The human machine in industry / by Richard T. Dana.

Contributors

Dana, Richard Turner, 1876-1928.

Publication/Creation

New York : Codex, 1927.

Persistent URL

https://wellcomecollection.org/works/haxwnv9d

$4

THE HUMAN MACHINE IN INDUSTRY

THE HUMAN MACHINE IN INDUSTRY

BY

RICHARD T. DANA
Consulting Engineer

Mem. Am. Soc. C.E.
Mem. A.I.M. & M.E.
Mem. Yale Eng. Assn.

ASSISTED BY
ARTHUR P. ACKERMAN

CODEX
BOOK COMPANY INC. 1919

NEW YORK

1927

PRINTED IN THE UNITED STATES OF AMERICA

PREFACE

The purpose of this book is to make more readily available those facts which bear upon the capabilities and limitations of mankind for work to the end of promoting the efficiency of Management and the welfare of Labor.

The work here considered is of two general kinds:—mental, which cannot be done otherwise than by the exercise of human intelligence and cannot be measured in foot pounds; and physical, which can be measured in foot pounds and might conceivably be accomplished by animals or machines.

Our present habits of living are the result of inheritance through countless generations of ancestors who acquired these habits under conditions which differed in many respects and in radical degree from those of the last fifty years. Now, very recently, we have been moved to study our living and working habits in the light of present conditions and to apply to our industrial problems the laws pertaining to mental and muscular effort. Many of the possibilities of improving human efficiency were entirely unsuspected before recent years.

The question of how much more hard work a man can do in 9 hours than in 10 would have seemed absurd to the executives of the last generation. We all feel better on a cool, dry summer's day than on a hot, moist one, but we have waited a long time for the inspiration to impel us to evaluate that fact. We always have known that when employees go home sick the employer loses money; but it has taken us several thousand years to find out that much of this illness costs more than its prevention. We in the temperate zone have paid out countless millions of dollars to avoid too much dampness, but almost nothing at all to obtain enough. We have always disliked too much noise, but it is only lately that we have learned to measure its cost in money. Cæsar knew that a tired man worked more slowly than a fresh one, but we are only just beginning to realize how well it pays to keep a man fresh. Now, awakened by the war, we are beginning to use the long familiar facts and find out a few new ones to open a new golden store of living treasure for humanity.

Our general propositions are two: first, if a man is more comfortable he will be happier and will live longer; second, if we properly control the conditions of his comfort, fatigue, and health he will turn out more work at less cost. The first of these propositions we have always known, the second we are just beginning to find out. Of course the propositions are true only between certain limits which vary much among individuals and sets of conditions and which must be known and appreciated in order to apply the principles successfully. The principles are applicable to any business, and their application is certain to be of benefit to any kind of business and to all kinds of men.

The driving force behind the labor unions owes its existence to our first proposition, which owners of capital have too often considered in the light of economically impossible philanthropy. The second proposition, with its limitations, is gaining recognition by employers and is joyfully welcomed by labor at large, which, for the time being at least, is disposed to ignore, or at least to minimize the limitations.

The possession of these facts by business executives, who bear the responsibilities of capital, and by those who think for labor is bound to have a threefold result:—

(1) Increased efficiency in Production,
(2) More prosperity for Labor,
(3) Greater harmony between Entrepreneur and Employee.

At Sea, S. S. Pennland, July 21, 1926. R. T. D.

CONTENTS

The Kata thermometer.—Wind Velocity and Kata Cooling-power.—Influence of Ventilation on Output.—Hot Industries.—Underground Conditions.—Curves Showing Output of Work Done with Hammer and Rotary Machines in Comparison with Cooling Power as Measured by Kata Thermometers.—Effect of Ventilation on Health.—Cost of Artificial Humidification.—Cooling Value of Weather.—Rate of Cooling.—Rate of Heating.—Cooling Effect of Climate on Men at Work and at Rest.—Climate.—Conclusions.

General Phenomenon of Fatigue.—Fatigue Curves.—Hourly Variations in Working Capacity.—Daily Variations in Working Capacity.—Table Showing Percentage Decrease in Working Capacity.—Energy Capacity of Human Machine.—Physiological Character of Fatigue.—Psychological Character of Fatigue.—Causes of Fatigue.—Impure Air.—Unbalanced Food Ration.—Extremes of Temperature.—Mental Effort.—Distracting Effects of External Influences.—Monotony of Occupation as a Factor in Inducing Fatigue.—Speed Hazard.—Vibration.—The Effect of Rhythmic Action on Fatigue.—Results of Fatigue.—Symptoms.—Influence of Fatigue on Young Persons.—Indications of Fatigue.—Measurement of Output—. Amount of Power Used.—Other Indications of Fatigue.—Laboratory Tests of Fatigue.—Carbon Dioxide as Index of Fatigue.—Cubic Centimeters of CO_2 Exhaled per Second.—CO_2 Exhalations of Two Firemen under Observation.—Ways of Reducing Fatigue.—Ventilation of Work Rooms.—Seats.—Adequate Lighting.—Noise and Vibration.—Adjustment of Hours of Work.—Introducing Recess Periods.—Adjusting Speed.—Omitting Unnecessary Motions.—Introducing Variety into Work.—Avoiding Overtime.—Alternating Day and Night Work.—Conditions Outside Factories.—Conclusions.

Rest Problem.—Several Kinds of Rest Periods.—American Experience with Rest Periods.—English Experience with Rest Periods.—Output as Measured by Power Consumption in a Factory.—Output as Measured by Power Consumption in a Factory Where Working Day was Divided into Three Spells.—The Need of Rest Pauses. Economic Duration of Rest Periods.—Benefit Derived from Rest Pauses.—Effect of a 10-minute Rest Pause on Output.—Effect of Numerous Short Rest Pauses.—Effect of a 5-minute Rest per Hour on Output.—Variation of Rest Pause Effect on Different Individuals.—Variation of Rest Pause Effect with Type of Work.—Experimental Investigation of Rest Pauses.—How Rest Pauses Should be spent.—Variations in Output, Adding Figures, With and Without Rest Pause.—Relative Value of Different Diversions During Rest Pauses, Based on Experimental Data.—Occupations During Rest Periods.—Conclusions.

Parties interested in length of working day.—Hours of work vs hours of duty.—Effect of lost time on work schedule.—Difference in effective hours of work for various types of work and workers.—Women engaged in moderately heavy labor.—Table, women turning fuse bodies.—Women engaged in sedentary occupations.—Table, Women milling a screw thread.—Men engaged in heavy labor.—Men sizing fuse bodies.—Youths sizing base plugs.—Men engaged in moderately heavy labor.—Men boring powder chamber.—Men and youths engaged in light labor.—Men, finishing, turning and forming shells.—Table, Youths boring top caps.—Comparison of results.—Comparison of long and short days for women workers.—Summary of output.—Results.—Comparison of last hour's output.—Effective hours of work in various industries.—Limit of practicable work hours.—Night work.—Comparative efficiencies of night and day work.—Advantages of night work.—Objections to night work.—Introduction of night work.—Number of working days per week.—Sunday labor.—Influence of Sunday Labor on Output.—Overtime.—Objections to overtime.—Conclusions.

Comparison of Men and Women in Industry.—Comparison of attendance.—Type of work satisfactorily performed by women.—Occupations unsuited to women.—Methods for improving output of women workers.—Extension of women's industrial work as result of war.—Employment of women in metal trades.—Output of work of women in manufacture of electrical products.—Employment of women on electric railways in England and France.—Objections to employment of women as street car conductors.—Management and supervision of women.—Conclusions of British Health of Munition Workers' Report.—Working standards for women.—Hours of Labor.—Wages.—Working conditions.—Conclusions.

Influence of Age on Employment.—Municipal Day Labor.—Age distribution among Nationalities.—Table, Age group male employees, by nativity and race.—Age distribution of employees in large steel mill by departments.—Table, Computation of age groups.—Table, Expectation of Service from Employees.—Occupational Age Limits for Women.—Age of Female Workers by Industries.—Table, Per cent of total Female Employees in specified age groups, by Industry.—Duration of Industrial Life of Women.—Table, Number and per cent of Female Workers of each specified age.—Proportion of Older Women in Industries.—Number and per cent of Female Workers 30 years of age and over in each specified Industry.—Relation of Age of Workers to Fatigue.—Relation of age of women workers to Fatigue.

LIST OF ILLUSTRATIONS

LIST OF TABLES

THE HUMAN MACHINE IN INDUSTRY

CHAPTER I

GENERAL PRINCIPLES

In the United States, especially in the manufacturing districts, much has been accomplished by way of multiplying human power through mechanical means; so that today the workman has for the reinforcement of his arm an almost unlimited supply of manufactured power costing, per foot-pound of work performed one-half of one per cent of the amount it would cost, if done by his unaided muscles. An even greater economy has been effected in the application of power to functions controlled by women.

These results have been accomplished through engineering methods, not by increasing the efficiency of the human machine itself, but by furnishing it with artificial aids. On the average, man lives a good deal longer now than he used to; but he is physically or mentally no stronger, he has simply a better set of tools.

A quarter century ago, when the epoch-making discoveries of F. W. Taylor startled the industrial world, a great deal of attention was directed toward stimulating the ambition and increasing the voluntary efforts of men, which, perhaps, partly obscured the more complex but not less vital problem of increasing their capabilities.

In the early part of the last century, primarily in America and then in Europe, mankind developed the use of natural resources to such a degree that now the cost of engine power is roughly one-tenth that of horses and one-two hundredth that of men, and, as a result of our industrial organization, the American workman has at the turn of his hand a practically unlimited supply of this power. Fifteen million American homes have electric light and electric-driven appliances; the power of forty million horses in the mines and factories is at the service of the mechanics of the country. In spite of the rising tide of general prices since the war, the cost of electric lighting current has remained practically constant since 1913, and the cost of lighting has continuously and largely declined for forty years. These facts are significant of enormous development in civilization, in the personal comfort of the general population, and in man's ability to make the earth yield him a living and still have enough left for comfort. The farmer's wife to-day in these United States has more real living comfort than Queen Elizabeth's court in the 16th century.

While all this has been accomplished in an engineering way, by the application of the forces of nature to the problems of industry, comparatively little has been done toward the improvement of the human mechanism itself. Physically, we are no better than our grandfathers, though we have learned to live longer by controlling disease. Mentally, there seems to be no evidence that we are a bit better than the early Greeks, whose industrial labor was mostly by man-power. There is, however, the necessity for constant use of all the human power that we have, and this power is costing relatively more and more as we succeed in cheapening power from other sources. Since it already costs two hundred times as much as engine-power, it is two hundred times as important to conserve it properly in order to apply it effectively. To this end comparatively little had been done up to the middle of the great war.

Since then a good many facts have been ascertained, a knowledge of which is extremely useful in directing human activities of any kind whatsoever. They ought to be known to all persons in an executive capacity at least, notwithstanding the fact that much of our information is yet fragmentary, and in some respects so indefinite as to be a reproach to our boasted science. As an illustration, take the rest problem. We know that for the most effective work we need rest periods and that the number and duration of these are some function of the character and intensity of the work. Since there are so many kinds of work to be done, it follows that an adequate solution of this problem involves the collection of a tremendous quantity of data, and the application thereof to subjects who are highly variable, and who work under highly variable conditions. This explains why we have not, as yet, got a categorical solution of the problem for many of our cases, but it does not justify anyone to whom the problem is of major importance for remaining in ignorance of the available facts. Many of these are in the files of the technical publications of the last few years; some of them came out in 1918 in the admirable little book by Professor F. S. Lee, entitled "The Human Machine and Industrial Efficiency". Many of the mechanical data are given in "Le Moteur Humain", by Jules Amar, Paris, 1923; still others are in the files of various corporations and generally unknown or otherwise unavailable. New facts on this subject are coming to light with increasing volume, and helping toward a proper appreciation of the old ones, to the end that we may confidently look forward to a near future wherein we shall make better use of our resources of brain and brawn.

The comparison of man to a machine, while very suggestive in some respects, is not quite parallel in others mainly because of two characteristic differences. A machine has no emotions, and is not subject to fatigue, whereas in these two respects mankind is singularly frail. Until the Great War there had been comparatively small progress in the study of the effects of fatigue and the working capacity of men and women, and it has only been within a short time that attention has been called, in anything like a general way, to the intimate relation existing between emotional reactions and susceptibility to control. We control a horse or a dog through his emotions, and by the same principles we control the man or the woman in the industrial field through the effect of the available means upon their emotions. The psychologists have given us a catalogue and description of these emotions to which mankind is susceptible. We are enabled thus to draft certain rules and laws whereby methods of control can be standardized and developed to a degree not formerly thought possible. Physiological psychology has given us tests whereby the fatigue of muscles may be investigated. Fatigue as an industrial problem has received much study, resulting in Josephine Goldmark's "Fatigue and Efficiency" and many excellent papers.

These problems of the Human Machine are very important. A tired man will have an output very materially less than a fresh one and he generally can be rested by an expenditure of time less costly than that wasted through the slowing up caused by fatigue. Some of this resting may well be done on his own time and need not be paid for by his employer at all. Much of the resting done on the conventional arrangement of working hours now in force takes place in the noon hour, which is not included in the standard working day's time. The atmospheric conditions as regards temperature and humidity have much to do with the fatigue of workers and their resultant output, to say nothing of their comfort and general contentment. These conditions often can be controlled at an expense far less than the cost of their harmful effect on output if uncontrolled. Absences from ill health may often be deducted from the pay roll, but the overhead portion of their cost remains, as well as the interruption of schedules, and all the other indirect disadvantages. We hear much of the eight hour day, but we hear very little of the economic difference between eight hours at active work and eight hours of being on duty. People of different sizes and weights have different capacities for different kinds of work, and it stands to reason that anything less than their scientific adaptation to the work for which they are physically best fitted must be uneconomic. Women usually receive less pay than men for the same kinds of work. For certain of these kinds they are less efficient in terms of output per hour, while in other kinds they are more so. The scientific subdivision of work as between men and women workers is therefore obviously important. These illustrations cover but a fraction of the field, yet they seem to point very surely to the importance of the human machine in our industrial life.

Among the obstacles to the efficient working of human machinery are those which are due to sociological conditions. Most people prefer to live in the larger cities rather than in the smaller towns and villages, and the tendency of labor is to seek the large communities where there is a large employment market, and where there is more social opportunity for the wives and daughters of the household. Employers are apt to favor the large cities, for here are the great free labor markets, and in normal times plenty of labor can be had without the necessity of raising capital to solve the housing problem. As the industries grow and their organizations develop, their tendency is to move into the country, carry their own labor market with them and secure the economies that go with country conditions. This usually requires more capital than it does to settle in the towns but in the long run is usually more economical. The logical development of this idea is the industrial community specially planned and built for the purpose of providing just those conditions that make for the satisfactory community life and the most effective industrial results. Such a community can be planned for a population of from thirty to forty thousand and can serve a considerable number of industries. Others, like Gary, Ind., may be large enough to provide many of the advantages of city life and serve only one corporation. Palmerton, Pa., of less than 5,000 population, is a thoroughly successful community of this kind built and almost entirely owned by the New Jersey Zinc Co. Here the living conditions are far superior to those in almost any large city. The advantages of these better conditions are very great both to the employees and to the corporation, but these advantages are difficult to express in figures. Many of the factors are buried in personal prejudice, religious feeling, social attitude, climatic influence, and many others, all of which are hard to evaluate.

There are a number of definite trends in our industrial life than which perhaps none is more marked than the decreasing amount of exercise taken by most people. Cheap power in the factory and the Ford car outside, the commercial development of baseball, with the drift of population to the cities and in larger groups, all have their effect in encouraging us to omit the regular exercise that to our fathers was incidental and necessary in the daily routine of living, and which to us is equally necessary for the regulation of our bodily functions. The factory worker a generation back was apt to get too much exercise; to-day he is just as apt to get too little, and for this pills are not the remedy.

The food problem is growing in importance, largely because of the growing lack of proper exercise and the increasing use of pills as a substitute. The young matron of two generations ago had been trained by her mother to cook for the men, and her mother was an expert. The industrial woman of today has had very little training in the preparation of food. She lunches in a cafeteria, her dinner is prepared in a kitchenette, largely from canned stuff and out of the delicatessen store; and when she marries she brings to her new household an almost complete inexperience in culinary affairs coupled with a lively disinclination to be bothered with the discomforts of cooking. We have, therefore, inadequate breakfasts, fancy lunches and fried dinners with their inevitable consequences.

Because of the greater facility of short distance transportation due to the motor car, as well as greater density of population, social activity is increasing among all classes, and it is speeded up by various commercialized forms of entertainment like the movies, resulting in late hours at the expense of sleep.

The human machine is an unique and complex combination of three units: 1. A thermo-dynamic apparatus for the transformation of food energy into work; 2. A telegraphic apparatus for stimulating and coördinating the operation of the machine; 3. A thinking instrument subject to emotional control.

The above mentioned combination differentiates the human from all other machines, making it, of course, enormously more valuable in its capacities, while at the same time being subject to special limitations of its own, of which the principal one is the element of fatigue.

To what extent fatigue acts as a limiting factor is not exactly known in spite of many careful investigations recently conducted on this subject. There is, however, reason for considering it in the light of an asset rather than a liability. The human machine is habitually overloaded with consequent fatigue in lieu of the breakdowns common to all mechanical machines. Capacity to sustain and recover from fatigue is capacity to stand the punishment of overload and is in reality a distinct advantage. However, while a considerable amount of work may be accomplished without fatigue, this is not enough to satisfy our present day civilization, which still requires of a man a higher output of work than is consistent with his comfort. While this condition obtains the element of fatigue will continue to be regarded as a limitation.

Like other industrial machines, the human one can be worked at different speeds, but because it is a highly organized, self-contained unit, and must perform many operations in turn to keep itself going, it cannot be worked for an indefinite period on a single task as is the case with other machines. Under such conditions it quickly becomes subject to the limitations of fatigue. Over-fatigue delays work, diminishes output, spoils goods, causes accidents and sickness, keeps workers at home, and in all these ways is an obstacle to efficiency. How it can be kept down to its lowest reasonable limit, and how the working power of the individual can be maintained and made to yield a maximum output without detriment to itself,—in other words, how the human machine can be used to the most profit, constitutes one of the most interesting, profitable and elusive problems of our times.

The study of industrial fatigue received great impetus from the late war. To a large extent interest in this subject centered about efforts to employ women on tasks previously performed by men only. Investigations carried out on this and other phases of war industry have since been extended to industry in general. Chief of the agencies undertaking these investigations were the Committee on Industrial Fatigue of the Advisory Commission of the Council of National Defence in America, and the Health of Munition Workers Committee in Great Britain. Since the war the work has been carried on by The Industrial Fatigue Research Board of Great Britain, who have prepared many valuable reports on fatigue in various branches of industry.

When in a laboratory experiment a single muscle of an animal is stimulated for a considerable period by a series of slight electric shocks and is made to contract and lift a given load with each stimulus, the work performed in each of the successive contractions from beginning to end may be plotted as a curve, which, while differing in details, will be perfectly typical of all muscles. This curve at first gradually rises to a maximum, indicating for a time a progressive improvement in working power. Following the maximum there is a gradual slow decline in the curve, indicating fatigue, which may continue until the muscle is totally exhausted and can no longer lift the load. This is the simplest type of fatigue curve and may well be kept in mind in considering the curves of output of the industrial worker in a working spell.

In the human being the fatigue conditions are infinitely more complex than in a single muscle because the various organs are individually susceptible to fatigue and must act in coördination with the muscles, and the highly complicated nervous system is subject to its own peculiar type of fatigue in acting as the general coördinator of all the bodily functions.

A curve of output that closely resembles the muscle curve has been found in work that requires close attention and exact muscle coördination. There is at first a gradual rise, continuing through the first hour or two, then a fall gradually increasing throughout the remainder of the working spell. After the luncheon hour the general form of the curve is repeated, but with slight changes in detail. The rise in each spell is often called the "practice effect" although it is analogous to the increase in working ability found in a single muscle. The greater height of the curve just after, as compared with its height just before, the luncheon hour, represents the restorative effect of rest and food; and the lower point of the curve at the end of the second, when compared with that of the first spell, signifies the cumulative fatigue of the day.

In occupations that are distinguished by their muscular character, the output curve seems to show progressive fatigue, but the practice effect may be wanting, and a rise followed by a fall appears in the latter half of the spell. This late rise indicates a temporary inhibition of fatigue, perhaps a "second wind"; this is less, and the fatigue is more marked in the second spell.

Where work is monotonous and where it is frequently broken by natural pauses a curve may be obtained which for both working spells is nearly a horizontal line, showing a slight practice effect but no fatigue.

Another type of output curve shows striking uniformity from day to day and even from week to week, leading to the conclusion that the workers are not working up to their full capacity. One form of such curve shows an early fall with often a marked spurt before the close of the spell. as if the worker were taking it slowly at first but afterward hastening to reach some set output by the close of the working period. The fact that a pronounced spurt was possible indicates that capacity had not before been reached. This so called "stereotyping" of output occurs where piece rates prevail as well as where wages are paid by the day. Its cause is complex and may be due to any one of a number of elements—the unthinking recognition that a certain amount is enough for a day's work; the fear that if more is accomplished piece rates will be cut; the disinclination of many rapid workers to surpass their fellows; unwillingness or inability of the foreman to drive until individual capacity is reached; and last but not least, in many cases just human laziness.

The amount of fatigue to which a worker may be subjected without harmful results is not clearly known. It is perfectly evident, however, that when fatigue reaches such a point that ouptut falls below an economic limit, work should be stopped. The stop may be a recess, breaking a working period into two parts, or it may be the shortening of the working day.

This brings us to another problem of industrial physiology, that of the duration of daily and weekly labor. It has been widely believed, and especially by employers of labor, that longer hours meant necessarily a greater output. Recent investigations have repeatedly demonstrated the fallacy of this notion. A man can generally accomplish more in two hours than in one hour, but it does not follow that he can accomplish more in fifteen hours than in twelve, or more in twelve than in ten, or even more in ten than in eight hours. A striking illustration of this fact was discovered in an American munition factory, where a night shift was working twelve hours. After 5 A.M. the curve of output showed a rapid decline and during the last 40 minutes there was little or *absolutely no production.* The elimination of the last two hours would have been greatly to the advantage of the men and probably would have resulted in an actual increase in the total product turned out. Most striking evidences of the beneficial results of a reduction of the hours of labor were accumulated in England during the war. Two instances will serve to illustrate. With a group of 80 to 100 women turning aluminum fuse bodies the reduction of the weekly hours of actual work from 66.2 to 45.6, a saving of more than 20 hours, increased the gross production by nine per cent. When the actual weekly working hours of 56 men, engaged in the very heavy labor of sizing fuse bodies, were reduced from 58.2 to 51.2 the gross output was increased by 21 per cent.

A study of industrial physiology shows that in the interest of large output the hours of labor must be kept down to a reasonable limit and this limit must be chosen in accordance with the fatiguing effects of the different occupations. It shows the advisability of recess periods in long spells of labor and the inadvisability of Sunday, or overtime work. Indeed, overtime is only justifiable in rare emergencies and then only when compensation can be given by free hours later. Industrial physiology tells us further that each worker and each task possesses a specific standard of strength, and it indicates in which task each worker will probably prove most efficient. It tells us that each worker has a rythm that is best adapted to his own neuro-muscular mechanism and that it is advantageous to place in a squad of workers doing a specific task, only those possessing similar rythms, eliminating the faster and the slower individuals, and then to adjust the speed of operation to the common rate. Such instances reveal the field for study and show some of the ways in which the most intricate of all industrial machines, the body of the worker, must be used in order to bring out its greatest usefulness.

Dimensions and Capacity of the Human Machine. Men vary greatly in size and innate ability to do work. Regardless of this fact large and small are given the same tools and set at the same tasks so that there is considerable standardization of capacity, the small men habitually working a little harder, and the large men taking things a little easier than the average. This leveling effect is not peculiar to industry but extends to every walk of life. One hundred pound men and two hundred pound men sit in the same chairs, eat from the same dishes and push the same lawn mowers. Their working habits become so nearly alike that ordinary variations in size are considered of but little importance from an industrial standpoint.

Haswell reports that the average weight of 20,000 men and women weighed in Boston in 1864 was—men 141.5 lbs. and women 124.5 lbs. In the first million U. S. A. draft recruits, white and colored, in 1917 and 1918, of 868,445 men measured, the mean height was 67.49 inches and mean weight 141.54 pounds. On demoblization the respective figures on 100,000 troops were 67.72 inches and 144.89 pounds. The army accepts men ranging in weight from 110 lbs. to 211 lbs., armed them with the same rifles and gave them the same packs to carry. In the army however, it was recognized that although weight alone is not a matter of much moment, the proportion of weight to size, and particularly to height is of great importance. Standards for acceptance in the army are given in Table No. 1. Men coming within this wide range of sizes were found suitable for military duty. Of the two and a half million men examined, 2.91 per thousand were found to be under the minimum height and 26.50 per thousand were under the weight requirement for their height.

A trained man can, as a stunt, lift considerably more than a ton but very long rest periods are required between such efforts. Working continuously with a good pump, a laborer can perform 2,000,000 ft. lbs. of useful work in ten hours. This is equivalent to an output of 1/10 mechanical H. P. Work can be done at much greater rates for short periods of time. As an extreme example of this it is stated that a runner, making 100 yds. in eleven seconds expends 13 H. P. of energy.

TABLE 1

PHYSICAL EXAMINATION STANDARDS

U. S. DRAFT BOARD

A. Standard accepted measurements.			B. Variations from Standard shown in column "A" permissible when applicant is active, has firm muscles and is evidently vigorous and healthy.		
Acceptable Standard			Minimum Permissible		
Height Inches	Weight Pounds	Chest measurement at expiration. Ins.	Height Inches	Weight Pounds	Chest measurement at expiration. Ins.
61	118	31	61	110	30
62	120	31	62	110	30
63	124	31	63	112	30
64	128	32	64	113	30
65	130	32	65	114	30
66	132	32½	66	116	30¼
67	134	33	67	118	30½
68	141	33¼	68	121	30¾
69	148	33½	69	124	31
70	155	34	70	128	31¼
71	162	34¼	71	133	31¾
72	169	34¾	72	138	32¼
73	176	35¼	73	143	32¾
74	183	36¼	74	148	33½
75	190	36¾	75	155	34¼
76	197	37¼	76	161	34¾
77	204	37½	77	168	35¼
78	211	38¼	78	175	35¾

The following table is from Haswell's Mechanics' and Engineers' Pocket-Book.

TABLE 2

EFFECTIVE POWER OF MEN FOR A SHORT PERIOD

Manner of Application	Force, Lbs.
Bench vise or Chisel	72
Drawing-knife or Auger	100
Hand-plane	50
Hand-saw	36
Screw-driver, one hand	84
Small screw-driver	14
Thumb and fingers	14
Windlass or Pincers	60

This table emphasises the general lack of information on the adaptability of tools to their users. The proportion of carpenters who can exert a force of 50 lbs. on a hand plane and the size of plane best adapted to respond to that force, are equally unknown. To the author's knowledge the only tool that has been scientifically fitted to the ability of the worker is the hand shovel. This, designed to hold a load of twenty-one lbs., has greatly increased output and has, in a measure, helped in establishing the eight hour day by enabling the shoveler to do his maximum work in that time.

Man as a Mechanical Machine. The amount of energy contained in food, like that in fuel for heating an engine, is expressed ordinarily in so-called calories, more exactly—gram calories, one gram calorie being the heat necessary to raise one gram of water 1°C at a mean temperature of 15°C. 1000 gram calories = 1 kilogram calorie or "large calorie" which is equivalent to 30.86 ft. lbs. of energy of 3.968 B.T.U'S. The large calorie is what is usually spoken of in food analyses, etc. as a calorie, and 5500 of these "large calories" represent the energy contained in the food necessary for a man at very hard muscular work.

Such a man performing 2,000,000 ft. lbs of useful work, like walking twenty miles or pumping water, converts $\frac{648}{5500}$ of the energy in his food or a very little less than 12% which is not far from a third the efficiency of a good mechanical engine.

Thus, the laborer pumping all day to perform 2,000,000 ft. lbs. of work will have put forth about one H. P. hour of mechanical work, the equivalent of which can be bought in electrical form for two cents.

Physical Fitness. So far all mention of the human machine has presupposed an operating unit in good working order. In reality men and women often are obliged to work at a disadvantage. Few are without some physical imperfection, and many have defects that impair their ability to work efficiently. Human machinery, therefore, is not only complicated of itself but it must be operated under conditions of repair that are different for every individual. The wide prevalence of defects among men in the United States is clearly shown in the reports of the Surgeon General of the United States Army on the findings of the United States Draft Board. 2,510,596 men between the ages of 18 and 30 were examined, among whom were found 1,289,403 or slightly more than half, with defects sufficient for notice. The proportion of defective men from the different states varied from 64 to 35.4 percent.

This careful physical examination of two and a half million young men is such a perfect index of the physical condition of the male population of the United States as to be of utmost importance to industry. Data given in the voluminous government reports are briefly abstracted in Table 3. Here results are given for the United States as a whole, for the highest and lowest states, and for New York, which is selected as a representative industrial state and in which about 1/10 of the population of the country live and work.

Color Blindness is a factor not adequately covered in the foregoing table. Its victims are unsuitable for such occupations as physician, chemist, artist, weaver, upholsterer, tailor, milliner, florist, and a host of others where colors are worked with, as well as the railways and maritime services, where colored signals are used.

TABLE 3

DEFECTS FOUND PER 1,000 DRAFTED MEN EXAMINED

	U. S.	High State	Low State	N. Y.
Pulmonary and Suspected Tuberculosis (Reject)	22.02	63.61	10.22	23.93
Venereal Diseases, Alcoholism & Drug Addiction	57.58	163.57	13.37	31.81
Curvature of Spine	5.53	9.03	1.93	6.26
Deafness	1.22	2.97	0.02	1.19
Defective Hearing	5.47	12.06	3.36	5.91
Mental Deficiency, Dementia Praecox, (Rejection Psychopathic Statis)	15.08	37.92	3.36	13.71
Myopia	2.85	8.30	0.45	8.30
Defective vision	30.07	60.42	13.50	48.03
Eye Enucleation, Blindness in One Eye, Blindness in Both Eyes	7.81	12.53	5.00	6.41
Hernia	20.83	29.39	15.36	18.84
Fracture, Malunion of, Upper and Lower Extremity, Shortening of Lower Extremity	7.75	12.31	4.92	6.75
Ankylosis, (Stiff Joints)	6.75	13.14	4.63	4.63
Arthritis ("Rheumatism")	2.31	5.75	0.96	1.55
Foot Deformities (All)	128.72	259.40	56.87	133.56
Hand Deformities and Loss of Fingers	7.50	13.06	3.55	5.98
Deficient Chest Measurement	0.87	3.13	0.26	0.61
Under Weight	26.50	92.85	8.96	28.56
Under Height	2.91	12.42	0.72	4.75
Defective Physical Development, deficient Chest, Under Weight and Under Height	32.93	112.51	12.88	36.20
Grand Total Mechanical Defects	215.43	370.60	123.61	214.70

Mary Collins in her book on color-blindness, (Harcourt Brace and Co., New York, 1925), says that 3.5 per cent of all men have this affliction. She quotes statistics covering the examination of 71,994 males, including groups in England, Denmark, China, and Japan, of whom 3.69 per cent showed color-blindness, whereas only 14 women, or 0.088 per cent out of 15,855 were so afflicted.

Because of the curious manner in which it is inherited, color blindness in women is almost negligible. The sons of a color-blind man are not color-blind and do not transmit the defect, but his daughters, while not afflicted themselves may transmit color blindness to their sons.

There are many forms of this visual defect, the chief of which is inability to distinguish between red and green. Another form, more apt to be the result of disease or accident, leaves its victims unable to tell yellow from blue. A very few individuals cannot see any color at all.

The Evaluation of the Human Machine, as a problem in statistics has been made by Dr. Louis I. Dublin of the Metropolitan Life Insurance Company. In an article in the November, 1926, issue of Harper's Magazine he states that for a typical American family whose total family resources are about $2,500 per year the cost of rearing a child to the self-supporting age of 18 years, including food, shelter, clothing, education, and about 38 per cent for interest on capital and mortality allowance, is just over $10,000, not including anything for the cost or value of the mother's care.

The "present worth" of the average future net earnings of a boy of this age Dr. Dublin computes at about $29,000. The "present worth" of a man in this class is a maximum of $32,000 at the age of 25, $17,500 at 50 years and $8,500 at 60, and zero before 70. The economic value of the average child at birth he finds to be $9,333, which is the amount necessary to put out at 3½ per cent interest in order to bring up the child to age 18 and to produce the average net income throughout the average working period of life. At 4½ per cent the value at birth works out at about $4,600.

In these computations it has been assumed that prices and wages remain constant at the average figures obtaining in 1926.

The Metropolitan Life Insurance Company published a little pamphlet early in 1927 entitled "The Value of Human Life at all Ages," from which the following very interesting statements are quoted:

"Unfortunately, there is no means of obtaining even a rough estimate of the economic value of the majority of women since the housewife's contribution to the conduct of human affairs cannot be measured in dollars and cents, but if the value of women as economic producers is estimated at only half that of men, this makes the total value of our Vital Assets more than 1,500 billion dollars ($1,500,000,000,000).

"Our national wealth in ordinary material assets, in 1922, was 321 billion dollars ($321,000,000,000). The value of human life, therefore, is about five times that of material wealth."

There also appeared in this pamphlet the following tables:

TOTAL COST TO PARENT OF REARING A CHILD TO THE AGE OF 18 YEARS

1.	Cost of being born	$ 250
2.	Food	2,500
3.	Clothing and Shelter	3,400
4.	Education (minor items met by individual family purse)	50
5.	Health	284
6.	Recreation	130
7.	Insurance	54
8.	Sundries	570
		$7,238

VALUE OF A MAN: ANNUAL INCOME $2,500

			PRESENT WORTH AT STATED AGE		
Age	Expectation of Life in Years	Earnings per Annum of those Employed	Of Gross Future Earnings	Of Gross Future Personal Expenses	Of Net Future Earnings
18	46.59	$963	$41,285	$12,631	$28,654
21	44.16	1,463	43,398	12,580	30,818
30	36.87	2,225	42,623	11,585	31,038
40	28.84	2,453	35,933	10,138	25,795
50	21.28	2,393	25,900	8,390	17,510
60	14.53	2,203	14,920	6,421	8,499
70	9.04	2,105	5,008	4,446	562

VALUE OF A MAN: ANNUAL INCOME $5,000

			PRESENT WORTH AT STATED AGE		
Age	Expectation of Life in Years	Earnings per Annum of those Employed	Of Gross Future Earnings	Of Gross Future Personal Expenses	Of Net Future Earnings
18	46.59	$910	$57,280	$22,959	$34,321
21	44.16	1,352	62,004	22,828	39,176
30	36.87	2,548	69,542	20,980	48,562
40	28.84	3,640	67,531	21,861	45,670
50	21.28	4,940	52,551	22,197	30,354
60	14.53	4,530	28,120	17,864	10,256
70	9.04	4,330	5,708	11,696	—5,988*

*Living on his savings.

These facts are immensely interesting and it is understood that more elaborate tables are shortly to be published by this company which is entitled to credit for having compiled a mass of facts that cannot fail to be of interest and value to all classes of society.

The Responsiveness of Human Machinery to Skillful Management is everywhere exemplified in reports on increased efficiency in manufacturing operations. A single example will serve to illustrate the possibilities:

The Derwent Iron Foundry at Derby, England was occupied during the war in moulding and casting hand grenades and also in moulding, casting, and machining fusehole plugs. The capacity of the foundry was estimated by the Ministry to be 3,000 of these articles weekly. The number of employees was increased from 130 to 160 and the output capacity increased to over 20,000 plugs weekly.

These results were obtained from a combination of motion study, training of workers, improvements in appliances, shorter hours of work, and higher wages.

The movements required to perform each task were studied and reduced to a simple minimum, and a set of standard instructions prepared, this with the full consent and coöperation of the men. The securing of this consent and coöperation was considered a vital part of the program.

Working hours were reduced from 54 to 48 per week and a training period was started, each man being supplied with a card of printed instructions for his particular task. During the training period wages were paid by day rate, the daily wage being raised to about 25% more than the standard for the district.

This training proved to be of extreme importance. Different men responded differently, some requiring careful watching for weeks before they could fix the better working habits, while others were able to adapt themselves from the start merely by following the printed instructions. Capable individuals with no previous experience except the training course could sometimes beat more experienced workers who had to fight against inefficient habits previously acquired. Individual output was greatly increased. On work that had previously called for an output of 80 units in ten hours three workers soon averaged 144, 151, and 143 respectively in the shorter day. These were experienced workers profiting merely by the improved arrangement of their tools and materials. In contrast, a bricklayer without foundry experience who had received the training course was able to average 173 per day.

As a result of the time studies, training courses and improved factory layout it was possible to set a figure for a "Standard Output" far in advance of any previously made. Men were paid day wages during training until they were able to equal or surpass the standard output. After that they received piece rates based on the same standard. An increasing bonus was paid on piece work so that the more work a man turned out the greater was his rate of compensation. This is an eminently just arrangement as it is possible in this way to reward the worker for the saving in overhead costs made possible through his increased output.

Although the increased output per worker at this plant was roughly five times that estimated possible by the Ministry, there was apparently no increase in fatigue. The workers were more contented, much better paid, and probably better fed than formerly, all of which conditions not only resulted from increased output but contributed to further increase.

Conclusions. Men and women workers in industrial plants require proper selection, placement, operation, inspection, and repair, just as do the machines they operate. Therefore, without disparagement to the workers as individuals, it is convenient to think of them collectively as Human Machinery. Although this human machinery is more valuable than any other it is also far more complicated, for which reason as well as because it has largely been ignored, the art of its management has not kept pace with that of mechanical equipment. Some of the elements which are to be considered in any attempt at scientific management of the human machine are:

1. *Fatigue.* The most striking difference between man and an inanimate machine is that the former is subject to the element of fatigue. Whenever fatigue is incurred to such an extent that total recovery in available rest periods is not possible, output will be decreased. It is

therefore of vital importance to consider the difficulty of the task and the ability of the worker, and to arrange amounts and times of work accordingly.

2. *Rhythm.* Each worker has a strength and speed of muscular movement that is best adapted to himself. In the interests of efficiency he should be set at tasks rquiring similar strength and speed.

3. *Size.* Differences in ability due to differences in size of individuals are apt to be overlooked because of the standardizing effects of working habits. It would seem that size selection would be worthy of more attention on special work at least.

4. *Proportion.* Individuals, who are out of proportion, either through lack of physical development or because of improper ratio of height to weight, will not make capable workers.

5. *Fitness.* A very large proportion of the population have physical defects to some degree at least. It is important that these defects be discovered and that no man be placed at a task in which he will be handicapped.

6. *Mechanical Ability.* The human machine is of so little value as a source of power that it should never be employed in this capacity. Indeed every human movement requiring strength should be aided, if not entirely supplanted, by mechanical power wherever economically possible.

7. *Tools.* With the exception of the hand shovel no tool has been scientifically designed to fit the maximum capacity of the worker. This would seem to offer a large field for research and invention.

8. *Management Possibilities* though complicated are very great. Human and mechanical contributors to industrial production are inseparable, so it is difficult to say to what extent an improvement is due to each, and unsatisfactory to improve one element without the other. Under improved conditions of mechanical equipment, management,

and training of workers, the output per individual employed at one plant has been increased to five times the amount originally thought satisfactory, and similar stories in other establishments are common enough. Fred Taylor's classic tale of the pig-iron loader is sufficient case in point.

9. *Susceptibility to Mechanical Aids.* The mental and physical parts of human machinery can work together, the former being far more elastic than the latter in its range, adaptability and capacity to stand overload. The power loom not only introduced great economies in the textile industry, but it developed a new type of weaver, in whom the mental work is more, and the physical work less in watching forty looms than in running one. The bricklayer, on the other hand, has much the same kind of life that his father had before him, except that his hours are shorter, his pay greater, he goes to work in his own car, and has far more time for rest and recreation. He ought to live longer, while the weaver may not live as long under the new conditions unless he can adapt his mind to the greater strain of its work and relieve it by exercise as the result of his greater physical freedom. He ought to walk to work.

