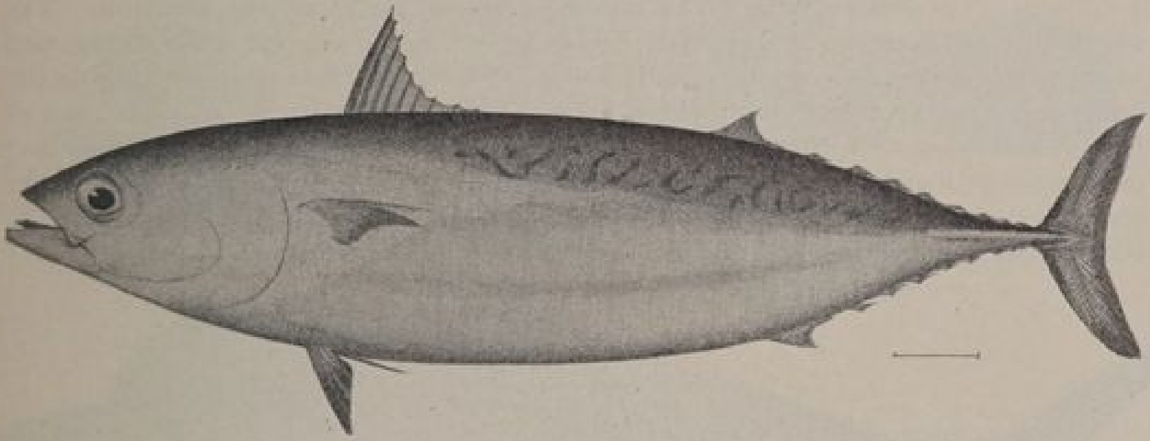


FIG. 76.—*Auxis thazard.* (Bulletin, U. S. Fish Commission.)

In this family the genus *Auxis*, or frigate mackerels, are poor fish of little value as food. The *Auxis thazard* or *Auxis vulgaris*, a species found in all warm seas and in the West Indies,,has at times been reported dangerous. It has a very slender tail with a rather large keel on each side and, while the plump body is mostly naked posteriorly, it is anteriorly covered with very small scales forming a corselet, and there are scales along lateral lines. The first dorsal of flexible spines; the second dorsal widely separated from the first; the anal are small and soft and followed of course by the usual detached finlets. It has blue back with oblique dark bars and stripes on sides and silvery-white belly.

In this family is also the genus *Sarda* in which is the *Sarda sarda* or the bonito. It is a poor food-fish, reaching a length of 2 or 3 feet and a weight of 10 or 12 pounds. The *Euthynnus pelamis* is frequently called the bonito. It has been responsible for many cases of poisoning, but all of them seem to have been due to rapid putrefactive changes.

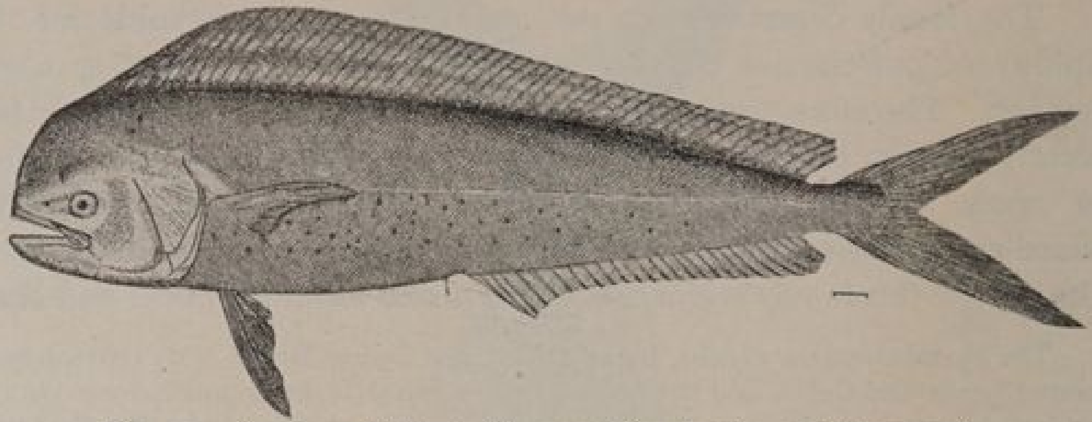


FIG. 77.—*Coryhæna hippurus* Linnæus (after Jordan and Evermann). (Bulletin, U. S. Fish Commission.)

The *Coryphænidæ* or the dolphins are of only two species:

The *Coryphæna hippurus*, or the common dolphin, may reach a length of 6 feet, and the *Coryphæna equisetis*, or the small dolphin, reaches a length of only 2 1/2 feet. The illustrations given here are sufficient for their identification. The colors are brilliant in life, but they undergo very rapid change while dying, and after death there are only faint indications of former colors. They inhabit the high seas in warm regions and, having a tendency to play about ships, are at times harpooned by sailors. They are considered excellent food, but have caused poisoning probably from rapid putrefactive changes. Yet there is a belief that they are at times true poisonous fishes and that at such times a piece of silver placed in the vessel in which they are cooked turns black.

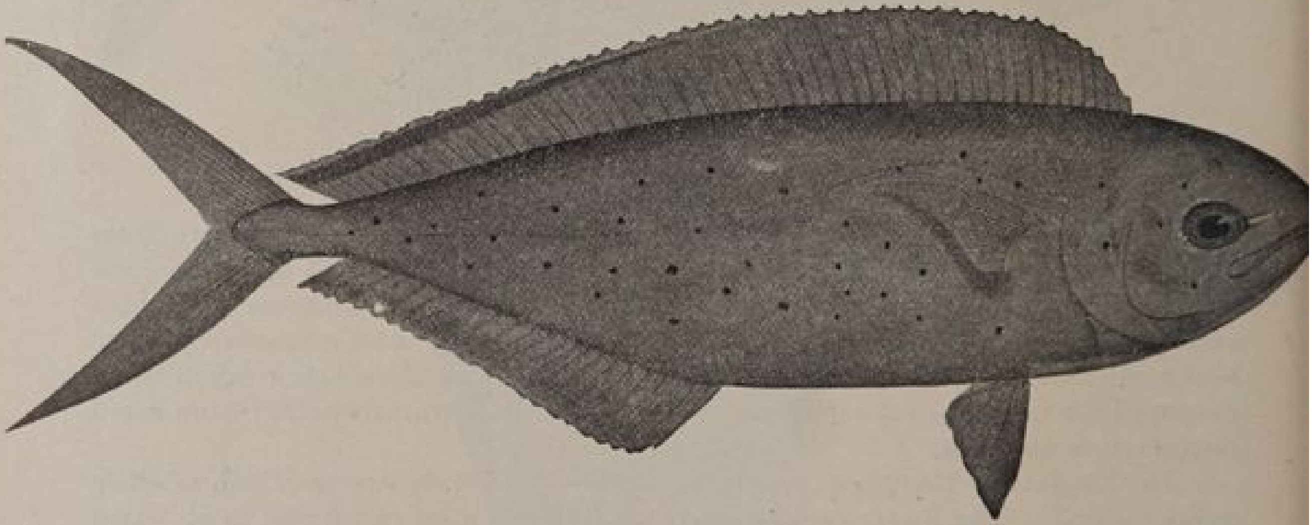


FIG. 78.—*Coryphæna equisetis* Linnæus (after Günther). (Bulletin, U. S. Fish Commission.)

The *Scorpænidæ* or rock-fishes, are a large and interesting family of about 30 genera and more than 250 species inhabiting all seas, but especially abundant in the temperate parts of the Pacific Ocean. They live about rocks, and most of them are of large size. Many of the species are used as food, though some of them, particularly species of the genus *Scorpæna*, are in some places regarded as poisonous both as food and in the production of wounds. Many of the species of the family are viviparous, the young being produced after reaching considerable size. Their appearance is quite characteristic and their indentification may be facilitated more by the illustrations given than by description. The head is large with one or more pairs of ridges above, which usually terminate in spines; opercle usually with 2 spinous processes; preopercle with 4 or 5; lateral line single, continuous, concurrent with back. Ventral fins thoracic; dorsal fin continuous, sometimes so deeply notched as to divide into 2 parts, with 8 to 18 rather strong spines and about as many soft rays; anal short with 3 spines and 5 to 10 soft rays; soft rays in all fins branched except some or all rays of pectoral.

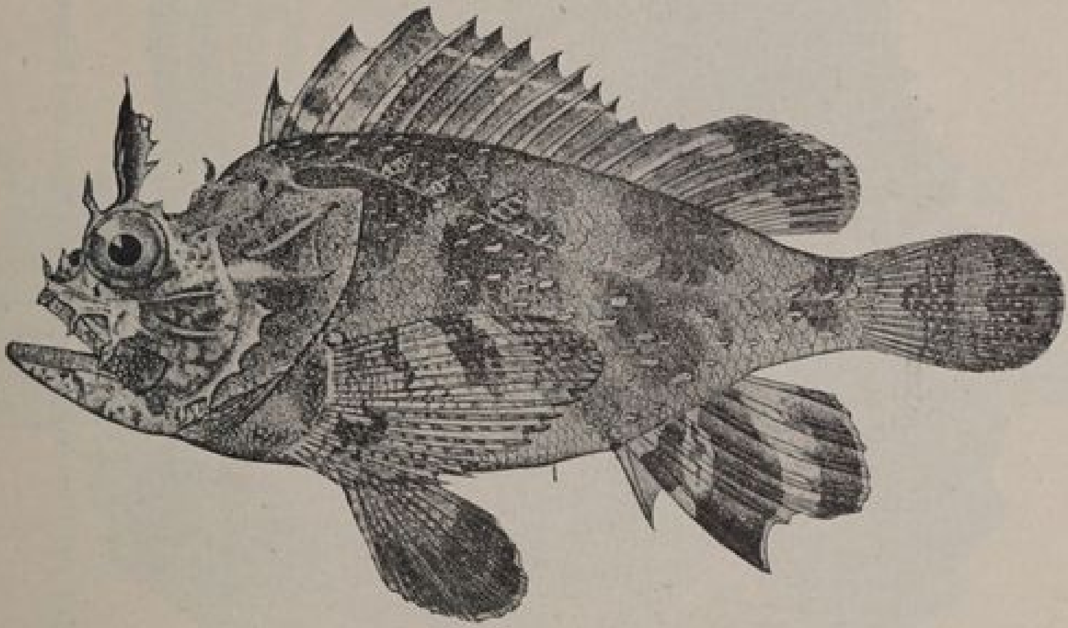


FIG. 79.—*Scorpæna grandicornis*. (Bulletin, U. S. Fish Commission.)

The *Scorpæna grandicornis*, or the lion-fish, has a head rough with many spines and ridges; a deep quadrate pit on occiput and a supraocular filament long, broad, and fringed, more than twice length of eye; a short filament on front of supraocular ridge and a small one on upper part of eye; anterior nostril with a short fringe; a pair of short filaments at tip of snout. The lion-fish occurs from the Florida Keys to Brazil, as does also the *Scorpæna plumieri*, or Rascacio, which is much like it in appearance and in poisonous qualities. It frequents shallow water among algæ. It reaches the length of a foot or less and color is variable, but body may be dark brown inclining to brick red, belly pale reddish, and top and sides of head olive-brown; dorsal brown; caudal reddish-brown, crossed by 2 narrow pinkish bars; anal brownish with large black blotch near base of rays, then a broad whitish bar with reddish blotches, then black spots, then brown, and then a pale border. There is not much information in regard to the flesh of this fish, some regarding it as poisonous, but the natives of the West Indies cannot be induced to touch it as its spines are capable of causing poison wounds.

FIG. 80.—Scorpænopsis Catocala (Jordan and Evermann) or Gibbosa (Bloch and Schneider). (Bulletin, U. S. Fish Commission.)

The *Scorpæna diabolus* or *Scorpænopsis gibbosa* is found in Tahiti, Hawaii, Samoa, New Guinea, and East Indies. It has a wide, depressed interorbital area, much wider than the eye, and a deep nuchal pit. There is a black band at the shoulders covering part of the spinous dorsal fin and a black notch at tip of upper jaw. There is a broad black band on the inner side of the pectoral fin near the margin, and this, in the adult, breaks up into spots. It is excessively mottled, streaked, and spotted with body dark purplish-brown or claret shaded, the spaces gray tinged with sulphury-yellow. It seems to have the same poisoning qualities as the *Scorpæna grandicornis.*

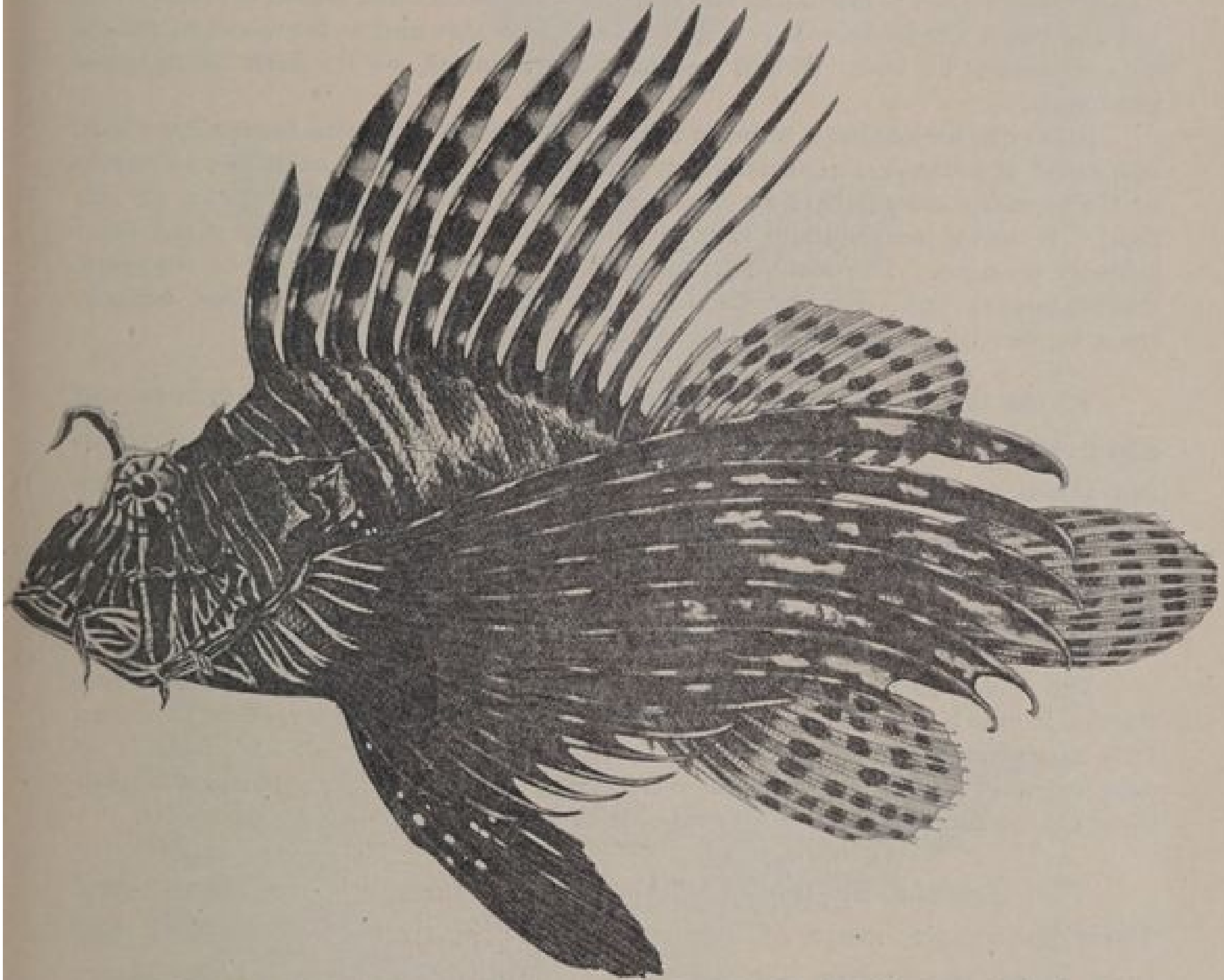


FIG. 81.—Pterois Volitans (Linnæus.) (Bulletin, U. S. Fish Commission.)

In the same family is the genus *Pterois* of which the species are of rather large size, abounding among coral reefs in the tropical Pacific and much dreaded by fishermen on account of their venomous spines. Of this genus the *Pterois volitans* may be taken as an example. This large and violently stinging fish is found in New Guinea, New Britain, and the East Indies. It is not rare about Sâmoa where it is called *Sausaulete*, and is blackish-red fading to pale olive-brown posteriorly; the front of the head abruptly pale brownish-red; body covered by narrow sharply-defined white streaks, bounding black streaks of the ground color. The ventral fin is deep red streaked with white.

The family *Sparidæ*, or the porgies, has a genus *Lethrinus*, Cuvier, which contains a species designated *Lethrinus mambo*, Montrouzier. Most of the porgies are much valued as food, but this species has a bad reputation, especially in New Caledonia, where it is called *Mambo* by the natives and where its use as food has caused a number of cases of poisoning.

The *Serranidæ* or sea basses include the genus *Mycteroperca.*

The species *Mycteroperca venenosa*, or the yellow-fin grouper, is found from the Florida Keys southward among the West Indies and is a large, handsome fish reaching 3 feet in length. Its color is olive-green above and blue or pearly below. Its upper parts have blotches of light green and the entire body is covered with orange-brown spots. The dorsal fin is olive brown with whitish blotches. The *Mycteroperca apua* is much like the above except in coloring which is scarlet with red and black markings. It is caught in deeper water and as far south as Brazil. The *venenosa* at least should certainly be avoided, as its flesh is reported poisonous.

It may be noted that a number of the best food-fishes in this family have been suspected of poisonous qualities from time to time, including such fine examples as *Epinephelus adscensionis*, or rock-hind, and the *Epinephelus guttatus*, or red-hind. It seems not unlikely that the accidents have been due to rapid post-mortem changes. The same may also be noted of the *Lutianidæ* or snappers, the *Neomænis jocu*, dog snapper or jocu, and the *Neomænis griseus*, or gray snapper, having been called in question.

In the family *Holocentridæ*, or squirrel-fishes, there are 4 genera and about 70 species, all gayly colored inhabitants of the tropical seas, abounding about coral reefs. The dorsal fin is very long, deeply divided, with about 11 strong spines, depressible in a scaly groove; anal with 4 spines, the third longest and strongest; ventrals are thoracic with 1 spine and 7 rays. General color red.

The *Holocentrus ascensionis* is a species very common in Cuba and Porto Rico. It may be from 1 to 2 feet long, but is more often found from 6 to 10 inches. It is occasionally found in the market, but the natives regard it as "malo." It does not seem that that opinion is founded upon its effect when taken as food, but upon the poisonous wounds it is capable of inflicting with its dorsal spines.

The *Esocidæ*, or the needle-fishes, are generally good food-fishes. Their habits are much like those of the pike, but when startled they swim along the surface with extraordinary rapidity, often leaping above the water for short distances, and have been known to pierce the naked abdomen of natives. The green color of the bones of the larger species often cause them to be avoided as food for no good reason. Yet in Guadaloupe, a number of poisonings have been caused by eating the flesh of the *Belone caribbæa* (Lesuer) or the *Tylosurus caribbæus* in which species the mouth does not close completely, the upper jaw is arched at base, the dorsal rays are 22 and the anal 24, and there is a bluish lateral band. The scales are small and green.

In China the flesh of the porpoise is highly prized by the people for its flavor, but it is said that scarcely a spring passes without fatal cases of poisoning from that source. The cases seem to occur inland chiefly.

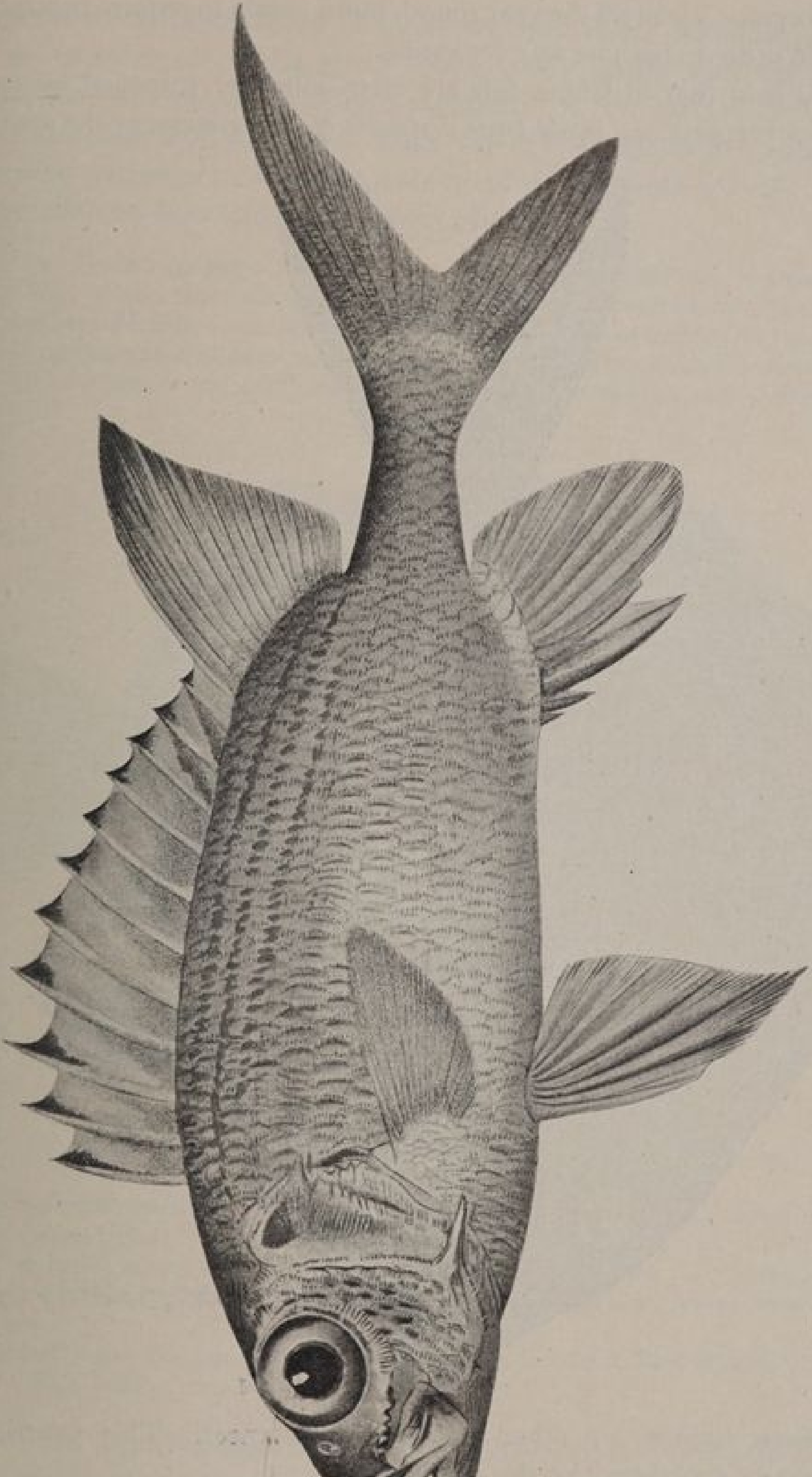


FIG. 82.—Holocentrus Ascensionis (Osbeck). Squirrel-Fish; Candil. (Bulletin, U. S. Fish Commission.)

Dried porpoise is sold all the year round, but it is said to require protracted boiling in order to become safe for eating.

It is said that in China fish are often killed or stupefied by using poisonous preparations made from a species of *Polygonum*, or the seeds of the *Croton tiglium*, or other vegetable substances. This practice is occasionally prohibited by the magistrates.

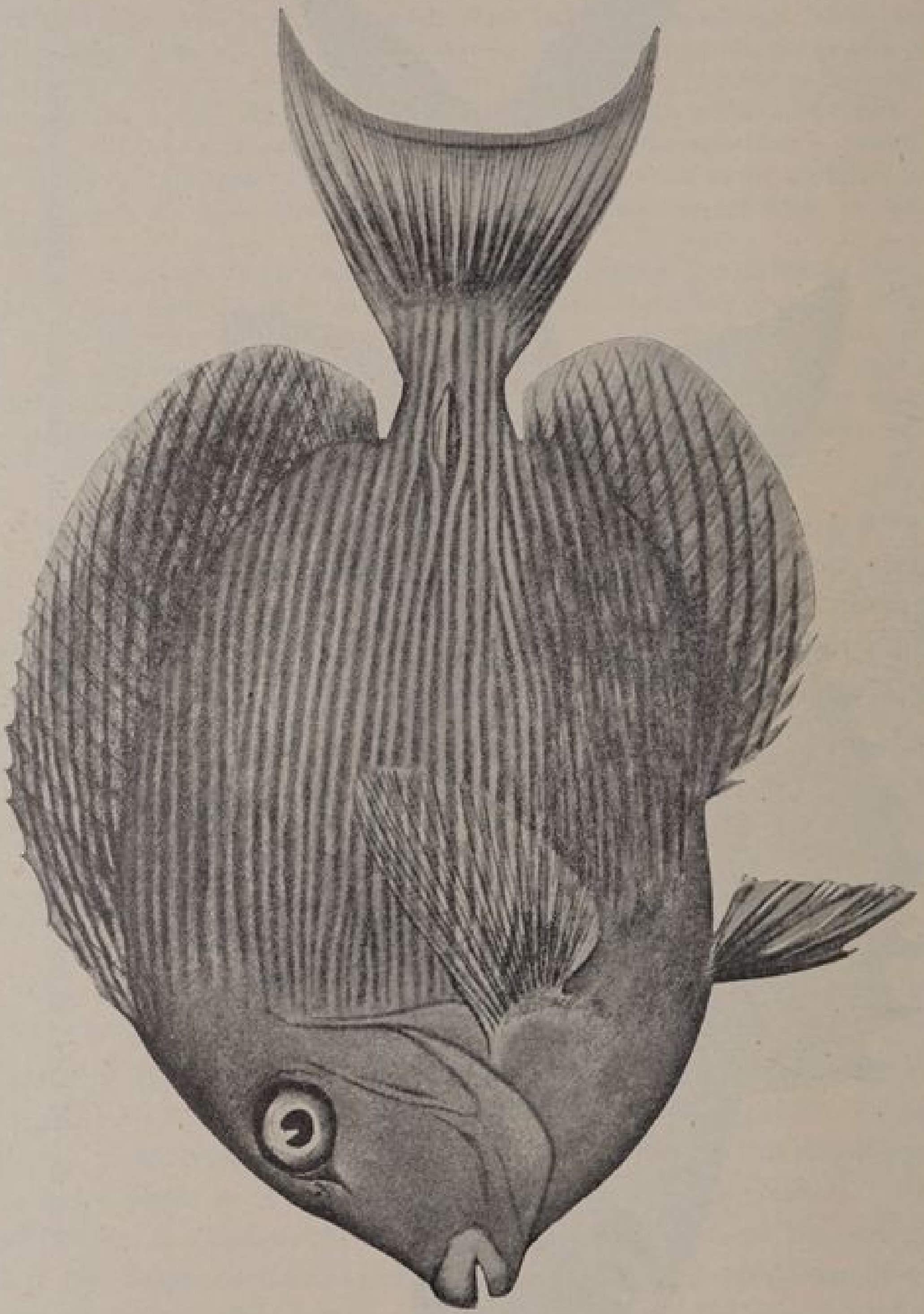


Fig. 83.—Teuthis Cœruleus (Bloch and Schneider). Blue Tang; Medico. (Bulletin, U. S. Fish Commission.)

The family *Acanthuridæ* or *Teuthididæ*, or the surgeon-fishes, includes the genus *Teuthis* or *Hepatus*, or the tangs, in which the caudal peduncle is armed with a sharp, antrorse, lancet-like, movable spine.

They are herbivorous fishes living about coral reefs, the adult protected by the murderous caudal spine which grows larger with age and by which they are usually readily recognized. A few species are of some importance as food-fish. Yet while the caudal spines are entirely for defensive purposes they are capable of producing ugly wounds and are supposed to be associated with poison glands.

The *Teuthis hepatus*, Linnæus (*Acanthurus phlebotomus*), doctor-fish or lancet-fish, is the most abundant of the tangs, and is found from the Carolinas and southern Florida south to Brazil. It reaches a foot in length, and is in Porto Rico of considerable importance as a food-fish. It is dark olive-brown with on the sides 12 black vertical bars narrower than interspaces and plainer in the young.

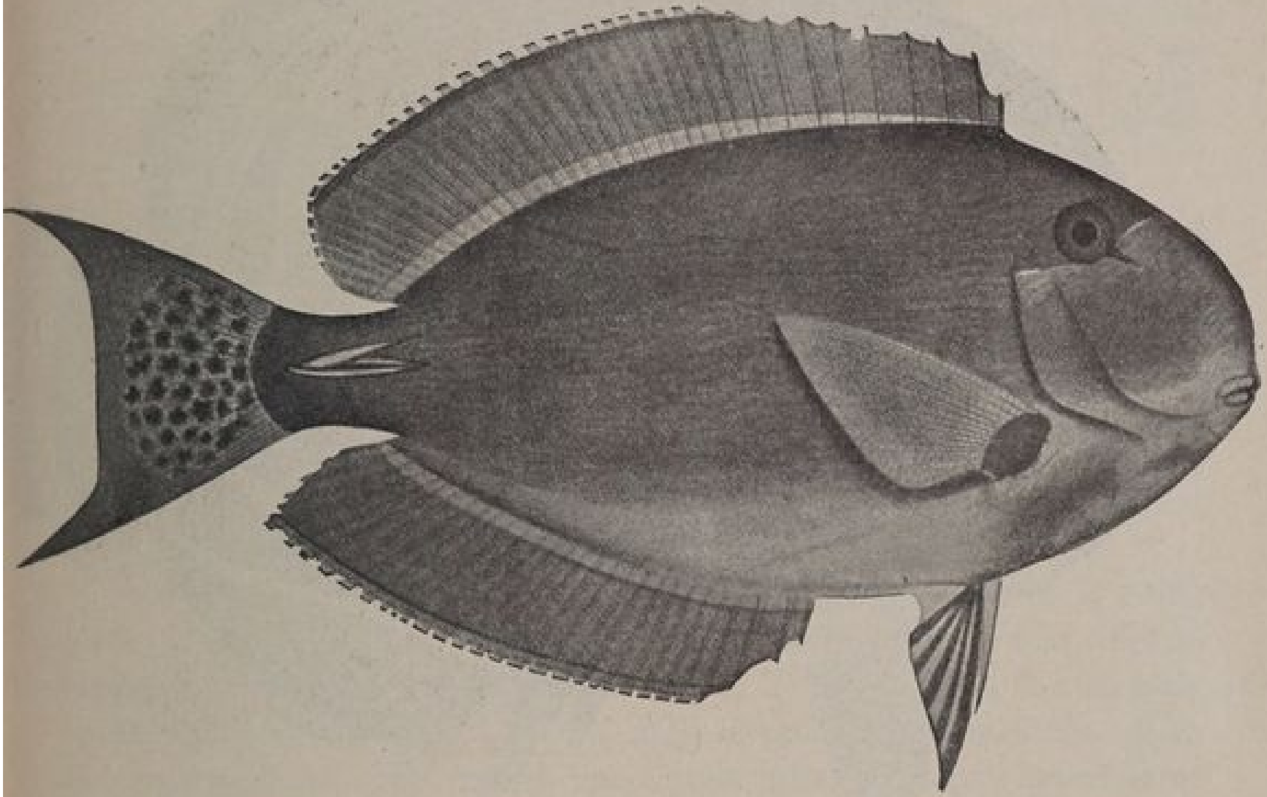


FIG. 84.—Hepatus dussumieri (Cuvier and Valenciennes); after Günther. (Bulletin, U. S. Fish Commission.

The *Teuthis cœruleus*, or blue tang, is of a rich blue color with about 45 or 50 narrow longitudinal lines of lighter blue or purplish on body; no blue lines on breast or head; no cross-bars. It is generally common from the Bermudas and southern Florida to Brazil. It ordinarily does not reach a greater length than 10 inches.

The *Hepatus dussumieri* is the species common about New Guinea, Hawaii, and the East Indies.

In the family *Chætodontidæ*, or butterfly-fishes, which are carnivorous inhabitants of tropical seas, and in the genus *Chætodon*, which is characterized by large scales, usually 35 to 50 in lateral line and 12 to 14 dorsal spines, is a species said to be poisonous at certain times when taken as food.

The *Chætodon trifasciatus* or *Chætodon vittatus*, Bloch, is found off Sumatra and Java, in the East Indian Archipelago generally, and also at Honolulu and Guam. It is widely distributed throughout Polynesia. It is said to become poisonous when feeding on certain poisonous crustaceans.

The family *Dasyatidæ*, or sting rays, is well known. The tail is armed with a large sharp retroversely serrate spine on its upper surface toward the base. In some, 2 or even 3 spines are present. There are about 10 genera and 50 species. In the family *Myliobatidæ* or *Ætobatidæ* or Eagle Rays there is usually a strong retroversely serrated spine very near the root of the tail. The sting rays are common and on the beach at seine hauling are capable of inflicting very troublesome and even serious wounds. These fish are probably too well known to require description.

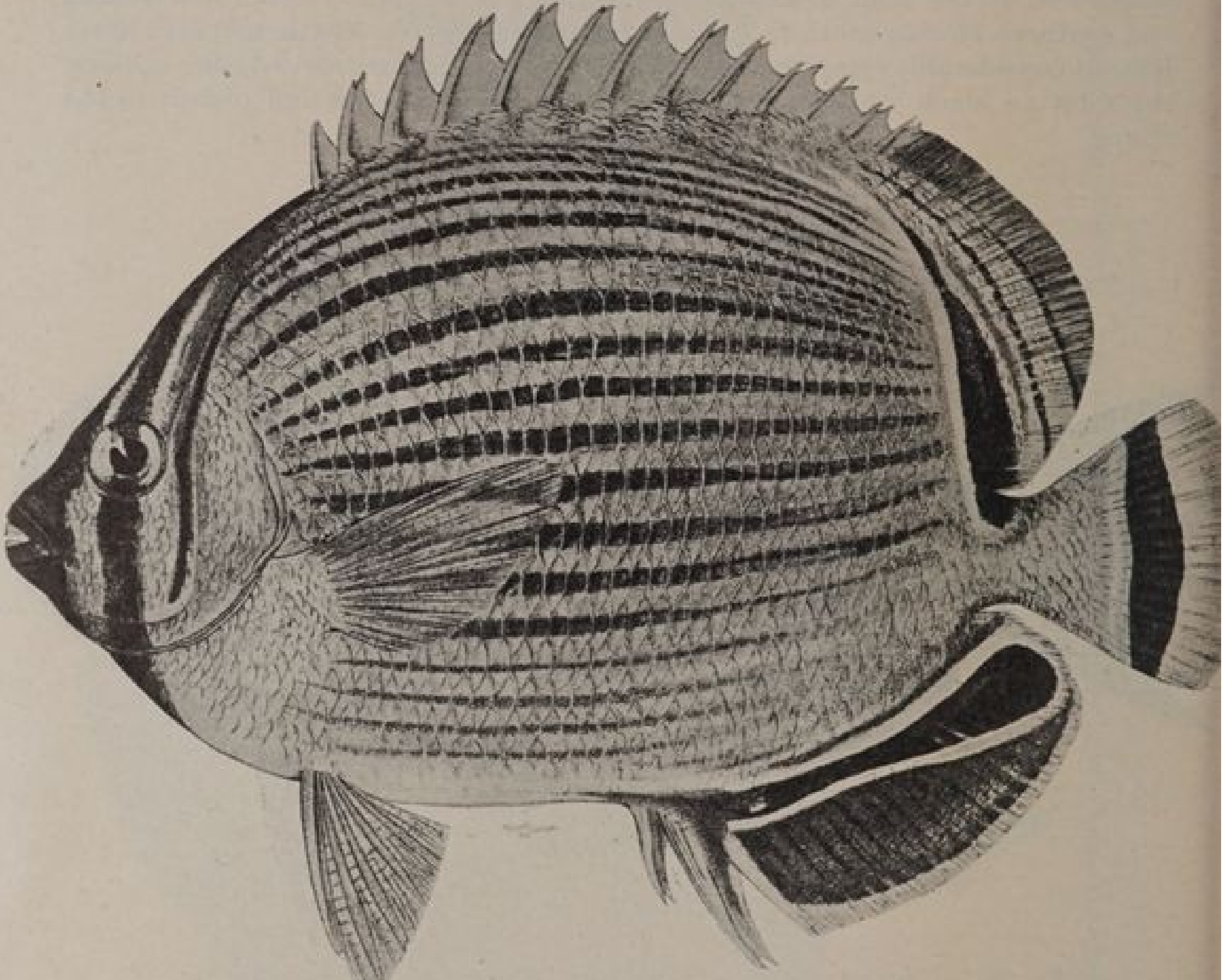


Fig. 85.—Chætodon Trifasciatus Mungo Park. (Bulletin, U. S. Fish Commission.)

In the family *Murænidæ*, or the morays, are grouped the most degenerate type of eels, so far as the skeleton is concerned. They may be readily distinguished from other eels by their small round gill openings and by absence of pectorals. They inhabit tropical and subtropical waters being especially abundant in crevices about coral reefs. Many of the species reach a large size and all are voracious and pugnacious. The coloration is usually strongly marked. In these fish the jaws are usually narrow and armed with either knife-like or else molar teeth. The secretions of the mouths are often poisonous or rather venomous as the result of the presence of poison glands rather similar to those of a snake. There is no canal for injection as in the tooth of poisonous snakes, but the poison is merely distributed in the mucus of the mouth.

The *Lycodontis funebris* or *Murœna infernalis*, or black moray, is a species of this family of the genus *Lycodontis* which is characterized by sharp teeth and the dorsal fin beginning with head. The jaws of this species do not completely close. It is a dark olive-brown, nearly plain, paler on throat; dorsal and anal fins with dark lines running longitudinally; belly without dark transverse lines. It is found in tropical America on both coasts, and reaches a length of 5 or 6 feet or more. It is extremely ferocious; common from Florida Keys to Rio Janeiro and from Gulf of California to Panama.

It is not clear to what extent the subject of poisonous fishes should be treated in a work on naval hygiene or even how far it is susceptible of treatment in certain directions, as it cannot be said that a complete list of either venomous or poison food-fishes has been made. That such exclusive lists would be of much value is very evident, but they can only result from the accumulated and sifted experiences of a large number of observers in warm seas, among whom the naval medical officer should have a prominent place.

There is considerable information now available, but it is either more or less scattered or in many instances in need of that kind of verification required for a scientific basis. To condemn a fish as truly or always poisonous requires not only testimony but evidence, often as the result of experiments on lower animals. Such experiments would naturally follow such accidents as have placed a given fish on the suspicious list. It is, therefore, primarily necessary in each case to identify the species and subsequently, should it be condemned with or without limitations, to recognize it on sight. In that connection a certain working knowledge of ichthyology is requisite. Reports of cases should be sufficiently definite for the identification of the fish in question, or they should be made in connection with specimens put up in alcohol, and contain clear statements of all the circumstances including also the locality where the species were found.

The testimony of natives, while not conclusive, is important, as it is often based upon accumulated experience. Such testimony, pending more complete information, should always be sufficient to cause the rejection of any given species as food on a ship and lead to steps for the diffusion of the knowledge of it throughout the service as at least suspicious. For instance, the family *Lutianidæ*, or the snappers, is usually reported to be made up only of food-fishes; yet:

> The species *Lutianus bohar* (Forskål), called by the natives of Samoa *Mumea*, has the reputation of being always poisonous. This fish is found also at Tahiti, Paumotus, Solomon Islands, New Guinea, Marcus Island, Thornton Island, and the East Indies. Most fish poisonous as food seem to be Plectognath, but this species certainly forms an additional marked exception. It may be distinguished from other species of its genus *Lutianus* (Bloch) by two round pale spots below the dorsal fin. It is deep brick-red everywhere, blackish on back, each scale with a whitish vertical spot, these forming lines along the rows of scales which are very oblique above lateral line, horizontal below; two rounded pale blotches along base of soft dorsal; dorsal blackish maroon, a narrow pale edge; caudal dark maroon, a narrow dark edge (the lower lobe longest, the fin deeply forked); anal darker red in front, with pale edge; pectoral deep red above, pale below; ventral mesially blackish-red, pale edge. Dorsal X, 13; anal III, 8; scales 8–64; canines large.
>
> Our service has had one very unfortunate experience with this species, *Lutianus bohar*. The report was made by Surgeon Raymond Spear, U. S. Navy, from the U. S. S. Wheeling, in 1904. The ship was off Leone, Tutuila, and 20 men were poisoned by eating this fish caught by one of the crew. The first symptoms appeared in one or two hours after ingestion. Abdominal distension marked, weakness, vertigo, violent abdominal pain, severe pain in calves of legs, vomiting in some cases, great prostration.
>
> Recovery was slow requiring from four to six weeks. As the acute symptoms subsided there was marked muscular weakness manifested by inability to walk more than a few steps. The pulse rate, not much affected at first, became greatly increased later, in one case reaching 160 and remaining above 100 for six weeks. There was a burning sensation of skin, tingling and formication. Hyperæsthesia was present in the legs of some, and no loss of sensation was observed in any case. A peculiar symptom was the sensation of burning induced by the application of water to the skin and mucous membranes; the eyelids in some cases "burned" and the urine "scalded" on being voided, one man describing his act of urination as passing "scalding water," the fæces also burned in passing and in some cases there was severe tenesmus. The digestive apparatus remained affected for some time, diarrhœa or constipation, usually the latter, being the rule. The stomach as well as intestines appeared to act as if partially paralyzed. There was no death, but the relative amount of the fish consumed by each is not stated.
>
> The ship's cat ate some of the fish and suffered with the same symptoms as the men. The dose was larger in proportion and "the muscles remained in a state of paralysis for two weeks, during part of which time the bladder was unable to expel the urine." The muscles were weak and at times did not coordinate six weeks after the poisoning. At no time did the animal lose consciousness or have convulsions. The fish was eaten on January 14.

Passed Assistant Surgeon Henry A. Dunn, U. S. Navy, reported from the U. S. S. Frolic, in 1902, as follows: On February 3, while en-route to Gilbraltar, about half the ship's company were taken with violent headache, gastric fullness, nausea, and a macular rash on face, arms, and chest. A brief investigation showed that the outbreak was due to eating ill-prepared fresh fish (skip-jack).

In those cases the natural inference seems to be that the fish was really the *Caranx latus*. The incident is singularly like that reported in Wilson's Naval Hygiene (1879): "Many accidents occur from fish-poisoning. One of our ships approaching the Straits of Gibraltar, the crew, in a calm, caught a great number of Spanish mackerel (*Scomber colias*), a much esteemed and very common European fish; and some thirty of the crew were poisoned, though none fatally, before the fish was suspected (Horner)." He also reports that during the first Japan expedition, our ships at Simoda were supplied with a very excellent small fish, the *Clupea thryssa*, which abounds there. After a week or so, it was observed that the fish were not so good as usual, and several persons who ate them were attacked with fish-poisoning.

In 1902, Ralph O. Marcour, then an Assistant Surgeon, U. S. Navy, reported a large number of cases of fish-poisoning among the crew of the U. S. S. Abarenda at Pago Pago. The cases appeared on the morning of March 28, and resulted from the ingestion at breakfast of fish that had been caught with the ship's seine two days before. No statement is made whether any of the same species had been eaten in the meantime without ill effects or how the fish had been kept, but apparently the trouble was not attributed at the time to post-mortem changes as the following statement is made: "The fish, which are caught in the harbor here, live in very shallow water and feed principally on sewage and fæcal matter. On the strength of all this and the possibility of the fish being diseased, I recommended to the commanding officer that fish caught in the harbor of Pago Pago, Samoa, should not be allowed on board."

The symptoms appeared in some cases five minutes after breakfast, but in the majority from 20 minutes to an hour. There were vertigo, cephalalgia, gastralgia, ptyalism, nausea, tremor of the lips and of the muscles of the face and of the lower extremities, muscular incoordination, and some disturbances of vision. In a few cases there was vomiting. The face and neck were intensely congested, lachrymation was increased, heart sounds were rapid and irregular, and respiration exaggerated and labored. The principal symptoms disappeared rapidly after the action of an emetic.

One cannot determine from the report what species of fish caused the trouble. It is stated, "the fish in appearance resembles good-sized mackerel, and are most likely a species of the genus *Scomber*." The report continues as follows: "On several occasions I have been called on shore to treat natives for fish-poisoning. The prevalence of this affection may be due to the method employed by them in preparing their fish, which are generally kept about 24 hours before being cooked, and are not eaten until several days later."

About the only *Scomber* common in Samoa is the *Scomber loo* (Cuvier and Valenciennes), which is noted as an excellent food-fish. The *Auxis thazard* is reported from Hawaii, but not from Samoa. The *Carangidæ* are well represented in Samoa and especially by the *Caranx forsteri* (Cuvier and Valenciennes) and the *Caranx melampygus* (C. and V.). The former is a species closely related to the *Caranx latus* of the Atlantic, but it is the food-fish par excellence of the mid Pacific, both in Samoa and Hawaii.

On the U. S. S. Raleigh in 1897, when at Gibraltar, there were cases of poisoning from the ingestion of "Spanish mackerel" for supper. Those cases were considered by Surgeon E. H. Marsteller, U. S. Navy, the medical officer of the ship, to be due to ptomain poisoning. It is noticeable that in all those cases marked relaxation of the peripheral vessels was the symptom first noticed, preceding the vomiting in all cases. On the "Abarenda" intense congestion of the face and neck was also a very prominent symptom. And it is undoubtedly true that members of the family *Scombridæ*, as other surface fishes, are noted for rapid post-mortem changes.

The post-mortem changes incident to bacterial life have a prominent position in the subject of fish-poisoning which is also complicated by the toxic properties of the flesh of certain fish incident to pathological conditions or toxic properties of their food in warm waters.

If every fish when caught were at once bled and well cleaned (gutted) there would be fewer cases of fish-poisoning as the post-mortem changes would be much less rapid. Soon after death the blood of fish congeals, but when post-mortem changes are advanced it runs out as a dull red more or less odorous liquid when the fish is cut. A fish fit for food should have at least bright unsunken eyes and bright red gills, but in the tropics even such a fish may have started to decompose internally. Removing the intestines, liver, and roe, and thoroughly cleaning the fish should be done very early, especially in tropical countries. The liver should always be included and also the roe of fish taken in warm waters. Removing the head before cooking is also good policy.

A fresh fish should sink in water. It should also have a certain degree of stiffness as a flabby fish is certainly at least beginning to decompose. In many fish in the flabby state strong pressure between thumb and index-finger will cause the flesh to move off, leaving practically only the skin. Such soft flesh shows that decomposition is well advanced. If a fish taken by the tail and shaken up and down gives a cracking sound from the back-bone it is certainly not sufficiently fresh for food. Cold storage or packing in ice greatly delays decomposition, but lessens flavor. The ideal method is to keep the fish alive in cars, whenever practicable, until it is time to prepare them for immediate cooking. It is, moreover, a method more often feasible than is supposed.

There are about 200 fish families and more than 12,000 species. Mathematically, the chance of poisoning from the use of a true poisonous fish as food is, in view of their relatively small number, especially those who appear fit for food, quite remote. Yet where fish, especially from warm waters, are consumed there is this danger which should not be ignored. And the cases cited here and elsewhere are sufficient to show the advisability of a better acquaintance with the subject than is general on ships.

Wounds from fish are more common than reports tend to show. Exceptional cases are reported from time to time, as is shown in the following from Passed Assistant Surgeon Middleton S. Elliott, U. S. Navy, on the U. S. S. Annapolis in 1901:

> "A gunner's mate, third class, while bathing in the harbor of Iloilo, P. I., on June 24, was bitten by a shark, the left leg being torn away at the knee. The man had gone ashore with a firing party at 1 P. M. and about two hours later went in swimming. While about 30 feet from the shore, in a depth of water of 10 or 12 feet, he was heard to give a cry and was seen to disappear for a few moments; when he arose to the surface he swam to the dingey 10 feet away and was helped into the boat. It was seen that the left leg was gone. A tourniquet, improvised of a silver match box and handerchief, was immediately applied by one of the men and the dingey started off to the ship, which was distant about 2 miles. When the boat reached the ship, the medical officer being absent, Assistant Surgeon Jacob Stepp, U. S. Navy, was summoned from the "Isla de Luzon" and a circular amputation was performed, the lower third of the femur being removed. Subsequent surgical work was required, but recovery resulted.
>
> The wound was peculiar, the thigh having been grasped about 4 inches above the knee-joint, stripped down to the bone and the leg torn away at the joint, thus leaving the lower extremity of the femur free from all tissue. He stated that he remembered nothing except that he felt something suddenly seize his leg and draw him down. When seized, he evidently thrust his hand down in his efforts to free himself and caught his fingers in the shark's mouth as on the thumb and index-finger of his left hand were two small triangular wounds."

Such extensive wounds are of course exceedingly rare, and, ordinarily, wounds from fishes are not the result of aggressive action on their part—the sting ray in its flutterings in the net or on the beach, or the handling of fishes with dorsal, ventral or pectoral spines under which are at times poisonous glands. The question includes the action of physiologically toxic serums more or less similar to the venomous secretions of snakes.

As an aid to investigation or study in that connection, the following more or less incomplete list of fishes capable of causing very painful, peculiar, and even serious wounds may be consulted: The *Diodontidæ* (porcupine fishes)—*Diodon hystrix* Linnæus; the *Squalidæ* (dog sharks)—*Acanthias vulgaris* Risso (dorsal spines); the *Dasyatidæ* (sting rays)—

Trygon pastinaca Cuvier, etc., etc. (jagged spine on tail); the *Myliobatidæ* (eagle rays)—*Myliobatis aquila* Dumeril, *Stoasodon narinari* Euphrasen, etc., etc. (serrated tail spine); the *Siluridæ* (catfishes)—*Plotosus anguillaris* Bloch, *Arius militaris* Cuvier and Valen., *Bagrus barbatus* Lecepede, *Doras costatus* Bloch, *Doras maculatus* Cuvier and Valen., etc. (dorsal and pectoral spines, poison glands in *Plotosus anguillaris* and some others); the *Holocentridæ* (squirrel-fishes)—*Holocentrus ascensionis* Osbeck, *Holocentrus spinifer* Forskâl, *Therapon jerbua* Forskâl, etc., etc. (dorsal rays seem to be venomous); the *Psettinæ*—*Psettus sebæ* Cuvier and Valen. (dorsal and ventral spines venomous); the *Siganidæ*—*Amphacantus siganus* Ruppell, *Amphacantus lineatus* Cuvier and Valen., *Amphacantus luridus* Cuvier and Valen., *Amphacantus sutor* Cuvier and Valen. (dorsal and anal spine venomous); the *Teuthididæ* (surgeon-fishes) —*Teuthis hepatus* Linnæus, *Teuthis cæruleus* Bloch and Schneider, etc., etc. (dorsal, anal, and caudal spines); the *Scorpænidæ*—*Scorpæna grandi*cornis Cuvier and Valen., *Scorpæna plumieri* Bloch, *Pterois volitans* Linnæus, *Synanceia verrucosa* Bloch and Schneider, *Scorpænopsis gibbosa* Bloch and Schneider, *Pterois zebra* Cuvier and Valen., *Pterois antennata* Cuvier and Valen., *Pterois muricata* Cuvier and Valen., etc., etc. (venom glands under dorsal rays); the *Cottidæ*—*Cottus scorpius* Linnæus, *Cottus bubalis*, Euphrasen (opercular and preopercular spines); and the *Callionymidæ*—*Callionymus belenus* Risso, *Callionymus maculatus* Rafinesque, *Callionymus lyra* Linnæus (opercular and preopercular spines).

The bibliography of the subject of poisonous fishes is somewhat extensive, but among all sources of information special mention should be made of the *Bulletins of the United States Fish Commission from which have been taken descriptions and illustrations;* and also of Pellegrin's and Coutièrés works. In every ship's library, natural history volumes are important, and it is also much to be desired that there will soon be available for ship use a reasonably complete list with full descriptions and colored plates of all fishes considered on good evidence to be always, or in certain localities or at specified periods, naturally deleterious to man either as food or in the production of poisonous wounds.

In the meantime Fonssagrives' advice to naval surgeons on tropical stations may be of interest. (1) Make inquiries among the natives in regard to poisonous fishes, procure specimens and demonstrate to officers and men. (2) With any suspected fish, make feeding experiments on lower animals. (3) Instruct cooks, in warm countries, in cleaning fish to remove thoroughly all particles of liver, roe, intestines, and head. (4) Secure and preserve specimens of suspected poisonous fishes. To these might be added (5) Carefully and systematically report to proper authorities in such form as will be of the greatest practical value each incident of poisoning from any species of fish.

Butter and milk and cheese are three important articles of food, but milk has a restricted place in a naval ration and is chiefly used in its evaporated form. The relative amount of nutrients obtained from milk in the Navy ration is so small and the use of fresh milk so restricted that its inspection as to quality except from the point of view of infection has not the same degree of importance as in civil life. And such examinations as are practicable on ships are no more trustworthy in determining infection in the case of milk than they were in the case of water received from shore.

Undoubtedly cleanliness should be required in all milk supplied and great lack of cleanliness may be declared by sediment. But milk, as drawn, is never free from bacteria, and its composition is such as to greatly favor their growth or multiplication. It thus happens that the temperature at which the milk has been kept and its age become important questions. At 50° F. the bacteria increase with relative slowness, and at that temperature the lactic organisms do not develop to any extent. But in time this lack of development of the *B. lactis acidi* may in the development of other organisms cause milk to become harmful. Thus, while a relatively low temperature (50° F.) is favorable to the delivery of fresh milk, as opposed to sour milk, it also tends to the keeping of milk longer than it should be kept. Milk may be sweet and yet, merely from the time it has been kept at ordinarily low temperatures, unfit for consumption or even dangerous. And all this is apart from any question of disease in the herd from which the milk is obtained or from infected water used to wash utensils or for purpose of dilution. It merely relates to organisms of putrefaction which under certain conditions decompose protein into poisonous compounds.

Boiling is undoubtedly the safe way of dealing with fresh milk, but it alters taste and composition and thus leaves it with few advantages over so-called evaporated cream. Pasteurization is a distinct advantage in relation to both preservation of the milk and killing of certain pathogenic organisms it may contain.

It is true that enormous numbers of individuals use milk daily not only without injury, but also to their advantage, yet a ship is ordinarily a transient and thus is at a disadvantage in relation to dealers in a commodity that has to be taken so greatly on trust, and, with a ship in stream, deliveries are often delayed much to the detriment of the milk. Besides in a milk epidemic large numbers are affected, and in view of the evoporated milk available and the subordinate position fresh milk necessarily has in a naval diet, it does not seem reasonable to inject into the life of the enlisted man the danger a fresh milk supply entails. It does seem reasonable, however, to eliminate the use of sweetened evaporated milk and to utilize the unsweetened milk for all purposes. Care should, however, be taken in the purchases to obtain only the evaporated whole milk and not milk from which the cream has been separated.

Fresh milk should not contain much less than 4 per cent. fat, unsweetened evaporated milk about 9.6, and the sweetened milk 8.3. In evaporated milk the use of such preservatives as salicylic acid, boric acid, and formalin so prominent in the examination of fresh milk ceases to be a factor.

The following are the notes on the bacteriological examination of fresh milk, which are official at this time:

The quantitative is of less importance than the qualitative; thus:

	Total	Lactic acid	Liquefiers	Miscellaneous
1. Number of colonies per c.c.	6,800,000	6,324,000 (93%)	68,000(.1%)	438,000
2. Number of colonies per c.c.	17,000	500(2.8%)	5,300(31%)	11,200

No. 1. Milk might be good, simply old. No. 2. Probably fresh, but suspicious. The best medium is a 3 per cent. lactose gelatin to which sufficient litmus has been added.

Quantitative.—Take an Erlenmeyer flask holding exactly 99 c.c. of sterile water. Shake or stir thoroughly the sample of milk (important). With sterilized pipette add 1 c.c. of the mixed milk to the 99 c.c. of water in the flask. Thoroughly mix (dilution 1–100). Take 1 c.c. of this mixture and add it to 9 c.c. of sterile water in a test-tube. Mix thoroughly (dilution 1–1000). With a sterile pipette run 1 c.c. into a Petri dish and pour on (mixing thoroughly) a tube of melted lactose litmus gelatin at 37.5–40 C. Make 0.2, 0.3, and 0.5 c.c. plates if desired. Enumerate colonies, and if 1 c.c. used multiply number on plate by 1,000.