10. *Dexterity* varies greatly among individuals, between the sexes, and between right and left hand work. Ambidextrous individuals are far more efficient at certain tasks, and where laborers work in pairs, a right and a left handed man may often be a more efficient combination than two right handed men.

11. *Physical defects* should be ascertained and considered in the assignment of tasks. They amounted to over 21 per cent in the men examined for the draft, and doubtless average much higher than this among men and women applying for industrial positions. Their proper allocation with respect to efficiency at their tasks, coördination of their tasks with others, and the safety of themselves and their co-workers, are essential to economic and safe plant operation.

CHAPTER II

FUEL REQUIREMENTS

A mechanical machine is actuated by the energy derived from the combustion of fuel, or transmitted to it from a prime mover.

The human machine is related to the mechanical one in this respect, but presents a more complicated problem because of the different elements of food (fuel) required. In the case of the mechanical machine the fuel consumed consists of but one element such as wood, coal, oil, or some derivative of these. The human machine cannot exist for long on only one food element. To function at its best it must have the proper combination of three, namely fats, carbohydrates and proteins.

In addition to these three fuel supplying elements, small quantities of mineral salts and of the lately discovered vitamines are necessary. These exist to some degree in many foods and are entirely lacking in others. They have no fuel value but must be included in proper proportions in the diet if the human machine is to be kept in good working order.

The farmer is the best fed worker for several reasons. His work in the open air gives him plenty of exercise and an appetite that makes him relish the simplest and most easily digested foods; he has plenty of it, fresh and in abundant variety; and his wife, who is generally an expert, does the cooking. It is doubtless because of this in large part that the agricultural class has the superior vitality that has enabled it to maintain its numbers from generation to generation and supply a surplus of individuals to the manufacturing and other industries.

Compared to the farmer the industrial worker is handicapped. His work is more harassing, more apt to lead to nervous exhaustion and impairment of digestion, and he therefore needs more digestible food. At the same time he is limited in variety, particularly in the matter of fresh foods, and his choice of diet is apt to be badly influenced by the large numbers of manufactured substitutes put up in an attractive manner and which can be prepared more conveniently than the elements of the better balanced rations. Under these circumstances, the selection of a proper diet is not easy for an experienced dietician, and it is practically impossible for a single family without skilled advice. The easiest way to cook the principal foods, especially those that are put up in cans, is to fry them in grease, and the grease, which used to be olive oil and butter and lard, now consists of cotton seed or cocoanut oil and various other substitutes from a can, entirely innocent of vitamines, and tasting like sawdust. The farmer's breakfast is a real meal while that of the factory worker is too apt to consist of a large cup of coffee, which at that hour is an unnecessary stimulant, a roll and possibly a fried egg. Lunch, or dinner, is very generally carried cold with a hot thermos bottle containing more coffee, from the bottom of the pot that was used at breakfast. The main item is the sandwich, soggy, tasteless and cold.

Probably for more than 100,000 years man has had his principal food cooked and hot, with raw fruits, nuts and some vegetables. The tribes that had advantages in this respect were able to survive by reason of their superior vitality. Now, for about one generation we have been trying to get accustomed to the cold lunch, with no great success. Even where it does not lead to definite digestive difficulties the habit of eating cold food has a very definite result in the impairment of general vitality and working efficiency. It is a well known fact that dogs thrive better and hens lay more eggs when fed on hot food, and more especially in cold weather.

The degree with which food is relished has a lot to do with its value and efficiency as a fuel, and in this respect there is a good deal of variation in individual taste, and from time to time among the same individuals. If a man likes and relishes his food he will do more and better work than if he lacks appetite for it.

The reaction of the larger industrial establishments to the above facts is the organization of company cafeterias wherein the employees can get excellent hot meals at cost or less, where they can eat in considerable comfort and among pleasant surroundings. One of the very best of these institutions, which well might serve as a model for the world at large, is operated by the Baldwin Locomotive Company at their plant just outside of Philadelphia. There the food costs about half of what would be charged at a restaurant giving similar portions of comparable quality.

After eating, an extra supply of blood goes to the stomach, leaving the rest of the body, and particularly the head, subnormally supplied. Therefore people do not do their best and hardest work just after meals, and are inclined to rest, if possible, for at least a few minutes after each meal except breakfast. This is a strong argument in favor of the full noon hour, only half of which is needed for eating. Where cafeterias are provided there is often no satisfactory place to rest after eating, special rooms for the purpose being expensive to the management and frequently not popular with the personnel. The author recalls a bitter complaint made by the manager of a new foundry plant who had built a special room, rather tastefully decorated, and fitted up with tables and chairs which the men were invited to use for eating the lunches which they had brought from home. Not a soul used the room, but the men all preferred to eat in little groups of not more than two or three, more often singly, sitting on the cold foundry floor and enjoying that fancied freedom of action during the free noon hour which is as the breath of life to the American.

It seems clear that the selection of a proper diet from the low priced foods available to urban and industrial communities is a task beyond the ability of the majority of present day industrial housewives, and one that may well tax the ingenuity of managers of all but the largest industrial establishments. Much can be done by management in scientific and tactful supervision of the midday meal, whose dietary value should receive as much attention as its fuel value in order to obtain lasting results.

Food Requirements. Chittenden in "The Nutrition of Man" (N.Y.-1907) published a monumental series of experiments indicating that all of the normal functions of a healthy adult could be performed on a balanced diet containing less than half as much material and at from 1/3 to 1/2 the cost of the average per capita food consumption in the United States.

"The human body requires far less protein than is ordinarily eaten. Since the high protein foods are generally the most expensive a scientifically balanced ration is generally less costly than the ordinary one. Temperance in diet, like temperance in other matters, leads to good results, and our physiological evidence points out plainly, like a signpost all can read, that there is no demand on the part of the body for such quantities of food as custom and habit call for. Healthfulness and longevity are the prizes awarded for the successful pursuance of a temperate life modeled in conformity with Nature's laws. Intemperance on the other hand, in diet, as in other matters, is equally liable to be followed by disaster."

It is important to balance our rations properly, not only because this is necessary for industrial efficiency and for the maintenance of health, but because a scientifically balanced ration is generally less expensive than an unbalanced one. Man has spent several hundred generations as a mainly carnivorous animal living in the open and hustling for dear life, with starvation, or a violent death, only a few days behind him. Whenever he had enough meat he ate as much as he possibly could, not knowing when he would get any more. His refrigerator was his own stomach. His life in the open air, generally cold and very often wet, required the stimulating and heating foods high in protein that he got from the flesh of wild and domesticated animals killed for the purpose. This meat did not keep as well nor as economically as the grains and nuts, and was always eaten in preference to these when available, for the same reasons that govern the practice of all pioneers and of the American Indian. Man today, therefore, has come honestly by the habit of eating more meat than is good for him under present day conditions, and it is not easy, after one generation of scientific cold storage, to overcome the habits acquired during several hundred generations of carnivorous living.

Productive output is dependent upon physical efficiency, which in turn is dependent upon nutrition. Bodily exercise and the cooling effects of fresh air stimulate nutrition, and its needs must be met by a suitable food supply.

The human body calls for a constant supply of food, first for its growth, for the building up of its tissues and for repair, and secondly as a fuel for the production of heat and energy. The body is always losing energy in the form of heat and mechanical work. The loss of energy due to cooling of the surface of the body is greater than that due to mechanical work which is variable and may be small, or may amount to as much as 2,000,000 ft. lbs. per day in the case of a man employed at hard labor. The amount of food required bears a closer relation to the extent of the surface of the body than to its weight. Tall, lean men have a greater body surface than short, fat men and require more food accordingly.

Growing boys and girls require comparatively more food than adults for two reasons: their bodies present a greater cooling surface compared to their weight, and they have not only to make good the daily loss of energy but require both energy and material for growth.

The amount of physical force expended in daily work and the environment in which the work is done have a great effect on the food requirements of the body. Hard labor and exposure to the open air call for increased food supply; sedentary work in an artificially heated and confined atmosphere, on the other hand, consumes a smaller amount of energy and reduces the amount of food required.

When work is nervously exhausting, the food of the worker should be particularly light and digestible, well cooked, and appetizing. The organs of digestion then lack an adequate supply of nervous energy and cannot deal successfully with heavy, indigestible and unappetizing meals. Proper adjustment of food to the expenditure of nerve energy saves a great deal of indigestion and the resulting minor complaints and lost time. Fatigue prevents the proper digestion of food, one of the earliest symptoms of over work being some form of digestive derangement.

Food, particularly when served hot, has an immediately stimulating effect. This is demonstrated by the rise in the production curve after meals and by the increased output that has been obtained after serving hot bouillon during a ten minute recess in the morning.

Certain kinds of food which are relatively rich in protein and mineral matter, (meat, fish, milk, peas, beans, and wheat flour, and its products) contribute both to the formation of the body and its repair, and supply it with fuel for the production of heat and mechanical energy. Other foods such as fat, sugar, and starch, afford an abundant supply of fuel, but cannot maintain growth and repair. Still other foods such as fresh fruits and green vegetables are of small value as sources of energy, but provide the body with certain important elements conducive to good health. Natural foods contain these essential elements and also supply salts and certain substances of little known nature, called "vitamines," which exist in minute quantities in fresh foods and are necessary for the growth and health of the body. Vitamines are removed by some of the processes of milling. They are destroyed by prolonged cooking and are absent from some canned foods. They are present in butter and margarine when made from beef fat, though absent when it is made from vegetable fat.

Fats and carbohydrates can partly replace one another in a diet, but the body digests and deals best with a certain proportion of each. Fat, however, yields, weight for weight, more than twice as much energy as carbohydrate and is therefore more valuable in cold climates.

The drinking of strong tea or coffee many times in the day is physiologically unsound, as is also the consumption of sweetmeats between meals, especially by boys and girls. Sugar is not a natural food, but an artifically separated foodstuff. It should not be allowed to lessen the appetite for the natural complete foods.

The Selection of a Diet. In the present state of our development there are in the markets of nearly every industrial community a large number of available foods from which an immense number of combinations may be made that will satisfy all the requirements of the human body for the replacing of all tissues and the development of energy from the food as fuel. It is obvious that where there are many possible combinations, some of these will cost less than the others with given market conditions. Unfortunately, it generally happens that the most economical foods are either comparatively unpalatable or more difficult of digestion than the more costly ones, and therefore anyone who has to make up a ration must attempt a sort of arbitrary balance between that combination which gives the least cost per unit of food value and the one which is sufficiently attractive in taste to meet the requirements of the palate. It is interesting to observe, in this connection, that persons who have been living upon an unbalanced diet, meaning a diet in which the principal food elements are contained in the wrong proportion for physiological assimilation, are very likely to find that their food will become much more palatable as soon as these proportions are adjusted to those of a balanced ration.

Although the palate more or less automatically rejects some of the unbalanced ration, the tendency is to eat too much of one or two of the food elements in order to get enough of the third. A striking incident illustrative of this, is cited by the Arctic explorer, Steffansson, who nearly starved to death when he had a very large quantity of lean caribou meat available. It was at a season of the year when the caribou were exceedingly thin; there was practically no fat on the meat. Steffansson had no supplies of blubber, seal oil, or other food containing fat ingredients. The consequence was that until his party could secure some fat they were compelled to live upon this lean caribou meat which they ate in enormous quantities without satisfying their hunger.

The Energy Value of a Food can be determined by burning a weighted quantity of it in a calorimeter and ascertaining how much heat it gives off. The large calorie, which is used as the unit of energy value, is the amount required to raise the temperature of 1 kilogram (1¾ pints) of water through 1 degree Centigrade (1.8 degrees Fahrenheit) when starting at from 15 to 16 degrees C. Calculation has shown that, when dried, foodstuffs possess the following energy values:

TABLE 4

ENERGY IN DRIED FOODS

Food Element	Calories per Gram	Calories per Ounce	Calories per Lb.
Protein	4.1	116.2	1859.8
Carbohydrate	4.1	116.2	1859.8
Fat	9.3	263.7	4218.5

The energy expended in mechanical work can also be expressed in calories, for one calorie has been found by experiment to be equivalent to the energy expended by a man 70 kilograms in weight (about 154 pounds), in walking up a staircase 6 meters in height (about 20 feet). Such a man would require one extra calorie in food to make good this expenditure in energy, if his thermo dynamic apparatus operated at 100% efficiency.

Investigations made by a number of scientific workers indicate that about 15 per cent of the energy expended is derived from protein, and about 80 per cent from fats and carbohydrates combined; that is to say, that normally protein supplies only one-seventh of the total energy expended. Numerous investigations have shown that the energy required by a man engaged in moderately light munition work is about 3,500 calories of food as purchased. Where calculations are based on food as eaten, the minimum diet may be taken to be about 3,000 calories, when balanced among the three classes of foodstuffs in the following proportions of dried weights:

Protein	100 grams
Fat	100 grams
Carbohydrates	400 grams

Such would be contained in the following diet:

Lean meat	5 oz.
Fat	1 oz.
Butter	1 oz.
Bread	16 oz.
Potatoes	16 oz.
Oatmeal	3 oz.
Milk	¾ pt.

Men engaged in hard physical work, especially in the open air, require a good deal more energy-producing food, and may consume as much as 4,500 calories with advantage. On the other hand, the energy required by a man clothed, lying at complete rest at ordinary room temperature in a still atmosphere, is about 1,600 calories of eaten food; while for a man engaged in a sedentary occupation, tailor or clerk working in a warm room, as little as 2,200 calories may suffice.

An average adult woman worker requires rather less by 10% to 20% than a man.

Calculation of Rations by Means of the Trilinear Chart. Heretofore the principal difficulty to be met in obtaining economical balanced rations has been that of making the necessary computations. The following method, which elimates this difficulty, is recommended whenever it is necessary to select foods to meet the requirements of protein content and heat value.

The trilinear chart consists of an equilateral triangle, which, because the sum of the perpendiculars from any point to each of its three sides is equal to the altitude, is admirably adapted to the investigation of problems involving a whole made up of three parts. If the altitude is made equal to 100% then the three perpendiculars to every point in the triangle add up to 100%, and any ratio of three percentages that add up to 100 can be plotted somewhere in the triangle. Thus in Fig. 1 we let the triangle A B C represent the properties that we desire to investigate in a balanced food ration. Let the side *a* represent the line of zero carbohydrates; the side *b* the line of zero protein; the side *c* the line of zero fats. The triangle is ruled in parallel lines giving 50 divisions between each side and its opposite apex. Each division will then represent 2% in any mixture of foods. Now we can locate milk containing 19% protein, 29% carbohydrate and 52% fat by one definite point, and only one, in the triangle, these percentages representing the proportions of food value measured in calories obtainable from the respective elements in a given quantity of milk.

In a similar manner we can represent any food by its constituents, and if we further make a note, preferably on the chart, indicating the quantity necessary to develop 100 calories of nutritive energy, we have a ready means of computing a balanced ration, or of obtaining at sight a survey of the various foods to be considered in making up such rations that is of immense help both hygienically and economically.

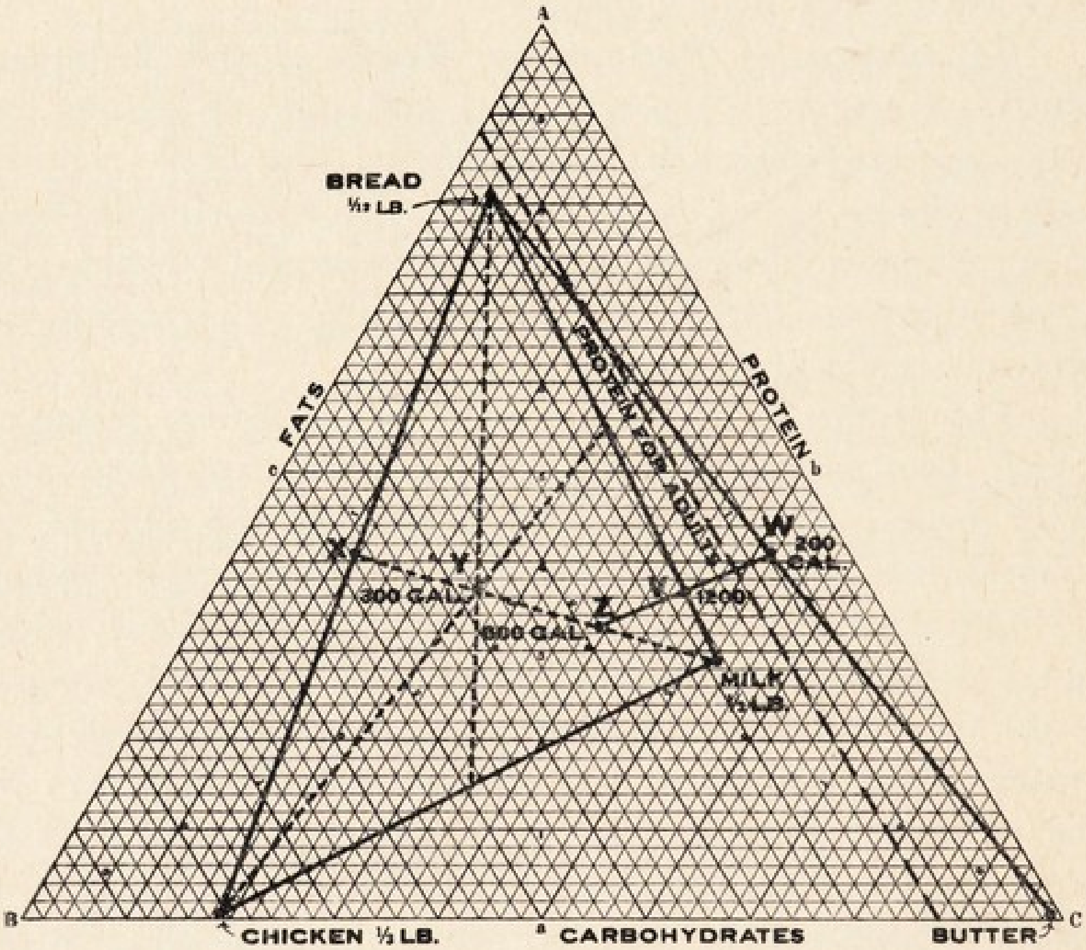


Fig. 1—Food Components Plotted on a Trilinear Chart

Without the aid of such a chart the computation of a balanced ration, whether for soldiers, babies, or live stock, is a matter of cutting and trying, and involves the use of a great deal of arithmetic.

As an example illustrating its use, take two points on the chart, one representing 1/12 lb. of bread, the other 1/3 lb. of chicken, each the equivalent in fuel value of 100 calories.

If we draw a straight line joining these two points, a point on this line midway between them will represent the composition of a mixture of an equal number of calories of each.

Thus, the point x will indicate a bread and chicken mixture containing 41% carbohydrates, 47% protein, and the balance, 12% fat. This line indicates, moreover, that by mixing bread and chicken in various proportions we can make a ration indicated by various points along this line, but no mixture of bread and chicken will enable us to put up a ration indicated by any other point than one on this line. If we wish to keep our protein element near to 15% we must make the mixture mostly bread, or if we wish to keep our carbohydrate quantity low we must put in a larger amount of chicken and a smaller amount of bread. If, now; we wish to add another element to the ration we can do so graphically. Let us add enough milk for 100 calories, or say 1/3 lb. and if we take 100 calories each of chicken, bread, and milk we may determine the food value of our mixture by drawing a smaller triangle connecting the three points and finding the center of gravity of this triangle by drawing the median lines (lines joining each apex to the middle of the opposite side) as indicated by the point y in Fig. 1. We can then read directly from the chart that such a mixture will contain 37% protein, 37% carbohydrate and the balance, 26% fat.

We know that for an adult it is desirable to have a food ration containing about 12% protein, which we can indicate by drawing a line 12% from the side *b* of the large triangle. It is apparent that the mixture indicated by the point *y* is too far to the left of this line for proper economy, and in order to properly balance it we should add more elements low in protein. Point *y* carries 300 calories. We can add more milk if we so desire by drawing a line connecting the point *y* and the point representing milk and remembering that the point *y* has a weight of 300 calories and the milk point a weight of 100 calories. By adding say 200 more calories of milk we will obtain another point *z* containing 600 calories, represented by 1-1/3 lb. of milk, 1/3 lb. of chicken, and 1/12 lb. of bread. In order to come still closer to our balanced protein line we may add more bread and butter by taking a bread and butter portion amounting to ½ ounce of butter and 1/12 lb. of bread, thus adding element *w* containing 200 calories which we can combine with the *z* point above determined by drawing a line between them, and since *w* has a value of 200 calories and *z* a value of 600 calories the point represented by the mixture of *w* and *z* will be ¼ of the distance between them from the *z* end. Two more portions of bread and butter added to the above figures would locate our final point halfway between *w* and *z* and gives us a point *v* which is quite close to our economic protein line and contains enough fuel value for an ordinary workman's dinner. It is also well balanced as to fat and carbohydrate. This final point *v* contains approximately 18% of protein, 37% carbohydrate, and the balance of fat. This entire computation can be made on the chart in less than two minutes.

If we desire to analyze the ration with respect to its protein and fat elements alone, we may draw a line from *A* through the point *v* and cutting the line *B C* at a point which shows us that of the protein and fat elements the ration contains 28% of the former and 72% fat.

In order to obtain an economical ration it is necessary to know how much the various foods cost per 100 calories. These figures for a number of the most important foods are shown in Table 5. For greater convenience in these computations the data have been rearranged in Table 6, the arrangement being in the order of food costs per 100 calories, as expressed in Table 5. This is not by any means the whole story of the food problem. Many of the cheaper foods are less digestible than the more expensive ones, as well as less appetizing. The individual

TABLE 5

COST OF FOOD PER 100 CALORIES

	% Protein	% Carbohydrates	% Fat	Fuel val. per lb. Cals.	Price per lb.	Price per 100 Cal. Cents
†Almonds	22.4	18.6	59.0	1,660	.48	2.90
†Apples, fresh	2.6	94.8	2.6	220	.08	3.64
*Apricots, dried	6.9	91.6	1.5	1,290	.27	2.09
§Bacon	13.2		86.8	2,685	.50	1.86
*Beans, baked	23.8	67.6	8.6	600	.083	1.38
†Beans, string	2.3	7.4	0.3	195	.25	12.80
§Beef, fresh	44.3		55.7	1.040	.30	2.88
*Beef, canned	52.0		48.0	1,425	.22	1.55
†Beets, fresh	14.3	84.6	1.1	170	.10	5.90
§Bologna sausage	47.7		52.3	1,170	.32	2.74
*Bread, rye	14.3	84.7	1.0	1,180	.11	0.93
*Bread, white	14.5	83.5	2.0	1,215	.11	0.91
*Bread, whole wheat	16.1	82.5	1.4	1,140	.15	1.32
*Butter, fresh	1.2		98.8	3,605	.47	1.30
†Cabbage	21.3	74.7	4.0	145	.08	5.50
*Cake, plain	8.0	80.6	11.4	1,675	.30	1.79
*Cheese, cream	41.7	4.0	54.3	1,950	.60	3.08
§Chicken, broilers	89.6		10.4	505	.48	9.50
*Chocolate	14.0	33.0	53.0	2,860	.36	1.26
*Corn, canned	12.2	82.6	5.2	455	.15	3.30
*Corn meal	9.7	84.9	5.4	1,545	.16	1.04
*Cocoanut, prepared	6.6	33.1	60.3	3,125	.48	1.53
*Crackers, soda	10.6	79.5	9.9	1,925	.18	0.94
*Dates	2.5	94.2	3.3	1,450	.35	2.41
*Eggs	58.5		41.5	720	.19	2.64
†Figs	5.5	94.1	0.4	1,475	.25	1.69
*Fish, salmon, canned	72.2		27.8	680	.37	5.45
§Ham, smoked	30.5	69.5		1,670	.38	2.27
§Lamb	42.8		57.2	1,055	.35	2.26
†Lettuce	27.3	65.9	6.8	90	.10	11.10
*Macaroni	15.2	83.8	1.0	1,665	.15	0.90
†Meat Stew	32.0	38.2	29.8	370	.18	4.85
*Milk	26.8	40.7	32.5	325	.10	3.07
†Mushrooms	32.7	63.6	3.7	210	.75	35.70
§Mutton	34.6		65.4	1,255	.25	1.99
*Oatmeal	17.7	74.3	8.0	1,860	.10	0.54
†Onions	13.2	84.0	2.8	205	.08	3.91
†Oranges	6.5	92.4	1.1	170	.10	5.88
*Peanuts	29.1	27.6	43.3	1,935	.25	1.29
*Peas, canned	26.5	72.0	1.5	255	.15	5.88
†Peas, shelled, fresh	26.5	72.0	1.5	255	.08	3.15
§Pork, fresh	8.1		91.9	2,835	.35	1.28
§Pork, salt	9.8		90.2	2,655	.35	1.24
§Pork sausage	35.5		64.5	1,695	.35	2.06
†Potatoes, white	10.5	83.7	5.8	310	.08	2.68

†Potatoes, sweet	5.8	91.7	2.5	460	.15	3.26
*Raisins	3.1	92.8	4.1	1,455	.13	0.90
*Rice	9.2	90.5	0.3	1,630	.10	0.61
†Spinach	37.5	57.1	5.4	110	.10	9.10
*Sugar	....	100.0	....	1,860	.06	0.32
*Tapioca	0.5	99.4	0.1	1,650	.12	0.72
*Tomatoes, canned	22.2	74.1	3.7	105	.13	12.40
§Veal	70.6	....	29.4	555	.54	9.72
*Walnuts, English	17.2	16.8	66.0	1,700	.30	1.77
*Wheat, b'kf'st food	13.6	84.4	2.0	1,685	.22	1.31

tastes of the consumers must be more or less considered. All of these considerations point to economic dietetics as one of the higher arts, rather than a cast iron science. It should be noted, in studying this chart, that the most common foods come to the left of the normal average protein line (Fig. 1.) Thus, the common tendency, which must be resisted, is to get a ration which would be too rich in protein. In order, therefore, to obtain a balanced ration certain foods from the right of the normal protein line should generally be included. There are a number of foods which lie close together on the chart but which vary a great deal in cost. For instance, rice and white potatoes are so close together on the chart that practically it matters little which is used in a ration yet the white potato per unit of food value costs much more than the rice. Further applications of the chart and these tables will suggest themselves to the reader and need not be gone into here.

Charts similar to Fig. 1, on which have been plotted about one hundred different foods for the purpose of performing these computations graphically, may be purchased from Codex Book Co., Inc., New York City.

It is important that the ration after having been designed be prepared in such manner as to meet the requirements of the various classes of people to be fed. With the majority of restaurants, and company cafeterias as well,

---

*Eagle Grocery Store, 632 Park Avenue, Weehawken, N. J.
§Vogt & Merkel, Butchers, Park Avenue, Union City, N. J.
†California Fruit Store, Park Avenue, Weehawken, N. J.
(Retail Prices obtained May, 1926)

a portion is a portion whether it is to be eaten by the president's stenographer or by the head porter. The works superintendent of one of the most efficient of the industrial plants in the East is a large man who generally orders for his lunch three portions of ham and eggs. Women doing stenography and adding machine operators are more apt to want a lettuce and tomato sandwich with a cream puff for

TABLE 6

FOODS ARRANGED IN ORDER OF COST PER HUNDRED CALORIES. PRICE PER HUNDRED CALORIES IN CENTS

Raw Foods		Ready To Eat Foods	
Oatmeal	0.54	Sugar	0.32
Rice	0.61	Raisins	0.90
Tapioca	0.72	Bread, white	0.91
Macaroni	0.90	Bread, rye	0.93
Corn Meal	1.04	Crackers, soda	0.94
Pork, salt	1.24	Chocolate	1.26
Pork, fresh	1.28	Butter, fresh	1.30
Walnuts, English	1.77	Wheat, b'kf'st food	1.31
Bacon	1.85	Bread, whole wheat	1.32
Mutton	1.93	Baked beans	1.38
Pork sausage	2.06	Cocoanut, prepared	1.53
Apricots, dried	2.09	Beef, canned	1.55
Lamb	2.26	Figs	1.69
Potatoes, white	2.68	Cake, plain	1.79
Beef, fresh	2.88	Ham, smoked	2.27
Almonds	2.90	Eggs	2.64
Peas, shelled, fresh	3.17	Bologna sausage	2.74
Potatoes, sweet	3.26	Milk	3.07
Onions	4.22	Cheese, cream	3.08
Meat stew	4.85	Corn, canned	3.30
Cabbage	5.50	Apples, fresh	3.64
Peas, canned	5.88	Fish, canned	5.45
Beets, fresh	5.90	Oranges	5.88
Spinach	9.10		
Chicken, broilers	9.50		
Veal	9.72		
Lettuce	11.10		
Tomatoes, canned	12.40		
Beans, string	12.80		
Mushrooms	35.70		

dessert. Those workers who are most useful to industry are often of value largely in consequence of the fact that they have worked beyond their nervous limit, are highly strung and therefore live on a diet rather specially adapted to their physical limitations. The more highly skilled workers generally require a more highly specialized, as well as a more costly ration than common labor.

Purchasing Food Supplies for the operation of a company or coöperative restaurant can best be done from a complete list of all desirable foods showing the amount of each required per man per day. This is done on an elaborate scale by the United States Army. The Army ration embraces a great many items and the amounts of each are therefore small. The cost of one complete ration is figured from time to time and is established as the allowable cost of a man's food for one day. Commanders are usually permitted to draw the ration, partly in kind from the Commissary, and partly in cash to be spent on fresh foods in the local markets.

A simpler ration, serving to illustrate the method of procedure, is given in Table 7, which is taken from an article by S. H. Brockkunier in the Engineering and Mining Journal for April 6, 1918. This ration was used at a western mining camp in 1915 and could be supplied to the men at that time for a total cost of $28.20 per month.

The amounts given in the table were multiplied by the number of men and by the number of days to be covered in order to find the amount of an order. By recording the amounts of food prepared for a given period and comparing with the amount calculated from the table it could be determined whether the food was being consumed and the diet properly balanced.

Table 8 gives a sample menu prepared from this ration which is intended for men at hard work in a cold climate. Note that meat was served three times a day. It was considered that a meal composed too heavily of carbohydrates

TABLE 7

PROPOSED DAILY RATION GIVING AVERAGE OUNCES OF BALANCED RATION CONSUMED PER MAN PER DAY; WEIGHTS IN FOOD AS PURCHASED

	Oz. as Purchased
Meats	15.00
Proportions: Beef, 2; Ham, 1; Bacon, 1; Fish, 0.2; Pork, 1.2; Corned beef, 0.5	
Eggs	2.50
Lard and cooking fats	0.60
Butter—liberal	4.00
Cheese	1.60
Milk—condensed	4.00
Vegetables:	
Beans	2.50
Potatoes	16.00
Peas	1.50
Corn	1.30
Tomatoes	0.50
Onions, parsnips, carrots	1.70
String beans	0.50
Coffee	1.00
Sugar	3.30
Syrup	2.00
Chocolate	0.09
Jelly	0.50
Flour	14.00
Oatmeal	1.30
Rice	0.30
Cornmeal	0.30
Cornstarch	0.30
Macaroni and spaghetti	1.00
Fruits:	
Evaporated apples, peaches, apricots	4.00
Canned blackberries and peaches—pie	
Canned peaches, pears, pineapples—table	
Prunes	
Raisins and currants	
Tea	0.13
Coffee	1.14
Total ounces	81.26

left the stomach quickly and would leave the worker without adequate fuel before the completion of his shift.

By way of contrast a mid-day meal served to women

TABLE 8

MENU FOR A MINER OF AVERAGE WEIGHT. ENERGY REQUIREMENT IN CALORIES: SLEEPING, 640; SITTING 384; MODERATE EXERCISE, 480; LIGHT EXERCISE, 640; SEVERE EXERCISE, 2,880; TOTAL, 5,024.

Meal	Measure Served	Av. Weight Oz. of Food as Purchased	Protein Cal.	Total Cal.
Breakfast:				
Oatmeal	1½ cups	1.30	25	150
Prunes (or apple sauce)	1 service	1.50	3	111
Meat—				
bacon (ham, steak, or fish)	3-4 large pcs.	3.00	64	307
Eggs	1	2.50	25	70
Hot cakes (or French toast)	2	3.60	28	200
Bread (muffins or corn bread)	2	2.60	28	200
Butter	Av. 1¼ sqs.	1.25	2	250
Syrup	2-1/3 tbsp.	2.00	......	150
Coffee		1.14	......	....
Milk		0.93	11	50
Sugar for coffee and fruit		0.80	......	90
Total				1,578
Dinner:				
Soup, bean				
(pea, corn or vegetable)	¾-1 cup	2.85	22	145
Meat pie (hash or beef stew)	1 serving	7.00	40	400
Macaroni (or spaghetti)	1 serving	0.50	8	51
Succotash (or baked beans)	1 serving	2.00	37	197
Potatoes	2	7.20	16	149
Bread	2	2.00	21	150
Butter	1 square	1.00	2	200
Cheese	1 piece	0.80	26	100
Fruit (or pie)	1 serving	4.10	5	130
Cake—alternate days	1 piece	1.50	12	150
Coffee or tea		....	......	....
Milk for coffee		0.25	......	30
Sugar for coffee		0.25	3	12
Total				1,714

Supper:				
Soup, pea (corn, vegetable or bean)	¾-1 cup	2.85	22	145
Roast beef (pork or mutton)	2 slices	5.00	138	300
Potatoes boiled (or mashed or salad)	1 serving	5.50	11	100
Onions (turnips, parsnips or carrots)	1	4.00	7	61
Macaroni (or spaghetti)	1 serving	0.50	8	51
Peas (tomatoes, beans or corn)	1 serving	1.00	15	96
Cheese	1 piece	0.80	26	100
Bread	2 large	2.60	28	200
Butter	1 square	1.00	2	200
Pudding (or pie)	1 serving	5.80	22	321
Cake—alternate days	1 serving	1.50	12	150
Tea or coffee		....	.....	....
Sugar for tea		0.25	.....	30
Milk for tea		0.25	3	12
Total				1,766
Total for day		5.07 lb.	672	5,058

When several foods are given the ones in parentheses are to be substituted on following days. The weights and calories in this table are averages for the group.

in a factory restaurant in England and reported as satisfactory by the Health of Munitions Workers Committee to the British Ministry of Munitions is given in Table 9.

TABLE 9

Meal	Amt. Served Grams	Amt. Served Ounces	Protein Calories	Total Calories
Dinner:				
Roast Mutton	50	1.76	29	687
Boiled Potatoes	123	4.33		
Cabbage	73	2.54		
Syrup roll	157	5.54		

These two menus illustrate the wide range of requirements that must be provided for in any attempt at feeding industrial workers. The problem is more difficult where instead of being all miners, or all machine tenders, the workers are engaged in a number of different occupations as they are at many large industrial plants.

Methods of Serving Food. Industrial Canteens were highly recommended to the British Ministry of Munitions by the Health of Munitions Workers Committee in a report rendered in 1918. They found it difficult adequately to feed those workers who had to travel considerable distances to their work.

The simplest plan was for the worker to bring, or receive from his home, food ready prepared for eating. This arrangement was considered objectionable because the kinds of food suitable were limited, and whatever was selected had to be eaten cold and possibly stale. Such food when kept for any length of time in a hot workshop was apt to spoil.

An alternative was for the workers to bring food which could be either warmed up or cooked at the factory. This, while better than bringing cold food, was objectionable because food is not so nourishing when warmed over. Facilities for cooking many different kinds of food were difficult to secure and the workers engaged in cooking lost valuable time from their work.

In some districts workers could obtain substantial meals at public eating places, where the accommodations were often inadequate.

A final alternative was the industrial canteen at or near the works. This might consist of:

1. An available room in which the workers could eat their prepared food.
2. A room provided with hot water and furnished with a hot plate, or warming cupboard, which might be a cabinet of sheet iron with wood and asbestos covering and iron shelves. Food would be left on the shelves in the morning and secured at noon, the cabinet having been steam heated to a specified degree in the meantime.
3. A refreshment bar to perambulate the workshop at appointed hours. This is particularly useful for serving light refreshment during long working spells or night shifts.

4. A fixed refreshment bar or buffet.
5. A dining room or canteen supplying cheap hot and cold dinners.
6. Such a dining room associated with an institute or club, with facilities for rest and recreation.

The amount and character of the accommodation necessary would depend on the situation of the factory with respect to the workers' opportunities to go home for meals; or the proximity of outside restaurants, the hours of work and meal intervals; on the character of the work and on the customs of the districts in respect to food.

Three methods of serving meals are practicable, No. 1 being generally recommended by the committee for large service.

1. Long serving counters (with short barriers as at railway ticket offices) at which workers secure their food. A number of portions should be prepared beforehand and stored in hot closets under the counter. Portions should be standardized.

2. Food placed ready on the table before workers are admitted. This may be convenient for breakfasts or teas, or where the food provided is cold and the same for all, but it is not always practicable for hot dinners.

3. Waiters or waitresses, organized in shifts.

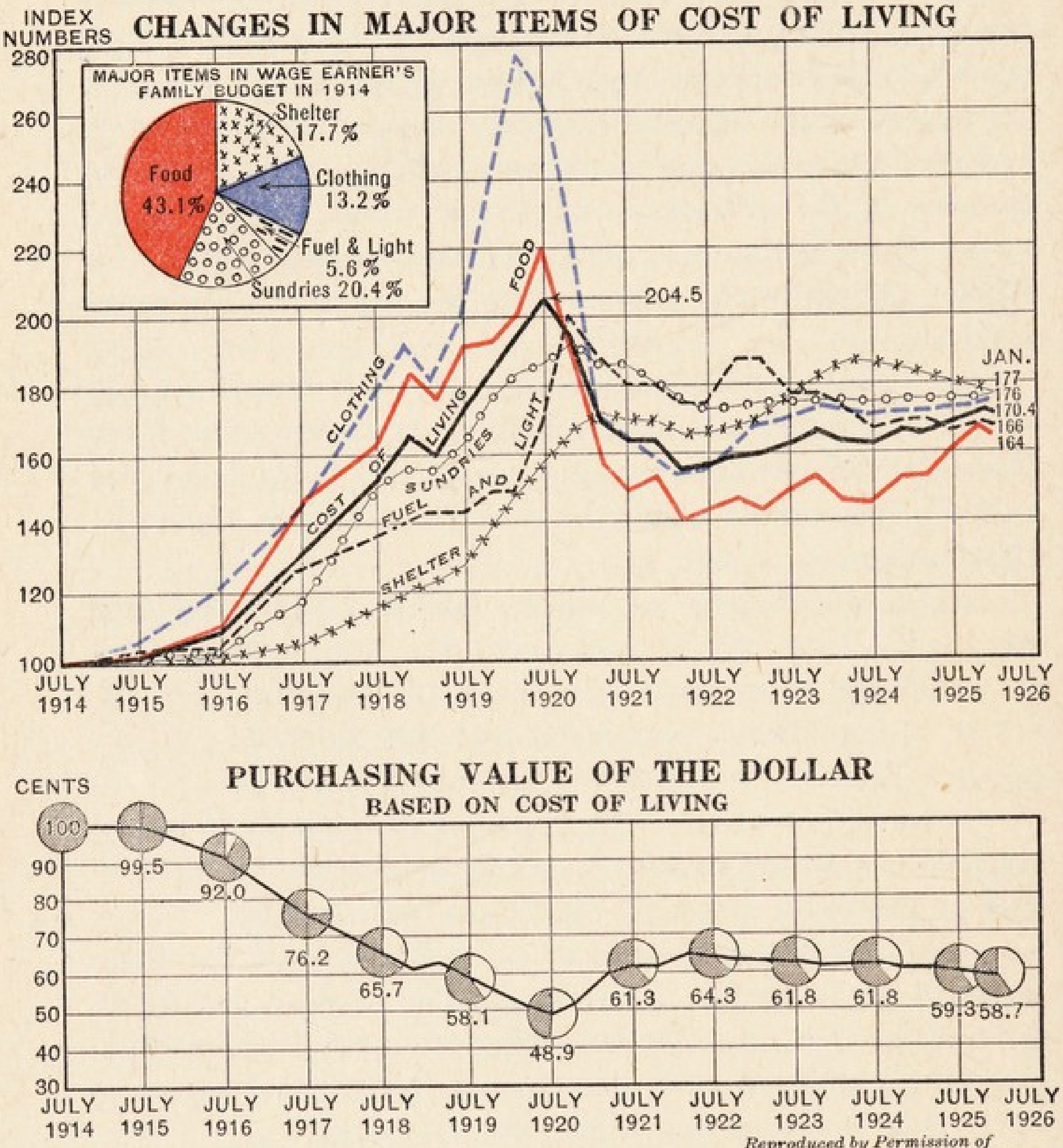
A variation of 1, is the Cafeteria which if properly serviced enables its patrons to secure as elaborate a meal as may be desired in a period of one or two minutes.