Example.—Found 156 colonies: 156 × 1,000 = 156,000 = number of bacteria in 1 c.c. of milk.

Qualitative Bacteriological Examination.

When possible, best to use lactose litmus gelatin plates, but if great abundance of liquefiers may have to use lactose litmus agar. Plates are best studied in 5–6 days.

Normal milk contains lactic acid bacteria (old milk many), many showing neutral reaction and a few liquefiers. (If many liquefiers, milk suspicious.) Gas producers make a milk suspicious.

To preserve butter by the use of salt alone would require about 10 per cent., an amount that without washing would render it unfit for use. As a result some additional preservative, chiefly boric acid, has been frequently employed. The amount usually stated as permissible is about 0.5 per cent., but even then the daily issue in the Navy of two ounces of butter per man would contain 4.375 grains of boric acid, an amount not conducive to the best health, and consequently not advisable from a sanitary point of view.

This question of preserving butter has given much trouble in the Navy, but during recent years much advance has been made and the sustained quality has been very greatly improved. This has been accomplished under the specifications about as follows: The butter shall be fresh and made during the period most suitable for butter-making in the locality of creamery, from pure pasteurized milk or cream, none of which shall contain before pasteurization more acid in 50 c.c. than will be neutralized by 15 c.c., or 13 c.c., of N/10 alkali solution, as determined by Mann's acid test for butter scoring, as designated in the trade, 94 and 95, respectively The quality shall be strictly of the grade of creamery "extras," and must score not less than 94 and 95, respectively, at the time of packing. The moisture in the butter must not exceed 13 per cent., there must be no preservative used other than common salt, and that shall be at a rate giving not less than 2 1/2 per cent. nor more than 3 1/4 per cent. at time of packing. The tins to be made of perfect "melyn" of specified weight and must be thoroughly cleaned and sterilized by heating just before filling with butter. Tins must be key-opening, packed completely full, leaving no air space, and hermetically sealed by mechanical process without use of solder. Each tin must be carefully wrapped in paper and packed in sawdust, the boxes or cases to be completely filled by tins and sawdust. In addition to the usual inspection after delivery at navy yard, the ingredients, manufacture, sanitation, packing, boxing, and marking shall be subject to inspection by government inspectors. All the butter must be kept at a temperature below 50° F. after packing and until placed in cold storage where it must be kept at a zero or lower temperature until delivered. It will be withdrawn from cold storage for delivery as required between specified dates and the contractors guarantee it will keep good in any climate for six months after date of delivery.

The above is given as a sample specification to illustrate the care taken to secure food of good quality in the Navy and to preserve the good quality during storage on ships. Government inspection and the standards of purity, as established by the Department of Agriculture under Food and Drugs Act of June 30, 1906, are made to enter into all questions of quality of food supplies in the Navy to-day, and contractors are required to afford every facility to the inspector of the Department of Agriculture.

In the case of meats this extends to the process of selecting, cutting, trimming, freezing, etc., and in assisting the pay officer of the vessel concerned in determining whether the meat complies in all respects with the requirements of carefully drawn specifications. It, therefore, has seemed necessary here to put forward the subject of inspection only in those directions in which action on the ships themselves is concerned. However, in the case of deterioration in storage on ships, it is always important in assigning cause to be sufficiently explicit to be of help in assisting to improve method of preparation and packing.

Flour is an article used in very large quantities in a navy, and in regard to which there has been trouble in preservation during storage. It requires a dry and well-ventilated storeroom. The original quality of the flour is secured under specifications and inspection. It must be made of good sound wheat free from smut. It must be strong, of good color, high ground and well dressed, and contain 90 per cent. of the whole product of wheat in flour, 10 per cent. of low grade being taken out. It must be capable of yielding a well-risen loaf of good texture, color, odor, and taste. Good flour is white, with faint yellow tinge. After being pressed in the hand it should fall loosely apart; if it stays in lumps it has too much moisture. When taken between the fingers and rubbed it should give some idea of individual particles and not be too smooth and powdery. If put between the teeth it should crunch a little and its taste should be sweet and nutty, and without suspicion of acidity.

It is not so much the quantity of, as the quality of gluten that determines the quality of bread. Two flours may contain the same percentages of protein and carbohydrates, and yet the breads made in the same way from them may vary greatly in quality. It is the relative proportion of the gliadin and glutenin in the gluten that is the determining factor in such cases. Therefore, while flour should contain at least 10 per cent. of protein there should always be the additional requirement of capacity to yield a well-risen loaf of good texture. It is the gliadin or plant gelatin that binds or holds together the particles to form a dough.

There are variations in the method of making raised bread, but the principle is the same in all cases in which yeast is used. Yeast is an organized ferment that converts sugar into alcohol and carbon dioxide. The carbohydrates in flour are chiefly in the form of insoluble starch, but there are also other insoluble carbohydrates, such as pentozans and lignin. There are also soluble carbohydrates, such as invert sugar, sucrose, and dextrin. These latter are only about 0.5 per cent. of the flour, but during the fermentation process about 6 per cent. of the insoluble carbohydrates are changed to soluble forms. Thus, although there is a loss of carbohydrates in bread-making, due to the formation of alcohol and carbon dioxide, the bread formed contains from 3 to 4 per cent. of soluble carbohydrates. The starch grains or grains of insoluble carbohydrates are also to a large extent ruptured during the fermentation and baking, making them digestible.

The dough is made by mixing the flour with water, at least lukewarm. Yeast develops best at temperatures between 77° F. and 95° F. Therefore, the mixing and raising are done in a warm place free from drafts. As the raising is due primarily to the formation of carbon dioxide, and all parts of the dough must be under its influence to secure an even or satisfactory result, the yeast must be thoroughly mixed with the dough. The growth of the yeast is also favored by the presence of oxygen in the air. The mixing must therefore be accomplished by kneading. It is in this connection that the question of cleanliness becomes most marked. Everything in a bakery should be scrupulously clean and this applies to the individuals engaged in the work. In kneading with the hands, the person is brought into very intimate contact with the dough. It is true that in baking bread there is destruction of bacteria, but during the fermentation if cleanliness has not been observed, it is possible for undesirable substances to be formed. On a ship it is, therefore, very advisable for the work of hands to be eliminated by the use of a kneading machine. Bread made with the aid of machinery is more sanitary.

The amount of yeast employed depends upon the strength of the flour which is the strength or expansive power of the gluten depending upon the gliadin-glutenin ratio. This also has relation to the amount of water employed which, however, is ordinarily three parts of flour to one of water. The use of more or less whole or skimmed milk in place of water adds to the nutritive value of the bread by increasing the fat content. Bread made with water is somewhat whiter and lighter than that made with skimmed milk and skim milk bread rises more slowly, requiring two or three hours more time. On ships the amount of fat is increased by the addition of lard. Seven per cent. of weight of flour is issued in lard, but ordinarily 2 to 3 per cent. should be sufficient. Of compressed yeast about 0.4 per cent. of the weight of the flour is an average amount. The addition of from two to three per cent. of sugar is also generally advisable as making the bread more acceptable. About 1 per cent. of salt is added to give flavor, but as salt tends to retard fermentation, it is better to add toward the end of the mixing. It is also advantageous because it checks the acid fermentation that tends to follow alcoholic fermentation. On ships wet or potato yeast is often employed.

In the fermentation, the carbon dioxide permeates the dough, making cavities that are kept from collapsing by the tenacity of the gluten. When too much yeast is used, or the gluten is deficient in tenacity, and thus unable to resist the pressure, the gas escapes and the dough becomes heavy and soggy. Too much yeast also gives an unpleasant flavor. In general, to obtain good results, there must be some experience with the flour in question. The dough is put in a warm place to rise, and as the fermentation goes on, the carbon dioxide stretches the bubbles of gluten. If some of those bubbles break there will be large cavities in the dough. Sometimes the original dough is used as a "sponge," only part of the flour having been mixed with yeast. After eight or ten hours of fermentation the sponge is mixed with the remaining materials and all is left for a second rising of a few hours. Bakers ashore often use a less strong flour in this second mixing, as it is subjected to less pressure and it gives the bread a better flavor. This second mixing has to be very thorough, or the bread will contain lumps that have never been under the influence of yeast. Flour contains about 12 per cent. of water, and fresh bread about 35 per cent. Therefore, although the bread-making has cost the flour about 10 or 12 per cent. of its weight, the water and other ingredients permit 1 1/4 to 1 1/3 pounds of bread to be made from 1 pound of flour.

In the process there are changes in the protein as well as in the carbohydrates. All normal flour contains a small percentage of acid, and some acid is formed during fermentation. There is a reaction between the protein and the acids. In the process albumoses and other peptone-like bodies are formed, and also maltose and dextrin. There are thus chemical as well as physical changes that make the contrast between yeast-made bread and bread made by using baking powders with which the fine separation or fine spongy condition and palatableness of good bread are not obtained. If a baking powder contains alum there is union with the phosphates in the flour forming insoluble compounds which, lacking in digestibility, deprive the body of an important constituent. In a beaten biscuit air is enclosed during the persistent pounding, which expanding in the baking makes light and porous bread without leavening. Ship's biscuit is also an unleavened bread made simply of a mixture of flour and water.

In the baking of bread the expanded gluten is further expanded by the effect of heat on the contained gas. At the same time the heat stiffens or sets the gluten so that as the gas escapes the porous condition is maintained. The loaf loses some water, the starch and protein undergo further changes, and a crust is formed as the surface is caramelized. The crust forms from 28 to 44 per cent. of the loaf. A loaf of bread contains no appreciable amount of alcohol and but little carbon dioxide.

Adulterations of flour are rare in our country, though bleaching has been common. Rye flour, corn flour, rice meal, potato starch, or meals from beans or peas may be used for this purpose. Alum, borax, chalk, carbonate of magnesia, or bone may be put into flour to whiten it or relieve it of acidity, but the use of such substances pertains more to the baker and thus may have relation to fresh bread obtained from shore. A good-looking loaf of bread may be made from poor flour by using alum. The use of alum to improve the appearance of bread has not been so very uncommon. It is very objectionable and should not be tolerated. A bread containing alum gives a bluish color in a solution of tincture of logwood and ammonium carbonate.

Fresh bread is not retained on a ship, but is consumed as delivered or made, consequently its deterioration during storage is never in question. Sour bread is ordinarily about the worst fault in fresh bread. If this occurs through lack of cleanliness it is most objectionable, as probably representing putrefactive changes with formation of butyric acid. Acidity is apt to be noticeable when the dough has stood too long and objectionable bacteria have been allowed to propagate as the alcoholic fermentation has ceased.

The method of packing flour for storage in ships seems to be in a transition stage. It is found in half-barrels having a paper-bag lining; in export bags or a double bag, the inner being made of strong new cotton and the outer of gunny material; and in hermetically sealed tins containing 50 pounds.

The *Acarus farinæ* is a common parasite especially of inferior flour. When present it has generally been introduced at the mill, but its propagation is facilitated by dampness. Its presence shows that flour is changing and, in number, unfit for use. The weevil, or *Calandra granaria*, is another parasite that may appear in flour. It was formerly very common in navy biscuit, though recently as the biscuit is packed in tins they have become somewhat less common. Navy biscuit may remain on ships for many months or be a year or two from the primary inspection to consumption. Not as much hard-tack is used now as in the old days. It is very commonly the bread of men undergoing confinement, and it may be accused of mustiness or of weevils. The diagnosis of mustiness depends upon odor of the biscuit as a whole, and when broken and the flavor as developed during thorough mastication. The examination should be carefully made in all cases, as all such complaints are worthy of careful attention. Weevils are found by breaking one or more biscuits with the hands and looking for the insects. The weevil is a snout beetle perhaps less than 1/4 of an inch long, and is very readily seen. Mustiness and parasites in bread are causes for rejection.

The weevil is also found at times in rice, but is not of the same variety, being the *Calandra oryza*. Perhaps the *Tribolium confusum* is the commonest variety of beetle in flour and the most objectionable, as it gives the flour a disagreeable odor. It is about $\frac{1}{8}$ of an inch in length and has a brownish-red color. The flour mite or *tyroglyphus* is not uncommon in damp flour. All parasites show change, and they soon render flour and other vegetable foods, such as beans, worthless. It is very advisable to have a good idea of their appearances and life histories, but the information can be readily obtained from other sources, even recent dictionaries containing cuts of most of them. Many of them are in food material at time of purchase, but if the packing is not practically perfect they may take charge of storerooms and do very much damage. The volatilization of carbon bisulphide is used by millers and others to destroy the insects in the material, but inflammability bars its use on ships. Ordinarily the material is condemned. Sulphur disinfection is efficacious in the empty storeroom, though often a thorough washing out with vinegar is sufficient in a bread-room.

The best qualities of flour are slightly acid, but not to the taste. Good flour should not have an earthy taste or even the slightest mouldy or musty odor.

Bumboats are usually inspected by the medical officer before the men's breakfast, dinner, and supper. The men should not be kept waiting through any lack of promptness on the part of the inspector who is informed when the boat is alongside at the port gangway. The inspector should go down to the boat and carefully scrutinize its general condition and the general arrangements of its contents from the point of view of chances of contamination from dirty water of the boat or of the harbor. Ships in visiting ports should undertake to impress upon any bumboatman that he cannot serve the ship unless he takes great care to bring his material off with due regard for cleanliness. That is much more difficult than it seems, but it is facilitated by limiting the number of such boats through cooperation with the executive branch by which prices are settled during the preliminary or first competition.

It is very advisable in many localities to have a good bumboat service, and when practicable selection should be made of those who appear to be able to furnish a sufficient amount of the things desired. Not allowing a boat to trade on account of lack of cleanliness or proper care of material is a part of the education of the bumboatman when the reasons are understood by him. In harbors not well protected, it is difficult to keep dry the material in small boats. Some protection is afforded by baskets and boxes by which also fruits are kept off the bottom of boat, and thus free from the water the boat itself may contain. No material that is brought off unprotected from harbor water is safe, and such protection is often the most difficult to obtain. In every ship there are boxes, half-barrels, or the like, representing original packages in which food materials have been issued during the day. Some of those are suitable for use in bumboats where a few would be gladly received in localities where such things are scarce. The ship will thus, when the occasion arises, take an active part in securing good conditions in such boats as have seemed most promising.

The contents of a bumboat are usually cigars, cigarettes, the various fruits of the locality, perhaps home-made candies or guava jelly or paste, sometimes bottles of pop or syrup of some kind, curios, and occasionally fowls and eggs. The cigars and cigarettes usually require no attention. Among the fruits some are more desirable than others, and it is well to have an understanding of what is most wanted, such as oranges, lemons, and limes. The orange is generally acceptable if not overripe. The greenness of an orange is not in question, and many good oranges in the tropics look green. There is, however, a frequent attempt to sell them when overripe or soft in spots. Such a question can only be determined by selecting several samples of the fruit indiscriminately and examining them. There should be no hesitation in utilizing samples of any fruit in the boat when it is necessary to form correct conclusions.

In relation to oranges, lemons, and limes, the object is always to determine decay or overripeness, and in that condition they should be invariably rejected. In the case of the pineapple the object is to determine ripeness, and unless the pineapple is thoroughly ripe, it should never be admitted, and the same is true of mangoes, a fruit often brought off out of season. Bananas are good enough if they are ripe. One cannot pass judgment in that case entirely on color. It is best to try them, when the sample should break up easily in the mouth. Unripe bananas cause trouble in a crew. Cocoanuts are not apt to be too popular unless the milk has been replaced by rum. It is well to look at the eyes of some selected indiscriminately. Rum may get into a ship inside of a cocoanut.

It is safer, as a rule, not to allow any drinkables to be sold, such as ginger pop and the like. It may also be generally well not to encourage the sale of home-made candies, especially as ordinarily there is candy in the commissary store, and a denial of sale is thus no hardship. Guava jelly or guava paste in the manufacturer's wooden boxes is acceptable. Doubtless much of that in glass jars is free from objection, but its history is always in question. It is, therefore, generally best not to introduce it on board without knowing something of its origin. The other tropical fruits in such boats are generally not popular and are ordinarily free from objection. A bumboat should be inspected carefully but expeditiously and the report made to the officer of the deck of such articles as are recommended for exclusion.

CHAPTER VI.

THE NAVY'S CLOTHING.

The relation of clothing to health is fairly well understood in certain important directions, but no material has yet been found that can be utilized to thoroughly satisfy all requirements. This is made evident by the advocates found everywhere for each of the materials in more or less common use for underclothing—wool, linen, silk, and cotton. The various contentions have emphasized the important facts that all men have not the same requirements in the same degree, that the conditions under which men may live in relation to clothing vary sufficiently to require differences in clothing, and that methods of construction of fabric have as much importance in relation to clothing as fiber of construction. These facts may be deduced from a study of the requirements of the body in relation to clothing and of the properties of the materials in common use.

The human body is a working machine that is generating heat all the time. The cut and fit of clothing should interfere as little as possible with the functions of the body as a working machine, and the style of garments should be secured from material that does not place a burden upon the body, in the comfortable regulation of its own temperature, that is beyond its physiological limit. Apart from the fit and cleanliness of clothing, comfort or discomfort depends upon relation to body heat and therefore clothing in relation to health has to be considered primarily in relation to regulation of body temperature.

The integument of man is a living organ. It is a living thing having among its most important functions the regulation of body temperature. It presents a radiating surface by which the body loses heat but, as the skin is an organized structure, it differs essentially from other radiating surfaces in forming part of a mechanism by which, in automatically varying the blood supply, its own temperature is varied.

There is in this something essentially different from the radiating surface of a stove, for instance. They both radiate heat and thus tend to diminish the temperature of the radiating material, but in the case of a stove its radiating surface furnishes in its conductivity, color, and area a fixed relation, in amount of heat radiated, between the heat sources within and the heat sources without. Thus the colder the surrounding objects the more readily the surface of a stove radiates, but in the case of the skin the colder the surroundings the less it tends to act as a radiating surface for the amount of heat it has to radiate is diminished by reflex action manifested in vasomotor control of its blood supply or warming fluid.

The exciting cause of this action is loss of heat, the lowering of temperature of body surface causing the body to conserve its heat by diminishing supply of heat at the surface. In other words, it does not exist for the purpose of warming other objects, but for other purposes in which the conservation of its own heat in cold weather is a paramount necessity.

The normal body is acting all the time to maintain a fixed temperature. It strives to have its loss of heat equal to its production of heat, and when its surroundings tend to take heat too rapidly it diminishes loss by, among other things, limiting surface blood supply. But when its surroundings are themselves relatively warm the body resorts to methods to facilitate heat loss—it increases the flow of its warm circulating fluid to the skin, it covers itself with water in the form of sweat, it avoids the neighborhood of objects warmer than itself, and seeks air in motion that sweat may be evaporated and that the particles of air streaming over the body may each carry away not only some amount of water, and therefore heat in latent form, but also some amount of sensible heat.

In all this it necessarily lives under natural laws and *accomplishes* its purpose by virtue of the properties of matter, radiating heat in accordance with the laws of radiation and utilizing the power of air to take up water in the form of vapor and also the property of air particles to be heated and thus convey or carry heat from any surfaces warmer than themselves—the property of air known as convection. The body, then, loses heat by radiation, evaporation, and convection and also to some extent by conduction, as it is more or less in contact with material conveying heat by virtue of the property of conductivity.

But the action by which the circulation of blood through the skin is varied is a physiological action—the action of a living organism—and therefore, though the same in character in all persons, varies in degree and rapidity in different persons and in the same person at different times, even when the exciting cause is identical. It is essentially the action of involuntary muscles, and therefore beyond direct individual control. It is under the influence of heredity, as are human machines in general, but can be greatly influenced by educational methods, such as physical culture and baths followed by skin friction.

Naked skins exposed to the same low temperature, but within certain limits, are not affected with the same rapidity or to the same extent. In one individual the skin will blanch rapidly and profoundly, causing goose-flesh, involuntary movement of the voluntary muscles known as shivering, blueness of the lips, and even chattering, all signs of the very close nervous connection between the skin and the body as a whole. And if the exposure be prolonged the natural reaction on resumption of clothing may be slow, eventually excessive, and associated with inflammations of internal organs or surfaces and with marked increase in *heat production*. In another individual the same degree of exposure under same conditions may cause few or no signs of distress, and the resumption of clothing is quickly followed by a moderate reaction giving a comfortable sensation of warmth.

It is the weak muscle that under exercise more often tends to be spasmodic in action, and thus many have found that the exercise of involuntary muscles incident to the short cold bath and to physical exercise lessens the sensitiveness of the skin to variations of temperature and leaves the body less dependent upon exact adjustment of clothing to surrounding conditions.

But the degree of education that is practicable in the case of the muscles of the arteries is variable, and the sympathetic system of nerves is also under the varying influence of the internal secretions of the body, such as those of the thyroid gland and suprarenal bodies, and also of the by-products of the food used in diet. It is also evident that the skin mechanism can be profoundly affected by alcoholics ingested, the involuntary control being greatly limited or even abolished and thus, with continued flushing of the skin and undue exposure, the loss of body heat is excessive.

If the use of alcoholics be habitual the mechanism is often permanently injured by continued dilatation of superficial vessels. It is thus recognized that to depend upon the oxidation of alcohol for increased heat production is detrimental, especially where the demand upon the body is to conserve its heat as in Arctic explorations or at any time during direct exposure to cold. When the reaction after exposure to cold is unduly delayed, the spasm of the involuntary muscles continuing in warm surroundings, alcohol hastens reaction and diminishes internal congestions. But in accomplishing that result it can stimulate the production of sweat and, as its direct effect lessens, the body without sufficient covering is exposed to the danger of subsequent chilling by, among other things, the too rapid evaporation of its own perspiration.

It is true that in the regulation of temperature there is not only a regulation of loss, but also a regulation of production of heat and that there is normally a correlation between them in the struggle to maintain a fixed temperature. In cold weather there is a tendency to increased loss of heat and also to increased production of heat, for, within limits, metabolism depends greatly upon the amount of heat-loss at the surface, and there is thus a relation between metabolism and superficial area. The loss of heat not only causes a reflex action by which there is less heat at the surface to be lost, but it also causes a reflex action by which the metabolic activity of the cells of the body is increased. The appetite in cold weather is increased, and the body undertakes by increased consumption of fuel to maintain its temperature. There is thus a relation of clothing to food or to those variations in metabolism constituting the *chemical regulation of temperature* as well as to the variations in surface loss of heat or the *physical regulation of temperature*.

It is in the dynamic value of protein that meat eaters find comfort in cold weather and discomfort in warm weather, and there may be some relation between the uneven production of heat in those who eat meat to excess, and the increased tendency to catarrhs exhibited by them, there being greater variations in the action of the skin to regulate heat-loss and therefore more dependence upon a balanced protection by clothing.

The effect of clothing as man's artificial covering is found very largely in control of the air it tends to keep under the influence of the skin. If the clothing greatly limits the movement of air in contact with the skin it is called warm, and if its control in that respect is much less it is called cool. Therefore, in wearing clothing, man undertakes to regulate the amount of air that shall circulate about his body. He does not aim to completely stagnate any particular amount of air, because he must have such degree of motion as will permit it to carry off such excreta as heat and water, but he undertakes to *control* the motion because the excreta must not be carried away too rapidly or too slowly. He is seeking *regulation* of body temperature.

Clothing itself furnishes no heat. It is warm when it greatly limits the passage of heat from the body and cool when its action in that respect is relatively small. This limitation of heat-loss by clothing is not due in any great degree to the action of the materials as conductors. Wool, cotton and even linen do not rank high as conductors of heat and may even for practical purposes be generally regarded as almost non-conductors. If perfect conduction be represented by unity, then copper would be represented by 0.91 and a strand of wool by 0.000122 and cotton by 0.000139. And air is even a much poorer conductor of heat than they, for it is represented by 0.000049. As, then, both the air imprisoned by the clothing and the clothing itself are such poor conductors, the loss of heat in that direction must be relatively small. As the surface of clothing is to a great extent substituted as radiating surface for body surface, loss of heat by radiation is thus very greatly limited. The loss, therefore, not being chiefly by radiation and conduction, must be chiefly by evaporation and convection, and, therefore, by moving air as the medium.

Clothing is never in perfect contact with the body. If the clothing is tight the amount of air between it and the body is relatively small, and if loose it is relatively large. This body of air is in touch with the air filling the meshes of the clothing itself, which varies in amount and movement with character of fiber and number of air spaces, and that in turn is in touch with the atmosphere or the contained air of a room. It is through the study of the air relationship, the properties of air, the varying degrees of stagnation secured, and the varying ability of different fabrics to take up and part with water that an understanding of the action of clothing is derived.

The properties of air upon which the action of clothing depends are ability to take up water in the form of water-vapor and ability of air particles, when in motion, to carry heat. These properties have been considered in the chapter on air, but it may be well to recall that perspiration forms on the surface of the body and is always present, being small in amount in cold weather and large in amount in warm weather. Therefore, in winter the loss of heat by evaporation is relatively small and by convection relatively large, while the reverse is the case in summer or in the tropics. But that in exercise or work there is an enormous increase in the production of heat with corresponding effort on the part of the body to maintain an equilibrium of heat by facilitating loss of heat. This effect is manifested largely in increased amount of water on the skin by the evaporation of which the body seeks to lose heat. Thus, even in cool weather when, under exercise, loss of heat by convection is insufficient, evaporation is utilized to secure a balance between heat production and heat dissipation. And it is also in cold weather, when the clothing may not be sufficient to diminish to the desired degree the loss by convection, that exercise is utilized to secure a balance by *increasing heat production.*

Men standing in ranks in cold weather feel the cold which is not noticed when on the march, but on the march the heat production in view of limitation of loss of heat by clothing may be relatively excessive, and thus lead to the production of sweat. Under such circumstances, if men are again kept standing in ranks the evaporation of perspiration, and also loss of heat by convection, may be sufficiently rapid to produce a chilling effect that tends to increase the sick list. After exercise additional clothing stagnates an additional amount of air, brings a dry surface in contact with the air in place of a moist one, and thus makes the loss of heat by both convection and evaporation much less rapid, thus avoiding chill. When men of a ship are exercised in ranks, say on shore at a navy yard in cold weather, the period of danger is not that when the men are in motion, but during a halt which for one reason or another may be prolonged. Standing in the cold without additional clothing when heated by exercise is dangerous.

Perspiration forms *on* the skin. It is taken from the skin both by clothing and by the air in contact with the skin. Clothing in contact with the skin takes up sweat by virtue of its absorbent power in much the same manner as a sponge takes up water. Where clothing next to the skin is loose, or has few points of contact, more water passes directly to air than where clothing is tight and especially when the cut and fabric of material tends to permit more air movement.

Perhaps this fact may not have been given the importance it deserves. It is noticeable that officers and men of the Marine Corps prefer to wear a single shirt and no coat in the tropics—a flannel shirt with no undershirt. The shirt is loose in body and sleeves, but like an ordinary shirt fits in at the neck and wrists and is worn within the trousers. The contact with the skin above the waist is thus more or less limited as well as the direct passage of perspiration into material and more water tends to go into the air in contact with the skin. The single layer of clothing above the waist permits more movement of air through meshes, and thus the air next the skin as it acquires water and heat becomes lighter than the outside air and facilitates movement. A breeze of course facilitates this movement much more. New air replacing the old keeps up the loss of heat by convection and evaporation. Of course, as the outside air approaches the temperature of the body its power of taking heat from the body by convection diminishes. When it is at the temperature of the body surface it cannot take away any heat at all by convection, but when the difference is marked the loss of heat in that way is great as is evident from the amount and number of layers of clothing necessary for warmth in cold weather and especially in cold windy weather.

The single flannel shirt would be insufficient in cold weather because it would not sufficiently stagnate the air next the body. It might be insufficient even in the tropics if cut low in the neck and worn over the trousers as a jumper is, because the rate of movement of the contained air would be increased not only directly on account of the enlarged openings, but also because the movements of the body and of the jumper itself would facilitate a rapid circulation of air over the body. It would also be insufficient as a single garment if made of any ordinary cotton cloth even in direct relation to contained air because cotton cloth is made of a fiber consisting mainly of cellulose, and as ordinarily woven has not the power to stagnate the air in its meshes to the extent found in flannel which is made of wool, a fiber having on its surface imbrications or serrations that cause them to adhere tightly to each other, make a close texture and form air spaces in which there is increased opposition over cotton to air movement.

There are also other reasons why ordinarily in the tropics a marine is comfortable in a single flannel shirt while a sailor man wearing a cotton jumper has to wear an undershirt for safety. These reasons have relation to stagnation of air, but also to the evaporation of that perspiration which is absorbed by clothing. Perspiration that passes into the single flannel shirt, as from the shoulders, upper part of back, and belly, is not converted into watery vapor as rapidly as in the case of a *single cotton* shirt and at the same time *does not lose its own heat as rapidly by convection.*

It is understood that air is a poor conductor of heat. In heating air, as in heating water, the volume arrives at a common temperature by transfer or currents of particles. The air in contact with the heating surface does not pass its heat to any great extent to other air, but becoming lighter rises and the colder air falls into contact with the heating surface and is heated. This is continued until the entire body of air, as in a room, is heated. This property of air by which it carries heat away from a surface warmer than itself is called convection. It is quite evident that the loss of heat by the heating surface is greatly increased where the movement is assisted by wind as then the colder air is brought in contact much more rapidly. Thus, in the case of the body, the colder the air and the more wind or draft there is the greater the chilling effect or the more rapid the loss of body heat irrespective of evaporation. But this action of air is applied to anything it may come in contact with that is warmer than itself. Perspiration as it forms on the body is, under any ordinary cricumstances, warmer than the surrounding air. Clothing therefore takes up warm water from the body. Such water is in contact with air at the surface of the clothing and also with air in the meshes.

When clothing absorbs water, the air, if not saturated, immediately endeavors to get it, and at the same time if colder it immediately endeavors to bring it to its own temperature. Now, these attempts may have no relation to one another, for it is apparent that if air is saturated it cannot take water, but if at the time it is colder than the water it will take its heat. This situation is very unfortunate for the body, for the chilling effect may be quite pronounced and, what is more unfortunate, confined to limited areas. It is common, for instance, on ships anchored off the coast of tropical West Africa, especially at night. At anchor off the Congo the air at midnight being from the swamp land is often nearly saturated and of high temperature, but lower than that of the skin. The part of the body in contact with the bed becomes covered with sweat of relatively high temperature. On turning, this part of the body is brought into contact with nearly saturated air of lower temperature and, losing to the air only a little water, is soon in the position of wearing wet clothing at about air temperature if the garment is a cotton one. Some persons, with marked tendency to the formation of perspiration, obtain considerable relief at such times by sleeping in flannel pajamas.

All clothing next to the skin takes up water, but in different ways and in different degrees. The water may go into the fibers themselves or into the meshes, or into both. The water that goes into the fibers is called hygroscopic water, and that in the meshes, or between the fibers, water of interposition. When a woolen garment takes perspiration the percentage of hygroscopic water is high, while in the case of a cotton garment the percentage of water of interposition is high. It is claimed, and ordinarily with reason, that hygroscopic water is parted with more slowly than interposed water. Certainly a cotton garment, such as muslin, can readily acquire sufficient water of interposition to be wet through and to adhere to the skin, while the exposed water rapidly loses heat. On the other hand, a woolen garment, still retaining or stagnating air or keeping its water more completely from the external air, will keep perspiration more completely under the influence of body temperature. In addition, while a woolen garment does not tend to get wet to the point of adhering to the skin—a fact that depends not only upon relation to water of interposition, but also to character of surface—it parts with its water more slowly than a muslin garment, for instance, and thus also limits the abstraction of heat by evaporation.

But there is very much to be learned not only in relation to the *exact* situation of water in articles of clothing made of different materials, but also to the mount of water that can be absorbed, not so much in relation to differences of material as to the different ways in which the same material may be utilized in construction. Everybody knows how soon a damask towel seems to get wet through or saturated in comparison with a huck towel, and how much more water than either of them a bath towel whether of cotton or linen will hold. Also all water of interposition while situated in the same general way does not offer equal facilities for evaporation. A muslin shirt or muslin drawers will part with water rapidly and give a sensation of chilliness, when the garments made of the same material (cotton) but on a knitting-machine instead of on a loom can be worn with comfort. It seems to be a question of the shape of the spaces between fibers and their multiplication as well as the amount of material in the fabric. The cellular form of construction irrespective of the kind of material employed, permits a larger amount of water of interposition to be absorbed and diminishes or regulates the rapidity with which it is evaporated. In doing this, it also regulates air movement. It is along such lines that the value of linen mesh is found.

However, as a general proposition it can be stated that while linen and cotton can thus be woven to meet certain requirements better than wool, the latter still retains supremacy in its particular tendency to retain air and perspiration and in that it may be desirable or very undesirable according to circumstances of surrounding or to individual peculiarities. For, inasmuch as the object of clothing is to aid the body in the regulation of its temperature, it follows that this function is defeated when clothing offers too much resistance to the dissipation of heat by convection and evaporation. In other words, the character or amount of clothing may too greatly exaggerate the efforts of the body to dissipate its own heat. If it limits too greatly the movement of air in contact with the body, such air becomes incapable in view of its very high temperature of sufficiently assisting the individual to lose heat by convection. As the surface temperature thus increases, the blood supply to the skin increases, and the amount of sweat becomes so great that it keeps the body in wet clothing all the time.

This excessive activity of the skin leads to danger in several directions. It unduly increases the sensitiveness of the skin by lowering its power to protect itself, as its capillaries are kept too greatly distended and the involuntary muscles concerned unduly respond to any lowering of surface temperature subsequently incident to drafts or conditions that may tend to lower the temperature of the large amount of sweat available or to increase its rapidity of evaporation. It also leads to complaints on the part of the skin which may be manifested in the form of prickly heat, and such a complaint interferes with function, interrupts sleep, and irritates the body as a whole. This inflammation of skin primarily incident to its high temperature and consequent excessive activity is facilitated by the surface qualities of the wool itself and by the quality of sweat. Wool is modified hair, and such hairs standing out from the surface next the skin act as an excitant and, under the circumstances indicated, as an irritant.

This quality of a woolen garment in whipping or scratching the skin may have value in cold weather in causing an additional sensation of warmth by increasing flow of blood to surface, but it becomes a factor in increasing the distress under circumstances favorable to the production of heat eruption. Some skins are so sensitive that the itching caused by a woolen undershirt is intolerable even in cold weather, but ordinarily that symptom is temporary, as the skin being a living organ presents a varying degree of adaptability.

Civilized man has cultivated his skin to conform to the condition in all climates of a more or less fixed tropical temperature, and as a result there is danger to man in any case of quick variation in this temperature. It is the *variation* that acts as an excitant, whether it be *above* or *below* the standard to which the skin has been accustomed. If *below* there is the reflex action from a sensitive skin leading to rapid withdrawal of blood from it with disturbance of circulation in distant parts, and if *above*, there is an increased sensitiveness of the skin making any subsequent lowering of its temperature more capable of chilling, or there is primarily a loss in the integrity of the skin itself incident to the too violent effort on its part in the attempt to dissipate heat.

Wool by its stagnation of air and hold upon water protects the body from chill, but in warm weather, or at any time if in excess in material or layers of material, not only makes the skin more sensitive, but by its *excessive protection* or interference with heat-loss is an enemy to its integrity.

In the use of linen and cotton, the effort has been directed to evolve a *form of construction* that, in varying amount of material with conditions, will stagnate air sufficiently but less than wool, thus causing less sweat and more loss by convection, and part with water not too rapidly, but more rapidly than wool. For while the body pours out its sweat during work or exercise, there is an increase in amount as the result of the clothing itself in its interference with the dissipation of increased *heat production*. At rest the production of heat at once diminishes, there is thus no longer necessity for sweat remaining, and reason for its immediate separation from the body *as water*.

This may be accomplished by the rapid change from wet clothing into dry. But if the change be not made, there must be *sufficient* stagnation of air to prevent the warm sweat from losing its own heat too rapidly by convection and *sufficient hold* upon the water to prevent a too rapid loss of heat by evaporation. In all this, however, the clothing *must have* a sufficient tendency toward a return to dryness, for when at rest, the body ordinarily rebels under conditions that cause the production of sensible perspiration. It does not tolerate a continuous bath in its own stagnant sweat, and in its constructive metabolism it depends to a certain extent upon impulses received from the skin which are lost when the clothing tends to keep the surface at an excessive temperature. Clothing that is too warm not only debilitates the skin, but also debilitates the body.

In evaporation, heat is lost because water changes its physical state from a liquid to a vapor, more heat being required for the maintenance of the latter form. Such heat becomes latent, to appear again as sensible heat when the vapor condenses.

The water-monkey, or porous earthenware receptacle used in warm countries to cool water, operates under the same physical law as the human body in losing heat by evaporation. A certain amount of the contained water finds its way through the porous earthenware and tends to collect on its surface. It is taken from the surface by the air. The higher the temperature of air the more water-vapor it can contain, and the lower its humidity the greater its drying power or the more additional water it is capable of taking up. For the water to pass from the wet surface to the air there is a change of physical state, with abstraction of heat from the surface and consequent lowering of the temperature of the contained water. The more rapid the evaporation the greater the amount of heat abstracted. If the porous material of the monkey permits the water to pass through it at a rate equal to the maximum drying power of the air that comes in contact with it, there is a maximum cooling effect.

But the maximum drying power of air depends not only upon its initial temperature and humidity, but also upon its movement. The longer air remains in contact with a wet surface the nearer it gets to saturation, and therefore, the less its drying power becomes. Consequently any wet surface dries more rapidly in a current of air than in quiet air. Therefore, in the old days on ships or in those days without ice machines, it was not uncommon to find monkeys swung in hatches or in places where there was air movement as the result of an attempt to bring the contained water to the lowest temperature possible under the conditions.

It is the same way with the body. It passes water from within to its surface, but it increases the amount in warm weather, and it is in warm weather, as a rule, that the air is most capable of taking it. Yet, at a given air temperature, the capacity for water depends upon degree of humidity, and the rapidity of evaporation has an intimate relation to amount of draft or wind. If the temperature is high there is more sweat and at the same time if the relative humidity is high there is less evaporation. The body, is therefore, distressed by inability to rid itself of its own heat with sufficient rapidity unless there is wind or draft, as from a fan. It is the quiet warm day of high relative humidity that is most distressing in relation to heat because the evaporation is low and the loss of heat by convection is also small. It is the blustering cold day of high humidity that is most distressing in relation to cold because moving cold air has its power of convection greatly increased and cold damp air can carry away heat from the body more rapidly than cold dry air.

Damp air distresses the body in summer because it cannot take the body sweat. Damp air distresses the body in winter because it has the greatest power to take heat by convection. A breeze is acceptable in summer because it facilitates both evaporation and convection. A wind in winter causes distress because it increases loss of heat by convection.

An overcoat is put on in winter because as additional clothing it keeps air in contact with the body longer—it stagnates more air and thus more completely stagnates the air in direct contact with the body by removing it more completely from outside influences. Additional clothing is often put on after exercise, even in warm weather, to lessen rapidity of evaporation and of convection and thus avoid chilling. A sweater is worn during exercise because, by virtue of its construction, its amount and character of material, and as an outer garment, it may not only take up a large amount of sweat, but can also so control its evaporation and its loss of heat by convection that there is no subsequent chilling. A blanket is used in cold weather because, by virtue of its *construction*, its power to stagnate air in its spaces, and thus air in contact with the body, is large. It is preferably made of wool because by virtue of material the spaces are increased in number and *improved in character* in relation to air stagnation. A sheet is utilized under a blanket to protect the blanket, to *protect the body from contact with wool*, and to increase stagnation of air by an additional layer of clothing. A blanket contains a very large quantity of air. A sheep's wool contains a very much larger volume of air than of wool.

Man ordinarily wears more than one layer of clothing and increases the number of layers as the temperature diminishes or as the convection increases. He recognizes, however, that it is too rapid variation of surface temperature to which the body chiefly objects and especially if the surface has been accustomed to relatively high temperature. He removes his overcoat in the house or reserves it for low outside temperature not merely because the air itself is ordinarily warmer in houses in winter and has less movement, thus causing the additional article to constitute clothing in excess by too greatly stagnating air, but also because he is seeking more or less uniformity in surface temperature. The skin kept at high temperature indoors, even if sensible perspiration is not in evidence, responds more quickly to variations incident to greater loss by convection under outside conditions. And of course, in addition, if the clothing indoors is sufficient to cause sweating, the work thrown upon the overcoat when outdoors is greatly increased, as it not only has to guard against the chilling of *sweat* by convection, but also to guard the body from increased loss of heat by evaporation, as even cold air is ordinarily capable of taking some additional water.

It is important to recognize that the question with the skin in relation to chilling is largely one of *contrast*. An overcoat removed in a cold room makes a danger not only because the body is chilled by convection, but because in coming to rest there is an immediate *diminution in heat production*. On every occasion there is the question of balance and as *loss* of heat *after* exercise tends to continue as if the exercise with its increased production of heat continued there is tendency to danger in the period following exercise. This danger is intimately associated with the management of the sweat incident to exercise and is greatly increased by the *partial* removal of clothing, especially in draft or cold air, and is *diminished* or *abolished by additional clothing* or by entire removal of sweat, returning the body to its condition prior to exercise. In the partial removal of clothing following exercise there is immediate diminution in degree of stagnation of air and, with increase of air movement, there is increased loss of heat by convection and evaporation. The sweat becomes cold and *remains cold*. Thus, the exposed undershirt saturated with warm perspiration soon becomes much more dangerous than no clothing at all.

If the outer clothing is removed after exercise, the immediate removal of the underclothing is necessitated and while *still warm*. This leaves a skin *warm* and often with more or less moisture. The warmth of the skin can be maintained for the time by friction and towel, or at once secured by rapid change into dry clothing, but the quickest return to normal conditions though not always the safest is secured *if the body is still warm* by a short cool bath followed by friction and dry clothing. The bath *at once removes the sweat*, the bath substitutes a *short* and *evenly distributed* chilling effect for the *more prolonged* and *very often more or less local chilling effect of perspiration*, and towel friction secures *dryness* and a *prompt reaction in the robust* which is maintained by dry clothing. The loss of heat incident to partial removal of clothing is often rapid, prolonged, and *over a limited* area, the part of the body upon which air in movement impinges. This is at all times the danger in drafts. They cause differences of temperature, areas of skin ordinarily at the same temperature being made to have different temperatures. One does not take cold in the open when moving. It is in a room that movement of air is received on a limited body area. The stagnation of air by clothing is greatly influenced by movement of surrounding air and thus evaporation and convection are greatest on that area upon which the movement of air is greatest.

The entire removal of clothing and the use of a special night garment when turning in is very advisable. Bed clothing contains quantities of air, but they are at room temperature. Therefore the plunge into bed in cold weather is apt to be a cold plunge. Clothing does not heat the body in the sense that bottles of hot water do. In fact, under ordinary circumstances, the body has to heat clothing chiefly by heating the air it contains. Clothing permits the body to maintain its warmth or to secure a sensation of warmth by stagnating the air the body heats. The underclothing worn all day should be removed from the body at night for several reasons. It has been taking water all day and also retains odor. It will free itself from some of the odor and all the water it has taken, and if it is to be again worn before it is washed will at least be dry when placed in contact with the body. It should also be removed because the outer clothing has been removed. To plunge into a cold bed in underclothing that is damp and has perhaps already lost much heat only prolongs the chill. The skin should be dry on turning in, and should begin the day dry, and that can be best accomplished by putting on dry clothing.

This dry clothing is also of much importance in hot weather when no bed clothing is used, for otherwise the body is in the state of partial removal of clothing with dangers incident to too rapid loss of heat, especially if there is draft, as near a louver in plenum ventilation. *All enlisted men sleep in their underclothing*, though at sea on a hot tropical night on a hot ship between decks some may be found sleeping in little or no clothing of any kind if the ventilation is bad. The air is near body temperature, and therefore with reduced power of convection and with little production of sweat or little air movement there is not sufficient evaporation to cause chill. In certain men having a good skin circulation, there may be no ill effects. Such conditions are, in general, unhygienic, and, if owing to appreciation of bad air or for any reason or in any way as from change in ship's course, movement of air is caused, or the temperature falls in the early morning hours, the conditions contain an element of decided danger.

With dry clothing on turning in and hot air, movements of contained air, as by an electric fan, may be very agreeable, and if the air is sufficiently hot, say well in the nineties, may even be received directly on the clothed body. Yet with a body that readily forms perspiration such a situation is capable of causing very undesirable results unless the loss of heat by convection is practically negligible. A naked body at rest subjected to the movement of even hot air as from an electric fan in high temperature is liable to very serious injury.

A modern ship subjects its personnel to very many dangers from drafts, and the situations just described are among those not unknown with contained air of high temperature. Men in underclothing not altogether dry and sleeping in hammocks under the influence of the undistributed air from a louver is not uncommon, and in the tropics a hammock so situated may be desired. In cold or cool weather the blanket is utilized, but the draft is neither desired nor desirable and a blanket does not retain its place on a hammock as readily as on a bed. On gun decks the lack of artificial ventilation and closure of ports at sea tend to foul air, and in warm weather, to little clothing. In the tropics bare extremities hanging from hammocks are much in evidence, an undershirt with no sleeves being often the only garment. It is thus quite evident that, even in relation to sleeping conditions, the question of clothing in a navy is one of many complications.

In studying the relation of convection and evaporation to loss of body heat it is quite evident that for comfort the relation of the amount of heat lost by the one to the amount of heat lost by the other is often the determining factor. For instance, in a steam-heated room the air tends to have a low relative humidity and may become drier than that of the desert of Sahara. Under such circumstances a higher temperature is required for comfort than if the air had additional water-vapor. The required higher temperature in a room means a greater expenditure of coal. In such dry air the body loses heat rapidly by evaporation, and the temperature of the room has to be raised to make a corresponding diminution in the loss by convection. The addition of water to the air of such rooms diminishes the temperature necessary for comfort. For the same reason the addition of water makes the former temperature too great for comfort.

That is the condition in most tropical climates—high temperature and high relative humidity. Yet, there has been a tendency of late to assert that suitable clothing for use in the tropics cannot be deduced from a study of clothing in relation to *heat*, and should only be deduced from a study of clothing in relation to *light*. It seems quite evident, however, that in tropical climates as in cold climates the *chief functions of clothing are in relation to body heat*, but that in connection with *both heat and light*, clothing has a relation depending upon its *color*. This latter relation has received consideration elsewhere in this work, and *is worthy of note in a service where in the tropics white outerclothing is the rule.*

The tendency of the civilized man is to secure at least two layers of clothing and to multiply layers over the belly, often unduly. The two layers apply also to the feet, an inner layer usually of cotton or wool or a mixture of these, and an outer layer of leather or canvas or rubber. The same principles apply to foot clothing as to other clothing except that in the case of feet there is more necessity for protection from injury resulting from contact with other bodies. The feet also bear the entire weight of the body, and thus as an incident of pressure is more liable to injury by friction in shoes or to be incapacitated by distortion. The skin of that part of the body is at least as sensitive to differences of temperature and to distress from the poulticing effect of sweat. Dry feet are even more to be desired than dry shoulders or a dry back. The whole body rebels against the sensation of wet clothing whether that sensation comes from its own sweat or from water received as rain or otherwise.

The foot covering is also more in contact with cold solids and therefore more prone to lose heat by conduction, and this is facilitated, as well as loss of heat by convection, by being, as a rule, *lower* than the rest of the body. Lower objects are often colder and lower air is in any locality almost always colder than the higher air to which man is exposed. Foot coverings, in view of the tendency of water to seek the lowest levels, are also much more apt to become wet as the result of external conditions. Clothing worn in naval life is liable to be repeatedly soaked by exposure to weather and the conditions necessarily give water-proof coverings some prominence.

Leather, as it is ordinarily used for external foot coverings, absorbs more or less water and permits more or less movement of air through its substance. It takes up water rather slowly and thus, when put into well-made shoes, keeps the foot dry for a considerable period unless the supporting surface is retaining much water. It meets all the average conditions well, in view of the fact that *impermeable materials are very undesirable articles of clothing and should never be worn except to meet special conditions when they should be regarded as necessary hygienic compromises to be discarded so soon as usual conditions prevail.* In view of the principles already given, it is evident that for comfort and health dependence is placed upon the absorbent and porous properties of leather to keep the feet free from accumulation of their own sweat and at the same time, while controlling evaporation, to also sufficiently control movement of air to prevent undue loss of heat by convection.

It is with the feet as with other parts of the body—they must be *dry* as well as comfortably *warm*—and to accomplish this the perspiration of the feet must be taken up by socks and by shoes and must find its way to the external air with sufficient rapidity to maintain dryness of skin. If the covering is excessive the amount of perspiration is increased and if then there is exposure to draft—especially of cold air—there will soon be such loss of heat by convection that there will be a sensation of cold damp feet and much danger to the body as a whole. A wet foot-covering is dangerous whether the water be derived from the body or from external sources, but especially when at rest with the feet in cold moving air. The question of the proper material for foot underclothing or socks is as complicated as that relating to other underclothing and for much the same reason.

The rubber boot, as well as the rubber coat, being non-absorbent and without porosity, while preventing the access of water forces the body to remain in contact with its own sweat. This keeps the skin poulticed and leads to maceration. Such boots are generally worn large to secure more or less movement of air through the tops, the foot acting in a limited way as a plunger. They are also lined with cotton or even woolen cloth to limit loss of heat by conduction in cold weather and to permit some absorption of sweat. The socks become wet, and when the boots are discarded for shoes, unless the socks have been also changed, the feet remain wet and an additional load is thrown on the leather to prevent chill—a load beyond capacity in cold weather.

The rubber boot is, and should always be, used on ships in wet weather by those exposed *whenever the temperature requires any covering at all* and also under the same circumstances when washing decks or clothes. But *when the exposure ceases, immediate removal and dry socks* and shoes are necessary. Salt water ruins shoes and wet shoes are dangerous. Rubber boots are to be worn merely because they are much to be preferred to wet shoes and wet trousers in cool weather. They should be regarded as suitable only during the exposure and as furnishing the means to make *dry shoes available* so soon as the exposure ends. Their tendency to cause tender or sensitive feet is diminished by friction when the change to dry coverings is being made.

Rainclothes are worn for much the same reasons—to prevent the dangers from wet clothing. These are necessitated in a seaman's life *during the exposure*, especially in cool or cold weather. When at rest, in all temperatures, water overtaxes the capacity of clothing to protect the body from excessive loss of heat, and especially in drafts. Wet clothing demands immediate shifting into dry clothing as the danger is greatly increased when after exposure there is inaction of the body. And this is especially applicable to wet feet in view of their position in colder air and of their greater exposure to draft.

Canvas is a more or less valuable material for uppers of shoes in hot countries, as it permits more air movement than leather and thus while lessening the production of sweat increases its loss under circumstances where air has diminished power to carry off heat. It does not sufficiently resist moisture in wet weather and therefore is suitable for wear in hot weather by those in position to keep out of rain or have facilities to readily adapt footwear to external conditions or to change shoes immediately on coming to rest. Its value is, however, much in evidence under many ordinary conditions, and shows quite clearly the disadvantage of *heavy* or stout shoes of very close material in ordinary tropical life. Life on board ship does not ordinarily involve campaigns in rough country and therefore the mechanical effects of vegetation or prolonged soaking of shoes in wet weather on shore in tropical countries are not usually incidents in naval life. A shoe of fine-grained leather in the tropics leads to feet of too high temperature and too much sensitiveness. And the same is often true in cold weather when patent leathers are worn. Much walking in patent leather is often a painful exercise.

It necessarily follows that much of the material or many of the varnishes used in blacking or shining shoes are unhygienic, inasmuch as they interfere with the porosity of leather, and thus tend to seriously interfere with its valuable properties. The old blacking interferes little with the power of leather to dispose of the perspiration that forms on every foot, although it soils clothing that comes in contact and as it is affected by water requires more frequent use to maintain a polish, but the application of layer upon layer of shoe *polishes* causes leather to acquire some of the properties of rubber, inasmuch as it becomes unable to prevent the foot from wetting itself with its own sweat, especially in damp air. It is also apparent that canvas shoes kept white with blanco soon become almost as influential in stagnating air as leather and that therefore a brown canvas is much more comfortable.

A very important conclusion from a study of the action of foot coverings is that, in warm weather on a ship, that crew enjoys the best general health which is in bare feet. There will be some additional injuries, especially at first, and men working in certain parts of a ship, as in coal bunkers and firerooms, or during certain exercises, always require foot coverings, but, with the decks of a ship in their usual condition, the men are generally in the best health in warm weather while in bare feet. They are free from the dangers of wet coverings in washing decks or in washing clothes (and that is a potent cause of sickness in any weather, though of course especially in a cold climate), and in warm weather the loss of heat by convection is small. Undoubtedly on a ship, shoes should be reserved for general use when the temperature is sufficiently low to cause discomfort, for occasions of ceremony, and for wear in certain parts of a ship, during certain exercises, and on shore.

When clothing is considered with a view to the selection of the best articles for use in a naval service, there are immediate difficulties, some of which are incident to styles that form a part of a navy's traditions. From certain points of view the subject is no more susceptible of practical consideration than questions of trousers, *versus* knee breeches or kilts, and of corsets in civil life. A navy has come to use certain styles of outer dress that form its uniform which in the case of the bluejacket has undergone relatively little change. In the case of commissioned officers there is no regulation underclothing, but to enlisted men all clothing is issued, and, as in their case a part of the undershirt is generally in evidence, uniform underclothing becomes a feature of administration.

The outer clothing for all persons in the Navy is either blue woolen cloth or flannel, or white cotton or linen goods, linen duck in the case of officers and cotton drill in the case of the men. The men also have a navy-blue jersey or sweater that may be worn, when ordered, over the undershirt. If is never worn without an undershirt, but may be worn over the outershirt or jumper or as the outside garment. Each person has an overcoat of blue cloth. An officer has also a mackintosh to which a cape reaching the ends of the fingers is fitted, and an enlisted man's rain clothes are hat, coat, and trousers of black painted material of same pattern as Cape Ann suits. A petty officer not going aloft or in boats may have a long water-proof coat instead of the water-proof coat and trousers. Rubber boots come at least to the knee. Khaki-colored cotton duck leggings are worn when under arms for infantry or artillery drill, or for duty with a landing party. Dungarees of blue denim may be worn by engineer force on duty or by gunner's gang and mechanics when at work below. Men wearing dungarees are not allowed on deck except in the case of torpedo-vessel crews which are required to wear dungaree suits most of the time.

Officers' blue caps are made of cloth with rounded visor of black patent leather sloping downward. The white cap has the same general appearance, but the top and quarters are made of linen duck in the case of officers and of cotton drill in the case of chief petty officers. These caps of course afford no protection from the sun at sides or back.

Officers until recently were also required to have helmets made of cork, pith, or grass, but with covering of white jean. The brim was lined with green silk and the crown was unlined. The brim at the front could not be less than 2 1/4 inches nor more than 2 1/2 inches wide and diminished in width to one inch on the sides again increasing at the back to 3/8 of an inch greater than in front. The slope in front was from 48 to 56 degrees, at the back from 45 to 48 and on the sides not less than 55 degrees. On the top of the crown was a ventilator and the sweat band had a ventilating space between it and the body of the crown. There was perhaps no more unpopular article of clothing in the Navy. It was generally very much too heavy, and thus whether worn in or out of the sun was apt to cause headache.

Under the tropical sun, even a sloping brim that does not extend to at least four inches from the head during the whole round is insufficient, and a head covering in the tropics, even more than anywhere else, whose weight exceeds 5 or 6 ounces is a cause of discomfort to many and a reasonable cause for objection. The white cap should be skeletonized to less than that weight, but from its color and lack of brim is not suitable outside of awnings in the tropics, especially on shore. It is, however, a very useful article on the ship *if the white material is thin and free from* *starch*, as the ventilation is through the meshes. The blue cap has two eyelets on each side for ventilation.

In cold weather, in view of the drafts common on ships, officers tend to acquire the habit of wearing caps in quarters, and as a habit is persistent, the same practice may well be too much in evidence in a warm climate. This places the hair at a disadvantage as it deprives it of air movement and thus retains perspiration and keeps the surface temperature of the scalp too high. There is ultimately a tendency to loss of integrity manifested by thinning. The hair of the head has the function of protection, and when that is too much ignored, an artificial covering being substituted for it when no additional protection is required, the result is the same as elsewhere in the body, a part not normally used being subject to change.

The hair grows more rapidly in warm weather, the increase being about 27 per cent. and at the same time its sebiparous, as other sebaceous glands, become more active. This increase in oily material may have a relation to dissipation of heat. At any rate, in that direction there could be some interesting experimentation. It is not uncommon to use an oily material on the hair. It keeps the scalp from being dry and facilitates combing and cleaning the hair. But it may also diminish the temperature of the scalp. Those who use a hair oil in winter seem to consider that it keeps the hair at a lower temperature and causes the scalp to give the sensation of cold to a degree that may even be disagreeable. Oils on the skin do not seem to interfere mechanically with the formation of sweat, yet the additional loss of heat is not due to evaporation. The skin normally contains a sufficient amount of oily material to prevent water from coming truly into contact with it, and this amount is increased in warm weather. In the case of the hair, brushed down upon the scalp, oil also diminishes the amount of contained air.

Very greasy hair has a disagreeable appearance and from its stickiness catches dirt, but on hair that seems dry the *moderate* use of an oily substance, such as vaseline, that does not tend to injure by becoming rancid, may very well be of advantage from a hygienic point of view in preventing the hair and the scalp from acquiring high temperatures, and thus, if for no other reason, preserving integrity. This question of high temperature of the head is intimately associated on a ship with the head covering in hot climates in view of tendency to keep heads covered between decks, but in the sun would assume special prominence. The effect of an oily substace on the temperature of the scalp under a hat in a tropical sun might be different, but is worthy of investigation in spite of the fact that wool, an oiled material, lends itself to the making of very warm clothing. In a naval or military service especially, the hair should be kept rather short, as it is then readily kept clean.

The naval service does not seem to have evolved a satisfactory helmet. This is due to the association of weight with the necessity for stability of structure, as otherwise it is very liable to injury in naval life. Its hygienic specifications are as follows: Weight not to exceed 5 ounces; brim to slope downward with edge at a horizontal distance of at least four inches from the head all round; means for ventilation by space between sweat band and hat, and by a top ventilator; a light external surface to secure heat reflection as the internal temperature of the helmet exposed in a tropical sun at noon should be at least 25° F. less than sun temperature. A hat made of straw or grass, or any head covering that permits the passage of light, if worn in the tropics, should, it is recommended in view of the contention in relation to actinic rays, have a lining of reddish or orange silk.

An ordinary Panama hat weighs about 2 ounces, but its turned-down brim is only about 2 1/2 inches from the head. The Manila straw is much lighter (1/2 ounce) and may be found in somewhat wider brim, the so-called wide-awake being a comfortable shape. On board ship a helmet does not seem to be a necessity. On shore in the sun of the tropics the Bangkok grass topi (weight 3 ounces) has been highly recommended by civilians, but in service with troops the campaign hat of the Army, if properly made with separated sweat band and side ventilation and is water-proofed, seems to answer the purposes fairly well.

Enlisted men below the chief petty officers' grade wear a blue cap of special shape and at times a conical watch cap 10 inches long which is knit of all wool navy-blue worsted with a hem 2 1/2 inches deep at the bottom. The watch cap may be worn at sea or during night watches in port, but is not allowed in day watches in port except under special circumstances, when ordered, such as work in severe weather. The blue cap is made of woolen cloth and without any brim. The band is 2 inches wide and is lined with a thin leather sweat band. The quarterings are from 1 5/8 to 2 inches in width and sewed to the crown. A grommet of steel corset wire is ordinarily worn with this cap except in windy weather on the ship, and this causes a considerable projection of the hat crown beyond the upper line of the band, thus, as it were, making a brim around the upper part of the hat in the form of a horizontal overhang. The grommet is an addition used for the sake of style. The hat is designed essentially as a head covering that will remain in place during the performance of sailor's duty as in wind. It is therefore made without brim. There is, however, no provision for ventilation, and an enlisted man wears his cap nearly all the time, as in a crowded ship he cannot afford to allow it to become separated from him. In quarters he is, in view of small air space and unheated air supply or natural ventilation, commonly under the influence of disagreeable drafts in cold weather and is at all times liable to frequent calls for duty on the open deck.

The majority of a crew seem to wear head-cover during most of their time awake. But in hot weather this cover is a white hat made entirely of bleached cotton drill, weighing 6 1/2 to 7 ounces to the linear yard, and with a brim of 2 inches that can be turned up or down as in a Panama or in soft hats generally. This hat weighs about 4 ounces, the same as the blue cap without grommet which weighs about an ounce, and can be readily kept clean by ordinary scrubbing as in the case of cotton goods in general. White head gear is worn when white is prescribed for any other portion of the uniform and is therefore always in evidence in hot weather on the ship. This particular hat has good qualities in view of the special situation on a ship as it can be packed in a small space without any injury, stays on the head fairly well in wind and can be readily washed. Its color is against its use in the sun. for while as white it reflects many heat rays it also permits the passage of much unmodified light. Its brim is also not sufficiently wide when considered with reference to sun, and thus cannot be made to give sufficient protection to the back of the neck. There is difficulty in getting cotton of suitable color that would stand the frequent scrubbings on a ship, and hats of different colors would not be tolerated. Much increase in width of brim, stiffened as it is with considerable stitching, would also make the hat less useful in much wind. A hat that goes overboard may represent a total loss, and an enlisted man cannot afford to lose much clothing. The blue cap is worth more money, especially as it also carries the ship's cap ribbon.

An officer's service dress or usual dress consists of trousers of ordinary cut and a single-breasted coat fastening to the neck and having a standing collar. It is made of navy-blue woolen cloth for cold weather and of white linen duck or white cotton twill for warm weather. The collar of the white coat is closed in front, fitted with a hook and eye at base and top, and made of several thicknesses in order to admit of being worn without a linen collar.

The question of the merits of the suit of white as the daily outer clothing in hot climates has provoked much discussion. It appeals to the æsthetic taste when clean and well laundered, and looks cool. When the weather is especially warm it permits the elimination of the ordinary shirt, and thus the removal of one layer of clothing. The removal of the linen collar, ordinarily worn, is often of considerable advantage in very warm weather and if the undershirt is of some thin cotton material, especially Japanese crape, the clothing under the blouse is reduced to the practicable minimum.

But the outerclothing remains objectionable for several reasons. It can only be kept presentable when proper laundry work is available. Its material is selected almost solely for ship use, as in service on shore it so soon shows the effect of external influences that it becomes impracticable. This, for instance, has left naval officers on duty with men on shore in tropical countries, without any suitable uniform for daily wear. In active work or during exercise it readily takes up perspiration as interposed water and causes the uniform to present an untidy appearance, especially where it is in contact with the underclothing as at the upper part of the back. It then also may become a menace to health because of undue loss of body heat. As it comes from the laundry its meshes contain much starch. Starch by limiting air movement can convert a cool garment into a very warm one. The well-starched bosom of the ordinary shirt is very objectionable on that account in hot weather. In the case of the white service dress this objection obtains more or less to the entire outer dress. Linen does not permit much loss of heat by radiation, but a white garment, while very greatly lessening absorption of heat in the sun, limits its loss by radiation in the shade and thus doubtless becomes a factor between decks.

Even persons who live in the tropics and who utilize thin cotton underwear have much to say in favor of very thin blue serge as material for external clothing under ordinary conditions. If the serge is lighter in weight than one ordinarily finds it, it can be made into outer garments more suitable for use on the ship than the white service dress. The single flannel shirt has been found the ideal garment for military use in the tropics, and if the underclothing of an officer on a ship in the tropics is reduced to the minimum, as is usually the case, a thin serge should be found more suitable for the outer garment. Such light weight serge interferes less with air movement than khaki cloth as it is usually obtained, although khaki by its smooth surface and close texture has the durability necessary in active campaigns on shore. The material known as *Solaro* fabric in which threads of yellow and blue are used in the warp and red threads for the weft, the combination being made to secure a khaki color on the outside and a reddish color on the inner surface, is regarded by many as ideal material for tropical use. As a general proposition, if woolen underclothing is regarded as unsuitable for wear on ships in the tropics, then under the ordinary conditions of an officer's life a *very light weight* open woolen material should form the outer clothing. It is worthy of note that the Navy has no uniform suitable for service on shore with troops in the tropics.

Chief petty officers have coats and waistcoats of blue woolen cloth and also white coats of bleached cotton drill, and the same is true of bandsmen and of officers' stewards and officers' cooks. Chief petty officers may take off coat and waistcoat when on duty below the spar deck in warm weather. All men are required to wear underclothing. Officers' cooks at the galley are required to wear cook's white caps and white aprons.

All other enlisted men wear instead of coats either an overshirt of flannel or a jumper of cotton drill, according to circumstances. The overshirt is worn as a shirt within trousers and the jumper descends outside the trousers to 2 or 3 inches below the hips. The former does not permit the use of suspenders and the latter would, but the trousers are not fitted to be supported in that way. The trousers both white and blue are provided with a gusset at center of back 2 inches wide at top (when open) and 4 1/2 to 5 1/2 inches deep. This gusset has from 6 to 8 eyelet holes on each side that carry a lacing by which the trousers can be made to fit snugly about the belly and hips. This area of snug-fitting clothing is relatively large, giving even compression, and thus causing less objection than the belt common in civil life. Yet this method of suspension is not free from objection. Any compression of the abdomen diminishes lung capacity and in the male tends to the appearance of an increased percentage of inguinal hernias. It is also noticeable that in those who desire to appear smartly dressed there is a tendency to have blue trousers markedly tight over hips, buttocks, and belly.

Of course the use of suspenders on trousers would necessitate an entire change in the style of blue dress. In a naval service there is a traditional influence toward the widest movement of arms and shoulders, as in the days of sails there was much work aloft. The character of duty has, however, undergone considerable change since that time, but in those days abdominal pressure was prominent in disabling seamen as the lying on yards in furling sails was believed to be the most potent factor in the production of hernias. Since that time the duties of a sailor have been moving toward those of the soldier in fortifications. It would be a gain to introduce the suspender into his life in such a way, however, as to continue to secure a uniform having a very smart appearance, as appearances are of much value in the preservation of discipline.

The seamen's trousers are large at knee (about 23 inches) and at bottom (about 24 inches). Such a cut is advisable because it facilitates rolling up the trousers in warm weather when washing decks or clothes.

The overshirt and jumper are cut loose in the body and with back and breast of double thickness to 4 inches below the line of the shoulder-blades, except in the undress jumper. They are not open anywhere in front except at the neck, but the opening extends downward 7 inches in the form of a V. In the overshirt and dress jumper the sleeves end in cuffs 3 inches deep, but in the undress jumper the sleeves are cut off square just above the wrists. The collar is of double thickness and 9 to 10 inches deep and 14 to 18 inches wide with square corners. Under this wide collar, covering the upper back, is worn a black silk neckerchief tied in a square knot with knot directly under neck opening, thus leaving the undershirt exposed at the neck opening.

The neck opening is distinctive and consequently also the undershirt exposure. The exposure of white undershirt greatly aids in keeping the men in clean underclothes and perhaps in the weight of underclothes considered proper. It, however, represents a degree of exposure of the upper part of the chest greater than is found in clothing elsewhere. In civilian attire that part of the body has a smaller number of coverings, as a rule, than the rest of the trunk, but the shirt comes well up to the neck and often carries a starched linen collar and frequently a starched bosom upon which there is often a necktie. In this case even the undershirt itself may be rather low in the neck. It is without openings in front or rear, but the collarette or neck finish is about 19 or 20 inches in circumference. It is 3/4 of an inch wide and for that width the thickness of the shirt is increased. In warm weather white dress or white working dress is worn, and therefore the neck opening in a jumper may even be regarded as advisable in a hot climate. But in a dress devised for cold weather it excites comment.

It seems probable that in those thoroughly accustomed to the dress it causes no discomfort, but that in recruits it represents a too marked change. The clothing question is also complicated at training stations by the fact that when recruits are received only such portion of the outfit prescribed is issued as climate, season, duty to be done, and other circumstances render advisable. When the men are received on a cruising ship their outfits are at once completed. At the training station the clothing question has prominence on account of loss of personnel by medical surveys and otherwise, and because many men have not learned to take care of the articles that may be issued, and if all articles are issued there is tendency for not a few men to be unable to keep them together in the condition in which they should be at transfer to cruising ships. Thus, as the cold weather approaches, the white working dress may continue too much in evidence. This may be and often is supplemented by the jersey which affords good protection to the upper part of the body and at the same time, being practically a sweater, gives covering without neck opening; but if cotton trousers are continued in cold weather there is always insufficient protection for the legs as the loss by convection is necessarily excessive.

The jersey weighs about 1 1/2 pounds and has ribbed collarette 2 1/2 inches wide. It is important for this collarette to be narrower so as not to come up much upon the neck. A part so accustomed to be uncovered as the neck should never be closely covered in our climate, especially with wool. At the time of removal of such a covering the surface is overheated and moist and the *variation* in surface temperature for *that* part of the body becomes much greater than usual. Woolen wristlets worn outdoors and removed in the house soon cause painful joints, and muffling the throat is a fertile cause of colds, including tonsillitis.

At this time the question of underclothing in the service may be regarded as in an experimental stage. There are three kinds of such clothing—the heavy-weight cotton and wool mixture (shirts and drawers), the light-weight cotton and wool mixture (shirts and drawers), and the all-cotton undershirt. The mixtures are from 33 1/3 per cent. to 35 per cent. wool, and are knit with two threads—one composed of cotton and wool and the other of cotton. The light-weight undershirt weighs about 6 ounces in size 36 and the heavy-weight about 13 1/3 ounces. The light-weight drawers weight about 8 ounces and the heavy-weight about 13 2/3 ounces in size 34. In the light-weight the length of sleeve is 5 1/2 inches and in the heavy-weight about 20 inches. The all-cotton shirt weighs about 6 ounces in size 36, and its length of sleeve is also the same as in the light-weight mixture. The cotton shirt is knit with one thread of No. 18 cotton and is close, as the work is done on a machine of 10 needles to the inch in width and has 28 stitches to the inch in length.

There is always a tendency to the substantial in naval clothing, in view of the marked variation in the exposure of its personnel, the way clothes are washed, and the whipping effect of wind on the lines. Cotton and wool are combined because the mixture washes better and with much less shrinkage and there is an attempt to secure some of the advantages of wool without all its disadvantages. The cotton shirt was introduced in view of the complaints in the tropics in regard to the light-weight cotton and wool mixture.

There are complaints that the all-cotton shirt is too warm in the tropics, and it is said that a shirt of more open texture is under official consideration. Such a shirt should not be entirely without sleeves and should be improved more by cellular texture than by diminution in amount of material. The shirt should be capable of taking up considerable water and yet not of unduly exciting its formation. With cotton external clothing, underclothing can be made to hold too little air for safety. And after all, an enlisted man is a working man, who in the tropics would be much better off in a single loose flannel shirt made like any ordinary shirt. Wool is an important material for clothing even in the tropics, but *it is not suitable for underclothing in hot climates.* And as the enlisted man remains in cotton external clothing, the underclothing can be made to contain too little *material* for safety in view of the sweat incident to work. Six ounces is not too much material for a cotton undershirt, but the garment should be quite loosely knit.

An additional supply of underclothing is also very advisable in the tropics. Men should have at least two or three times more undershirts for use in warm weather than in a cold climate. And if suitable arrangements could be made for all hands to shift into dry clothing at sundown there would be considerable gain.

If after sundown white clothing is found to be too cool for the officer of the deck, it is also too cool for the men on deck. Relatively slight downward changes of thermometer cause the sensation of chilliness much more readily in the tropics than elsewhere. However, on a typical tropical night it is not believed that shifting into blue is necessary or even advisable. The tendency in the old days was undoubtedly toward keeping the skins of crews at too high temperature in the tropics. The object was the good one of preventing too great *variation* as the result of convection upon the body as a whole and upon its sweat. But extreme measures often lead to results the reverse of those desired. If men are too warm in blue there is a tendency to strip to undershirts between decks at night, and having been in blue, the amount of sweat has been increased and the *variation* in surface temperature becomes greater than if they had remained in white.

It is true that the present tendency, in warm climates, toward cotton underclothing requires a more careful consideration by those in authority of the question of shifting into blue at any time when there is much difference between night and day temperatures, but the *ordinary* tropical night on a ship that spreads awnings does not appear to furnish the conditions that require a change into wool. White clothing is not a suitable uniform for the *day*, when the temperature at 7 A. M. is much below 75° F.

The situation on a ship, in view of the proximity of men to their outfits of clothing, readily permits changes to be made to accord with atmospheric conditions, and as the sun goes down on a tropical day shifting into *dry* undershirts is a distinct advantage. This is recognition of the fact that while the all-cotton undershirt limits the suffering from heat during the hours of excessive temperature, a wet undershirt leaves the wearer more exposed to variations in surface temperature by the change incident to the going down of the sun. In a temperate climate the difference between day and night temperatures is more often marked, and under such circumstances the change into blue at sundown should be the routine. In coming north from the tropics a few hours is often associated with marked atmospheric changes, and at the same time the men are more susceptible to such changes.

Prompt changes of clothing as required have a very important relation to the health of a crew. These changes, as a ship travels into cold weather, should not be confined to the outerclothing, but should extend to the character of underclothing in the cold season, and there should never be a tendency at any time to keep crews in white when they are uncomfortable from cold. The white or blue uniform of the day should not result from some idea of appearance, but should be derived from consideration of the health and comfort of officers and crew.

The care of clothing has received consideration elsewhere and in several varying hygienic relations. It may not be amiss, however, in connection with the purposes of clothing as they have been declared herein to emphasize the danger from wet clothing and to indicate some of the difficulties on ships in complying with hygienic requirements. It is quite apparent that a man's clothing, wet with his own sweat, may become as dangerous as if wet by rain or in washing clothes. In the first case the water starts warm, but, as has been shown, may become of the same temperature ultimately as that resulting from rain. In both cases there is tendency to loss of body heat varying with the power of air in relation to convection and evaporation, but of course rain water, varying with its temperature, is itself rapidly taking up body heat, and the same is true in the case of water in clothing resulting from a fall overboard.

In the case of the engineer force the men often come off watch in clothing saturated with sweat. *No man should ever go on watch in wet clothing or remain in wet clothing after coming off watch.* The members of the engineer force are allowed to make for themselves blue undershirts of heavy navy flannel or other similar material, with the neck opening fastened in front by buttons. Such shirts may be worn on duty in the engine- and firerooms. But whatever any member of the engineer force may wear at work, he should always have immediate opportunity to remove wet clothes at the end of the watch and to place such clothes where they will become entirely dry by the beginning of his next watch. Such place is almost invariably provided in the form of a drying-room about the uptake space. In view of the high temperature in that space the drying is rapid, and if the clothing is frequently washed or even rinsed in fresh water it can be kept in good condition.

With the deck force the proper care of wet clothing is more difficult, though the necessity for drying clothes wet on the body is less frequent. The place to dry clothes is on the ship's lines, but such lines are frequently crowded with wash clothes. Yet, it is undoubtedly true that men should not be allowed to wear wet clothing, though there are often difficulties in the proper care of the wet clothing after it has been removed from the body. A man's clothing is kept in a canvas bag—even his bed clothing, for a hammock when lashed is practically a closed canvas bag. Each man has in addition a locker of open metal work that is large enough to contain rain clothes packed in the form of a roll, a few odds and ends, such as toilet articles, including towels, and perhaps a suit of white in a roll.

The canvas bag necessarily contains nearly all his clothing not in use or on the lines, and into it generally goes any clothing that comes off his body at hours not prescribed for washing clothes and putting them on the lines. Clothing wet with his own sweat if changed would naturally find its way into the bag containing clothes that he has managed to keep clean and dry. If men changed undershirts at sundown in the tropics or white clothing it would all generally find its way into the clothes bags in its damp state unless the lines were made available, and then all clothing may well be wet by rain before morning when the line may be desired for wash clothes.

It must happen, that even rather wet clothing is stowed in these bags at times, and there is naturally much difference in the cleanliness and general condition of the clothing they do contain between the usual monthly inspections. There is relatively little movement of air within a closed canvas bag, and consequently damp clothing has little tendency to dry when so located. No clothes bag should ever be painted, as under those circumstances there is practically no air movement within it. It is the rule to give opportunity for washing clothes, and every effort is made to encourage cleanly personal habits, but nevertheless the clothes bag represents a violation of hygiene that so far has been regarded as necessary in ship life in view of the limited space available. The same idea prevails in regard to the hammock that must often when stowed contain clothing damp with the sweat of the occupant.

A second bag for soiled clothing would be of considerable value, and the placing of all clothing on the deck in the sun as a routine *whenever* circumstances permit, will be found very advantageous in the effort to maintain the health of crews. Bags turned inside out and exposed in the hot sun have their condition greatly improved, and changing bags as a matter of routine that they may be as regularly scrubbed as hammocks relieves the situation considerably from a hygienic point of view. These measures are especially available in warm weather when clothes can be washed even on ships without danger to the man from exposure and when perspiration is most in evidence.

It is clear that the management of clothing is of great importance on a ship as well as the character of clothing. Men in motion produce and tolerate dampness, but man at rest is intolerant of the *sensation* of dampness in the clothing or in the air of quarters; but, when the element of cold air, especially moist, cold, moving air, is added, the crowding of sick-bays is much more quickly in evidence.

CHAPTER VII.

DISINFECTION ON THE SHIP.

The body of each person having a transmissible disease contains, or has contained at some time during the course of the disease, a living exciting cause which is capable under favorable conditions of producing the same disease in another person or in many persons. That exciting cause, depending upon its life history, may be able to act as it leaves the diseased body in which it has multiplied or may be impotent to cause disease of the human body without subsequent development in which a certain intermediary or definitive host is commonly required.

All these living entities or creatures may be regarded as parasites belonging either to the vegetable or animal kingdom. Not a few of them have been recognized and directly studied, but many are still unknown except through their works or effects. The existence of the latter class is, however, very clearly demonstrated by the logic of events and, from the human point of view, each member of it is convicted by the strongest circumstantial evidence of the crime of living to cause disease. As a matter of fact, they live, as man himself does, at the expense of others, but, as in this case man pays, they are sentenced to death *wherever found* in any civilized community and the executioner is the disinfector and the agents employed by him are disinfectants.

It is evident, however, that, as these pathogenic organisms are, when producing disease in man, within his body, they frequently cannot be disabled or killed *in situ* without too much injury to their host. In certain cases where parasites are localized, as in the intestines, they can be dislodged by the administration of chemical substances which, while not endangering the life of the host, do make an environment unfavorable to the life of the offending organisms, but as a rule in the infectious diseases the micro-organisms causing disease are so located as to be safe from interference by the disinfector whose only agents of destruction are either physical or chemical.

This rule is not invariable, and as the knowledge of disease increases may cease to have application. In the case of the malarial parasite destruction may be regarded as secured within the body by the administration of quinine, a chemical substance which, though ordinarily a life product, can be made as the result of chemical manipulations, and in syphilis a slow but sure cure can be secured under the influence of the salts of mercury, chemical substances in the production of which neither vegetable nor animal life has been concerned. Even it has been claimed of late that the administration hypodermically of the succinimide of mercury in small doses is unfavorable to the life of the tubercle bacillus within the body, either directly or by causing conditions under which it cannot survive and multiply, and that such administration, while limiting the life of the parasite, is at the same time of benefit to the host. But, however that may be, the meaning of each term is decreed by custom, and the term disinfection as here employed is limited to the destruction by physical or chemical means of those agents on the surface or elsewhere outside of the body that cause infection.

It is clear that those pathogenic micro-organisms thrown off or out of the body and capable of exciting disease in susceptible individuals do not generally find conditions which are at once sufficiently detrimental to cause loss of their vitality. In fact, under certain environment they are enabled to multiply and, whether or not increasing in number outside the body, cause disease in a large number of persons. In whatever way they may gain access to human bodies they are dangerous from the instant they are separated from the body of the diseased, and therefore, especially on the ship which is always crowded with men living in closed spaces, any suitable means by which such infective material can be kept in a limited space or destroyed without being allowed to develop lines of travel are of the greatest importance. In all such cases it should be clearly understood that the diseased individual is the source of danger and that treatment in *isolation* and *bedside disinfection* are of extreme importance in limiting spread.

Isolation exerts at all times a powerful influence not only in preventing cases of epidemic disease, but also in often directly limiting the area to be disinfected. Such a precautionary measure is directly opposed to the general diffusion of infection and thus is of special importance on a ship as, with crew on board, complete general disinfection can be accomplished, if at all, with much difficulty, especially in cold weather. Therefore, with a case of epidemic disease that throws off infective material the first essential is early recognition of the case and treatment in isolation that the diseased individual and his effects may be removed from the well and that the infected area or space may be confined to the place of isolation. But in recognition of the fact that the diseased person contains pathogenic micro-organisms at the time the case is detected, it is also often advisable to at once disinfect the particular part of the ship where the case developed and also the effects and persons of those billeted in that locality.

It is not advisable to consider generally that disinfectants are primarily applicable to infected spaces or compartments. The primary object should be to prevent the spaces of a ship from becoming infected. Ordinarily the first case has resulted from infection on shore. The problem is either to prevent the appearance of the second case or to limit as much as possible the number of subsequent cases. The first step, as has been stated, is isolation of the effects and of each case as it appears, *even of the suspected case*, and the second step is to apply disinfection primarily at the source of infection *so long as the case remains on board.*

For example, disinfect the stools and urine of the typhoid patient, of the cholera patient, and of the dysenteric patient; the sputa of the tubercular patient; the mouth, throat, and sputa in cerebrospinal meningitis, in measles, mumps, small-pox, and scarlet fever (in the ordinary eruptive fevers, as has been stated elsewhere, considerable success in preventing spread has also been obtained on ships from measures directed to the skin itself); clinical thermometers, tongue depressors, and mess gear; and soiled decks, clothing, and persons—in a word, bedside disinfection, *including the hands of nurses*, utensils, and all surfaces infected or likely to be infected by excreta. If the proper disposal of the excreta of the well on a crowded ship is necessary from a hygienic point of view, the careful disposal of the excreta of the sick is of the highest importance. Apply disinfectants primarily at the source of infection and in isolation, and, *as the third important step in preventing the spread of epidemic disease on a ship, remove the case and effects from the ship at the first opportunity.*

The early removal from the ship of the patient having one of the epidemic diseases and of his effects is of prime importance. It is an extension of the idea of isolation, and the transfer of the first case promptly detected may remove, not only from parts of the ship but also from the whole ship, the *known* source of infection *provided locality of isolation and all it contains be disinfected immediately after removal of the case.* But at all times removal of the case removes the prominent and a known source of infection and abolishes the chance of infringement upon isolation on a crowded ship. Each case promptly multiplies the opportunity for infection unless there is complete isolation which is always in question on a crowded ship. But in a number of diseases, such for instance as measles, the ability to infect is present prior to earliest manifestation of case and at the time of its isolation the living cause of the disease may very well have already effected lodgment within the bodies of some susceptible individuals. Yet, *delay* in effecting isolation of each and every case and of effects greatly multiplies that chance as also does non-recognition of the probable means of conveyance of such infections.

The lack of knowledge of the manner in which a given infection is transmitted from one person to another has frequently caused a lack of confidence in disinfection. The disinfector employs a number of agents, but as his object is to destroy infection and his agents have not the same power in all directions, it is necessary to know the direction required in any given case in order to know which one of the agents of destruction to select. For instance, the results of experience and the results of laboratory work were more or less in conflict for years in relation to the merits of sulphur in disinfection. Dry sulphur dioxide as evolved from burning sulphur was found in laboratory experiments to have limited penetration and power in killing micro-organisms. It had been utilized for many years on ships in relation to yellow fever and continued to be so utilized as it was found to be more efficacious than any other disinfectant in preventing the spread of that disease. It was only when it was discovered that a mosquito was the carrier of the exciting cause of the disease from one person to another that the disagreement ceased and the value of that agent in opposition to the spread of yellow fever became established to the satisfaction of all.

It has been the same way with plague, pounds or tons of corrosive sublimate in solution having been uselessly expended in an effort to combat that disease. In the laboratory, the corrosive sublimate solution is shown to be a powerful disinfectant, and in actual practice it has been found of the greatest value when utilized within its sphere of usefulness, but flooding a compartment does not kill the rats on a ship or in a building, and even if the watery solution should be applied to the flea itself death would not result under ordinary circumstances.

In those diseases as in malaria and dengue the exciting causes are not thrown off or discharged from the body, at least in any form dangerous to man, but they are taken away by certain insects which transmit the diseases by placing the infective agents within the bodies of susceptible individuals. In the propagation of those diseases it is evident that three things are essential—the case, the infected insect and the susceptible individual. The last can always be considered to be present on the ship when the disease is present. *If the case is present the insect should be assumed to be present,* and if the case has originated on the ship the insect *is* present.

Isolation of such cases is not of less importance because the body is not discharging material dangerous to others, as protecting the patients from insects is protecting the crew from infection. Disinfection is not of less importance because the infection is not air-borne or on surfaces or in the discharges of patients, for the rule that it is the duty of the disinfector to destroy infection wherever found still holds. In those cases he has the advantage of knowing where the infection outside the body is located. He not only knows that it is within the ship, but that it is within the ship, because it is within the bodies of certain insects the ship harbors. He knows that so long as those insects continue to live the crew is in great danger in case of yellow fever or plague, and that to destroy them an insecticide is needed and one whose action cannot be escaped. He will therefore in relation to yellow fever or plague give no thought to corrosive sublimate, carbolic acid, chlorinated lime and the long list of material used in solution, or even to formaldehyde which is a very untrustworthy insecticide, but in the case of yellow fever he will seek to destroy every mosquito in the ship, *immediately after the recognition of the first case, to abolish their breeding places,* to protect the case on the ship and to remove it from the ship if possible, and to place the ship itself in isolation with all persons on board by at least changing anchorage to a location at a distance not facilitating the access of the carriers of the disease and often to a location, such as a quarantine station, where with special appliances and better facilities generally, the work of disinfection can be done to better advantage.

In the case of plague he will seek to destroy all the fleas in the ship wherever they may be. With that intent he will also select an insecticide and so utilize it that all the rats harbored will be destroyed with the fleas they harbor. If the case has originated on the ship there will be dead rats in the ship from which fleas deprived of warmth have found the clothing and surfaces of members of the crew. Therefore, in that case, while attention is especially directed to the lowest parts of the ship, the disinfection will be carried out to include not only all spaces, but also all clothing, and attention will be given to the bodies of the men themselves.

This situation in relation to plague can very rarely arise in a naval service, for ordinarily the infected localities are known and avoided. But in relation to this disease as in relation to other epidemic diseases the situation on the ship itself should not *favor* spread whenever the conditions under which extension is possible can be avoided. For instance, in this case as the rat is such a prominent or essential factor, the ship should not be allowed at any time to harbor that animal. Traps properly utilized should be in evidence about storerooms and in certain other locations. As naval vessels are very rarely at wharves, other than their own navy-yard docks, the access of rats from shore is not facilitated if effort be made to exterminate them in the yard, and thus with ordinary care the ship should be practically free from them and also from mice at all times. At wharves a favorite route of travel for rats seeking admission to a ship is the hawser, and under such circumstances each line to the wharf should at one point contain an effective shield closing the route in that direction. There can be no disinfection, unless there is infection, and the routine on a ship should be opposed to infection so far as is possible under service conditions.

Any insect on a ship should be regarded as a menace. The roach, the bed-bug, the mosquito, and the fly are all very undesirable associates. The first two remaining with a ship will seek to obtain complete possession. The roach in warm climates multiplies rapidly, and roach powders or pastes that are liked by them as food and are poisonous when consumed should be a part of each ship's equipment in the tropics, though the roach is an enemy of the bed-bug. The fly has long been a recognized danger. In bedside disinfection it is often even more important to prevent flies from gaining access to excreta than it is to disinfect the excreta. Covers on utensils and a screened place of isolation are important.

Most insects are beyond the reach of solutions, and even when brought in contact with watery solutions of chemicals are frequently not killed by them. The bed-bug, having a more localized habitat, may frequently be destroyed together with its eggs by the application of certain liquids, but their extermination in the presence of sheathing is often impracticable by that means. They gain access to ships with laundry and at times under the broken cloth covering of trunks. A ship that has been disinfected by burning sulphur has also secured the advantage of being free from insect life. But the burning of sulphur in disinfection is ordinarily reserved for occasions when the destruction of insects is necessary to prevent the spread of a death-producing disease, as its action is to injure surfaces more or less. It is practically never used to disinfect clothing, for it renders it unfit for use and in the case of the mosquito diseases disinfection of clothing is not at all necessary.

In measles, mumps, scarlet fever, and small-pox, the exciting causes have never been isolated. They are regarded as contagious because, so far as is known, the positive factor in their extension is ordinarily direct association with the diseased. They are considered to be air-borne because the air seems to be the only carrier available. To prevent infection of the air in the vicinity or in contact with the well is therefore ordinarily regarded as the whole problem under the light of present knowledge except in the case of small-pox in relation to which there is the additional measure undertaken to eliminate the susceptibility of individuals by vaccination. In the presence of diphtheria immunity is also conferred by the serum injection.

In all these diseases the object of isolation is very clear, but a considerable part of the problem remains for solution, inasmuch as a case of measles or mumps, for instance, placed in complete isolation at time of onset, or appearance, is not infrequently followed by others. This is especially true of measles which, while competing with small-pox in degree of contagiousness, is noted for lack of power to cling to locality. One of the great objects of ventilation is to secure dilution, and undoubtedly in all these diseases good ventilation is much opposed to extension. Yet while the cause of measles does not cling to locality it quickly finds lodgment within the bodies of the susceptible where it is beyond reach, as it cannot be affected by any amount of disinfection, and where it will multiply and develop a new source of infection.

From the point of view of disinfection of ship's spaces in connection with measles, the solution of the problem is further complicated by the fact that when each case is isolated, as it appears, the succeeding cases are only a small percentage of the susceptible. An epidemic disease is present, but the number of cases at any one time is greatly limited. The ship's company tends to remain under the influence of the disease a long time because the susceptible are attacked in small batches with considerable and nearly fixed interval between each. This sequence of events in spite of isolation strongly suggests that the same sequence would obtain even if the entire ship were disinfected on the appearance of each case, and induces the idea that in *its very early stage* measles may not be an air-borne disease, but one propagated by direct transfer of secretions of mouth as at scuttle butt or by use of pipes in common or in the innumerable ways practicable on a ship. The same is probably true of mumps.

At any rate, it is clear that in relation to those diseases the work of the disinfector lacks precision because there is lack of knowledge of method by which they are spread. It looks as if in measles and mumps a certain damage has been inflicted before the first case and each subsequent case are recognized. It seems, however, that on recognition, drinking cups should be immediately disinfected, if the ship is not fitted with a "sanitary scuttle-butt," and kept in a disinfectant solution, *decks* of quarters disinfected, mess gear properly cleaned or sterilized, and instructions issued to the ship's company to carefully refrain from mixing mouth secretions, the several methods being specified. After decks of quarters have been once disinfected, following the first case, they should be disinfected daily, beginning after an interval of a week and continuing until the appearance of the last case of the following batch of cases.

As in these diseases insects are not in question, sulphur disinfection is not usually considered. In disinfecting place of isolation after removal of patient suffering from those diseases, formaldehyde is to be selected, but for disinfecting the ship's decks or surfaces without direct regard for contained air, chemical solutions are employed and preferably a solution of corrosive sublimate. With drinking cups a dilution of formalin is used. With clothing that has the appearance of being clean, that is, clothing in general or clothing that has not been in contact with the diseased, fumigation with formaldehyde can often be employed to much advantage on the ship, especially as at the same time the contained air and ship's surfaces are also disinfected. It is the method applicable to uniforms including gold or gilt and is generally applicable to unsoiled clothing that can be hung on lines and thoroughly exposed to the gas in a closed space.

Dry or moist heat is also frequently used in the disinfection of clothing, but, in the absence on the ship of a disinfector of sufficient size, has not been generally utilized when a large number of articles are to be disinfected, though frequently utilized in relation to soiled clothing. Soiled clothing can be disinfected by immersion in chemical solutions, but a mattress or pillow used by the diseased requires steam, destruction, or indefinite separation from the ship. Quite generally when a definite article, or a definite surface, is to be disinfected suitable chemical solutions can be employed, and that rule holds in relation to fæcal matter, urine, sputa, and the surface of man himself. But as solutions cannot act unless in contact they are useless in disinfection of air.

Gases form an intimate mixture and come in close contact with surfaces. A gas is an ideal form in which to apply a disinfectant to a closed space in the absence of an occupant, and steam by virtue of its heat is the most powerful of all the agents a disinfector can employ, unless destruction by fire be the exception. Formaldehyde is the gas in common use when insect life is not in question, as it is efficient without damage to surface or material.

The object of the foregoing is to facilitate the recollection of a number of important facts in relation to ship infection and to emphasize others, among which the following may be enumerated:

1. Nature is constantly at work to destroy infection and as in the unnatural concentration of human beings on a ship the tendency of men to foul their abodes chiefly by their own excreta is greatly increased, the construction of a ship should, so far as is practicable, permit the utilization of Nature's forces in opposition to infection, and the ship routine should constantly lend itself to facilitating and intensifying that work by securing cleanliness and dryness at all times. If the ship is required to be in questionable localities or harbors, an anchorage should be selected that does not favor the access to the ship of the exciting causes of disease and, if additional precautions are necessary to control the relation of crews to unfavorable influences on shore, they can be found in restriction of communication with the shore that may vary in degree in accordance with conditions.

2. The natural influences opposed to infection are dilution, dryness, heat, and light. Dilution cannot be secured without cleanliness of surfaces and ventilation. Surfaces that are not clean are themselves examples of concentration of material that should not be in a ship's spaces. They are liable at any time to add to the air substances dangerous to the well-being of a crew. Cleaning removes micro-organisms from a surface, and ordinary scrubbing and mopping destroys many.

But as influential as such work is in relation to disinfection itself it has marked limitations in a ship's routine as it is opposed to dryness. The difficulty of cleaning with avoidance of dampness emphasizes the necessity in ship life for stringent rules to limit as much as possible the fouling of the environment. Every time sputum is deposited upon a deck the difficulties in the way of securing a clean ship are greatly increased. Within a ship, soap-water and cloths, frequently rinsed, must be employed from time to time, but only fresh water should be used and in minimum amounts. This should be done at times when spaces are not apt to be occupied and upon surfaces made non-absorbent with paint or shellac. All such surfaces should be carefully dried by wiping with dry cloths.

Ventilation is not only conducive to dryness, but is directly opposed to concentration, as by its very nature it secures *renewal* of air, and heat in the occupied compartments of a modern ship is conducive to dryness because it greatly increases the power of air to take up water. It is recognized that all pathogenic organisms are not killed by the degree of desiccation secured, but very many are, and, by wiping dust and other material from surfaces, many are removed, and the number that finally reaches the air is greatly reduced; while if large amounts of water are employed in cleaning ill health is invariably caused by the continuous damp surroundings. *One should not expect good health in any compartment in which cleanliness is secured at the expense of dryness. It is the dry ship that is healthful.*

3. Ventilation in spite of the dilution it secures has marked limitation in occupied compartments. In practice the problem is not the most rapid separation of man from his excretions, but the most rapid separation consistent with safety. The ventilation is for benefit and not for injury, and men are made sick by disagreeable drafts. Even if all diseases had a specific cause no disease would be produced without a predisposing cause. There is more trouble caused by drafts of cold air in occupied spaces or even by damp clothing than by all the epidemic diseases. Yet it is very evident that the spread of many epidemic diseases is greatly encouraged by more or less stagnant air and that in spite of the increase in cold weather of the forces concerned in natural ventilation it is in cold weather that the ventilation is poorest and many epidemic diseases are most in evidence. Stagnation of air in cold weather is the result of the tendency of man to keep warm and to avoid disagreeable drafts. It is clear that the ventilation of ships must be secured under those limitations. When ships are constructed to properly warm all its contained air as it is supplied in cold weather the tendency to many diseases, including some epidemic diseases, will be greatly diminished.

4. Heat has its limitation on a ship in the effort to secure dryness because in excess it debilitates the body and causes it to be covered with *water* in the form of sweat. Warming the air supplied limits the sensation of draft up to a certain air temperature, but hot air either as supplied or as in the space makes for evil by its general effect upon the body. The environment of men on a ship should tend to the maintenance of good general health, and thus to the preservation of their vital resistance.

5. Light as a natural influence against microbic life has a limited application in the homes of seafaring men, but the application should be greatly extended. There are many parts of a ship to which sunlight never has access and to which it never can be admitted in view of the limitations under which a ship must be constructed. But sunlight streams upon the upper deck, and its action is very generally available upon clothing and bedding spread out in that part of a ship. Frequent airing and sunning of bedding and clothing is opposed to the introduction of infection and to its diffusion. And this action of light and air is as essential to the well-being of the storeroom keeper and members of the engineer

force in maintaining general health as to the proper condition of clothing and bedding.

6. While the disinfector cannot depend upon dilution and light, such natural influences greatly contribute to keeping a ship free from disease and by limiting the tendency to the appearance of disease lessens the chance in favor of infection and, in the presence of infection, the infected area or the intensity of the infection.

7. Disinfection is the destruction of agents causing infection. Therefore, for its successful operation there must be consideration of the *position* and character of the infection and of the qualities or applicability of each disinfectant available in order that the proper agent of destruction may be selected and then applied to the best advantage.

Material is said to be sterilized when all forms of life within or upon it have been devitalized. Therefore, all agents that sterilize are disinfectants. But all disinfectants do not sterilize as they are not required to destroy all living forms but those capable of producing disease. In disinfection it makes no difference how many living forms may be left, provided not one of those left can cause disease. This frequently has force in relation to spores. The spore is a stage in the multiplication of certain micro-organisms when it is very resistant to external influences. Fortunately, none of the general epidemics seems to be caused by micro-organisms with resistant spores. This fact simplifies the work of the disinfector and enables him to use substances as disinfectants that in particular cases could not be so classed if resistant spores were in question. One can frequently disinfect and yet leave alive many harmless organisms, but one can never sterilize without killing all the forms of life present.

Antiseptics inhibit the growth or activity of micro-organisms. They do not destroy the micro-organisms, but prevent their multiplication and therefore prevent putrefaction or fermentation. Salt is an antiseptic, but not a disinfectant. Yet inhibition of growth is a step in the direction of disinfection, and thus many disinfectants in much dilution while not present in sufficient concentration to kill are in sufficient concentration to inhibit and thus act as antiseptics. A disinfectant is a killer of germs, and therefore a germicide.

A deodorant is a deodorizer or a substance that has the power to destroy odor. Doubtless such substances act in different ways. Charcoal is a deodorant and the first part of its action is purely mechanical, as it takes the odorous gases into its interstices, thus preventing them from reaching the air. Subsequently the action is a chemical one, as the offensive gases thus retained undergo chemical changes in mixture with the oxygen the charcoal also contains. But charcoal is not a disinfectant; in fact, it gives substances to water that encourage bacterial growth. Yet, a disinfectant can also be a deodorant. Chlorine gas has strong disinfectant properties—that is, it kills germs—but it breaks up such hydrogen compounds as sulphureted hydrogen, ammonia, and the like, and thus acts as a deodorant. Ferrous sulphate, commonly called copperas or sulphate of iron, is a deodorant, but with little power as a disinfectant. Bichloride of mercury is a powerful disinfectant, but has little power as a deodorant.

Prophylaxis has been defined elsewhere. The use of vaccines as in the prevention of small-pox, diphtheria, and typhoid fever, is the use of the so-called vital processes of prophylaxis against infectious diseases, whereas disinfection is the use of chemical and physical prophylactic measures directed to conditions outside of the body. The former confers immunity and thus prevents spread by diminishing the number of susceptible individuals or entirely eliminating susceptibility. The latter has no relation to susceptibility, but prevents spread by destroying exciting cause.

The use of vaccines is in its infancy. In view of the fact that as a rule the pathogenic micro-organism that gains access to the body is beyond the reach of the disinfector, vital processes of prophylaxis are of very great importance in preventing the spread of disease. Disinfection is in many directions as undeveloped as is the use of vaccines, inasmuch as the *position* of the infection outside the body, its life history, and the various routes by which it gains access to the bodies of both the susceptible and immune, who are often carriers, are not sufficiently known in the case of a number of diseases.

If in the presence of a case of infectious disease all susceptible individuals were made immune, there could be no extension, and if in the presence of such a case all infection were destroyed, there could be no second case however great the number of susceptible individuals. In practice the vaccines that are applicable are at present limited in number and not absolute in effect in all cases; and, as has been shown, disinfection, while holding a very prominent and well-deserved place in prophylaxis, has limitations that are emphasized by the necessity for quarantine of persons. It, therefore, follows that while the battle against the epidemic diseases is being fought each year to better advantage, *all* known measures of prophylaxis have their important places or positions in the fight. One vaccinates as well as disinfects in the presence of small-pox, inoculates the young adult and the minor with antidiphtheritic serum, as well as disinfects, and while carrying out strict bedside disinfection in a case of typhoid fever, recognizes with satisfaction that the time is near at hand when insusceptibility to that disease will be more general in a naval service as the result of inoculation.

It has been stated that the disinfector uses chemical and physical agents in his work of destruction. The chemical substances at the time they come in contact with the infected material must be in solution, or in a gaseous or at times merely in air-borne state as in the condition of smoke when pyrethrum powder is burned to stupefy insects that they may be caught and burned. In physical disinfection, physical agents are employed and ordinarily heat is the agent, whether derived from boiling-water, steam, hot air, or direct combustion as in burning.

Chemical solutions act as chemicals in producing death by effecting chemical changes in the protoplasm of the microscopic forms of life. As heat is a very influential agent in hastening chemical changes or reactions, the disinfector cannot afford to ignore the fact that frequently in practice the line of demarcation between chemical and physical agents should not be sharply drawn. For instance, a hot or even warm disinfecting solution is much more powerful or more rapid in its action as a disinfectant than a cold one, and as satisfactory as formaldehyde may be in disinfecting a compartment in which the thermometer is above 60° F., it fails to accomplish satisfactory results when the temperature is below that point. It is true that in the latter case a low temperature tends to change the physical state of formaldehyde from a gas, in which the substance is represented by the single molecule CH_2O, to a white unctuous substance known as paraform having the formula $(CH_2O)_2$, and that to the extent in which formaldehyde is deposited as paraform, it loses disinfecting power; but, nevertheless, without regard to change in physical state the higher the temperature of either a chemical solution or a gas used in disinfection the more potent is its lethal action.

But the chemical activity of perfectly dry gases is frequently low or entirely absent. In spite of the remarkably wide range of the chemical attraction of oxygen for other elementary bodies perfectly dry oxygen will not combine with other elements, a third substance, usually water or moisture, being essential to the oxidation. Metals will not tarnish or rust in dry air and sulphur which burns in moist oxygen at 260° C. may be distilled in dry oxygen at 440° C. Of course entirely dry air is not found in nature, and consequently sulphur can always be burned in any compartment of a ship. But when sulphur is burned, sulphur dioxide or sulphurous anhydride is formed. An andyhride is a compound which produces an acid when brought into contact with water, and when sulphurous anhydride (SO_2) meets with water it forms sulphurous acid (H_2SO_3).

Sulphur dioxide as a dry gas will kill insect life just as carbon dioxide will, as it possesses in even higher degree the power to extinguish flame or to mechanically prevent processes of oxidation or combustion, but it has little power to destroy or kill micro-organisms unless it can meet with moisture to form sulphurous acid which is the true disinfecting agent. It therefore follows that when sulphur is burned in disinfection against micro-organisms there will be relatively little accomplished unless sufficient moisture is present. The same may be considered true in formaldehyde disinfection although the explanation of the value of moisture in that case is different.

Although water is necessary for oxygen to form oxides, its chemical relation cannot always be shown. It can be shown in the formation of rust which is a hydrated ferric oxide in the production of which water has been decomposed, and even the CO_2 in water utilized as ferrous carbonate has been an intermediate product; but under the influence of heat 32 parts by weight of sulphur unite with 32 parts by weight of oxygen to form SO_2 and although the presence of some moisture is necessary for the oxidation its constituents cannot be said to appear in the oxide formed. It is also true that some substances decompose by mere contact with many other substances which are themselves unchanged. Water probably has no such catalytic action in connection with formaldehyde, but, nevertheless, formaldehyde has increased disinfecting power in the presence of water-vapor. The explanation is more probably found in polymerization or along the same line that leads to an explanation of the inefficiency of formaldehyde in low temperatures. The behavior of this gas is at times capricious, but its lack of definiteness in action depends upon its tendency to form polymerides.

If an aqueous solution of formaldehyde is allowed to evaporate, paraformaldehyde is formed, and if that is heated it becomes trioxymethelene $(CH_2O)_3$ which, however, becomes formaldehyde if heated to its melting-point. It appears that in the absence of water-vapor formaldehyde is polymerized, and in passing from a state of gas ceases to act as a disinfectant. Its maximum disinfecting power is therefore secured at temperatures well above 60° F. and in saturated air.

It is this tendency to polymerize that greatly diminishes its power to penetrate fabrics such as clothing, as it tends to deposit paraform upon them rather than in a gaseous state to penetrate the material. As a general rule, if sufficient concentration of the gas be secured it can be trusted to penetrate *wherever infection has been carried by air*, but not where infected material has been carried in other ways. For instance, it can be trusted in the disinfection of the crew's clothing when that clothing is thoroughly exposed or spread out, as on lines, but it should not be trusted when used in fumigation to disinfect clothing that has been soiled by discharges of the sick, or mattresses or pillows that have been in contact with them. But when soiled clothing is *immersed for a sufficient time in a solution of formaldehyde* very satisfactory results are obtained.

A solution that contains 16 parts of the gas in 1,000 parts of water is as efficient generally as a 1 : 1,000 solution of bichloride of mercury and more efficient in the presence of albuminous matters. That solution of formaldehyde is obtained by the dilution of the more concentrated one called formalin. Formalin is put on the market as a 40 per cent. solution of formaldehyde. That seems to be the maximum concentration that can be obtained, and consequently a particular preparation may contain less, especially if it has not been kept well-corked. Formalin may also have its available strength diminished by cold, as at low temperatures one of the polymerides is precipitated, consequently in making calculations for dilutions the formalin should be at a temperature above its point of precipitation. All formalin used in disinfection should be at least a 38 per cent. solution. It often has an acid reaction (formic acid) and therefore its *solutions* might spot material of delicate coloring.

In making a solution of formaldehyde of desired strength from formalin it is of course necessary to realize that formalin is itself a *solution* of that gas. Considering formalin as a 40 per cent. solution, a 1 per cent. solution of formalin would contain only 0.4 per cent. of the gas and consequently it would require a 4 per cent. solution of formalin to give a 1.6 per cent. solution of the gas. Such a solution may be regarded as about equivalent in disinfecting power to a 1 : 1,000 solution of corrosive sublimate in general disinfection and much superior to it in disinfecting fæces. In view of the tendency of formalin to lose strength, its 5 per cent. solution is commonly employed. A 1.6 per cent. solution of the gas will kill all germs, even anthrax spores, in ten minutes, and a 0.4 per cent. (formalin 1 per cent.) will kill all ordinary bacteria in an hour.

In using formaldehyde in fumigation, even spores are readily killed if good concentration is secured, but not vermin. In disinfection with sulphur, while spores are not killed, its range is not much limited on that account. It is not applicable in relation to anthrax or tetanus, but in the presence of moisture it can be trusted to kill the infections of the ordinary epidemic diseases, such as small-pox, scarlet fever, and diphtheria. Sulphur is cheap and can be bought in almost any port; but even against infectious material that does not contain spores it is not as extensively used as formerly because it injures paintwork more or less and also clothing by weakening fabrics and attacking their dyes, and because in recent times formaldehyde has obtained a well-merited recognition as having great value as a disinfectant without causing injury to the material holding the infection.

But formaldehyde can never be allowed to eliminate the use of sulphur on ships. That fact is of great importance because formaldehyde should be regarded as of practically no value in relation to yellow fever. Sulphur dioxide can be trusted to kill vermin, and formaldehyde is not worthy of trust in that direction. Sulphur dioxide, even when in relatively small amounts, will kill mosquitoes, while such insects have a way of escaping from formaldehyde by hiding in folds of clothing and out-of-way places where they avoid concentration necessary for their destruction. Formaldehyde cannot be trusted to kill rats, mice, fleas, bed-bugs, or roaches, and thus an agent in the front rank of germicides is carefully placed well in the rear when the attack is directed against insects. Sulphur dioxide is also now commonly considered to have rather greater penetrating power than formaldehyde, and as a gaseous disinfectant in the presence of moisture to be worthy of entire confidence against diseases due to micro-organisms not containing spores.

It is commonly stated that a gas is an ideal form of disinfectant in a closed space, as with the air it surely disinfects all surfaces, while the application of solutions to the *entire* surface is accomplished with difficulty, and to keep them in contact a *sufficient time* is as difficult. There is, however, a disposition to regard gaseous disinfection as *nothing more than surface disinfection.* It is believed that this idea has been carried to an extreme. Gases are decidedly limited in penetrating power and cannot penetrate masses of infected material. They cannot be used about the sick or in disinfecting their excreta in masses wherever found, whether on surfaces or in clothing, but, while solutions are necessarily employed, disinfecting gases in the presence of heat and moisture can be trusted if in good concentration and with sufficient time to find all air-borne infection wherever it may have lodged, and to at least penetrate any ordinary unsoiled clothing. They cannot be expected to get far into mattresses or pillows or be trusted to disinfect clothing holding infected discharges, but on a ship, in spaces that can be well closed, formaldehyde can be trusted to render suspected clothing harmless if the clothing is so spread or hung that the gas can come in contact with its surfaces.

It is proper to rapidly place a liquid disinfectant over a deck when gaseous disinfection is to be employed, not only because it will disinfect what it is in contact with, but *also* because it will furnish the air with some moisture after the compartment is closed. It is customary to apply disinfecting solutions to paintwork after gaseous disinfection because there is a chance there may be sputa or other material in masses the gas was unable to penetrate in sufficient quantity, especially as even with contained air of relatively high temperature *side plates are such good conductors that with outside air of low temperature the gas in contact with them may be chilled to the point of comparative inefficiency.* This latter consideration may become of special importance when in cold climates formaldehyde is used on a ship unprovided with non-conducting sheathing. *Broken linoleum may also contain, in pockets under it, filth in masses that gases cannot penetrate.* It is therefore quite evident that, even in the general disinfection of ships' spaces, gaseous and liquid disinfectants must both be employed even when good closure of such spaces can be secured, and that with reference to clothing soiled with infected discharges warm solutions are available or heat as a physical agent when the articles are of such character as not to be injured by it or the heat can be so regulated as not to injure them.

Sulphur dioxide and formaldehyde may be regarded as the only chemical gases now practically available on the ship for disinfection. In using a gas for that purpose concentration is essential. All gases are elastic fluids or fluids that tend to expand indefinitely. Consequently to obtain concentration they must be evolved in sufficient quantity and imprisoned within a closed space. Otherwise the very marked tendency to expand and to diffuse into the atmosphere will prevent concentration, and concentration is essential. Success will therefore depend upon the amount of the gas evolved and the rapidity of evolution and upon its confinement within the space to be disinfected.

The tendency of a gas to leave a space is so strong that too much care cannot be exercised in securing closure. It is idle to attempt to disinfect with a gas any part of a ship that cannot be closed sufficiently to secure the required concentration for the time necessary to accomplish the result desired, and any leakage whether through natural or accidental openings is, in proportion to its extent, directly opposed to concentration. An hermetically closed space represents the unattainable, but it is the ideal for which every disinfector should work in gaseous disinfection. But he recognizes that in every case there is some degree of leakage which, continuing for some time, will have effect upon concentration. From this fact there is evolved another essential to success in gaseous disinfection—*the gas must be evolved with the greatest practicable rapidity*. This is of even more importance than the total amount of gas evolved, for with ordinary care in effecting closure rapid evolution quickly secures lethal concentration for some period, the length depending upon degree of closure, while, if the same *amount* of the gas were slowly evolved, concentration would be for a limited time even with complete closure and, with the same degree of leakage, might very well not be secured at all.

The necessity for rapid evolution of the gas may be illustrated by considering the amount of water in a stationary basin as a measure of the concentration of water. If the plug be removed, thus leaving the discharge pipe open, the basin may be momentarily filled by dumping a gallon or two of water into it, but, if water were allowed to run into the basin at a rate less than or equal to the capacity of the discharge to empty it, the basin would never contain water, *however large the total amount supplied*. If the rate of supply were somewhat in excess of the discharge at all times, the basin would gradually fill, but to secure that result a large amount of water would have been wasted and *it would be a long time before the entire interior surface of the basin would be covered* or have its desired concentration. In gaseous disinfection concentration must be secured, and a rapid evolution of the gas secures that result, inasmuch as under those circumstances the rate of evolution is in excess of the rate of dissipation or leakage. It is also under such circumstances that not only is concentration quickly obtained, but also, with a stated time for disinfection, maintained for the longest period on a given amount of gas in a properly closed space.