Fig. 2 indicates the advances in the cost of the 1914 standard of living for the average wage earner's family at different periods up to the beginning of 1926. It shows that since the spring of 1922 the cost of living has been on a fairly even level, with a slight upward trend.

The chart also shows for different periods up to January, 1926, the relative purchasing value of the dollar in terms of the same quantity and kind of commodities and services that it bought in 1914.

COST OF LIVING CHANGES
UNITED STATES
CHANGES RELATIVE TO JULY, 1914 AS BASE 100

COPYRIGHTED BY
NATIONAL INDUSTRIAL CONFERENCE BOARD, INC.
NEW YORK CITY



Reproduced by Permission of
Natl. Industrial Conference Board, Inc.

Fig. 2—Cost Changes in Food and Other Items of Living, 1914-1926

Conclusions. The energy output of all Human Machinery depends so greatly on the manner in which the energy is supplied as to make this a matter of primary importance to any one who would control and improve its operation. It is to be borne in mind that:

1. The human machine is a self contained unit deriving its energy from the "internal combustion" of fuel in the shape of food.

2. Besides the food required to produce energy, special food elements are required to repair and maintain the health of the body.

3. Foods are made up of a number of elements all of which must be consumed in proper amounts and proportions for maintenance of health.

4. The selection of foods to make up a diet with the right amounts and proportions of all the required ingredients is a matter of painstaking calculation.

5. These calculations can be greatly simplified by the use of tables and charts.

6. The selection of a proper diet is complicated for most industrial housewives by the need for economy and by the difficulty of obtaining an abundance of fresh natural foods.

7. For the above reason industrial workers are apt to be improperly fed.

8. If wages are low to begin with, an increase will be spent to some extent for food, and the better food will result in better efficiency.

9. The provision of a mid-day meal, besides supplying fuel required, can do much toward correcting deficiencies in diet.

10. The meals served should be designed for the needs of the workers for whom they are intended.

11. The method of service should be adapted to the number of workers fed and should be suitable to their occupations.

CHAPTER III

COOLING REQUIREMENTS

Human machinery, like other apparatus in which combustion takes place, requires cooling, for which it depends on the surrounding atmosphere. It is a fundamental requirement of health that the human body must be maintained within a narrow range of temperature variation, differing somewhat in individuals, but in general limited to a total difference of about one degree, with a mean value of about 98.4 degrees F. To maintain this temperature under constantly changing conditions, radiation and combustion must balance, and as combustion is a function of activity, and therefore highly irregular, it follows that radiation must be susceptible to rapid and delicate adjustment. The slightest acceleration or retardation of this process brings discomfort, and any greater disturbance is physically injurious.

Human comfort therefore depends so largely on the cooling power of the air as to make this the foremost factor involved in any consideration of climate or ventilation. Indeed from a practical standpoint it is of such overwhelming importance as to overshadaw all the other factors.

We are wont to be concerned with the chemical content of the air and to feel that we must have "fresh air" to satisfy our need for oxygen, when in reality it is difficult to escape a sufficiency of it. Professor Winslow in his address* to the Sanitary Engineering Division of the American Society of Civil Engineers, January 20, 1925, calls attention to this fact in the following words: "On mountain tops and in the vast spaces of the empyrean where the air-man goes, the most serious atmospheric hazard is the lack of oxygen. At the other extreme of human pioneering —in the bowels of the earth—the same danger is met in a

---

*Trans. Am. Soc. C. E., Vol. 89, p. 320.

different form. In the deep parts of mines and in oil wells, the normal atmosphere may be replaced to so great an extent by carbon-dioxide that men entering such places may perish of oxygen starvation.

On the surface of the earth itself, however, in the normal haunts of man, the problem of oxygen content need give no concern. Even in the worst ventilated classroom, auditorium or workshop the oxygen in the atmosphere never falls below 20 percent (normal is 20.9 per cent) on account of leakage through cracks and the rapid diffusion which takes place even through solid walls and ceilings."

The following attributes of climate affect the existence of man. Of these it is not possible to say that one is more important than the others, for the absence of any one of several would be fatal:

Light.
Atmospheric Contents:
  Oxygen,
  Carbon-dioxide,
  Moisture.
Freedom from fumes and odors.
Atmospheric Conditions of:
  Pressure,
  Temperature,
  Motion,
  Capacity for moisture.

Light is essential to all higher orders of plant and animal life. Direct irradiation with sunlight is used as a cure for certain diseases, notably rickets and tuberculosis, the curative effect being due to the ultra violet rays. These, being largely screened out of the sunshine that passes through window glass, may be admitted through windows made of fused quartz. The smoke pall that hangs over many industrial cities is a menace to health and a matter of cost to every inhabitant thereof, shutting off, as it does in extreme cases, up to 40 per cent of the light. No matter how important it may be for the welfare of the workers, sunshine cannot be brought into mines, and until fused quartz is more readily available than at present, it will not be practical to let its beneficial rays into factories and workshops. The best that industry can do for the workers in this regard is to see that they have recreation time during daylight hours, and to obviate the smoke nuisance as much as possible so that they may spend these hours in unrestricted sunshine. A partial substitute for direct sunlight is the carbon arc light, to the rays of which the naked skin may be exposed, and the ultra violet rays from which have somewhat the same effect as natural sunlight in toning up the system and giving it resistance to the attacks of the germs of common colds and allied diseases. An apparatus for this sort of treatment with a double arc costs $65 and works at 20 amperes on a 110 volt circuit. Exposure to the rays from a distance of 14 inches at first for 5 minutes per day, increasing to 20 minutes after a week, gives most people a coat of tan and a very greatly increased resistance to certain infections.

Atmospheric Contents. *Oxygen.* Man requires oxygen for every breath and cannot live many minutes without it. It is separated from the other atmospheric gases in the lungs and, passing into the blood stream, is carried into every part of the body. In the tissues it unites with glycogen, releasing heat and mechanical energy, and giving off carbon-dioxide and other wastes. The carbon-dioxide is carried back to the lungs and released by them. Thus men and all other breathing animals are constantly removing oxygen from the air and contributing carbon-dioxide to it. This is also done by combustible processes and by the respiratory action of plants. On the other hand, carbon-dioxide is constantly being consumed and oxygen contributed to the air by the process of photo-synthesis as carried on in the green part of plants. In spite of the complicated process of additions to and deductions from the supply of these two gases, the relation maintained between the four principal gaseous constituents of the atmosphere remains constant. It may be stated volumetrically as nitrogen 78.1%, oxygen 20.9%, argon 0.9% and carbon-dioxide 0.03%. Quoting again from Professor Winslow, "The proportion of oxygen in winter or summer, in town or country and even in the interior of dwellings rarely varies near the surface of the earth beyond the extreme limits of 20 and 21 per cent." This being the case we have no occasion to consider the effect of oxygen on human machinery other than to remember that certain precautions are necessary to underground workers.

Carbon-dioxide is subject to somewhat wider variations. Normally present to the extent of 0.03 per cent, it may rise to about 0.5 per cent in the worst ventilated rooms, in which concentration it is harmless. Greater concentrations increase the rate of breathing. As much as 2 per cent, which will increase breathing about as much as moderate exercise, can be borne with no discomfort. Greater concentration would be noticeable. Edward Levy, referring to findings of J. S. Haldane and J. A. Priestly, says (Technical Paper 285, U. S. Bureau of Mines, on Compressed Air Illness and its Engineering Importance): "With a pressure of 2% of an atmosphere of carbon-dioxide in the inspired air, the pulmonary ventilation was increased 50 per cent; with 3%, about 100 per cent; with 4%, about 200 per cent; with 5%, about 300 per cent; with 6%, about 500 per cent. With the last amount panting is severe, while with 3% it is unnoticed until muscular work is done, when the pant is increased 100% more than usual. With more than 6% carbon-dioxide the distress is very great, and headache, flushing, and sweating occur. With more than 10% there is loss of consciousness after a time, but no immediate danger to life. Even 25% carbon-dioxide takes a long time to kill animals."

Except for its effect on the rate of breathing, carbon-dioxide is not a poison. Its effects are sometimes fatal because it displaces such a large proportion of oxygen that a man can drown in the resulting atmosphere. It is the densest of all the atmospheric gases, being about 38% heavier than oxygen, and will settle to the bottom of absolutely still air. For this reason it will collect in the bottoms of abandoned mine workings and in old wells and machinery pits in dangerous concentration. Men should never be sent into such places without oxygen helmets, nor without some precaution being taken to stir up the air. For this purpose the old test of lowering a candle into a well is as good as any. If it is snuffed out a man may expect the same fate.

Some industrial processes evolve carbon-dioxide, but if there is any movement of air at all it will be mixed and diffused and will not collect in harmful concentration. The removal of expired carbon-dioxide is amply cared for by the imperceptible interchange of gases that is always in progress through cracks and other openings. It is practically never a problem in ventilation.

Moisture is always present even in the driest air and can be completely removed only by chemical means in the laboratory. Its chief interest to humanity lies in the effect of its presence on cooling power, in which connection it will be further discussed later. Aside from this it is an important factor in many manufacturing processes, and as under normal conditions the amount present varies widely, artificial means of control are resorted to. Factories handling hydroscopic materials get better and more uniform results by maintaining their workrooms at even temperature and humidity. The effect of this practice on the operators, who must work in artificially humidified air, is a matter for present consideration. Apart from its effect on the cooling power of the air, excessive moisture is undoubtedly harmful, especially at relatively high temperatures.

Warm moist air is favorable to the growth of mildew, fungi, and other bacteria.

Most factories and workshops are afflicted with the opposite condition, dryness. This is especially true in winter when the relative humidity of the air is reduced by heating, sometimes to as low as 10%. It should range from 60 to 70% with a temperature of 68 degrees, for with less moisture in the air the linings of the nose and throat tend to become dry and irritated. Excessive dryness requires the gland to secrete extra moisture for the protection of these membranes and a condition is produced that increases the probability of colds and catarrhal infections. While a fairly wide range of relative humidity content of the atmosphere is permissible and will seldom be exceeded under natural conditions, when artificial means of heating or cooling the air are resorted to extremes of dryness or moisture are possible. These, particularly the former, are to be guarded against. Every heating system should be provided with means of adding moisture to the air as it increases its temperature. In order to equal the temperature comfort of 68 degres at 70% relative humidity, it is necessary to heat air of 20% relative humidity to 75 degrees. The hotter air wastes heat (because radiation depends on the difference in temperature) that might better be spent in evaporating water, for the cooler, moister air is less productive of colds and kindred infections.

Freedom from fumes and odors. The importance of the atmosphere's freedom from fumes and odors is entirely a matter of degree. They are probably always present in the air of workshops and, in most cases, are entirely unnoticed. In general, fumes are definitely known to be harmful if present in sufficient concentration. The effect of odors, however, is not so well understood. There is some psychological reaction to the distaste with which they are tolerated, but apparantly the harm lies in the smelling instead of the smell, for a man with a bad cold suffers no inconvenience from them. This is a subject in which the personal element is uppermost. Some individuals can work unperturbed amidst the foulest of air in rendering plants where most others would be overcome with nausea. The extremely vile odors arising from the putrification of organic matter can be mitigated, if not entirely eliminated, by releasing carefully controlled amounts of chlorine gas into the air. Special apparatus is available for this purpose. Odors of this sort are exceptional and are not of so much concern to industry as a whole as are the indefinite body odors that are associated with the smell of hot stale air in crowded rooms. Here again the problem of ventilation becomes one of cooling, for cool air does not "smell" except to betray the presence of some positive nuisance whose removal is not a problem of ventilation.

Atmospheric Conditions, while of no more importance to the operation of the Human Machine than atmospheric contents, are subject to much greater irregularity. Their control therefore is a more difficult problem and warrants more extensive consideration. Pressure, temperature, air motion, and capacity for taking up moisture are so interrelated in their physical effects that their separate consideration is difficult. An increase in pressure raises the temperature of the air. The higher temperature adds to its capacity for carrying moisture but increased pressure with temperature held constant would decrease the capacity for moisture to a minor extent. Pressure, however, while intimately related to the other conditions, may be considered apart, for its normal regulation is quite beyond the control of man at present.

Pressure itself is not a factor of primary importance. Its fluctuations at any one altitude cannot be felt, and even a very considerable difference in altitude is not perceptible. It has, however, an indirect effect through the quantity of oxygen in the air. While the proportion of oxygen remains approximately the same, the total amount present decreases as one rises above sea level until at 5000 ft. elevation there is 83 per cent, and at 10,000 ft. elevation only 68 per cent as much in a given space as at sea level. Less oxygen can be drawn into the lungs with each breath and therefore breathing and heart action become more rapid. This effect is noticeable with some people as a result of a transfer from sea level to an elevation of 5000 feet. Nearly everyone will experience it at 10,000 feet and at 13,000 feet above sea level breathing becomes a serious problem. Lack of pressure itself is first manifested in a tendency to nose-bleed which is noticeable to sea level dwellers somewhere above 5000 feet and is dangerous at altitudes above 10,000 feet. These combined effects of low pressure at high altitudes, known as mountain sickness, may affect the workers at a few scattered mining camps. Otherwise they are of no interest to industry which is almost entirely confined to elevations of less than 1000 feet.

There is also a very small group of workers who are affected by the other extreme of pressure. Subaqueous excavations for tunnels and foundations are carried on by holding back the water with compressed air. This requires men to work in pressures ranging from that of the atmosphere up to 50 pounds per sq. in., or more than three times the normal. They experience no discomfort from the pressure and even find the increased amount of oxygen present stimulating. The process of going into the pressure however, is uncomfortable and that of changing back to normal is both uncomfortable and dangerous. Under high pressure, the inhaled gases become more soluble in the blood, and when pressure is decreased to normal they are released from solution. If the decompression is too rapid minute bubbles of nitrogen may form in any part of the tissues. The result is painful, dangerous, and even fatal, depending on the extent to which the gas bubbles are formed and their location.

Compressed air work involves a serious problem in ventilation. The workers under pressure get an ample supply of oxygen without deep breathing, which is well, as excessive breathing will increase the absorption of nitrogen by the blood and hence the liability to trouble on decompression. Any carbon-dioxide that may be present in the air will be concentrated by compression and will serve to stimulate breathing to an unnecessary extent. It is therefore extremely important that the air supplied to compressed air workers be as free from carbon-dioxide as it is possible to get it.

Temperature, Capacity for Moisture, and *Air Motion* are the atmospheric conditions that most vitally affect the human machine, for it is dependent on them for the disposal of the excess heat it generates. When the chemical processes taking place in the body react on food to produce mechanical energy they also evolve heat. This heat is lost into the surrounding air, and as the body temperature must be constant the rate of heat loss must balance the rate of heat production. If the air takes up heat too rapidly additional food can be consumed and entirely devoted to producing heat, and clothing can be added as insulation against radiation. When the heat loss is so great that resort to these expedients does not keep up the body temperature, a man will shortly perish. If, on the other hand, heat is produced within the body faster than it is being dissipated, there are a number of ways in which the rate of cooling can be increased. Heat passes from the body through the agencies of conduction, convection, radiation, and the evaporation of moisture. Conduction, convection, and radiation can become more effective when a greater supply of blood, heated within the body, is pumped to the skin to be cooled, while, at the same time, perspiration is increased, and the evaporation of a greater amount of moisture adds to the cooling effect. When heat can no longer be given off as fast as it is produced, a man's temperature rises, his breathing increases abnormally and, if the condition continues, he will die from exhaustion. Dr. Leonard Hill in an article on ventilation and human efficiency, appearing in Mining and Scientific Press, February 25, 1922, lists the following ways in which the human body regulates its temperature:

"1. By varying the blood circulation near the surface of the skin and thus the heat loss by radiation and convection;

2. By varying the output of sweat and the consequent loss of heat by evaporation;

3. To a minor degree by varying respiration and evaporation from the respiratory membrane;

4. To a minor degree by taking hot or cold food, drink, and baths;

5. By varying the amount and character of clothes, and so the loss by radiation, convection, and evaporation;

6. By exposure to sun and wind, by confinement in still air, and by artificial sources of heat or cold, such as fires, steam coils, cool surfaces, or fans."

Heat transfer by convection, conduction, and radiation varies directly with the difference in temperature. Radiation does not depend on the atmosphere but on the temperature of surrounding objects. It is not an important source of heat loss and need not be considered. Conduction of heat by the air is small in amount because, like all gases, air is a poor conductor. However, everything we handle or touch, particularly our clothing, is cooled to air temperature and readily conducts heat away from the body. Moist clothing conducts more readily than dry clothing and, therefore, moist cool air feels colder than dry cool air. Convection is an important source of heat loss. The air in immediate contact with the skin becomes heated to nearly body temperature, as result of which heat is very slowly transmitted through the layer of warm air to the cool air beyond. This layer of air however, tends to expand in heating, and the greater the difference in temperature the more readily it is displaced by a fresh layer of denser.

cooler air. These very small air movements known as convection currents carry a large amount of heat away from the body.

Moisture. Human comfort is affected not by the amount of moisture in the air but by its capacity to take up more moisture. This depends upon its temperature and its degree of saturation. At 0 degrees Fahrenheit the atmosphere will hold only 0.5 grams of water vapor per cu. ft. At 68 degrees Fahrenheit the amount increases to 7.5 grams and at 98 degrees to 18.7 grams. There is more moisture per cu. ft. in air at 80 degrees with 20 per cent saturation than in air at 35 degrees with 85 per cent saturation, but the warmer air of lower relative humidity will be much more avid in absorbing moisture from the body and will thus be more drying in its effect. It will evaporate the perspiration more rapidly and in this way will regain some of the cooling power lost through its greater temperature. The familiar wet and dry bulb thermometers furnish an example of this phenomenon. With saturated air, at any temperature they will both read alike, but whenever the air has a capacity for more moisture, evaporation from the wick on the wet bulb cools it and it gives a lower reading than the dry thermometer. For any temperature the difference in these readings increases with the air's ability to take up moisture, that is, with its decrease in relative humidity.

Air Motion. The convection currents, which are set up in still air by changes in density due to changes in temperature, have the effect of cooling by removing the heated gases from the surface of the body and replacing them with colder ones. The same service is performed in a much more thorough manner by a general movement of the air. The greater the velocity of this movement the more rapid this process, and the greater the rate of cooling. Even very slight air currents are effective. The direction of the wind can be perceived from its cooling power when it is imperceptible by any other test. Air motion also aids in the loss of heat by evaporation. The film of air next to the surface of the body becomes saturated with water vapor and loses its power to take up more. If it is carried away by an air current and replaced with drier air evaporation can continue. The greater the velocity of the current and the faster dry air is brought into contact with the surface of the body the greater will be the rate of evaporation and consequently of cooling.

A certain amount of cooling power in the air is stimulating and beneficial to health. If the body temperature be maintained with the surrounding air at 65 degrees F. more food and exercise can be taken than if the balance be kept at 90 degrees. It must be understood that the temperatures here stated are merely given for comparison. Temperature alone as applied to cooling power and hence to human comfort is meaningless. All three factors, temperature, moisture, and air motion, must be taken into consideration and their complicated relationship understood in order to arrive at an index of comfort which, for want of a better term, may be called

"Effective Temperature." The extent to which temperature, humidity, and air movement may vary for a given degree of comfort has been investigated in the Research Laboratory of the American Society of Heating and Ventilating Engineers, and is extensively reported in the proceedings of that society during the years 1923, 1924, and 1925. A résumé of their findings is given by C. P. Yaglou in the Journal of Industrial Hygiene, for January, 1926, of which the following is an abstract*:

"Different combinations of the three factors which produce the same feeling of warmth give what are called equivalent conditions. The curved lines in Fig. 3 show equivalent conditions in still air and in air which is moving with a velocity of 300 feet a minute, as they were determined in the psychrometric chambers of the Research Laboratory

---

*Copyright 1923, Am. Soc. Heat. & Vent. Engrs., Published by Permission.

at Pittsburgh by three subjects at rest, stripped to the waist. One of the chambers was maintained at a saturated condition of 70 degrees, represented in the figure by point *c*. The wet bulb temperature in the second chamber was kept lower than that in the first, and when the feeling of warmth of the two rooms was compared, it was found that the dry bulb temperature of the second room had to be increased successively to the values represented by points *d, e,* and *f,* for the two chambers to feel alike as to warmth.

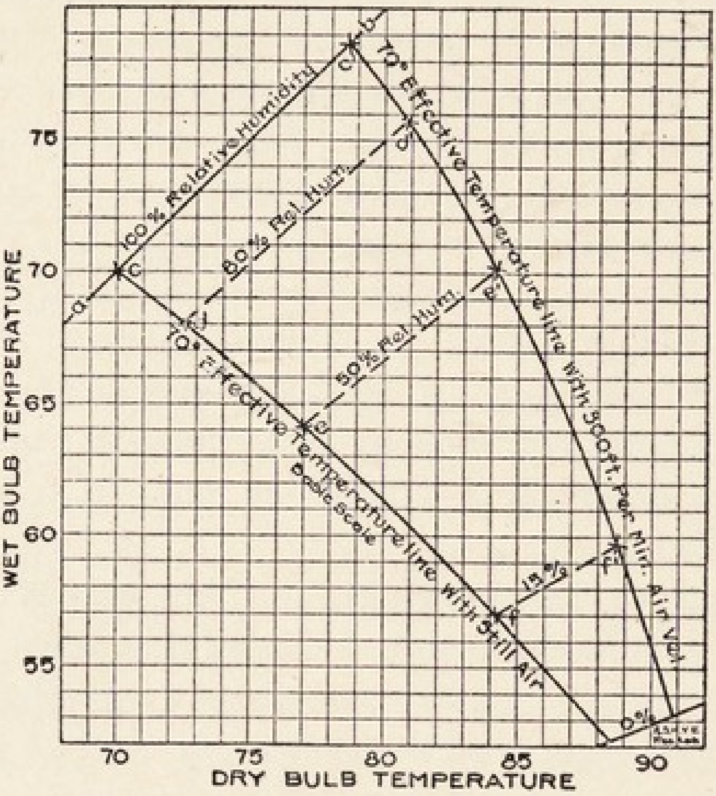


Fig. 3—Chart Showing Equivalent Condition of Temperature, Humidity and Air Movement in Still Air and in Air Moving with a Velocity of 300 Feet a Minute*.

"In experiments with air movement the conditions represented by points *c, d, e,* and *f* were produced in one chamber in still air, while a uniform air velocity of 300 feet a minute was set up in the other. It was then found that, with the same relative humidity in both chambers, the dry bulb temperature of the second chamber had to be increased to the values shown by *c′, d′, e′,* and *f′*, to counter-

---

*Copyright 1923, Am. Soc. Heat. & Vent. Engrs., Published by Permission.

balance the cooling effect of the wind. Line *c′ f′*, was then found to be the 70 degree line of equivalent conditions, when the air velocity was 300 feet a minute. The term "effective temperature" is applied to conditions of equal comfort and is based on the degree of comfort felt in saturated still air. Thus an effective temperature of 70 degrees means that the atmospheric conditions have the same effect on the body as saturated still air at 70 degrees.

"The investigations were made covering a range of from 28 degrees to 170 degrees Fahrenheit dry bulb, and from 25 degrees to 115 degrees wet bulb, for human beings at rest, both stripped to the waist and normally clothed. Two scales were worked out, the basic and the normal. For the former the subjects were stripped to the waist so that the problem could be studied under maximum sensitivity to external temperature. The normal scale of effective temperature was determined with subjects wearing customary clothing.

"Fig. 4 gives the result of the tests for the basic condition in chart form as determined from sense reactions alone. Subsequently other physiological reactions of men to high temperature conditions were investigated and it was found that these reactions, which could be definitely measured, followed the effective temperature closely, regardless of dry bulb or wet bulb temperature, dew point temperature, relative humidity or air motion. Table 10 shows the close agreement between the effective temperature of the air and the corresponding rate of increase in the physiological reactions produced on three subjects at rest, stripped to the waist. It will be observed that with constant effective temperature, the physiological reactions are practically constant, while the dry and wet bulb temperatures, the relative humidity, and the dew point temperature vary considerably.

"*The comfort zone* is shown in Fig. 5 by the dotted area. It was determined by the consensus of opinion of one hundred and thirty subjects of both sexes, engaged in widely

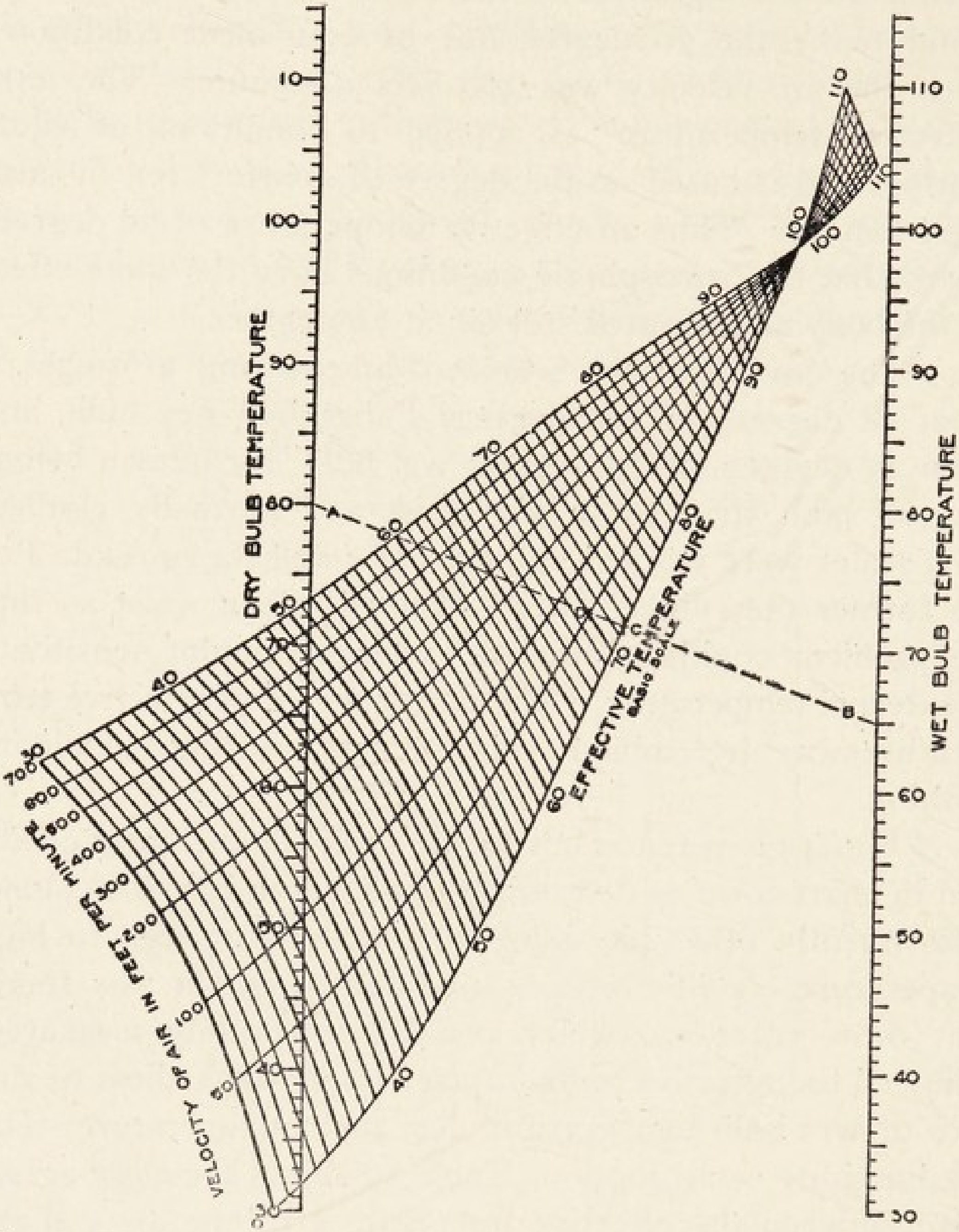


Fig. 4—Thermometric Chart Showing Basic Scale of Effective Temperature*.

Example in Use of Chart

Given dry bulb 80°, wet bulb 65°, velocity of air 50 feet per minute.

1. Draw line AB. Its intersection with the 50-foot velocity curve at D gives 70° for the effective temperature of the condition.
2. Follow line AB to C and read 71.6° for the effective temperature with still air.
3. The cooling produced by the movement of the air is:
   71.6° — 70° = 1.6° effective temperature.

---

*Copyright 1923, Am. Soc. Heat. & Vent. Engrs., Published by Permission.

different occupations and wearing various types of indoor clothing. Conditions of maximum comfort are represented by the 66 degree effective temperature line, the preference of 98 per cent of the subjects regardless of the temperature or humidity of the air.

TABLE 10

SHOWING AGREEMENT BETWEEN EFFECTIVE TEMPERATURE AND PHYSIOLOGICAL REACTIONS, AND ALSO EXTENT OF DISAGREEMENT OF PHYSIOLOGICAL REACTIONS WITH ANY OTHER SINGLE AIR FACTOR*.

	Test Conditions					Rate of Change in Physioligical Reactions		
Test No.	Effective Temperature °F	Dry Bulb Temperature °F	Wet Bulb Temperature °F	Relative Humidity %	Dew Point Temperature °F	Rise in Rectal Temperature °F/hr.	Increase in Pulse Rate beats per min./hr.	Loss in Body Weight lbs./hr.
56	106.0	106.0	106.0	100.0	106.0	4.27	104.9	2.78
72	106.2	120.0	104.6	60.0	102.2	4.70	127.8	2.58
80	106.4	157.0	100.4	15.0	89.1	4.60	124.2	3.19
53	101.3	102.1	101.2	99.2	101.1	2.53	56.3	1.90
76	101.8	129.3	97.5	30.2	91.1	2.45	51.6	1.57
78	101.1	130.0	96.4	30.0	89.4	2.44	54.3	2.05
79	101.2	146.0	93.6	15.0	80.1	1.90	42.5	1.67
44	95.1	97.1	94.6	91.2	94.1	0.85	14.4	0.93
58	94.9	106.0	92.2	60.0	89.0	0.72	10.3	0.93
74	95.2	120.0	89.2	30.0	81.0	0.87	14.0	0.86
81	95.1	144.7	81.8	5.0	54.0	0.75	12.8	1.03
83	85.0	85.0	85.0	100.0	85.0	0.06	1.0	0.07
45	89.3	99.0	86.2	60.0	82.8	0.32	6.6	0.50
71	92.8	116.0	86.2	30.0	77.3	0.52	7.3	0.64
81	95.1	144.7	81.8	5.0	54.0	0.75	12.8	1.03

"It can be seen from the charts that at low temperatures the dry bulb is a better index of comfort than the wet

---

*Copyright 1923, Am. Soc. Heat. & Vent. Engrs., Published by permission.

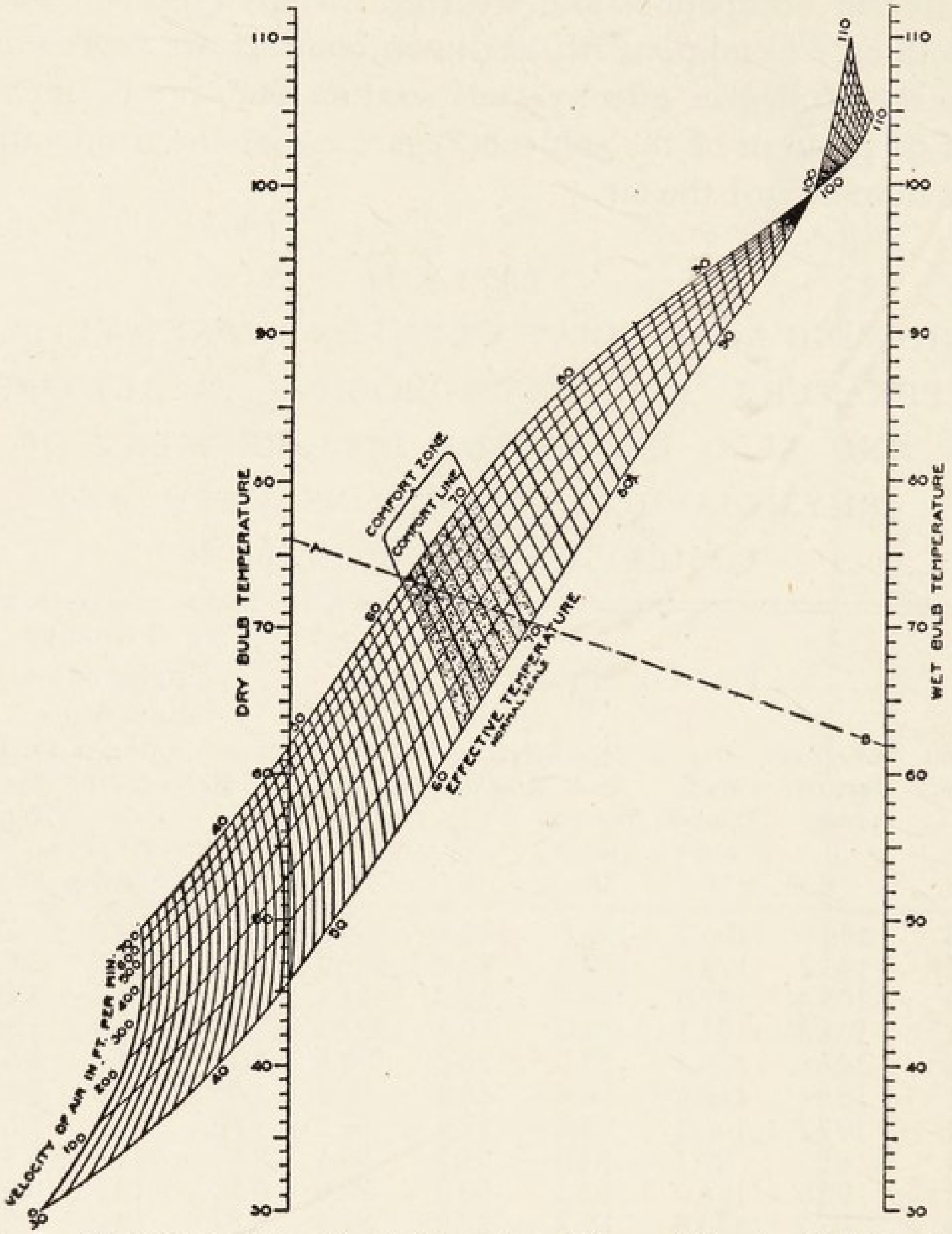


Fig. 5—Thermometric Chart Showing Normal Scale of Effective Temperature*.

Examples in Use of Chart

Given dry bulb 76°, wet bulb 62°, velocity of air 100 feet per minute, determine: (1) effective temperature of the condition; (2) effective temperature with still air; (3) cooling produced by the movement of the air; (4) velocity necessary to reduce the condition to 66° effective temperature.

1. Draw line AB through given dry and wet bulb temperatures. Its intersection with the 100-foot velocity curve gives 69° for the effective temperature of the condition.

2. Follow line AB to the right to its intersection with the 0 velocity line, and read 70.4° for the effective temperature with still air.

3. The cooling produced by the movement of the air is 70.4° — 69° = 1.4° effective temperature.

4. Follow line AB to the left until its crosses the 66° effective temperature line. Interpolate velocity value of 340 feet per minute, to which the movement of the air must be increased for maximum comfort.

---

*Copyright 1923, Am. Soc. Heat. & Vent. Engrs., Published by Permission.

bulb. This is because the body surfaces are dry and so approach the condition of the dry bulb thermometer. Conversely at high temperatures, where sensible perspiration comes into play, the reverse is true and wet bulb temperature is a more accurate index.

"*The Application of Effective Temperature, Sedentary Occupations.* The use of air movement is the simplest and most inexpensive method of cooling. At very high temperatures however, as shown in the charts, the benefit derived from air movement is small and the effective temperature must be lowered by some other means.

"The evaporation of water, one of the oldest and most important principles of air conditioning, can be applied for lowering the effective temperature of the air. When unsaturated air is brought into direct contact with water—when, for instance, it is passed through a humidifier or air washer—a certain amount of heat is abstracted from the air, cooling it appreciably. Unless heat is added to or subtracted from the system, the wet bulb temperature of the air remains the same and the dry bulb decreases until it becomes identical with the wet bulb when the saturation point is reached. When this saturated air is set in motion, its cooling power is very great.

"This method of artificial cooling is especially adapted to use in industrial plants where temperatures are high and the humidity is low. It requires simple and inexpensive equipment, such as humidifiers and blowers, the costs of which are very much less than the cost of a refrigerating plant.

"The thermometric chart in Figure 5 is applicable to ordinary conditions where normal clothing is worn and where physical activity is slight. The comfort zone and the comfort line represent conditions that should be maintained in dwellings, office buildings, theaters, schools, and other places of the kind, where mental or light physical activities are carried on. In summer, when thinner clothing is worn, the comfort line will approach the lower limit of the comfort zone; with the heavier clothing worn in winter, it will approach the higher limit.

"Although all the equivalent conditions represented by the comfort line are equally effective, practical considerations limit the range of humidity from 30% to 70%. This reduces the limits of the dry and wet bulb temperatures in still air from 68 degrees dry and 62 degrees wet bulb to 72 degrees dry and 54 degrees wet bulb, each difference of 1 degree dry bulb on the chart being equivalent to 2 degrees wet bulb.

"It is not advisable to increase the air movement beyond 100 feet a minute."

In Hot Industries. The New York State Commission on Ventilation found that men perform 28% less physical work in a temperature of 86 degrees F. with 80% relative humidity than they do in a temperature of 68 degrees F. with 50% relative humidity.

In the experiments carried out at the research laboratory of the American Society of Heating and Ventilating Engineers it was found that the subjects were capable of performing about five times as much work in a temperature of 90 degrees with a relative humidity of 30% as they were in saturated air at body temperature. They also showed that the highest temperature which can be maintained for muscular work to proceed without loss of efficiency is about 80 degrees effective temperature. With an effective temperature higher than 85 degrees, the body loses its heat equilibrium and physiologic reactions continue to increase with length of exposure. These temperatures are higher than the optimum for men at rest because the workers in hot industries are very lighly clad and become acclimated to higher temperatures. Adequate ventilation in hot industries, therefore, should prevent the effective temperature from exceeding 80 degrees, and should at the same time dispose of the injurious dusts and fumes incidental to the process of manufacture.

Conditions observed at a steel mill near Pittsburgh illustrate how the effective temperature charts may be applied to the problem of cooling. The average conditions in this mill in summer were about 112 degrees dry bulb and 86 degrees wet bulb, with an air movement of 100 feet per minute created by the natural circulation of the air. A marked drop in output was observed during the summer months and various methods were considered for remedying the condition.

The chart in Fig. 5 shows that the effective temperature in the work rooms was 91 degrees, or 11 degrees above the proper limit. By simply saturating the air at the wet bulb temperature of 86 degrees the effective temperature becomes 86 with the air still, and 83 if it continues to move at its present rate of 100 feet a minute. In order to reduce the effective temperature to 80 degrees it will be necessary to blow air on the workers with a velocity of 400 feet a minute.