From the foregoing the following may be stated as necessary in gaseous disinfection: Closure of the space, exposure of contents and lockers, a sufficient total amount of the gas, rapid evolution of the gas, warm contained air supplied with plenty of water-vapor (sulphur dioxide is effective at much lower temperature than formaldehyde, but both have increased power in very warm air), and sufficient time exposure.

Preliminary to effecting closure, it is necessary to examine the boundaries of each space to be disinfected, locating as completely as practicable all accidental openings, such as rivet-holes in bulkheads, and appreciating the facilities provided for closing under ordinary circumstances such openings as air ports, hatches, and doorways. At that time it is also necessary to realize the *number* and relation to each other of compartments to be disinfected and the cubic contents or air space of each.

It is always wise to disinfect simultaneously as many spaces as is practicable. Such a course is advantageous for several reasons. If it is the intention to disinfect several spaces—two or more or all on one deck or on more than one deck—the more rapidly the result is obtained the sooner they cease to be a menace. When an entire ship is infected, one of the great advantages of a quarantine station is the facility afforded to simultaneously apply the work of disinfection to the ship as a whole.

One of the advantages of prompt isolation and other precautionary measures is to confine the infection to a part of the ship. As man himself is the source of infection it is ordinarily practicable to limit the infection to one or more of the spaces occupied by him, and in the majority of epidemic diseases they are the infected ones. Under those circumstances the infection can be much more readily destroyed, especially in a habitation such as a ship where, in the absence of quarantine station or other facilities, the crew, remaining on board, is deprived of the use of all compartments during the time of fumigation.

Fortunately, in the case of yellow fever, the disinfection is done in a warm climate and the required time of exposure is short, as the insects are killed in an hour even when hidden in clothing and fabrics and no great concentration of the sulphur dioxide is secured. The advantage of disinfecting all compartments at one time in that case is obvious. In the case of rats a time exposure of two hours is quite sufficient if reasonable concentration is secured, but rats are famous for passing from one part of a ship to another, and consequently if the ship cannot be disinfected as a whole it is best to start the fumigation at one end of the ship and work toward the other, *including in each disinfection all compartments on the different levels between their water-tight bulkheads.*

Another advantage derived from the simultaneous disinfection of *contiguous* compartments is that loss of concentration from leakage is minimized. Each compartment should be as completely closed as if it alone were to be disinfected and have the concentration of gas calculated for its size, but if there are overlooked or undiscoverable openings between them, they merely tend to leak into each other.

All air ports of ships close on rubber gaskets, and the same is true of water-tight doors. Windows and doors on shore never close a room sufficiently to satisfy the disinfector, and therefore he uses strips of paper and paste to cover cracks, crevices, and keyholes. But if an air port or a water-tight door be *tightly* closed, there will be no need for additional precautions in their case. Paper and paste will, however, always be necessary in effecting closure on a ship. In all ships there are a number of ordinary doors and quite a number of hatches having covers that are far from air-tight. As in hatch covers and around ordinary doors, the openings are more or less linear, the paper, preferably ordinary wrapping paper, should be cut into strips and then carefully put on with flour paste, always leaving one door or hatch for exit to be closed in the same way after it has been utilized for that purpose.

As closure is for the purpose of securing concentration of the gas, it is essential for the compartment not to receive air during the disinfection. The ventilation blower affecting the compartment must therefore be stopped, the valves in terminals closed, and all louvers covered with paper held in position by paste. It is essential to close every opening, keyhole, crack, or crevice of whatever character, but when only one compartment is in question, it is better to apply the paper on outside surfaces that cracks may themselves be disinfected.

One advantage in having plenum ventilation on a ship is that deposits within pipes have been derived from outside air and not from the contained air of the ship, and even such deposits can be prevented by using a method of washing air. Exhaust pipes may readily contain more or less undesirable dirt. In either system there is now a tendency to accumulation of dirt at louvers which should be removed in routine cleaning, but which in disinfection should be made wet with solution of a disinfecting substance.

Yet in view of the large amount of air going through a louver, and the even greater velocity in branches and main, it has been doubted whether the contained air of a ventilating system is a menace from the point of view of infection. In an exhaust system the discharge is into the open air and in the supply system the pipes are filled with fresh air.

However, the situation may have possibilities for evil, even though it has not seemed to have, and especially in a low deck-discharge from a place of isolation. Measles and small-pox are very contagious diseases, and it is quite conceivable that a person standing even in the open but *near* the deck outlet from a place of isolation might contract disease, especially if the isolation ward should happen to have its own independent system. It would therefore seem advisable to use a gauze strainer on the louver within the space while utilized for isolation, such a space being ventilated by exhaust.

The compartment or compartments to be disinfected having been prepared for closure, or better while such preparations are made, all contents of the space that are to be disinfected with it should be carefully arranged for as complete contact with the gas as is practicable. Lines should be stretched across the compartment and clothing placed upon them as if to dry, ditty boxes opened and their contents exposed, all locker doors opened that the gas may have access to every surface and to all contained air, and all hammocks unlashed, mattress covers taken off and mattresses placed on edge, in general all the material contained by the compartment so arranged that the gas will come in contact on all sides. For reasons already given this exposure of clothing is avoided when sulphur dioxide is employed, and is thus in practice limited to formaldehyde which has no effect upon colors or strength of material.

While the space is prepared for disinfection the amount of the gas that is to be evolved should have been determined with reference to the size of the space and arrangements made for the evolution. The concentration of the gas per 1,000 cubic feet of space has been determined by laboratory experiment and also the time exposure required, but in order to utilize such data it is necessary to know the size of the space in cubic feet of air it contains. As the conditions in practice are variable, depending chiefly upon degree of closure secured, it is better to be rather liberal in the estimate of the amount of gas required, and thus to calculate the amount of material to be employed rather more from gross space than from air space, that is, ordinarily from the measurements of the space as a whole without deduction for room occupied by hammocks, clothing, lockers, and the like.

On a ship there should be no cause for delay in making such calculations, as early in commission the gross space of each compartment should be calculated and tabulated, together with net air space in the study of the occupied compartments in relation to degree of crowding and ventilation. At the time such calculations are made, it should be appreciated that they are also preliminary to just such emergency work as disinfection, and the amounts of the different materials that may be required in the gaseous disinfection of each space susceptible of sufficient closure should be a part of the tabulation.

On our ships there are usually two sources of formaldehyde available—formalin or formaldehyde solution (40 per cent.) and formalin pastils. There is ordinarily no formaldehyde generator, though one or more generators may be found at navy yard, and thus are available for cruising ships at times if desired.

Formaldehyde is generated when the vapor of methyl or wood alcohol is passed over red-hot platinum in the presence of air or oxygen. The alcohol vapor acquires oxygen and its molecule splits into formaldehyde and water: $CH_3OH + O = HCHO + HOH$. The heat evolved during this process is marked, and thus if the platinum or platinized asbestos disk be once heated to a sufficient temperature and then continually supplied with the alcohol vapor, it will maintain its own heat so long as the vapor and air are passing over it.

This is the principle of the Kuhn Formaldehyde Generator in which many of the difficulties met with in some generators are overcome. In that generator there is a large pan into which the wood alcohol is poured over mineral wool that acts as a wick. Around the pan there is water which supplies moisture by evaporation during the process and also acts as a water-seal for the stove-like metal cylinder that covers the lamp, and fits into the water around it. The cylinder contains two partial diaphragms as cones one above the other thoroughly platinized except the interior surface of the lower. That surface is toward the lamp or pan of mineral wool and alcohol, and thus as no formaldehyde is formed there, the alcohol in the lamp is not subjected to sufficient heat to ignite it.

The process is started by igniting the alcohol, the stove-like superstructure which moves on a hinge having been slightly lifted and kept in that position until the platinized disks have been heated. The superstructure is then lowered over the lamp and into the water, thus excluding air, smothering the flame, and stopping combustion. Under these circumstances the alcohol vapor ascends, comes in contact with the hot platinum, and is mixed with air admitted through openings in the cylinder or superstructure just below the lower cone. Those openings are of size and number determined by experiment as sufficient to admit the amount of air required for the complete conversion of the alcohol vapor into formaldehyde. But any vapor that may escape such conversion has to pass through a number of layers of copper mesh above the upper cone. If a considerable quantity of alcohol vapor were to pass into the room it might be ignited with more or less serious results. This generator has been found to include sufficient provision in that direction and by its lower cone to prevent flare-back or ignition of the alcohol within the lamp which would of course prevent the formation of formaldehyde.

No diagram of the apparatus in included here because it is believed that all generators are lacking in the rapid formation of gas stated to be necessary for the most satisfactory work. Some improvements have been made in the Kuhn apparatus in recent years, but it did take about two hours to convert three pints of alcohol, the amount considered necessary to disinfect 2,000 cubic feet of space, and all generators are relatively slow. The first cost of such an apparatus is not small, one is required for about 2,000 cubic feet, and it remains within the space until the disinfection is completed, thus necessitating a number of generators for rapid work on a number of spaces or more than one in larger spaces.

In fact, the view is taken here that much of the apparatus usually described in connection with disinfection by formaldehyde is complicated, expensive, and at least not necessary. But a generator has a certain value claimed for it that should be noted. The gas, as recently or newly generated, may have some of the more marked properties that belong to nascent gases in general. A gas at moment of liberation on generation might be supposed to be still in condition of free atoms and therefore more active. The gas from a formaldehyde generator has seemed to have less tendency to polymerize, as appears from the rapidity with which the odor of the gas disappears when the space is opened after disinfection. However, in view of slow generation of the gas, very good closure is considered necessary and an exposure of 12 and perhaps preferably 24 hours. With a method of very rapid evolution, the desired result can be obtained in six hours, the difference in time being of manifest advantage, especially on a ship where a large number of persons are deprived of their quarters during the disinfection.

Much the same objections are considered to hold against the autoclave, retort and spraying methods of liberating formaldehyde from formalin. In the case of the autoclave, formalin is placed in a retort where it is boiled under pressure. There is a water gage, pressure gage, and safety valve. A kerosene lamp, a gas jet or a gasoline flame under the retort boils the formalin. Ten ounces of formalin are used for each 1,000 cubic feet to be disinfected, but as during the process the formaldehyde may polymerize, or be left toward the last as paraform, some neutral salt, such as sodium chloride, borax, or calcium chloride to the extent of 20 per cent. is added to raise the boiling-point and facilitate the discharge of the gas from its solution. The disengagement of the gas is thus accomplished with considerable rapidity and the evolution of the gas by boiling formalin under pressure has been the most common method of obtaining it. As the solution is boiled outside the compartment, the steam and formaldehyde are led into the space by a tube that passes through a key-hole or other small opening. The method, therefore, not only furnishes the gas, but also the water-vapor.

Yet, into a large space, the gas, having admission by only one small opening, does not diffuse rapidly, and thus *uniform* concentration is obtained too slowly. It is true a large amount of gas comes off in 10 or 15 minutes, practically all the formalin contains, but the *distribution* is not satisfactory, and with the slowness of distribution there is said to be a greater tendency to polymerize. The apparatus is cumbersome and requires care and watching, as the usual pressure is at least 45 pounds, and the method is not received with as much favor as formerly, some authorities going so far as to give it their decided disapproval.

Another method is the simple retort in which formalin is boiled as water in a kettle or not under pressure. In that case, the steam from the solution precedes most of the gas, for under the degree of heat obtained in the absence of pressure, paraform is soon evident in the solution, and by the time half the water has disappeared as steam a rather thick liquid has resulted, but one that has steadily increased in temperature as the boiling-point has been raised. Then the gas begins to come off with increasing rapidity and continues to come off until the last, for as the concentration continues the boiling-point continues to rise. In an autoclave the liquid remaining contains little formaldehyde 10 or 15 minutes after a pressure of 45 pounds has been reached and the delivery tube has been opened, but in the retort without pressure there is relatively little gas evolved at first. In the open retort it has been necessary, as a rule, to evaporate all the solution, while in the case of an autoclave the liquid that remains has little value.

Very good results have been obtained by boiling formalin in a copper kettle over a large alcohol flame obtained by using mineral wool for a wick. Water is boiled in the kettle first and then formalin poured into it. In that case 20 ounces of formalin are recommended to be used for each 1,000 cubic feet and additional water-vapor to be supplied by boiling water in another kettle or permitting steam to have access from radiator. The method seems to be satisfactory in a general way, but it requires an open flame within the compartment to be disinfected and does not seem to be altogether satisfactory for use on ships. The flame must last a sufficient time, and a good quality of alcohol (95 per cent.) must be employed. The kettle is made of copper, as formalin attacks iron.

The method of spraying formalin on clothing or sheets and then closing the compartment is not satisfactory. During the time of spraying the irritating quality of the gas is trying, and to use in the form of a spray even six ounces of the formalin per 1,000 cubic feet is rather difficult. Besides, it has been found that the results are uncertain as too much of the gas is lost for disinfection there being a marked tendency to deposit paraform as the solution evaporates.

However, there is a method applicable to ships by which formalin can be made to give up its gas by chemical means, no flame being required and no cumbersome, expensive or complicated apparatus. The formula of formaldehyde is CH_2O, and when brought into contact with potassium permanganate ($K_2Mn_2O_8$) the following reaction may be considered to result:

$$2K_2Mn_2O_8 + 3CH_2O = 4KOH + 4MnO_2 + 3CO_2 + H_2O.$$

It therefore appears that approximately 630 parts (grams) of $K_2Mn_2O_8$ oxidize 90 parts (grams) of formaldehyde with formation of water and carbon dioxide.

Considering the formula of formaldehyde (CH_2O), it may be assumed that in the process the CO is oxidized into CO_2 and the H_2 into H_2O. The thermal equation of the oxidation of CO may be expressed as $CO + O = CO_2 + 68{,}000$ gram calories. In other words, in the union of 28 grams of carbon monoxide with 16 grams of oxygen the heat formed is sufficient to raise 68,000 grams of water from 0° C. to 1° C. In the same way the thermal equation of the oxidation of H_2 into water may be expressed as $H_2 + O = H_2O + 68{,}300$, the chemical union of 2 grams of hydrogen with 16 grams of oxygen forming sufficient heat to raise 68,300 grams of water from 0° C. to 1° C.

As 630 grams of permanganate of potassium oxidize 90 grams of formaldehyde, 94.5 grams (3 1/3 ounces) would oxidize 13.5 grams of formaldehyde, as:

$$630 : 90 :: 94.5 : x \therefore x = 13.5.$$

Then, as the molecular weight of CH_2O is 30, of which 28 is CO and 2 is H, the 13.5 grams of formaldehyde would contain 12.6 grams of CO and 0.9 gram of H, as:

$$30 : 28 :: 13.5 : x \therefore x = 12.6.$$
$$30 : 2 :: 13.5 : x \therefore x = 0.9.$$

As, however, it has appeared from the thermal equations given that 28 grams of CO in combining with 16 grams of oxygen yield 68,000 small calories and that 2 grams of H in combining with 16 grams of oxygen yield 68,300 small calories, it is evident that 12.6 grams of CO when oxidized yield 30,600 similar calories and 0.9 grams of H yield 30,735, as:

$$28 : 68000 :: 12.6 : x \therefore x = 30600.$$
$$2 : 68300 :: 00.9 : x \therefore x = 30735.$$

Therefore, the total calories obtained from the oxidation of 13.5 grams of formaldehyde by 94.5 grams of potassium permanganate are 61,335, or sufficient to raise 61,335 grams of water from 0° C. to 1° C. or about 613.35, grams from 0° C. to 100° C. As the specific gravity of formalin (40 per cent.) may be taken as approximately 1.077, the 613.35 grams may be roughly considered to be 569.5 c.c. of formalin, or about 1.2 pints. It may therefore be assumed that when 1.2 pints of formalin (40 per cent.) are poured upon 3 1/3 ounces of potassium permanganate, sufficient heat is generated to raise the solution from the freezing-point to the boiling-point, and that during the process 13.5 grams of the formaldehyde are destroyed, or about the amount contained in 31.3 c.c., or very little more than a fluid ounce of the formalin.

It is quite evident that the chemical reaction will begin so soon as the substances come in contact, and that from their nature the heat will be formed so very rapidly that the particles of the solution will be intimately and violently shaken and separated by the heat and by the steam as it seeks to escape from the bottom during the ebullition. At the same time that part of the carbon dioxide formed during the process and not taken up by the potassium hydrate is adding its influence to facilitate the escape of contained gases. The effect on the formalin, which is in a sense a supersaturated solution, is the very rapid discharge of formaldehyde. There are doubtless a number of factors in the disengagement, but the object here is merely to declare the general nature of the process upon which this method of disinfection by mixing formalin and potassium permanganate depends.

As in the process it would seem that the more rapid the chemical reaction the better the result, it is perhaps advisable to use the permanganate in fine needle-shaped crystals rather than in the larger octahedral form. However, it does not appear that very much is gained by powdering the potassium salt when the needle-shaped crystals are available. In either case the chemical reaction is practically completed in about three minutes and is at its height in three-quarters of a minute. When the crystals are used the ebullition is marked in 20 seconds, and when the powder is used in about 5 seconds. These times declare the advisability of leaving the space or compartment quite promptly after the process is started and, where the gas is to be liberated from more than one container in the same compartment, of having assistants to start the process in the containers simultaneously.

As heat is an important factor in causing the discharge of the gas from the formalin it is advisable to utilize to the full extent practicable all that is generated. To that end it is best to have the container surrounded by some good non-conductor. Asbestos paper has been very successfully used for that purpose as a covering for a container made of tin. However, a double container could be readily employed, the outer to be of wood or any non-conducting material. Under the best circumstances some heat will be lost, and therefore it is found advisable in practice to increase the potassium permanganate to at least 3 1/2 ounces and to diminish the formalin to one pint, those amounts having been found in laboratory experiments to be sufficient for the disinfection of one thousand (1,000) cubic feet of air space.

Taking the amount of potassium permanganate in crystals as at least 3 1/2 ounces and the amount of formalin as one pint per 1,000 cubic feet, it is necessary in constructing or selecting a container, to realize the enormous increase in the volume of contents incident to the ebullition. The original volume occupies not less than 8 times the space when the process is at its height, and in view of splashing it is safe to assume that it will require a container capable of holding ten times the amount of formalin employed. In other words, for a pint of formalin used with 3 1/2 ounces of permanganate in crystal form, the container should have a capacity of ten pints, and for two pints of formalin and seven ounces of permanganate, a capacity of 20 pints.

Twenty pints are 2 1/2 gallons, and it is not advisable to have any one container of greater capacity than is necessary for the disinfection of 2000 cubic feet. In all gaseous disinfection distribution of the gas is an important requirement, and better distribution is secured with the gas coming from several containers located in different parts of a large compartment than with the total supply coming from one container. A container capable of holding twenty pints is also readily handled at all times and conveniently stowed when not in use. It approaches the size of the agate buckets found in the medical departments of our ships, which hold about 3 gallons, and could be utilized for this purpose, each partly nested in a wooden bucket, such as a deck bucket. The entire apparatus required is a large open metal or non-absorbent vessel covered with non-conducting material or placed within a vessel made of non-conducting material.

Such an arrangement can be secured on ships without resort to special construction, but the Maine State Board of Health has designed a special container made of bright tin and covered with asbestos paper. It is described by the Illinois State Board of Health as a tin can with broad flaring top. The lower part is a cylinder with base or bottom 10 inches in diameter and height of 7 1/2 to 8 inches, and thus a capacity of about 20 pints. The upper part is an inverted truncated cone having an altitude of 7 1/2 inches and a diameter at top of container of 17 1/2 inches. Thus the full height of the container is about 15 1/2 inches. It has a double bottom with 1/4-inch air space. The following is the diagram:

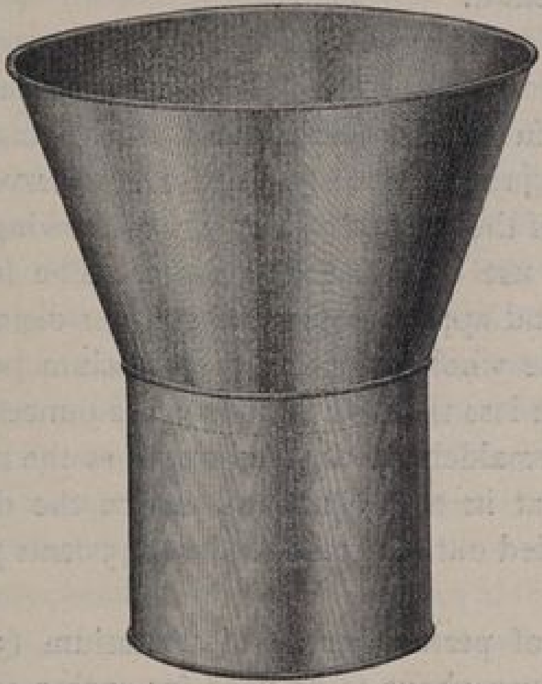


FIG. 86.—Disinfecting apparatus. (Designed by the Maine State Board of Health.)

In this process perhaps about 36 per cent. of the solution is evaporated when the amounts given above are employed. It may therefore be assumed that for each pint of formalin employed with 3 1/2 ounces of permanganate about 2,500 grains of water in the form of vapor are intrusted to the contained air. In a steam-heated compartment that will ordinarily be insufficient to secure saturation. Air at 80° F. can contain 10.98 grains of water per cubic foot, and at 90° F. can contain 14.85 grains. The latter temperature might well be attained in the closed compartments of a ship ordinarily used for quarters. With a contained air of 70° F. and relative humidity of 70 the water vapor secured would be quite sufficient. As in that case the air can hold 8.01 grains per cubic foot, and does hold $8.01 \times .70 = 5.607$ grains, only 2.403 grains per cubic foot are required to cause saturation, or 2,403 grains for the 1,000 cubic feet, and even more than that amount is supplied.

If the air is at 90° F., with, in a steam-heated compartment, a relative humidity of 25, about 11,137.5 grains of water would be required for saturation, or 8,637.5 *grains more than the process furnishes.* It is, therefore, advisable to spread a disinfecting solution over the deck before the chemical reaction is started or, if the construction of the heating plant permits, it is perhaps better to arrange for the constant access of a *small amount* of steam, during the six hours the compartment remains closed, through the slightly opened pet-cock of a radiator. The latter method not only supplies water-vapor, but increases the temperature of the contained air, thus greatly facilitating the action of the gas as a disinfectant.

The only additional precautions necessary in carrying out this method of disinfection are to pour the formalin over the permanganate, not drop the permanganate into the formalin, and on leaving the compartment and carefully closing the exit, to systematically observe, from the outside, all the boundaries of the space that any places showing leakage of the gas may be closed by use of paper and paste. The latter precaution is always important and applies equally to sulphur disinfection.

Considering the wholesale price of potassium permanganate to be 22 cents a pound, or less than 5 cents for 3 1/2 ounces, and that a 40 per cent. solution of formaldehyde can be bought at the rate of 30 cents per pint, it appears that in a government service the disinfection by this method can be carried out at a cost of about 35 cents per 1,000 cubic feet of space.

The amounts of permanganate of potassium (3 1/2 ounces) and formalin (1 pint) given above to be used for each 1,000 cubic feet of air space are those that have been utilized by a number of boards of health and appear to have been based upon results obtained by them with pathogenic organisms under the influence of the gas so liberated. But, at least from a chemical point of view, there is a very large waste of formaldehyde represented by the amount that remains undischarged. This is shown when, after using the 3 1/2 ounces of permanganate, a similar amount of the salt is added to the fluid remaining after the process has been completed. The ebullition is then as marked as that originally obtained and the evolution of the gas apparently as great.

It therefore appears that the method given above is either lacking in adjustment or essentially deficient in some respect from a chemical point of view. It seems highly probable that both are the case, and that while an additional amount of permanganate may be employed to advantage from several points of view, the method itself may be ultimately modified in some important particular, as formalin alone cannot be mixed with any reasonable amount of permanganate that will be capable of discharging all the formaldehyde in excess of the amount necessary for the chemical reaction itself.

If 500 c.c. of formalin are poured upon 200 grms. of permanganate of potassium, practically all the fluid is evaporated under ordinary conditions, little or no free fluid being in evidence after the completion of the reaction. But if additional water and permanganate are added to the residue, a violent ebullition with liberation of formaldehyde results. Thus, when about 6 ounces of the permanganate are used with 16 ounces of formalin the maximum amount of water-vapor is obtained, and also a larger evolution of the gas than when 3 1/2 ounces of permanganate are employed. Yet even then it is apparent that nothing like all the formaldehyde is discharged, although all the fluid is evaporated. Even if 500 grams of permanganate are used with 500 c.c. of formalin, a large amount of formaldehyde remains as a polymeride, for if water and then permanganate are added to the residue, a violent ebullition results.

These facts seem to show that the process is lacking from a chemical point of view and, as the addition of water to the formalin employed may not be expected to answer the requirements, it is not improbable that some salt will be found which, added to the other substances, will more thoroughly utilize the heat producing power of the permanganate.

Taking all the circumstances into consideration, it may be concluded that 6 ounces of permanganate of potassium and 16 ounces of formalin per 1,000 cubic feet should give better results in a ship's compartment than can be uniformly obtained from 3 1/2 ounces of the salt and 16 ounces of formalin, but that, if it were considered necessary in this process as in others to liberate for each 1,000 cubic feet of air space the formaldehyde contained in 10 ounces of formalin, then 8 ounces of permanganate and 20 ounces of formalin would be required. With the method in its present stage of development, the former amounts can be used to advantage on the ship.

Formalin pastils cost about one dollar and forty cents per 1/2 kilogram. Each pastil weighs about one gram, and it is customary to use at least 60 and often 75 for each 1,000 cubic feet of air space. Therefore the cost is only about 17 cents, exclusive of the original cost of the formalin lamp (disinfector) and the alcohol expended in melting and breaking up the pastils into formaldehyde. The pastils are paraform, probably mixed with trioxymethylene. The apparatus is very simple, consisting essentially of a cup supported over an alcohol lamp. The pastils are placed in the cup and the heat of the alcohol flame causes them to disappear by conversion into formaldehyde.

The method has its advantages and disadvantages. The application is very convenient, the expense is relatively small, the pastils occupy very little space in storage, and alcohol is on hand or readily obtained, as a rule. The disadvantages are that the method leaves an open flame within the compartment; *unless the alcohol is of good quality*, the flame may not continue a sufficient length of time; the method supplies little or no moisture and unless considerable moisture is supplied the polymerization percentage is large; the gas does not come off very rapidly, and if the alcohol flame is too large the pastils will ignite, and thus disinfection will not be accomplished, burning paraform not producing formaldehyde.

In the method by mixing formalin and potassium permanganate, not only is the liberation of formaldehyde certain, but also the very rapid evolution. In using pastils there are several factors that in practice may cause no evolution at all or very little. There are a number of wicks in the alcohol lamp, and as too much heat will cause the paraform to ignite, the wicks should not project more than 1/12 of an inch. The small flames may be much in evidence when left in the compartment, but will not continue unless the quality of alcohol is good or even unless that used previously in the lamp was good, if any still remains. The alcohol in the medical department of a ship is always good because it is up to the pharmacopœial requirements, but the supply may not be sufficient to meet the repeated demands for disinfection, and thus recourse to the general supply of the ship may be forced. Such alcohol is placed on a ship chiefly for mixing with shellac, and either from accidental mixture with a small quantity of shellac or from its grade may give an uncertain flame or one that starts well but does not continue.

It is most disadvantageous to start the disinfection of a ship's space (sick-bay, operating-room, or any other), keep it closed for at least the 12 hours required by this method, and then on opening it to find the pastils remaining, the alcohol flame not having continued. It may be said that all this can be avoided by using good alcohol and wicks in good condition. That is true, but in naval life as in any other a method that does not require so much attention to details or in the evolution of the gas does not require any such attention has marked advantages over another that does. Besides, the formalin and potassium permanganate method requires only 6 hours' closure, while with pastils a closure of at least 12 hours is the rule. Thus, with the former there is not only certainty of disinfection, but also a great diminution in the time the space remains out of use.

The difference between the two methods in time of exposure is apparently due not only to the difference in the rapidity with which the gas is evolved, but also the greater tendency to polymerize where pastils are used. In the latter case, the greater tendency of the gas to deposit as paraform is declared by the more marked tendency of the odor of formaldehyde to cling to the space after it has been opened. This is in turn largely due to the fact that the pastil method does not supply water vapor. Thus the greater tendency to deposit paraform may be considered to declare less ability to penetrate. Consequently a greater time exposure is allowed, and at the same time additional means for the supply of moisture during the disinfection become more urgent. The deck should always be made damp with a disinfecting solution, and a little steam obtained from radiator if practicable.

The pastil method, giving less penetration, is apt to result in a disinfection that is more nearly confined to *surfaces* than is the case with the formalin and permanganate method in which the penetration is naturally greater. Yet if the pastils are converted into formaldehyde and water-vapor is supplied the results are *very generally satisfactory*, so far as disinfection is concerned. However, the difficulty after disinfection of ridding the compartment of the odor of formaldehyde is not a small objection, especially in a sick-bay or operating-room, and the longer time exposure required may be a serious disadvantage at times in the employment of this method.

On our large ships there are two disinfectors for the employment of these pastils. Of course in fleet additional ones can be readily secured in port. In view of the better distribution secured when the gas is evolved from a number of locations in a large space it is advisable, if such an attempt is to be made, to have not more than 2,500 cubic feet of space on one disinfector, and 2,000 is much better, thus limiting the number of pastils over one lamp to from 150 to 190. It takes some care to invariably secure the vaporization of many pastils, and it is ordinarily much the *best* to confine the method to smaller spaces, say 1,000 cubic feet and 75 pastils.

With good alcohol and good wicks the pastil method is valuable under naval conditions as, with limited storage and absence from sources of supply by purchase, alternative methods are of more importance than on shore. Yet, in view of certainty in evolution of gas, greater rapidity of evolution, greater penetration secured, and shorter time exposure required, it is believed that the formalin and permanganate method is the one most suitable for use on all naval vessels in formaldehyde disinfection, and that the pastil method should be regarded as an important alternative, most suitable for relatively small spaces, but utilized then to conserve the supplies of material necessary in the other method.

If sulphur is to be employed against micro-organisms, the compartment or compartments must each be closed as carefully as if formaldehyde were to be used, and in the same way. As has been stated, the combustion of sulphur produces sulphur dioxide which rapidly kills insects, but which cannot kill micro-organisms unless it combines with water to form sulphurous acid or is at any rate in the presence of moisture. Then against insects it is not necessary to supply water-vapor but against micro-organisms it is essential to do so. While sulphurous acid (H_2SO_3) has not been obtained in a separate state, water absorbs 43.5 times its bulk of the gas at the ordinary temperature and the solution is generally believed to contain H_2SO_3 formed by the reaction $H_2O + SO_2 = H_2SO_3$. In disinfection with sulphur the primary object is said to be to secure this reaction in the air by union of SO_2 with water in the state of vapor. The disposition of sulphurous acid to absorb oxygen and pass into sulphuric acid makes it a powerful deoxidizing agent.

The atomic weight of sulphur is 32, and therefore 32 grams of sulphur unite with 32 grams of oxygen to form SO_2. To burn one pound of sulphur an equal weight of oxygen is required and two pounds of SO_2 are formed. One thousand cubic feet of air at 32° F. and 29.92 inches weigh about 86.4 pounds and at 80° F. weigh about 78.7 pounds. In the former there would be about 19.95 pounds of oxygen, and in the latter about 18.17 pounds, considering the oxygen to be 23.1 per cent. by weight. There is therefore sufficient oxygen in one thousand cubic feet of air to burn about 18 pounds of sulphur, if it were all available for that purpose. But, as in the case of a combustion forming CO_2, the sulphur cannot burn in a closed space until it has taken up all the oxygen within the space, but only until it has formed sufficient SO_2 to smother the flame, and that is accomplished, as a rule, in the burning of about 4 pounds per 1,000 cubic feet. There will then be 8 pounds of SO_2 liberated in each 1,000 cubic feet of space.

By the formula $SO_2 + H_2O = H_2SO_3$, 64 pounds of sulphur dioxide require 18 pounds of water, and thus the 8 pounds of sulphur dioxide formed during the burning of 4 pounds of sulphur would require 2.25 pounds of water-vapor for its conversion into sulphurous acid, or about 0.56 pound of water for each pound of sulphur, including the water-vapor already in the contained air and incident to its humidity. It has long been recognized that the former disappointment in the use of SO_2 against non-spore-bearing organisms was due to the lack of water-vapor, the dry gas being practically inert even in 10 per cent. concentration, and a time exposure of two days, while a concentration of even less than 1 per cent. has been found to be lethal in one day when sufficient water-vapor is present.

When 4 pounds of sulphur are burned in 1,000 cubic feet of space, the concentration is about 4.47 per cent. For a liter of SO_2 weighs 2.8672 grams at standard. As a liter is about 61 cubic inches, a cubic foot of the gas will weigh 81.22 grams. The 8 pounds formed by burning 4 pounds of sulphur will weigh 3,628.72 grams, and will therefore have a volume of 44.7 cubic feet. Then as the 44.7 cubic feet are generated in a thousand cubic feet of space, the concentration is 4.47 per cent. It has been found that a concentration of 4.25 per cent. is effective in 16 hours when in the presence of sufficient water-vapor.

But in the crude sulphur obtained on the market there is a percentage of impurity and in burning sulphur some trioxide is formed which gives the foggy appearance always present. In addition, some of the sulphur is sublimed. Consequently, it is the custom to use 5 pounds of crude sulphur for each 1,000 cubic feet of space in the attempt to secure a concentration of 4.47 per cent., especially as the effort is also opposed by some leakage in spite of care in securing closure.

The minimum time exposure is 16 hours with extension to 24 hours when practicable. But when the disinfection is directed against insects, one hour is quite sufficient for mosquitoes and two hours for rats. As mosquitoes are killed by the gas in low concentration, the burning of a smaller amount of sulphur will also be found sufficient—about 2 pounds per 1,000 cubic feet in a *well-closed space.*

Sulphur dioxide is a much heavier gas than carbon dioxide, being more than twice the weight of air, and therefore during the combustion of sulphur the gas tends to settle upon the flame and end the oxidation. As the weight is opposed to distribution and tends to stop the combustion, it is important not to attempt to burn too much sulphur in any one part of a compartment. As a rule, not more than 25 pounds of sulphur should be in any one pot, and if practicable the combustion should occur above the deck level so as to be as little as possible under the smothering influence of the heavy gas. But as the gas comes off at a high temperature, and the source remains at a high temperature so long as the combustion continues, the location of the pot at the deck or floor level does not prevent a large percentage of the sulphur from being burned on a ship in view of the small distance between decks.

It is not always safe to have sulphur burning in a pot placed on a table, and on a vessel of war it should not be so placed unless stability can be assured. The danger of fire should always be in mind, and thus the receptacle containing the sulphur should always be within another receptacle, such as a tub, containing water. The water should come well up on the sides of the metal receptacle containing the sulphur, but such an arrangement is important not only for safety, *but also because it is the means of supplying water-vapor*, the burning sulphur furnishing the heat by which not a little of the water is evaporated. If a thousand cubic feet of air is at 80° F. and is considered to have the low relative humidity of 25, it would furnish 2.745 grains of water-vapor per cubic foot, or 2,745 grains in all. The four pounds of sulphur burned require 15,750 grains or about 13,000 grains more than the air contains. Therefore, theoretically, about a quart of water evaporated by each four pounds of sulphur would be sufficient and that can be accomplished in the pot method.

In practice it is found that better results are obtained by an evaporation exceeding one quart of water for each four pounds of sulphur burned The direct chemical union of SO_2 with water is more or less questionable. When the gas is brought into actual contact with water it is true that an acid liquid is a result, but the actual amount of the gas taken up by the water depends greatly upon the temperature and the total result is in some respects suggestive of a solution of the gas rather than a true chemical union with the water. At any rate in disinfection with sulphur dioxide the best results are obtained against micro-organisms when there is a *liberal supply of water in the form of vapor.* The great advantage of the pot method is that it furnishes water-vapor, but inasmuch as the compartment is to remain closed for at least 16 hours, a deck or floor wiped over with a swab wet with a disinfecting solution, is an advantage. *Much* water seals cracks and prevents penetration. Sulphur dioxide condenses into a liquid at 0° F. and, although it is effective at much lower temperatures than in the case of formaldehyde, a warm contained air increases its activity.

The pot method is the one generally available on a ship, and it is an efficient method. If the sulphur is in the form of sticks or rolls it must be crushed into small bits or better into a powder. The powdered sulphur is then placed in a metal container, but not in amount to entirely fill it. The container should not only never be heaping full, but not even quite to the level, and there should be a decided concavity or crater at the center. The number of such metal containers required will depend upon their size and the size of the space to be disinfected, but not more than 5,000 cubic feet should be on one pot or pan and the pots should be distributed uniformly about the space. Each is then put in a tub of water and securely placed upon its feet, if an ordinary iron pot or Dutch oven, or upon bricks or well submerged blocks that the water may be under and well up on the sides.

The containers being distributed and together holding 5 pounds of sulphur per 1,000 cubic feet, the sulphur in each is ignited in turn, beginning with the one at the greatest distance from the exit. It is rather difficult to ignite sulphur directly, and therefore it is always best to use alcohol, pouring a liberal amount of it into each crater just before the light is applied. The method is easy, sulphur is cheap and the result is satisfactory from the point of view of gaseous disinfection. But in view of injury to paintwork, exposed metals (which should be covered with vaseline), clothing and stores of various kinds, its use is now generally restricted to destruction of infected mosquitoes and rats when formaldehyde is available in connection with the ordinary epidemics in which generally only living compartments and clothing are concerned in gaseous disinfection.

In relation to the ordinary epidemics, a ship is very rarely infected throughout. If isolation has been the rule, it is ordinarily sufficient to confine the gaseous disinfection to living compartments that can be closed and, as in that disinfection much clothing may be profitably included, formaldehyde should be employed. It is not always easy to determine the area of infection, and it is best to include doubtful areas. But a medical officer living on board can form a good idea of the necessities and, for instance, would not be inclined to disinfect officers' quarters or storerooms because a case of scarlet fever or small-pox had occurred among the crew.

Gaseous disinfection should not be regarded very strongly from the point of view of disinfection of *air*. In any ordinary degree of ventilation, the air in a ship's space is changed several times an hour. It seems much more probable that the good results from gaseous disinfection, when vermin are not concerned, are really due to the disinfection of surfaces, dust, and contents, such as clothing—material that retains micro-organisms. Hence, while there can be no disinfection unless there is infection, disinfectants are often used on a naval vessel in a precautionary way, and a gaseous disinfectant such as formaldehyde is a convenient means of treating large questionable spaces and their contents. Under ordinary circumstances, the clothing included if well spread out during the fumigation does not require additional treatment other than exposure to air on the ship's clothes lines. It is not soiled clothing, as a rule, and is not the clothing of the sick.

But in view of the relation of dust to the spread of disease, it is always best after gaseous disinfection to use chemical solutions on the surfaces of the space itself. These solutions should not be confined to paintwork, but should be applied to the deck *after careful examination of the linoleum*. Any bulge in the linoleum as a sign of a pocket under it, should lead to the removal of suspected area. The presence of such pockets at the time disinfection is undertaken should have been avoided by a careful weekly routine inspection of the linoleum. It is of more importance on a crowded ship than elsewhere to have a routine of the ship opposed to infection by opposition to accumulations of dust or retention of excretions. Dust or dirt in sight is often not as dangerous as dust or dirt that is concealed. Linoleum is intended to be *attached* to the deck and to have an unbroken surface. When it is not in that condition, it is a receptacle for filth, and therefore a menace.

Thus, when a ship's space that can be closed is undergoing gaseous disinfection, arrangements should be made for the use of solutions or chemical disinfections when the space is opened. There are, however, parts of a ship above the berth deck where sufficient closure may not be obtained for the application of a gaseous disinfectant. The degree of closure that can be obtained may, however, be quite sufficient for the destruction of mosquitoes, but in all such cases an excess of sulphur will have to be used to make up for the loss by leakage. When micro-organisms and not insects are directly in question, the clothing from spaces not susceptible of proper closure can be disinfected in the spaces that are, and the spaces themselves can be treated with chemical solutions. Therefore, while some spaces are closed for gaseous disinfection, others can be undergoing disinfection with liquids. And then when the closed spaces have been opened, the chemical disinfection can be extended to them.

The thorough opening of a space containing formaldehyde or sulphur dioxide is not always readily accomplished in view of the irritating qualities of those gases. When the door has been opened, the object is to get an air port opened so soon as practicable, break the paper over a louver in a supply system, and, closing the door, to have the ventilating blower started that the gas may reach the outside air without permeating the ship. To open the air port is often quite troublesome, as two hands are required and some little time. A cloth wet with solution of bicarbonate of soda should be tied over the mouth and nose and, taking a long breath, a rush made for the nearest port. Several attempts may have to be made. The best disposition of the gas is to have it leave the compartment by ventilation.

Ammonia has been used frequently to neutralize formaldehyde. But some disinfectors believe, although it is not the common experience, that ammonia and formaldehyde form a monamide that is more persistent than formaldehyde and, as it also has odor, only prolongs the objectionable evidence of disinfection.

As the pot method of fumigating with sulphur dioxide is the only one generally available on our ships away from a quarantine station, other methods are not considered here. In the case of plague, the destruction of rats can be accomplished expeditiously and satisfactorily only at a quarantine station, where the sulphur furnace is available. If practicable, every ship should be at a properly equipped quarantine station under such circumstances. As sulphur dioxide can be readily liquefied, it is also available in the market in that state, being supplied in tin cylinders.

The method is relatively expensive, but has the advantage of liberating the gas *rapidly* and without fire. As it takes four pounds of sulphur to produce eight pounds of sulphur dioxide, the liquid gas employed should be twice the weight of the sulphur that would be required. And as the method does not supply moisture, liberal provision has to be made in that direction. There are manifest disadvantages relating to storage that militate against this method in relation to naval vessels.

Pyrethrum can be burned in confined spaces for the destruction of mosquitoes. Five pounds for each 1,000 cubic feet are usually employed. However, by this method some of the mosquitoes are only stupefied and consequently they have to be carefully swept together and destroyed. As this method is not altogether trustworthy, it cannot be considered as capable of displacing sulphur dioxide.

During the yellow fever epidemic in New Orleans (1905) successful trials were made against mosquitoes in closed spaces by vaporization of campho-phenique. This liquid formed by mixing carbolic acid and camphor has been employed in a limited way for years as a disinfectant, especially by dentists, two parts of camphor being mixed with one part of carbolic acid. Whatever the chemical reaction, the resulting liquid has little corrosive action upon the body tissues. Mim's culicide is composed of equal parts of camphor and carbolic acid. From 4 to 6 ounces are used for each 1,000 cubic feet and put in an evaporating dish over a *low* alcohol flame. The result is a cloud of vapor that is said to destroy mosquitoes without injury to fabrics or colors. If too much heat is employed, the campho-phenique takes fire. There has been very little or no experience with this method in the naval service, and it does not seem likely that it will be much employed on ships in view of the tendency of the vapor to affect persons. It is said that smoky urine has resulted from exposure to the fumes, and, therefore, it cannot be said that the method would be satisfactory on ships, neither is it clear that all the mosquitoes are invariably killed.

Camphor may, however, be used profitably at times in another mixture. Spirits of camphor (2 parts), oil of citronella (2 parts), and cedar oil (1 part) can be used with considerable success in keeping mosquitoes away from a bed, though of course it cannot be relied upon to displace screening, especially in a case of yellow fever. However, a few drops of the mixture on a cloth about the head of a bed will have a marked effect for a considerable time in deterring mosquitoes from approaching.

In addition to solutions of formalin, the chemical substances employed in solution as disinfectants are bichloride of mercury, carbolic acid, chlorinated lime, and lime. In the disinfection of ships' spaces with solutions, bichloride of mercury 1–1000 is employed almost exclusively.

The same solution in one-half strength (1–2000) can be used very generally in the disinfection of clothing known to be infected, *provided it is completely immersed for two hours.* However, if the clothing is stained with blood or fæces, the stains are set by either bichloride solution or hot water. In those cases a formalin solution is satisfactory.

Corrosive sublimate occurs in lustrous colorless masses having a crystalline fracture. It fuses at 288° C. to a colorless liquid and is soluble in 16 parts of cold water, but unless the masses are pulverized, the solution is effected in any amount of cold water much too slowly. It dissolves more rapidly when powdered, and especially if hot water is used, but of course if then in greater strength than 1 : 16 some will be deposited on cooling.

The facts that the bichloride dissolves more readily in an aqueous solution of ammonium chloride and that the soluble double chloride ($HgCl_2.2NH_4Cl.H_2O$) formed makes a solution little subject to change, and with preservation of disinfecting qualities, have led to the common use of the ammonium salt in making the solution. Such a combination is effective against the bed-bug, although the simple solution of the bichloride has little value and it is thought to somewhat diminish the great objection to the bichloride of mercury as a disinfectant, which is its tendency to form compounds with any albuminous matter—a disadvantage that limits its use and unfits it for the disinfection of fæcal matter in masses such as stools.

One gallon is equal to 3.7852 liters, and therefore 3.7852 grams or 58.4 grains of the bichloride in sufficient water to make a gallon is a 1 : 1000 solution. In practice 1 drachm each of corrosive sublimate and ammonium chloride in a gallon of water make a solution suitable for wetting the deck and paintwork of a compartment. As these solutions are made in wooden buckets at the dispensary, the bichloride can always be powered, warm or hot water employed, and *care taken to see that solution is complete.* Sea water has been extensively used at quarantine stations for making bichloride solutions, but there is some reason for thinking that chloride of sodium as well as hydrochloric acid lessen somewhat the power of the solution. Bichloride solutions attack metals, and therefore exposed metals should not be washed with them.

No solution is effective unless brought into contact with the material to be disinfected, whether dust, clothing, or fæces, and kept in contact for the time determined by laboratory experimentation with reference to the strength of the solution.

On a naval vessel any number of men desired can be obtained for the work of disinfection, and it is customary to apply the solution of bichloride to surfaces by means of swabs, as many deck buckets as may be required containing the solution. With a considerable number of men and good supervision it takes only a short time to go over the interior surface of one or more compartments or an entire gun deck. As owing to evaporation the contact is necessarily short, warm solutions are more effective just as in many other chemical reactions, the reaction of a disinfectant upon protoplasmic cells being chemical in its nature. When swabs are properly used, the result is at least as good as when the solution is applied by use of pump and hose. However, the hose is advantageous because a smaller number of persons are required to do the work, and thus the chance of infection during the work is diminished. *Fumigation prior to the use of solution is also of great value from the same point of view.*

Some advantages may also be gained by selection of the working force with reference to the characteristics of the disease in question. Diphtheria and scarlet fever are most apt to attack *minors* and *young adults;* small-pox, those who have not been successfully vaccinated; and measles, mumps, and scarlet fever, those who have never had the disease. Against yellow fever, chemical solutions are of no value when applied to paintwork and decks, but the direct work against that disease is incomplete when confined to fumigation with sulphur dioxide, for it is essential to eliminate all the breeding places of mosquitoes, such as water in trimming tanks and in division tubs.

When the bichloride solution is applied with deck swabs, it is best to wet the deck first, the working force being in rubber boots, as the chances are that a larger percentage of the objectionable material is in that locality and by that course the dust is laid. Deck swabs can be used to thoroughly spread the solution so that no part may escape. That having been accomplished, it is advisable to next apply the solution to the surfaces overhead, beginning at one end of the compartment and working down on the sides, the work being so apportioned and supervised that *no part* can be overlooked. Every washer should be made to thoroughly understand that the object is to *spread* the solution over the entire surface, and into every corner, crack, and crevice, and that no dust on any ledge must escape a thorough wetting, but that where dust is in large quantity, it must be saturated with the solution before any attempt is made to disturb it by wiping.

It should be appreciated by the supervisor that the use of chemical solutions in disinfection of ships' compartments is not a mere additional process under the assumption that gaseous disinfection is the essential method because when practicable it is made the primary one. Not a few authorities dispute the claim made for gaseous disinfectants that they are efficacious in sterilizing dust, and regard sulphur dioxide and formaldehyde as little more than surface disinfectants when used in fumigation. Such disinfectors pay little attention to gaseous disinfection and make their attack directly by the use of chemical solutions.

There is no doubt that a gas is the ideal disinfectant, but the ideal gas is yet to be found. However, sulphur dioxide and formaldehyde, when warm and in the presence of a liberal supply of water-vapor, have somewhat greater power to penetrate than has been commonly allotted to them, and on the other hand it is difficult to be certain that a chemical solution has been brought into contact with every particle of dust or having been brought into contact that it will remain in contact a sufficient length of time to cause destruction of the micro-organisms the dust contains. Nevertheless, even in spaces that cannot be closed for fumigation, satisfactory results can usually be obtained provided the chemical solution is thoroughly applied in sufficient quantity, *the deck after its preliminary wetting being again wet* when all other surfaces have been disinfected.

The main point is that chemical solutions should be more frequently utilized on ships in general disinfection as they should not be regarded lightly merely because a space cannot be closed for fumigation. The process can be generally carried out and repeated with little discomfort to the crew as a whole, and much good can be accomplished under circumstances when repeated fumigations of large spaces would be impracticable, as in follicular tonsillitis or even measles and mumps, when fumigation after the appearance and segregation of each case would probably not prevent other cases and would cause much discomfort on a crowded ship. Wiping surfaces with the disinfecting solution, an even more rigid routine in relation to sputa, careful inspection and treatment of linoleum, more care of mess gear, immersion of drinking cup in formaldehyde solution, and airing and sunning of clothing and bedding are all measures tending to secure dilution of the poison by at least partial destruction.

Solutions of chlorinated lime, of carbolic acid, and of lime are of value chiefly on ships in the disinfection of excreta. In the disinfection of stools a 4 per cent. solution of chlorinated lime is the most valuable in practice if the lime has been kept well-stored in dark amber bottles or well-closed crocks, though a 5 per cent. solution of pure carbolic acid, a 1 per cent. solution of crude carbolic acid or a 4 per cent. solution of formalin is efficient. About 155 grams, or 5 ounces apothecaries' weight, or 6 ounces avoirdupois, of chlorinated lime well stirred in a gallon of water may be considered a 4 per cent. solution, though as a matter of fact most of it remains undissolved.

Chlorinated lime is made by passing chlorine gas over moist slaked lime. Its formula is generally written $CaCl.OCl$, and when mixed with water calcium hypochlorite and calcium chloride are formed: $2\ CaCl(OCl) = CaCl_2 + Ca(OCl)_2$. If an acid be added chlorine is liberated, and the best chlorinated lime should have 37 per cent. of available chlorine. Carbon dioxide causes a slow evolution of hypochlorous acid which has even more power as a disinfectant than chlorine as it is very unstable. The different changes making for the activity of the disinfectant may not be thoroughly comprehended, but chlorine is the chief agent ultimately and in practice its principal disadvantage is tendency to lose strength during storage. It is liable to decomposition into calcium chloride and oxygen ($CaOCl_2 = CaCl_2 + O$), and by the gas thus evolved may even break bottles. It may split into calcium chloride and calcium chlorate.

In good condition it should be a white powder having a peculiar odor not quite like that of chlorine. When converted into calcium chloride, it attracts moisture and deliquesces. If in good condition it is thoroughly reliable as a disinfectant, and is specially applicable to stools and the disinfection of sputa deposited in spit cup. Its solution may also be used at place of isolation for disinfection by submergence of mess gear, and a 1 per cent. solution is suitable for disinfecting hands of nurses. It should not be used for the disinfection of clothing. It is really a bleaching powder and is also destructive if clothing is kept submerged in the solution for a long period. White material, such as soiled bed linen, can be immersed in a 1/2 per cent. cold solution for perhaps an hour, and then thoroughly soaked in fresh water, but a solution of formalin is applicable to all clothing soiled by discharges and is more satisfactory, or a cold 3 per cent. solution of carbolic acid in which some soap may be dissolved. Soiled clothing left to soak in such solutions for two hours and then rinsed in clean water may be considered safe. In disinfecting a stool, the amount of 4 per cent. solution of chlorinated lime employed should be a volume at least as great as that of the material to be disinfected and the time of exposure an hour.

A solution of chlorinated lime can also be used very profitably in and about urinals, and the troughs of ships' heads. Chlorinated lime is not only a good disinfectant, but also a good deodorant, as chlorine attacks hydrogen compounds, including ammonia and the ammonium compounds, sulphureted hydrogen and the various gaseous compounds of carbon and hydrogen.

Quantities of disinfectants can be expended on water-closets. The tendency is to either utilize them as deodorants or to substitute one odor for another. Crude carbolic acid has been extensively used for this purpose, but a solution acts only by contact, and the odor about a water-closet often comes from using the water-closet bowl as a urinal instead of using the urinal provided. The odor of stale or decomposed urine is very often beyond the action of deodorants poured into the water-closet bowl, as the offending material is on the deck or on the rim of the bowl or on the undersurface of the hinged wooden seat, which has become contaminated when lowered. An officer's water-closet that requires the use of deodorants is faulty in design, or is not utilized with sufficient care, or is utilized as a urinal, a purpose for which it is not intended.

At all urinals and in the water-closet troughs the conditions are different. At urinals there are deposits of urine outside the flushed area, and drippings upon the deck below where there should be a depression provided with an unbroken covering of metal or, better, of concrete. In troughs there are accumulations either due to faulty shape, roughness of interior surface, or splashing. In every ship's head there are very many pounds of urine and fæces deposited daily, and so far no construction has been devised that avoids a certain degree of concentration of odor, especially in the tropics or warm weather. This subject has received more or less attention elsewhere in this work and consideration has also been given to the experiments in the French navy in the use of electrolyzed sea water for flushing. At present in our service the odor from heads and urinals may become a disagreeable factor in ship life, especially in the tropics.

With the means at hand, the proper use of the solution of chlorinated lime seems to give better result than any other. If the flushing of urinals be stopped for a very short time twice daily, and the solution of chlorinated lime contained in a bucket be applied on a deck swab, used solely for that purpose, to all the surfaces, including the metal or concrete surfaces below, and then in a few minutes water be used to remove the solution, there will be practically no odor at individual urinals when the flushing has started and relatively little in the trough urinals. The same method has been employed with good effect in relation to trough water-closets. Chlorinated lime should not be employed as a powder in or about urinals, as it leads to disagreeable conditions under foot and tends to clog pipes. Chlorine attacks metals, and chlorinated lime should not be used in quantity in urinals or heads, but if employed in the manner indicated, the effect upon pipes will be too slight to be considered.

Lime (CaO) or quicklime is generally employed as the hydroxide in the form of milk of lime or as whitewash. When good lime is sprinkled with water a very energetic chemical change ensues, as the calcium hydrate ($Ca(OH)_2$) or slaked lime is formed. Much heat is evolved, the bulk increases 2 1/2 times, and the calcium hydrate appears as a light white powder. A lime that slakes feebly is a poor lime. Air-slaked lime has lost very much of its power by combining with CO_2. In this process water is also absorbed and about 57 per cent. becomes $CaCO_3$ and 43 per cent. $Ca(OH)_2$. A poor lime contains considerable quantities of silica and alumina, and an overburnt lime contains masses of silicate of lime. Poor lime and air-slaked lime are not rare, and they are of comparatively little value in disinfection.

Slaked lime or calcium hydrate or calcium hydroxide is more soluble in cold water than in hot, though little soluble in either, as 700 parts of cold water are required. Milk of lime is slaked lime mixed with about four times its volume of water. It has the appearance of cream and is useful in the disinfection of stools. It takes about 60 parts of water by weight to slake 100 parts of good lime. If, then, one part of the powder resulting be mixed with eight parts by weight of water, a cheap and reliable disinfectant is obtained if used on stools in volume equal to that of the material to be disinfected and an exposure of two hours be allowed. It should be recognized, however, that air-slaked lime is worthless, that the hydroxide obtained from good lime undergoes change when exposed to air, and that therefore freshly slaked lime and milk of lime made at most within a day or two are required for good results.

The same is true of whitewash, which is valuable in relation to typhoid fever and cholera, and is therefore advantageously applied as a routine to the interior of water tanks after cleaning. Whitewash can also be used on old casks or barrels when holds are broken out. It not only produces the appearance of cleanliness, but is actually valuable as a disinfectant when carefully applied to surfaces that, as in breaking out holds, are only occasionally exposed.