This elementary method of artificial cooling can be satisfactorily applied in small industries by the use of small humidifiers which will saturate the air locally and blow it directly upon the heads of the workers. In large industrial establishments it is more efficient to saturate the air in a central humidifier and then blow it through overhead ducts upon the workers. In such cases outside air can be drawn in through the humidifier, and, since its wet bulb temperature is lower than that of the air in the workrooms, a greater cooling effect can be obtained. With outside air of 95 degrees dry bulb and 80 degrees wet bulb, the effective temperature of the air striking the workers can be reduced to 74 degrees with an air velocity of only 200 feet a minute. This method of artificial cooling not only lowers the temperature; it also provides a supply of fresh air and removes the products of respiration and the dust and fumes created in the process of manufacture. Moreover, saturation gives moisture to the relatively dry air and eliminates the burning effect of the hot air and its harmful influence on the respiratory organs.

The Limitation of Air Movement as a Cooling Agent is reached as soon as the effective temperature of the air becomes equal to the temperature of the body. Figures 6 to 8, from a paper by F. C. Houghten and C. P. Yaglou appearing in the Journal of the American Society of Heating and Ventilating Engineers for February, 1924*, illustrate this point. The investigators found, in regard to the effect of air velocity on cooling power, that:

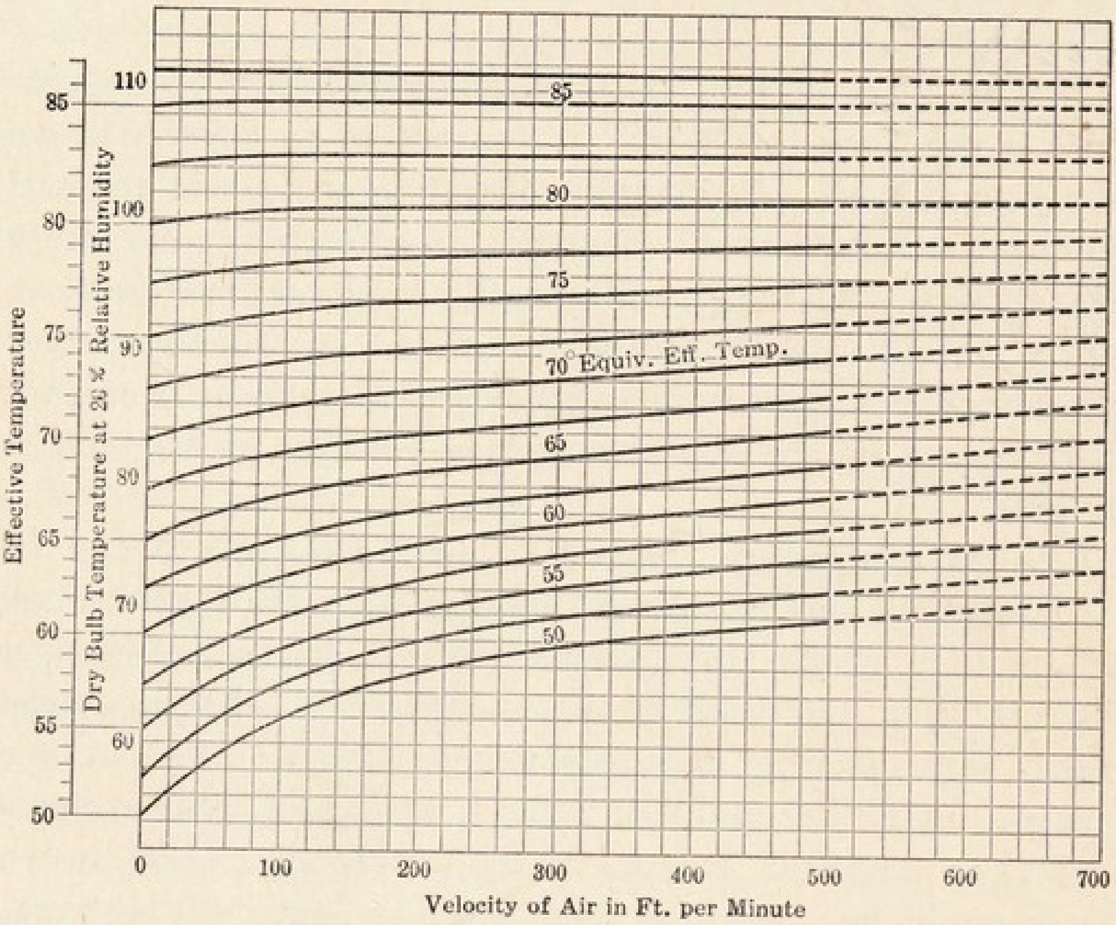


Fig. 6—Chart Giving Effective Cooling Temperatures Produced by Air Velocities from 0 to 700 Feet per Minute for Conditions of 20% Relative Humidity with Various Dry Bulb Temperatures*.

---

*Copyright 1924, Am. Soc. Heat. & Vent. Engrs., Published by permission.

1. The greater the air velocity, the more nearly parallel the equivalent temperature lines become to the dry bulb temperature lines. In other words as the air velocity increases, dry bulb temperatures become more predominant as an index of comfort. Also the greater the velocity, the higher the temperature at which the equivalent effective temperature lines become vertical, in which case comfort is independent of wet bulb temperatures.

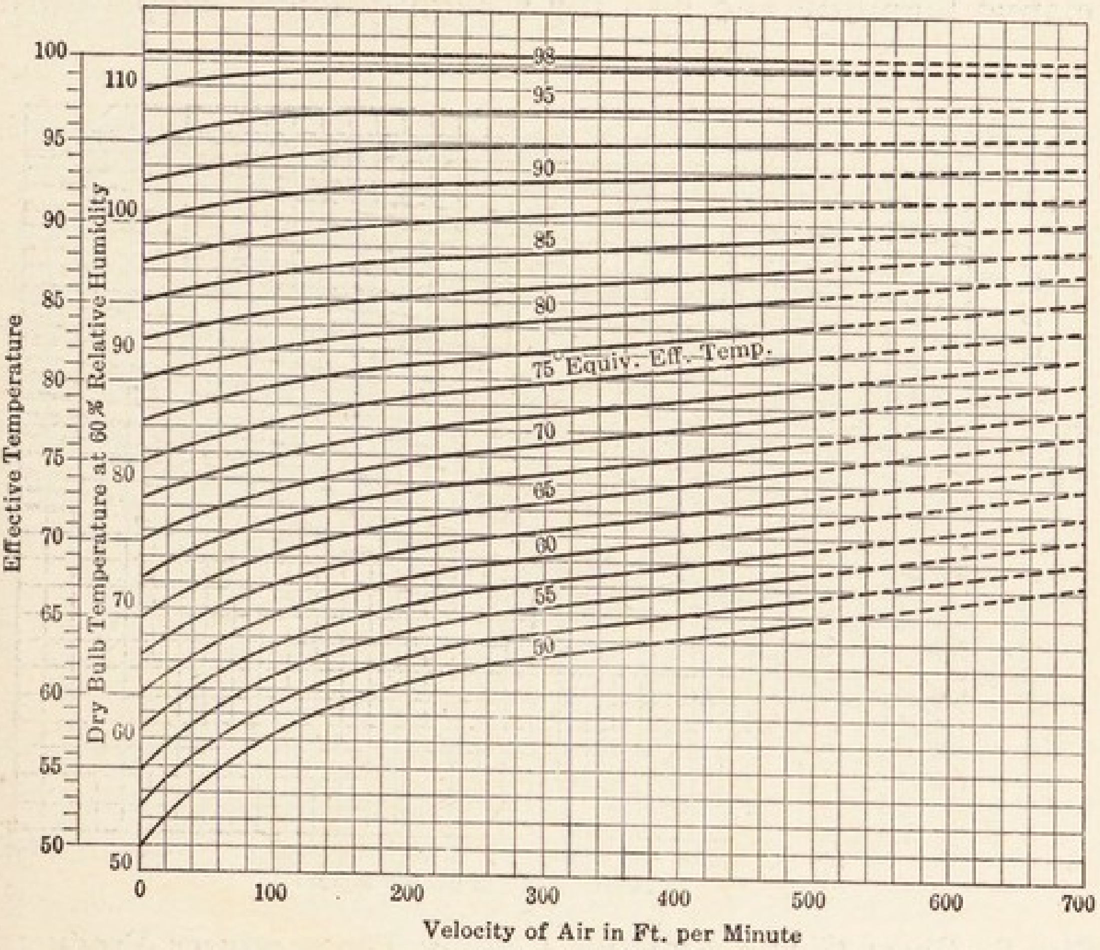


Fig. 7—Chart Giving Effective Cooling Temperatures Produced by Air Velocities form 0 to 700 Feet per Minute for Conditions of 60% Relative Humidity with Various Dry Bulb Temperatures*.

---

*Copyright 1924, Am. Soc. Heat. & Vent. Engrs., Published by permission.

2. At ordinary temperatures the higher the relative humidity for a given dry bulb temperature the greater the cooling produced by any air velocity.

3. There is no cooling produced by moving air for a dry bulb temperature equal to body temperature at 100% relative humidity and also for a slightly lower temperature at zero relative humidity. The highest temperature at which cooling results from air motion is 123.5 degrees dry bulb and about 30% relative humidity.

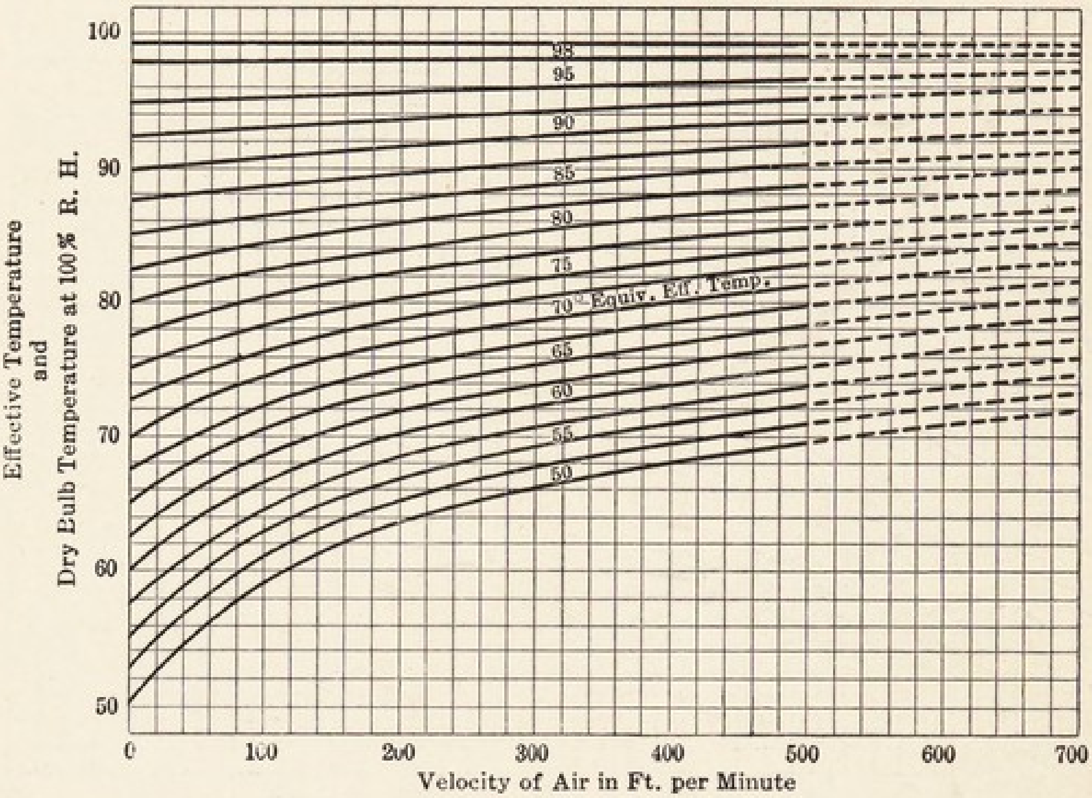


Fig. 8--Chart Giving Effective Cooling Temperatures Produced by Air Velocities from 0 to 700 Feet per minute for Conditions of 100% Relative Humidity with Various Dry Bulb Temperatures*.

4. For any condition there is greater cooling per unit increase in air velocity for low velocities than for high.

---

*Copyright 1924, Am. Soc. Heat. & Vent. Engrs., Published by permission.

Above 300 ft. per minute cooling is approximately a straight line function of velocity. It is therefore evident that extrapolation beyond the limits of the experimental data gives results sufficiently accurate for practical purposes.

For conditions where air motion gives considerable cooling it is probably the most effective and inexpensive means available. Unfortunately, as noted above, at high temperatures and humidities no great relief can be had by this means. The curves clearly show that with effective temperatures of from 50 to 70 degrees it is remarkably effective and it would seem an ideal method therefore, for cooling workshops devoted to hard manual labor. As higher effective temperatures are reached uncomfortably high air velocities are required to produce much cooling, for which reason the method is not as satisfactory when applied to sedentary workers.

The Influence of Clothing on human cooling requirements is somewhat complicated. In general, clothes are worn for warmth and to prevent cooling, but under certain temperature conditions they have no effect at all, and under still other conditions they promote cooling. A better understanding of the value of clothes in this respect would add greatly to the comfort of workers in hot industries.

The insulating value of clothing is due to the air caught and held stationary within its meshes and between its layers. For this reason two layers of light porous fabric are more effective than a single layer equal to them in weight. Cotton or woolen clothes of the same thickness and size of mesh are equally good when dry, but when wet, woolen materials are much better for preventing heat loss. Normal clothing at normal humidities decreases the cooling effect of wind to half of its value to a man stripped to the waist and wearing only light trousers, socks and shoes.

The cooling value of clothing lies in the greater surface it presents to the air and the greater amount of evaporation resulting therefrom. This is particularly true when very high dry bulb temperatures are accompanied by humidities below 20% and when the wet bulb temperature is well below 99 degrees F. An elastic cotton union suit which will cover tightly as much of the body's surface as possible has been suggested as an ideal costume for exposure to hot atmospheres. It will absorb the excess perspiration, which otherwise runs off the body, and will materially increase the amount of evaporation. At the same time it will moisten and protect corner areas of the body that are not adequately protected by perspiration.

When the wet bulb temperature exceeds the temperature of the body clothing should not be removed. The air in such cases should be kept as still as possible and ample clothing worn to prevent the transfer of heat from the air to the body.

Quantitatively, the insulating value of clothing has been stated by Dr. Leonard Hill in the following manner:

If the radiant heat emitted from the naked skin in a room at 59 degrees Fahrenheit is taken as 100 it will be reduced to 73 by a wool vest (undershirt;) to 60 by a wool vest and linen shirt; and to 46 by a wool vest, linen shirt and waistcoat.

The American investigators found that with temperatures of about 65 degrees F., a man stripped to the waist will require a decrease of 0.9 degrees wet bulb temperature to counterbalance an increase of one degree dry bulb and maintain the same condition of comfort, whereas a man with ordinary clothing will require a decrease of two degrees wet bulb to counterbalance an increase of one degree dry bulb.

The Katathermometer has been widely used in investigations of cooling power. It is the chief means of measurment and comparison employed by British investigators and it is considered satisfactory by some authorities in the United States. The investigators of the American Society of Heating and Ventilating Engineers however, found that conditions giving equal kata cooling value gave unequal sensations of comfort, and C. P. Yaglou doubts that any single instrument can be designed that will answer the purpose.

The "Kata" is an alcohol thermometer with a bulb about four centimeters long and two centimeters in diameter and a stem twenty centimeters in length, with graduation marks at 100 degrees and 95 degrees F. The bulb is heated to above 100 degrees in hot water, dried, and suspended in air, and the rate of cooling observed, that is, the time in seconds that it takes to fall from 100 to 95 degrees. By dividing the time into a factor (determined for each thermometer) the rate of cooling at the surface of the bulb is obtained in millicalories (1/1000 gram calories) per square centimeter per second. The rate of cooling depends on both air temperature and air movement and this instrument is very accurate for determinations of small air velocities. It does not take evaporation into account unless fitted

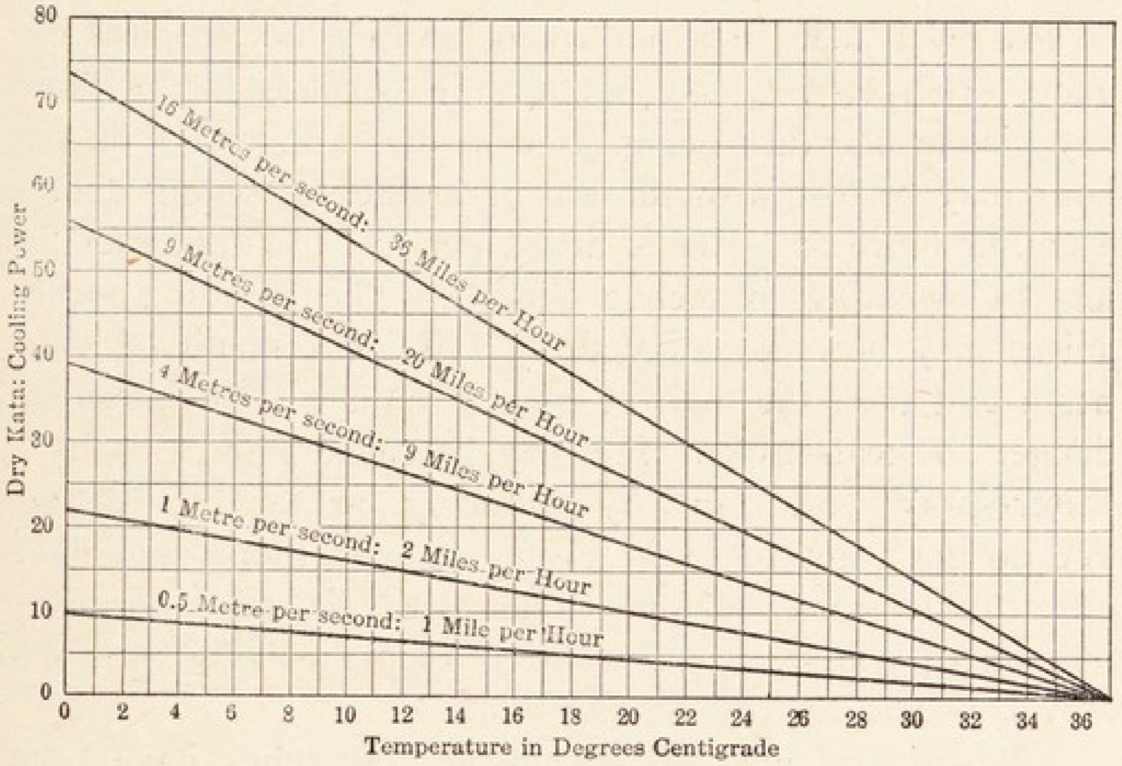


Fig. 9—Wind Velocity and Kata Cooling-power

with a wet jacket, after the manner of the wet bulb thermometer. Used in this manner it is known as the wet katathermometer.

Discussing the use of the Kata thermometer in an article on Ventilation and Human Efficiency, appearing in Mining and Scientific Press, February 25, 1922, Dr. Leonard Hill says:

"By adjusting the cooling-power to the heat production of the worker, sweating can be prevented, and the work done with comfort and ease. The curse of Adam can be removed by the aid of a fan; 2 lb. of sweat per hour can be lost by a man in a hot room, or in a hot tropical climate. In relatively dry hot air the sweat is lost without any visible moisture being seen on the skin, and 1 lb. per hour may be lost without skin or clothes becoming damp; 3 gal. or more of water is drunk per day to counteract the loss of sweating in such a climate. The sweating mechanism may become fatigued, or fail, as a result of sickness; and then the man in such a climate is in imminent danger of heat-stroke. He may be saved from this by a water-spray and fan, by inducing artificial sweating. We do not want to sweat visibly in workshops, and have our clothes made damp. The sweat is an emergency method of cooling. We want to keep the body comfortably cool and dry by cooling wind.

"Using my methods, extensive researches have been carried out; these show that the cooling and evaporative powers are frequently beneath the standards I have fixed. The figures obtained show how different are the conditions to which the indoor worker is exposed compared to those of the outdoor worker; the latter, in spite of low wages, has a much higher expectation of life. The effect of windows and artificial ventilation has been studied; the conclusion reached was that extraction fans offer the most effective means of securing movement of the air. I have calculated from the heat output of different workers, and their evaporative loss at rest, that the tailor requires a dry 'kata' cooling-power of 5 to cool him by convection and keep him from increased heat loss by evaporation; a shoe-maker, 7; a man sawing wood, 18. We need not stop any increase of insensible sweating, but we may stop, with advantage, visible sweating and any feeling of heat stagnation and lack of comfortable freshness. At the same time we do not want to produce over-cooling. The adaptation of people to warm or cool surroundings is great; they require to be brought gradually from an enervating over-warm environment and accustomed to one that is fresh and stimulating. Most people detest cool drafts; but consumptives that are used to open-air treatment like them, and dislike closed rooms; it is a matter of custom. So, too, with clothing. Many nowadays over-clothe themselves for fear of catching cold, which is really caught by confinement in stuffy rooms and from microbic infection. This is a lesson that people require to learn; traditional lore now keeps many from acquiring healthy hardness and from enjoying life."

The Influence of Ventilation on Output. *Hot Industries.* Dr. H. M. Vernon, Investigator for the Industrial Fatigue Research Board of Great Britain, found that in many hot industries in England the output in summer was materially less than that obtained in winter. Data secured by him on the output of the millmen in the tinplate trade, for periods of from one and a half to seven years, showed that in every case there was a seasonal variation. It was smallest in August when the average production was 10% less than in January. Throughout the rest of the year it showed intermediate values which closely paralleled the mean temperatures in their variation. This process was a hot and heavy one, and the men worked at it continuously for six or eight hours except for occasional short pauses of two or three minutes duration. At most works a system of artifical ventilation was installed in order to cool the air.

These systems were most efficient where large fans were used revolving in a vertical plane immediately above the heads of the men. Under such conditions summer output was only 3% less than winter output. In a moderately well ventilated works supplied with cold air douches, the difference was 6.4% while in a works without any artifical ventilation whatever, the difference was 13.4%. The following paragraph is from Dr. Vernon's paper on "The Influence of Atmospheric Conditions on Industrial Efficiency" which appeared in Engineering and Industrial Management for December 29, 1921:

"It is probable that a seasonal variation of output occurs to a greater or less extent amongst the workers in all of the hot and heavy trades, unless special precautions are taken to neutralise the temperature effects. I found that it was present in the output of the steel melters engaged in producing steel by the open hearth process, and in one works, where the ventilation was very poor owing to the narrowness of the shop and the low pitch of the roof, the summer output was 11% less than the winter output. In another and better ventilated works the seasonal variation was not half as great, and in two others it was practically non-existent. Again, the output of steel from the rolling mills was found to be 10% less in the summer than in the winter at an old-fashioned works where most of the manipulation of the red-hot steel ingots was effected by hand labor, whilst at more modern works, with more mechanical appliances, the seasonal difference was smaller or non-existent. Still again, the output of men engaged in puddling wrought iron, which is effected entirely by hand labor, was found to be 6% smaller in summer than in winter."

Underground Conditions. Experiments undertaken by A. J. Orenstein and H. J. Ireland in the Rand Mines, Johannesburg, South Africa are reported on by them in the Journal of Industrial Hygiene for May and June 1922.

They tested the abilities of two negro workmen, one with a hammer dynamometer, the other with a rotary (crank turned) ergometer. Each worked as hard as he could for four hours and tests were conducted on the surface and at various points underground. Before and after the working tests the subjects were tested with a finger ergograph as a means of recording fatigue.

Working stations were chosen, after katathermometer readings had been taken in several places, with a view to securing widely different cooling powers together with general convenience. The positions chosen were:

Surface:

1. Cable shed in store yard.

Underground:

2. 19 Station near Turf Shaft, dept 4550 feet below datum level.
3. Stope J 20 (disused), depth about 4500 feet, 75 feet from station.
4. 23 Drive East at blind end, depth 5125 feet, 2500 feet from station.
5. 24 Drive West at blind end, depth 5260 feet, 2500 from station.

Depths are given below datum level which is 6000 feet above sea level.

The results of these tests are shown graphically in Fig. 10. The investigators found it extremely difficult to build a dynamometer that would measure the work done in hand hammer drilling. The one adopted gave satisfactory results when used with extreme care but it had to stand 14,000 heavy hammer blows a day and was difficult to calibrate and manage. For this reason the hammer records are not complete. So far as they go, however, they show a fairly close parallel with the rotary records, which in turn show a very close variation with both the wet kata cooling powers. The report includes a table giving wet and dry "kata" cooling powers and wet and dry bulb thermometer readings together with the output of work in foot pounds and comments on the condition of the men for some fifty tests. The maximum output of work done by the rotary boy was 1,104,000 ft. lbs. with dry and wet

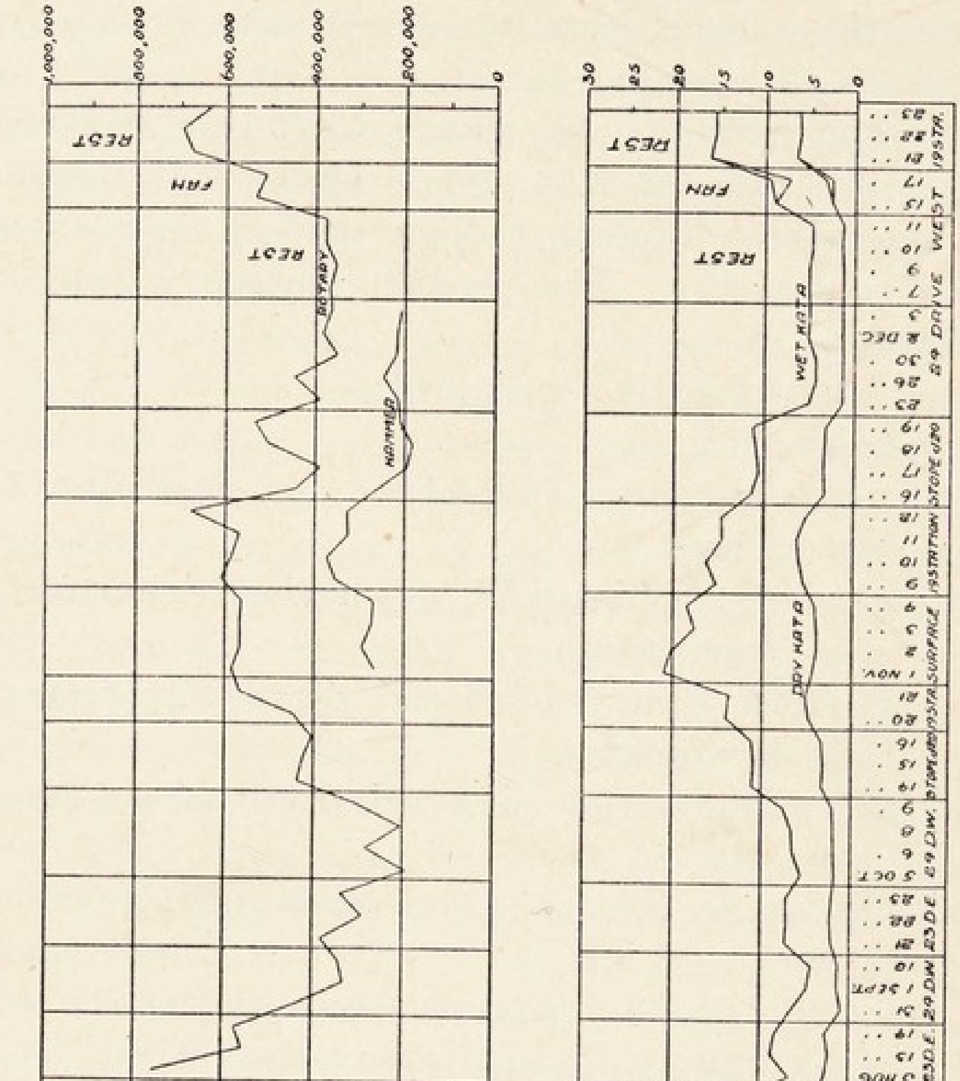


Fig. 10—Curves Showing Output of Work Done with Hammer and Rotary Machines in Comparison with Cooling Power as Measured by Kata Thermometers

"kata" cooling values of 7.2 and 19.7, and dry and wet bulb thermometer readings of 62.7 and 60.6. Under these conditions he experienced very slight fatigue. This performance in four hours bears out the general experience that a man can do 2,000,000 ft. lbs. of useful work in a day. The minimum output for the same man on which measurements were considered accurate, was 290,000 ft. lbs. It was accomplished at the expense of great fatigue with dry and wet "kata" cooling powers at 2.32 and 7.1 and dry and wet bulb thermometer readings of 84.2 and 82.4 respectively.

As a result of these tests the investigators concluded that either dry or wet "kata" cooling powers could be used as an index of working efficiency. They assume working efficiency to be 100% with a dry "kata" cooling power of 6, and find the following relative efficiencies with reduced cooling powers:

Dry Cooling Power	1,	2,	3,	4,	5,	6.
Working Efficiency, %	50,	60,	70,	80,	90,	100

The Effect of Ventilation on Health. Professor Winslow in his address to the Sanitary Division of the American Society of Civil Engineers, quoted elsewhere, said:

"Recent investigations, particularly those carried on in New York, have made it clear that these thermal problems of ventilation are of the very first importance, and that even slight degrees of overheating may produce far-reaching results. In the first place the studies of the New York State Commission showed that even an atmospheric temperature of 75 degrees F. in still air caused a definite increase in body temperature and heart rate, a marked decrease in general vasometer tone, and an increased rate of respiration. In the second place this relatively slight overheating caused a decrease of 15% in the physical work performed by subjects not compelled to maximum effort but stimulated by a moderate cash bonus. The inferences from this fact in regard to the economic losses due to overheated factory workrooms are of far-reaching significance. Finally, the studies showed that in fan-ventilated schoolrooms, at an average temperature of 68.5 degrees F., there was an excess in respiratory illness amounting to 70% and an excess in absence due to such illness of 18%, as compared with window-ventilated schoolrooms at an average temperature of 66.5 degrees F.

"The conclusions to be drawn from these investigations are of immediate practical importance to ventilating engineers, architects, schoolmen, and legislators. In a large number of States there are now laws which require the positive ventilation of schoolrooms by methods which effect an air change at the rate of 30 cu. ft. per min. These laws have been advocated by the American Society of Heating and Ventilating Engineers in complete good faith on the basis of the older physiological assumption that air vitiation was a chemical condition requiring a definite degree of dilution for its control. The New York State Commission results make it clear that the supply of 30 cu. ft. per min. of air in the schoolroom is not only needless but actually harmful to health and comfort as it almost inevitably leads to objectionable overheating. In the interest of health and of economy these laws should be modified so as to permit of the construction of school buildings ventilated by regulated window inlets and gravity exhaust which the New York studies have shown to be, under some conditions at least, distinctly preferable to the fan-pressure system."

The Cost of Artificial Humidification. Humidification is resorted to in order to correct the dryness of artificially heated air; to provide very moist air which is found to facilitate the mechanical handling of some materials, particularly yarns in the textile industry; to keep the moisture content of the air constant so that hydroscopic materials can be worked to advantage, for example, the fitting of wood parts in aeroplane factories; and to promote cooling.

In commenting on the cost of humidifying equipment, Mr. D. C. Lindsey, physicist of the Carrier Engineering Corporation, calls attention to the fact that this item is uncertain, as air conditioning equipment cannot be completely standardized. The conditions to be established differ in almost every plant. The type of building affects the cost, and there is considerable difference in cost depending upon whether the work is a part of the initial construction of the building or whether the installation is made in an old building. A rough estimate for the initial installation of Air Conditioning, which includes humidification, heating and evaporative cooling, but does not include refrigeration, is approximately fifty cents per cubic foot of air to be supplied per minute. Thus if a room 100 by 100 by 20 feet, containing 200,000 cubic feet, is to have a comfortable change of air every ten minutes, 20,000 cu. ft. must be supplied per minute and the installation will cost about $10,000.

The Cooling Value of the Weather. The United States Weather Bureau in casting about for a means of evaluating and comparing climate have recently attempted a classification based on its effect on human comfort. Their findings while still tentative indicate a profitable direction for further research. Papers on this subject by C. F. Brooks and E. C. Donnelly were published in the Monthly Weather Review for October 1925. Unfortunately their determinations are worked out on a basis of cooling power as shown by kata-thermometer readings which involve a complicated formula, and, which are not a perfect indication of the cooling effect on man.

Obviously the rate of cooling and hence the degree of comfort experienced under a given set of climatic conditions depends both on atmospheric factors and on the surface temperature of the body to be cooled. For this reason, in studying the comfort value of a climate separate curves must be worked for each degree of human activity.

Rate of Cooling. According to Mr. C. F. Brooks, the rates of cooling and heating depend on the following factors:

1. Air temperature (effects well worked out with katathermometer.)
2. Wind velocity (effects well worked out with katathermometer).
3. Rate of evaporation from a man's body. (Average of 570 kilogram calories of heat lost per 24 hours. Extremes vary with humidity, water imbibed, work performed, and air temperature.)
4. Intensity of radiation (combined with air temperature.)
5. Clothing (variable).

Rate of Heating involves:

1 Metabolism from food recently eaten (Variable but an average may be used.)
2. Work being performed (Variable but the heating effects of well known sorts can be specified.)
3. Sunlight and incoming sky radiation (Variable with cloudiness, humidity, and solar altitude, and with the color and texture of the surface.)
4. Air temperature when above 98.6 degrees F. (Effect depends on wet bulb temperature and wind velocity.)
5. Wind velocity when air temperature is above 98.6 degrees F. (Heating only when wet bulb temperature rises above 98.6 degrees.)

Mr. E. C. Donnelly has worked out an elaborate formula involving the foregoing factors and has applied it to a year's weather at Los Angeles, Cal., giving his results in graphic form. Curves drawn for men at work and at rest both in the sun and in the shade are shown in Fig. 11.

The curves on the right of the diagrams indicate the cooling requirements for various tasks as given in Dr.

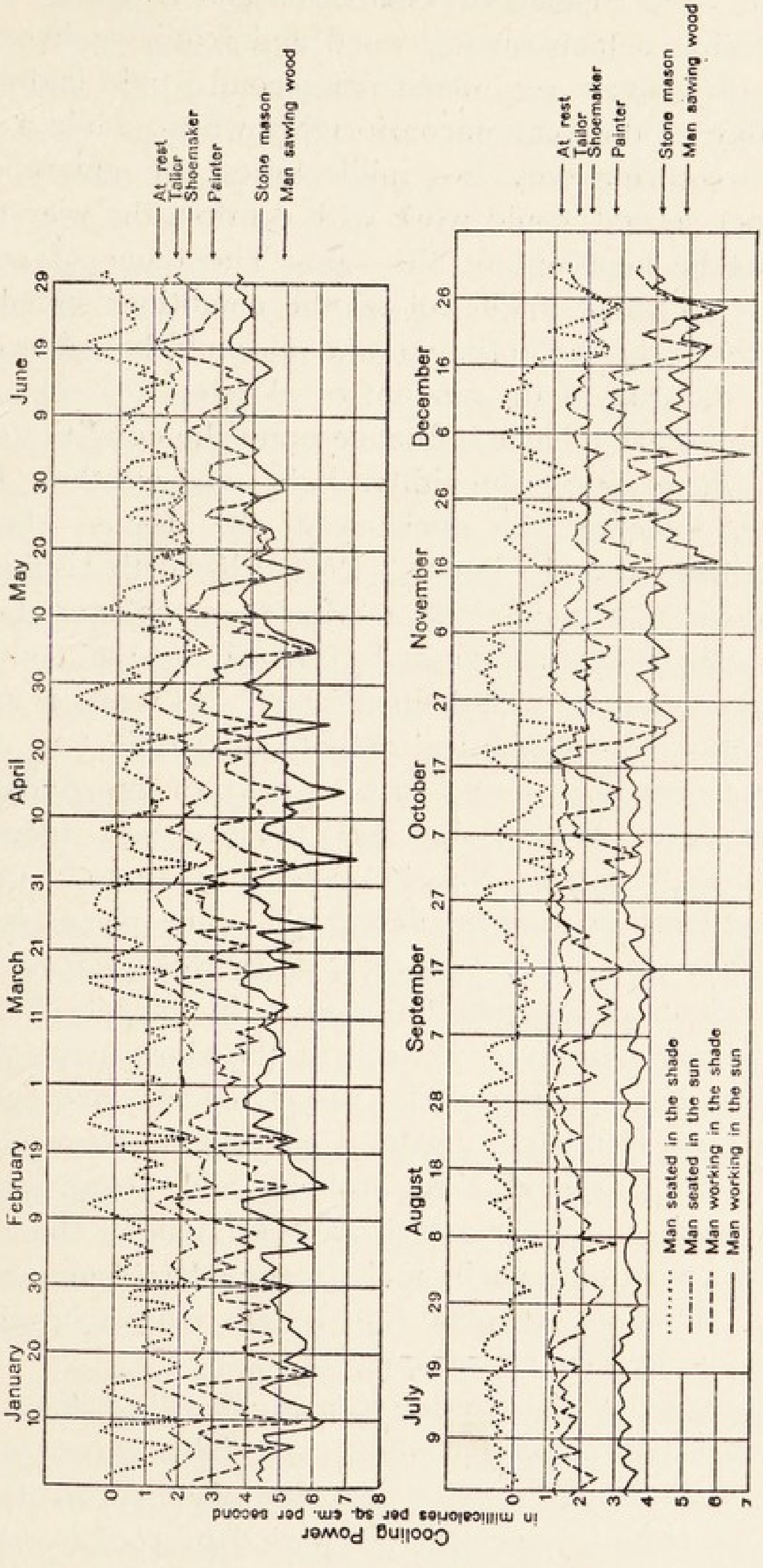


Fig. 11—Cooling Effect of Los Angeles Climate on Men at Work and at Rest

Leonard Hill's Science of Ventilation and Open Air Treatment. Thus a man sawing wood and requiring five millicalories per square centimeter per second would find nearly every day of the year uncomfortably warm, while a shoemaker, requiring only two millicalories per square centimeter per second, could work with comfort the year round provided he kept out of the sun. The range of cooling effect is so small under all of the conditions noted that any excess over the optimum amount could be balanced by a small increase in the amount of clothing.

Climate, as a basic influence upon the conditions that control temperature, humidity, light, and weather, has a profound effect on the efficiency of the Human Machine. In "Civilization and Climate," Prof. Ellsworth Huntington has shown that there is a marked seasonal variation in human efficiency, mental and physical, in the temperate zone, according to well-defined laws. He made a critical examination of the physical activity of 410 factory operatives in Connecticut, from 1910 to 1913, of 240 students in mathematics at West Point, 1909 to 1912, 220 students in English at Annapolis Naval Academy, 1912 to 1913, and 1300 students in mathematics at the same place, 1907 to 1913. The time of best work is when the mean temperature is about 40 degrees Fahrenheit, in the late Fall and early Spring. January, in each of the above cases, is the month of least energy. The results of his investigations are that in Denmark, Japan, Connecticut, Pennsylvania, New York, Maryland, the Carolinas, and Georgia, mental and physical activity reached their maxima in the Spring and Fall, with minima in midwinter and midsummer. In Florida, the most energetic time of the year is in midwinter and the least in midsummer.

Hot weather is irritating to men as well as dogs, and a protracted period of hot days, especially if not accompanied by cool nights and a low dew point, is so depressing as to require a considerabl period of cool weather to enable people to get back their normal vigor. A long period of cold weather without alternate warm periods likewise tends toward human inefficiency, which has been marked in Siberia. A climate of satisfactory mean temperature with small variations from the mean is stimulating but not so good as one with considerable variations which occur at short intervals. Prof. Huntington's conclusions are that the best climates for human vigor, mental and physical, are found in western Europe, most of the continental United States and southern Canada.

For the great majority of business men in the executive class, whose work is largely sedentary and who naturally suffer from a deficiency of physical exercise, midsummer is the logical time for a vacation, because then there is the seasonal let down in energy, business in most industries is less active, they can most easily get away, and it is the most favorable time for getting out of doors. There has of late years been a decided movement in favor of taking a supplementary vacation of shorter duration at the other seasonal low vigor point, in midwinter, at the expense, when necessary, of the summer period. At such periods the time is most economically spent, because it is taken when it is of the least value for work, and when rest and recreation have maximum recuperative effect. The same idea applies to the problem of relieving men from exhaustion when they have high temperature tasks in hot weather, such as foundry or furnace work, by having them exchange tasks for short periods with somewhat less efficient men, perhaps, whose regular tasks are less trying.

Conclusions. Ideas on the subject of ventilation have undergone a radical change in comparatively recent years. Theories of poisioning due to "stale" air and of partial suffocation due to lack of oxygen have alike been discarded, and it is now generally accepted that the problem involved is thermal rather than chemical. Ventilation is largely, if not entirely, a matter of proper cooling for the human body. The cooling effect of the air depends on a number of factors whose relations are complicated and whose evaluation is difficult. Attempts to establish a standard for cooling value may be classified in two groups: first, those depending on some instrument or set of instruments; second, those depending on bodily sensations as judged by a number of observers. Investigations along both lines are recent and are still under way. Their results to date, though extremely valuable, must not be regarded as final. Further studies may result in changing factors and values, and may greatly simplify present ideas. The general aspect of the problem, however, is pretty well established. It is evident for instance that:

1. Under industrial conditions, the oxygen and carbon-dioxide contents of the air do not vary beyond limits consistent with human comfort.

2. The moisture content of outdoor air does not vary beyond limits consistent with health. Indoor air is frequently too dry when heated.

3. Odors are largely psychological in their effect. They are seldom noticed in cool air.

4. The cooling power of the air is a function of its temperature, its capacity for moisture, and its motion.

5. The cooling effect of the air depends upon the above factors and upon the supply of blood pumped to the body surface to be cooled.

6. Men working require a higher rate of cooling than men at rest, and men working at different tasks require different rates of cooling.

7. Rate of cooling can be stated as heat units lost per square centimeter of surface per second, and can be measured by a katathermometer. In so far as the katathermometer cools at the same rate as a man, it is a proper instrument for measuring the air's ability to cool him. It has its limitations, for if used dry it does not take account of evaporation and if used wet (wet katathermo-

meter,) it cannot vary its cooling rate as does a man whose skin is wet at some temperatures and dry at others. It is nevertheless a convenient and useful instrument and is a satisfactory means of comparison under the normal range of industrial conditions.

8. The dry bulb thermometer does not indicate the cooling value of the air, for by varying the three factors of temperature, moisture, and air movement, a number of conditions can be produced which give equal sensations of warmth and comfort. Comparison with the comfort value of saturated still air of a given temperature makes it possible to establish a set of equivalent conditions which may be said to have the same effective temperature as still air.

9. Effective determinations are based upon opinion of comparative sensations and are not a matter of scientific precision. They appear nevertheless to offer a satisfactory means of comparing the comfort value of different atmospheric conditions. Investigations along this line show that the human body when at work cannot maintain its temperature balance at an effective temperature of more than 85 degrees F., (85 degrees in saturated still air or equivalent condition) but will experience a continuous rise in temperature so long as subjected to this degree of heat.

10. The effective temperature may be lowered by artificially humidifying the air to the saturation point. This procedure will lower the dry bulb temperature until it equals the wet bulb temperature, which remains stationary. Effective temperature may be further lowered by imparting a velocity to the saturated air. This should not be more than 100 feet a minute for sedentary workers, and not more than 700 feet a minute for men at strenuous work in hot industries.

11. Humidifying the air will not lower its effective temperature at dry bulb temperatures of 40 to 50 degrees F. or less or when the wet bulb temperature is above body heat. Air movement will increase instead of de-

crease the effective temperature when it rises above the body temperature.

12. No amount of fresh air will make up for the injurious effects of overheated rooms, especially in winter. In schoolrooms and factories a brief period of overheating is more injurious to health than an equal period of underheating.

13. If the effective temperature, or the cooling power of the air as measured by katathermometer can be kept within proper limits, no other means of ventilation than open windows are necessary, except where industrial processes producing poisonous fumes are carried on, and except to dilute the dust, often germ-laden, of crowded rooms.

14. It seems possible to classify climate on a basis of its cooling or comfort value to men at different occupations. There is a marked seasonal variation in human efficiency, its maximal periods coming in the spring and fall, minimal, in the middle of winter and summer, in the temperate zone. The best climate has a mean temperature of about 40 degrees F., with considerable but not excessive variations therefrom.

CHAPTER IV

FATIGUE

Fatigue is the most characteristic of all the attributes differentiating the Human Machine from the mechanical one. It is "the sum of the results of activity which show themselves in a diminished capacity for doing work," according to the Russell Sage Foundation, which has listed the following six phases in the problem of fatigue from an industrial standpoint, namely:

1. The relation of fatigue to industrial accidents.
2. Fatigue and industrial efficiency. Presumably poorer work is done and less of it in the last hour of a day's work than in the others.
3. Fatigue and contagious diseases. An overworked person is probably more susceptible to tuberculosis, pneumonia, etc., than a person of normal vital resistance.
4. Fatigue and nervous diseases. The evidence indicates that long hours of feverish haste among factory workers lead to nervous breakdowns.
5. Fatigue and future generations. The children of overworked parents are likely to be weaklings.
6. Fatigue and morals of working people. Long hours of monotonous labor probably increase the susceptibility of the human organism to harmful temptations.

There is no doubt that this list could be augmented. Organs that are inherently weak are certainly not benefited by an exhausted state of the body, so that organic diseases may well be added to the list of those due to this cause.

The General Phenomenon of Fatigue. Everyone knows what it is to be tired, though to some the term means only that pleasant feeling of languor which comes in the Spring. The fatigue of exhaustion that is of such grave concern to industrial enterprise is a very different matter. It comes chiefly through the exercise of trained muscles, and consequently to trained workers. The amateur, though he be stiff and sore with an ache in every member, is not apt to be exhausted. To illustrate this let anyone try chinning himself. No effort of the will can force the biceps into lifting the body more than a few times. Ten minutes afterward the arms may feel sore but otherwise no ill effects result from the exertion. A ten mile walk on the other hand, is easy to accomplish. The leg muscles respond throughout without driving and may not even feel tired at the finish. Yet the ten mile walk results in a general feeling of weariness. This is the harmful aspect of fatigue.

The industrial worker is in the position of the man walking, in that he uses trained muscles that enable him to exert a large amount of energy. He may, without feeling it, suffer from fatigue to an extent harmful to himself and to the work he is engaged in. His ability to work may be impaired, resulting in a slowing down of activity and decreased output, or in a lack of muscular coördination, spoiled work and accidents.

The way in which fatigue is accompanied by a fall in production as the working period progresses has been briefly described in Chapter I. In general the individual works rapidly at first and even increases his production progressively throughout the first hour or two, thus revealing the effect of practice. The maximum is not long maintained, but soon gives place to a progressive diminution in production. This continues throughout the rest of the working spell, the production of the last hour usually being much less than at any other time. After the midday meal, as a result of rest and the stimulus of food, the production of the second spell begins at almost as high a rate as that of the first; there is then an increase, usually less than in the first spell, and later a progressive decrease which carries the production to a lower point than at the end of the first spell. Now this decrease in production is a most important manifestation of fatigue, and the fact that the decrease in the second working spell is greater than that in the first indicates that fatigue is cumulative.

The production curve differs for different kinds of work; thus, with a worker engaged in heavy physical labor, rather than that requiring coördination, it shows no rise due to practice but does show a decrease due to fatigue. Some tasks are so light and varied that they do not produce enough fatigue to affect the curve of daily production. Nevertheless, if a worker were kept at such employment indefinitely without a vacation, a decrease in production would result. This too would be the result of fatigue, though such fatigue might be psychical rather than physical. Generally, fatigue is physical, and the degree to which a man can suffer from it depends on how nearly his muscles are trained to exert the total amount of energy that his body can supply.

Fatigue Curves cannot always be constructed directly from output records, for with some highly automatic machinery the decrease in output is not an adequate measure of the fatigue involved. Figs. 11 and 12 are taken from report No. 23 of the Industrial Fatigue Research Board of Great Britain on "Variations in Efficiency in Cotton Weaving." They are based on a special treatment of data derived from an investigation of work done with automatic looms in plants where the humidity was artificially controlled.

Women operators each handled a number of automatic looms which were set to run at a definite number of *picks* per minute. Pick counters on the machines would show how nearly they operated to the entire possible time, or in other words, how much time was lost because of breakage. This could also be told for the entire factory by meter readings of the power consumed, for the looms used current only when running, which averaged about 85% of the time.

While the looms were running the operators had nothing to do, so their working capacity was not correctly reflected in the output of the machines. When they were attending to loom stoppages however, their ability was reflected in efficiency. Thus, in the case of an efficiency of 90% of duration the stops would be only six minutes in an hour. If in another hour it fell to 89%, the time taken to repair breakages would have increased to six and six tenths minutes. In this way a decrease in productive efficiency of only one per cent results from a decrease of ten per cent in human efficiency.

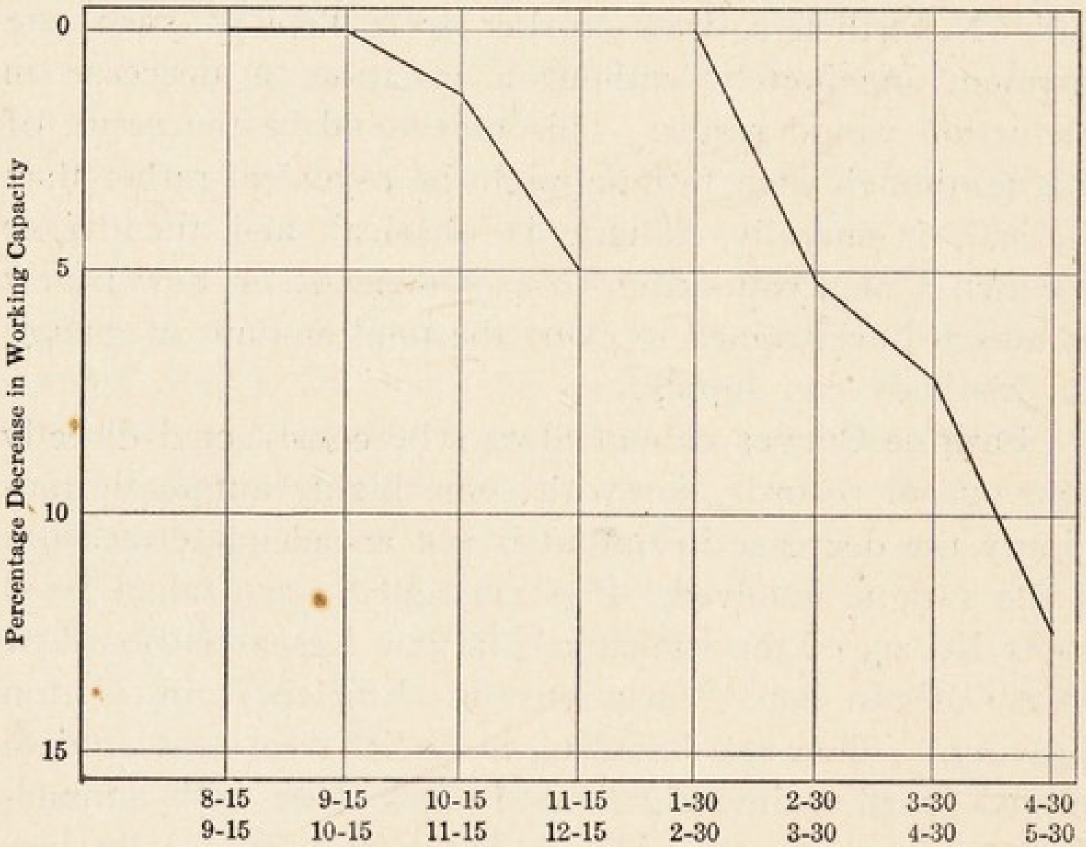


Fig. 12—Hourly Variations in Working Capacity (Typical Day)

This method of treatment, used by the Industrial Fatigue Research Board, makes it possible to put variations in efficiency in a semi-automatic process such as weaving, on a comparative basis either with handwork or with other partially automatic processes. Where decreases in efficiency are due to the effects of fatigue, it is possible by this means to transform small variations in efficiency in highly mechanical operations into significant expressions of fatigue.

It was assumed that the working capacity of the operatives, when at its maximum from 8:15 to 10:15 A. M., represented a condition of no fatigue, and the measure of fatigue was taken as the percentage increase in time required to repair breakages during the subsequent periods of the day. Thus if breaks could be repaired in six minutes of each hour in the first period of the morning and the same work required 6.76 minutes in the last period of the afternoon the increase in time required would in-

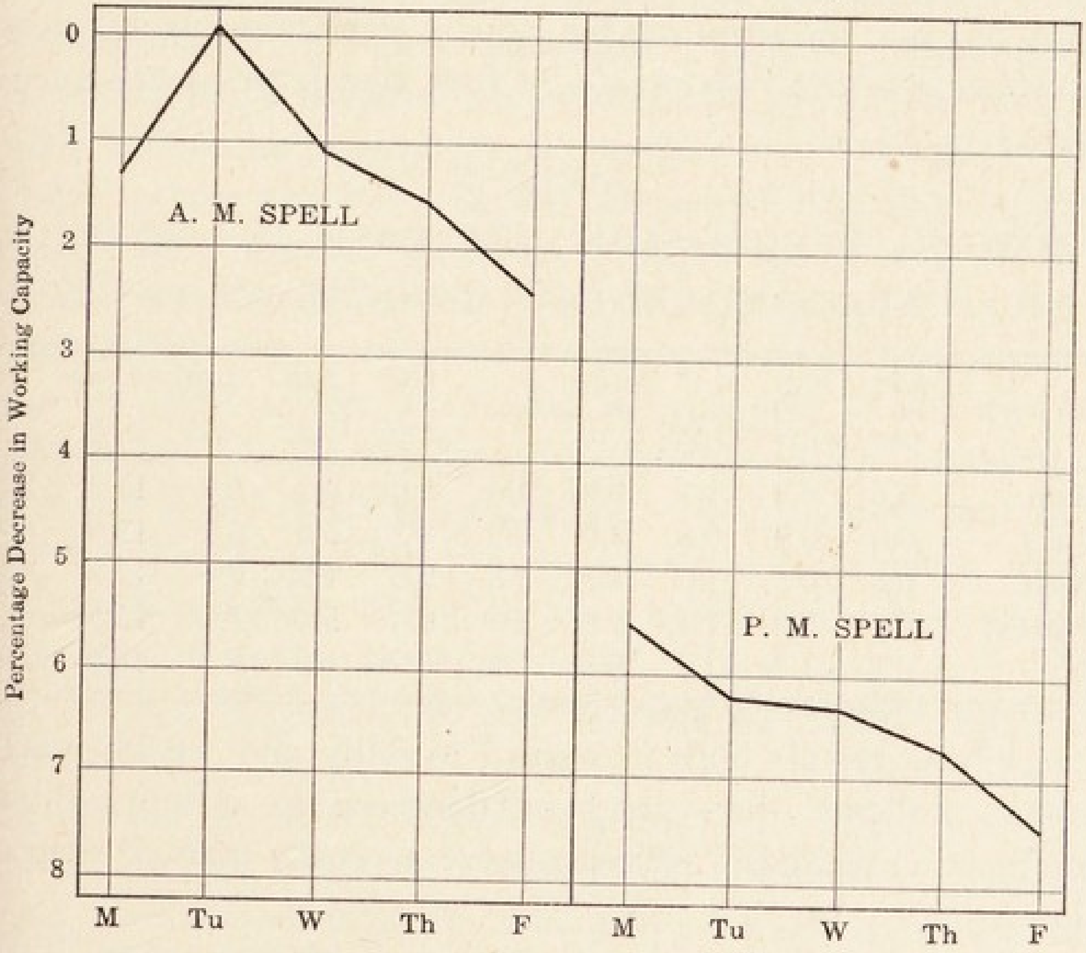


Fig. 13—Daily Variations in Working Capacity

dicate a decrease of 12.7% in working capacity. Results for a composite day are shown in Fig. 12.

In a similar manner the decreases in working capacity due to fatigue for morning and afternoon working spells during a typical week are shown in Fig. 13. In this case, Tuesday morning was the time of maximum production and the curves are based on a consideration of it as a period of no fatigue.

Hourly variations during a typical week based upon the assumption that operatives were most efficient from 8:15 to 10:15 on Tuesday morning are given in Table 11. The morning spell clearly shows the practice effect in the rise of the curve from Monday to Tuesday in Fig. 13. This did not show up on the hourly variation curves, possibly because the results of the first two hours were averaged.

TABLE 11

SHOWING PERCENTAGE DECREASE IN WORKING CAPACITY DURING A TYPICAL WEEK

	8.15 – 9.15	9.15 – 10.15	10.15 – 11.15	11.15 – 12.15	Avg.	1.30 – 2.30	2.30 – 3.30	3.30 – 4.30	4.30 – 5.30	Avg.
Mon.	1.6	0.9	1.1	2.8	1.6	0.0	4.8	6.5	11.8	5.8
Tues.	0.0	0.0	0.8	2.9	0.9	0.2	5.6	6.9	12.9	6.4
Wed.	0.6	0.8	1.6	4.2	1.8	0.6	4.9	7.4	12.7	6.4
Thurs.	0.5	0.9	1.4	5.9	2.2	0.4	5.4	7.2	13.8	6.7
Fri.	0.8	1.2	2.0	6.3	2.6	0.9	6.0	8.1	15.0	7.5

These results, both in regard to daily and weekly variations, indicate the extent of decrease in output which might be expected if weaving were a purely manual operation.

In connection with the shape of these curves it is interesting to quote from another part of the report. Referring to the plants investigated it says: "In all the sheds the temperature rises throughout the day, rapidly at first, but more slowly afterwards, though there is a small decrease during the dinner hour. The increase is due to the following causes:

1. The heat produced by the machinery in motion.
2. The artificial heating, and, in the humid sheds, the introduction of steam.
3. The gradual rise in temperature of the outside air.
4. The presence of the operatives.

"Thus, there is an accumulation of heat in the sheds throughout the working day, and in summer the afternoon conditions at times become trying. The decrease during the dinner hour is due to the temporary suspension of the first two and the last two factors given above, and it appears probable that the subsequent afternoon temperature could be much reduced by a thorough ventilation of the sheds while the machinery is stopped and the operatives absent. Any reduction in the degree of humidity in the sheds which resulted could be restored by turning on the humidifiers shortly before work is resumed in the afternoon spell.

"In most of the sheds the temperature shows an inclination to rise during the week, being initially higher on each day from Monday to Friday. This suggests that the cooling of the shed during the night is incomplete, with the result that there is a gradual accumulation of heat which is dissipated during the week-end."

Energy Capacity of the Human Machine. In our previous illustration the average man chinning himself could scarcely exert 1000 foot-pounds of energy whereas in walking ten miles he would exert a thousand times as much. By considering the quantity of work necessary to raise his body to the ordinary extent for each step, it has been found that the man of average weight, say, 150 pounds, will do about 2,000,000 foot-pounds of work in walking 20 miles. Likewise, an ordinary laborer, with a good hand pump, can accomplish about 2,000,000 foot-pounds of work in raising water, without excessive fatigue, in one day. On the first day of the six-day bicycle-race in 1898, Miller, the winner, performed more than 15,000,000 foot-pounds of work, as calculated by Carpenter, and averaged on each of the six days over 9,500,000 foot-pounds. These classes of work, involving rhythmic motion, can be accomplished with far less fatigue than the kinds of work in which the motion is intermittent and in varying degrees of intensity as, for instance, loading one-man stone into a wagon, handling earth with a shovel, handling rather heavy castings in a shop, etc. When work is found to be very fatiguing to the men, and yet to come well within the 2,000,000 foot-pounds per day of performance, it can usually be accomplished by so rearranging it as to make it more rhythmic and by planning to include an arrangement of rest.

Physiological Character of Fatigue. Johannes Ranke, in Munich, in 1865 showed that fatigue is due to something which arises within the organ rather than to the absence of something used up by the process of muscular contraction, and that it is to be explained on the basis of a full ash pit rather than an empty coal bin. His principal evidence consisted of the fact that when a fatigued muscle was irrigated with an indifferent fluid, as salt solution, it resumed its power of contraction. He argued that since the irrigating fluid could not have supplied anything neccessary to the muscle, it must have removed something detrimental to it. Further tests by physiologists and biologists on various muscles of the body have enabled them to identify, as products of exertion, various poisons, which, though produced within the body, are as harmful as noxious drugs.

Psychologists, on the other hand, have believed that fatigue is brought on by certain mental conditions of the workers. This idea arose from the fact that when a worker is fatigued, that is when he feels physically tired, by giving him a certain stimulus in the form of a pleasureable thing to do, he is enabled to exert the same muscles in a way to show that they have lost little by their previous tired condition. This would seem to disprove the contention that the fatigued muscles are handicapped by the accumulation of fatigue substances if it were not for the fact that fatigue is cumulative. Given a very interesting piece of work to do, such as building or repairing an article for his own use, the worker can continue far into the night even though he has been working at the same thing all day for someone else. This additional work done under the mental stimulus of interest is in the nature of a spurt that cannot be maintained for long. The worker will not be able to deliver his accustomed output on the following day. He has merely been able to force his muscles to produce and endure a greater amount of poison than usual, and he will require more than the usual amount of rest before it can be removed.

Josephine Goldmark in "Fatigue and Efficiency*" says: "A tired person is literally and actually a poisoned person —poisoned by his own waste products. But so marvelously is the body constructed, that like a running stream, it purifies itself, and during repose these toxic impurities are normally burned up by the oxygen brought by the blood, excreted by the kidneys, destroyed in the liver, or eliminated from the body through the lungs. So rest repairs fatigue.

"This balance is kept true and fatigue is repaired just as long as it remains within physiological limits; that is, as long as activity is balanced by repose, when the noxious products of activity are more quickly eliminated and tissue is rebuilt. Just as soon as the metabolic equilibrium is destroyed the organism becomes clogged by its own poisons, exhaustion results, and health is impaired.

"At the termination of hard muscular work the muscle contains a lessened supply of energy-yielding material, be-

---

*Published by Russell Sage Foundation.

cause during contraction the processes of disassimilation or catabolism are in excess of those of assimilation or anabolism.

"The stored glycogen of the muscles keeps uniting chemically with the oxygen of the blood. The glycogen is broken down into a simpler chemical form, giving off the gas carbon-dioxide and other acid wastes, and releasing heat and mechanical energy in the process.

"When the muscle is active and contracts energetically, there is a run upon our glycogen. It is used up faster than it is built in muscle. The glycogen is spent so rapidly that there is not time for the bloodstream to bring back to the tissue the potential material for its repair. Glycogen may even be entirely consumed and disappear from the muscle.

"There is another organ of the body which acts further as a storehouse for glycogen. This is the liver, whose cells are so constructed that they too convert the dextrose or sugar in the blood into glycogen and retain it, until the store in the muscles is so far depleted that it must be replenished. This stored glycogen of the liver is then supplied to the muscles at their need."

There is another factor in fatigue, namely, the consumption of the tissues themselves. Again, quoting from Miss Goldmark:

"Not only does tissue manufacture poison for itself in its very act of living, casting off chemical wastes into the circling bloodstream; not only are these wastes poured into the blood faster with increased exertion clogging the muscle more and more with its own noxious products; but finally, there is a depletion of the very material from which energy is obtained. The catabolic process is in excess of the anabolic. In exhaustion, the organism is forced literally to use itself up."

Burn itself up, might be a better expression as we shall see later, because the breaking down of glycogen and even the destruction of tissue are largely oxidation processes, their progress is accompanied by an increase of carbon-dioxide in the exhaled air. The higher body temperatures produced and the increased amount of carbon-dioxide in the lungs lead to increased breathing which in turn adds to the sum total of fatigue.

Dr. E. R. Hayhurst in a report prepared for the Ohio State Board of Health says that the sensation of fatigue is due to the accumulation of waste products within the system. These products are definite chemical substances, called fatigue poisons, as well as fatigue toxins. The poisons are acid in character and a fatigued muscle is acid in reaction, while one at rest is alkaline. Poisons of one type called leucomaines, are similar in action to the ptomaines obtained from putrid meats. The presence of such substances is easily demonstrated in the dog experiment, in which a few cubic centimeters of blood are removed from the veins of a dog that has been run until fatigued, and then injected into another dog not previously exercised. Within a few moments after the injection symptoms of fatigue appear in the second animal. Even paralyzing effects and death may follow for the second dog if the exhaustion of the first has been extreme.

Dr. Hayhurst says further that there is more in the matter of getting accustomed to work than the establishment of a good circulation of blood to the parts used. Workers who begin a new process at first feel the symptoms of fatigue very quickly but gradually the period of continuous application is extended until the person has become used to the work. This seems in part due to an anti-toxin carried within the blood which destroys the fatigue toxin at its source in the muscle. "Getting in training is but the working up of this fatigue anti-toxin."

Fatigue poisons are not confined to the muscles but spread to other organs and react upon them; thus the activity of one physiological mechanism fatigues others.

In fatigue, muscles are weakened, and the quickness and accuracy of muscular action are decreased. The senses become less acute; attention is less sharply focused, and the power of discrimination is lessened. Glandular secretions appear to decrease; the heart beat may be slower, or in extreme cases, quicker and more irregular; the blood vessels of the skin are dilated (where fatigue is the result of violent exertion) and draft an undue quantity of blood away from the brain. Whether the fatigue be incurred at hard manual labor or at some sedentary occupation a sense of weariness obtrudes and oppresses. This feeling of weariness, however, is a very uncertain index of the amount of fatigue in the tissues.

Three points regarding the physiological character of fatigue should be kept in mind. They are: 1. Symptoms of fatigue are usually no more prominent in the particular muscles or parts used than throughout the system in general. 2. The brain always suffers from fatigue no matter what part of the body is overworked. 3. Fatigue poisons do not accumulate in the system if time intervals between periods of exertion are sufficient for the circulation to counteract and remove them.

The Psychological Character of Fatigue. Nervous fatigue is recognised as being distinct from muscular fatigue, but it is difficult to tell where one leaves off and the other begins. The human middle finger has been tired out to the point where it was impossible for its owner to raise a weight with it by any effort of will, after which electrical stimulus applied to the nerves enabled the muscles to react much as before. From this it appears that in the first instance the nerve was exhaused while the muscle had a good deal in reserve. Although distinct objectively, it is agreed that nervous fatigue has the same double origin as fatigue of the muscles, namely, accumulation of toxic waste products and the consumption of certain substances that are necessary for activity. Further experiments have shown that nerve fibres are very much less fatigable than muscular tissue but that nervous fatigue affects the central nervous system rather than the nerve fibres themselves.

A report made to the British Ministry of Munitions in 1917 says on this subject:

> In the conducting nerve fibre fatigue may be said not to occur; it is unrecognisable probably because of the extreme rapidity with which recovery here follows the very small changes associated with activity. The distributing nervous mechanisms of the brain and spinal cord are more quickly fatigued than the contracting muscles, and the important result follows that, in the animal body, the impulses to activity springing from the brain cannot bring the muscles far towards complete fatigue before their sources are themselves fatigued and impotent. Even beyond that point, when the central nerve cells are inactive, impulses artificially sent, in experiment, along the indefatigable nerve fibres will still fail to produce more than partial fatigue in the muscles, for fatigue advances faster still in certain structures known as the endorgans, which connect nerve fibre and muscle; there the impulses become blocked so that the muscle again escapes from further activity.

In the tired man, the symptoms of fatigue are referred to the muscles; they ache, or they may appear to "give way under him" but in reality the most severe bodily activity fails to produce any close approach to complete fatigue of the muscles. The fatigue is fatigue of the nervous system, though in sensation its effects may be referred to the muscles themselves. A hunted animal may be driven to intense muscular fatigue, but in this extreme case the blood becomes charged with chemical products of activity, for the elimination of which no opportunity is given, and the muscles, with every other organ of the body, become poisoned. Even in laborious work it is doubtful whether a man by voluntary effort can cause his muscles to approach advanced fatigue. It is well known that a man, apparently "run to a standstill" in a race, may, upon some new excitement, run freshly again, under augmented stimulus from the nervous system, initiated there perhaps in part along new paths.

The problems then of industrial fatigue are largely those of fatigue in the nervous system and of its direct and indirect effects.

Causes of Fatigue. We know that fatigue of muscles may be caused by excess of work and by the exercise of improperly trained muscles. Bodily fatigue arises from these and from a number of other causes among which are impure air, improper diet, extremes of heat and cold, mental effort, worry, distraction, monotony, working at high speed, and working under the influence of vibration. An incorrect posture at work is also conductive to fatigue, and the performance of work by an untrained person, who cannot apply the advantage of habit toward the economizing of effort, often brings fatigue to an undue degree.

Impure Air may or may not contain active poisons. In either case it forces the lungs to handle a greater supply in order to secure the requisite amount of oxygen. This in turn requires deeper and more rapid breathing and harder pumping by the heart, all of which actions consume energy and produce fatigue.

An Unbalanced Food Ration, such as one containing an excess of protein, overloads the system with substances that must be eliminated and which, pending their elimination, are subject to the attacks of toxin-producing bacteria. Thus there is fatigue produced by the extra work placed on certain organs, and at the same time poisons are liberated which are similar to fatigue poisons in their action.

Extremes of Temperature. A certain amount of cold air, or rather of cooling power in the air, is stimulating and beneficial to health. The optimum amount of cooling requires the consumption of considerable fuel in order that body heat be maintained. Greater cooling power requires greater amounts of fuel, and, as the combustion products are carried in the blood stream, a more powerful circulation is required. The heart must work harder and fatigue results. It is interesting to notice how extreme heat also makes the heart work harder.

The skin may be considered the largest organ of the human body for it is indeed an organ and serves not only as a covering but is an important means for eliminating waste products. Its chief function, however, is that of an automatic radiator. The heat produced by the internal combustive processes which are constantly in progress and which vary greatly in amount must be radiated at such rates that the body temperature remains constant. This the skin normally accomplishes through the evaporation of variable amounts of secreted moisture. When the body is at rest and the weather is comfortable there is no sensible perspiration although it is a constant process. Exertion and hot weather make the perspiration perceptible, and extreme heat or work may bring it forth faster than it can evaporate. All this moisture secreted by the sweat glands is supplied to them from the blood, which must be pumped to the skin in ever increasing quantities as the rate of internal combustion or external temperature increases. The blood vessels serving the skin are extremely small and the hydraulic friction involved in flowing through them is correspondingly great. Thus the pumping of a cooling circulation for the skin may be an extremely strenuous task for the heart. For this reason the process of cooling the body after a task done under conditions of extreme heat may be more fatiguing than the task itself. A common manifestation of the fatiguing effect of the cooling process is the intolerance of frail persons, particularly women, to heavy clothing. They are constantly adding or removing light wraps to make up for slight changes in temperature, whereas a more robust individual wears sufficient clothing to keep himself warm at all times and maintains his temperature balance by added cooling effort.

Mental Effort seems to consist chiefly in fixing attention. This becomes constantly more difficult as the mind tires of a task and must be forcibly kept at it. The physiological processes involved are not so clearly understood as those of muscle action but the general effect is very much the same. Different tasks require different degrees of attention. Thus in order to grasp a theory of calculus everything else must be put out of the mind for the time being while on the other hand simple operations in arithmetic can be performed without interrupting a conversation. In a report, 1917, to the British Ministry of Munitions, it is stated that "mental processes, like those involved in adding up figures, may be maintained for very long periods—subject to the need of change of posture and diurnal sleep—with no great loss of capacity, that is without marked fatigue in that particular process. Such diminution of capacity as accrues, and the sense of fatigue that is felt subjectively by common experience in such a task, appears to be due to 'monotony' and to be removable by means of 'interest'."

The complete fixing of attention is difficult if not impossible and can only be approximated by trained workers. Man's descent from a hunting animal accounts for his alertness to all that goes on about him. Even the shadow of a passing cloud will interrupt a train of thought and require effort to get the mind back at work. All such effort produces fatigue. It is even harder to hold the attention against distractions originating within the mind itself. Worry, the greatest of them all, requires great effort of the person who must work his mind in spite of it, and is markedly conducive to fatigue.

The Distracting Effects of External Influences produce fatigue through their added demand on the attention. Thus the noise of machinery adds to the fatigue of factory workers even when they are used to it and claim not to mind it. It has been shown by laboratory experiments that most people take about 134/1000 second before responding with the hand to a touch on the foot, but that fatigue of the attention may double the length of this reaction. Noise, like fatigue, retards the time of reaction. In an experiment the reaction time of an individual was increased from 1/10 second to 144/1000 second by playing an organ where he could hear it. This retardation took place in spite of a greater intensity of attention, and whenever the disturbing sound ceased, the time of physiological reaction became as before.

Noise has another effect that workers find objectionable even when they are accustomed to it. Boot and shoe operatives interviewed by the Bureau of Labor reported that "The effort to be heard in the workroom makes their voices loud, high pitched, and harsh." Here is an effort, small in itself, yet sufficient to add to the fatigue of an already tired workman.

Monotony of Occupation as a Factor in Inducing Fatigue. Owing to increasing specialization in industry, an individual often performs a single operation only. This may require little muscular effort but the motions performed, whether complicated or simple, are started and controlled from the same nerve centers, which must send forth the same impulses time after time. While uniform acts tend in a sense to become automatic as the nerve centers become trained, and their necessary ratio of rest time to action is diminished, the repetition of a monotonous series may result in fatigue in what may be called the psychical field, and a sense of "monotony" may diminish the capacity for work.

The Speed Hazard. The piece-rate system is a constant incentive for speeding up to the worker. When he is doing the same thing over and over and has reduced the necessary motions to a minimum he has little to think about except the speed at which he can drive his hands. Under these conditions machines are voluntarily speeded up to tremendous rates and the operators, having set themselves a pace, exert every effort to maintain it. Although interest in output may do away with all sense of monotomy, work under these conditions may be very fatiguing. There is the fatigue that comes from muscular exertion repeated often and at such frequency that the intervals do not suffice for rest; the monotony effect, even if it be not noticed, that comes from repeated exercise of the same nerve centers; and the mental fatigue that comes from the high degree of attention necessary. The sum of these factors may produce an amount of fatigue that lowers resistance to disease and slows up the processes of coördination, so that in the very act of speeding, the workman increases his liability to accident from speed. This is not meant to be taken as an argument against the piece rate as a method of wage payment. To pay a man in proportion to his output is so obviously fairer than to pay in proportion to time consumed as to need no argument. It is important, however, and especially where piece rates prevail, scientifically to prevent the effects of fatigue in which the workers are apt to become involved through misdirected ambition.

Vibration. The general experience is that severe vibration tends to tire workers and to make them nervous, irritable, and inefficient. Women, in particular, often find it impossible to stand vibration even temporarily. Operators on fast vibrating machines have found it necessary to stand on specially constructed pedestals in order to save their legs from the vibration which proved extremely tiresome.

Dr. E. R. Hayhurst in a report to the Ohio State Board of Health sums up the causes of fatigue as: (1) laborious work, (2) long hours, (3) piece work, (4) speeding up, (5) monotony, (6) constant standing (constant standing upon cement, stone, or brick floors should be provided against by supplying wood platforms or even plain boards upon which to stand. Correct methods of standing—the toes and heels parallel—should be taught,) (7) constant strain, (8) chairs and stools without backs, (9) faulty postures, (10) jarring processes, (11) pressing or holding objects against the body, (12) eye strain, (13) loud noises, (14) irregular hours for sleep, and finally, (15) the absence of work variation or periods of relaxation and recreation which in the case of females, means, also, rest rooms.

The Effect of Rythmic Action on Fatigue. The necessary time-relation between an action and the recovery from it in rest has been mentioned already. For every acting element, a given rhythm of activity will allow exact recovery after each act and will maintain the balance between action and repair throughout a long series. The heart, for instance, in alternating contraction and relaxation, may continue to beat incessantly through the life of a man without any accumulated fatigue for seventy years or more. Among the great variety of nerve functions there will be found a great variety in these time-relations. Some may allow a relatively rapid rhythm, as in the act of breathing, where it may be incessant for years, while at the other end of the scale there are slower rhythms like those shown in the need for diurnal sleep.

In connection with the natural pace of the animal machine, to and fro, from action to rest, reference must be made to the wide adaptability of the animal mechanism, and especially to that of the nervous system, in response to training and use. Complicated co-ordinations in the nervous system, at first easily fatigued, may by training, and, as it seems, by some improvement on the routes of connection due to the increase in traffic itself, become capable of maximum efficiency at a more rapid rhythm. A man will swing each leg, weighted with a heavy boot, as in walking, for 10,000 times in an unbroken march without notable fatigue, but he cannot as an impromtu exercise raise his lightly weighted finger for more than a few score times, at no faster rate, before the movement comes to a complete standstill.

"The rhythms of industrial conditions, given by the hours of labor, the pace of machinery or that of fellow-workers, or otherwise, are imposed upon the acting bodily mechanisms from outside. If these are faster than the natural rhythms, they must give accumulated fatigue, and cause an increasing debit, which will be shown in a diminished capacity for work. It is therefore a problem of management to discover, in the interests of output and of the maintained health of the workers, what are the 'maximum efficiency rhythms' for the various faculties of the human machine. These must be determined by the organised collection of experience or by direct experiment. They must be separately determined, moreover, not only for the performance of relatively simple muscular movements, all of which depend on the action of 'lower' nervous centres, but also for the 'higher' coördinating centres, and for both of these the natural rhythms must be studied for the best arrangement of short spells, and again for that of the hours of shifts, of the period of sleep, and, at the last point of the scale, of holidays."

The Results of Fatigue. A normal amount of fatigue is relieved by the rest period between working days, but when the work is too strenuous or too long continued and the rest periods do not suffice to correct it, fatigue passes over into a pathological state which is known as exhaustion and which is much harder to recover from. In this state the power of achievement is still further diminished and susceptibility to specific diseases is increased. There may be a general neurasthenia or other diseases of the nervous system, including nervous affections of the organs. The will may be weakened, and resistance to immoral temptations may be lessened. Intemperance is one of the common results of bodily exhaustion, and even crime is sometimes due to this cause.

Dr. E. R. Hayhurst says:

"Fatigue symptoms are, in a minor way, tiredness, sore muscles, stiff joints, aches and pains, etc., while in a more severe form we have such signs as muscular cramps, obstinate lumbago, wry neck, neuritis, neuralgia, and 'occupational neuroses,' in which any attempt to return to the regular work results in spasms of the muscles used, accompanied by soreness, constant aches and pains, trembling, gradual emaciation, and partial paralysis of the parts. In time, ligaments weaken so that flat feet occur (perhaps with varicose veins, eczema, and ulcers,) round shoulders, bowed backs, and sunken necks. Internal organs drop downward (especially the kidneys and the female organs,) causing much chronic invalidism. Such signs are usually accompanied by a mental condition of anxiety which is out of all apparent proportion to what can be seen, and along with headache and constipation make up the diseased condition known as 'neurasthenia.' Neurasthenia is practically always occupational. In females 'hysteria' is a frequent associate. The next stage is 'nervous breakdown.' Many persons, of slightly unsound condition to begin with, develop a 'fatigue psychosis,' that is, insanity which may be sudden and violent, or just a gradual deterioration characterized as 'played out,' 'no good any more,' 'can't make his day's wages,' etc.

"Loud noises fatigue the ears, and are a common cause of partial or complete deafness. Cotton stuffed in the ears during work, and removed immediately afterwards greatly limits this deafness.

"*Young persons,* particularly those under 18 years of age, are permanently and more seriously damaged by the poisons and toxins of fatigue than are those of maturity. This is because during the age-period from about 15 to 18 in boys, and about 14 to 17 in girls, a marked increase in growth should normally take place (greater than any other period of life, except the first two years of infancy,) and, there is also, not only growth in stature, but a *concrescence* or 'growing together' for firm union for adult life of the muscles, bones, tendons, etc.,, which are concerned in voluntary acts. Furthermore, the cartilaginous parts and junctions, are, during this age, finally replaced by bony matter. During this age-period, then, energies must especially be conserved for the functions of growth. Where fatigue substances are allowed to factor, growth is stunted, concrescence is interfered with, and reserve forces so dissipated that there result deformities, weakened constitutions, and a greatly increased liability to the inception of chronic diseases, particularly of tuberculosis and organic heart disease."