In the latrine of a camp either the lime itself or the milk of lime can be profitably employed. For both urine and fæces about an ounce of lime or the equivalent as milk of lime, per day per man is not excessive.

However, in dealing with fæces and urine, whether on board ship or ashore, protection from flies is of prime importance. Fæces of the sick should be received in a receptacle containing some of the disinfectant employed, and then additional amounts used. The receptacle should then be covered to avoid flies. At sea there are few flies within the ship and there is also no danger then from infected excreta when it is overboard, but there are reasons at the bedside why even under those circumstances discharges should be received in disinfecting solutions and at the sick-bay water-closet, why they should be carefully deposited and the water-closet at once thoroughly flushed.

A sick-bay water-closet should never be allowed to remain out of order, and when it is not in perfect order there is every reason even at sea why infected discharges should be disinfected. The deck about the water-closet of a sick-bay and the seat demand much attention at all times, and with an infectious case, say typhoid fever, in that locality, the bichloride solution should be used from time to time, as also on the deck about the cot or in the neighborhood of the patient. However, an isolation ward is the proper place for all such cases, but every precaution is called for even there and especially in port where there is swimming, washing ship's sides and decks, or proximity to other vessels.

It is a safe rule to disinfect discharges under any circumstances, whether they be fæces, urine, or sputa, and to regard all sputa deposited in spit cups as infected. In a receptacle on hand to receive the fæces or urine of an infected case some of the chemical solution should be kept, whether it be a urinal, bed pan, or a closed stool, and the sputa of the sick should always be deposited in a solution such as chlorinated lime, and the spit cups subjected to heat, such as that from boiling water, at stated times that the sputum may have no chance to dry on any part of it. Lime should not be put into water-closets, as it tends to cause clogging.

Carbolic acid is utilized from time to time as a disinfectant. It is available both in crude and pure form. The former can be used in 1 per cent. solution to disinfect stools if an equal amount be employed, and has been used within water-closet bowls, but it tends to stain clothing. The pure acid in 5 per cent. solution is applicable to clothing soiled by discharges of the sick. It is much inferior to the crude acid in the disinfection of stools, but may be considered suitable for that purpose. If employed to disinfect clothing, at least an hour's exposure is customary. It cannot be depended upon to destroy spores within a reasonable time and in disinfecting paintwork, the odor, effect on hands during prolonged contact, and the chance of splashing into the eyes have caused it to be rarely employed. It does not injure clothing, wood, or metals. About 6 1/2 ounces to a gallon of water makes a 5 per cent. solution. It is not readily soluble and requires time and thorough mixing. It has been commonly considered a trustworthy disinfectant except against spore-bearing organisms.

In disinfecting clothing with any chemical solution submersion is always necessary and considerable time. Clothing may remain in a disinfecting solution for some time without becoming wet in all its parts, and simply dipping clothing into a solution is of little value. The difficulty in thoroughly wetting a fabric is found where the attempt is made to wet lint without submerging it and without repeatedly wringing out the liquid and resubmerging it. In disinfecting clothing it must be thoroughly wet and left submerged for the prescribed time. If the clothing is not soiled the hotter the solution the better.

Commercial sulphate of iron has long occupied a place on the supply table of the Navy as a disinfectant, but laboratory experiments show that it has little value as such. It has some power as a deodorant, but is untrustworthy as a disinfectant. It is a ferrous sulphate and has a strong tendency to absorb oxygen by conversion into ferric sulphate. It dissolves readily in twice its weight of water. It can be used in 5 to 10 per cent. solutions and has been frequently employed in the bilges of ships.

Potassium permanganate is rarely utilized in connection with disinfection on a naval vessel, except for the liberation of formaldehyde from formalin. Its use in relation to purification of water has been already considered, but on a naval vessel its employment for that purpose or in relation to the interior surfaces of water tanks would be most exceptional in view of arrangements at hand by which infected water can be boiled *in situ* by steam passing into it through a steam hose.

As has been stated, the chief physical agent in disinfection is heat. The power of heat to disinfect is certainly beyond question, but the problem ordinarily is to apply this agent without injury to the material to be disinfected. There is no greater purifier than fire, but combustion is at the expense of the thing consumed, and destruction should be strictly confined to articles of little value or to articles that under the immediate circumstances cannot be disinfected in any other way. Whether property be destroyed by fire, ruined by unsuitable liquid or gaseous disinfection or excessive heat, or sunk at sea, the result to the owner is loss that in view of other methods available is seldom justified.

It is important to select the disinfectant not only in relation to the character and location of the infection, but also to the integrity of the material to be disinfected. It is true that in the naval service the entire loss does not fall upon the owner, as there is provision by which reimbursement is ultimately made for the actual value (not the original cost) of personal effects destroyed to prevent the spread of disease. But considerable time passes before reimbursement can be made, the actual value to the owner is often the original cost, and, as no issue can be made in lieu of effects so destroyed, an enlisted man can be greatly embarrassed in his financial relations to the ship by the destruction of his clothing.

The question of complete loss in this relation may be considered on the ship to apply almost solely to mattresses and pillows utilized in connection with the epidemic diseases. It is undoubtedly true that a mattress or pillow used by the sick cannot be regarded as safe merely because it has been subjected to fumigation. Such bedding comes into very intimate contact and becomes deeply infected. To disinfect it requires much greater penetration than can be secured by the use of gases or is ordinarily practicable by means of chemical solutions.

Steam seems to be the only agent that can be trusted to accomplish the desired result, but ordinarily on our ships special means have not been provided up to this time for its application in such cases, though repeatedly apparatus for that purpose has been improvised and of late there has been some tendency toward the installation of a suitable steam chamber. The opposition to such an installation is entirely in relation to space and location on a ship of war, crowded with men and with other appliances, but at least in one ship the difficulty has been partially overcome, and there are indications that such installations will be common.

The supply of steam on a modern ship is practically limitless and it is noteworthy that an agent of such value in disinfection has had only a very limited direct application in the destruction of micro-organisms inimical to the well-being of a navy's personnel. Barrels have been set up with suitable connections and utilized to disinfect with streaming steam the clothing, mattress and hammock of individual cases, but not infrequently when a case of the epidemic diseases has been treated out on the ship, in the absence of opportunity for transfer, or in some tent on shore, the mattress has either been weighted and thrown overboard at sea or has been wrapped in a sheet wet with bichloride solution to secure transportation without danger and burned in ship's furnace or when on shore destroyed by fire in the ordinary way.

An enlisted man's mattress is made of hair and is quite thin in order to fit it for use in a ship's hammock and to facilitate lashing and stowing. Its usual value is about three dollars. As having a practical bearing upon this question of loss in individual cases, it may be observed that a ship's mattress being quite thin can be carried very conveniently under the medical department mattresses in the bunks of sick-bays. If a few are acquired from time to time as deserters' effects are sold at public auction at the mast, they can be very conveniently utilized in a number of ways in a medical department. The regulations require a survey to be ordered when it becomes necessary to destroy clothing or other personal effects of officers or men to prevent the spread of disease. The report contains a list of the articles and the actual value of each. The approved report goes to the Navy Department and, if there approved, reimbursement is made by certificate from the Treasury Department.

In disinfection heat is applied as hot dry or moist air, or as boiling water, or as steam. Hot dry air is not only inefficient when much penetration is required, but its temperature is difficult to control and, unless well controlled, is destructive to fabrics. A mattress even when exposed for a long time to a dry-air temperature of 220° F. is not penetrated throughout by the heat, and woolen clothing tends to scorch at about 230° F. A dry-air temperature of 220° F. will destroy spores in four hours, and at 300° F. and an hour's exposure, sterilization is accomplished. Such degrees of heat are applicable to crockery, but dry air even at the lower temperature is too eager for water not to endanger the integrity of fabrics, tending to make them brittle, at least until they have been allowed to acquire water again. Moist heat is much less destructive, is efficient at lower temperature, and has greater penetrating power. It may be considered to have displaced dry heat in disinfection. Steam at 212° F. or boiling water will accomplish in a few minutes a disinfection that might require hours if dry heat were employed.

Boiling is an important method of disinfection so generally available as to be often unappreciated. Boiling water should be frequently utilized each day in sick-bays, as a matter of routine, and heat either as boiling water or as steam has important application in relation to the work of the barber on a ship in preventing the spread of parasitic disease.

An exposure of half an hour in boiling water will disinfect. The fact that certain spores are known to resist for a longer period is not of practical importance, as a rule. Ordinarily anthrax and tetanus are not in question, and should they be in question, the exposure can be prolonged to two hours. It is important to realize that boiling water almost immediately destroys the micro-organisms of all the usual diseases, such as diphtheria, typhoid fever, erysipelas, pneumonia, and tuberculosis.

All cotton fabrics, whether body-clothing or bed-clothing, can be completely disinfected in this way without injury, provided they are not stained with blood, pus, or other albuminous material. In that case and in the case of woolen clothing that may have been in contact with the sick a formaldehyde solution can be employed. Yet even under those circumstances, if suitable chemical solutions are not available, boiling water can often be utilized to advantage on the ship. Even a boiling temperature is not necessary, as in laboratory experiments water at or a little above 160° F. if continued uninterruptedly for a half-hour kills the usual pathogenic germs. The addition of one of the chemical solutions under those circumstances will in that time secure a result beyond question.

Spit cups in use should contain a disinfecting solution (usually chlorinated lime solution). When, in cleaning, boiling water is added the action of the solution is greatly increased, and if subsequently the cup be immersed for a short time in boiling water, the disinfection may be considered complete. Some such course should be the routine at stated times daily.

At least two tongue depressors should be kept in the sick-bay in a wide-mouth bottle of 5 per cent. carbolic acid solution with only the handles protruding. When one is taken from the bottle for use, the surplus solution should be shaken off, and after use the depressor should be held for a minute under running hot water before it is returned to the solution. Thermometers should be kept in a similar solution, the surplus shaken off each before use, and after use *mechanically* cleaned and returned to the solution before it is again used, another thermometer from the solution being next employed.

In the absence of appliances for using steam, the clothes of the itch case should be immersed in *boiling water*, other clothing, recently washed, being donned after the application of sulphur ointment. It is as much in relation to scabies as to other diseases that the argument for a steam chamber on the ship has been advanced. The desire is to have means provided on the ship for the immediate sterilization at one operation of practically all the effects, including the mattress, of individual cases. This is readily accomplished at hospitals on transfer, but cases of scabies are not uncommonly treated out on the ship.

In view of the fact that each mattress has its mattress cover, the association of the itch-mite with the mattress is somewhat presumptive. If, when the case is placed under treatment, the *mattress cover* and blanket be subjected, with the clothing then worn, to boiling water, it has not appeared that the mattress itself has ordinarily been a factor in extension of the disease. The itch-mite is not one that being in proximity to the body visits it occasionally for food as in the case of the bed-bug which breeds in beds, on the ticking of mattresses, and in the cracks, crevices, and joints of woodwork, but it makes the integument of man its home and is not seeking to leave the food, warmth, and breeding places man affords for locations under the mattress cover.

Each enlisted man has two mattress covers and, while the *Sarcoptes* may very well be found upon surfaces that have been in contact with the victim, it appears from experience that a careful change of mattress covers and treatment of the removed cover with boiling water is very apt to leave the mattress unobjectionable. An important point in these cases is to have the same underclothing worn for several days after the treatment has been commenced, and to render innocuous the clothing worn at the time the nature of the case was determined.

In relation to the extension of parasitic and other communicable diseases on the ship, the work of the barber has received more or less attention in another chapter, but there is some reason for thinking that not uncommonly the sanitary requirements in that direction are not given the consideration their importance deserves. In the barber's chair and from the deck in that neighborhood excretions of a crew may be readily and rapidly transferred from person to person. The frequency of harmful transference may be easily overrated, but that such transference is more frequent than is commonly supposed is very probable.

In that connection, the barber himself may be a prominent factor as well as his apparatus or implements, and even the hair clippings that tend in some measure to become disseminated about the ship.

The barber's work is a part of a ship's routine and should be regularly provided for in a ship's construction, especially on the larger ships. A certain part of a ship should be regularly designated for the purpose and provided not only with a stationary basin supplied with hot and cold fresh water, but also a small electric sterilizer from which a shaving cup and brush can be taken as required for each customer and in which cups and brushes previously employed can be sterilized. The rubber-set shaving brush can stand boiling water without injury, and with the various shaving soap-creams or in other ways a small but fresh supply of soap can be employed with each customer. A razor blade is not apt to be a vehicle, but if dipped for a very short time into boiling water very probably becomes incapable of transferring disease.

The point is to have the necessary sanitary appliances in the most convenient form and then to establish a *routine* in regard to them. A barber cannot be consistently required to wash his hands before doing work for the next customer unless suitable provision is made for that purpose, or to dip his razor blade into boiling water before beginning the shave or to keep razors in a formaldehyde solution during the working period unless there is suitable provision for that purpose, or to do the same with his clipper and scissors before cutting hair, unless it can be rapidly done. The work of a barber is very strenuous for some hours before the departure of a large liberty party, and such precautions as he is required to take should constitute a convenient and rapid routine.

There should be a receptacle for clean towels and another for soiled towels, and it should be recognized that each customer is entitled to a clean dry towel. *A damp towel has often been the means of spreading disease.* Tissue paper, renewed for each customer, should cover the head rest of chair, and combs and brushes should be disinfected *at least* once each day. Each man on a ship has his own brush and there is no necessity for *brushing* hair in a ship's barber chair. However, a *good brush* or a metal comb can be disinfected in the sterilizer, but a 4 per cent. solution of formalin is also applicable.

Alcohol for obvious reasons should not be available for disinfection in this connection, and it is best for a barber to avoid carbolic acid solutions in connection with his work. Poisonous solutions should not be in continuous evidence on a ship. Heat in the form of boiling water or steam can be made to answer every purpose, though a formalin solution may be made conveniently applicable to razors and brushes.

In a barber's work cleanliness should always be apparent. Hair clippings should not be allowed to accumulate on the deck and it is even more important to have the deck kept free from sputa. No one should be permitted to use tobacco while in the chair, and a barber should be responsible for the cleanliness of the deck in his locality during the entire period of work. A recognition of this responsibility and that hot water is made available not simply to make a shave easier, but also to prevent the transference of material from person to person will go far to eliminate danger.

Each barber should also be made to recognize his responsibility in relation to the individual case presenting abnormalities of scalp or face. A barber has some knowledge of barber's itch, of parasites, and of diseased scalps. In even doubtful cases he should be required to refer individuals to the medical officer, and at any time he may be required to do work in cases of ringworm or other skin affections, the obvious special precautions should be taken. And, certainly of as much importance is the absence of communicable disease in the barber himself. Conversations with spraying of mouth secretions are not so very uncommon at the barber's chair. The barber should be under sufficient supervision to be known to be free from communicable disease of any kind, and he should recognize that he is also required to directly aid in the prevention of the dissemination of disease.

Steam like every other disinfectant has its disadvantages as well as advantages and not a little clothing has been injured by the operation of that agent. It is employed either as streaming steam or as steam under pressure. Streaming steam has generally about the same power in disinfection as boiling water, and thus requires about the same time (one-half hour) to accomplish its result. But as ordinarily there is considerable loss of heat in heating the apparatus itself and, more or less interference by contained air, it is the custom to make the time exposure one hour.

In this case, while there must be a container for the articles to be disinfected, and for the steam, it is not tight for there must be a steam escape in order that the steam may be streaming or in motion through the container. But unless special apparatus is used, there is, as a rule, considerable condensation, and the articles are more or less permeated with water and while thoroughly disinfected at 212° F. a mattress requires considerable time in which to dry and woolens are more or less shrunken. The mattress is not injured, but is simply unfit for use on account of its wet condition, and cotton fabrics are in about the same state as if they had been boiled, provided they have not been hurt by contact with rusting metal. Steam, however employed, ruins shoes as well as rain clothes and rubber boots usually.

The Arnold sterilizer is an example of an apparatus for the use of streaming steam on a small scale. Barrels have been used on ships from time to time in the application of this method, the steam which is lighter than air being admitted at the top of the barrel and the air or steam escape being at the bottom.

Trouble in the disinfection of woolen goods by steam has led to the formaldehyde attachment commonly found on most steam chambers. By using the steam in the jacket to syphon or discharge air from the chamber a considerable vacuum is produced within the chamber which has also been heated by the jacket steam. In that condition the chamber receives formaldehyde from formalin which, in view of loss of air by the contained articles, the temperature and high concentration of gas and the moisture admitted with it, penetrates much more deeply and acts more efficiently than in ordinary fumigation.

This method of formaldehyde in heated air of a partial vacuum has been used very successfully, as it is efficient without injury. It has been frequently employed for the disinfection of mattresses and pillows, but while with much concentration of the gas, all articles of clothing even the thickest, can be intrusted to the method and with them very possibly the thin mattress of an enlisted man, it may not be regarded as thoroughly dependable in the case of mattresses and pillows of much thickness used by the sick with epidemic disease, unless a short disinfection by steam be also employed.

But with well-devised apparatus steam can be employed with much satisfaction in disinfection. Its great power to penetrate and to sterilize has been recognized for a long time, but its extensive use was greatly delayed by difficulty in controlling its operation, tending to condense on material in amount to damage some varieties and to make subsequent drying of all necessary.

That it has marked penetrating power may be deduced from comparison of its physical properties with those of air, but in that comparison it is desirable to recognize that outside of questions of pressure or temperature all steam is not the same.

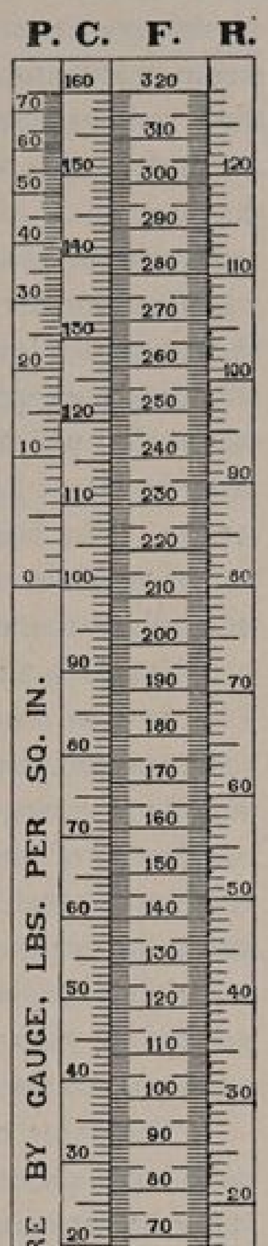
The difference is chiefly designated by applying the terms saturated and superheated. Saturated steam is at the temperature at which it can directly condense into water, while superheated steam has had its temperature raised above its condensing point. Steam is a physical state of water as truly as ice is, but as a gas it may be near or far away from its condensing or liquefying temperature. Ice may have any temperature, at or below the freezing-point of water, as after formation it acts as a solid in tending to acquire the temperature of surrounding objects. It may therefore be near to or far away from its melting-point. Steam may have any temperature, at or above the boiling-point of water, for as a gas or vapor it can acquire heat, tending to expand as its temperature increases and contract as its temperature is diminished, as in the case of air, but with varying coefficients.

Being vapor, steam tends to expand, and therefore, as in the case of sulphur dioxide or formaldehyde, if it is to be used in concentration, it must be confined. Thus, as it results from boiling water, the water must be within a container, but as the steam forms and is confined within the same container, such as a boiler, it remains in contact with the water or its source. All such steam is saturated, for if its temperature were lowered it would go back into the state of water. But so long as its temperature is not lowered, it may be considered dry. Saturated steam does not mean steam containing water, for all steam is a physical state of water. Saturated air contains the maximum amount of water for its temperature and consequently its actual temperature and dew point are practically the same. But saturated steam passes into water when its temperature is lowered, *leaving a vacuum in the space it occupied before condensation*, if air be excluded.

But saturated steam may also be at any temperature, and consequently its condensing point varies accordingly. This is apparent when it is recalled that steam is formed by boiling water and that the boiling-point of water varies with pressure. Water at the sea level boils at a higher temperature than water on the mountain because the atmospheric pressure is greater. As steam is formed within the boiler it exerts pressure upon the water, and as it goes on forming the pressure increases, and consequently the boiling-point rises. The steam remains saturated, but its temperature follows that of the water from which it is formed. Consequently, as its pressure increases, its temperature increases. As the water at the beginning of its ebullition is subjected to atmospheric pressure, the steam at the beginning, exerting no pressure, has the same temperature as that of water boiling under pressure of one atmosphere, but as the excess pressure increases to about 15 pounds to the square inch, it has the temperature at which water boils under two atmospheres. Thus given the pressure of steam as it is ordinarily formed its temperature may be considered declared or given its temperature the pressure may be, of course, as readily deduced, pressure and temperature being convertible terms. One may therefore speak of saturated steam as either at a certain temperature or at a certain pressure.

In the following illustration this relation is shown by scale, the first column being a scale of pressure and the other columns being the corresponding scales of temperature in Centigrade, Fahrenheit, and Réaumur.

If saturated steam at whatever temperature is carried to a higher temperature, as for instance by steam pipes passing over a fire, it becomes, as has been declared, superheated steam. Superheated steam is a much more perfect gas than saturated steam and the more it is superheated, the more perfect it becomes. It has properties much like those of hot dry air. It takes up water with avidity, and thus in disinfection there may not only be danger in overheating, but there is always danger in the abstraction of hygroscopic water by which goods are rendered brittle, and perhaps weakened beyond recovery. Saturated steam is not seeking water and in condensing adds water, but superheated steam is seeking water and thus becomes a powerful drying agent in degree depending upon its temperature above the saturated steam from which it was derived.



AMERICAN STERILIZER CO.
ERIE, PA.

Fig. 87.

When water passes into a gaseous state there is an enormous disappearance of heat. Saturated steam has the same temperature as that of the water from which it has been formed, but to effect the change from water to steam very much additional heat has been required. Thus the liquid and the gas while at the same temperature have a marked difference in capacity to part with heat when brought into contact with cooler material. Such material immediately causes the steam to condense as it is brought below its condensing point and in that condensation or passing back into the state of water, all the latent heat acquired by the steam, or necessary for the steam to form at the temperature or pressure at which it was formed, is made kinetic and thus available for heating the object with which it is in contact. This not only represents heat available in the case of a steam radiator, but also very much of that which is directly utilizable when steam condenses within the meshes of fabrics undergoing disinfection in a steam chamber. One pound of steam not under excess pressure, or rather merely under the standard atmospheric pressure under which it has been formed, and thus at 212° F., gives out 965.7 British thermal units, or 536.5 calories for each kilogram, as it passes back into water at its same temperature, 212° F.

But steam at 212° F. occupies 1,644 times the space it occupied as water, and that is important in relation to the penetrating power of saturated steam in disinfection. Degree of pressure has relation to degree of penetration, but saturated steam has much greater penetrating power than superheated steam at same pressure. This is due in great part to its remarkable diminution of volume in condensation. For the great opponent to the diffusion of steam is air, and all fabrics as they are placed in a steam chamber have their meshes filled with air at about the temperature of the surrounding air and at the pressure of one atmosphere. Unless the steam is able to displace such air it cannot penetrate and will thus be capable of acting much like so much hot air under pressure.

But the air contained by the fabrics and the material composing them are at a lower temperature than the saturated steam in contact and effecting a degree of penetration by pressure or air compression. The steam that penetrates, having its temperature lowered, condenses, liberating its latent heat and, by change of volume, making room for additional steam. The fabrics themselves are absorbent, capillarity assists, and the tendency of the water is to make its way into the mass and with the steam to displace the air.

Yet air is a stubborn opponent to the diffusion or expansion of steam. This is seen whenever steam is let into a space containing air. Steam has a specific gravity of 0.625 as compared with air under the same pressure and they show a marked disinclination to mix. Air is also a very poor conductor of heat. An air-bound steam radiator is thus inoperative, however liberal the steam supply, but when the pet-cock is opened the steam pressure readily forces out the air it has been compressing and, occupying the entire space, makes the radiator a radiating and heating surface by virtue chiefly of the liberation of latent heat incident to steam condensation induced by the continuous loss of heat.

The same condition exists when steam is let into a closed chamber used for disinfection. The incoming steam being much lighter than air takes its position at the higher level and the compressed air below readily prevents its occupation of the space as a whole. Therefore one essential of every steam chamber is provision for the expulsion of its air. This provision is practically a bottom blow by which the steam under pressure within the chamber is utilized to force out the air and is thus permitted to diffuse or to occupy the space. Thus in all cases the first condition desired after the admission of steam to the chamber is that of streaming steam. But even then the complete exclusion of air from the chamber itself is not accomplished, for air is marked by its tendency to accumulate in pockets, and a certain amount of air may thus be deprived of exit by the steam itself. It is therefore best during the process to return to the condition of streaming steam from time to time, the intervals permitting readjustment of position of residual air and its ultimate expulsion. Circulating steam is also of direct advantage in the first stage of disinfection.

But the expulsion of air from the steam chamber is more readily accomplished than the expulsion of air from the articles to be disinfected. The pressure of steam is available in relation to the chamber as a whole in view of difference in the specific gravities of air and steam. But clothing tends to retain its air just as a sponge will retain water and with the same or nearly the same pressure surrounding the clothing, pressure would not seem to be sufficient for expulsion.

Such considerations in connection with experimentation have caused the belief that the penetrating power of steam is greatly increased when a degree of vacuum has been secured in the chamber prior to its admission. Consequently, many of the steam chambers in use to-day are provided with the vacuum attachment by which steam from the boiler or from chamber-jacket is utilized to secure by aspiration a considerable degree of vacuum before the steam is admitted from the jacket to the chamber.

Certainly as the air is rarefied within the chamber, the articles or clothing it contains will lose air, and it seems quite evident that the less air they contain the more quickly the steam will secure the deep penetration desired.

Experimentation with thermometers placed within packages undergoing disinfection declares that such is the case, and therefore it may be accepted that in steam disinfection the vacuum prior to the admission of steam has considerable value. The vacuum is also of value in other directions, such as in the admission and action of formaldehyde and in the drying of articles within the chamber at the end of the process. It is the common rule in steam disinfection to begin and end with a vacuum, and while the chamber is occupied by steam to have it flowing or streaming through from time to time.

But practically the power of steam in disinfection is not in proportion to the total amount of its condensation. Only sufficient concentration of heat is required for disinfection by heat, and it has appeared that the application or operation of such heat is sufficiently secured by penetration in connection with a degree of condensation. Disinfection by steam is not in its final expression the same as boiling. One pound of steam condenses into one pound of water. One pound of steam at 212° F. contains 965.7 British thermal units as latent heat, while water into which it condenses contains only 212.9 thermal units. Thus the pound of steam in condensing rapidly gives up nearly five times as much heat as the pound of water starting at boiling temperature gives up more slowly as it is cooling. Besides water boiling at standard pressure is at 212° F., while steam condenses into water at the temperature of that from which it would be derived.

This is not intended to be a comparison between disinfection by steam and disinfection by boiling, for cooling water is not boiling water. It is intended to show that a sufficiently large volume of steam may penetrate fabrics and condense into a small volume of water and that in the condensation a large amount of heat has been available for disinfection without undue wetting of goods or even condensation beyond the ultimate drying power of a properly constructed apparatus, which thus permits articles to be at once utilized at the end of the process. Yet, such condensation, though limited, is not only the additional source of heat, in contrast with dry air or superheated steam, but is itself by virtue of the water, a protection to the goods in avoiding scorching and the abstraction of its hygroscopic water. It is interesting to note that in disinfection with sulphur dioxide or formaldehyde moisture is necessary, so in disinfection with steam moisture also holds a prominent place in the process, though for a different reason.

But, as has been stated, one of the chief objections to the utilization of saturated steam in disinfection has been the difficulty in *sufficiently limiting the condensation.* Much water is very undesirable, as it then becomes not only a damaging influence by matting and shrinking woolen fabrics, but otherwise unfits goods for use until they have been subjected to a period of drying of considerable duration. Therefore, in the construction of all good steam-chambers, the design is directed toward the greatest limitation of condensation, as under the best construction and the use of saturated steam sufficient water will always be acquired and even then unless care is taken some perceptible damage may result.

In order to limit or prevent condensation upon the interior surfaces of the steam-chamber the temperature of its shell must always be at least as high as that of the saturated steam it contains. In practice the temperature of the shell may be advantageously somewhat higher, for, in view of the primary condensation within and upon the goods undergoing disinfection, a higher shell-temperature facilitates reevaporation or drying, when the articles containing the moisture have ultimately acquired the same temperature as that of the steam surrounding them.

To secure the required shell temperature, the steam-chamber is within another chamber called the jacket, the space between them being the jacket-space. That space completely surrounds the steam chamber, except usually at the door or doors necessary for access to the chamber. Into the jacket-space steam is admitted and allowed to accumulate until the required or designed pressure is attained, provision being made for expulsion of jacket air and avoidance of accumulation of water due to condensation within the jacket.

The steam within the jacket-space thus surrounds the chamber shell and rapidly heats it. When the chamber door is closed there is more or less expansion of the air the chamber contains, but as such air is heated equally on all sides, there is relatively little movement of its particles; and air being a poor conductor of heat, it arrives at a uniform temperature quite slowly.

It is not unusual at this stage to keep the chamber open for a while, the car or metal basket or cradle, having been loaded, being placed within the chamber and the chamber closed as the jacket pressure is secured, and the apparatus becomes somewhat heated.

There is more or less expansion of the air within the chamber after closure and the excess volume is allowed to escape just before the jacket stream is admitted to the ejector by which a degree of vacuum is secured. The ejector is ordinarily a steam nozzle that is jacketed, its jacket-space communicating with chamber and external air and the nozzle receiving steam from the chamber jacket and discharging it into the air. As the steam escapes, or the nozzle acts as a steam jet, it creates a vacuum in its rear within the nozzle-jacket and thus draws air from the chamber. The degree of vacuum that can be secured depends of course upon the amount of steam pressure within the chamber jacket—the higher the pressure, the greater the vacuum. The degree of vacuum may be measured by a gauge provided for that purpose, and with high pressure and a good ejector the indicator may readily show 15 inches within two or three minutes.

With the apparatus in this condition the formalin attachment may now be utilized when formaldehyde disinfection is to be employed rather than steam disinfection. A receiver is charged with formalin. Then on opening a valve the formalin is drawn by the vacuum through a long tube that runs within the chamber close to the shell where it is subjected to the high temperature derived from the heat of the steam within the jacket-space. The heat is sufficient to boil the formalin in transit and to vaporize its water liberating the formaldehyde within a hot space in a state of partial vacuum. The small amount of formalin employed is calculated to accord with gross space of the chamber at the rate of about 10 ounces per 1,000 cubic feet. There is also an ammonia attachment that is operated in the same way, delivering through the same tube and neutralizing the formaldehyde at the end of the disinfection that clothing ultimately removed may have little odor and that the opening of the chamber may not constitute a nuisance.

But if steam disinfection is to be employed, steam is rapidly turned into the chamber directly or from the jacket as soon as the vacuum is obtained; and when sufficient pressure is obtained within the chamber, it is utilized to drive out air in the manner already described. When steam is admitted from the jacket, the pressure within the chamber seeks to become the same as that within the jacket; and as the jacket continues to receive steam, the pressure will ultimately be that originally in the jacket, provided a reducing valve is not employed.

Whether a reducing valve is placed in the steam lead from jacket space to chamber depends upon the relation of jacket pressure, secured from a given boiler, to desired pressure within the chamber. An excess pressure within the jacket may be desirable. A pressure of 20 pounds within the chamber ought to be a maximum, and 15 pounds is quite sufficient when the steam has been admitted on a fairly good vacuum. Therefore, if the steam pressure within the jacket may exceed 15 or 20 pounds, a reducing valve should be provided. Saturated steam at 20 pounds is at a temperature of 260° F., or 126.6° C., and at 15 pounds 250° F., or 121° C. At 10 pounds the temperature is 240° F., or 115° C., and at that pressure results have perhaps been rather inconclusive in relation to *spores* where much penetration was required.

Especially when lower pressures are employed does a plan of alternating pressure and vacuum become of more importance. So far as penetration is concerned, the admission of the jacket steam into the chamber in a state of partial vacuum is at least equivalent to utilizing steam at greater pressure. The result depends largely upon the effect of vacuum in reducing the amount of air within the articles to be disinfected. But if, the chamber having received its steam and permitted to retain its full pressure for two or three minutes, the jacket steam is shut off from the chamber, the excess steam within the chamber allowed to escape and another vacuum produced and broken with the steam from jacket, an additional amount of air will have been worked out of the goods and more rapid penetration secured.

This plan tends to permit steam at lower pressures to be employed with as good effect in disinfection as steam at higher pressure without vacuum. Delicate fabrics sometimes lose their gloss with the steam at 20 pounds or about 126° C. But in view of all the difficulties in obtaining the full action of steam, incident to air within chamber and within goods, the chamber pressure under any system of working the apparatus should not be below 10 pounds, and it is even better to work the apparatus so that it may not be at all times constant, but vary between 10 and 15 pounds. Varying pressure once from high to low and back to high enables the steam to more readily work air out of the bundles of material it is disinfecting, and also out of the chamber itself if in accomplishing this the chamber pressure is allowed to reduce itself through its own bottom blow or drip valve.

In the construction of the apparatus provision should be made for the steam to enter the chamber in directions along the shell that condensation may be limited by the higher temperature in that part of the chamber.

In view of the air the chamber contains, the temperature is lower in the axis of the chamber than at the shell. Within some chambers a copper guard or hood extending the full length and breadth, is provided to deflect the current of steam toward the shell, or away from material to be disinfected, and in others the steam is admitted through openings in directions radial to the axis of the pipe or directions corresponding to the spokes of a wheel. This prevents rapid wetting of goods, and diminishes shrinkage of woolen goods.

With steam admitted into a chamber having a fairly good vacuum, an exposure of twenty minutes from the time the chamber pressure of 15 pounds is obtained should be sufficient if the condition of flowing steam is obtained from time to time and there is one variation of pressure from 15 to 10 pounds and back to 15 pounds. Thirty minutes should be the maximum exposure in a well-constructed apparatus. But no chamber should be overcrowded, at least several inches of free space on all sides of the cradle or car.

At the expiration of the twenty or thirty minutes, the steam should be shut off from the chamber and its steam blown off. The jacket steam is then employed to produce a vacuum and the heat from the jacket is utilized to dry the goods wet by condensation. In this part of the process is found the chief danger so far as injury to fabrics is concerned, although during the time steam is in the chamber there is liability to injury from rust unless the cradle is rust proof, or it has been lined with an old blanket or other material. This lining also limits the tendency of clothing to show marks of the wire mesh of which the car or cradle is composed and against which it has been forced by the steam pressure.

The partial vacuum for drying is secured from a chamber filled with saturated steam and having its shell at high temperature. Therefore, when the partial vacuum is secured, the chamber is filled with very attenuated steam at a minus pressure. There is also a large amount of radiated heat from the hot shell. If the steam remaining be regarded as superheated steam, the total conditions will be recognized as exceedingly favorable to the rapid loss of water by the goods wet during the steaming. But the tendency to loss will be greater at their surfaces, and if the jacket temperature is too high, there is tendency to scorching. Each apparatus will vary in time and exact condition required for drying without injury, but with 15 pounds or less in jacket, and the small vacuum of only 6 inches, the operation should be completed in less than 10 minutes in a chamber that has limited condensation. But the rapidity of the drying and the temperature and degree of vacuum required to complete the process without injury can be readily determined for each type of apparatus by a little experimentation, and thus can be made a part of the directions issued by the maker.

When the drying is considered sufficiently complete, the vacuum is broken by the admission of air, the door is opened and the goods removed.

This process of disinfection by steam is susceptible of a modification that is frequently utilized with mattresses and woolen goods. The time exposure to steam may be greatly diminished, perhaps one-half, and then when the final vacuum has been produced, the disinfection is completed by use of the formaldehyde attachment. This lessens the yellow tint acquired by new blankets in steam disinfection and the result is generally very satisfactory. *Leather and rubber clothing should not be placed within steam chambers* for steam disinfection or in a chamber with steam in jacket. They can be disinfected with formaldehyde in a vacuum produced by separate steam-lead for which provision is made in large disinfectors.

In using steam for disinfection, its condition depending upon the amount of oil and other material it may contain, is not a matter of indifference as, in view of the moisture and high temperature, goods may be permanently stained and discolored. On ships, boiler steam is often very dirty, and that condition has necessitated the placing of an evaporator between boiler and distiller in making fresh water. It seems highly probable that the same condition would frequently render steam from the boilers of ships unsuitable for the disinfection of clothing without injury.

It is this consideration that has prevailed in the design to be suggested of a steam-chamber for use on ships. In the illustration of that design, which will be considered later in detail, it will be noted that a small evaporator has been provided, the steam from boiler entering the evaporator tubes and generating steam within the evaporator shell by the boiling of the evaporator feed water, as in the case of the evaporator supplying steam to the distiller in the fresh-water plant. However, in this case the amount of feed water required will be small and should always be fresh water. The steam generated in this evaporator shell goes to the jacket-space of the steam-chamber and with a pressure of at least 35 pounds in the evaporator tubes furnishes in a few minutes sufficient pressure within the jacket to carry out the disinfection in the manner that has been described. Automatic safety devices are supplied in the form of safety valves and of an automatic arrangement by which when the jacket pressure becomes excessive, steam is shut off from the evaporator tubes themselves.

In its more recent work of disinfection or sterilization with steam under pressure, the attention of the Navy has been favorably directed to the products of the American Sterilizer Company, Erie, Pa., and, in view of the foregoing discussion of the operation of steam in disinfection, some of the apparatus of that company may be profitably utilized to illustrate the application of the principles involved. In doing that there is no intention to make comparisons with the apparatus of any other company. The type considered here is one of the best in practice, and while it is recognized that there are a number of different steam chambers on the market, it is not practicable to do more than utilize one of them as the idea is to advance principles rather than special products, and to suggest applications from a navy's point of view.

For disinfection on a large scale with steam under pressure that company, as some other companies, manufactures both rectangular and cylindrical disinfectors. On account of size and weight, such disinfectors have not been regarded as suitable for installation on vessels of war where questions of available room and additional weight assume great importance However, these large disinfectors are necessary at the naval hospitals and at the training stations. At the training stations, as has been shown in the chapter on vital statistics, the epidemic diseases have been most prominent in the Navy, and the history of such diseases on the ships declares the important fact that, during the ten years of which the statistics are given, the training station was the chief menace to the health of the force afloat from the point of view of contagious disease. It should always be regarded that extraordinary precautions against epidemic diseases are necessary at such stations not only to preserve their efficiency, but also to protect the crews of the ships, the efficiency of which is the object of naval effort.

Such considerations have emphasized the necessity for a disinfecting station wherever recruits are congregated on shore, and at this time no training station is considered complete without special appliances for the disinfection with steam of the personal effects in bulk of recruits. The recruit should be regarded as a menace to the health of the training station at the time he is received from any of the recruiting stations established throughout the country. His clothing should therefore be disinfected at time of receipt and cleanliness of body surface secured, and new arrivals should be segregated from others for a period of three weeks before they are considered in suitable condition to have the freedom of the station. For that purpose provision should be made for special quarters, and new arrivals should, during that period, be drilled and instructed generally apart from others.

However, the separate building provided at such a station for purpose of disinfection has much value not only in relation to recruits at the time they are received, but also to the management or control of epidemic disease that may be present, as in all such cases disinfection of clothing in bulk and also of the bodies of the men themselves are measures of prime importance.

The following cut shows the design of a disinfecting station equipped with an "American" cylindrical disinfector and proposed for the Navy Yard, Philadelphia, Pa.

The entrance opens into room "A," which is provided with a toilet. After disrobing, the men leave their clothing in room "B" and pass into room "C," which is provied with six shower-baths, six lavatories, and a bath-tub. In that room bodies can be thoroughly cleansed, and if necessary disinfected with a bichloride solution (1:5000)

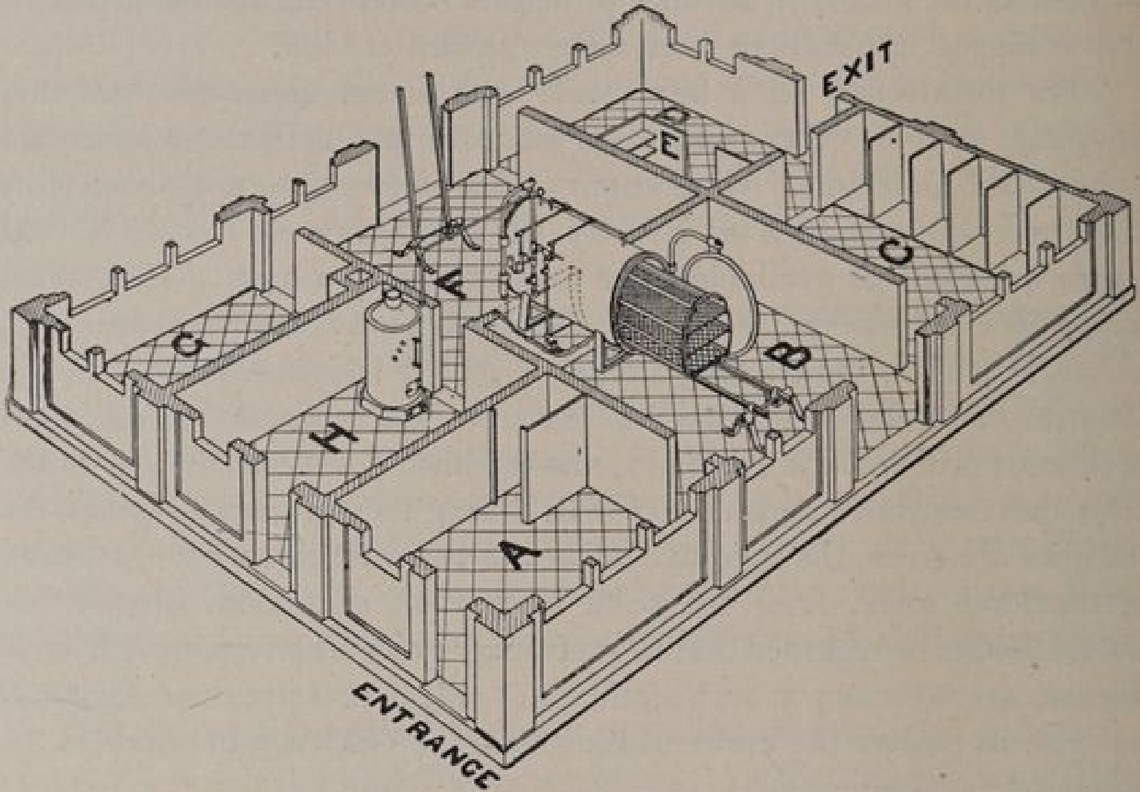


FIG. 88.—Perspective plan of a naval disinfecting station.

While the bathing is in progress, the clothing, except rain clothes and shoes, has been placed in the disinfector car and run into the disinfecting chamber, the door closed and the contents disinfected and dried. After that has been accomplished, the door of the disinfector in room "F" is opened, the car drawn out on the tracks provided and the sterile clothing is then ready for delivery in the dressing- and inspection-room "D", where it is given to each individual owner who, after inspection and dressing, passes out of the building through the door marked "exit."

The room "B" is sufficiently large to provide for much material, such as mattresses and bedding in addition to wearing apparel. This room has no communication with room "F" except through the disinfector itself, and in practice both doors of the disinfector are never opened at the same time. All the operating valves and the formaldehyde and ammonia generators are located in room "F" on the side of the disinfector nearest the boiler, which is located in room "H." This arrangement facilitates the operation of boiler and disinfector by one person in rooms "F" and "H."

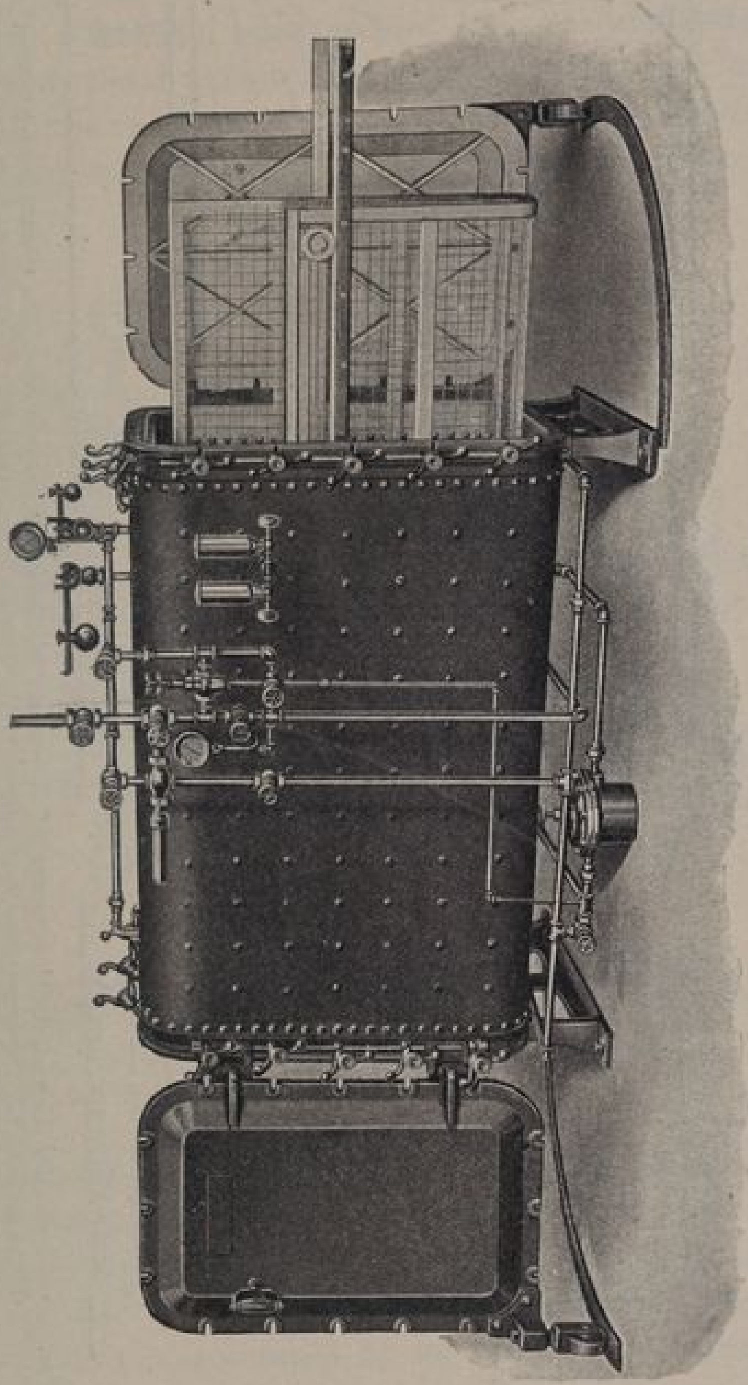


Fig. 89.—American Rectangular Steam Pressure Disinfector.

The dressing- and inspection-room "D" is also provided with toilet and wash-basin and connects with the linen-room "E" employed for the storage of towels and other supplies. Room "H" contains the fuel supply and also the boiler which generates steam, not only for the disinfector, but also for heating the building and providing hot water required in connection with bathing. Room "G" is for general storage purposes.

Figs. 89 and 90 show the "American" rectangular disinfector and its steam chamber and jacket, giving an idea of the steam circulation in that apparatus.

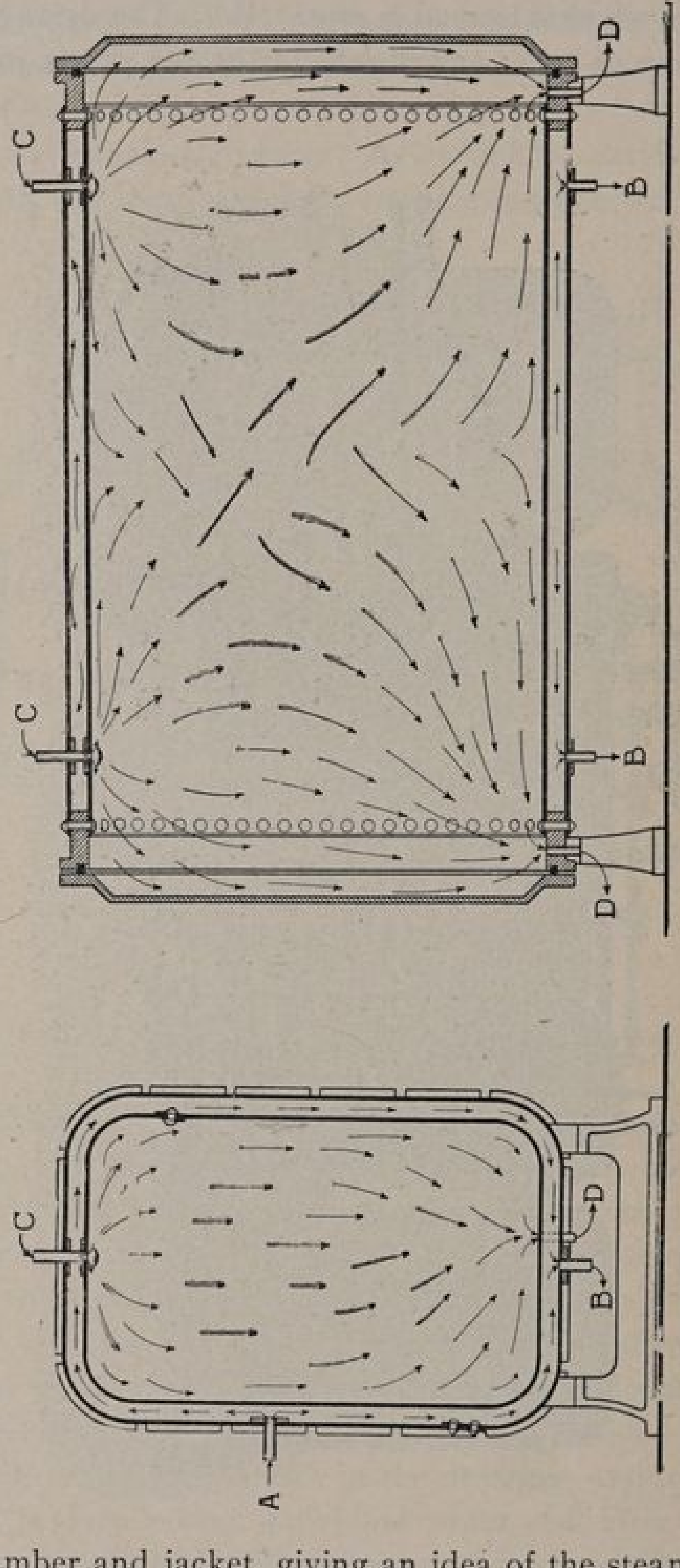


FIG. 90.—Cross and Longitudinal Sections of American Rectangular Disinfector. (A. Steam inlet to jacket; BB. Drains from jacket; CC. Steam inlets to chamber; DD. Drains from chamber. Circulation indicated by arrows.)

It should be noted that in its essentials, the apparatus consists of a steam-chamber and of a jacket-space; and that the steam is first admitted into the jacket-space and then at the top into the chamber, drains from jacket and chamber being at the bottom, thus securing not only drainage incident to condensation, but also the expulsion of air to the best advantage by means of streaming steam. As the installation on ships of these large disinfectors is not contemplated, it does not seem necessary in a naval hygiene to give their construction in detail and the usual operating directions supplied by the manufacturer with each apparatus.

On naval vessels an apparatus of less size and weight could be devised to satisfy those ordinary requirements which have been indicated elsewhere. In the endeavor to meet such requirements, the design shown in the following cut, furnished by the American Sterilizer Company, is proposed:

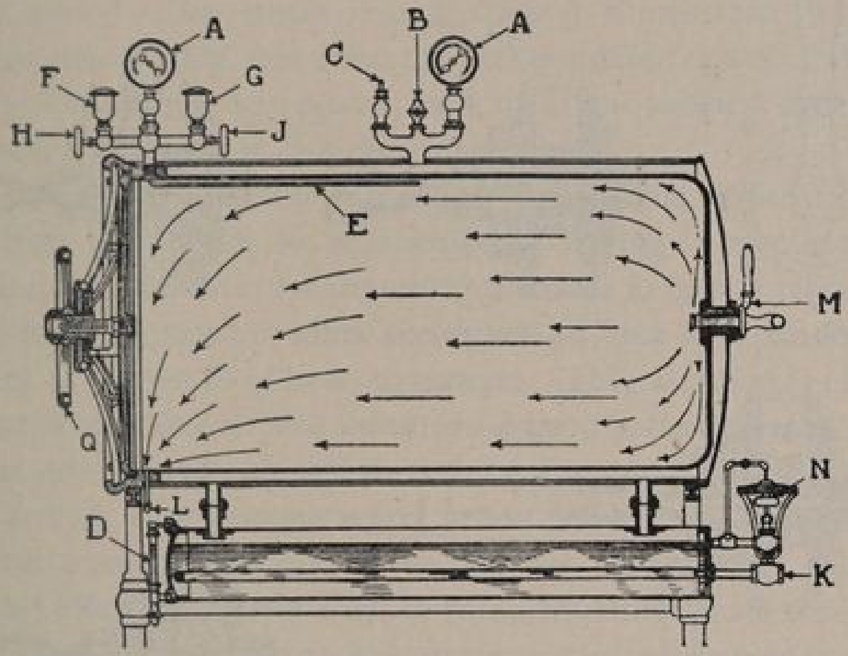


FIG. 91.—Design of a ship's disinfector.

A. Pressure gauges for jacket and chamber. B. Air cock for jacket. C. Safety valve. D. Water gauge glass for generator. E. Formaldehyde and Ammonia pipe to chamber. F. Formaldehyde cup. G. Ammonia cup. H. Formaldehyde valve. J. Ammonia valve. K. Steam governor. L. Drip valve from chamber. M. Back valve. N. Water valve to generator. Q. Hand wheel for locking door.

This apparatus may be called a "Sterilizer-Disinfector," and is a compromise design for use on a naval vessel. It may be regarded as a large dressing sterilizer, consisting of a steam-chamber and jacket and provided with the "American vacuum formaldehyde-ammonia generators". The steam is generated by an evaporator, having fresh-water feed, situated below the chamber and receiving its steam supply from any one of the many available steam leads of the ship.

The apparatus is designed to operate under a jacket pressure of from 15 to 20 pounds of steam. It has a safety valve "C" set at 20 pounds, and automatic control secured by the governing valve "K" which, when the pressure generated by the evaporator exceeds 18 pounds, shuts off the steam supply to the evaporator coil until the generated pressure falls below 18 pounds, when the valve "K" again opens, thus limiting the maximum pressure that can be obtained.

The special feature of this apparatus is found in the single lever control valve "M" by means of which the steam is admitted to the chamber, withdrawn from the chamber, and a vacuum created within the chamber by operating a single lever.

The following cuts show the design of this ingenious device designated as "M" in the previous cut:

FIG. 92.

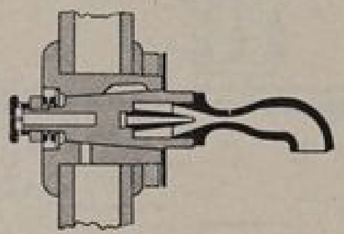


FIG. 93.

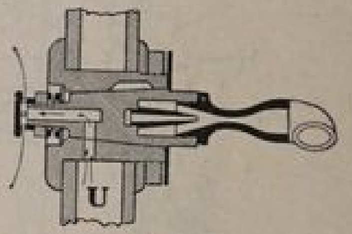


FIG. 94.

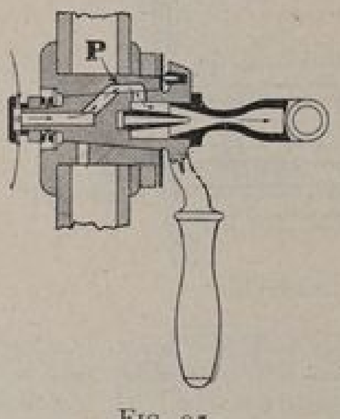


FIG. 95.

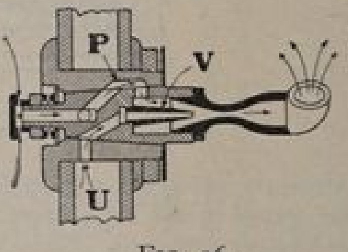


FIG. 96.

FIG. 92.—Plan view of "American" Single Lever Control Valve.

FIG. 93.—Position of valve with indicator at zero or with all connections closed.

FIG. 94—Valve with indicator at 1 in which position the connection at "U" between jacket and chamber is opened and steam admitted from jacket space into the chamber.

FIG. 95—Valve with indicator at 2, showing connection closed between jacket and chamber and steam escaping from chamber to atmosphere by channel designated by "P."

FIG. 26.—Valve with indicator at 3, showing steam escaping from chamber to atmosphere as in previous cut, but also with steam escaping from jacket to atmosphere through connection at "U," within the chamber.

To operate the disinfector the evaporator feed water is admitted by the water valve "N" until the water-gauge "D" shows that the designed water level is secured. This is when water in gauge is within 1/2 inch of top of gauge glass. It is necessary to secure the level in order that the evaporator tubes may be well covered with water at all times. Steam is then admitted to the evaporator tubes by opening the valve in the steam lead to "K." As "K" is a governing valve, it automatically regulates the steam supply to the evaporator tubes. There may also be a return-valve from evaporator tubes, which must always be partly opened to let out the condensation and secure steam circulation as in a steam radiator.

As the steam forms within the evaporator shell it gains immediate access to the jacket-space through the two connections shown in the cut from the top of the evaporator to the bottom of the jacket. These connections also serve as drains for any water due to condensation in the jacket-space.

When steam is admitted to the evaporator tubes at "K," the air-cock "B" is opened for the escape of air from the jacket-space and the air-cock is closed when steam issuing from it shows that the space is occupied by steam. By that time the jacket pressure gauge "A," to the right in the cut, begins to register, and in a few minutes a pressure of 18 to 20 pounds is shown within the jacket-space.

This formation of steam thoroughly warms the apparatus and in the meantime, the articles to be disinfected having been placed in the cradle or car and run into the chamber, the door is tightly closed. The valve "L" is then opened to allow the excess air, due to expansion within the chamber as the result of heat, to escape. This situation is allowed to continue for from three to five minutes under a jacket pressure of from 15 to 20 pounds that the air within the chamber, and with it the articles to be disinfected, may become more or less heated, and the subsequent condensation upon and within them limited. Then the valve "L" is closed and lever "M" is utilized to bring the index from 0 to 3 when, as is shown in Fig. 96, the jacket steam is utilized to secure a partial vacuum within the chamber. The steam nozzle is allowed to operate from two to three minutes, the time necessary to secure the greatest vacuum as shown by the chamber gage "A" to the left of the cut. The lever "M" is then turned until its index points at 1, when, as is shown in Fig. 94, the steam is admitted from jacket-space to chamber. Of course, if the vacuum is not desired the steam can be at once admitted to chamber by bringing the index from 0 to 1.

As the steam is admitted to chamber the steam gauge "A" to the right of cut necessarily shows diminished jacket pressure, but as the evaporator goes on making steam, the original pressure, 15 to 20 pounds, is soon again obtained and at the same time the chamber pressure gauge "A," to left of cut, shows about the same pressure. When pressure is shown within the chamber, the valve "L" is opened until streaming steam is secured. It is through "L" that the small amount of water condensing on the door also finds its way, as well as the remaining air as it is compressed by the steam within the chamber. This valve "L" may be left slightly open during the entire sterilization, but perhaps it is better to close it from time to time and then return to the condition of streaming steam.

When the articles to be disinfected have been subjected to a steam pressure of 15 to 18 pounds for from 20 to 25 minutes, the valve "L" is closed and the lever "M" is turned to 2 when, as is shown in Fig. 95, the steam from chamber is allowed to escape while at the same time the steam from jacket-space is shut off. In about one minute there is no excess pressure within chamber, and the index can be turned again to 3 in order to secure the second vacuum. In that situation the vacuum is again secured in from two to three minutes, when the index should be again placed at zero.

It is at this stage that the vacuum formaldehyde-ammonia attachments, F and G in the cut, can be employed to secure formaldehyde disinfection in addition to steam disinfection. This attachment can also be employed in connection with the vacuum first obtained and thus without admission of steam to chamber. It may often be employed to advantage after a shorter steam disinfection than 25 minutes, thus securing as complete disinfection with limitation of time during which woolen articles and mattresses are subjected to steam.

In using this attachment the cup "F" is charged with formalin and the cup "G" with *aqua ammoniæ*. The valve "H" is opened when the vacuum is obtained, and the formalin is sucked into the chamber through the long tube "E" shown in the cut and situated near the hot chamber shell. While in the cut the formaldehyde and ammonia attachment is shown on top of the sterilizer, the best result will be secured by situation at the side where through an additional bend in delivery tube a slower delivery can be obtained and vaporization more surely secured, as any formalin escaping vaporization within the tube would fall upon the very hot chamber shell.

The amount of formalin employed is calculated at the rate of 10 ounces per 1,000 cubic feet of chamber space. In this case, the cut representing a chamber 24 inches in diameter and 42 inches in length, the amount would be about an ounce, as the calculation is made without regard for space occupied by articles undergoing disinfection.

When the formaldehyde disinfection is used without steam disinfection it is advisable to admit a small amount of steam by turning the lever "M" so that its index points to 1 for a second that moisture may be available in the disinfection. The amount of steam admitted should, however, never be great enough to greatly diminish the vacuum. When used without steam disinfection an exposure of one hour to the concentration of formaldehyde obtained is quite sufficient in a fair degree of vacuum. But it is ordinarily best to admit steam to the chamber, even for a short time, that the vacuum may be obtained from steam and not from air before the formaldehyde is liberated.

After the formalin disappears from its cup "F," which it does rapidly and with noise characteristic of suction, the valve "H" is immediately closed and after the time exposure has expired, the ammonia is admitted in the same manner by opening the valve "J." The quantity of ammonia employed is only one-half that of the formalin employed. The neutralization is almost immediate.

When formaldehyde is in use *the steam pressure in jacket should be allowed to fall after the vacuum has been secured* and a little steam has been admitted to supply water-vapor. The steam pressure should be caused to fall in a few minutes to almost nothing by opening air-cock "B" and steam should be nearly shut off from evaporator tubes. A relatively low chamber temperature, about 180° F., is desired, as in relatively dry air high temperature may injure fabrics, and injury by scorching has been caused by maintaining too high temperature when using formaldehyde and dry heat in partial vacuum.

There is less chance of injury when formaldehyde is used in vacuum after a short disinfection by steam under pressure as then there has been some condensation; but even then the drying of goods is at times so rapid that unless the jacket steam is allowed to lose much of its excess pressure there may be injury.

After disinfection by steam under pressure and a drying vacuum has been secured it is often astonishing how rapidly goods will dry under a jacket pressure of from 15 to 20 pounds. Ordinarily, about five minutes will be sufficient. And yet the vacuum itself makes for lower temperature. In the large disinfector having a jacket pressure of from 50 to 75 pounds, the central chamber temperature with a vacuum of 15 inches runs down to about 195° F., although with a jacket pressure of 75 pounds the jacket temperature is practically 320° F. With a jacket pressure of from 50 to 75 pounds and a chamber pressure of 15 pounds, the chamber temperature does not appear to exceed 250° F.

In the apparatus described for ships, the jacket and chamber pressures tend to become uniform during the disinfection with steam and as the working pressure is from 15 to 20 pounds, the degree of drying vacuum obtained by use of jacket steam is necessarily considerably less than 15 inches. With steam at 20 pounds, the jacket and chamber temperature would be about 260° F. It does not appear that even at that temperature there is any marked shrinkage of woolen goods in the 25 minutes employed. But with the degree of vacuum obtainable the drying period should not be extended for fear of injury. The necessary period could be readily determined should the apparatus suggested ever be utilized under service conditions.

When the drying period has been completed, the vacuum is broken by opening valve "J." The door is then opened and the goods removed.

The entire clothing outfit of an enlisted man can with his mattress and hammock be readily made to form a roll 18 inches in diameter by 36 inches in length. The cut is that of a sterilizer with steam chamber having an inside diameter of 24 inches and a length of 42 inches. The diameter might be increased with advantage to 30 inches, but it is not clear that a seamless drawn brass shell of that diameter is now readily obtained.

The apparatus could be constructed to the best advantage with all castings of bronze or brass; exterior shell heavy, hard, cold-rolled copper; inner shell or disinfecting chamber of seamless drawn brass heavily tinned; evaporator of copper or brass; doors of bronze and cage of nickeled heavy brass wire. A cheaper construction is of course practicable, the door being of iron, the shell of galvanized steel, and the cage of galvanized iron wire. The weight of the entire apparatus would probably be from 600 to 800 pounds.

There is no doubt but that this disinfector would frequently be of value on ships for the sterilization of an individual's clothing, but it is also evident that it would have an important place in the medical department in time of war. At present the operating-rooms of ships are supplied with small dressing sterilizers. Such operating-rooms are often outside of armor bulkheads and therefore without adequate protection in battle. If the disinfector shown in the cut were installed near a dressing station inside the citadel, the dressing sterilizer in operating-room would become unnecessary and at the same time large amounts of dressings could be sterilized for use in battle or to meet conditions subsequent to action. A sterilizer so situated would certainly have much better protection from injury, and consequently a better chance for continued availability. And thus in view of both size and situation it would offer increased facilities in both peace and war.

The disinfection of mattresses and of individual effects in general of those sick with epidemic disease is limited on the ship by transfer of such cases to hospital. As a rule, in port such transfers are made with little delay, the effects (hammock, clothes-bag, and ditty box) being in isolation with the patient for the short time prior to transfer, and the regulation requiring that when a person is transferred his personal effects shall go with him.

As has been stated, the place of isolation should always be immediately disinfected after such transfers and, after use, all material, such as mess gear, that may have been utilized in connection with the case. In a place of isolation there should be no *unnecessary* articles and if, pending transfer, a mattress is required, as is generally the case, the patient's own mattress being considered as already infected should be employed. In many cases during the short interval pending transfer, no pillow is required, as clothing placed under the hammock at the proper end makes a fairly comfortable headrest. In view of better facilities at the hospitals the object should be to have as few infected articles left on the ship as practicable.

It is important in making the transfer not to utilize an ambulance in which there are other patients without the disease. In some localities the transfer can be made by boat to the hospital landing, and in that case the boat should be in tow and, if the disease is "*quarantinable*," under the yellow flag, and its interior surfaces disinfected with corrosive sublimate solution on its return. When an ambulance is used, the nature of the case should be known at the hospital at the time arrangements are made for the transfer, and when a boat is used, the hospital should be expecting the case at the landing.

In the transfer there should be compliance with all local requirements. No naval vessel conceals the presence of epidemic disease. All health authorities recognize a difference in such diseases. In our own large cities mumps and measles are of daily occurrence, but small-pox is dreaded in all communities. In certain ports of the West Indies even a single case of measles in isolation may cause a ship to be deprived of any communication whatever with shore.

In our country and in most countries the diseases that are regarded as "quarantinable" from a maritime point of view are cholera, yellow fever, small-pox, typhus fever, plague, and leprosy, but in the case of the last disease it is chiefly the individual and his effects that are in question, and not the ship as a whole and other persons on board. There is, however, the general recognition that scarlet fever, mumps, measles, varicella, diphtheria, typhoid fever, cerebrospinal fever, dysentery, and tuberculosis are also among the communicable diseases. In a naval service such cases should be and are surrounded, to the extent practicable, with as many precautions against extension as in civil communities. Cases of scarlet fever, mumps, measles, and diphtheria are transferred from a ship with every precaution and a ship on which those diseases are appearing does not permit visiting parties or transfers of men to other ships. A ship in squadron or at a navy yard seeks not only to protect itself from any epidemic disease, but also, such disease being present, to prevent its spread not only on board, but to other persons wherever they may be.

However, there are occasions when the case cannot be transferred and must be treated out in isolation. Isolation not only means confinement in a particular space or locality, but also bedside disinfection and the prevention of any escape from the place of isolation of infection whether during the progress of the disease or at its conclusion. It relates to the care of case by special attendant and with separate material, such as thermometer, tongue depressor, bed clothing, mess gear, and closed stool or bed pan, and also to release of patient and effects at conclusion of case in such manner as to avoid extension of disease.

In regard to the space the rule is not only to have no articles leave that are not protected, as by sheet wet with corrosive sublimate solution, or have not been disinfected either by boiling water or chemical solutions, but also to secure disinfection of all articles and excreta as soon as practicable in order to avoid concentration of infection within the space.

Proper ventilation on the exhaust system and careful attention to all excretions, wherever they may be, go far to make the isolation absolute. The application of ointments to skin during desquamation also limits dissemination, and the method previously described for using corrosive sublimate solution throughout all stages of the acute exanthemata is also applicable. The deck about the bed should be treated as previously described, and knobs or handles at doors should also be frequently wiped with disinfectant solution. A nurse should use a cotton coat or covering extending close to the deck. This should be dropped close to the exit on leaving the space along with the loose overshoes he should have been wearing. Such things should be disinfected daily, and a nurse should disinfect his hands frequently and always *immediately* after supplying the wants of the patient. As has been stated a 1 per cent. solution of chlorinated lime is suitable for the disinfection of hands under such circumstances.

The face and hair of the nurse should also be made damp with a 1 : 5000 corrosive sublimate solution when he is about to leave the space, and solution of the same strength may also be utilized for disinfection of hands. A nurse should take a daily bath and should, whenever possible, be immune to the contagious disease in question. No person leaving an isolation ward should seek to mingle with others and a short exposure in the open air is desirable.

In the care of small-pox, an isolation that did not include attendant would not be considered satisfactory, and this is true in a strict sense in relation to all the epidemic contagious diseases. But in regard to the latter, as such a course is not always practicable, the precautions mentioned should be utilized to the full extent.

On a crowded ship there is also a degree of uncertainty attached to all attempts at isolation, and this is recognized in the regulation requiring arrangements with authorities of the port for the care and treatment of patients on shore or on board a hulk to check the spread of disease on board a cruising ship. Not infrequently in the absence of other facilities, ships have undertaken to establish suitable places on shore for the treatment in isolation of contagious cases. For instance, tents pitched on one of the small islands in Guantanamo Bay have been utilized in the case of small-pox and coal barges in the same bay have been made suitable for cases of measles. Camps have been repeatedly established both in relation to diphtheria and cerebrospinal fever. Such camps secure a division of personnel into groups, permit a rapid separation of the sick from the well, and, in the removal of persons, afford opportunity for the general disinfection of ship, effects, and persons.

On the ship itself at sea in warm weather and in the absence of a suitable place between decks, a bridge or a boat has been utilized under awning and a sentry placed to prevent the approach of unauthorized persons. It is evident that the presence of one of the epidemic diseases on a crowded ship frequently taxes the ingenuity of those taking measures to prevent its spread and often demands ability to recognize and utilize every available facility, whether on the ship or on shore. Not infrequently in port the sterilization of bedding and clothing of a crew is accomplished with great advantage at a quarantine station even when the crew is not removed from the ship. A change of clothing having been sterilized, an entire crew can strip on a part of the open deck in warm weather, all personal effects having been brought up on that deck and the ship's spaces undergoing fumigation. After the crew has taken a bichloride bath, the disinfected clothing on another part of the deck can be donned, all other effects having been deposited in a barge alongside for disinfection at quarantine station. In a general infection or on the appearance of serious epidemic disease having source within the ship, such measures are of great value and may be properly undertaken whether general occupation of ship is to continue or a camp established.

In relation to the above, the following quotation (Report of Surgeon-General, United States Navy, 1908) is made from a report by Surgeon G. F. Smith, U. S. Navy, from the U. S. S. Maryland, the clothing, bags, and hammocks having been disinfected at the quarantine station at Mariveles, Luzon, and all living spaces fumigated with formaldehyde:

"Two cases of cerebrospinal fever developed on board while making passage from Hongkong to Manila in January. This was plainly due to the absence of ventilation on the gun deck within the armor belt and on the berth deck. The former space is entirely dependent for its ventilation upon the gun ports and hatches, which have to be closed in bad weather. There is no artificial ventilation of this space, and yet 600 men berth there.

> Interesting features of these cases were that both occurred in men who slept on the deck (the linoleum had become very defective and filth and moisture had collected beneath it), and also that the period of incubation was well established in one of them. This man belonged to the crew of one of the steam launches, but owing to bad weather he slept for one night on the linoleum of the berth deck. The disease appeared on the fifth day after this event. The other case appeared several days before.
>
> This disease was promptly checked by making the whole crew sleep on the upper decks in the open air. The gun deck was thoroughly aired by opening all ports and hatches. All living spaces were scrubbed down with a 1–500 solution of bichloride of mercury and then sealed and fumigated. The clothing, bags and hammocks were sterilized by steam. Later on the old linoleum was taken up and new linoleum put down."

When contagious cases have to be treated out on the ship, the required time in isolation varies with the disease, and in some cases, as in scarlet fever, has relation to the severity of attack as manifested by the degree in which the integument has been involved. In diphtheria the apparent return to normal conditions is not a sufficient guide, as frequently the pathogenic micro-organisms can be found for a considerable period after the date when recovery seemed complete. The time of release of convalescents from that disease should, therefore, be determined by the result of bacteriological examination. Neither in that disease should isolation be confined to those showing the clinical signs and symptoms. Very commonly when a case of diphtheria is discovered among a body of men there are already a number of throats which on bacteriological examination will show the presence of the exciting cause.

The history of diphtheria in a navy shows the special difficulty in preventing spread and leads to the conclusion that when the disease is spreading at least all younger persons on board, minors and young adults, should be regarded as having been specially exposed. There should be as a primary measure frequent inspections with a view to separation of even suspicious cases, and certainly those giving positive results in bacteriological examination should receive prophylactic injections of antitoxin, provided sufficient serum is available at the time with due regard for the treatment of cases of the disease. Under such circumstances a ship at sea is at a great disadvantage, which should be eliminated by going into port where facilities for separation into groups as result of bacteriological examinations are available. At sea something can be accomplished by separating the sick and also the suspicious from the well and using suitable gargles. But when such segregation involves many, the ship ceases to offer suitable opportunity for preventing spread.

When, as the result of special facilities, separation into groups is secured through bacteriological examination, the spread of this disease, already in epidemic form, has been prevented when associated with disinfection of ship, persons, and clothing. Camps have been established for this purpose and, as at the Naval Academy in 1907, ships in reserve have also been utilized. Early recognition of primary cases and their early transfer, close inspections with measures addressed to the throats of the suspected, and use of antitoxin where indicated, if associated with such precautionary measures throughout the ship as have been stated elsewhere, have, however, not infrequently succeeded in preventing dissemination of a disease that under favoring circumstances is quite capable of taking ship and crew off duty.

While bacteriological examination should determine the time of isolation in the particular case of diphtheria, the period of infectiousness may be considered as usually three weeks.

The isolation of measles can be terminated in three weeks, small-pox ordinarily in a month and sometimes in three weeks, scarlet fever ordinarily in six or seven weeks, and mumps in three weeks.

In taking from the place of isolation the individual who is to be returned to his fellows, it should be recognized that while he is no longer giving out the cause of disease, he and his effects are within a space that contains the cause in more or less concentration. It thus appears that his own body is much like that of any other object within the space in being infected. It therefore becomes necessary not only to disinfect the space and all the inanimate objects it may contain, but also to disinfect the body of the individual, and after such disinfection to have it supplied with clothing free from infection.

The individual who has been isolated should receive a bath in a solution of bichloride of mercury (1:5000), the entire body, including the hair, being wet with the solution. He should then step from the place of isolation into a tub of warm water, where he should take a complete bath, using soap to the extent necessary to obtain a good lather over the entire body.

The day preceding the release, a suit of underclothing and of white outer clothing immersed in a solution of corrosive sublimate (1–2000) should have been taken from the place of isolation and after thorough disinfection, followed by rinsing in fresh water, hung on the line to dry. That change of clothing having been provided, it should be utilized on the completion of the soap and water bath.

Shoes should be left within the place of isolation, and after withdrawal of the individual, closure should be obtained and space together with contents disinfected with formaldehyde, all surfaces being subsequently washed with bichloride solution. The mattress should have been treated in the manner previously described.

If the circumstances are such that the place selected for isolation is not susceptible of closure, then it should be disinfected with chemical solution and articles subjected to the like treatment in the manner previously stated.

With a steam-chamber available, clothing in the place of isolation can be placed in the clothes-bag, with which each man is provided, and the bag put in a roll with the mattress and bedding. Then the bundle covered with a sheet wet with disinfecting solution can be transported for disinfection by steam.

This chapter on disinfection is intended for consideration in connection with the prophylaxis in contagious diseases given in the first chapter under the vital statistics of each. An attempt has been made to advance principles and to show in terms not too general the varying application of disinfectants to meet the varying requirements of naval vessels. There are limitations in specifying details, for it is recognized that, while the routine employment of disinfectants should be more general on ships, the conditions in the presence of any one of the epidemic diseases are not always the same. Ships vary greatly in design and move from one climate to another. Seasons change and climatic conditions may either facilitate the work of the disinfector on a crowded ship or multiply the difficulties whether at sea or in port. In different ports the facilities at hand may vary greatly. There is always room for both energy and judgment, and in disinfection it is a cardinal rule that it is much better to take the trouble to do thoroughly even more than may seem necessary, than to do too little or to fail through lack of system or through the selection of inappropriate methods.

In preventive medicine it is also generally recognized to be much better to avoid difficulties than to show skill in the presence of difficulties. But as the history of the epidemic diseases in the service has been shown in the chapter on vital statistics to have depended very largely upon the presence of such diseases at the training stations, it is quite evident that the problem of elimination cannot be solved on the ships, but depends for its solution largely upon efforts directed to improve conditions under which recruits are massed on shore. It is also there that disinfection is of primary importance in a naval service.

The varying relations of ships require much alertness if information of value is to be obtained in regard to the probable influence upon a crew of conditions on shore. The naval sanitarian should recognize that the service is acting under one code and that the history of epidemic disease shows that a particular civil community may be acting under another. Regulations require commanding officers of ships, on entering a port, whether foreign or domestic, to comply strictly with all its regulations regarding quarantine and, whether liable to quarantine or not, to afford every facility to health officers in making their visits and to give all the information the latter may require. It is also required that should a ship of the Navy arrive in port with an infectious or contagious disease on board, or should such disease break out while lying in port, the captain shall hoist the quarantine flag and prevent all communication liable to spread the disease elsewhere until pratique is received. It is enjoined that no concealment shall be made of any circumstance that may subject a ship of the Navy to quarantine.

On the other hand, the medical officer of a naval vessel is required to keep himself informed of the health of the port in which the ship is lying and to immediately report any facts that may influence the sanitary condition of the personnel of the ship.

In the former case information is not only offered but is declared, while in the latter there are occasions when information not only has to be sought, but is obtained with much difficulty. On arrival in port, the primary source of information is the health officer himself and then medical officers of other ships and, in a foreign port, the representative at that port of one's own country. But any source should be utilized, for example the public press, common report, and the bulletins of the Public Health and Marine Hospital Service. From such sources information leading to change in a ship's itinerary may also be obtained at times. Medical officers are required to report to commanding officers immediately upon becoming aware of danger from any contagious or infectious disease. A medical officer is also required, under his commanding officer, to use every measure in his power to prevent the introduction of such a disease on board, or, if existing on board, to prevent it from spreading.

CHAPTER VIII.

NAVAL RECRUITING.

No one who has studied with ordinary care the vital statistics of the service as given in the first chapter can fail to agree with the conclusion therein expressed that *the health of a navy is primarily in the hands of the medical officers at the recruiting stations.* A recognition of that fact is essential, inasmuch as it gives the examiner an appreciation of the very great importance of his work and of the necessity for skill and care in its performance. It dignifies a work that is too often regarded as merely onerous and undesirable, and places the subject as just as worthy of being made a specialty from a service point of view as any other of the many in which special knowledge is sought with the eagerness that is fostered by ambition for personal professional distinction.

Unfortunately, the results of the work of an examiner may *not* be susceptible of consideration from quite the same point of view as the results secured from professional work along some other lines. If a capable surgeon operated in 1,000 cases of appendicitis and lost the ordinary or usual percentage, there is no criticism attached to his work because conditions not under his control have varied, and it is presumed that the surgical work has been done as skillfully in one case as in another. But, if the same individual had examined 1,000 applicants for enlistment, the number of good men secured may not become so much of a factor in the judgment passed upon the work as those who are ultimately subjected to survey for causes prior to enlistment.

In the work of the examiner it is the mistakes that attract attention, and not the successes, and the personal question tends to make the work unacceptable and to eliminate the subject from the list of those desired for special study. It is clear, however, that the good of the service demands such study and that the necessity for special development along that line is as urgent in a navy as along any other line of medical work. In fact, *the importance of such duty cannot be overestimated and it cannot be too clearly understood that it is one of the most difficult and one of the most responsible duties a medical officer can be called upon to perform.*

It would, therefore, appear that for the proper performance of that duty a prerequisite is knowledge of service requirements. No words can convey to the uninitiated the disadvantages in active service afloat of even a relatively small percentage of undesirable men, or the variation in the physical demands of the different ratings, or the methods of life on ships and the mental attitude of the recruit in comparison with that of sea-faring men as a class. It therefore follows that, in recruiting, an additional percentage of errors may be expected from examiners who have never had sea service and who, having thus had no opportunity to acquire other knowledge of service requirements than is expressed in printed instructions, are not impressed with the full importance of the work in which they are engaged or, from a service point of view, the value of departures from the normal in degrees that in life on shore might even be regarded as of little consequence. Such an examiner is badly placed, at least unless his selections are to be carefully considered by more experienced minds and under better conditions before the undesirables have cost much in money and in loss of service, or perhaps have even managed to secure pensions or have passed into some hospital for the care of the mentally disordered.

This phase of the subject may be profitably carried to a still higher plane. If the good of a navy demands that the physical examination of recruits shall be a specialty, and it is then recognized that such work is one of special difficulty, it is evident that as in all other specialties only certain minds can have the aptitude necessary for its most successful cultivation. It, therefore, follows that even among those available to make such examinations, service at sea is not the only prerequisite for most satisfactory results.

Another question of importance that must be answered in the affirmative is whether in its ultimate expression the ideal physical examination of a recruit does not include the work of several specialists? In other words, it may be deduced logically that a naval service needs a number of good examiners in the field selected as far as practicable with regard to special aptitude for such work (a specialty in itself), and also central boards each member of which has been carefully selected on account of his knowledge along certain lines, one member, for instance, examining eyes, nose, throat, and ears, another the chest, abdomen, and limbs, and the third, perhaps the most important, passing judgment upon the availability of the individual considered as a whole under an appreciation of the fact that the object of the medical examination in recruiting is not only to secure human machines that appear to be in good order, that are working well, that are not in a state of disease, but also those made of *sufficiently good material* in the proper proportions to stand the strain of naval life.

In general terms it is not merely a question of size and freedom from disease, but also a question of vigor and freedom from tendency to disease. Standards of measurements in inches and in pounds have their great importance, but a knowledge of the appearance of good health and of a vigorous and healthy personality is as essential in securing good results. For, while breakdowns in the human machine are the common causes of death, such breakdowns are closely connected with the *quality* of the material in the machine. Environment in any given case is far from being the only factor. The existing cause of a breakdown in a human mechanism is often operative because of the presence of a predisposing cause—a condition of susceptibility or small vital resistance.

It does not appear that the members of such central boards should have additional duties in view of the extent of the special work, the necessity for care and its importance. These boards of physical review would be required to carefully and thoroughly reexamine 20,000 or perhaps many more men annually and to pass final judgment upon the physical condition of each recruit before the outfit of clothing has been issued. When one considers the expense entailed upon a naval service each year by men found to be unfit from causes existing prior to enlistment, the naval economy resulting from such an exclusive system of review would itself appear to more than justify that exclusive duty or effort necessary for the best performance of any special work.

The question of money is, however, only a factor, as the great object of all naval effort is to secure efficiency. Enlistments in our Navy are for four years and the period of peace is the period of preparation for war. No service duty is of more importance than that which has for its object the placing in time of peace upon vessels constructed for war or to maintain peace a personnel capable of giving that construction its best expression. All navies are in competition for the best designs of ships, including capacity to take maximum punishment and ability in machines to inflict maximum punishment, but the most indispensable physical mechanisms are the men themselves, and to secure a personnel of maximum physical and mental efficiency is as much to be desired in time of peace as to secure any other engines of war of maximum efficiency. And as in the case of all other machines, the main problem of human efficiency divides itself into two essential problems: 1. To secure the best machines, and 2. To maintain those machines in the best condition. It is in the solution of the former of those subsidiary problems that the necessity for the best system of recruiting is declared and it is in the solution of the latter that administration and hygiene find expression.

Now, every navy has some system of physical review of recruits—an important fact to be appreciated by each examiner. In our service the medical examiner at each recruiting station or with each recruiting party makes out, in connection with other records and as a part of the enlistment record, a "descriptive list" in duplicate of each man accepted, both of which he signs, but appended to one is the following: "I certify that I have carefully examined agreeably to the Regulations of the Navy, the above-named recruit, and find that, in my opinion, he is free from all bodily defects and mental infirmity which would in any way disqualify him from performing the duties of his rating, and that he has stated to me that he has no disease concealed or likely to be inherited."

The enlistment record and descriptive list, now called "Service Record," accompanies each man during his entire naval career, being kept on file on the ship or shore station to which he may be attached. It thus passes primarily with the recruit to the training station or receiving ship to which he is at once transferred after enlistment. The signature of the recruiting surgeon is then in evidence whenever the physical condition of the enlisted man is in question.

The regulations provide that medical officers shall exercise great care in the performance of recruiting duty, and that whenever hospital tickets or reports of medical survey represent a disability to have existed prior to enlistment, the fact shall be reported to the Bureau of Medicine and Surgery, and the medical officer who passed such recruit shall be held accountable for the improper enlistment. The medical officer who makes out a hospital ticket or the board that makes out a report of medical survey—in practice chiefly the latter, although not infrequently the survey follows the hospital ticket—expresses opinion upon the work of the medical examiner who passed the recruit. Yet, the sense of responsibility should not do more than act as a steadying influence, for otherwise, especially with first duties, it tends to breed timidity rather than caution, and thus, for instance, an examiner who has impressed upon his mind in too great degree the question of relaxed inguinal rings will reject a number of very good men.

There are such things as professional judgment and pride in doing good work and a desire to act for the good of the service. No number of jolts should deprive any officer of such conceptions, but just criticisms should be recognized as an analytical method of arriving at certain conclusions of value, and so far as they denote carelessness or lack of knowledge strongly indicate the direction for personal effort. An examiner, for instance, who overlooks an ankylosis, say of an elbow-joint, or a marked defect in vision, or complete color blindness, must expect to be considered careless or deficient in knowledge of clearly defined or simple tests or lacking in a proper system of making the examination. To exclude such cases is clearly the function of the examiner in the field, and if they are not excluded it is only reasonable to hold him accountable.

Hospital tickets and medical surveys for causes prior to enlistment, originate frequently at the training stations at which recruits are received from recruiting parties. It is at such stations that special boards of physical review would be of value. It is at such stations that a navy now undertakes its first physical review; the second, a general, or only partially special review, being at transfer to cruising ship or other station; and the third, equally general, being on the cruising ship receiving a draft from training station or receiving ship. In all cases where men are transferred there is an examination prescribed at place from which transferred and at place to which transferred.

Men are then subjected to a degree of physical examination whenever there is a change of duty, and at each inspection the original descriptive list is in evidence. Yet on the cruising ship cases are not infrequently noted of disability from causes prior to enlistment and the number of prescribed examinations may not be considered to militate against the argument in favor of special boards for physical review of recruits. Besides, the further a man goes in the service the more difficult it is in general to decide the question of origin of disability with reference to causes prior to enlistment, and in addition one may not lose sight of the main object which is to secure desirable men outside of the primary question of specific disability, tendency to disease being as much in question as the presence of disease.

The primary physical review of recruits at training stations, as now undertaken, is for all the purposes indicated above, as each recruit received is required at once to have his hair cut, bathe and report for physical examination and it is only upon the verdict then given that the recruit can be considered to have qualified, and it is only to qualified recruits that the outfit of clothing is issued.

The object of such regulations is evident and the interests of the service seem to be well safeguarded, each man who does not qualify being surveyed, as a rule, by a board of medical officers who recommend final disposition, discharge from service if condition permits or warrants. Yet a number of surveys are held on men who have received their outfits and who are suffering from "causes existing prior to enlistment." In fact, a training station is the place for trying out recruits before they go into the cruising ships, and they are drilled there at the guns, field pieces, and small arms, heaving the lead, exercising in boats, with sails, etc. Sometimes a thousand or fifteen hundred recruits may be at one station, many of them minors and thus very susceptible to the influence of environment.

Such a station requires, without regard to recruiting, the close attention of its medical officers, some of whom may possibly themselves be examining recruits for the first time, and be also engaged in a number of other time-consuming duties, especially during the cool and winter months when epidemic and other diseases are most apt to be in evidence. Besides, drafts of recruits are not only being received and examined, but other drafts are being examined from time to time prior to transfer to ships. These latter drafts may contain several hundred men and "every man about to be transferred from one ship or station to another shall be subjected to a careful physical examination conducted by the medical officer, who shall enter on his enlistment record his medical history while on the ship or station and his present condition of health. Except in emergency, no man who is known to have been recently exposed to any infectious or contagious disease or who is found to be suffering from such disease or from active venereal disease which may be a menace to others, shall be recommended for transfer to another station or ship except for treatment in hospital or for passage to hospital. When emergency requires that the transfer of men with these diseases be made, a full report shall be forwarded through official channels to the medical officer of the station or ship to which transfer is made. If any cases of those diseases are found and retained, they shall be promptly admitted for treatment, and a report of the fact made to the commanding officer."

Every transfer thus involves not only examination, but written work, and hospital tickets and reports of medical survey are also time-consuming papers. Transfers of drafts containing several hundred men may also be made from stations under considerable pressure for time. The holding of sick calls, the record made each day of each case on the sick list, hospital tickets, boards of medical survey, care and treatment of patients, sanitary inspection of the station, reports of various kinds, enlistment of men at the station itself, quarterly returns, requisitions, inventories, vaccinations with subsequent examinations to ascertain and report results, constant precaution to prevent the introduction or spread of epidemic diseases, and other duties tend to prevent the concentration of mind upon the physical review of recruits on receipt, the special study of the subject, and the special consideration of the individual necessary to secure the best results.

Besides, emergencies of service in an expanding navy are apt to lead to many changes in duty, and thus the physical review is apt to lack that precision which ordinarily results from aptitude associated with continuous experience and which would be secured from a more stable and responsible board specially selected for the purpose and to which the review has been consigned as its special work. And at all stages *the* responsibility is now with the medical officer who passed the recruit and whose signature is with the descriptive list—as it is he who is responsible for the improper enlistment—but it is he who, if with a recruiting party, examines under the greater physical difficulties and is perhaps, under a certain pressure incident to the competitive spirit between various recruiting parties to obtain the greatest number of men.

It is recognized, however, that the contention for special boards of physical review is a project subject to various and important service limitations, including number of medical officers available in connection with service requirements in general for that work. But such boards would pay for themselves many times over, although it is not advanced that their work would make obsolete the expression "causes prior to enlistment" as applied to disabilities in some recruits who might have "qualified" before them.

The finding of disability considered to have existed prior to enlistment or to have originated from causes or tendencies prior to enlistment does not necessarily show fault on the part of the examiner who accepted for enlistment and, indeed, may even result from fault in the medical officer or medical officers who made the finding. During the trying-out process at the training station or even on the cruising ships themselves there are among recruits a certain number of changes of mind with reference to the service. In a life so radically different from that in civil communities there are varying degrees in the rapidity of adaptation and a development of dissatisfaction that may be pronounced in some, especially during the first six months of enlistment. This change in mental attitude is something each examiner should keep in mind with reference to many abnormalities in varying degrees, for instance varicocele, and, in connection with conditions following operation, appendicitis, and even slight deformities following certain injuries and the varying degrees of flat feet, varicose veins of legs, bunions, and the like.

When an individual is under examination for enlistment the tendency is for him to make light of any abnormality whatever, with the declaration that it has never given him the slightest trouble. He is anxious to enlist. But the very moderate varicocele at the recruiting office not infrequently becomes a painful and disabling varicocele at sick-call a few days or weeks or months later in view of the anxiety to return to civil life. A varicocele that has followed the plough day after day is stated to cause much pain during drills in boats, and the scar following appendicitis, though of several years' standing and declared at recruiting station never to have given trouble, may be stated to have become very painful under like circumstances. And the medical officer holding sick-call is viewing a case in which there is a mental attitude altogether different from that at the recruiting office, and *his* mental attitude is also quite different from that of the original examiner.

Epilepsy and recurrent and alternating *insanities* are also cases to which "causes prior to enlistment" applies. The former is clearly recognized as usually showing no fault on the part of the examiner. It is also a disease simulated at times as may any form of "weak or deranged intellect." At the recruiting station the mental state of a candidate who reaches the medical examiner has to be determined more or less rapidly, as he is only under observation during the time of the physical examination, and chiefly by rapid and persistent questioning in obtaining family history and history of educational opportunities and progress, of diseases and injuries, and of character of work, and by eliciting comments on his manner of life and perhaps on current events. The questions are both leading and in the nature of a cross examination, and the replies and the manner in which they are given often have an important bearing upon the physical as well as mental examination. Yet the curiosity the examiner has in regard to the personality of the recruit varies greatly as well as the ability and *the time* to bring out the history desired. It is also during such questioning that many defects of hearing become apparent, even without special tests, as well as defects in understanding.

But at the training station or after enlistment there are opportunities for prolonged observation under circumstances of comradeship incident to massing of men and along educational lines in the facility to acquire the special knowledge necessary in naval life. There are mental disorders that require time for their manifestation and recognition and there are tendencies that permit developments under special conditions. In relation to the latter it is important to exclude all men from the naval service who have ludicrous peculiarities or who would become butts among their comrades on account of physical defects. The stammerer, the child's or woman's voice, the marked facial birthmark, the abnormally large head, nystagmus, and marked strabismus are examples. The man who has had skull and crossbones tatooed on his bald scalp may be considered as already showing mental disorder. At any rate, he is an example of the peculiar and undesirable in spite of the absence of discernible disease.

Enuresis is another affection that has frequently led to medical survey for causes or tendencies prior to enlistment. Individuals having that affection may have the facies and manner of an unstable nervous system. They may also when stripping give the odor of urine. It is a subject in regard to which every applicant should be made to declare himself in answer to direct and indirect questions such as, "Have you ever wet your bed at night?" "No." "Never in your life?" But in spite of all efforts on the part of examiners a number of such cases will appear at training stations and even on cruising ships, and many have been surveyed as having the trouble prior to enlistment and have been discharged. Yet many of these men are persistent malingerers actuated by desire for discharge from service and entirely willing to make themselves nuisances in order to accomplish that result. If they are all made to spread their hammocks together on the floor or deck and are called every hour during the night as a part of their treatment it is astonishing how rapid will be the cure in very many cases. The true case is not unknown, but the large majority are not true cases and *surveys can breed epidemics.*

Defective vision is another frequent cause of surveys in which origin is stated as prior to enlistment. It is quite common for men who appear at sick-call on that account to state that when they were examined for enlistment, the doctor was in a hurry, and either did not examine their eyes or failed to examine both of them. It is noticeable, however, that the failure, especially in the Marine Corps, very often applies to the right eye or the one used at target practice. Nevertheless, unless there is a system or method in making all physical examinations for enlistment any particular defect may be readily overlooked. Degree of vision is not a part of the "Descriptive List" heretofore mentioned, but it is an important part of the record made on Form X or "Abstract of Persons Examined." It is on that form that the original entries are made, and each examiner should be so satisfied of their correctness that in any case he can make positive assertions in relation to them. If a man who, being recently passed, has been surveyed on account of a vision of only 4/20, it is satisfactory to be able to state positively that at the time of examination the vision was normal or at any rate up to standard.

One of the important duties of the examiner is to have his records correct, and in order to accomplish that he must at least know the tests and faithfully apply them. A man found color-blind by the proper application of the usual tests after enlistment represents an error that is not lessened because the original records in his case show good color-perception, but rather heightened thereby, as the method employed for testing color-perception affords the means of making the man himself declare his deficiency or the fact of malingering. It is not by any means clear, however, that the prescribed test is always properly applied either at the recruiting station or at the place of physical review. Nevertheless, the test prescribed is amply sufficient for all purposes of the service.

But, in the case of defective vision considered due to error of refraction it is not at all improbable that men have been frequently discharged from service as the result of deception. Because in any given case the man declines to deliver his true degree of vision or professes to be unable to see type at prescribed distances, there is not sufficient cause for "medical survey." Wherever that is considered sufficient there is apt to be an epidemic of defective vision among new men, and the original examiner will find marked differences in a number of cases between records made at time of enlistment and those made at time of survey. A man who wants to enlist desires to see and the man who wants his discharge does not desire to see. It is obvious, therefore, that in all such claims suitable tests are required by which the true vision may be determined in spite of the desire of the claimant, or at least the fact of malingering declared.

Tests for that purpose are well known, but many of them require more or less special or complicated apparatus and some special skill in application. Ordinarily a simple test may be found in the use of a prism placed vertically before the eye *in which good vision is claimed*, or in the use of a fairly strong convex lens before the eye *for which poor vision is claimed*. In the former case the object is attained through displacement of images, the *avowed* object being to ascertain what *very good vision* there is in the eye for which good vision is claimed in order that comparison may ultimately be made with the *poor vision in the eye for which poor vision is claimed*. By rapid work, and therefore no time for special consideration on the part of the examined, he is led to compare the clearness of the upper image or apparent upper type card with that of the lower although it is the lower that is seen with the eye for which poor sight is claimed. By rapidly slipping a blotter in front of both eyes on any sign of closure of either, or by quietly reversing the prism so as to reverse the position of the images, satisfactory conclusions should very generally be practicable from the use, say, of a 12 prism, ultimately varying distance from type if there is really any defect.

In the other method the *avowed* object is to find out how very *bad* the sight is in the eye for which *poor vision is claimed*. This is to be determined by the *large number* of lenses necessary before the 20-foot type can be seen. If the eye claimed to be good is covered and a *clean* 6 convex lense is put in the frame before the eye to be tested and then *clean* concave glasses be added slowly one at a time, the man himself perhaps ultimately holding some, until the correction is complete, the minus six to balance or correct the plus six, the type will be seen where there is no defect and *acknowledged*, as the vision is thought to be very poor to require *so many glasses*, or the value of the minus lenses in comparison with that of the convex lens employed will, where vision is obtained, help to determine the degree of defect. With a minimum standard for enlistment of 15/20 in either eye there may well be some defect in vision, and the point may be to determine to what extent the defect has been exaggerated. But, whatever may be the tests employed, a reserve on the part of medical officers in regard to them is desirable and the man to be examined should always be well apart from other enlisted men.

Hernia is a condition in a recruit often considered to have either existed prior to enlistment or to have resulted from tendencies prior to enlistment. The diagnosis of tendency prior to enlistment seems to be often based, in the presence of a hernia, upon "relaxed inguinal rings," the condition of the side not showing hernia being considered to give some indication of the condition of the affected side prior to the appearance of hernia. There are, however, a certain number of direct inguinal hernias, though more indirect ones, but it is doubtful whether there is any particular relation to relaxed inguinal rings, very many men who have relaxed inguinal rings never developing hernias.

Rupture is common in civil life and many cases appear under what seems to be slight provocation in and out of the service. The tendencies are congenital and in not a few cases may be beyond the appreciation of the examining surgeon. If a man has been in the service for some time, say a number of years, the natural tendency, in the absence of evidence to the contrary, is to give line of duty, but if the length of service has been short, say a few months or less, the tendency is naturally in the other direction, the burden of evidence being considered on the man.

Nevertheless, there is evidence to show that a number of the cases that do appear in the service are due to faulty enlistment, to great carelessness in conducting the examination. The examiner should make every effort, at least along prescribed lines, to thoroughly satisfy himself that there is no evidence of hernia or reason to suspect one, however incomplete it may be. Yet it must be admitted that, even when every recognized effort has been made, there are cases presenting special difficulties even to an experienced and careful examiner as the relation and condition of the abdominal contents vary as well as size of opening, making the opportunity for a hernia to recur very variable in some cases. Every medical man has had the experience of returning certain hernias without being able to elicit them again for some time, and it is well known that a number of small incomplete hernias if promptly returned and continuously retained for a considerable period may not exhibit "tendency" again under the most skillful examination.

It is well, therefore, to recognize that there are cases for which the examiner may not be held very strictly accountable. But, accountability is subordinate to the desire to do good work. Good work is not work free from mistakes, but free from avoidable mistakes. Mistakes may be due to special difficulties, but they may also be due to ignorance or carelessness. They are more often due to lack of method, though in traveling recruiting parties a considerable percentage of mistakes is due to hurry to secure recruits or to get men off on certain trains.

In examining for hernia the hands of the candidate for enlistment should be extended above his head and the chin should be well up. Coughing *in which the abdominal muscles are given full play* thus tends to make a hernia show itself. Such coughing gives the examiner an opportunity to estimate the relaxation of the umbilical and inguinal regions, and with the index-finger to secure information of the degree of relaxation of inguinal rings and to find whether there is impulse within the canal on coughing showing tendency to formation of hernia or at least disclosing a suspicion of hernia or incomplete hernia. A suspicion of hernia under such examination should be a cause for rejection.

It is during this period of the examination, the applicant being already nude, that evidence of venereal disease should be sought, especially beneath the prepuce, within the meatus, and in the state of the inguinal glands. It is also then that varicocele, undescended testis, hydrocele, and abnormal condition of the testes, including orchitis and sarcocele, should be sought. The regulations are that hernia, undescended testicle, large varicocele, sarcocele, hydrocele, stricture, and diseases of the genito-urinary organs are sufficient to cause rejection. *No examiner can properly examine for any trouble within the scrotum without handling the parts.*

Tuberculosis is a disease that is frequently ascribed to causes prior to enlistment. There is no doubt that the statistics of our service show an increasing number of cases and that the actual increase has been chiefly incident to service expansion. It is therefore the appearance of the disease among the more or less recently enlisted which, together with better methods of diagnosis, has dominated the statistics so far as relative increase is concerned. This question has been already rather fully considered in relation to the vital statistics of this very important disease where it has also been shown, for instance, that during the ten years (1895–1905) there was no greater percentage increase in the total deaths and discharges from tuberculosis than in the discharges from epilepsy. It might, however, be considered that if in every 100 or 200 men accepted for first enlistment a certain man had been excluded there would have been little or no increase in cases as shown by ratios. But the exclusion of that man presents difficulties that it is practicable to overcome only in part.

In this connection one might recall the physical examination of those known to have had pulmonary tuberculosis but said to have recovered under the influence of high altitude. In a number of those cases the physical examination by auscultation and percussion gives negative results, although the individuals may not present a picture of health and their subsequent history in low altitudes or at sea level may show that they either had not recovered from the original disease or had retained their predisposition to it. Many of those cases still show evidence of impaired general health at the time recovery is claimed, although they may come up to all the standards prescribed in measurements by tape line and scales. The situation at the time of the examination of some of those cases prior to redevelopment or reinfection is not unlike that of some men who present themselves for enlistment and are accepted. It is true they do not give history of tuberculosis, for there may be none or it may be concealed, but they either have not the appearance of good health or from their make-up they suggest the lack of a good constitution.

It has long been evident that in the examination of recruits sufficient emphasis is not placed upon those causes of rejection expressed as "feeble constitution, general poor physique, or impaired general health," and that efforts have been confined too exclusively to the discovery of specific disease and to questions of standards in weight and dimensions of body. Regard for the general *quality of material* is essential for success in recruiting. A recruit should be active, have firm muscles and be evidently vigorous and healthy *at the time of enlistment.* Sickly-looking men may become robust in the service, but the Navy is not a sanatorium, and the records show that the good of the service requires that the chances should not be taken. Merely because no lesion can be discovered at time of examination does not excuse acceptance in view of the subsequent records of such cases in relation to tuberculosis and general physical incompetency. *However, in this connection underweight in a young man has been shown by statistics to have much value as a cause of rejection.*

The chest is the most important dimension of the human machine, and the long-legged, long-necked man with a short chest does not make a good recruit. The lank, slight, puny man with contracted figure should not be accepted. The voice should be strong and chest *well-formed.* Huskiness, the white or straw-colored skin of fine texture, fine hair, sallow appearance, soft and otherwise not well-developed muscles on limbs, and often a very fair complexion give an idea of many undesirables. Deformities of a chest may interfere with the requirement for an ample chest and often interfere with an even and proper mobility. The staying power of a man is largely in his chest, as the heart and lungs are there.

No adult chest should have a circumference, *precisely at the level of the nipple,* of less than 32 inches on forced expiration, or an expansion less than 2 1/2 inches. Such minimum measurements have relation to minimum adult height (64 inches) as increases in mean circumference are prescribed as height increases. *Minimum chest measurements for height demand maximum attention directed to the make-up of the recruit considered in his entirety.* He must be evidently vigorous and healthy whatever the measurements may be. The ill-formed chest or what is known as the weak chest should not be accepted whatever the measurements may be. A man's chest should be considered in relation to the man as a whole and apart from the fact that disease is a cause for rejection.

In fact, at some time during the routine and generally at once, or at least after obtaining degree of vision and color perception, the applicant, entirely nude, should stand before the examiner in good daylight and present successively front, rear, and sides. This is a very important step in the examination, as it is then that questions are considered of retarded or insufficient development, perhaps general position of apex beat, deformity, or asymmetry of body or limbs, knock-knees, bow-legs, or splay feet, spinal curvature, feeble constitution, strumous or other cachexia, emaciation, obesity, cutaneous or other external diseases, including parasitic diseases, glandular swellings or other tumors, nodes, varicosities, cicatrices, indications of medical treatment, leech bites, blister stains, seton or scarification scars and evidences of small-pox or successful vaccination.

This is followed by a presentation of the dorsal and palmar surfaces of both hands; the flexion and extension of every finger; grasping with thumb and forefinger and with whole hand; flexion and extension, pronation and supination of wrists and forearms; all motions of shoulder-joints especially circumduction; extension of arms at right angles to body and bending elbows to touch shoulders with fingers; elevation of extended arms above head with palm to palm and then dorsum to dorsum; eversion and inversion of feet; standing on tiptoe and coming down upon the heels quickly and lifting toes from floor; flexion of each thigh alternately upon the abdomen while standing; hopping; performing all motions of hip-joints and walking slowly and going double quick.

It is now that one can note the effect of violent exercise on the heart and lungs and examine the chest by percussion and auscultation, front and rear. And it is after such examination that with the candidate in the position of body forward, knees stiffened, feet wide apart, hands touching the floor and nates exposed to the light, hæmorrhoids, prolapsus, and fistula may be sought. It is then that firm pressure on each spinous process may elicit spinal tenderness.

It is by a careful and systematic observance of the above that an examiner avoids much trouble for the service and for himself. It is remarkable that, if for no other reason than self-protection, this routine is not carefully followed in every case. If one turns to Statistical Table 3 under title Vital Statistics, it will be noted that of all the medical surveys held in the service during 1905, on enlisted persons within six months of enlistment, 11.86 per cent. were on account of deformities. Among the deformities *spinal curvature* figured largely, as well as *flat feet*, but there were not lacking deformities, and more or less ankylosis, from old fractures. It is also notable that *valvular heart* troubles caused 16.9 per cent. of all such surveys. There were, then, 28.76 per cent. due to these causes. It will be noted also that there was a percentage of surveys on account of poor physique, deficient vitality, defective health, chronic pleurisy, goiter, aneurysm, undescended testicle, varix, and defective speech. In view of the fire of questions under which the examination should be held, defective speech should be impossible in anyone accepted.

In that table hernia figures to no small extent, and varicocele slightly, but those cases were in addition to a number in which operations were performed. The same also applies to hæmorrhoids, the percentage of surveys giving no indication of the loss of time and the expense incident to such cases. Any hæmorrhoid associated with varicose veins of the legs should cause rejection, as should any ulcerated or inflamed pile. Hæmorrhoids should be considered with reference to age, as their presence is of more significance in a minor. But a *single* old pile not exceeding the size of a marble, reddish-brown in color and having a thick covering will probably not give trouble, though history should be sought from applicant and his admissions may cause rejection. Such a pile is in contrast with the single bluish nodule which if *very small* may not have much significance. It is a good rule to reject any minor who shows any hæmorrhoid at all. Any ulceration or verruca about the anus or unusual patulousness should cause rejection. But the old tabs of skin not infrequently found in that location are of little consequence.

Questions should always be asked in regard to bleeding during stool or after. An examiner certifies that the examined has stated that he has no disease concealed or likely to be inherited and it is well to impress upon the applicant that before the recruiting officer he has to sign a statement that he has never had fits and that he has no stricture or internal piles. Fistula is always a cause for rejection, and the regulations also state that hæmorrhoids are.

It is the duty of every examiner to have the last "Circular Relating to the Enlistment of Men for the United States Navy." The standards and the conditions considered sufficient to cause rejection of the applicant are as stated therein. The circular is primarily for the information of applicants, but the examiner should carefully consider it in the light of a medical education, and also be guided by the standards of weight and measurement as they appear from time to time.

The circular states that a large varicocele is a cause for rejection. These bunches of veins feeling like worms appear in many sizes. The general rule as formulated by Tripler is as follows: "If the testicle upon that side is atrophied, whatever may be the volume of the varicocele, or if the volume of the latter exceeds that of the sound testicle, the recruit should be rejected." In the examination it is well for the examiner to ask himself the question whether the varicocele is large enough to be "on the mind" of the applicant.

As among the deformities causing survey spinal curvature and flat-feet figure so largely, it appears that those abnormalities do not receive sufficient attention at the recruiting station where they should attract special attention. The line of the spine can always be well seen, together with shoulders of unequal height or round shoulders or that flattening of the front of the chest associated with an arching back. Of course one sees certain differences in the height of shoulders that are merely incidences of habit, but whenever there are differences they should serve to accentuate the attention given to the line of the spine and to general development, as is also the case with the round shoulders and the arching with flattened chest.

So far as lateral curvature is concerned, it should be recognized that the spine is from the center of the base of the skull down to the end of the spine. Having such a line in mind the departures can be readily appreciated and surely if the departure is as much as one inch on either side one can make out a cause for rejection. In the arching spine one can get a more or less correct position with shoulders back and chest thrown forward and then consider departure from the point of view of interference with chest expansion and heat action. There should be no pronounced departure from the normal, and every man accepted should be capable of acquiring a reasonable carriage under the influence of setting-up exercises. If he cannot acquire such a carriage he becomes a marked man among his fellows on account of a physical peculiarity and thus at least becomes a dissatisfied man or one likely to complain of physical disability.

A close inspection of the limbs is necessary in recruiting, for if a man has not good use of his limbs or they are not in condition to promise well under naval life he soon becomes an incubus. It is necessary to go over them in detail, watching the man carefully during the exercises indicated and looking for stiffness of joints, shortness, atrophies, distortions of any kind, contractions, inequalities, signs of sprains or of old fractures, loss of parts, adhesions as of fingers, varices, knock-knees, bow-legs, ingrowing nails, bunions, bad corns or corns on the soles of feet, hammer-toe, club-feet, flat-feet, or lameness from any cause.

Atrophy of a limb from any cause, any impairment of motion at a joint or distortion of a joint should cause rejection, but a permanent partial flexion of a little finger not interfering with grasping an oar should not disqualify. Hands should be considered from the point of view of pulling an oar, using a rifle and knotting and splicing ropes. Adherent fingers, permanent flexion (other than that mentioned) or extension of any finger, loss of either thumb or of either index-finger and loss of any two fingers on the same hand should certainly cause rejection. And, in relation to fractures in or about joints, special attention may be given to old fractures of the clavicle with much deformity or breaks about its outer extremity.

Varicose veins of the legs forming clusters or knots should cause rejection, as a rule, as should knock-knees to the extent that the feet cannot be practically brought together without some degree of crossing of the knees. Questions should be put in regard to sudden and severe pain about or in either knee such as would be caused by loose cartilages, as such a condition clearly disqualifies, and history should be sought of all or any fractures, dislocations or sprains by direct question of injury in relation to each joint as it is tried during the exercises specified, with special reference, as each foot is stamped, to the ankle-joints.

In the examination of feet the attention should be at least as marked as in the examination of hands. The question of flat feet or splay feet seems to have attracted much more attention as the Navy has expanded, and there has been some idea that complaints along that line have originated at times as the result of a mere feeling of dissatisfaction. There are, however, a number of more or less obscure causes of painful feet, especially in the heels, and some of those cases have been associated with abnormal sweating in that locality, either in quantity or quality as represented by odor. Tender feet disable and fetid feet constitute a nuisance, especially on a ship. Something in the way of information in regard to foot tendencies may be obtained by close questioning, examining the feet in relation to moisture, looking for corns liable to give special trouble, such as between toes or *on the soles,* and noting the prominence of internal malleoli.