Indications of Fatigue. In a general way fatigue is thought of as the feeling of tiredness that results from exercise or work, but this physical sensation is a very poor index of the true amount of fatigue. The fact that trained muscles will work all day without tiring, whereas untrained ones soon give out, has already been mentioned. In addition to this, there is the factor of interest which enables a man to become so absorbed in his work that all sensation of tiredness is unnoticed. On the other hand there are individuals whose minds dwell more on their own sensations than on things outside of themselves and who will claim to be exhausted with fatigue before they have fairly started to work. For these reasons, and because the feeling of tiredness does not admit quantitative measurement, it is necessary to find some other measure of fatigue.

The 1917 report of the British Ministry of Munitions states that it is of vital importance for the proper study of industrial fatigue to recognize not only that bodily sensations are a fallacious guide to the true state of fatigue which may be present and a wholly inadequate measure of it, but also that fatigue in its true meaning advances progressively, and must be measurable at any stage by a diminished capacity for work.

Diminished capacity for work, therefore, is both the meaning and measure of industrial fatigue, and a falling off of output that can be attributed to no other cause than the workers' declining ability is an absolute indication of its presence.

Measurement of Output of the individual worker for weekly, daily, and hourly intervals is necessary if one is to know the amount of fatigue to which he is subjected. Where possible these measurements should be made by automatic counting machines and it is better that they be made without the worker's knowledge or at least without being drawn too strongly to his attention.

Amount of Power Used. A fall in the amount of power consumed in a factory, or in one of the departments, is often an excellent index of decreased output and hence of group fatigue among the workers. Decrease in total factory output may also be taken as a measure of group fatigue, but because of the introduction of many extraneous factors such determinations when applied to a large group are apt to be inaccurate. Moreover a knowledge of the existence of fatigue in a group of workers engaged in different occupations is of little value. It is in the adjustment of individual tasks to individual workers that these studies are valuable.

Other Indications of Fatigue. Spoiled work, accidents, absences from work, and even sickness are all indications of fatigue. It is to obviate these things that fatigue should be detected and remedied in its earlier stages.

Laboratory Tests of Fatigue. There are many laboratory tests for the muscles, the nervous system, sight, hearing, and chemical changes within the body. Some of these are applicable to industrial conditions. In their report on fatigue in the laundry trade, the Industrial Fatigue Research Board of Great Britain describe the use of such a device. As they found it impossible to measure individual output in the laundries, they resorted to a dotting machine in which a tape, marked with circles at irregular intervals, was passed before a small opening at constant speed. The operator was required to place a dot in each circle, and as the speed of the tape was fairly rapid and the spacing of the circles irregular, this task required attention and coördination. The operator was tested at the start of work in the morning and again in the afternoon, each test requiring but a few minutes. The percentage of correctly marked dots was lower in the afternoon, and the extent to which it was lower was considered to be a measure of the operator's fatigue.

Equipment of this sort can be devised to measure fatigue in every branch of industrial work. Its use requires a willingness and fairness on the part of the workers, in spite of which they are subject to the errors of personal equation. For this reason it should not be used when it is possible to measure output.

Carbon Dioxide as an Index of Fatigue. One of the accompaniments of fatigue is an excessive metabolism, from which source alone the output of carbon dioxide may be increased as much as 20%, and the body temperature may be raised by prolonged work or effort.

The physiologists Voit and Pettenkofer showed, as early as 1866, that during a day in which much muscular work was done a man expired almost twice as much carbon dioxide as during a resting day. During activity the internal combustion is more active, glycogen is broken down more rapidly, more wastes are thrown into the blood, and more carbon dioxide is evolved. Later studies have shown that the amount of carbon dioxide exhaled remains constant for constant work and that it increases with the rate at which the work is done. These findings are of immense value in that they offer further means of investigating fatigue.

Mr. Walter N. Polakov, in a paper appearing in Mechanical Engineering, Mid-November, 1925, describes the following method of analysis devised for use in every-day factory environment:

In order to obtain data under actual working conditions, volumetric measurements were dispensed with and small portable apparatus was devised for approximate determination on 50 c.c. samples. These were taken every 30 minutes by direct exhalation into a hand air pump. Tests were made in this manner on two firemen, who were stoking two hand-fired 250 HP boilers with 1700 to 2000 lbs. of bituminous coal per hour. The coal was handled in shovels of 23 lbs. capacity. Ashes were removed from the ash pits by means of long-handled shovels once a shift, while the fires were worked and leveled, and clinkers removed during the shift as conditions demanded. The results obtained are shown graphically in Fig. 14.

TABLE 12

CUBIC CENTIMETERS OF CO_2 EXHALED PER SECOND

Hour	Compositor	Type foundry	Page setters
5 p. m.	2.5	3.1	....
6 p. m.	4.8	....	....
7 p. m.	5.9	5.0	....
8 p. m.	6.1	6.5	2.6
9 p. m.	7.8	7.9	....
10 p. m.	9.8	10.0	6.19
11 p. m.	11.7	13.3	9.58
12 midnight		15.4	13.00
1 a. m.	12.8	18.2	13.40
2 a. m.	....	....	18.9
3 a. m.	....	....	20.4
4 a. m.	....	....	....

Table 12 is based on observations made by Waller and De Decker in the main printing plant of the London Times.

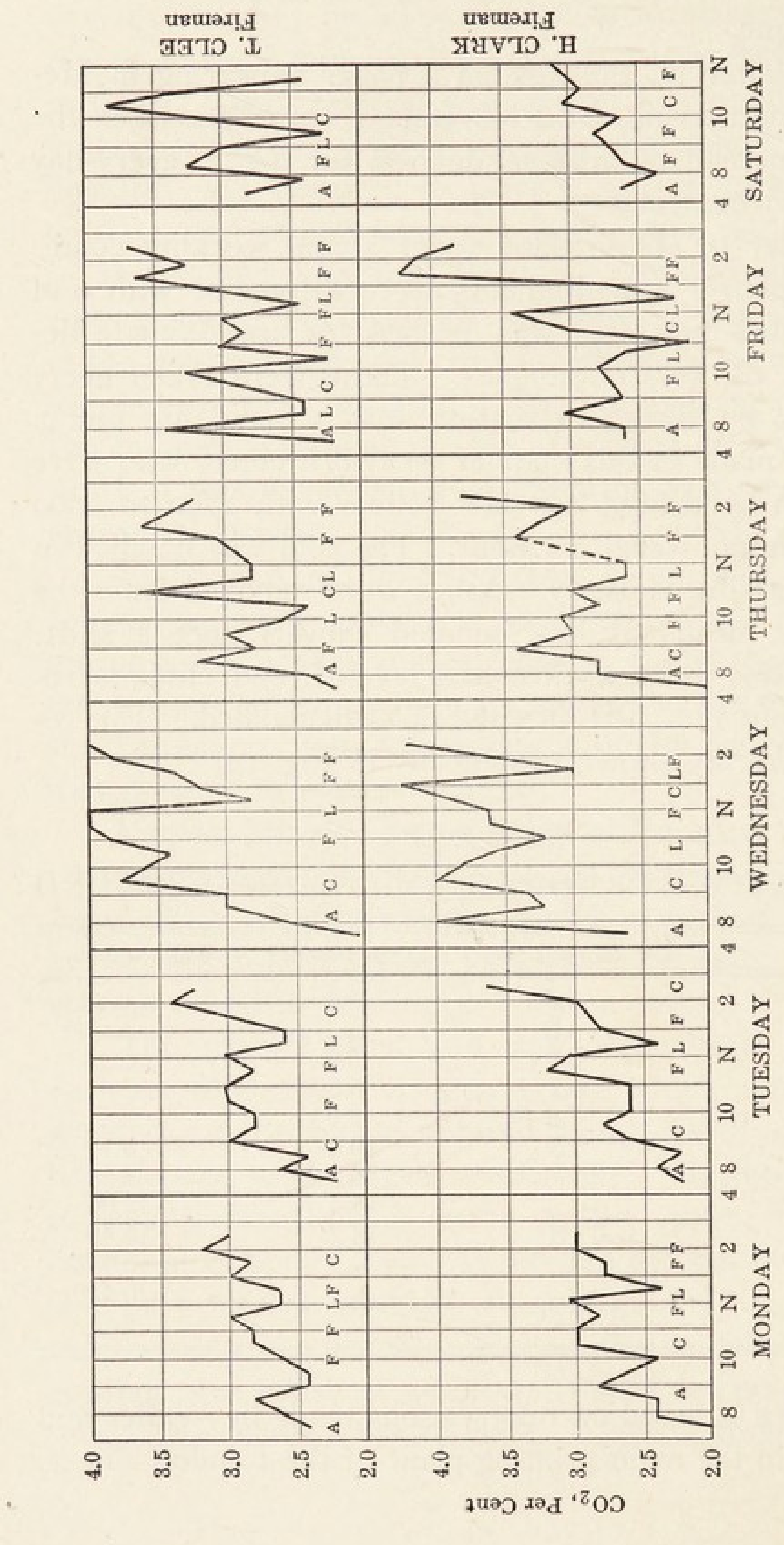


Fig. 14—CO$_2$ Exhalations of Two Firemen under Observation.
A—Ash removed F—Fires worked or leveled
C—Clinkers taken out L—Lounging or lunch

These observations show that the repetitive and uniform operations of compositors and page setters are reflected in a steady rise of the carbon dioxide exhaled, while sporadic exertions of firemen at physically strenuous operations, intermingled with less arduous coal shoveling and rest periods, manifest themselves in fluctuating percentages of carbon dioxide exhalation.

Mr. Polakov ends his article with the following conclusions:

1. Maximum CO_2 in exhalation is an index of full load on the muscles.
2. Decrease of CO_2 content in spite of continued work indicates overload and is a signal of fatigue.
3. Age and size of the worker influence the CO_2 content. The younger and lighter men produce more work with the same CO_2 discharge than the older and heavier men.
4. Peaks in the CO_2 curve immediately follow exertions.
5. Training of workers considerably reduces CO_2 exhalation for the same release of productive work.
6. The efficiency (biological) of work decreases and the expenditure of energy per unit of work increases as work continues (per day or week).

Ways of Reducing Fatigue. This problem should be considered from two standpoints: eliminating fatigue, and promoting rest. Under the first category should be included the elimination of unnecessary fatigue and the reduction of that which is inherent in the work to be done.

Much of the fatigue suffered by industrial workers is not essential to their work and is not the result of productive activity, but comes from overheated and under ventilated work rooms, uncomfortable chairs, poor light, noise, vibration, and other conditions, which are tiring to even the slowest and most easy going workman and costly to his employer.

Ventilation of Work Rooms. Proper ventilation of work rooms does much toward eliminating that fatigue which arises from discomfort. Excessive heat and humidity are to be avoided as far as possible, and the air should be kept in motion. Movement of air will add to its cooling power, so whenever possible windows should be left open; when open windows fail to keep the temperature below 68 degrees F. electric fans or blowers should be resorted to. As bodily discomfort is caused by excessive drafts, a gentle, varying movement of the air, such as is caused by an oscillating electric fan, is most desirable.

Seats. Whenever possible seats should be provided. These should be adjustable as to height and should have backs adjusted to fit. They are most comfortable when of such height that the worker may either sit or stand at his work resting himself by changing from one position to another. Seats of this character should have foot rests.

Adequate Lighting is essential. Proper distribution of light is equally important. There should be sufficient concentration of light on the work to prevent eye-strain and there should be no glare of either direct or reflected light.

Noise and Vibration. Noise is almost unavoidable with machine operation. It can however be shut in and intensified between walls. Hence a particularly noisy machine should not be installed in a confined space. Vibrating machines should be installed on solid, preferably concrete floors. Where their use on wooden floors is necessary, a heavy base of concrete set either above or below the floor level may reduce vibration which may be further reduced by the use of cushioned bases such as cork pads.

After eliminating all possible means of discomfort that cause unnecessary fatigue, it is proper to turn to the consideration of fatigue essential to the work in hand. Of first importance is:

The Adjustment of Hours of Work. There are many records to show that the reduction in hours of labor from nine and ten or more, per day to eight has been accompanied by increased output; but it does not follow that eight hours is the proper length of working day for all work and for all workers. It has been found that women and boys, even when engaged in moderate and light types of work, are unable to stand as many hours as men. The length of working day that avoids fatigue can be determined for a particular process and a particular set of workers only by a careful study of the effect of the work on the workers. There will be considerable variation among the workers in this respect, wherefore industrial necessity dictates that the length of day be not adjusted to the needs of the best or poorest workman, but to the best grade that will provide a working force. In their own interest, as well as to that of industry and society in general, it is desirable that those workmen who fall below the grade selected should find lighter employment.

There is a mistaken idea that a man's output is directly proportional to the time he puts in, as a result of which there is a tendency to increase the length of the working day by adding overtime whenever there is an added demand for production. Except for a short while, the longer day will not result in greater production unless the day regularly worked is inadequate for the best efforts of the workers.

Introducing Recess Periods. This is one of the common methods of reducing fatigue. Such periods to be effective should be obligatory and should give the workers opportunity to rest and relax. A little food, or a cup of tea or cocoa taken at such a time is often remarkably restorative. The most effective number and length of rest periods is a matter that can be established only through experimentation, which is apt to be difficult. British experience has found that the introduction of a short rest period is followed by an immediate decrease in output and that it takes several weeks before the workers can properly adjust themselves to it, after which there will be an increase in output. A plausible explanation of this phenomenon seems to lie in the difficulty of resting from nervous fatigue. Everyone has felt at some time that he would rather finish the task at hand, no matter how wearisome, than to stop for a while and start it again. Such a pause is not a rest for tired nerves that are keyed up to function until the task is finished. Under the conditions of most factory work, it is to be expected that the workers should require time in order to learn to relax in a period of as little as ten or fifteen minutes.

A further difficulty lies in the effect on piece-rate workers who do not want to rest idle at their own expense. They should be guaranteed that during the introduction of the change their total days' wages shall not be less than before. It is suggested that the introduction of a rest period be accompanied by an explanation of its puropse; and, in order that the workers may more readily learn to relax, the period may be made long, say half an hour at first, and later shortened according to the workers' behavior.

Men engaged in heavy manual labor take to rest periods readily and derive much benefit from them. A much repeated illustration of this fact is the account of two squads of soldiers digging adjoining sections of trench during the war. The squads were equal in number and were set at equal tasks. The men of one squad were allowed to work as they pleased, but as hard as possible. The other squad was divided into three sets, to work in rotation, each set digging their hardest for five minutes and then resting ten. The latter squad easily finished their section of trench ahead of the former.

Adjusting Speed. Where a single motor operates the machines for a group of workers, its speed must be adjusted to the normal pace. Faster and slower workers are at a disadvantage and might better be transferred to other work. It is of the utmost importance that each member of the squad should be able to work with the same rhythm and that the speed of operation should be adjusted to this rhythm. Fatigue is least when the speed is in consonance with the worker's customary rhythm. With such adjustment the output may be very much greater than with a speed a little slower or even a little faster.

Omitting Unnecessary Motions. The pieces which the worker has to handle should be so placed with reference to height and distance from his hands that he is obliged to make no awkward, unrhythmic and unnecessary motions, or excessive muscular exertions in handling them. His work can thus be done with the least possible waste of energy and time. Once the materials are in hand, the motions performed in placing them in and taking them from the machine are important. These are often more numerous and complicated than need be and their reduction in number and complexity has often greatly increased output.

Introducing Variety into Work. Much of modern industrial work consists of the constant and rapid repetition of the same series of movements. This oppresses the worker with a sense of monotony and adds greatly to the effort of attention required to continue the work. It has been suggested that workers be trained at more than one process and that they be allowed to change their work from time to time for the sake of variety. This plan has been tried only to a limited extent, and little information is available as to its operation. It offers however excellent prospects for future development.

Avoiding Overtime. If the day's work is such as to allow maximum output without undue fatigue, then the addition of overtime will produce undue fatigue. This, as it is cumulative, will soon reduce output below that of a normal day. The same thing applies to the addition of Sunday work to the normal week. Both should be avoided. If it be necessary to use the brief advantage that results in overtime and Sunday work, then the extra hours worked should be compensated by extra hours of rest so that the workers may recover from accumulated fatigue.

Promotion of rest is largely beyond the control of industrial management. Workers are off duty two-thirds of the time and are free to do as they please. Nevertheless there are a number of ways, both direct and indirect, in which management can promote the comfort and rest of the workers. It can supply:

Abundant drinking water within easy reach of the worker.

Attractive quiet rest rooms, especially for women, in which in times of need tired workers may find relief.

Lunch rooms, where a hot lunch of nourishing, well cooked food, of proper dietary value, may be purchased at cost price.

Clean, well ventilated modern toilets.

Washing facilities with soap and clean towels for all workers, and shower baths for men, particularly those engaged in hot dirty work.

Alternating Day and Night Work promotes rest because the day sleep of night-workers is likely to be curtailed. British investigators found that when the same night shift was employed continuously the output was less than when the shifts were alternated. As frequent changes of habit may be deleterious to health, the alternate periods of day and night work should generally not be less than a month in duration.

Conditions Outside of Factories. Anything toward betterment of social conditions, such as modern housing, attractive home surroundings, and opportunities for healthful recreation, tends to promote rest and contentment and to eliminate fatigue. Such things are more acceptable if they come from the workers themselves with the aid, rather than by the instigation, of the management.

Conclusions. The most striking difference between human and inanimate machinery is the fact that the former is subject to the element of fatigue. It is a very important difference and should be given the greatest possible consideration, if men are to be worked in factories along with other machines. Through ignorance it has not been duly considered in the past, greatly to the detriment of industrial populations, but since the war a great deal of interesting information has come to light and is being acted on. The main facts in regard to fatigue, as they are known today may be summarized as follows:

1. Muscles become fatigued through the effect on the muscular tissues of toxins, or poisonous compounds. These toxins may be:

(a) By-products of muscular activity.

(b) By-products finding their way into the circulation because of the imperfect functioning of the vital organs.

(c) By-products from the action of germs (bacteria) of disease.

(d) By-products from the incomplete assimilation of a badly balanced food ration.

(e) By-products from the use of drugs and stimulants like alcohol, coffee and tobacco.

(f) Excessive secretions within the body, due to high temperature and humidity.

(g) Insufficient excretion (perspiration,) due to low temperature and lack of exercise.

(h) Insufficient excretion from the lungs, due to improper ventilation.

2. Individual nerve fibres are not subject to fatigue, but the central nervous system may become fatigued through over-exertion, worry, insufficient rest, or any of the toxins in 1 above.

3. A fatigued muscle may recover its strength by rest, during which the toxins are carried away in the general circulation; or in the case of a frog's muscle, for instance, a rested condition may be effected by washing the muscle in normal salt solution, adrenalin, etc.

4. Any effect of rest may be obtained by artifically increasing the rapidity of the circulation of the blood, through the use of stimulants or merely by an attractive exercise.

5. Prolonged fatigue of a muscle, without enough rest, results in action of the toxins upon the muscle, tending to destroy the cells thereof and permanently to impair its strength.

6. Effect of rest obtained by stimulants, like alcohol, coffee, "coca-cola," tobacco, etc., is obtained at the expense of extra work done by the heart and other organs, and, unless followed by an abundance of sleep, is not of real recuperative value.

7. Effect of rest obtained by pleasurable exercise, like dancing and outdoor games, or exciting amusements like the '"movies," is due to the stimulating effect of these forms of recreation upon the heart and other organs, and to be of real recuperative value, should be followed by abundant sleep.

8. Food, particularly the carbohydrates (sugar, starch, sweets, etc.,) is a powerful stimulant. Hence, the rise of the output curve after the lunch hour. This is due to the combination of rest and stimulant. When one is tired or cold two lumps of sugar or an ounce of sweet chocolate will produce a very decided feeling of relief in five minutes.

9. Rest, for complete recuperation, must be taken in short, frequent periods, and also in longer and less frequent ones. The length and frequency of the shorter periods depends on the intensity of the muscular exertion necessary to the tasks involved. The longer periods depend on the

nervous strain incident to the general character of the employment. For instance, a man handling iron pigs may need a short rest every few minutes through the day, whereby complete physiological adjustment may be secured; on the other hand his general manager can work intensely for four hours at a time at his desk, or in the field, but he will need the less frequent week ends and the long annual vacation to keep himself in condition.

10. A certain normal amount of fatigue is common to all work and not in the least degree detrimental to the health of the worker, but rather the contrary. If without the use of artificial stimulants the workman is thoroughly brightened and refreshed after his rest, his fatigue has been normal and not injurious.

11. The normal amount of food, correctly balanced, is necessary to the health and efficiency of workers. More than this amount, by engendering toxic by-products, causes extra fatigue, and consequent reduction of output. Excess of proteins in the food, (meat, fish, etc.,) is more injurious in this regard and also more apt to be eaten than either fats or carbohydrates.

12. Diseases, whether of the graver varieties, or common colds, are very un-economic, since they always result in toxic products and fatigue, thus restricting output of work.

13. The economic length of the working day depends on:

(a) Physical strain of the work (expressible in foot pounds of energy per time unit.)

(b) Mental strain of the work (not expressible in tangible physical limits.)

(c) The extent to which the pace of the work is governed by the machine.

(d) The extent to which the pace of the work is governed by coördination with other workers.

(e) The physical capacity and condition of the worker.

(f) The age of the worker.

(g) The sex of the worker.

(h) The experience of the worker.

(i) The scientific arrangement of hours of work and rest periods.

(j) The hygienic conditions of the factory.

(k) Temperature conditions surrounding the worker.

(l) Conditions of atmospheric humidity.

(m) Excessive or deficient light, noise, etc.

(n) The environment of the factory.

(o) The home conditions of the worker.

(p) The social conditions of the worker.

(q) The conditions of transit to and from work.

(r) The habits of the worker as to stimulants, etc.

(s) The food of the worker.

(t) Climate and weather.

14. Excessive fatigue, besides reducing the output of the worker, reduces his accuracy and results in his producing more than the normal proportion of imperfect work.

15. Fatigue may be cumulative, and a worker may accumulate fatigue or the products thereof without being conscious of becoming tired, especially when the work is very interesting, or is performed under special stimulus. It would seem as though small quantities of fatigue could be stored up from day to day, finally manifesting themselves all at once in the form of either exhaustion or susceptibility to disease.

CHAPTER V

REST PERIODS

The Rest Problem is intimately related to the longevity as well as the efficiency of more than a third of the population. A race horse is old at five, a work horse at ten, while one kept for pleasure riding or driving ought to be good for fifteen years of usefulness; and the same principle holds true with men. Moreover, with proper rest periods, hygienic living being assumed, it seems more than probable that a normal man can produce, in his longer lifetime, a good deal more work than if he be pushed to greater speed of output in fewer years.

While regular periods of sleep are a necessity, it has been found that, in certain instances, additional rest periods during the working day will enable the worker to recover the necessary vitality to carry him through the day and at the end of it not feel unduly fatigued. It is not necessary that day time sleep be indulged in to effect this recuperative process. A relaxation of the mind and muscles, if it be as complete as possible, will in the comparatively short rest period remove much of the fatigue and allow the worker to resume his task with the advantage of his rested condition.

This rest period may be of short duration, say ten or fifteen minutes. In fact, even as short a period as five minutes, if the relaxation is complete, may suffice.

The problem of doing this correctly is simple in an office or shop where the continuous operation of machinery is not necessary. To have a beneficial rest period it is advisable that all distraction in the form of noisy machinery be eliminated. In the case of the large plant, this may be somewhat difficult to handle, but it may be done by the use of soundproof rest rooms whither the workers may go for the short period needed for relaxation.

Several Kinds of Rest Periods are necessary in order that healthy persons may accomplish their maximum production and remain in health. These may roughly be classified as follows, some classes not to be included in all occupations:

1. For the most strenuous exertion, like a hundred yard dash, rest should begin after not more than 15 seconds of work, and continue for such time as not to require more than one million foot pounds of work per day for total performances. This is half of what can be expected from light rhythmic work.

2. For troops on the march, where the daily performance may run over two million foot pounds, an hourly rest of ten minutes is effective, with a midday rest of an hour, totaling about 25% of duty time. In most industrial occupations the incidental pauses of the work amount to at least the above percentage of the total duty time. There is some tendency toward shortening the noon hour to 35 minutes, in order to allow an earlier quitting time in the afternoon, especially in the building trades in winter. This is partly to take advantage of the waning afternoon light. A mid-afternoon rest period of 10 to 15 minutes, or two or three per cent of the duty time, is desirable in many occupations.

3. A daily rest and recreation period of at least 14 hours, more generally 16, is practically universal in the United States.

4. A weekly rest and recreation period of about 44 hours is now quite general in the United States, of which one-third to one-half is for rest.

5. An annual vacation of at least two weeks is general in the United States for persons on monthly payroll, but not for daily payroll operatives whose pay is reckoned by the hour. These latter get vacations, if at all, on their own time or when out of employment from voluntary or involuntary lay-offs, this being one of the results and, at

the same time, one of the causes of high labor turnover. A shorter, semi-annual vacation, as referred to under the caption Climate, is economic for certain people in many occupations. There is an increasing trend in this direction.

American Experience with Rest Periods was reported upon by the National Industrial Conference Board (Research Report No. 13, January, 1919), who found that use of such pauses was the exception rather than the rule in this country. They canvassed a list of 388 employers who had been reported as having introduced rest periods. Only 104 replied that they had adopted them, and 15 of these later discontinued the practice.

They found that in a majority of the reporting establishments regular rest periods were allowed only to selected classes of employees and frequently only to women. Of 82 establishments which gave definite information on this point, only 21 allowed pauses for all workers. In 61 establishments reporting a total of 370,498 employees, 142,489 were allowed rest periods; of the latter number 136,531, or approximately 95% were women.

The general opinion among manufacturers contributing to this investigation was that regular rest periods are advantageous chiefly for monotonous occupations, those requiring much concentration or severe physical exertion, or those in which the worker is exposed to poor ventilation or has little opportunity for change of posture.

Among the most familiar examples of occupations making severe and constant demands on attention are those of telephone and telegraph operators. In the United States the leading telephone and telegraph companies have for many years allowed rest periods to their operators. Clerical workers, accountants, proofreaders, and dictaphone operators are also frequently granted such pauses. Inspection in factories and work at power sewing machines are among other repetitive tasks in which advantageous results from pauses were reported. At other factories the women employees were allowed to leave their work for rest as necessary and in one case utility women were kept to take their places.

Little definite information was secured as to the amount of benefit derived from pauses, but in general it was found that they occasioned no loss in production. The best results were reported by establishments where adequately furnished rest rooms were available and where the management organized methods for employing the pauses for setting-up exercises, games, chorus singing, and other group activities.

Practical difficulties with rest pauses were encountered in some establishments. Thus, in one factory the soldering irons grew so cold during the ten minute pauses that an additional ten minutes were required to reheat them. Also in a candy factory extra time was required for reheating the chocolate used in dipping. Pieceworkers were inclined to neglect the pauses and work through them, and in some plants the operatives took as much random time off during the day in addition to the pauses as they had taken before the pauses were introduced.

English Experience with Rest Periods. An investigation conducted by Dr. H. M. Vernon for the British Ministry of Munitions, published in the final report of the Health of Munition Workers Committee in 1918, brought out some interesting facts. The British investigators had the advantage of being able to make comparisons between many arrangements of working hours, under which all of the workers were doing their utmost because of patriotism inspired by the war. Dr. Vernon found, for instance, that while the night shifts in most factories worked more hours per week than the day shifts, the reverse of this arrangement was of greater advantage. He recommended that the greater strain of night work be recognized by reducing the time worked at night to an hour less than that worked each day. Thus 8 hours per night should be considered equivalent to 9 hours per day in its effect on the workers.

A 54-hour week, according to Dr. Vernon, is more effective if divided into five 10-hour and one 4-hour days than if divided into six 9-hour days (American investigations in the shoe industry, referred to elsewhere, led to contrary conclusions.) Some British factories divided the 10-hour day into two spells of five hours each, others used three spells of two, four, and four hours, the workers starting at 6 A. M. and stopping for breakfast, usually between 8:00 and 8:30 A. M.

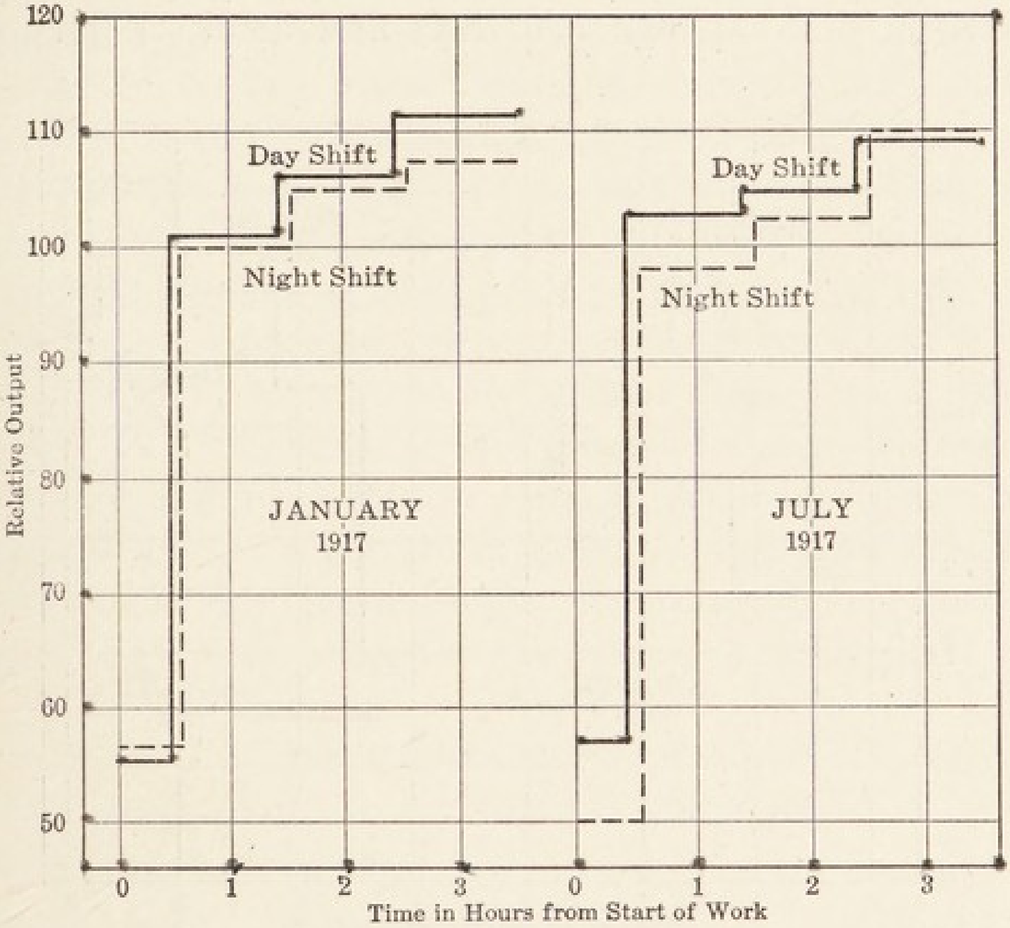


Fig. 15—Output as Measured by Power Consumption in a Factory Employing over 1,000 Lathe Workers, the Day Shift Working Two 5-hour Spells

A comparison of these two systems of working is given in Figs. 15 and 16 which show curves based on power consumption during the starting hours of the morning. These show the useful power only (i. e. total power consumed minus that required to run the machines idle) and are based on percentages of the average, which is taken as 100. Fig. 15 shows that under the two shift system, both day and night shifts, in both winter and summer, approximated average production within the first half hour. Fig. 16 applies to a factory under the three shift system where the day shift started work at 6 A. M. and stopped for breakfast from 9 A. M. to 9:30 A. M.; while the night shift started at 6 P. M. and had their first break at 9 P. M.

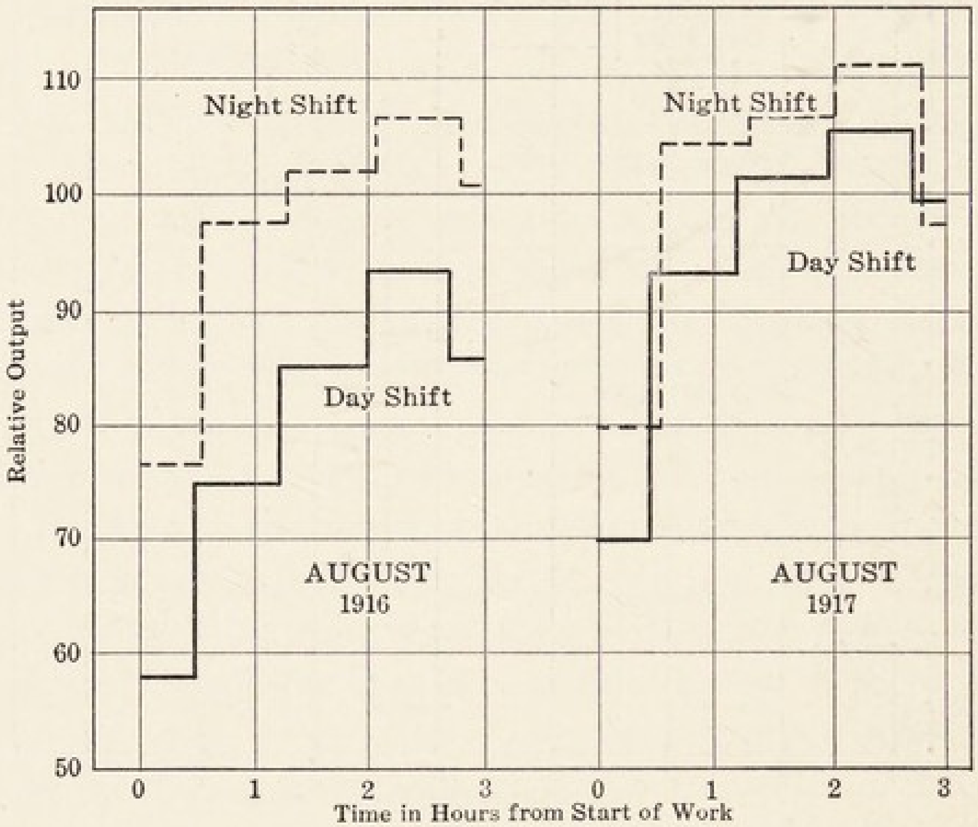


Fig. 16—Output as Measured by Power Consumption in a Factory Where Working Day Was Divided into Three Spells

It is to be noted that while the night shift got started fairly well, the day shift, working without breakfast, required two hours to reach average production in 1917 and in 1916 did not reach it at all during the early morning shift.

These diagrams should not be taken as showing an inferiority of the three shift as compared with the two shift system because the failing of the former is obviously due to the use of the first rest pause for breakfast. Dr. Vernon says, "I am convinced that five hours of continuous work are too long for a man and considerably too long for a woman. With the possible exception of passive work, such as the watching of automatic machines, no type of labor ought to be run continuously for more than four hours if it can be avioded."

In the factory whose output is shown in Fig. 15 the day shift worked from 7:00 A. M. to 12:00 M. and from 1:00 P. M. to 6:00 P. M., a total of ten hours. The night shift, on the other hand worked 10½ hours, but divided their time into three spells of four, three and a half, and three hours respectively, from 6:30 P. M. to 10:30 P. M. from 11:30 P. M to 3:00 A. M. and from 3:30 A. M to 6:30 A. M. Records kept of a group of women workers in this factory showed that in spite of the longer hours and disadvantages of night work, their average hourly output was considerably greater under the three shift system at night than it was under the two shift system by day.

How five hour work shifts can be avoided in a 10-hour day. Two methods of accomplishing this are suggested by Dr. Vernon, the first of which would be to divide the day as follows:

8:00 to 12:00	1:00 to 4:00	4:30 to 7:30
4 hours	3 hours	3 hours

This system requires that the workers have breakfast before coming to work and gives them their accustomed hour for dinner, but it has the disadvantage that work ends too late to leave time for shopping. For this reason an alternate arrangement which might be more advantageous would be:

7:30 to 11:30	12:30 to 3:45	4:00 to 6:45
4 hours	3-1/4 hours	2-3/4 hours

Of this system Dr. Vernon says: "Only ¼ hour is allowed for tea and this is too short an interval to enable the workers to leave the workshops and go to the canteen; so it would be necessary to supply them with refreshments by means of traveling canteens."

While American workers are not in the habit of having afternoon tea, this is nevertheless a valuable suggestion for any plant that has to work 10-hour days even temporarily. The time required by the workers for washing up and reaching their homes is apt to be considerable and the evening meal will be unduly late. An interval of seven or eight hours spent mostly at work and without food will be reflected in lower output during the following morning.

A second method of dividing up working hours consists in introducing a quarter hour rest period in each of two 5-hour spells. During these periods the machinery is stopped and the workers are supplied with refreshments from traveling canteens. Such an arrangement would be

7:30 to 10:00
2-1/2 hours

10:15 to 12:30
2-1/4 hours

1:30 to 4:15
2-3/4 hours

4:30 to 6:30
2 hours

This system was found to be superior to one that allowed the workers to go home for breakfast.

The need for rest pauses. While repeated observations showed that nominal one-quarter-hour pauses meant a cessation of work of from 20 to 25 minutes the British investigators found ample evidence that this loss of time was justified. Time studies of experienced operators on piece-work showed that they took an average of about eight minutes of voluntary rest pauses per hour in all except the first hour of work. These pauses were taken in a haphazard manner, but averaged about eight minutes per hour for both men and women on active work. Women operating automatic machinery averaged less than four minutes per hour in voluntary pauses.

The Economic Duration of Rest Periods depends on the severity of the work and of course varies with every kind of task. It is not difficult, however, to set certain practical limits. For marching troops in hot weather, a period of 15 minutes at the first hour and 10 minutes each hour thereafter, during which the men lie down and remain perfectly quiet, seem to be most satisfactory. This amount, about 17%, is enough to allow partial recuperation from heavy muscular work. For rapid muscular work involving considerable exertion combined with concentrated mental attention, such as driving hand rivets, a much larger percentage, up to 50% or even more, has proved effective. In the latter case the continuous working period must be a good deal shorter than in the former.

The Benefit Derived from Rest Pauses is difficult to measure because it is limited in extent and may be hidden by other variations. In conducting investigations for the Industrial Fatigue Research Board (Report No. 25, London, 1924,) Dr. H. M. Vernon and Mr. T. Bradford found that a small increase in output due to practice might extend over several years. Besides this, there were irregular variations, due to changing weekly hours of work, and to the change from artificial to natural lighting with the seasons. Also economic pressure at home, or an unpopular foreman in the factory might temporarily increase or decrease output. The investigators, however, frequently found a definite measurable improvement in output following the introduction of a short rest pause, that, while it might have been due in part to one or more of the above mentioned causes, could nevertheless be definitely attributed to the rest pause.

Fig. 17 shows the effect of introducing a single 10 minute rest pause on a group of 17 girls who were engaged in labeling small packages. These girls were on a 48-hour week, the usual hours of work being from 8:00 A. M to 12:30 P. M. and 1:30 to 6:00 P. M. The pause was placed at 10:20 when all the work was stopped and the girls were allowed to get a cup of tea and a little food. Work was resumed promptly at 10:30. The rate of production is recorded for an eight month period, during the last four months of which the rest pause was in operation. In the last six weeks the average hourly rate of production was 13% greater than in the pre-rest period, although the working time was two per cent less.