When there is so little arch that the entire inner border of the foot rests upon the floor the foot is certainly unfit for service. In such cases the malleolus is very prominent, giving the appearance of a degree of dislocation outward with a crushing of the foot downward. In that condition the axis of the leg does not terminate in the middle of the foot. But in the merely broad flat sole, that relation of the axis of the leg to the midline of the foot is not in evidence, as the foot does not appear to be carried out making the inner malleolus unduly prominent. The negro presents such a flat sole quite frequently and observation does not show that it lessens his ability to use the foot. Yet as such cases tend to furnish cause for survey, the examiner will save trouble in service by considering them as undesirable, and the flat-foot is a recognized cause of rejection.

One thing seems quite evident and that is that in the service, including the Marine Corps, as much care should be taken in fitting shoes as in fitting any other article of clothing, a coat or a pair of trousers for instance. A man looks smart if his clothes fit him, and in all cases, at least in the Marine Corps, men are required to try on garments before taking them, and special care is enjoined in their issue as size has relation to wear as well as to appearance. There are perhaps fifteen sizes of shoes in five widths, and at least the same care is required in fitting them. It has seemed probable at times that the attention given to fitting shoes in stores on shore has relation to the tendency to buy shoes there rather than use the service shoes. A shoe of fairly good general shape is now provided in the Navy and the fitting is an important question. And on ships the weight of the upper is also of consequence as some feet in warm weather require a shoe that does not stagnate the air in contact with the foot to the point of permitting excessive perspiration. In the tropics on warm ships a cool shoe is necessary to prevent trouble in some cases.

Other conditions of the feet demanding rejection are the great toe crossing other toes, great prominence of bunion joint, unusual crowding of toes, ingrowing great toe-nail if deep or showing signs of inflammation or ulceration, and permanent flexion of the last joint of a toe so that the border of the nail bears on the floor in walking (hammer-toe).

In examining the surface of the body it should be considered that scars from buboes are not usually signs of syphilis, but that a suppurating syphilitic bubo is not a curiosity. History should be sought in those cases, and considered in connection with the routine examination of the mouth and throat and with attempts to find enlarged lymphatics in the usual locations. The moth-eaten appearance of hair may be in evidence or history may be elicited of a temporary alopecia, and the condition of the skin may furnish all the information desired. In time of peace considerable loss of hair should be a cause of rejection. A groin scar is at any rate usually the sign that a history of some venereal disease should be forthcoming. Any existing disease of the genito-urinary organs is sufficient to cause rejection, and care should be taken during the examination of the genitals at the time already specified to obtain history of venereal infection, stricture, or cystitis and to examine carefully for traces of a lingering gonorrhœa. In that connection the presence of an enlarged testicle may be of service. It should also be mentioned that the favorite location for vermin is the hair of the head and of the genitals, that scabies is a much more common disease now than formerly, and that the prepuce or scrotum is a frequent location of the burrow of that parasite as well as between the fingers. Epispadias and hypospadias are also stated causes for rejection.

Motions of the head, neck, and lower jaw should be obtained and, passing the fingers through the hair, the cranium should be examined for malformations, depressions, cicatrices, and tinea. A scalp scar or unusual depression requires history of injury. Any abrupt depression, especially if associated with scar, is cause for rejection. Goiter and wry-neck are causes for rejection.

Examination of nose, mouth, and throat, while undertaken separately, should also be considered in relation to the ears. By modifications of the voice in asking numerous questions a fair idea of the general degree of hearing is obtained before special examination of ears is undertaken, but a man may be quite deaf or entirely deaf in one ear and carry on any ordinary conversation without difficulty. Often chronic congestion of the upper respiratory passages exhibited by enlarged tonsils, showing tendency to recurrent tonsillitis, associated or not associated with chronic pharyngitis or chronic nasal catarrh and causing mouth-breathing, gives some idea of probable condition of Eustachian tubes with effect upon acuteness of hearing then or during damp weather. A man whose nostrils will be more or less occluded much or all of the time, or in whom a single nostril is occluded by marked deviation of the septum is not suitable for enlistment. And ozæna or any cause of offensive breath marks an undesirable man. Chronic nasal catarrh, ozæna, polypi, and great enlargement of the tonsils are each specified as conditions sufficient to cause rejection. The man suffering more or less from chronic congestions of the fauces and nares is common at sick-calls, and the examiner should take special care to exclude such men from the service.

In all examinations of the mouth and throat the question of mucous patches should be kept clearly in mind. They are often seen on the tongue and on buccal surfaces in contact with teeth, but another favorite seat is in rear of the lower molars on either side. To pass the examiner, the recruit is required to have at least twenty sound teeth and of those not less than four opposed molars and four opposed incisors. Teeth properly filled are not considered unsound, but false teeth do not count as teeth.

Impaired hearing or disease of the ear are causes for rejection. By reference to Statistical Table 5, under Vital Statistics, it will be seen that *otitis media* ranks as 13 in the list of the important diseases of the Navy, and from consideration of Statistical Table 55, and the remarks in relation thereto, it will be evident that there has been a marked increase in prevalence of that disease intimately associated with faulty recruiting.

It is a reasonable conclusion that if ear drums were carefully examined at recruiting stations the prevalence of middle-ear disease would be markedly decreased. It is quite evident that tests for hearing should be associated with direct examination of the ears themselves and that such examination is frequently not sufficiently complete. It may be that in the examination to determine the degree of hearing the difficulty in occluding each ear in turn, against the wishes of the applicant in some cases, has not been always overcome. In good daylight, and all examinations should be conducted in such light, it takes a very short time to see both drums, and under the conditions of a recruiting party, the ordinary otoscope is convenient and sufficient. Such an examination may also ultimately permit the acceptance of a desirable man whose deafness is the result of an accumulation of wax. The examination of each ear should be associated with questioning in the endeavor to elicit history of discharges from the ear or of a continued attack of earache.

In determining the ability to hear, the size of the examination-room and often the noise from outside sources present difficulties. Noises are rarely continuous and the examiner should take advantage of quiet intervals. Ordinarily the natural or conversational voice may be heard at 50 feet, but that distance is rarely available. The examinee should stand with his back to the examiner and an assistant should close the auditory canal of each ear in turn by firm pressure with the thumb on the tragus. The examiner should then address the applicant in a voice modulated for the distance and then standing at a distance of fifteen feet require him to repeat letters and numbers spoken distinctly in a stage whisper. This method is considered more reliable than that by the ticking of a watch with eyes and one ear covered, though great defects are readily disclosed by that method, when a watch ordinarily heard at 40 inches has to be placed very much closer to the ear or on it before the sound is appreciated. The acoumeter furnishes a much more reliable method for general use, but there may be difficulty in obtaining the desired distance.

If reference be again made to Statistical Table 3, under Vital Statistics, it will be observed that 19.8 per cent. of the surveys were on account of defects in the visual apparatus (12.8 defective vision, 5.6 color blindness, and the remainder for other causes). In examining eyes of an applicant for enlistment one should carefully look for pterygium, corneal opacities, nystagmus, divergence, adhesions of iris, obstruction of puncta, exophthalmus, abnormal conditions of conjunctivæ, etc., but it seems that the shoals upon which the examiner too often grounds his work are defective vision and color-blindness. This would not be expected because a man under examination for enlistment readily delivers his vision, the standard is set and the test is sufficient and simple; and for the detection of red-green blindness the prescribed method is readily utilized with success.

The great difficulty in examining a recruit is the large number of things that have to be rather rapidly done, and the only way in which a satisfactory result can be accomplished is to do those things in order or in accordance with a system, but it cannot be accomplished even then if the pace be unreasonably rapid. One examiner may think a certain order better than another, but the main point is to have a system, and it is well to take that suggested in the Navy Regulations and to make such modifications ultimately as may seem to make it more convenient. It often seems that a considerable percentage of errors in recruiting duty is due to lack of method and another percentage to work too rapidly forced. Certainly, no man should be accepted whose degree of form-vision and of color-perception have not been carefully determined and recorded.

In determining visual acuteness it is important to have the test card placed in the best light. As the degree of vision is to be expressed by fractions with 20 as the denominator, the test will be facilitated by having marks on the floor, say brass-headed tacks driven at intervals of five feet from the card, the farthest to be twenty feet away whenever possible. It is at the farthest that the applicant should stand. Each eye must be tested separately, each in turn being covered by the *examiner* or *an assistant* using a blotter or a card or some efficient screen which is never the hand.

If the candidate, as he should be, is twenty feet away from the card, he is required to call out the letters from left to right and then from right to left and *then particular letters indicated at random* in the lines of Snellen type considered standard for that distance. If he can do that, even though he may perhaps mistake a P or T for an F, his vision in the eye under test may be considered normal or 20/20. If he cannot readily call the type at that distance he must very gradually approach the line until he can call the letters it contains. If that distance be 18 feet the vision in that eye is recorded as 18/20, if 15 feet 15/20, and so on; but, as the standard in the Navy is now 15/20 in either eye he must at least be able with either eye at 15 feet to call each letter designated as indicated in the 20-foot line without *any failure whatever*, and applicants for enlistment are required to be able to read English. A vision of only 15/20 is nevertheless a defect and the existence of several minor defects considered with a visual acuteness of 15/20 in each eye is regarded as cause for rejection.

In accordance with regulations every examination must be completed according to the official forms and can in no case be suspended on the recognition of a disqualifying defect. This necessitates the recording on Form X of any disability unfitting the applicant for service. Thus in every case the degree of visual acuteness has to be entered whether the applicant is rejected or accepted, and *the greater the departure from absolutely normal acuteness of vision the greater the care that should be exercised in determining just what the vision is, especially in cases that are accepted, as any defect recognized by the examiner tends to lead to exaggeration on the part of the dissatisfied.*

Such knowledge may also lead to deception at the time the examination for enlistment is made, as the man then anxious to come up to standard and having better sight in one eye than the other may, unless care is taken to prevent it, bring the better eye into action when it is supposed to be completely covered or blanked. No one undergoing examination should, therefore, be trusted to cover his eye and the examiner should have in mind that unless each eye is in turn well-covered the object of the examination will be defeated.

It has also been advanced at times that opportunities have been taken to learn test type by heart. In fact that claim has been occasionally put forward by dissatisfied men at training stations, and in examining-rooms it is not uncommon to keep the test card displayed. It is better to have the card so hung that when not in use the type can be turned to the wall, or not to have the card in evidence until it is used. It is also well from that point of view not to confine the examination to a single line of type and also even to take up lines for varying distances, for instance the line designated for normal vision at 15 feet, the candidate approaching to the 15-foot mark and required to read the line and also designated letters. And then if considered necessary he can be tried in relation to the 10-foot type. It is better to try more than one line at corresponding distance *if there is only one line of 20-foot type* and observe whether there is fair general agreement in results.

For instance, a man seeing the 20-foot type at 20 feet should see the 15-foot type at 15 feet, and if he sees the 20-foot type at 18 feet as his greatest distance he should for all practical purposes of the examination see the 15-foot type at 13.5 feet, as X/15 equals 18/20. A man reading without any failure the 15-foot type at 11.25 feet as his greatest distance may be considered to have at least 15/20 vision, as X/15 equals 15/20. A man having 4/20 vision as determined by the 20-foot type should have about 8/40 vision as determined by the 40-foot type, and in general he will have. One should observe whether the type card is arranged for feet or meters and fix the floor marks accordingly. If the visual acuity of each eye was not required to be determined with all the accuracy the method permits it would be advisable to emphasize that the vision in the right eye should receive special attention.

When the visual acuity in each eye is the same, the result is recorded as a single fraction, such as 20/20 or 18/20 or 4/20, as the case may be, but if the vision in each eye is not the same it must necessarily be recorded as two fractions using R and L, or D and S, to specify right and left as R 20/20, L 18/20, or D 18/20, S 16/20, or R 16/20, L 14/20. And if the record for either eye falls below 15/20 the applicant is to be rejected. A vision of just 15/20 in each eye should be determined with special care, and it is well to take rather more time than usual trying several lines without much interval of time, as a marked diminution of distance due to eye-strain should also be considered in forming conclusions.

Of course, in using the type of various sizes in connection with an eye that shows a degree of defective vision from error of refraction there will be rather wide differences in pure myopia. Considering the fact that the service does not require at a recruiting station a determination of the variety of error, but merely the degree of vision, and that is all that is practicable under the usual conditions of recruiting, it is very much the best to have on the same card a number of lines of standard type for 20 feet to be used in connection with a sliding card so cut out as to show only one line of type at a time. By sliding such a card up or down, memory of the type in the lines is abolished and the acuity of vision accurately determined without using any other type. The test card might contain one or two lines for a shorter distance than 20 feet in view of the probability of not having the full distance in each office occupied by a traveling recruiting party, but it appears that, as a rule, it is best to make the diagnosis on the 20-foot type alone, though a single line of such type is not at all sufficient in view of the readiness with which it may be memorized, and has been memorized.

Anyone who examines the different test cards on the market will be interested in the rather marked variations in the size and relations of the type put forward as standard. It has been stated that it is almost impossible, if not impossible, to find true Snellen letters. The Navy standard is based upon Snellen type, and of course for accurate work that type is required at recruiting stations, and for purposes of comparison uniformity is necessary. The cards used in the Navy are thought to be the best on the market, and it seems that special work is being done or is necessary to meet the requirements.

Recently many experiments have been made on land tending to show that in target practice even a marked deficiency in acuteness of vision is not of anything like as much consequence as has been supposed. It is believed that such a conclusion is fallacious, especially when applied to target conditions during war, and that, whenever it is practicable, standards should be raised instead of lowered. A movement toward higher standards of visual acuity, so far as target practice is concerned, is more practicable in a navy which uses big guns so generally than in an army where small arms are more general. In a navy the efficiency of a shot depends ultimately upon the gun pointer, and the number of gun pointers is a small percentage of the force, and can therefore be readily obtained with perfect vision, and as trained their numbers maintained under the same requirements. In that connection it can be realized that while 20/20 is assumed to designate normal vision, young men very frequently have 20/15 vision. Probably at least half the persons in the Navy to-day have that vision if tested by the cards now in use or perhaps by cards that are strictly in accordance with the Snellen standard. From the men who have the best sight it is recognized that as a general proposition the best gun pointers can be obtained.

The regulations prescribe that color-perception is to be always carefully determined and give in compact form the method to be employed. But it is at least doubtful whether the method is well understood by all examiners. Jeffries examined 19,183 males and found 802 color-blind, or 4.18 per cent. A committee of the Ophthalmological Society of London examined 14,846 males and found 617, or 4.15 per cent. color-blind. It appears from combining these results that the percentage of the color-blind among males is about 4.16. It may be considered that the very pronounced or most dangerous cases from a service point of view are at least 3.5 per cent. But from an examination of the records of 16,747 persons who had been examined for first enlistment in 1895 and 1896 it appears that 511, or 3.05 per cent., were found to be color-blind. In 1905 there were 27,788 examinations for first enlistment, and 2.99 per cent. were rejected for color blindness, but 23 men were surveyed for color-blindness within six months of enlistment. In 1906 out of 29,765 examined for first enlistment about 3.1 per cent. were rejected for color-blindness, but the number of subsequent surveys on account of color-blindness has not been obtained. And the number of color-blind persons who have passed examiners cannot be measured by the number of early medical surveys on that account. The question of the detection of color-blindness by the prescribed test would therefore seem to be a suitable subject for elucidation, as the importance of excluding the color-blind from a naval service is apparent.

It appears that the frequent physical examinations at the Naval Academy have been sufficient, during more than 28 years since the Holmgren method was first employed in the Navy, to keep its graduates free from defective color-perception. The test has also been utilized to exclude a very large percentage of the color-blind from the enlisted force. It can be utilized to exclude all from enlistment in any rating that can possibly be required in the performance of duty to recognize the color of lights or flags, or from enlistment in any rating which can furnish by *transfer to other ratings* any man required to do such duty. It would naturally seem that in a navy the question of color-blindness should only apply to the deck force, but it cannot be said on enlistment just where a man is going to serve on a ship. He may enlist as a coal-passer and later secure a change of rating involving duty as a lookout, or even as a mess attendant and ultimately serve on deck. Musicians are rarely, if ever, transferred to other ratings. Color-blindness is specified in regulations as a cause for rejection, and no person can be enlisted for the naval service unless pronounced fit by the commanding and medical officers, *except by special authority in each case from the Navy Department,* and in every such case the physical condition of the enlisted man must be fully described in the enlistment record.

In determining color-perception the *first essential is never to ask the examinee the name of a color.* Determining color sense is something very different from determining color ignorance. A man may have a normal color perception and yet not know the names of colors. A person who has normal color perception, is native born, and does not know how to invariably apply correctly such general designations as red and green is certainly dangerously ignorant from a service point of view, and is unfit for enlistment. The same is true of the foreign born not knowing the names necessary to make such a broad distinction, but *naming the colors is not a method for the determination of color-perception.* It is a method of determining color-ignorance, *but it should be applied only after the color-perception has been determined.* It is one method of testing the intelligence or education of the applicant in relation to colors, or his knowledge of English. And a man who, seeing the colors correctly, cannot report them correctly when doing lookout duty is almost as dangerous as one who is unable to appreciated them correctly. But he is not color-blind. He is color-ignorant.

And the color-blind may *name* a large number of colors correctly, as, for instance, he may pick out a number of greens simply because he has learned that people apply the name green to a certain color which while appearing in general as the *red* has a certain variation in degree of *brilliancy* or *luminosity* that he has found ordinarily sufficient to permit the distinction. In that case unless the examiner should *happen* to ask the name of some *particular* green, which may be as green as grass, he would fail to make the diagnosis in a case of complete green-blindness. And as brilliancy or luminosity is a variable color quality depending at sea upon varying atmospheric conditions, such as fog or mist, upon a dirty lantern glass or condensing steam, the *very greens* picked out in the examining-room and called correctly by the green-blind are very liable to be regarded as red under many service conditions. And what is true of the green-blind in relation to green is also true of the red-blind in relation to red. The different colors must be distinguished by hue and any test in which the results can be varied by brilliancy or luminosity is untrustworthy; and in naming colors the color-blind depend upon that very quality.

Every color can be defined by three qualities—its hue (red, green, violet, etc.); its purity or degree of admixture with white (deep or pale); and its brightness or luminosity (bright or dark). When two colors possess the same three-color constants they are identical. Now, the majority of persons, though their descriptions may vary somewhat, are shown by practical tests to recognize the same variations in colors. Those persons are said to have normal color vision. There are, however, quite a number who differ widely from the majority and that minority are said to be color-blind. That does not mean there is absolute insensibility to color, but merely that the ordinary distinctions between certain colors is defective. The term *achromatopsia* is employed in our nomenclature to designate this condition. It is evident to examiners that the variations in degree of this deficiency are many and when small are often very difficult to classify. But, in recruiting, the examiner has merely to consider those variations from a practical point of view, as his object is simply to detect color-blindness which may be dangerous in the naval service.

The color-blindness that is most common and which is dangerous is red-green blindness or the failure to distinguish between red and green. In those cases a certain hue of green is regarded as identical with a certain hue of red. In green-blindness the lighter shades of vivid green are generally regarded as the same as a vivid red, while in red-blindness the deeper olive tints are generally so regarded. Red-green blindness may then be divided into two species which for convenience are called green-blindness and red-blindness.

When the red-green blind look at the spectrum, rather more than its right half in the green-blind and about half in the red-blind (that is the violet, indigo, blue, and part of the green) appears in general terms as different shades of blue, the violet being a dark blue, the blue a light blue, and the dilution with white becoming much greater toward the mid-point until a band of white or gray is seen in the pure green by the green-blind and rather nearer the blue in the red-blind, but, with the red-blind, about the middle of their spectrum as in their case the spectrum is shortened because they fail to see at all in the extreme red.

The other part of the spectrum (that is, part of the green, the yellow, orange, and red) appears to the green-blind as all yellow, the red as dark yellow, the orange less dark, and the yellow as bright yellow, the marked dilution of yellow with white continuing into part of the green until the gray or white band is reached. To the red-blind the left half of the spectrum appears as different shades of green varying in the same manner as the yellow appears to do in the case of the green-blind.

In general terms it may be considered, then, that to both the red- and green-blind the right half of the spectrum appears as different shades of blue, but that to the green-blind the left half appears as different shades of yellow, and to the red-blind as different shades of green, in both cases the dilution with white being marked toward the middle where in each case there is a band of white or gray. The band of white or gray is conclusive evidence of color-blindness, as all persons of good color perception know there is no such band in the normal spectrum.

To the normal eye the brightest part of the spectrum is the yellow and to the green-blind the brightest part is also somewhat in that location, but to the red-blind it is in about the normal location of the green. Therefore, to the green-blind, red and yellow being the same color varying in shade, the yellow is the brighter and the red appears as a degraded or darkened yellow. While, as the red-blind regard green as brighter than yellow or orange, those colors appear as degraded green.

These variations in the appearance of the spectrum are interesting as showing the marked difference between typical cases of red-blindness and of green-blindness. They are indicated much more for that purpose than for any special consideration during the use of the different colored wools in the Holmgren test, for in making that test the examiner can readily arrive at conclusions, so far as the interests of the service are concerned, by *applying the test as prescribed with knowledge of the confusion colors* and without regard for the different interesting theories to account for color-blindness or for any detailed discussion as to why the red-blind make certain recognized mistakes and the green-blind certain other well-known and therefore expected mistakes. In applying the tests it is necessary to know just what mistakes are common *to both forms* and *thus indicate color-blindness without indicating its variety* and *then* just what character of mistakes may be expected from the red-blind and what from the green-blind that *the differential diagnosis may be made.*

The differential diagnosis is important at recruiting stations because it confirms the prior test as to the presence of color-blindness in some form and thoroughly satisfies the examiner that he has detected a *dangerous* form of color-blindness. It is of great importance to the medical officer who, in a position to criticise the work of a recruiting station, desires to know whether the man making mistakes in colors is really color-blind or is malingering, and it is of equal value to the board of survey anxious to decide the same question.

Skeins of *wool* are used in testing color perception because, as they are without gloss, each has about the same tone from whatever direction the light may fall upon it. The skeins, as a whole, also comply with an essential service requirement in being readily portable without breakage. But, as in testing form-vision it is necessary to have strictly standard type, so in using the wool test it is most important that the test colors used as standard skeins shall be actually those selected by Holmgren both as to hue and as to dilution with white. The variations in different sets of these wools is apt to be apparent in the first test skein or the light green which is often not even a pure green, but one mixed with yellow, and in the second standard skein, or the light purple or pink, which should be complementary to the green. And those skeins are the most important in the test. There is also considerable difference in regard to fast dyes. But all dyed wool ultimately changes color under the handling and exposure to light required in making the tests, and therefore it is important to have the sets renewed from time to time.

It is stated that the first standard is a light green color which can be matched with a green in the spectrum (λ 5660) when 40 per cent. of white is added; the second standard skein is a light purple or pink and its complementary color is a green in the spectrum (λ 5100) the color being diluted with 40 per cent. of white; and the third standard skein corresponds with a red of the spectrum (λ 6330) diluted with 18 per cent. of white.

The wools used in the Holmgren test or selections from them should not be suspended from a bar, as has been done from time to time, for the same reason that test type should not be kept displayed and for additional reasons. It is important that the examinee should himself be required to pick out the skeins he considers suitable to be placed with the test skeins, inasmuch as much information, such for instance as decides the question of a *feeble chromatic sense,* is conveyed by the *way* in which the different skeins are picked up. *For in the very first part of the test if the applicant evinces a manifest disposition to place confusion colors with the light green test skein, though he does not absolutely do so, he has a feeble chromatic sense.* This information is lost if the wools are suspended from a bar and, inasmuch as in such suspension there is an *order of arrangement* that might be known to the applicant and there is also apt to be an insufficient number of skeins, no information may be obtained.

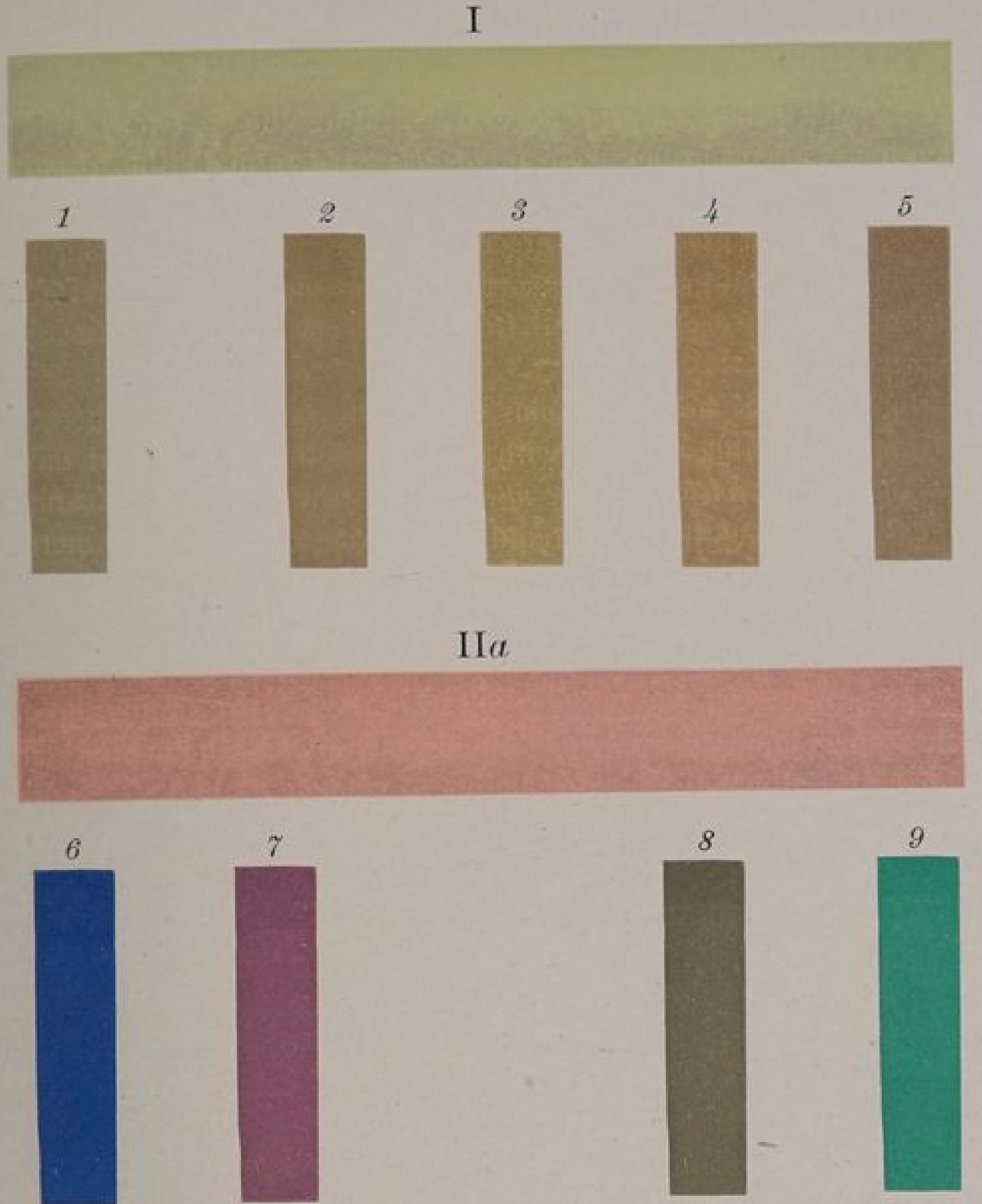
In a set of Holmgren wools there are three large skeins and a large number of smaller skeins. The large skeins are the test skeins, and must always be used in a certain order, the light green skein being *invariably* used first, its proper use constituting the *first test;* the pink (sometimes called purple) skein *invariably* used to make the *second test;* and the red skein to make the *third test.* The small skeins are reds, oranges, yellowish-greens, pure greens, blue-greens, blues, violets, purples, pinks, browns, and grays, with several shades of each color and at least five gradations of each tint and from the deepest to the lighest greens and grays.

But with this heap of skeins of varying colors placed before the applicant on a table covered with a white cloth and in good daylight *not the name of a color should be uttered.* On the contrary the candidate should be told that he is not required to name any color, but merely to pick out a number of skeins that are more or less nearly like the test skein the examiner has placed off some distance from the pile, and to place them beside that skein, that none of the skeins is exactly like any other and that all that are wanted from the pile are simply those like the test skein in its color whether those selected be lighter or darker, but that those about the same or lighter are chiefly desired.

It is necessary for the candidate to clearly understand what is required of him, which is resemblance in color, skeins that are lighter and darker of the *same color* and more particularly those that are as light or lighter, but always of the *same character of color.* If this does not seem to be well understood, the examiner himself should pick out and place by the test skein a number of skeins of the same *color* as the sample, but lighter and rather darker, thus showing in a practical way how the same shade may vary, and then return to the pile the skeins he has selected.

If there are several more at hand to be examined it is advantageous to make this explanation to all at once as it saves time. In the presence of the examiner it is not disadvantageous to have those to be examined watch the candidate under examination as he sorts out the wools, as they thus become familiar with what is required. As after each examination all the wools are again assembled in one pile, each man as he is examined, while more quickly doing what is wanted, will if color-blind perhaps even more readily make the characteristic mistakes than if he had not been allowed to become familiar with the method by watching the others sorting the wools.

Then with the skeins spread out in a pile on the table the test is commenced by the examiner putting the *green* test skein apart from the pile and requiring the candidate to pick out and place beside it the skeins that resemble it, and *especially the lightest shades.* In this test the examiner should state that the deep or vivid shades of the color are not desired, as he should recognize that a very light shade of green has been



Illustrating Holmgren's Method of Testing Color-Blindness and the Mistakes of the Color-Blind.

purposely selected as it is exactly this light shade that the color blind will confound with certain confusion colors, which themselves appear to him as light shades. If the color-blind is allowed in this first test to wander off into the selection of all the greens, he will readily or even intentionally drop into picking out the darker green and *all the time he is selecting them he is away from the dangerous ground where defect would certainly be discovered.* He would also soon include every variety of green and waste much time.

In the plate here given the green test skein is represented by the horizontal band of color designated I and the *character* of its confusion colors are shown as the small vertical bands designated as 1, 2, 3, 4, or 5. The confusion colors as given merely indicate the character of colors the red-green color-blind will select and not by any means necessarily the *identical* colors. The plate therefore merely *illustrates* the characteristic mistakes of the color blind. There is no difficulty here in the test, for the confusion colors do not suggest green in any degree to the normal eye, and are *actually* of the general character indicated.

Neither do the confusion colors as given mean that *all* those variations will be selected, but ordinarily only one or more of that class. Neither by the color-blind need one or more of the confusion colors only be placed with the test skein, for ordinarily other skeins of the same color as the test skein will also be placed with it. The rule is: "The examination must continue until the examinee has placed near the test skein all the other skeins of the same color, or else, with those or separately, one or more skeins of the class of 'confusion colors' (1–5) or until he has sufficiently proved by his manner that he can easily and unerringly distinguish the confusion colors, or given unmistakable proof of a difficulty in accomplishing it."

If this first test be properly conducted every dangerously color-blind individual at the recruiting station will be detected. It is therefore of the very first importance in the combined tests. But the *variety of color-blindness* or *the species of color-blindness cannot be shown by this first test.* If with the test skein the candidate places any of the confusion colors, such as 1–5 of the plate, thinking they resemble the test color, *he is colored-blind and that is all that can be said, for whether he is red-blind or green-blind that first test cannot determine.* And, if he manifests a disposition to place any of the confusion colors beside the test skein, perhaps placing them there and then returning them to the pile or taking them from the pile, considering them, or actually comparing them with the test skein before returning them to the pile, he has a *feeble chromatic sense.* And on the Form X the color perception in such a case cannot be entered as *good.*

There is a great deal of difference in the way different candidates tend to carry out the instructions given them in this test. Some tend to select too many colors, especially picking out all the yellow-greens or blue-greens, while others are very slow to do anything fingering the pile without making selections. In the latter case the candidate is ordinarily looking at the pile without consideration of the test skein and if told to look at the big skein and then at the pile and to repeat that until he sees something in the pile that resembles the test skein he will generally overcome his nervousness.

It may, however, be necessary for the examiner to take up one skein after another and to ask the candidate whether it resembles the test skein. In that case it is best to select at first the confusion colors themselves. If he rejects them he generally has a characteristic smile. If he is color-blind and overcautious, he will also reject some correct shades—a combination not found in a person having a normal color perception. But in all cases where such assistance is given, all the selections should be submitted together to the candidate and he should be asked if he is satisfied or would like to make a change. This is also best in the case of those who have shown a feeble chromatic sense. But those having a normal color-perception very often give more trouble than the *color-blind who generally make the characteristic mistakes without much delay.*

If the examiner feels that he is somewhat inexperienced and is desirous of forming correct conclusions he will gladly resort to the *second test* or the test with the pink or purple skein. And the regulation provides that the second test shall always be applied. *By using the large pink or purple skein as the test skein the differential diagnosis between red-blindness and green-blindness is made in cases found by the first test to be color-blind* or in a case of color-blindness which in the event of a too hurried examination may not have been discovered in the first test. It also is of value if carefully carried out in the detection of a malingerer at training stations or on ships, as in such cases it is impracticable for the *characteristic* mistakes of all the tests to be made without considerable coaching. They will always be greatly inconsistent, as their action is either based upon a general non-recognition of color or on the mere conception that they must appear unable to distinguish any red from any green. They will therefore very rarely make the characteristic mistakes in the first test, but if they should from knowledge of the test make such mistakes they can be expected to mix the forms of color-blindness in the second or third tests. It will not be practicable to arrive at the semblance of a differential diagnosis in their cases, and the conclusion can readily be based upon their glaring inconsistencies.

Recognizing that the *second test is for the purpose of making the* *differential diagnosis between red-blindness and green-blindness* and perhaps also, though unnecessarily if care and skill has been exercised, to act as a check on the first in the discovery of color-blindness at the recruiting stations, the examiner, to comply with the regulations, places the large pink or purple skein off from the pile just as was done with the green skein in the first test. A good attempt has been made to represent the color of this skein in the horizontal band marked II*a* in the color plate, but colors in such plates are necessarily never much more than very useful approximations. The same instructions are given as in the first test, though experience in that test should facilitate the second, and just as the diagnosis of red-green blindness was made in the first test on *confusion colors, so the differential diagnosis between red-blindness and green-blindness* is made in this second test *on confusion colors, each variety having its own confusion colors, the red-blind never selecting the confusion colors taken by the green-blind in this test.*

The character of the confusion colors in this second test are represented in the plate by 6 and 7, or blue and violet, for red-blindness, and 8 and 9, or gray and green, for green-blindness. If, then, the candidate, in picking out skeins which he thinks resemble the test skein, selects with those that do resemble that skein *blue and violet, or one of them*, he is *completely red-blind*, but if he selects *gray and green, or one* of them, he is *completely green-blind.* Not a few of the completely green-blind while selecting gray and green, or one of them, will also select a very *bright blue*, or *violet*, but, notwithstanding that, *if a person in this test selects gray and green, or one of them, he is green-blind* whatever else he may do. The red-blind never select in this test either a gray or a green, and *in their own confusion colors tend, as a rule, toward the deeper shades of blue and violet* (6 and 7), but may select lighter shades.

It is important, however, to recognize that there are many degrees of color-blindness, varying from the complete to different degrees of incomplete color-blindness and grading toward the normal into a feeble chromatic sense, and that the first test or test with the green as the standard skein may, from selection of a confusion color, show color-blindness which in the second test may be too incomplete to bring about the selection of confusion colors or even hesitancy in regard to them. A person, then, who *proven color-blind by the first test, in the second test selects only skeins that resemble the test skein is incompletely color-blind.*

It is also admitted that there are some cases of more marked incomplete color-blindness which in the long series of degrees of incompleteness present variations that make a differential diagnosis difficult or even impracticable. Something more or less definite can often be obtained in those cases by watching the hands and observing tendencies, but in a few the border line between forms is too confused for a satisfactory conclusion as to kind. The first test is, however, sufficient at a recruiting station to determine even a feeble chromatic sense if well applied, and such a case cannot be said to have "good" color perception. And with a confusion color or confusion colors selected in the first test, the examiner will very generally have sufficient confirmation in the second test.

In the *very small* number of cases in which he may still have some doubt, he may not expect much assistance from the third test which is not regarded as at all necessary to the diagnosis, but merely confirmatory of *complete color-blindness.* The third test may nevertheless shed some light on a few doubtful situations. It is also at the *end of the third test* that a trial can be best made to determine whether the applicant is color ignorant and when for the first time the names of colors should be mentioned. In that trial the candidate may be told to put in one pile all the skeins he would call *red or pink,* and in another all those he would call *green.* At a *recruiting station,* any glaring failure, such as a decided green, whether yellowish-green or blue-green, put on the red or pink side, is cause for rejection.

The *third test* or the test with the large vivid red skein is the one the malingerer desires and the one in which the man who has practised himself in distinguishing colors feels most at home. The former usually defeats his object by putting all greens with the red, and the latter, if color-blind, while he *may* keep the greens from the red will *very generally* at least confound green and brown, though not always. This third test, in view of the fact that it involves red and green, is often the most convincing test in the eyes of a parent that a son, who very generally has not been suspected of color-blindness, is actually completely color-blind. To the examiner the test only serves as a confirmation, and, although as a rule the confirmation is obtained, he should never regard the test as of sufficient importance to contradict the determination by the prior tests. The regulations do not require this test to be made.

In the color plate the red skein, which is to be employed as the other test skeins were, is represented by the horizontal band of color marked II*b*, and the character of confusion colors is designated by 10 and 11, or dark green and dark brown, for the red-blind, and 12 or 13, or a lighter green and lighter brown, for the green-blind. In this test the completely red-blind select green and brown that seem *darker* than the red to the normal eye, and the completely green-blind select those that seem lighter, but in each case it is a green or brown or both. *The test is, as a rule, of little value except in relation to the completely color-blind or in relation to the malingerer,* who invariably professes to be *completely* color-blind. In this test, as in the others, in selecting confusion colors the color-blind will also usually select correct colors. The test is continued until the person examined has placed beside the test skein all those that resemble it or the greater part of them or else one or more of the confusion colors.

In connection with these tests *violet-blindness* has not been included because at sea as the running lights are red and green it is negligible. It is not advisable to recognize a defect of that kind, but if blue becomes a confusion color in the first test it may be suspected and if in the second test red and orange become confusion colors, the suspicion may be regarded as a very reasonable one.

Color-blindness may be produced by injury or disease or acquired by excessive use of tobacco, especially when combined with the use of alcohol. In those cases the variation in color-perception is usually confined to only a part of the retina, but it is the central area or that area employed in direct vision. The loss of proper appreciation of color precedes the amblyopia due to tobacco, and therefore raises the question of possibility of undetected color-blindess subsequent to enlistment. These cases may not be detected by the Holmgren test as usually conducted, particularly when the diseased area is confined to a small spot in the retina, the colors being distinguished outside the central area of the retina, but some can be detected by keeping the applicant at a distance from the skeins.

The danger seems small, as defective form-vision is either associated with the condition or follows it relatively soon. The defective form-vision as the result of amblyopia therefore acts as a considerable safeguard. All officers are tested for form-vision and for color-perception at each promotion and enlisted men at every enlistment or whenever promoted to warrant or commissioned grade. It would therefore seem that the danger is fairly well provided against. However, whenever color sense is tested it is well to introduce the element of distance and direct vision to the extent that is practicable by having the pile of skeins between the applicant and the test skein, directly opposite the applicant, some distance away from him, as far as three feet if the size of the table permits.

The candidate should also not be allowed in making his selections to hold more than one skein in his hand at a time, but on the contrary he should be required to toss beside the test skein each skein as it is selected. At a distance of three feet he can show his hesitancy by approximating the doubtful skein to the test skein, and after all selections have been made and during the selecting he will view the result from a distance which, while sufficiently convenient, may itself be the means of disclosing deficiency.

It is not advisable for a man to pick out the colors as if he were myopic to colors or required very close approximation of the colors to the eye before he is certain of them. It is therefore well to have the selections ultimately viewed at about the distance indicated, and as the candidate tosses his selections from the pile he also has in view those skeins already selected, and, as viewed from the distance, he may show tendencies to make changes or actually make them which may be of value to the examiner in showing variations in the appreciation by retinal areas.

In many of the vision test sets issued in our Navy will be found a bound copy of the Report of the Committee on Colour-Vision appointed by the Council of the Royal Society of London. Much additional information can be obtained from that source.

Color-Blindness, by B. Joy Jeffries, is a standard.

There are quite a number who present themselves at recruiting stations without appearing before the medical officer, as they are rejected by the commanding officer for one reason or another as being undesirable or not coming within the regulations in relation, for instance, to the age limit specified for different ratings, to minimum height, to experience or training required for enlistment in certain ratings, and to appearances. The idea is to enlist only those persons who can reasonably be expected to remain in the service, and that idea includes the exclusion of the vagrant and the alcoholic. "No minor under the age of 17 years, no insane or intoxicated person, and no deserter from the naval or military service of the United States shall be enlisted in the naval service."

It is evident that as the period of childhood and the period of old age are those when death is least successfully resisted that there are limits of age without which it is not reasonable to expect the human race to adapt itself successfully or economically to the change involved in the selection of a life at sea, or in the case of a certain maximum extreme to acquire the habits of such a life with a sufficient period of usefulness remaining to warrant the naval service in filling its quota to any extent from that class. Under these considerations, as they have been evolved from experience, no person under 17 years of age is now enlisted in the naval service and no person over 35 years of age is taken for a first enlistment, persons for enlistments in the lowest deck rating, the rating requiring no previous experience and the one in which the majority of first enlistments are made, being between 17 and 25 years of age, and in the rating of coal-passer, the lowest rating in the engineer force, between 21 and 35 years of age.

From a purely hygienic point of view the age of 17 does not seem sufficiently great for enlistment. Everywhere in the service it is noticeable that minors furnish cases of sickness altogether out of proportion to their number. They are not only more subject to mental conditions predisposing to sickness, but they are very much more susceptible to a large number of adverse influences in their environment and are more prone to infectious disorders, such as diphtheria, mumps, and measles, by which even the usefulness of a ship may be limited as well as transfers from one ship or station to another. It is, to say the least, doubtful whether the naval service of minors of *merely average development for their age* and who, it is assumed, at time of enlistment are free from discoverable disease, is worth the price paid by a government in their maintenance when sick, in the payment for services not rendered at that time, and in the payment of resulting pensions that may continue for many years.

These considerations are worthy of notice because they induce the belief that in the examination of minors for enlistment *even* greater caution is necessary than in the case of adults, and the idea of possible great changes in physique as result of future development should be discarded if, at the time of examination, there is absence of the required picture of good health and of the appearance of a vigorous, healthy, and otherwise desirable personality. It was a common experience that, in the required verification of descriptive lists on ships when a draft of apprentice seamen had been received, some would be observed who, in their general appearance when nude, and in their facial expression, bearing, and manner, more than suggested undesirability from a physical point of view as well as a disciplinary point of view.

In the case of adults a degree of variation in weight and chest measurements is prescribed as admissible provided the applicant is active, has firm muscles, and is evidently vigorous and healthy, *except for enlistment in the rate of coal-passer, for which rate full standard measurements are required.* The above considerations in relation to minors have, however, operated to *fix* the minimum requirements in their cases and tend to raise those requirements as exigencies of service permit. At the present time a minor enlisting as apprentice seaman must have at 17 years of age a minimum height of 62 inches and a minimum weight of 115 pounds; at 18 years, minimum height 64 inches and minimum weight 120 pounds, and at 19 and 20 years the same minimum height 64 inches (which is the minimum height of the service at large) and a minimum weight of 124 and 128 pounds, respectively.

In view of the medical history of minors in the service, it should be recognized that in enlisting them there is an important point of view outside of the purely medical. A youngster is more readily molded as, in growing as it were with the service, he is more readily taught. He knows much about the service or has acquired a more or less extensive service education before the adult just starting has acquired anything. The difference is certainly very noticeable, and if there is a sufficient number of reenlistments the gain is very large, as the question of efficient petty officers is intimately associated with the future of minors enlisting. A good seaman is a man with a large fund of information of a special kind, and a good petty officer must not only be a man of really good physique, but also of intelligence and spirit. It would seem that a medical officer in the examination of minors should think of them as probable material for future petty officers.

While fraudulent enlistment, and the receipt of any pay or allowance thereunder, is an offense against naval discipline, and is punishable by general court-martial, the records show that such fraud is perpetrated from time to time. Many of these frauds are in relation to age, and, as minors, under the age of 18 must present consent of parents or guardians to be lawfully enlisted, fraud very commonly results from a minor under, but claiming to be over 18 years of age. In such a case the minor in a physical examination has to come up to the requirement for the greater age and therefore, from the point of view of the physical examination, the examiner is more interested in those minors who not well developed assume ages less than their own. It is also from this point of view that the enlistment of minors increases the difficulties of the examiner and enjoins caution.

The enlistment of recruits results from the concurrent action of the recruiting officer and the medical officer. The recruiting officer concerns himself chiefly with aptitude and character and the medical officer with physical and mental condition. They both want to obtain desirable men and are interested in excluding the alcoholic, the vagrant, and the criminal. When the candidate reaches the medical officer he has already appeared before the recruiting officer and has been considered to meet the requirements as to general fitness, aptitude, and character and to meet the special requirements for the rating for which he has been considered, so far as they may be determined without the physical and mental examinations required to be made by the medical officer. The candidate will, therefore, appear before the medical officer with the rating for which he is to be examined designated and by his appearance it is understood that the recruiting officer thinks him a likely or suitable person.

The regulation that no intoxicated person shall be enlisted may be considered to apply equally to the person of intemperate habits. It is prescribed that no applicant shall be examined unless he is clean and sober. In a physical examination in which as much evidence as practicable is gathered from every available source that may tend to indicate undesirability, cleanliness and present condition in relation to the use of alcoholics are each of much importance. The fact that the applicant is dirty tells much in regard to his habits, and those cases in which dirt is caked on the body are certainly undesirable, as such persons have too many of the characteristics of the vagrant. An appearance of reasonable cleanliness of person and clothing may not be always expected in men who may be temporarily out of work or have recently left work, but in that case the working man can generally give a more or less satisfactory account of himself and generally *considers some explanation necessary*, and his body will not show evidence of habitual neglect.

At permanent recruiting stations there are not infrequently means provided for applicants to bathe when necessary before the physical examination, but persons in ragged or filthy dress or those in clean clothing who are filthy in their persons are not desirable for enlistment. If such men were self-respecting they would not appear in that condition for examination. It is some such idea that is applicable to the man who at examination gives the odor of alcohol, for even though not intoxicated, he induces the idea that he is unguarded in his drinking. He either feels the necessity for the primary steadying effect of alcohol or is ungoverned by proper ideas of his relation to the examination. There is at least a disregard for opinion, a condition of mind that is not promising.

The vagrant tends to try to enlist on the approach of winter. He has no idea of remaining in the service. The chronic alcoholic desires to enlist because he cannot hold a job on shore or because he wants to be taken care of in the sense of being kept away from drink. The naval service is not a reform school, and is not the proper place for drunkards. The drunkard or hard drinker presents certain signs. If at the time he is under the direct influence of liquor, he is of course not examined. But if he is not, the effects of his manner of life are generally in evidence unless his case is one of circular alcoholism, and he is some distance in time from his last spree. In the chronic drinker tremor of the hands is an important sign, and the hands are generally abnormally warm and moist. There may be redness of the eyes and attenuation of the muscles, particularly of the lower extremities where purple blotches may be found. There may be a marked sluggishness of the intellect with or without a bloated appearance of the face upon which eruptions may also be found. The chronic drinker presents a general appearance that may not be easily described, but which is much in evidence to the experienced observer.

The criminal who desires to enlist is anxious to conceal his identity and hopes to lose it in the uniform garb of the sailor man or to be separated by service in foreign parts from an environment in which his liberty or life is endangered. It is generally considered that evidence of a life of crime is marked in the features and person, and such is more or less the case in some professional criminals, but men commit crimes who are not professional criminals and who are nevertheless undesirable persons on a ship, and a number of professional criminals are able to play their selected parts because they have not the general appearance of the criminal type.

It appears, however, that this particular phase of the question has little prominence, as there is no evidence available to show that the recruiting station is utilized in that relation. The identification provided deters the criminal, and therefore the question of identification in the Navy has practically no direct relation to that class. Yet is appears from many points of view that a naval service is interested in the identification of men. One is the early recognition and elimination of those having merely unsavory reputations from a service point of view. In this the entire service should be interested as all are interested in the maintenance of its good character.

In a service having a certain uniform in common, everyone is interested in having that uniform a badge of good citizenship. A man who is not respectable, and yet wears the uniform of respectability, tends to injure the whole service by his acts. Individually, he may be regarded as a trivial affair, but unless eliminated is liable to do much harm to the service as a whole. The entire service, therefore, is interested in that elimination and *in the continued exclusion.* It follows, then, that a navy which by sentence of court-martial or otherwise discharges some undesirable men yearly is interested in preventing those men from reenlisting or from remaining in the service on reenlistment. Such men on reenlisting take other names and their influence is bad from many points of view. It is necessary, therefore, to identify them without delay.

A service is thus interested from much the same point of view in the identification of its own deserters. For a man to desert and then reenlist under some other name is not very uncommon. "No one who has already been in the naval or military service of the United States shall be enlisted without showing his discharge therefrom. Should it be claimed that the discharge has been lost, the circumstances shall be reported to the Navy Department." An enlistment is never terminated without some form of discharge, and men are not reenlisted who have been discharged with a bad conduct discharge or dishonorably discharged, or where the discharge shows that reenlistment is not recommended or where the discharge has been in accordance with report of medical survey. There is, therefore, more or less tendency to destroy undesirable discharges and to take up naval life again as new individuals.

All the foregoing cases come within the scope of a central system of identification, the identification being secured from records made by the medical officer at the recruiting station and kept in the Department. But identifications in large number are required at the places where men may be. The medical officer of a ship is required as soon as practicable after going into commission to examine the men *in order to verify the descriptive lists* as well as to ascertain if all members are physically qualified to perform the duties which will probably be required of them. This verification is not only for the purpose of correcting errors, but also for the purpose of identifying each man as the individual who enlisted. Such verification is made whenever men are received and primarily at the training station or receiving ship.

Identifications are also required at times in connection with injuries that may or may not involve loss of life. A person in the Navy injured on shore and carried to civil hospital may have to be identified especially if unconscious, and the same duty may have to be performed in another case at the undertaker's or at the morgue where there may be no other assistance than that of the descriptive list if the cause of death is drowning. Also in time of war it is quite evident that under many circumstances the question of identification may be of great importance. It is also of importance in relation to claims for pension, in which, however, a doubt may very well come within the scope of central identification.

In view of the above, it is apparent the records made at the recruiting station for purposes of identification should be very carefully made. The whole descriptive list is one such record, and in that list the color of eyes and of hair, the complexion, and personal peculiarities (characteristics, marks, etc.), should be as carefully entered as any other items, such as age, height, and weight. The descriptive list is for purpose of identification on the ship or the place where the man may be, and personal peculiarities should be given to the point of easy identification whenever possible.

These characteristics are generally scars, moles, warts, birthmarks, hirsuteness, a degree of knock-knees or bow-legs, peculiarities of teeth or of eyes, tattoo marks, and the like; but, recently, finger prints have also been made a part of the "Service Record." Marks or characteristics that are visible when clothes are worn are of special value, and description of marks are necessary by *location* and *special character*.

It is always best to also consider as personal peculiarities any defect that may have been considered under causes for rejection but not regarded as sufficient cause for rejection. They not only are often distinguishing marks, but when recorded show that they were noticed. Such entries may also be of great assistance ultimately in aiding a board of survey in determining that tendency to trouble existed prior to enlistment, and *are required to be noted.*

Methods of determining color of eyes, of indicating complexion and of locating and describing marks are given in regulations and instructions that require very careful study for reasonable compliance. There is a very strong tendency on the part of some examiners to be too indefinite in the location and description of distinguishing marks and to be too far away from facts in giving complexion and in stating the color of eyes. In determining the last with *accuracy* a standard eye chart is necessary, and has been recently supplied, in the vision test set, and comparison, with the face of the candidate in the *best daylight available.*

For central identification or identification at the Department or away from the man to be identified there is a combination card, called the Identification Record, on one side of which is the outline figure showing marks and descriptions of them and on the other side are finger prints. Both are records made at the recruiting station by the medical officer. The central identification is made entirely by comparison of finger prints made on enlistment with those that may have been made on a previous enlistment, every new card being classified and search being made for an identical card under that classification. The outline figure or personal description which also bears the recruit's signature merely serves in a confirmatory way and as easily understood evidence to be submitted to those who may have had little experience in the comparison of finger prints and yet may have ultimate decision in the case, as in a court-martial.

As the central identification is made entirely by comparison of finger prints it is absolutely necessary that they shall be *clear*, that the ridges shall be distinctly outlined and that the "*rolled*" *impressions shall be sufficiently large to include all the points needed for accurate classification.* The classification is made at the Department from impressions made at the recruiting station. The impressions are of two kinds, "plain" and "rolled." The latter are made first and are obtained of the thumb and each finger of the right hand and then of those of the left hand, care being taken to have the impression of each finger, as it is made separately, *appear in the space designated on the form for that finger.* The plain impressions are made of the four fingers of each hand simultaneously, and these impressions being necessarily in proper sequence serve as a check on the sequence of the rolled impressions.

The first step in making a rolled impression is placing the *side* of rather more than the last phalanx of the straightened finger on the inked plate with the *plane* of the nail at right angles to the plane of the plate, and *rolling* the finger, with only sufficient pressure to obtain good coaptation, over from one side to the other until the plane of the nail is again nearly at right angles to the plane of the plate. The bulb of the finger will then be facing in a direction the opposite of that at the start. This inking of the finger is directed to the last phalanx, but if the *side* be strictly placed on the inked plate at the start and the finger be evenly rolled it will not be the tip that will be inked, and the inking, as desired, will extend *to the flexure* and *over the ridge surface between the nail boundaries.* It is an impression of that part of the finger that is desired as it contains the points needed for identification.

Many failures are made because the impression does not include that part of the phalanx up to the flexure—the palmar surface and the sides of the finger *between* the tip and the flexure of the last joint. In a rolled impression the *whole* contour of the pattern of the ridges should appear. Therefore, in making the impression on the form provided, the finger should be carefully *rolled* on the paper in the *same manner* in which it was rolled in the inking, the side of the finger being on the plane of the paper and *enough* of the finger to bring the pattern *up to the flexure.* The greater surface obtained in a rolled impression enables a larger number of points for comparison to be selected than in the case of a plain impression.

The plain impressions are obtained simultaneously by simply pressing moderately with the bulb of the four fingers on the inked plate, and with the *plane of the nails parallel to the plane of the plate, the inking to extend to the flexure* and then pressing in the same way on the paper. There is no rolling, but the pattern is in evidence and clearly shows whether the rolled impression of each finger is in its proper sequence.

The plate used in inking is glass, 4 inches wide, 12 inches long, and about 3/8 of an inch thick, set in oak but slightly raised above frame level. The ink is printer's ink supplied in flexible tubes and the roller for spreading the ink on the glass plate is rubber. To secure good results it is necessary to have the plate free from dust, grit, or hairs, or any foreign matter. It must, therefore, as well as the roller be thoroughly cleaned after each day's work, every trace of ink being removed by use of cloth and benzine or even water. In inking, a *very small quantity* of the ink should be used and worked over the plate with the roller until the former is *evenly covered* with the *thinnest film.* The spreading takes some little time and may be facilitated by frequently turning over the roller. It is the *thin* film of ink that gives a clear and sharply-defined impression, and it is under those circumstances that undue pressure will do the least harm. As each finger is rolled and its impression taken a new area of the plate should be employed for the next finger, and when no unused part is readily available the roller should be employed to redistribute the ink.

There is no difficulty in inking each finger separately as the others will be out of the way, down below the level of the plate placed at the edge of a table about as high as the elbow, and the weight of the plate in its frame keeps it steady, but in making the impression on the paper form, the lower part of the *form* must be held out of the way at first and the form must be held steady to prevent blurring. This is all accomplished by the use of a special form holder fastened to the table. The form is held in position with lower end down, by spring pressure, and its position changed by bringing each part of the form into position as required. Thus, after the rolled impression of each finger of the right hand has been made, in the place indicated on the form, the form is moved further through the holder in order to take the impression of the left hand.

Good finger prints will not be made unless care is taken to see at the start that bulbs of the fingers of the recruit are clean and dry. The fingers should also be manipulated by the operator himself, the recruit being cautioned to relax the fingers, and not to attempt to make any pressure. And after the impressions have been made they should be inspected for clearness and proper sequence. A failure in proper sequence of fingers necessitates the making of new prints, but if there is lack of clearness in the impression, or *the rolled impression of a finger does not include the whole pattern,* sufficient space may be found in the form for another impression beyond the unsatisfactory one and within the area designated for that finger. Great care should also be taken to have the additional rolled print of right index-finger, required with the signature, made *immediately* after signature is written.

The pattern made by the ridges and found on the bulb of each finger is either a loop, an arch, a whorl, or a composite. An understanding of what constitutes a loop, an arch, or a whorl enables the taker of the impressions to better recognize whether he has secured all the points needed for accurate classification.

In this connection it is first necessary to understand what is meant by a *delta* or outer terminus and by the "point of the core" or inner terminus. These, as fixed points in impressions, are needed for classification, and are best illustrated by the diagram of a loop, in which the stream of ridges appearing on one side of the impression make a *backward turn* without twist. There is thus a core and one delta. This is shown in the following *diagram,* the ridges that make the backward turn leaving the impression on the same side as that of entrance, and the stream of ridges from the other side of the impression dividing to form a delta and practically *enclosing* the set of ridges that go to the formation of the core. They then necessarily leave on the side opposite or the side from which the core ridges enter and leave, as follows:

The delta is designated by D, and in this case is formed by the bifurcation of a single ridge. If at D instead of one line bifurcating there had been two lines diverging the point or ridge *immediately in front* of the place of divergence would have been the delta. The point of the core is designated by C. There are variations in cores. The core may be a single rod or two or three rods or a single or compound staple.

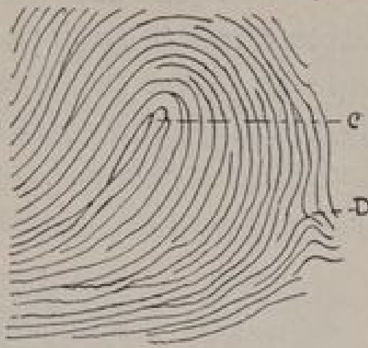


FIG. 97.—Diagram of a loop. (After Henry.)

In all such cases the point of the core is the shoulder of the staple farthest from the delta.

In a loop, a straight line is considered to be drawn between the delta or outer terminus and the point of core or inner treminus, and with the aid of a hand-glass a count is made of all the ridges that would be actually crossed by such a line, the delta and point of the core not being counted. In the diagram, for example, the count is 15. In addition to this ridge counting there is in the identification a study made of ridge characteristics in the way of bifurcations, islands, abrupt terminations and the like. It is quite evident, then, that in taking these impressions the delta *must* be included as well as the core, and the ridges must be clear. As loops are also classified as ulnar or radial according to the direction of the downward slope of the ridges forming the core, being ulnar if in the direction from thumb to little finger and radial if in the direction from little finger to thumb, the slope being therefore opposite in the two hands, it is also quite evident that the stream of lines to the flexure of the joint should be included. This is of even greater importance in a close classification and comparison of arches and whorls.

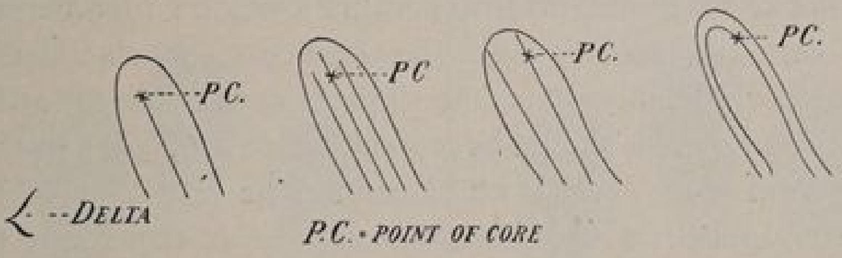


FIG. 98.—(After Henry.)

In an arch the stream of ridges comes in on one side and goes out on the other without backward turn as in diagram No. 99.

There is then no delta. When the ridges, toward and in the middle, have a sharp upward thrust as toward the formation of a defined core, the arch is called a tented arch. In such cases there may be the semblance of a delta, but such an appearance is negative by the fact that there is no intervening ridge. Ridge counting is not practicable.

A whorl is formed when ridges make complete turns thus forming circles or ovals as in diagram No. 100.

The core may be single or double and there are two deltas. The whorl may also be in the form of a spiral.

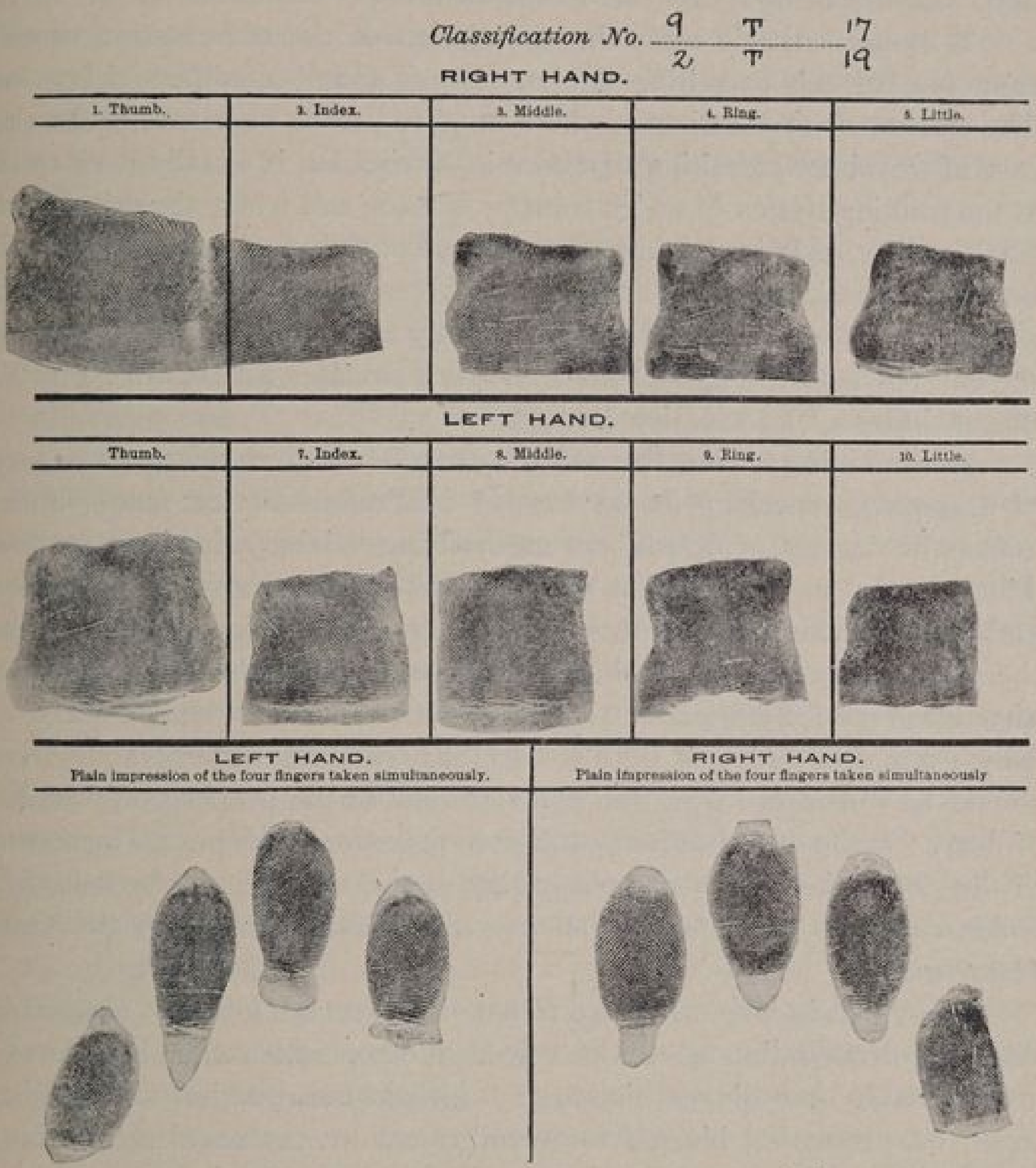
The accompanying plate is intended to be a reduced illustration of finger prints as made in the service. In this case the thumbs, middle and little finger are loops, the index-fingers are tented arches, and the ring-fingers are whorls. If comparison be made between rolled impressions and plain impressions of the four fingers taken simultaneously, it can be readily seen that the rolled impressions are in proper sequence. In the classification, the ridge counts of the little fingers are 17 and 19, the T/T shows that the index-fingers are both tented arches, and the 9/2 is a fraction evolved from a fixed but arbitrary value assigned to different fingers showing whorls, and used to make the primary or case classification. All the loops on the plate are ulnar, the slope in each being toward the little finger of its hand. This should be represented in the right hand by ╲, and in the left hand by ╱. The whorls should be indicated by W. Such marks are not made at the recruiting station as there only the finger prints are obtained. They serve, however, to show how the classification depends upon complete and *clear* finger prints.

FIG. 99.—Diagram of an arch. (After Henry.)

FIG. 100.—Diagram of a whorl. (After Henry.)

In the plate a number of *creases* not associated with the flexure will be noted as white lines crossing ridges. Creases on the bulbs may be very temporary or they may be characteristic. Sometimes they depend merely upon the fingers or plate not being clean, or the fingers not being dry. Generally, they are actual creases which, however, may not show again in a print taken some weeks, months, or years later. But the characteristic ridges will be there unchanged. Many of the creases shown in the plate happen to be permanent and would be found of value as characteristics. But it is one of the cautions not to place much reliance upon creases in comparing duplicate impressions. Yet two impressions of *manifestly* the same creases aid the eye. Creases should not be confounded with scars. In the last there is displacement of ridges due to their division.

It is not advisable in relation to recruiting to take up ridge counting, ridge characteristics, ridge tracing, ridge photographing and enlarging—



Classification No. 9 T 17 / 2 T 19

RIGHT HAND.

1. Thumb.	2. Index.	3. Middle.	4. Ring.	5. Little.

LEFT HAND.

Thumb.	7. Index.	8. Middle.	9. Ring.	10. Little.

LEFT HAND. Plain impression of the four fingers taken simultaneously.	RIGHT HAND. Plain impression of the four fingers taken simultaneously

FIG. 101.—Illustration of finger prints (reduced).

and altogether the remarkably complete method of identification evolved from finger prints. If the method is properly employed the chance of error is absolutely negligible. If there be any such chance it entirely disappears under the collateral evidence available in the form of descriptive list and outline figure card. The service is collecting about 20,000 cards of finger prints a year and the method of identification has been of great value in preserving the good character of the service. It is a method which all that is good in the service should greet with welcome. It is only the undesirable man who fears service identification and the taking of finger prints will only deter the man who has something to conceal. In hygiene a human being must be considered in his social relations as well as in relation to the natural conditions surrounding him. Health of body has relation to cleanliness of mind.*

It is immediately after the completion of the examination of the candidate at the recruiting station that if found qualified either for first enlistment or reenlistment he is required to be vaccinated. In the case of travelling recruiting parties this vaccination is usually performed at the training station to which transfer is made and where the descriptive list is verified. It is provided that in case of failure the operation shall be repeated until the medical officer is convinced that the person is protected. The "Service Record," recently adopted, which accompanies the enlisted man throughout his enlistment contains a "Health Record" that includes a "Vaccination Record."

In examining for reenlistment the examiner is given a larger measure of discretion, especially in the case of continuous-service men. Some defects or degrees of defects are naturally associated with long service. There is also in this relation the fact that a defect incident to service and disqualifying for reenlistment makes a claim for pension. But there are many defects not incident to service, and the main question after all is service efficiency. A person for reenlistment should be carefully examined and any defects carefully entered. Then the defects should be considered from the point of view of the proper performance of duty. Is the defect serious enough to prevent the proper performance of duty? If there is even a reasonable doubt, there should be rejection *under recognition of the fact that the case will be finally decided by the Navy Department.*

Every person who, upon expiration of enlistment, holds an honorable discharge or a continuous-service certificate upon which there is indorsed an honorable or ordinary discharge, with recommendation for reenlistment, on presenting himself for reenlistment at any naval rendezvous, or recruiting ship, or on board any cruising ship not in the presence of a rendezvous or receiving ship, within four months from the date of his discharge as shown thereon is immediately reenlisted provided he is physically qualified. But should he be found physically disqualified for reenlistment a copy of the record of his medical examination is for-

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*For additional information reference is made to Classification and Uses of Finger Prints by E. R. Henry, C. V. O., C. S. I., to which acknowledgment of indebtedness is here made.

warded immediately to the Navy Department *with the recommendation of the medical and commanding officers.* This record as sent to the Department constitutes the report of physical rejection and is made primarily by the medical officer on a prescribed form *whenever he rejects a candidate for reenlistment.* This is an invariable part of the routine in such cases. But in that report the medical officer has to make a *definite* statement of cause of rejection, and whether he *does* or *does not* recommend the reenlistment. For instance, in giving cause it is not sufficient to use such a general expression as "defective vision" but the degree of visual acuteness in each eye must be stated, and whether an error of refraction or an incident of disease. In all cases the information should be as definite as practicable.

In deciding upon the character of recommendation to be made, condition is the prime factor, but *length of service* and *medical history during prior enlistment as shown on the continuous service certificate or discharge are worthy of much consideration.* Every man examined for reenlistment has a discharge in some form. On that discharge the percentage of time on sick list during the prior enlistment is given, and also whether the medical officer who examined at time of discharge considered the man physically qualified for reenlistment. It is, therefore, very advisable to consult the discharge in every case examined for reenlistment, and to elicit from the candidate the medical history to account for the percentage of time he was on the sick list.

The examiner should, however, recognize that the responsibility in relation to the physical condition is with him and not with the medical officer who made examination at time of discharge, and if he entertains merely a reasonable doubt it is best to reject and recommend waivure. It is, however, necessary to recognize that any man recommended on his discharge for reenlistment by his commanding officer and capable physically of giving efficient service has a certain valuable ability evolved from years of service that should not be lightly considered in the presence of certain defects which, while they might cause rejection for original enlistment, are frequently found in men undergoing their second, third, or fourth enlistments and are not necessarily cause for rejection.

In examining discharges it is well to keep in mind the possibility of erasures. The medical officer who examines at time of discharge should give such information on the discharge as may be of value to the medical officer who may examine for reenlistment, but the intended information will only be misleading if even by a simple erasure a negative statement is converted into a positive one. Whenever a person is discharged upon recommendation of a medical survey the discharge shows that fact. When any enlisted person is dishonorably discharged, discharged for bad conduct, incompetency, inaptitude, or as an undesirable person for the naval service, or deserts, a report thereof, *with his complete descriptive list,* is sent to all receiving ships and naval recruiting rendezvous. These are other occasions when identification by descriptive list is of value.

It has become quite apparent that considerable written work is associated with each physical examination. This is provided for by a number of forms of which Form X or the abstract of persons examined, is the parent form. On that form data is entered primarily of all persons examined, whether accepted or rejected, and ordinarily only in case of any acceptance or in case of rejection for reenlistment are subsequent forms made out, and in the latter case only the rejection report is required until special instructions are received.

Occasionally when enlistments are greatly desired for some special rating, as, for instance, for that of bandsman, a rejection report may be forwarded even on rejection for first enlistment when the cause of rejection applies under general instructions, but is regarded as of greatly diminished value in view of special duty to be performed. For instance, an otherwise very desirable man for bandsman may be below the standard of visual acuteness and yet have vision wholly corrected by glasses and be an efficient man for a rating for which there may be difficulty in securing skilled men. A rejection report simply transfers a case to the Department for special consideration. Rejection reports also at times grow out of special instructions for them to be made out and forwarded in cases of complaint to the Department by persons who think they should not have been rejected. To properly provide for such a contingency, and for other reasons, it is necessary for Form X to clearly show all causes of rejection. A medical examiner as well as the service at large are in no small degree dependent upon the accuracy and completeness of written work.

The records to be made by a medical officer in examinations for enlistment are declared by a navy's regulations including the instructions that appear in print on the forms themselves. Each form, therefore, becomes the object of special study, and with regulations and instructions issued from time to time gives the information desired. It would therefore be useless here to take up in detail a subject in regard to which there are such well-defined sources of information always available.

However, it may be well to recognize that the Form X of our service has a double function as a form. It is used primarily as the record of examinations that remains at the recruiting station, while all the other forms, made out as incident to the examination of an individual, leave the hands of the examiner. But this Form X also contains the data from which the examiner makes out the regular Medical Department return of examinations. Such a return is made from shore stations, receiving ships, and recruiting rendezvous quarterly, and from cruising ships on January 1, or at the end of cruise, and is made by using the same blank form. The Form X remaining at place of examination necessarily contains the names of the examined in the order of examination, while the Form X utilized in making the return contains the same names arranged alphabetically. It is the only form relating to recruiting that does not pertain to only one individual. It is a record of all the individuals examined and, as utilized for a return, with all names arranged alphabetically, including the accepted and the rejected, with all persons whose disabilities have been waived by the Department appearing as rejections, the waiver being indicated in red ink. It passes into the records of the Bureau of Medicine and Surgery. This waiver indicated in red ink with date of order and with statement of defect also appears on the "Descriptive List" of the "Service Record" that follows the man. The last, being in pamphlet form, contains ample space for a "Health Record" which accumulates as the man is transferred.

The record on Form X is always made, and if the candidate is accepted then immediately the duplicate descriptive list is entered on the form called the "Service Record" which is sent to the commanding officer who completes and forwards, and with it is also the "Identification Form" (finger prints and outline figure). If the enlistment was in the hospital corps, the medical officer has also conducted the professional examination and in addition makes out an "Examination Report."

If the candidate was rejected for first enlistment no record is ordinarily made except that on Form X, but if the rejection was for reenlistment a "Report of Rejection" is always immediately made, and then if the enlistment is authorized the additional forms are completed as if there had been acceptance, only the fact of waiver is shown in red ink on the descriptive lists of "Service Record" and on Form X, where, however, the record is retained as a rejection for statistical purposes. Also in all cases where enlistment is authorized after rejection a "Report of Waiver" is made by the examiner.

Little has appeared here in regard to standardization of the recruit by measurements in pounds (weight) and in inches (height, chest, etc.). The attempt has been made to keep the subject a practical one from the point of view of the examiner operating under a navy's regulations in the construction of which he has had no part. The examiner works under regulations issued for that very purpose and cannot find in the measurements themselves a cause for rejection when the recruit comes up to those prescribed. And this chapter has been directed for very good reasons more toward the standardizing of the examiner than of the recruit.

Medical surveys for causes prior to enlistment are very generally for other causes than poor physique as declared by measurements. The causes generally leading to those surveys have been declared, and few of them would have been disclosed by use of tape line and scales. The examiner who does not look for the position and character of apex beat, who does not endeavor to account for its displacement, who does not recognize a heart murmur or know the interpretation to be placed upon it, who does not recognize the difference between the heart flurried by the examination and the heart operating under an hypertrophy, and who, for instance, overlooks a disabling varicocele, a spinal curvature, a defective vision, an old gonorrhœa, flat feet, color-blindness, defective teeth, ankylosis, an otitis media, and the appearance of an impaired general health, or apparent tendencies to disease, is much more worthy of consideration than the recruit himself in relation to measurements.

Yet there is no disposition to decry anthropometric tables as one means to an end. The difficulty at the start is in relation to the tables themselves, which, to be of value, must be constructed from the particular homogeneous material in relation to which they are to be used. Percentile tables evolved from measurements of college students cannot be properly used in relation to individuals presenting themselves at recruiting stations. In such tables comparison is properly made between persons of the same age and in relation to certain items of measurements as height, weight, and girth of chest and various parts. They, however, include variations of type without distinctions, as the short body with long legs or the long body with short legs, and then attempt a line or graphic relationship between, for instance, height and girth of chest, which thus makes a more or less unmathematical relationship between things more or less unrelated.

Nevertheless, a percentile table of some value, based upon ages and evolved from measurements made during the large number of examinations of which there are records in a navy, could be constructed and such tables could be utilized to place with some approach to accuracy the percentage position of each candidate for enlistment in relation to others of his own age and class. He could be said to be in a certain percentile grade, and thus could be used a sliding scale, a lower or higher percentile grade being employed as a minimum in accordance with the requirements for men, the widest variation resulting from peace and war.

For there are times when recruiting has to be conducted anyhow on a sliding scale, the bars being sometimes higher and at others lower. And even in time of peace there may be sources of trouble found in lowering bars during service expansion even when there is no apparent lowering of standards in measurements, for the very hurry in getting men begets a tendency to carelessness in their selection—the multiplication of examiners and the rapidity of examinations tend to lower the standard of examiners which is of even more importance than lowering the standard of the recruit.

The following is the table of physical proportions for height, weight, and chest measurements of adults utilized in our service to show what is regarded as a fair standard, but not put forward as an absolute guide to be followed in deciding upon the acceptance of recruits:

Height	Weight	Chest (Mean Circumference)
Inches	Pounds	Inches
64	128	33
65	130	33
66	132	33 1/2
67	134	34
68	141	34 1/2
69	148	34 3/4
70	155	35 1/4
71	162	36
72	169	36 1/4
73	176	36 3/4

These measurements all relate to the individual when nude, and it will be seen that 64 inches is the minimum height, and that up to and including 67 inches the weight in pounds is twice the height in inches. Above 67 inches the weight in pounds is twice the height in inches plus 5 pounds for each inch above 67. For instance, the weight at 68 is $68 \times 2 + 5 = 141$, and at 69 is $69 \times 2 + 10 = 148$, and so on. But in the instructions it is now prescribed that a variation not exceeding 10 pounds, *not to fall below* 128 *pounds in weight*, or 2 inches in chest measurement below the standard given in the table is admissible when the applicant for enlistment is active, has firm muscles and is evidently vigorous and healthy, *except for enlistment in the rate of coal-passer, for which rate full standard measurements will be required.*

Therefore, in practice the admissible reductions apply chiefly to enlistments in the rating of apprentice seamen, and the large majority of enlistments are made in that rating at an age not exceeding 25. As thus applied there is then also a relation to age. It is, however, the adult age most prone to the development of tuberculosis. Therefore, in making the reductions, the appearance of the tuberculizable type should always be in mind, and the stated precautions given full weight—active, firm muscles, and evidently vigorous and healthy. However, recent instructions include the very important provision that the *minimum weight* for acceptance of a man shall be 128 pounds.

There is no doubt that a navy should prefer to keep to the table of standards as a minimum, but it is evident that the variations permitted have been evolved from experience in relation of number of men required to number of men obtainable under standards. In practice, therefore, the variations within prescribed limits have to come after all under the judgment of the examiner and to *depend upon his being up to standard.* And that would be the case with any kind of table. Excess of weight is also often of importance, especially above thirty years of age, although it is not recognized as a cause for rejection unless the applicant is positively obese.

The mean circumference of chest as the expression is employed in the table is to be determined with the applicant nude, as in the case of weight and height, and standing naturally. The tape line is then placed snugly and evenly on the skin at *the precise level of the nipples.* It is held so that the slack can be entirely taken up during forced expiration and the measurement then taken with the tape still evenly applied at the level indicated. The chest is then expanded by forced inspiration and the measurement made with tape still evenly applied at the level. The difference between the measurements, as indicated by the increased amount of tape in inches required in full inspiration, is the expansion—an item required to be entered on Form X—and half the expansion added to the measurement at forced expiration, gives the mean circumference. The result is the same as half the sum of the measurements or half the expansion subtracted from the maximum measurement. A chest expansion of less than 2 inches in a minor or less than 2 1/2 inches in an adult is a stated cause for rejection. Those are small figures. The expansion should be full and free and the examiner should carefully scrutinize a chest that does not appear to him to be performing in that way.

There is a marked difference in these measurements as made by different examiners, and such must be the case if they are not carefully made and at the same level. Contortions of the body are also often utilized by candidates to increase expansion and should not be allowed. Some of the increased expansion obtained from men who, in connection with gymnastic work, are seeking an increase is due not to actual increase in lung expansion, but to practice in which they have learned to bring additional muscles into play together with a sudden change of position, or relation of shoulders to chest that rather represents more knowledge of how to disturb the tape than increased ability to actually expand the lungs as the result of exercise.

Perhaps more than 50 per cent. of those actually examined by the medical officer for first enlistment are rejected. Of the total number so examined at least 10 or 11 per cent. are barred from the service by reason of defective form-vision. Thus, about 25 per cent. of those rejected for physical disability are either color-blind or have a degree of form-vision in at least one eye that is less than 15/20. The number rejected by the medical examiner is far from the total number rejected, for it is quite common for applicants to leave recruiting stations without undergoing the physical examination, being considered for one reason or another undesirable by the commanding officer or, knowing themselves to be below the requirements in physique, declining to take the medical examination.

It appears that during the fiscal year ending June 30, 1908, there were 81,442 applicants for enlistment in the Navy. Of those, 29,919 were rejected for physical disability and 21,462 were found physically qualified and were enlisted, but 26,242 were rejected for other causes than declared physical disability. Thus, there were 56,161 applicants rejected out of 81,442, or nearly 69 per cent. It is true that of those rejected the disqualifications were waived in 467 cases, and thus 21,929 were actually enlisted, but the number of waivers affects the percentage of rejection but little. Of the number enlisted 17,852 were first enlistments and 4,077 were reenlistments, the number of reenlistments being 57 per cent. of those entitled to reenlist. In general, it may be said that of all who try to enlist about 32 per cent. succeed.

SECTIONS OF A BATTLESHIP*

WITH THE PARTS NUMBERED AND NAMED

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* These four plates are reduced *sections* of a Battleship Chart.

REFERENCE LIST OF PARTS

1 Fore stay.
2 Union Jack.
3 Jack staff.
3A Main deck.
4 Halyards.
5 Bower anchor davit.
6 Bower anchor cat falls.
7 Sheet anchor davit.
8 Sheet anchor cat falls.
9 Awning stanchions.
10 Companionway to crew's wash room.
11 Bitts.
12 Hawse pipes.
13 Bower anchor.
14 Sheet anchor.
15 Torpedo hatch.
16 Deck chocks.
17 Companionway to gun deck.
17A Railing.
18 Anchor chain.
19 Forward capstan.
20 Windlass house.
21 Forward gangway ladder davit.
21A Barbette—10 inch armor on deck—6 inch armor below deck.
22 12 inch guns.
23 Sighting hoods—11 inch armor.
24 Telescope in sighting hood.
25 Turret hatch.
26 Forward elliptical balanced 12 inch turret, 11 inch armor.
27 Recoil chambers.
28 12 inch gun mount.
29 Breech of 12 inch gun.
30 Electric rammer.
31 Companionway to gun deck.
32 12 inch turret ladder.
33 12 inch ammunition hoist track or runway.
34 Electric motor for turning turret.
35 Turning gear.
36 Electric 12 inch ammunition hoist.
37 Elevating gear for 12 inch guns.
38 Cable for 12 inch ammunition hoist.
39 Door to superstructure.
40 Decklights in superstructure.
41 Conning tower, 9 inch armor.
41A Conning tower shield, 9 inch armor.
42 1 Pound rapid fire guns.
43 1 Pound rapid fire gun shields.
44 1 Pound rapid fire gun mounts.
44A Superstructure deck.
45 Skylight over crew's galley.
46 Trunk to dynamo room.
46A Companionway from main to superstructure deck.
47 Ladder to forward bridge.
48 Forward bridge.
49 Chart room.
50 Commanding officer's room.
51 Railing on forward bridge.
51A Bridge deck.
52 Pilot house.
53 Ladder to upper bridge.
54 Railing on upper bridge.
54A Controller for Ardois signal lights.
54B Controller for truck signal lights.
55 Steering wheel, binnacle, etc., in pilot house.
56 Ship's bell.
57 Search lights.
57A Steering wheel on upper bridge.
57B Binnacle on upper bridge.
58 Brackets supporting lower fighting top.
59 Lower fighting top.
60 Foremast.
60A Mainmast.
60B Ladder inside masts to fighting tops.

61 Heavy 1 pound automatic guns.
62 Brackets supporting upper fighting top.
63 Upper fighting top.
64 1 Pound rapid fire guns.
65 Ladder to search-light platform.
66 Search-light platform.
67 Fore topmast.
67A Main topmast.
68 Lower signal yard.
69 Signal halyards.
69A International code signal, "PYE,"
69A "We can defend ourselves."
70 Lifts for lower signal yard.
70A Speed cone, "Full speed ahead."
71 Fore topmast shrouds.
72 Upper signal yard.
73 Outrigger for Ardois lamps.
74 Lifts for upper signal yards.
75 Truck lights.
75A Semaphore signal system.
76 Man-of-war pennant.
76A Rear admiral's flag.
77 Signal gaff.
78 Ardois signal lamps.
79 Braces for upper signal yards.
81 Braces for upper signal yards.
80 Braces for lower signal yard.
82 Braces for lower signal yard.
83 Smoke pipe.
84 Smoke pipe.
85 Smoke pipe.
83A Ladders on smoke pipes.
86 Cover frame for smoke pipe.
87 Cover frame for smoke pipe.
88 Cover frame for smoke pipe.
89 Main escape pipe.
90 Main escape pipe.
91 Main escape pipe.
92 Steam whistle.
92A Steam siren.
93 Smoke pipe guys.
94 Smoke pipe stays.
95 Traveler on boat crane.
96 Wire cable for traveler.
97 Boat hoist.
98 Guide sheaves on boat crane.
99 Boat crane.
100 Ventilator for boiler room.
101 Ventilator for boiler room.
102 Ventilator for boiler room.
103 Ventilator for boiler room.
104 Forward 8 inch guns.
105 Crew's galley.
105A Coffee kettle
105B Soup kettle
105C Galley stove.
106 Sighting hood.
107 Sighting hood.
108 8 inch forward gun turret—6 1/2 inch armor.
109 Electric rammers for 8 inch guns.
110 Turret hatch.
111 Elevating gear for 8 inch gun.
112 8 inch gun ammunition carriage.
113 Electric hoist for ammunition carriage.
114 Roller bearings for 8 inch turret.
115 Gear rack for turning 8 inch turret.
116 Companionway from main to superstructure deck.
117 Officers' galley.
117A Galley stove.
117B Galley dresser.
118 Skylight to officers' galley.
119 50 foot steam launch.
120 Life rafts or "balsas."
121 Life rafts or "balsas."
122 36 foot cutter.
123 30 foot cutter.
124 20 foot dinghy.
125 20 foot dinghy.
126 Electric hoist for boat crane.
127 Platform for electric hoist.
128 16 foot dinghy.
129 30 foot whale-boat.
138 30 foot whale-boat.
151 30 foot whale-boat.
130 Hoist for boats.
131 Cargo boom.
132 Hoist for boat derrick.
132A DeForest wireless telegraphy.
133 Electric hoist for boat derrick.
134 Derrick bracket.
135 Search-light platform.
136 Ventilators for engine room.
137 Ladder to after bridge.
138 30 foot whale-boat.
138A Hand steering gear on superstructure deck.
139 After bridge.
139A Signal tower, 5 inch armor.
140 Machinery hatch.
141 Ladder to superstructure deck.
142 After elliptical, balanced 12 inch turret, 11 inch armor.
143 After 12 inch guns.
144 Skylight.

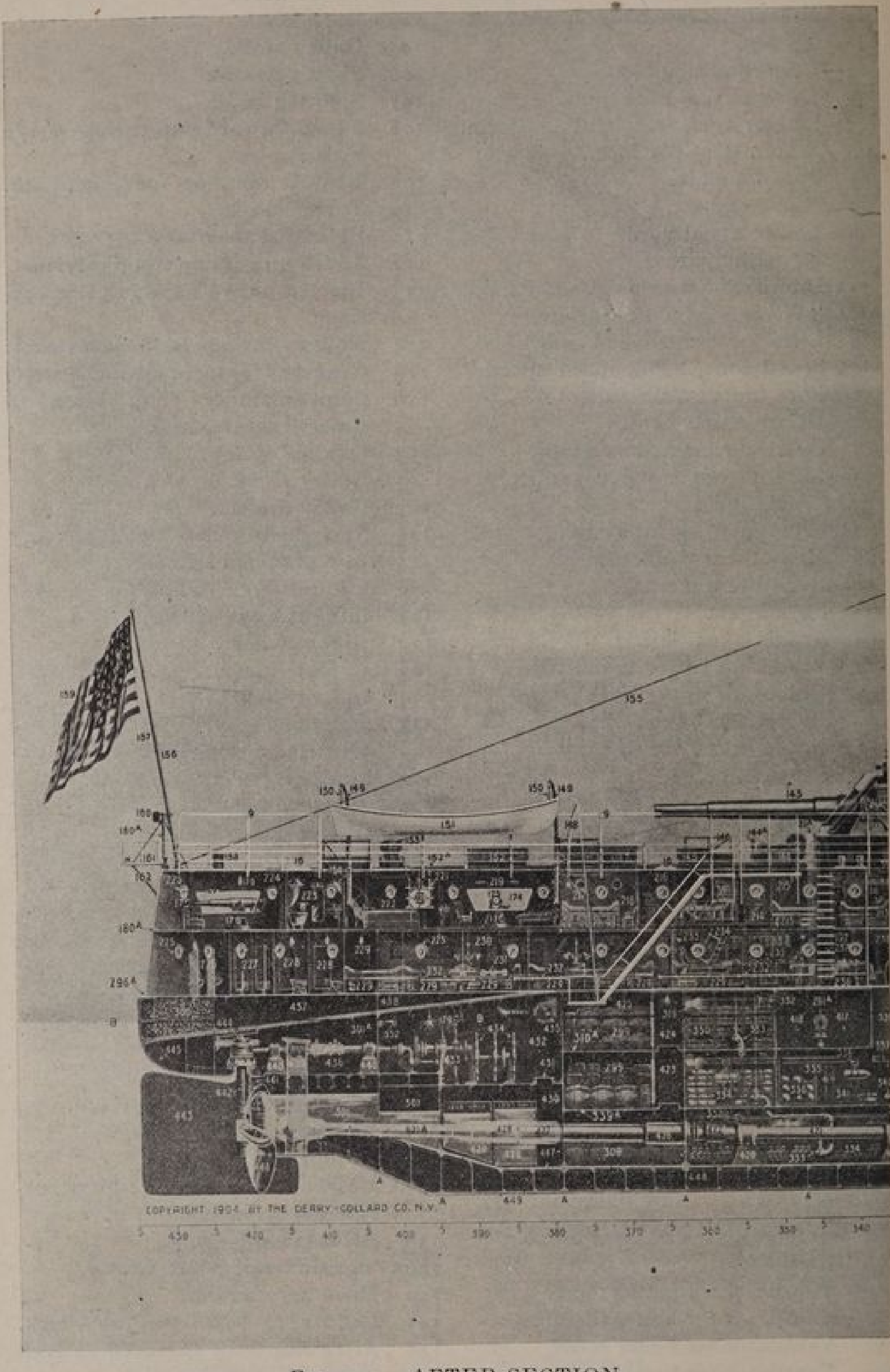

FIG. 102.—AFTER-SECTION.

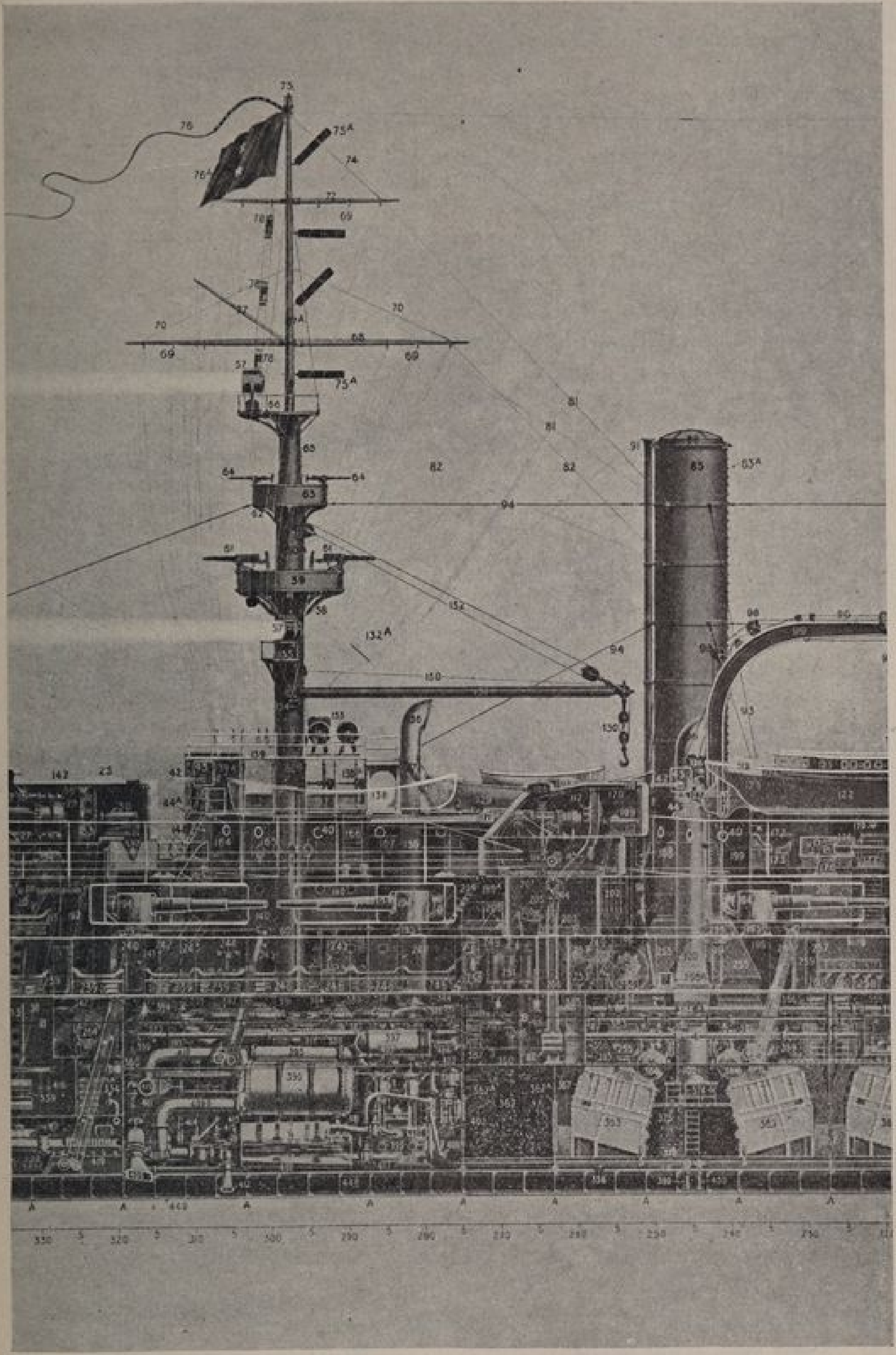

Fig. 103.—AFTER-MIDSHIPS-SECTION.

144A	Electric deck winch.
145	Skylight.
146	Companionway from main to gun deck.
147	Skylight to ward room.
148	After gangway ladder davit.
149	Quarter boat davits.
150	Quarter boat falls.
151	30 foot whale boat.
152	Skylight to admiral's cabin.
152A	Quarter deck, after part of main deck.
153	After capstan.
154	Companionway from main to gun deck.
155	Back stay.
156	Ensign staff.
157	Ensign halyards.
158	Reel for sounding lines.
159	Ensign.
160	Stern light box.
160A	After midship awning stanchion.
161	Sounding platform.
162	Sounding platform brace.
163	Companionway to gun deck.
164	Ward room officers' toilet room.
165	Junior and warrant officers' toilet room.
166	Companionway to superstructure deck.
167	Hammock berthing, or storage.
168	Door to superstructure.
169	Boat chocks.
170	After 8 inch turret; 6 1/2 inch armor.
171	After 8 inch guns.
172	Hammock berthing, or storage.
173	Executive officer's office.
174	3 inch gun ports.
175	3 inch rapid fire guns.
176	3 inch rapid fire gun mounts.
177	Companionway main to gun deck.
178	Hammock berthing, or storage.
179	Electric lights.
180	Crew's shower baths.
180A	Gun deck.
181	Anchor davit shank.
182	Crew's lavatory.
183	Exhaust blower in lavatory.
184	Sheet anchor bill board.
185	Bower anchor bill board.
186	Wash deck gear.
187	Swinging ports.
188	Companionway, gun to berth deck.
189	Windlass.
190	Windlass support.
191	Anchor chain pipe.
192	Turret supports.
193	6 inch guns.
194	6 inch gun shields.
195	6 inch gun mounts.
196	Conning tower tube; 6 inch armor.
197	Vent for wash rooms.
198	Crew's berthing space.
199	Air space.
199A	Barbette, 6 inch armor above deck, 4 inch below.
200	Companionway, gun to main deck
201	Firemen's wash room ventilator.
202	Armory.
203	Electric motor for turning 8 inch turret.
204	Ammunition hoist track for 8 inch gun.
205	Turning gear for 8 inch turret.
206	Hand gear for 8 inch turret.
207	Lower turret handling room.
208	Companionway, gun to berth deck.
209	Companionway, gun to main deck.
210	Roller bearings for 12 inch turret.
211	Gear rack for turning 12 inch turret.
212	Pinion for turning 12 inch turret.
213	Ward room officers' state-room.
214	Toilet room for chief of staff.
215	Upper gangway platform.
216	Admiral's office.
217	Companionway to vestibule.
218	Captain's cabin.
219	Admiral's cabin.
220	Life buoy.
221	Life buoy guard.
222	Admiral's state-room.
223	Admiral's lavatory.
224	Admiral's after cabin.
225	Deck light or air port.
226	Ward room officers' urinals.
227	Ward room officers' closets.
228	Ward room officers' lavatory.
229	Ward room officers' state-rooms
230	Ward room officers' dining room.
231	Mooring shackle.
232	Jack stays.
233	Ward room pantry.

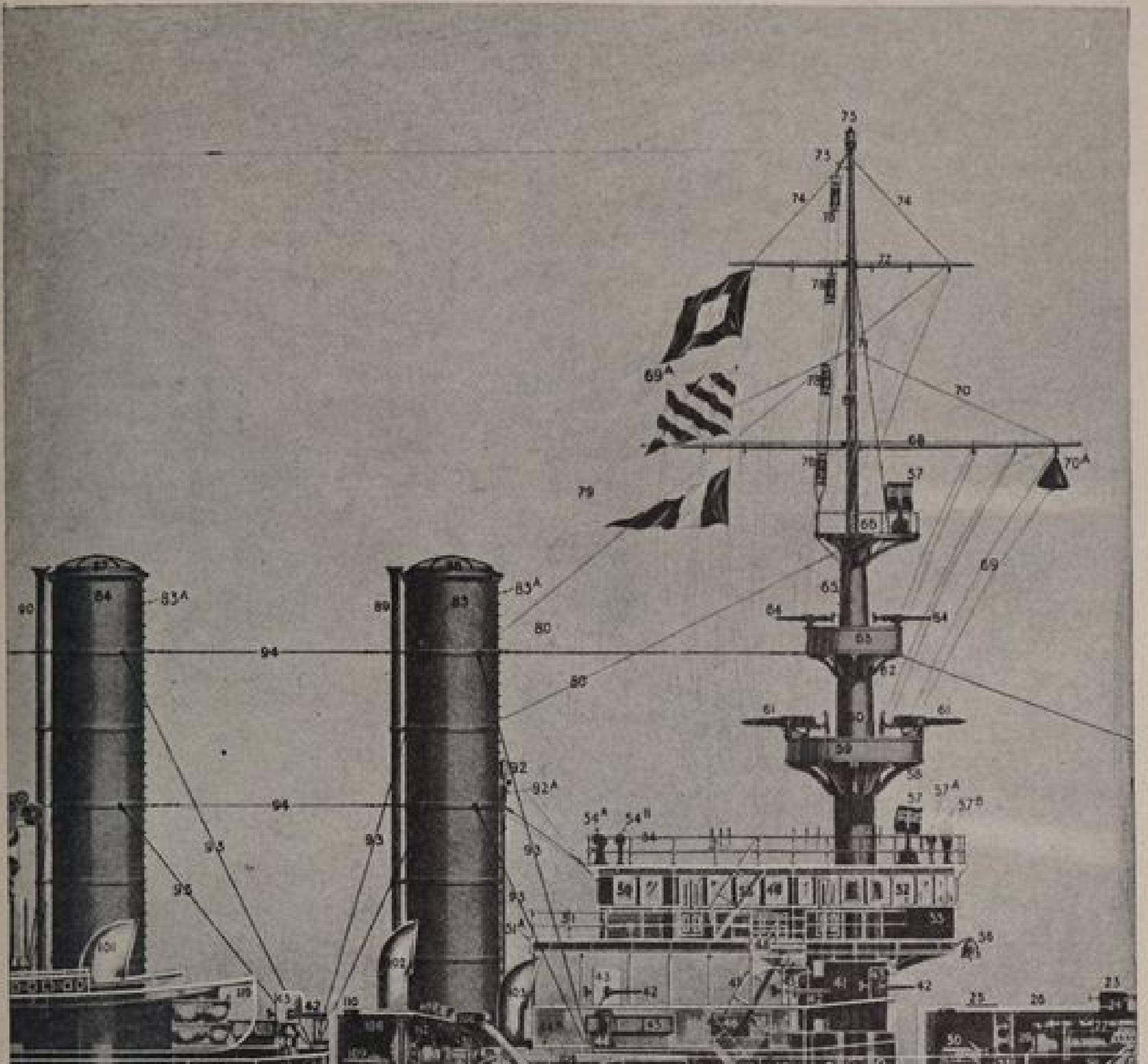

Fig. 104.—FORWARD-MIDSHIPS-SECTION.

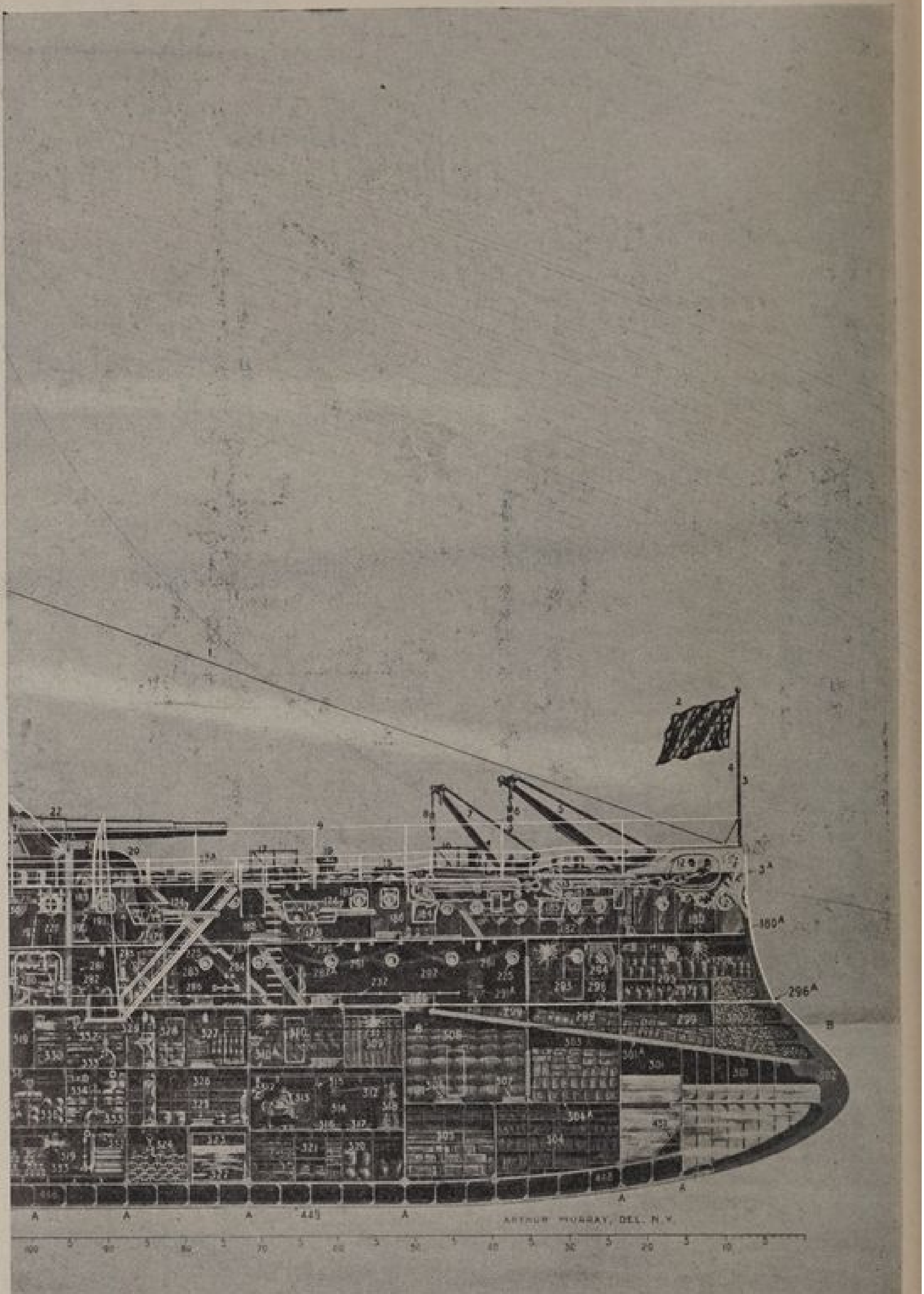

FIG. 105.—FORWARD-SECTION.

234	Companionway from berth to gun deck.
235	Junior officers' pantry.
236	Junior officers' dining room.
237	Sea ladder.
238	Steam heating pipes for turret.
239	Junior officers' state-rooms.
240	6 inch electric ammunition hoist from magazine.
241	Vent from 6 inch magazine.
242	Vent from engine room.
243	Companionway from berth to gun deck.
244	Warrant officers' dining room.
245	6 inch electric hoist from ammunition passage.
246	Warrant officers' state-rooms.
247	Warrant officers' pantry.
248	Door to engine room.
249	Evaporator room.
250	Circulating pump.
251	Distillers; 3,300 gallons capacity.
252	Evaporator.
253	Fresh water, brine and feed pumps.
254	Blower room.
255	Uptakes from boiler.
255A	Ash chutes.
256	Roller bearings for boat crane.
257	Firemen's wash rooms.
258	Wash basins.
259	Firemen's closets.
260	Ladders to boiler room.
261	3 inch gun electric hoist from ammunition passage.
262	Firemen's urinals.
263	Drying room.
264	Blower room.
265	Petty officers' wash room.
266	Laundry.
267	Wash tubs.
268	Ironing board.
269	Steam mangle.
270	Steam extractor.
271	Companionway, berth to gun deck.
272	Petty officers' quarters.
273	Door to machinists' quarters.
274	Printer's room.
275	Band room.
276	Crew's refrigerating room.
277	Captain's refrigerating room.
278	Admiral's refrigerating room.
279	Ice tank.
280	Ice machine.
281	Door to sick bay.
282	Vents from magazine.
283	Windlass engine.
284	Prison, or brig.
285	Shaft connecting engine and windlass.
286	Hatch to hold.
287	Door through armor.
287A	Torpedo directing stand.
288	Hatch to torpedo room.
289	Hatch to hold.
290	Hammock hooks.
291	Crew's hammocks.
291A	Fire hose.
292	Berthing space.
293	Lamp room.
294	Blower in lamp room.
295	Paints and oils.
296	Hatch.
296A	Berth deck.
297	Hatch to stores.
298	Hatch to stores.
299	Stores.
300	Cofferdam, filled with cellulose, for stopping leaks. Extends around ship.
301	Trimming tanks.
301A	Protective deck, 1 1/2 inch on flat, 3 inch on slopes.
302	Ram.
303	Bread and dry provisions.
304	Construction stores.
305	Construction stores.
304A	Forward platform lower deck.
306	Hatches to stores.
307	Hatches to stores.
308	Bread and dry provision.
309	Life preservers.
310	Paymaster's stores.
310A	Lower platform deck.
311	Hatch to torpedo room.
312	18 inch Whitehead torpedoes.
313	Broadside torpedo tube.
314	Compressor room and air tanks for firing torpedoes.
315	Chain hoist.
316	Hatch to torpedo stores.
317	Hatch to submarine mines, etc.
318	Air compressing engine.
319	Magazine lamps.
320	Submarine mines.
321	Torpedo stores.
322	Fresh-water tanks.

323 Anchor gear.
324 Anchor chain room.
325 Hatch to lower hold.
326 Hatch and cable tier.
327 Navigator's stores.
328 Equipment stores.
329 Forward gangway ladder.
330 14 pound magazine, for 3 inch guns.
331 Loading tube.
332 Fresh air to magazine.
333 Stand pipes for flooding magazine.
334 12 inch powder magazine.
335 12 inch handling room.
336 12 inch shells.
337 Ammunition handling track.
338 12 inch trolley and hoist.
339 12 inch ammunition carriage.
339A Lower platform deck.
340 Ammunition handling apparatus.
341 Ammunition handling apparatus.
342 Forward blower room.
343 Controlling panel for ventilating fans.
344 Upper dynamo room.
345 Lower dynamo room.
346 Generators.
347 Engine for generators.
348 Steam to engine.
349 Steam to circulating pump.
350 Main switch board.
351 Exhaust steam to auxiliary condenser.
352 Auxiliary condenser.
353 Circulating pump.
354 Discharge overboard.
355 Suction from sea.
356 Air pump discharge to feed tank.
357 Steam to dynamo room.
358 Exhaust air from dynamo room.
359 Auxiliary exhaust from condenser in dynamo room.
360 Ammunition passage.
361 Railing around generator set.
362 Coal bunkers. These extend across ship and outside of boilers.
362A Water-tight doors.
363 Water tube boilers.
364 Steam drum on boilers.
365 Handling room for 8 inch guns.
366 Blowers for forced draft.
366A Steam to anchor hoist.
367 Forced air draft.
368 Ash pan of boilers.
369 Grate bars in boilers.
370 Tubes in boilers.
371 Fire door of boilers.
372 Ash door of boilers.
373 Platforms in boiler room.
374 Ladders in boiler room.
375 Feed pumps in boiler room.
376 Feed pump suction from bilge.
377 Feed pump suction from auxiliary drain.
378 Feed pump suction from boilers.
379 Feed pump suction from feed tank.
380 Feed pump suction from sea.
381 Safety valves.
382 Steam to evaporator room.
383 Auxiliary steam pipe.
384 Main steam pipe.
385 Main feed pipe to boilers.
386 Machine shop.
387 Ladder to berth deck.
388 Bleeder.
389 High-pressure cylinder.
390 Low-pressure cylinders.
392 Low-pressure cylinders.
391 Intermediate cylinder.
393 Snifting, or back-pressure valve.
394 Steam to low-pressure cylinder.
395 Main exhaust to condenser.
396 Condenser.
397 Feed heater.
398 Feed pump.
399 Air pump.
400 Feed tank.
401 Air pump discharge to feed tank.
402 Hot well pump.
403 Feed pump discharge to feed heater.
404 Feed pump discharge from feed heater.
405 Platform in engine room.
406 Hot well pump discharge to feed pump suction.
407 Air pump suction from condenser.
408 Engine bed.
409 Centrifugal pump suction from sea.
409A Centrifugal pump.
409B Centrifugal pump discharge to condenser.
410 Centrifugal pump discharge from condenser overboard.
411 Auxiliary condenser.

412 Circulating pump suction from sea.
413 Engine frame.
414 Eccentric rods.
415 Connecting rod, low pressure.
416 Door to 8 inch magazine.
417 Door to 8 inch shell room.
418 Door to 6 inch shell room.
419 Thrust bearing.
420 Shaft bearings.
421 Main shaft.
421A Propeller shaft.
422 Shaft coupling.
423 Door to ward room stores.
424 Door to stores.
425 After gangway ladder.
426 Stern tube and out board bearing.
427 Stern tube and out board bearing.
428 Stern tube and out board bearing.
429 Fresh-water tanks.
430 After hold.
431 Hatch to after hold.
432 Steering engine room.
433 Steering engine.
434 Hand steering wheels.
435 Exhaust blower.
436 Steering gear room.
437 Captain's stores.
438 Admiral's stores.
439 Propeller strut.
440 Bearings for steering shaft.
441 Stern post.
442 Rudder post.
443 Rudder.
444 Rudder head.
445 Stern frame.
446 Propeller.
447 Keelson.
448 Inner or double bottom.
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