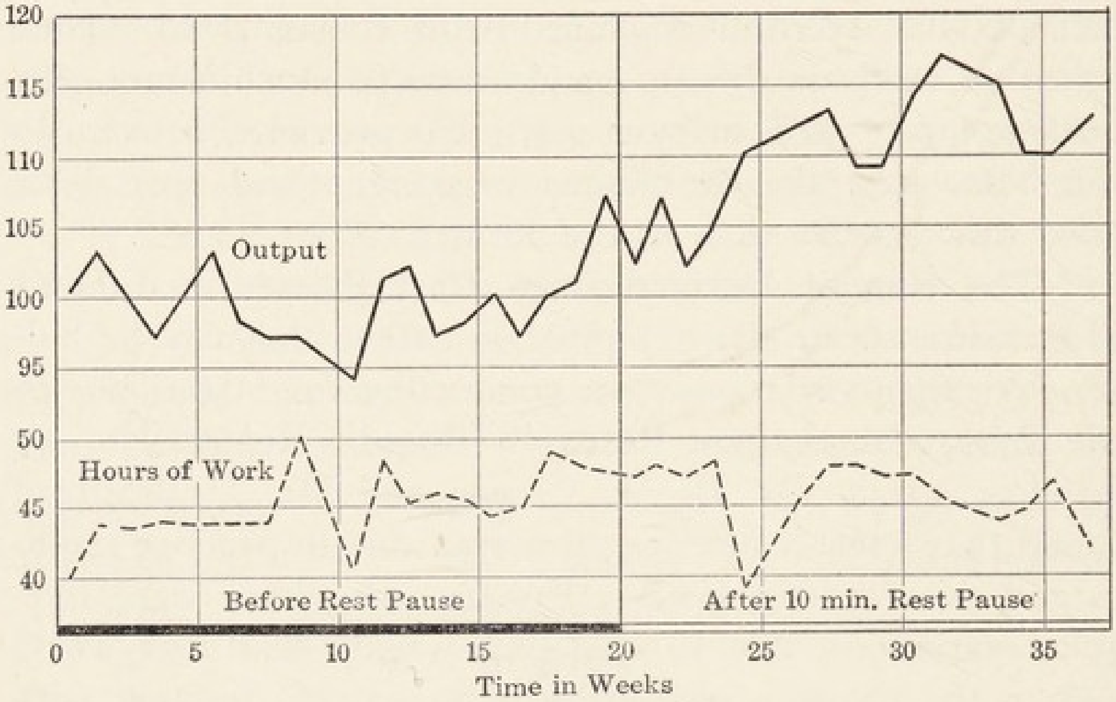


Fig. 17—Effect of a 10-minute Rest Pause on the Output of Girls Engaged in Labeling

Fig. 18 shows the improvement in output of a group of six girls engaged in pressing grooves in rectangular pieces of cardboard, which were afterward bent so as to form boxes. Their working hours were the same as those of the previous group and a 10--minute rest period was introduced at the same time in the morning.

Fig. 19 shows the effect of a 10-minute rest pause on a group of five thoroughly experienced women who were engaged in sewing the uppers of boots and shoes by means of electrically-driven sewing machines. Their usual hours ran from 7:30 to 12:15 and from 1:30 to 5:30 or for spells of 4¾ and 4 hours. The hours of actual work excluding bank holiday weeks, varied from 41.2 to 51.4. The statistical period lasted from November 26 to July 28, and during the first 8 weeks the women had no official rest pause during the 4¾ hour morning spell, though they had one

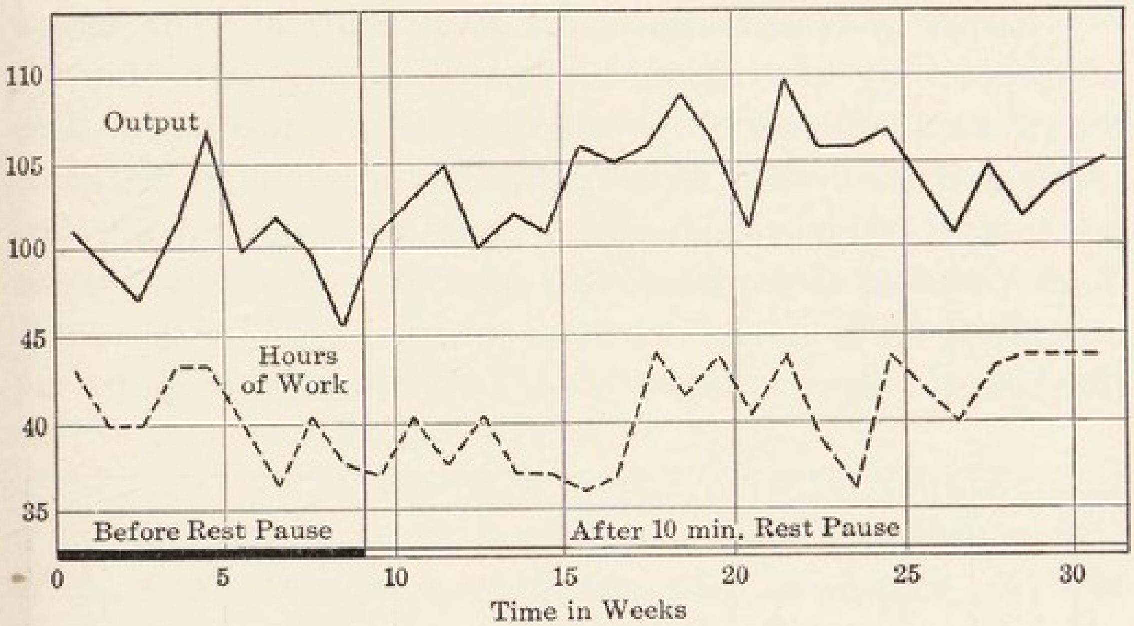


Fig. 18—Effect of a 10-minute Rest Pause on the Output of Girls Engaged in Pressing Grooves in Cardboard

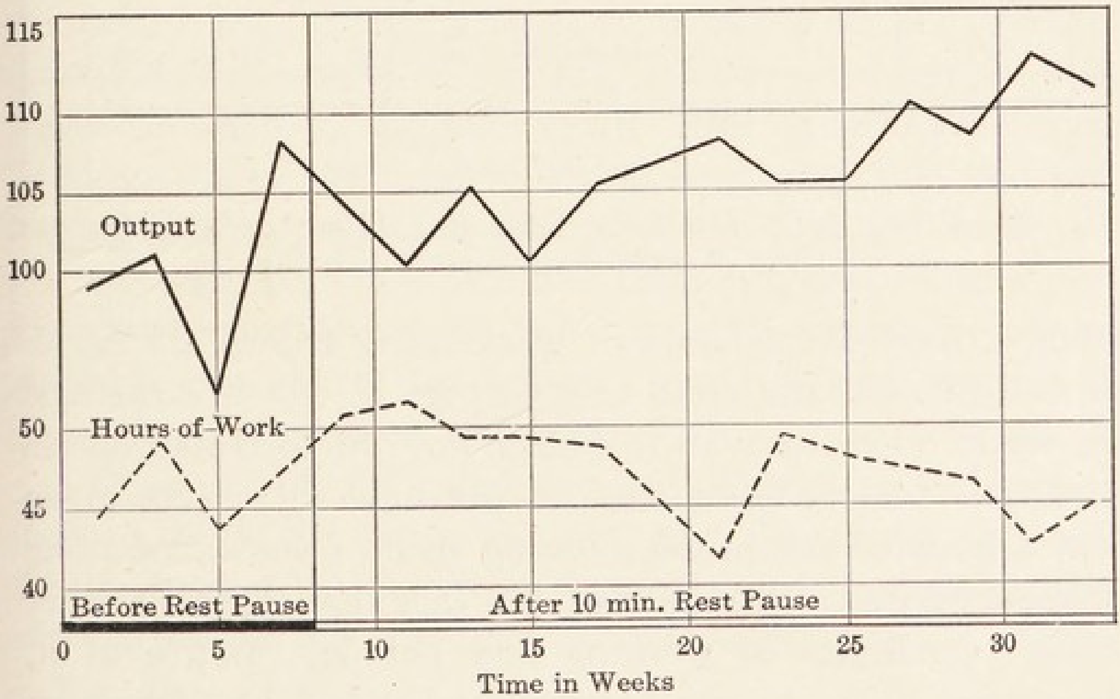


Fig. 19—Effect of an Additional 10-minute Rest Pause on Women Sewing Boots and Shoes

at 4 to 4:10 in the afternoon spell. During the remaining 26 weeks, they had a rest at 9:30 to 9:40, and it will be seen from the Figure that after the introduction of the rest, the rate of output showed a general tendency to rise. In the last eight weeks it was 11% above its pre-rest average.

Effect of Numerous Short Rest Pauses. The effect of introducing a 5-minute rest pause during each hour of the working day was investigated in one instance. The seven girls concerned were engaged in assembling the components of bicycle chains by means of pendulum presses. The operation took about nine seconds, and required close attention. The girls were on a regular 47-hour week throughout the 14 months for which their output was studied, their usual hours of work being from 7:55 A. M. to 12:45 P. M., and from 1:45 to 5:30 P. M. For the first six weeks (February 18 to March 30) the girls had no repose, but for the remainder of the time they were given four 5-minute rests in the morning spell of work, and three in the afternoon. In spite of the fact that the girls were losing 35 minutes of working time per day, or 7% of it, the output began to rise at once, and it will be seen from Fig. 20 that after 24 weeks it reached a fairly steady level

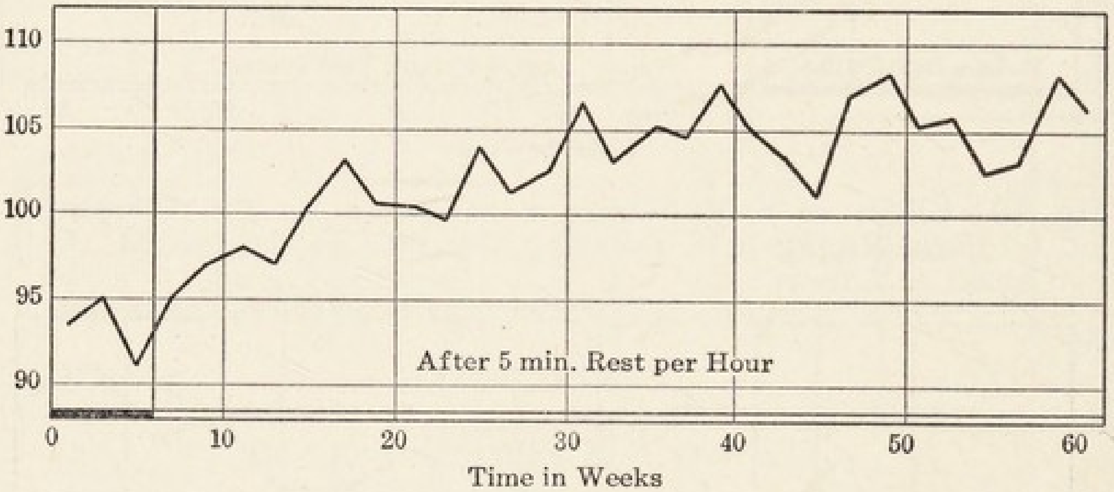


Fig. 20—Effect of a 5-minute Rest per Hour on the Output of Girls Assembling Bicycle Chains

which it retained for the remaining 32 weeks during which the observations lasted. The mean output for these weeks was 13% greater than that observed in the initial six weeks.

This was a more substantial effect than was observed with any of the other groups of workers except the labellers, and it was thought to be due to the more ample allowance of rest. Evidence in support of this conclusion was obtained from a group of 18 girls who were inserting disks of cardboard in metal caps. The operation took only a second to perform and was found to be very monotonous, and complaints were made. The girls were then given a 5-minute rest every half hour, or 80 minutes in the 8-hour day. Exact figures were not obtained on their output but it was learned that it did not deteriorate as a result of the time lost in rest pauses.

In all of the foregoing instances some improvement was noticeable from the beginning. Elsewhere the investigators found that the introduction of a rest pause was followed by a decline in output but that after considerable time the output recovered and even surpassed its orginal level. In a factory where handkerchiefs were being manufactured each of four groups of workers studied showed a small fall of output during the first few weeks of the rest pause followed by a gradual rise. The women were on a 48-hour week, and from Monday to Friday they worked two 4½-hour spells each day. For the first 3½ weeks of the statistical period, which ran from August to December, there were no rest pauses, but during the remainder of the period a cup of tea was brought round to each worker at some time between 10 and 10:30.

Observations indicated that on an average the women stopped work for seven minutes, and they generally took a little food with their tea. The effect of the rest on the average output of the four groups investigated is shown in Fig. 21.

A striking point exhibited by most of the observations was the slowness with which the output improved and the time taken for the full effect to show itself. The bicycle chain girls took six months to become fully adapted to their pauses, while the women employed in sewing shoe tops took over six months, and the labelers took about ten weeks. The investigators considered that the slowness of adaptation was due to the fact that as a rule it was brought about quite unconsciously. The workers got a little less fatigued because of the rests, and in consequence of their increased reserve of energy they gradually quickened their rate of production until finally they would fatigue themselves as much as they had done previously without rests with consequent higher production.

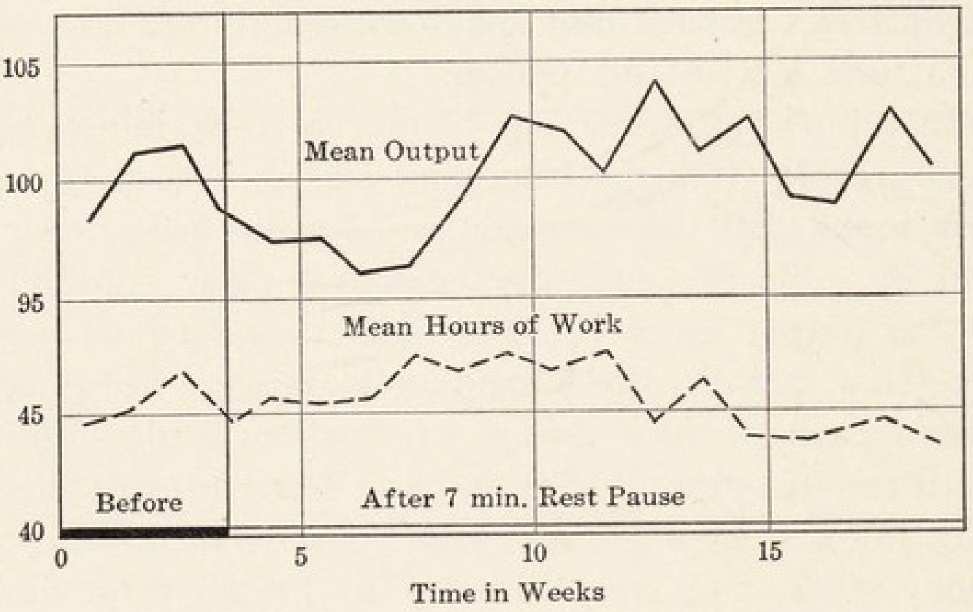


Fig. 21—Effect of Rest Pause on the Output of Handkerchief Workers

Variation of Rest Pause Effect on Different Individuals. Not all of the workers investigated benefited alike from the rest pauses. In the group of 17 labelers whose output was studied a comparison of the 9 week period immediately before the introduction of a rest pause with a 10-week period after the pause had been in force 10 weeks and had induced its full effects, showed that:

The five quickest girls, whose initial output was 112.1, improved 8.2%. The six intermediate girls, whose initial output was 100.7, improved 12.8%. The six slowest girls, whose initial output was 89.2, improved 17.3%. Obviously the workers who were suffering most from fatigue derived the greatest benefit.

Variation of Rest Pause Effect with Type of Work. The investigators found that if a worker is feeding an automatic machine of fixed speed the output must fall when a rest pause is taken, but if, on the other hand, speed depends on the operator's manual dexterity and the machine must wait on him, then a rest pause is likely to result in an increase in output, which observation would seem to agree with common sense.

An Experimental Investigation of Rest Pauses is reported by S. Wyatt, in part *B* of the Industrial Fatigue Research Board's report, No. 25, on Two Studies of Rest Pauses in Industry, London, 1924. The subjects of this investigation were set to doing easy examples in addition, each consisting of five digits, until no further practice effect could be noticed. The work was done in two 2½ hour shifts and was found to be monotonous but not fatiguing. The introduction of a 15 minute rest pause in the middle of each shift resulted in an increase, not only after the rest but before it. In the morning, the increase was 12.1% before and 20.5% after the rest, and in the afternoon it was 19.8% before, and 24.1% after the rest. The increase before the rest, averaging approximately 16%, was considered to be psychological and due to anticipating relief from monotony; that after the rest, averaging about 22.3%, was due to rest from fatigue. The results of this experiment are shown graphically in Fig. 22.

How Rest Pauses Should be Spent. Laboratory experiments were undertaken with 15-minute rest pauses introduced in the middle of two-hour shifts devoted to addition. The rest periods were spent in different ways, and it was found that the gain in output varied as shown in Table 13.

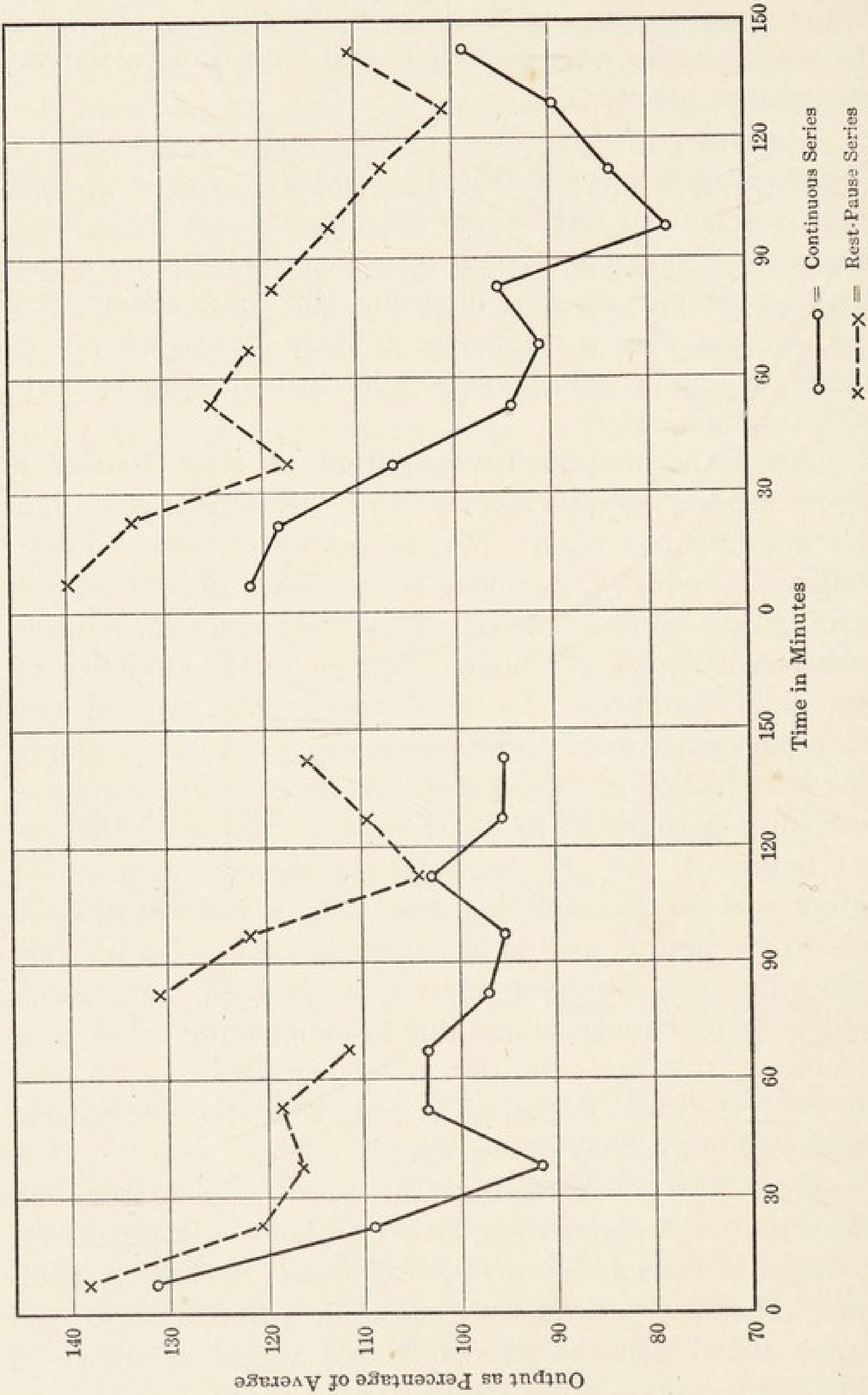


Fig. 22—Variations in Output, Adding Figures, With and Without a Rest Pause

Accidental enforced pauses occur in factories and may serve as rest periods, but a piece rate worker is not apt to rest when held idle against his will. Mr. Wyatt mentions a factory where the workers spent the first quarter of an hour in the morning in fetching material, and supplemented this work at odd times throughout the day as necessary. Changing the time for fetching materials to two 15-minute periods shortly after the middle of each working spell enabled these periods to serve as rest pauses and resulted in an increase of 14.2% in output.

TABLE 13

RELATIVE VALUE OF DIFFERENT DIVERSIONS DURING REST PAUSES, BASED ON EXPERIMENTAL DATA

Nature of Rest	Gain in Output, per cent
Absolute rest	9.3
Uncontrolled rest	8.5
Music	3.9
Tea	3.4
Walk	1.5

Occupations During Rest Periods. Whenever a rest pause is to be introduced, the use that the workers can make of it should be carefully considered. Merely stopping the machinery for a few minutes enforces rest, but if many of the workers have to remain standing the rest will not be as effective as it might be. Those who work seated in more or less trying positions can probably rest to best advantage by moving around. On the other hand men engaged in hard physical labor need more complete relaxation and will appreciate an easy chair. If a factory commands any sort of view the operators can relax and rest their eyes by sitting on benches arranged along the windows and looking out of doors. At night increased general lighting during the rest pause will give opportunity for distant vision and in this way aid in resting the eyes.

Rest rooms are generally installed in factories where women are employed, but these are of most service for occasional use in case of extreme fatigue or illness. An ideal arrangement would be to have rest rooms large enough to accomodate the entire force during the rest pause. When this is not practical, a rest room may be used in turn by different groups, in which case it should be sound proof, as this plan does not permit stopping the machinery.

Washroom and toilet facilities should be adequate so that there need be no waiting on this account.

The use of the rest pause for light refreshments is valuable when the working hours are long but it does not seem necessary with an 8-hour day. The method of serving food is important. If the workers go to a canteen or restaurant they must hurry there and hurry back. Time will be lost and more or less confusion result. The food obtained may be of value, but the time is not spent in effective rest. If, on the other hand, food is served from moving canteens some workers will be reached much later than others and will spend part of their rest pause in impatient waiting and the remainder in hurried eating, neither of which is restful. Cold food brought from home is unpalatable and is apt to be eaten with dirty hands.

There is no best way of spending a rest pause. Each factory and each class of work requires a method of its own that must be planned in advance and modified by experimentation. To be fully effective a rest pause requires much of management besides the mere stopping of work.

Conclusions. Rest pauses serve three somewhat different purposes. First, whenever hard labor that uses a great part of a man's strength is done, they are an absolute necessity. Second, when unusually long hours are worked, adequate rest pauses enable the workers to maintain their productivity to the end of the day. Third, when all other conditions affecting the work are arranged as well as they can be, a rest pause, by lessening momentary fatigue, may slightly increase efficiency. In this latter case it is important that other factors affecting the work be correctly adjusted, for it is useless to experiment with a rest pause of questionable value if the hours of work are too long or if there is room for improvement in lighting or ventilation.

The best rest pauses to adopt and the best uses to make of them depend both on the factory and the tasks of the individual workers and can only be arrived at by trial. However, such trials may be guided by a number of facts that are true of rest pauses in general.

1. The value of rest pauses is more or less independent of the sex of the worker.

2. Rest pauses are most effective on work whose speed depends on manual operations and least effective when the pace is set by automatic machines.

3. Those workers who are suffering most from fatigue receive the greatest benefit from rest pauses.

4. Whether a rest pause results in an immediate increase in output, or a decrease followed by a slow increase, or a permanent decrease, it will take several months to reach its full effect.

5. Rest pauses are most useful in monotonous occupations and in those requiring great physical exertion, or a maximum of attention to complicated operations.

6. On continuous operations that do not permit stopping, a rest may be effected by a change of work.

7. Working days of 10-hours or more should be broken into three or more working periods and the rest pauses may be profitably employed in serving refreshments. Five hours are too many for an unbroken stretch of work.

8. The use made of rest pauses is a matter of considerable importance. Unless the arrangements and facilities for resting are adequate and suitable for the workers who are to use them, much of the benefit of the pauses will be lost.

CHAPTER VI

ECONOMIC HOURS OF WORK

Wherever continuous operation is not necessary for proper functioning of the business the single shift is practically universal. Ships at sea have to run continuously both for practicality of operation and because the capital investment in the plant is so large that if not so operated the interest and depreciation costs would be so huge as to revolutionize the industry. The steel business in the United States has recently attempted to change from a two shift to a three shift basis, and the general trend is in this direction. Plants operating but one shift per day are in better position to inaugurate the most economic working periods than where the exigencies of the business require continuous operation.

Another trend in the United States is in the direction of more costly equipment involving greater capital investment per man and a heavier ratio of capital charges to labor cost per unit of output. This is bound more and more to make for continuous operation of plants and tends to emphasise the importance of the economic shift problem under such conditions.

The economic hours of work are those that will enable the worker to maintain a high rate of efficiency from day to day, week to week, month to month, and year to year. It has been shown that fatigue is cumulative, and while the worker can work overtime occasionally, he is not capable of continuous overtime without impairment of his productive efficiency, and finally of his health. In many cases men who do heavy manual labor can work for longer hours than those who do less heavy work but have to give considerable mental concentration to their tasks. Where many varied operations are required in a single plant and where it is impractical to have each class of operatives work a number of hours independent of the others, the best solution seems to lie in the most scientific placement of the worker and in adopting a length of working day, or shift, that will be the economic compromise for the combined types of work.

A mechanical engine can be worked continuously for considerable periods, and with proper lubrication may require an extremely small percentage of time for repairs. The modern marine engine, the automobile, high duty pumps, and even the coal burning locomotive can run for days or weeks, without stopping, and at uniform efficiency day and night. The human machine by contrast is very limited in the length of time that it can run without rest, and very much more limited in economic limits of duration of working time. These limits are affected by many conditions, time of day, light, temperature, moisture, nature of task, even social conditions. Wherever continuous operation is necessary the day must be divided into shifts which need not necessarily be of equal length (see Chapter V), but are generally some aliquot part of twenty-four hours. An exception is the universal practice on ships at sea of five four-hour "watches" and two two-hour "dog watches" for the purpose of evenly distributing the daylight hours to all the crew.

Plants which operate on one shift per day are not limited in their choice of working hours. They may find the most economical day's work to be anywhere from six to ten hours duration, and they can arrive at this information only by trial. The results obtained in similar lines of industry may serve to guide such trials, but as the working conditions are different in every factory they cannot supplant them.

The proof of the proper length of shift is the number of units of product turned out. Any test for this purpose should run over a period of time long enough to bring out all the factors that control production, and particularly to show the cumulative effects of fatigue.

In the preceding chapter it has been shown that rest periods in many cases either increase the production to a slight degree or result in lessening the cumulative effects of fatigue. To be effective these rest periods must be had in the proper atmosphere. It is thoroughly uneconomical to attempt to adjust hours of work without first correcting the conditions of ventilation, and without removing noise vibration, and other fatigue-producing distractions, so far as may be possible.

The Parties Mainly Interested in the Length of the Working Day Are: (1) the direct wage earners, (2) their employers, and (3) the general public. Each of these parties has maintained the more or less traditional attitude that its own interest was antagonistic to that of one or both of the others, and could prevail only by some kind of force. Considering the enormous losses in blood and treasure that have been suffered by the entrepreneurs of industry, the workers themselves and the public generally through strikes and lockouts, it is astonishing that industry should have struggled along for so many years with no definite attempt to arrive at a scientific solution of this three cornered problem, the main factor of which is not legal, nor moral, but economic. The wonder grows when, in the first stages of our attempt to apply scientific methods to the problem, we find still greater losses heretofore hidden behind false conceptions of mutual interest.

The initiative in the matter of selecting the length of the working day has rested from time immemorial with the employer, and the evidence seems to predominate that the hours have nearly always been too long for the most efficient work, too long for the health of the workers, and too long for the general welfare of industry. Of this condition the worker has been just as ignorant as the capitalist, and where the worker is his own entrepreneur, like the farmers in the south of France, his tendency is to set longer hours than would be suggested by employers to industrial labor, or tolerated under state control. In the Pyrenees, under living conditions and with methods that do not appear materially to have varied in 500 years the farm proprietor in the planting and harvest seasons works in the fields with his women from dawn till dark seven days a week, partly because he thinks he has to and partly, no doubt, because he has a minimum of the modern distractions in the way of commercialized amusements.

In the manufacturing industries the workers have always felt that their hours were so long as to result in their exploitation in the interest of "capital," and the efforts of trade unions have centered around the reduction of working hours at the sole expense of "management." These efforts would have had a more uniform record of success if they had not been complicated by endeavors to restrict production. Prior to the Great War it seems not to have occurred to the captains of industry, nor has it been used as an argument by grievance committees of employees, that for every kind of occupation and every class of labor there is a certain length of working day, and only one, whereby the largest production of goods of standard quality may be secured in the long run. Any longer average day than this leads to cumulative fatigue, shortens the industrial life of the worker, and is not economic to employers generally; industry, in the United States at any rate, having outgrown the idea that one employer can profitably wear a man out in his early years and hand him on as damaged goods to his next job. Any shorter average day than this would give to the worker an unnecessary amount of time for recreation, or for occupations less economic than that of his main employment, and would raise the cost to the public of his standard product. Under such conditions the worker's earnings would be less, his employer's profits would be less and the public would pay more for its goods. In 1914 (U. S. Statistical Abstract) about half of the wage earners in United States manufacturing establishments worked 54 hours and over per week; in 1919 this figure had declined to

48 hours. This was accompanied by a large increase in production much of which was due not to increased efficiency of the Human Machine but to the mechanical and organizational aids to its operation developed by Management. Among the trade unions the trend of hours is shown from 1907 by Table No. 14.

TABLE 14

INDEX NUMBERS OF FULL TIME HOURS PER WEEK BASED ON 1913 AS 100, FOR ALL TRADES REPORTING TO THE BUREAU OF LABOR STATISTICS, U. S. DEPT. OF LABOR

Year	Index Numbers		
	Rate of wages per hour	Full-time hours per week	Rate of wages per week, full time
1907	89.7	102.6	91.5
1908	91.0	102.1	92.5
1909	91.9	101.9	93.3
1910	94.4	101.1	95.2
1911	96.0	100.7	96.5
1912	97.6	100.3	97.7
1913	100.0	100.0	100.0
1914	101.9	99.6	101.6
1915	102.8	99.4	102.3
1916	107.2	98.8	106.2
1917	114.1	98.4	112.4
1918	132.7	97.1	129.6
1919	154.5	94.7	147.8
1920	199.0	93.8	188.5
1921	205.3	93.9	193.3
1922	193.1	94.4	183.0
1923	210.6	94.3	198.6
1924	228.1	93.9	214.3

The end of this trend is by no means yet in sight and cannot safely be estimated. We can say however, in general terms, as well as with reference to the problems of a specific industry or plant, that a maximum value of the production-to-cost ratio is consistent with the interest of the wage earner, the entrepreneur and the state.

Wage earners themselves are consumers, and as they acquire more leisure, greater earnings, and longer life so will their consuming capacity increase until ultimately we shall reach that economic balance which, heretofore unsuspected, will be consistent with the interests and welfare of all.

Hours of Work vs. Hours of Duty. Fallacies in regard to the advantages and necessities of short working hours are apt to occur, owing to the public discussion and excitement surrounding this subject, much of which has been aroused by a few over-earnest officials of labor unions. There is a great difference between working a certain number of hours and being on duty, for instance. A night watchman may consider that he works ten hours per night, when the only work he actually performs is the minimum necessary to prevent him from falling asleep. There is a good deal of difference between such a task and that of a marching soldier or the fireman on an ocean liner.

An illustration in point is from the record of a head brakeman, given in the Railway Gazette for July, 1918. This man reported for duty at 9 A. M. From 9:20 to 9:30 he took out the engine and coupled it to the train; from 9:50 to 10:00 he got the train ready, from 10:50 to 10:55, cut off the engine and took water at *A;* 11:20 to 11:30, helped set off cars at *B;* 12:40 to 12:45 coupled and uncoupled engine and took water at *C;* 1:00 to 1:10, set off cars at *D;* 2:00 to 2:06, coupled and uncoupled engine and took water at *E;* 4:40 to 4:45 cut off the engine at terminal. He was paid for ten hours work but was on duty only seven hours and fifty minutes. His actual working time was one hour and five minutes. This hour or so of work must have been in the nature of a rest from the vibration of the train which would have been the only fatigue-producing factor of his entire day, and which, from the record, could not have totaled seven hours in all.

A linotype machine operator, on the other hand, who goes to work at 8:30 o'clock finds copy at his machine and is generally at work before 8:35. It is safe to say that in most cases, the linotype machine man is not interrupted in his continuous work for a total of 20 minutes from the time he begins at 8:30 until he quits for lunch at 12:30. The same is true in the afternoon. In his 8-hour day therefore he is working at least 7 hours and 20 minutes.

These illustrations serve to emphasize a distinction between hours of work and hours of duty, which should be given due consideration, in adjusting the length of the working day.

The Effect of Lost Time on the Work Schedule is often considerable. In most industrial work an 8-hour day means 8 hours in the factory only. The operators cannot spend every minute of their time at their machines, so that even with the best of management 8 hours of productive work are not possible. Besides the inevitable small pauses taken for personal needs there are longer ones that can and should be prevented. Dr. Vernon in his investigation of British munition factories (Memorandum No. 5 British Ministry of Munitions, London, 1916) found that considerable time was lost in starting and stopping work, and that the extent of this lost time could be measured in terms of power load by recording watt-hour meters. Fig. 23 shows the increments of electric power, over that required to drive the free running machinery, on starting and stopping an afternoon period of work. The continuous line represents the power supplied to a large shell shop which turned out 30,000 three-inch shrapnel shells per week. It shows that the power supplied started mounting up two minutes after starting time, and reached half its full value in four minutes. The dotted line curve, representing the power supplied to a section of 200 women turning fuse bodies, did not begin to rise until five minutes after starting time and did not attain half its maximum value until 11 minutes after starting time. In other words these operatives wasted about seven minutes more in starting than did the operatives in the shell shop, most of whom were men. On the other hand the fuse turners finished more strongly than the shell shop operatives, as can be seen by comparing the two curves on the right side of the figure. It was found that each set of operatives lost on an average about 35 minutes during the course of the whole day through untimely starting and stopping. There was no inherent reason why work should have been started more promtly in one shop than in the other. It was merely a custom of the particular shop. A series of meter readings of the women's section, taken for several days before and after the Easter holiday showed that nine days before the holiday the average amount of time wasted in starting after dinner was 11 minutes; two days before it was 14 minutes. Two days after the holdiay it was 16 minutes; three days after, it was 15 minutes and five days after, it was 12 minutes.

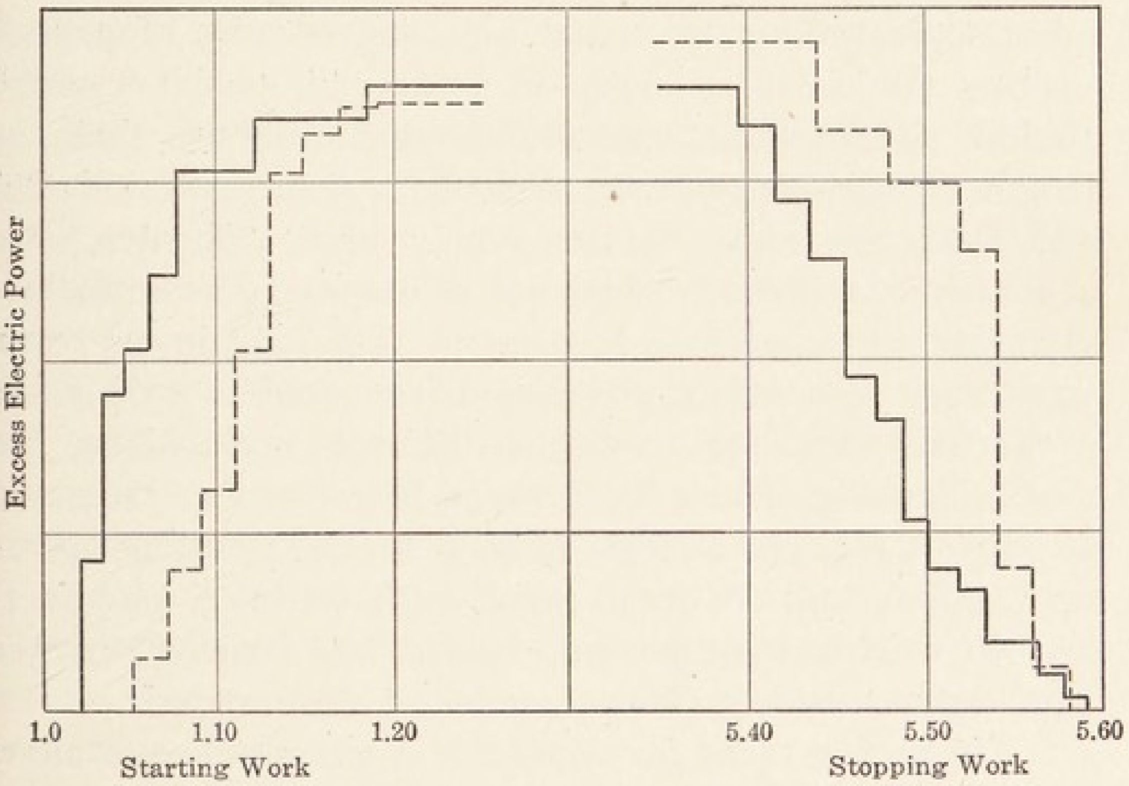


Fig. 23—Starting and Stopping Power Loads at a Munition Factory

Dr. Vernon concluded that ten or fifteen minutes should have been an ample allowance for starting and stopping work and if it were held to, the 20 minutes saved could have been deducted from working hours without any reduction in output.

The National Industrial Conference Board in its report on War Time Employment of Women in the Metal Trades (1918) says on the subject of idle factory time:

"An attempt was made to secure data on this point concerning women employees in the metal trades, but a question regarding the actual time lost because of pauses, waiting for stock, changes in tools and machinery, and similar interruptions, met the general response that the length of such delays was difficult to determine and that any statement must be based only upon estimates. No accurate data are available, but estimates by manufacturers place the loss from zero up to 25%, and in one case, 50%; they most frequently ranged from 10% to 20%. The proportion varies, of course, in different occupations. In a machine shop where the average time lost was estimated at 20%, it was put as high as 40% for gear cutting operations and at 10% for small turret lathe work. A manufacturer of electrical equipment who has had large experience with women workers for a number of years stated:

"In setting tasks for women it is our practice to allow an average of 20% for lost time. This allowance varies according to the nature of the work from 15% to 25%, but we believe 20% is a fair average.

"A machine tool establishment where women perform all kinds of machine and bench work reported, as a rough estimate, that, for about 45 minutes per day of nine hours, women employees are not engaged in actual physical effort. A very small part of this was attributed to waiting for work or for stock, or to delays caused by the management, but the loss was largely due to ordinary relaxations attending employment.

"On the other hand, several establishments reported the proportion of idle factory time as practically negligible. In one plant women performing machine operations were shifted to bench work during repairs or setting up; in another, extra machines were available. In other cases, routing of stock was so carefully planned as to reduce delays to a minimum.

"It should be remembered, however, that where no provision is made for systematic rest periods, chance pauses contribute to the recuperation of the employees. Furthermore, such time losses are also common where only men are employed."

Some Results of the Adjustment of Working Hours. A great many instances of an increase in production accompanying a shortening of the working day are reported. While it may be argued that these were reported because the results were novel and unexpected and that the sum total of the reports does not give a true picture of conditions, they nevertheless show that a great many industries have benefitted from a shortening of their working hours. That the workers also benefitted goes without saying.

A few of the many instances reported are:

The Zeiss Optical Works in Jena reduced hours from nine to eight with a resulting increase in daily output of about three per cent.

In the sheet steel and tin-plate trades of South Wales it is stated that after the change from the twelve to the eight-hour day the increase in output in the rolling mills amounted to 20% and in the open hearth melting process, to 12½%.

The bituminous coal mines in Illinois changed from a ten to an eight-hour day in 1897. For three years previous to that date the average amount of coal turned out daily by each individual was 2.72 tons. For three years after the reduction to eight hours per day the individual daily average was 3.16 tons, an increase of 16%.

At the Engis Chemical Works near Liége after a change from a twelve-hour day (ten hours actual work) to an eight-hour day (7½ hours actual work) the same men at the same furnaces, with the same tools and raw material, produced as much as before.

A granite cutting company found that the same man under identically the same conditions accomplished more of the same kind of work in nine hours than he did in ten and that his output showed a still further increase when his working day was reduced to eight-hours.

Differences in Effective Hours of Work for Various Types of Work and Workers. The following memoranda were published August 1916 in a report to the British Ministry of Munitions by the Health of Munition Workers Committee, Memo. No. 12, appendix to Memo. No. 5, "Hours of Work." These experiments were undertaken at a time when in the midst of the most serious period of the war, their importance was fully realized in England, and it would be difficult to exaggerate the tremendous value of their conclusions to all employers of labor and to the employees as well. In abstracting a very large part of the material published in the memoranda, we wish to pay tribute to the extraordinarily able manner in which Dr. Vernon's observations were presented in the reports. Nothing but absolute lack of space would excuse the omission of this extraordinary material. The following text and Tables 15 to 21 inclusive are taken practically verbatim from this report.

The statistical data collected with one exception concern the output of day shifts, and they were collected in large and recently built munition works where the conditions of labor such as lighting, warming, ventilation and the provision of canteens, were as favorable as possible. All classes of operatives were on piece work, they were paid at a high rate of wages, and there were no Trade Union restrictions whatever upon output. Hence there was every possible stimulus for them to exert their maximum powers of production. It is more convenient to describe first the data obtained relating to the output of women, as one group of them is specially complete.

Women Engaged in Moderately Heavy Labor. The complete series of output data just referred to concern women engaged in turning aluminum fuse bodies. The operatives were standing all day at capstan lathes, and had to subject each fuse body to seven successive boring and cutting operations. These operations required close attention throughout and some delicacy of manipulation, so that no relaxation of effort was permissible during the actual turning. Nearly 200 operatives were engaged on the work, but for the purposes of statistical analysis the output of only 100 of them could be considered. None were included unless they had attained their maximum output (which statistical examination of individual output showed was attained after three weeks' experience,) and were engaged on the operation for 15 or more weeks out of the 24 weeks of the statistical period dealt with. For many months previous to this period the hours of labor had usually been 77¼ per week, except that in the second week of each month there was no Sunday labor, or the hours were reduced to 69¼ per week.

The output data of Table 15 indicate that the beneficial effect on output of a reduction in the weekly hours of labor from 74.3 to 67.5 was not immediately manifest. Even a reduction to 52.0 hours seemed to have no influence, but this was owing to a temporary shortage of material. From February 27 onwards the hours of labor were 66½ per week (or 58½ in the second week of each month, when there was no Sunday labor) and we see that during a period of eight weeks the hourly output now averaged 23% more than in the pre-Christmas period. The total output is 7,343 per week, or 8% more than in the pre-Christmas period, in spite of the hours of labor being nominally 10.5 less, and actually 8.5 less. It is probable that the 60 hours worked per week were still too many to give the best total output, but at least they justify the statement that *in order*

TABLE 15

100 WOMEN TURNING FUSE BODIES

Week ending	Actual hours per week of york		Nominal hours of work per week	Hours of broken time per week		Relative output per working hour		Relative output X Hours of work	Remarks concerning output
Nov. 14	62.0	68.2	67.5	5.5	6.6	98	100	6,820	Hourly output fairly steady.
" 21	68.8		75.5	6.7		99			
" 28	66.7		75.0	8.3		102			
Dec. 5	70.9		77.2	6.3		96			
" 12	69.1		76.2	7.1		99			
" 19	71.8		77.3	5.5		107			
" 26	41.8		46.0	4.2		105			Typical rise in hourly output before holiday.
Jan. 2	32.8		—	—		89		—	Great fall in hourly output immediately after holiday.
" 9	65.2	68.6	69.3	4.1	5.7	113	111	'7,615	Subsequent considerable increase of hourly output, while total output rises to a maximum, 12% greater than that of pre-Christmas period.
" 16	70.3		77.2	6.9		107			
" 23	7.03		76.3	6.0		112			

"	30	62.4	61.6	68.5	6.1	5.9	111	107	6,591	Reduction of hours of labor from 74.3 to 67.5 has no immediate effect on hourly output, hence a considerable reduction of total output.
Feb.	6	60.8		66.5	5.7		102			
"	13	49.2	48.4	52.0	2.8	3.6	108			Temporary shortage of material and reduction in hours of labor.
"	20	47.6		52.0	4.4		106			
"	27	61.4	59.7	66.5	5.1	4.6	118	123	7,343	Effect of shorter hours of labor now established, and hourly output reaches a maximum. Total output 8% greater than in pre-Christmas period.
Mar.	5	62.2		66.5	4.3		125			
"	12	54.8		58.5	3.7		127			
"	19	62.1		66.5	4.4		121			
"	26	60.4		66.5	6.1		121			
Apr.	2	58.6		64.8	6.2		121			
"	9	54.9		58.5	3.6		121			
"	16	62.9		66.5	3.6		126			
"	23	47.0		49.5	2.5		125			Total rise in hourly output before holiday (Easter).

to attain a maximum output women engaged in moderately heavy manual labor should not work for more than 60 hours per week. Observations adduced below suggest that an equally good total output could be maintained if the actual working hours were reduced to 56 or less per week.

It might be thought that the great improvement in hourly output under the shorter hours régime was due, partly or wholly, to increased skill of the operatives or improvements in the machinery. Neither of these hypotheses can be substantiated. On classifying the operatives into two groups, according as they had been engaged in turning fuse bodies for about five months previous to the statistical period dealt with, or for about one and a half months on an average, the hourly output of the former group was found to be 1% less than that of the latter group during the pre-Christmas period, and 1% more during the spring period, or in other words it was the same within the limits of chance error. As regards the other alternative, no change had been made in the tools, the machinery, the nature of the operation or the quality of the alloy used during the statistical period dealt with, or for 4½ months previous to it.

Further proof of the advantage of shorter hours was afforded by the output data of some of the operatives on an earlier occasion. One group of them, 17 in number, worked only 51.8 to 62.6 hours per week for five weeks in June and July, and during the last three weeks of this period their hourly output was 18% greater than that of another group of 14 operatives who were working the usual long hours. Subsequently, when both groups worked the same long hours, their output was identical.

Women Engaged in Sedentary Occupations. In the next type of munition work to be described, the operatives were milling a screw thread on the fuse bodies. This necessitated their standing at semi-automatic machines, where they removed one fuse body and inserted another every minute or so. The requisite muscular effort was moderate and simple in character, and took up only about a fifth of the total time required for the operation. For the remaining four-fifths of the time the operative had nothing whatever to do, and so the call upon her attention and her muscles was very much less than that experienced by the operatives previously described. The output of 21 women was investigated over a similar statistical period, but it seems unnecessary to quote the results in full. The average records adduced in Table 16 show that the hourly output varied in the same direction as that of the fuse-turning operatives, but to a very much more limited extent. In the three weeks after Christmas it was only 6% greater than in the five weeks before it, and since the average hours of work were somewhat shorter, the total output remained practically unchanged. A considerable reduction of working hours did not lead at first to any improvement of hourly output, but this established itself after four weeks, and was maintained at a steady level during the next eight weeks. Since the average excess of hourly output amounted only

TABLE 16

21 WOMEN MILLING A SCREW THREAD

Statistical period	Average hours of actual work	Average hours of broken time	Average (relative) hourly output	Hours × output
5 weeks preceding Christmas (November 15 to December 19)	67.4	4.4	100	6,740
2 weeks at Christmas (December 20 to January 2)	44.7	3.5	98	——
3 weeks after Christmas (January 3 to January 23)	63.7	3.0	106	6,752
4 weeks later (Jan. 24 to Feb. 20)	53.1	2.6	104	5,522
8 weeks later (Feb. 21 to April 16)	59.3	3.6	109	6,463
2 weeks at Easter (April 17 to April 30)	39.4	2.7	108	——
3 weeks after Easter (May 1 to May 21)	59.8	2.6	112	6,698

to 9% above that of the pre-Christmas period, the total output became reduced to 4% *below* it. However, in the three weeks after Easter the hourly output improved a further 3%, so that the total output reached to within 0.6% of the pre-Christmas value. Probably the best number of hours is something between the limiting values investigated, or about 62 hours, for if the output of 109 per hour were maintained over this time, the total output would work out at 6,758, or slightly above that of the pre-Christmas period.

Men Engaged in Heavy Labor. The labor assigned to male munition workers is, as a rule, considerably heavier than that assigned to women, but making due allowance for the greater strength and endurance of the man, we find that his output is similarly affected by a reduction in the hours of labor. One of the most fatiguing types of munition work so far investigated by me is that of "sizing." In the sizing of fuse bodies the article is usually subjected to four separate operations, in each of which it is clamped to a small fly-wheel and handle, and is screwed through a steel

TABLE 17

27 MEN SIZING FUSE BODIES

Statistical period	Average hours of actual work	Average (relative) hourly output	Hours X output
6 weeks preceding Christmas (November 8 to December 19)	61.5	100	6,150
2 weeks at Christmas (Dec. 20. to Jan. 2)	38.3	89	——
6 weeks after Christmas (Jan. 3 to Feb. 13)	51.1	109	5,570
8 weeks later (Feb. 21 to April 16)	55.4	122	6,759
2 weeks at Easter (April 17 to April 30)	41.0	112	——
3 weeks later (May 1 to May 21)	56.2	124	6,969

tap so as to cut a screw thread on it. The operations require no manual dexterity, but they are a great and continuous strain on the muscles of one arm and shoulder, and to a less extent on those of the back. The operatives seldom use both arms, as they prefer to keep the "screwing" hand dry, and use the other one for picking up the oil-covered fuse bodies. The output of a group of 27 operatives was investigated, and the mean results are given in Table 17. The hours of labor were always shorter than those worked by the women. They never exceeded 71 hours in any one week, and seldom included Sunday labor. The hourly output showed a marked drop during the Christmas fortnight, and a considerable rise (to 118) for the first week after this fortnight, but the average output during the six weeks after Christmas was only 9% greater than that of the pre-Christmas period, in spite of the fact that the weekly hours of labor were 10.4 shorter. Evidently the operatives took a long time to adapt their rate of production to the shorter hours, for the hourly output subsequently averaged 22% in excess of that of the pre-Christmas period. This caused the total output to be no less than 10% greater, and it is probable that even this figure does not represent the full effect of reducing the hours of labor, for after Easter the hourly output improved a further 2%, and the total output was increased to 13% above that of the pre-Christmas period. However, a part of this improvement may have been only the temporary effect of the holiday. The week February 14—20 is omitted, as the operatives worked only 41 hours owing to shortage of material.

Youths Engaged in Heavy Labor. The operatives engaged in sizing fuse bodies were all full-grown men, but certain other sizing operations were performed by youths. The output of one of these groups may be quoted, but in that it concerns only nine operatives, the data are not so reliable as those just recorded. The youths, 14 to 17 years of age, were sizing steel base plugs, and from Table 17 we see that their hourly output was 16% greater in the four weeks after Christmas than it had been before, in spite of a slight increase in the hours of labor, whilst it was no less than 42% greater in the 11 subsequent weeks when the hours of labor were reduced from 70.3 to 57.0. In consequence, the total output attained a value 19% in excess of that of the pre-Christmas period. Even this value does not represent the full effect of the reduced hours of labor, for in the three weeks after Easter the hourly output was 55% above that of the pre-Christmas period, and the total output 38% above it. Such results are so astonishing that one is naturally inclined to doubt their validity, but there appears to be no reason for denying their substantial accuracy. The boys must have been seriously overworked by the long hours, and hence the 8 to 12-hour reduction of the working week accelerated their rate of production much more than did the 6-hour reduction accelerate that of the men "sizers."

TABLE 18
9 YOUTHS SIZING BASE PLUGS

Statistical period	Average hours of actual work	Average (relative) hourly output	Hours × output
5 weeks preceding Christmas (November 15 to December 19)	68.3	100	6,830
2 weeks at Christmas (Dec. 20 to Jan. 2)	46.3	106	——
4 weeks after Christmas (Jan. 3 to Jan. 30)	70.3	116	8,155
11 weeks later (Jan. 31 to April 16)	57.0	142	8,094
2 weeks at Easter (April 17 to April 30)	42.1	135	——
3 weeks later (May 1 to May 21)	60.9	155	9,440

Men Engaged in Moderately Heavy Labor. Typical examples of moderately heavy labor are found in shell-making, and all the data described in this section relate to the output of 3″ shrapnel shells. One of the most important and lengthy of the operations is that known as "boring the powder chamber." This operation is performed on capstan lathes provided with three sets of boring tools, and it requires considerably more muscular energy than that involved in turning fuse bodies, though not so much as in sizing. At one shell factory where the male operatives were being largely replaced by women, the writer was informed that though the women attained a good output in most operations, they produced only about half as many shells as the men did in this particular operation, since they had not the necessary strength.

The data in Table 19 concern the output of 23 operatives, all of whom had been four months or more at the process previous to the statistical period recorded. During these months they worked at first for 53 hours per week, and subsequently for 49½ hours, and had attained their maximum output for these particular hours of labor. When their hours were suddenly increased to 64 per week (seven hours on Sunday,) we see that they maintained their hourly output for three weeks with very little diminution. After this time there was a shortage of material at irregular intervals, so the output data were rendered valueless for statistical purposes, but even if the hourly output had fallen considerably lower, the total output would still have remained higher during a 60-hour week than during a 48-hour week.

TABLE 19

MEN BORING THE POWDER CHAMBER

Week ending	Weekly hours of actual work		Hours of broken time		(Relative) hourly output		Hours × output
November 7	48.5	47.8	1.0	1.7	100	100	4,780
" 14	47.1		2.4		100		
" 21	59.5	59.7	4.5	3.1	107	100	5,970
" 28	60.5		3.5		98		
December 5	59.1		1.4		94		

An important operation is to "finish, turn and form" the shell, which consists in taking off a fine turning and afterwards filing down the shell. This operation probably needs the expenditure of about as much muscular energy as that of turning fuse bodies. The data in Table 20 show the output of 22 men who had been engaged at this work for 10 weeks, on an average, previously to the statistical period dealt with.

The hours of labor in the immediately preceding week had been 64, but before that they had been 49 for three weeks, preceded by 64 or more for seven weeks. We see that, on an average, the hourly output during the last three weeks recorded in the Table, when the hours of labor averaged 51.8 hours, was 14% greater than in the first four weeks when they averaged 60.3 hours. It is probable that a portion of this improvement was due to increased skill of the operatives, who were found to require three or four months' experience before attaining their maximum output, but assuming that the whole of the improvement was the direct result of the reduced hours of labor, the total output is still less for the short hour weeks than for the long ones. The time-keeping was extremely good, and suggests that the operatives could easily stand the 60-hour week, for not only was the broken time one hour per week or less, but during the 60-hour period recorded the operatives were never absent for a whole week, and they put in only 4% of short weeks. It should be mentioned that in calculating broken time, the 45-hour limit referred to previously was retained for operatives working 58½ hours or more per week, but with operatives working a nominal 52 hours, only those were excluded who put in less than 40 hours of actual work, and with operatives working a nominal 49½ hours, only those who put in less than 38 hours of actual work.

Men and Youths Engaged in Light Labor. In the operation known as "rough turning", the rough shell is turned approximately to size. During four-fifths of the time required the operative merely watches the lathe, so the labor is very much lighter in type than that previously described, and resembles that required for milling a screw thread on fuse bodies. The hourly output of 18 men was investigated, and was found to be constant within the limits of chance error, whether they were working 49, 53 or 64 hours per week. For instance, on changing from a 49½-hour to a 64-hour week, the hourly output during three consecutive weeks was 100, 102 and 101 on that of the preceding weeks taken at 100. Again, when the 20 operatives of a permanent night shift had their hours increased from 47½ to 53½ for one week, and then to 67 hours for two weeks, their output was 99, 97 and 96 in the three weeks respectively, that of the preceding weeks being taken as 100. There can be little doubt, therefore, that these operatives could have worked longer weekly hours than 64 or 67 without greatly diminishing their hourly output, and so have attained a greater total output. This conclusion is strongly supported by the data for youths which are now to be recorded.

TABLE 20

MEN, FINISHING, TURNING AND FORMING 3-INCH SHELLS

Week ending	Weekly hours of actual work		Nominal hours of work	Hours of broken time		(Relative) hourly output		Hours × output
August 29	62.0	60.3	64	2.0	1.0	98	100	6,030
September 5	64.1		65	0.9		100		
" 12	51.6		52	0.4		101		
" 19	63.4		64	0.6		101		
" 26	52.3		53	0.7		105		
October 3	39.0		39	0.0		112		
" 10	51.2	51.8	52	0.8	0.8	112	114	5,905
" 17	53.0		53	0.0		118		
" 24	51.2		53	1.8		112		

The youths, 15 to 18 years of age, were engaged in boring out the top caps of fuses by means of semi-automatic machines. About four times a minute they unclamped one cap and clamped in another, these two clampings together occupying less than two seconds. For the rest of the time they stood at their machines doing nothing. From the average data recorded in Table 21, which concern the output of 17 operatives, it will be seen that before Christmas they averaged 75.6 hours per week of actual work out of the 78½ nominal hours. In the six weeks after Christmas their hourly output went up 6%, but in that they averaged 4.7 hours a week less than before, their total output was slightly diminished. The output of the week February 14-20 is omitted as there was a shortage of material but in the next eight weeks when the average hours were reduced to 59.4 per week, the output rose another 2%. This rise by no means compensated for the considerable reduction in working hours, so we find that the total weekly output was actually 15% less than in the pre-Christmas period.

TABLE 21

17 YOUTHS BORING TOP CAPS

Statistical period	Average hours of actual work	Average hours of broken time	Average (relative) hourly output	Hours × output
5 weeks preceding Christmas (November 15 to December 19)	75.6	2.9	100	7,560
2 weeks at Christmas	50.0	2.7	106	——
6 weeks after Christmas (January 3 to February 13)	70.9	4.6	106	7,515
8 weeks later (Feb. 21 to April 16)	59.4	4.4	108	6,415
2 weeks at Easter. (April 17 to April 30)	40.8	4.6	95	——

It seems probable, therefore, that to attain maximum output 70 hours or more per week of this light labor must be worked. It will be seen from the Table that when the operatives were working over 70 hours per week their broken time was not excessive. Moreover, they put in only 2.0% of short weeks, and 3.6% of absent weeks on an average, so the long hours did not appear to affect their health.

Comparison of Results. The various types of labor investigated may conveniently be divided into five, viz., very heavy, heavy, moderately heavy, light, and very light. Of these types the "very heavy," such as sizing fuse bodies, and the "heavy," such as boring the powder chamber, are not well suited to women. On the other hand, the "light" type, such as boring top caps and rough-turning 3-inch shells, had better be confined to women, as it is waste of muscle to apportion them to men, or even to youths. Very light types of labor such as sedentary gauging operations should evidently be confined to women and girls.

We have seen that for men engaged in the very heavy labor of sizing fuse bodies the maximum hours of actual work appeared to be 56 or less per week; for men engaged in boring the powder chamber and in turning and finishing shells they were probably 60 or rather more, whilst for men rough-turning shells and for youths boring top caps they were probably 70 or even more. On the other hand, for women engaged in the moderately heavy labor of turning fuse bodies the maximum hours were 56 or less, while for women on the light labor of milling a screw thread they were rather over 60 hours. In so far as time-keeping is a criterion, women and girls on the very light work of gauging fuses appeared to stand as much as 76 hours fairly well, but it is more than likely that their actual output was little, if any, greater than when they were working 64 hours, and so it is probable that this figure should be regarded as their maximum.

It must be realized that all of these data are provisional, but they clearly justify the conclusion that the hours of labor should be varied between wide limits according to the character of the work performed. This obvious fact is not realized by many managers of munition works, and the tendency is usually towards uniformity of hours for all types of labor and for workers of both sexes. The data adduced suggest that not only are women unsuited to the heavier types of work, but that even when engaged on the moderate and light types they are unable to stand such long hours as the men. Several sets of operatives, both male and female, were kept under close observation for many days in order that their powers of application might be investigated. Men engaged in boring the powder chamber in turning and finishing shells were found, almost without exception, to stick to their work with admirable persistence, and it was very seldom that they rested even for a minute. On the other hand, women engaged in turning fuse bodies rested for times which, in aggregate, amounted to one and one half hours of the twelve-hour day, and over an hour out of the ten-hour day, in addition to the hour or so of compulsory rest required for attention to their lathes at the hands of the tool-setters. About half an hour of the voluntary rest pauses occurred on starting and stopping work, but much of the remaining hour or half hour was probably due, not to idleness on the part of the women, but to fatigue, and to an instinctive knowledge that short rest pauses helped to prevent undue fatigue. Still, it would have been better if these pauses and the times lost in starting and stopping had been curtailed by half an hour a day, and the women had been permitted a corresponding reduction in their weekly hours of labor.

It is to be borne in mind that all of the times mentioned are the maximum hours of actual work, supposing that a maximum output is required regardless of cost of production. This necessarily imposes a great strain on the operatives, and there can be no doubt that in many instances the strain was too great to be borne, and the operatives had to drop out altogether. That is to say, the data quoted relate to the fittest who were strong enough to survive in the struggle, and not to the general mass of workers of all classes who tried their hand at munition work. It is almost impossible to discover the extent of this weeding out, but it is inevitably considerable. Hence the *best* hours of work, suited for peace times, are in every case considerably shorter than those mentioned, though the principle of graduating the number of hours of labor to the type of work performed still holds with undiminished force.

Studying these records of long and continuous weeks of arduous labor reported by Dr. Vernon, one cannot but be impressed by the spirit of patriotism with which these British workers were imbued. Kipling has caught and recorded it in his "Song of the Lathes", wherein the reader may find an explanation of the fact that women could and did carry the burden of 60 and 70 hours of work a week.

> "The fans and the beltings they roar round me.
> The power is shaking the floor round me
> Till the lathes pick up their duty and the midnight shift takes over.
> It is good for me to be here!"
>
> *"Guns in Flanders—Flanders guns!*
> *(I had a man that worked 'em once!)*
> *Shells for guns in Flanders, Flanders!*
> *Shells for guns in Flanders, Flanders!*
> *Shells for guns in Flanders! Feed the guns!"*

A Comparison of Long and Short Days for Women Workers is given in a very complete report by Ethel E. Osborne, M.Sc., which was published by the Industrial Fatigue Research Board, London, in 1919, and from which the following data are taken:

The work investigated was the "ripping" or "part off" operation of shell turning in a British munition factory. This is the first operation to which the rough forging is subjected, and consists of cutting off the end portion of the forging to reduce it to the required length. The operation was generally considered to be the hardest in shell-making.

for the shell was then at its heavies stage. Furthermore, the operation was a rapid one and involved constant changing of shells. A woman operator could handle up to 100 six-inch shells in a 12-hour shift (10½ working hours) and, as the forgings at this stage weighed about 140 pounds and were regularly handled by pulleys, sometimes the women lifted them by hand to save time, and thus their handling into and out of the lathes constituted a strenuous day's task.

TABLE 22

Shift	Arrangement of Hours			Weekly Totals	
	Days of week	Period of Employment	Meal times	Hours of attendance in factory	Hours of possible work
SCHEME I.					
Day	Mon.-Fri.	6 a.m.-6 p.m.	9-9:30 a.m. 1-2 p.m.	67	59
	Saturday	6 a.m.-1 p.m.	9-9:30 a.m.		
Night	Sun. evg. Sat. mng.	6 p.m.-6 a.m.	9-10 p.m. 1:30-2 a.m.	72	63
Total	—	—	—	139	122
SCHEME II.					
Morning	Mon.-Fri.	6 a.m.-1 p.m.	9-9:30 a.m.		
	Saturday	6 a.m.-noon	9-9:30 a.m.	41	38
Afternoon	Mon.-Fri.	2 p.m.-9 p.m.	5:45-6:15p.m.		
Night	Sunday	6 p.m.-6 a.m.	9-10 p.m. & 1:30-2 a.m.	35	32¼
	Mon.-Fri.	10 p.m.-6 a.m.	1:30-2 a.m.	52	48
Total	—	—	—	128	118½

In the National Ordnance Factory, in which this investigation was carried out, women had worked on this operation for a period of about 18 months, on shifts of 12 hours duration, with night and day work in alternate weeks, according to Scheme I, Table 22.

It then became evident that these hours were adversely affecting the women and a shortening of shift was decided upon; the plan of hours of work set out as Scheme II, was accordingly arranged.

The male workers remained on the 12 hours shift as outlined above, but the women workers (with the exception of charge hands, who worked the hours laid down for men), were placed on a three-shift system, the shifts being so arranged as to fit in with the two-shift system adopted for the men. Thus the hours of work were shorter than they would have been had the whole factory been transferred to a three-shift system of eight hours each.

Some months previously, data of actual hourly output had been obtained for all women workers on this operation. In the meantime a change had been made to an improved form of lathe which considerably reduced the demands made on the women, but which still required them to perform a very heavy day's work.

TABLE 23

SUMMARY OF OUTPUT

Shop and Shift	Hourly output of shells			Total Shells
	Per hours in Factory	Per possible hours of work	Per actual hours of work	
SCHEME I.				
A—Night	7.66	8.53	8.80	2,868
B—Night	6.43	7.35	7.57	2,316
A—Day	6.22	7.07	7.45	2,439
B—Day	7.61	8.66	8.86	1,477
Totals	27.92	31.61	32.68	9,100
Average hourly output of shells per shift	6.98	7.90	8.17	
Percentage Average	85.43	96.57	100	
SCHEME II.				
A—Night	8.41	8.97	8.97	1,397
B—Morning	7.59	8.20	8.20	911
A—Morning	8.51	9.19	9.19	1,817
A—Afternoon	8.04	8.66	8.71	1,634
B—Afternoon	7.63	8.22	8.41	1,336
Totals	40.18	43.24	43.48	7,095
Average hourly output of shells per shift	8.04	8.65	8.70	
Percentage Average	92.41	99.42	100	

After the modifications in machinery were made, and before the change in working schedule, a new set of output data was taken which is compared with output data under the three-shift scheme of working, in Table 23.

Because of operating difficulties, (at one time a different forging was furnished which disturbed the schedule and at another time a strike had to be contended with), it was five months before the women got into full stride under the three-shift scheme. It is to be recalled that Vernon found that a period of four months was necessary before an equilibrium output of work for a certain length of shift was attained in making fuses.

Results. 1. The average number of shells per operator per actual hour worked was 8.17 on the long hours, Scheme I, (an average of 55.85 hours per week) and 8.70 on the short hours, Scheme II, (an average of 35.65 hours per week) corresponding to an increase in output of 6.5% (for an average reduction of 20.20 hours per week.)

The actual cutting with the lathes used in these tests was automatic, and the increase in output must, therefore, have been due entirely to speeding up the heavy work of fixing and removing shells. A time study on the cutting period, which could not be hastened by the operator, showed that in each hour there were 18.88 minutes under Scheme I and only 16.21 minutes under Scheme II in which the operator could vary her speed. Hence the work (under control of the women as far as speed was concerned) was carried out in 19.5% less time.

If the output per operator per actual hour of work is taken as one hundred in each case, then, under Scheme I, the output per possible hour of work was 96.57 and under Scheme II, 99.42. On the long hours, therefore, there was a drop in possible output of 3.43%, while on the short hours there was a drop of only 0.58%.

Similar comparison of output per hour spent in the factory with actual hourly output shows 85.43% under Scheme I, and 92.41% under Scheme II.

These figures illustrate the advantage of short hours as compared with long hours in the case of women on heavy work, and, especially, of a shift of only sufficient duration to require a single meal break.

Outputs of various individual workers for the last hour of the working day were studied as an indication of fatigue. The results are given in Table 24.

Three of the five sets under Scheme II indicate that with the shorter day, high output could be maintained right up to the end of the shift. With the long shift, output decreased markedly in the last hour in every case.

A comparison of the records of day work with those of night work gave no evidence of any adverse effect of night work.

TABLE 24

COMPARISON OF LAST HOUR'S OUTPUT UNDER SCHEMES I AND II

SCHEME I

Last hour's Percentage Output	Average Percentage Output	Average Percentage Output for all hours except the last
5.93	9.52	9.9
7.61		9.7
6.16		9.9
8.01		9.7

SCHEME II

Last hour's Percentage Output	Average Percentage Output	Average Percentage Output for all hours except the last
12.20	15.39	15.96
11.28		16.13
14.96		15.46
15.76		15.31
12.64	13.33	13.44

Effective Hours of Work in Various Industries. *Metal Workers.* In a report on the metal manufacturing industries the National Industrial Conference Board concluded that considerable proportion of establishments could maintain production on a schedule of 50 hours per week, but that such a schedule could not be universally adopted without some loss in production. In establishments where a very large percentage of the work is performed by highly automatic machinery their evidence indicated that maximum production could not be maintained on a schedule as low as 48 hours or 50 hours per week. This conclusion was based on questionnaires sent out in 1917 and 1919. In the former year 18 out of 41 establishments, employing 83.5% of the workers involved, reported production increased or maintained after changing from a longer week to one of 48 hours. Of those establishments that shortened their working time to a 50-hour week, 32 out of 66 reporting, employing 52.7% of the workers, found production increased or maintained. Results from plants changing over in 1919 were not so favorable; five out of 39, with 12.6% of employees, found output improved or equaled by a 48-hour week, while of those changing to a 50-hour week, only 11 out of the 35, with 20.5% of employees, reported satisfactory results.

The Boot and Shoe Industry was reported on by the National Industrial Conference Board in June, 1918. They found a 54-hour week long enough to maintain maximum production for the industry as a whole. Several well equipped and well managed plants had obtained as large an output from a 52 or a 52½-hour week as from a longer one, while a few had found a 50-hour week feasible. Of special interest were their findings in regard to the manner in which the weekly hours of work were reduced in a number of establishments.

Of the 77 establishments reporting the effect on output of reduction in hours, 50 shortened the work-week by granting a Saturday afternoon holiday while 27 distributed a reduction in hours over the other days of the week.

Of the 27 establishments which distributed the reduction in hours through the week, 15 maintained production and 12 experienced a decrease; whereas, of the 50 establishments which adopted a Saturday half-holday, only nine maintained production. Apparently the method of reducing hours has a vital effect on results.

Tin Plate Manufacture. Dr. Vernon found that the hours actually worked by the tin plate operatives in England very seldom exceeded 54 per week and were usually considerably shorter than this. 40 or 48 hours made up of five or six 8-hour shifts were more common. The work was very heavy and the workers were subjected to extreme heat. The degree of fatigue caused by it is shown by an increase in hourly output when shorter shifts were worked.

It was found that when four-hour shifts were worked for ten months, the hourly output during the last seven months was 11.5% greater than when eight-hour shifts were worked. Observations on six-hour shifts (lasting in one instance for 18 consecutive months) showed that the hourly output was about 10% greater than for 8-hour shifts.

Dr. Vernon's report, a further abstract of which will be found in the chapter on cooling, seems to indicate that a 48-hour week was ample on this work and that an even shorter week might have been better.

Drop Forge Shops. Drop forge shops of the Cleveland Hardware Company, Cleveland, Ohio, according to Iron Age, March 4, 1915, were run on a two-shift system, the men working 12 hours a day, which was partly rated as overtime. In 1913 all employees were reduced to a 60-hour week, and the results were so successful that a further reduction to a 48-hour week was made in 1914. Practically all the shop employees were on piece work, and, although piece rate prices were not changed, they were able to make as many in eight hours as they had previously made in ten. Some operations showed a very decided increase in output for the eight-hour day.

Textile Manufacturing. An investigation made in the silk manufacturing industry by the National Industrial Conference Board showed maximum output to require between 50 and 54 hours per week. Similar studies made in the cotton and wool manufacturing industries indicated that the point of maximum production occurred with a week of less than 54 hours. No perceptible difference was found between the health of employees who worked 50 hours a week and those who worked 52 or 54 hours.

It is significant that, in general, those occupations requiring heavy muscular exertion reach their maximum output in a fewer number of hours than do the lighter types of factory work. This is because the lighter work is largely done by automatic machinery which allows the workers a constant succession of short rest pauses during the progress of their working day.

The foregoing notes on effective hours of work are based on reports of American and British investigators who concerned themselves only with human machinery as such. They sought to find the number of hours of work that would insure maximum production and have repeatedly stated in their reports that they were not considering the social aspects of the problem.

It does not follow because a given number of hours of work per week produces the greatest output in an industry that this is the number which should be adopted. Social as well as economic considerations must be given due weight. Custom and habit must be consulted, for a worker who puts in longer hours than his neighbors will be discontented even with a considerable difference of pay in his favor. While these factors alone may absolutly dictate the number of working hours, it is nevertheless to the advantage of both management and workers that the economic day for their particular work be investigated and made known. Thus, if a factory is working eight hours a day and is confronted with either the necessity of overtime or a demand on the part of the workers for a reduction in hours, a knowledge as to whether eight or nine hours of work will produce maximum output may well form a basis for adjustment.

The Limit of Practicable Work Hours. The following recommendations of the British Health of Munition Workers Committee (Memorandum No. 5, London, 1917, "Hours of Work") were published at a time when it was vitally important to get as much work done as possible. They were intended to apply to the needs of a country at war, and gave no consideration whatsoever to the social needs of the workers, or to anything other than their ability to produce the greatest amount of munitions. Subsequent British investigations, reported earlier in this chapter, showed that these hours were too long for some classes of workers, and that even where output was the only consideration, it was better to shorten them. The Committee's report read:

"In the agreement between the Engineering Employers Federation and the Engineering Trade Unions a limit of 32 hours of overtime per month was adopted, while the Home Office General Order for Munition Factories (which, though it applies directly only to the labor of women and young persons, affects indirectly the hours of work of male adults, since their work is generally dependent upon that of the protected persons) provides for a maximum of 67½ hours a week and has been found to meet the needs of the great majority of the employers. It is evident that within the limits of prescribed hours the speed of work and the energy exerted differ widely; the Committee, however, think that such hours cannot reasonably be exceeded without affecting the physical efficiency of the workers, and accordingly, on the facts at present before them, they make the following recommendations as appropriate to the special conditions imposed by the war:

(*a*) The average weekly hours (exclusive of meal times) should not exceed 65 to 67, including overtime. Hours in excess of 65 should only be worked for short periods and to meet sudden and unexpected circumstances. It may be desirable to differentiate to some extent between different kinds of work, and to fix a rather lower limit of hours for work requiring close individual attention.

(*b*) Where practicable the overtime should be concentrated within three or four days in the week, which should preferably not be consecutive.

(*c*) Where overtime is worked it is specially important that there should be no Sunday work.

(*d*) The practice prevailing in certain districts of working from Friday morning, all through Friday night and until noon on Saturday, should be discontinued. Such hours may be permissible for short spells, but cannot be satisfactory from the point of view either of health or output if continued for indefinite periods.

"*Women and Girls.* Important as it is that hours of work for men should be kept within reasonable limits, it is essential that hours of work for women and girls should be even more closely safeguarded. There is a general consensus of opinion (it is indeed beyond dispute) that women are unable to bear the strain of long hours so well as men, and, though there is some divergence of views, opinions as to what hours can profitably be worked vary to a much less extent than was found to be the case in regard to men."

Night Work. It stands to reason that if the machinery of a plant be used continuously, a substantial reduction in the fixed charges per unit turned out will be effected; but continuous operation involves a difficulty, for while day and night are all the same to the mechanical machinery, the human machine does not function equally well in the night time.

Man is a diurnal creature, naturally laboring in the day and resting at night, a division of time sanctioned not only by his habits but by his physiological needs. He is subject to a distinct cycle of changing physical conditions during the twenty-four hours, which is chiefly manifested in temperature changes. The difference, although the actual maxima and minima are not the same in different persons, is between one and two degrees F., the maximum appearing between 4 P. M and 8 P. M. and the minimum between 2 A. M. and 6 A. M. The natural explanation of this cycle is that it reflects the diurnal variations of bodily combustion, in particular that going on in the muscles. From this explanation one would expect that resting by day and working at night would reverse the cycle, whereas tests have shown that it only modifies it.

This fact is susceptible of two explanations: either the cause of the diurnal rhythm lies deeper than variations of metabolism, or the minority which strives to change its habits from those of society in general is practically unsuccessful. The second explanation is supported by two sets of experiments, in one of which monkeys, kept active at night and allowed to sleep in light and sound proof cages by day, developed a complete reversal of rhythm. In another experiment, performed under the conditions of Arctic night by the Danish Arctic Expedition of 1906-1908, bedtime was delayed, once four hours and once eight hours, so that, so far as their clocks were concerned, the entire party had changed day into night. More than half of the 26 members of the party felt just as usual as soon as the transition had been accomplished and by the end of five or six days only a few felt even slight inconvenience. The function which was changed with the most difficulty was the time of defecation, and it took roughly about a week before this occurred at the normal time. The temperature curves showed a reversal of rhythm, a delay in adjustment being found in the cases of those few who experienced difficulty in adapting themselves to the changed conditions.

Neither of these experiments makes adequate allowance for the effect of sunlight on the daily changes in rhythm, for although it may be possible to furnish men with light and sound proof rooms to sleep in it is impossible to compensate for the habit of rising in daylight and going to bed some hours after it has become dark. The chief significance of these experiments lies in the fact that it is necessary to go to these extremes to get a complete reversal of rhythm. Under conditions of everyday life there is merely a modification and the night worker is at a disadvantage. In many occupations, however, this is compensated for by the fact that the workshops are cooler at night.

Comparative Efficiencies of Night and Day Work in Munition Factories were reported on by the British Health of Munition Workers Committee, in 1918, Interim Report, whose conclusions are given in the following paragraphs:

"*Conclusions.* The investigations were not primarily aimed at comparing the output of day work with that of night work, as the case against night work was considered to be sufficiently established; some of the data, however, permit a comparison to be made, and in each case the comparison is to the detriment of night work. Night work, though necessary in the present crisis, is, then, undesirable; but the Committee consider that the extensive and varied data which have been summarised provide material upon which certain conclusions, having reference to relatively light repetition work, may be based as to the result upon output to be anticipated from different schemes of night work.

Women.—(1) In monotonous processes which call for little physical effort, such as those concerned with cartridge-making, discontinuous night work of women gives an output which rarely falls much more than 10% below, and usually approximates closely to that obtained by day.

(2) Continuous night work is productive of definitely less output than is the discontinuous system; and the Committee have failed to obtain evidence that the output of the continuous day shift balances this inferiority.

(3) (*a*) The timekeeping of girls and of women of 19 years of age and upwards, working for alternate weeks of day and night shifts, is even better maintained than when they work on permanent day shifts.

(*b*) Timekeeping of girls of 14 to 18 is practically the same whether they work on permanent day shifts or on day and night shifts.

The Committee, basing their opinion upon these conclusions, consider it *undesirable to adopt for women continuous night shifts in any factory not at present so working or not yet open, and suggest that wherever practicable this system should be discontinued.*

The Committee believe that this inferiority of the continuous night worker may ultimately be referred to a failure to secure proper rest and sleep in the day time. Women on continuous night work are liable to perform domestic duties which, when they work alternately in the two shifts, is impracticable; and this extra domestic strain may account for the inferior results of their industrial activities. The Committee has, indeed, some evidence of women employed in permanent night shifts who still carry on their ordinary day-time avocations, but it is not sufficiently extensive (statistically) to be offered as a proof of the suggestion just made.

Men.—The conclusions arrived at with respect to women are true, with slight modifications, for men.

(1) There is no significant difference between the rate of output in night and day shifts managed on the discontinuous system.

(2) With men, as well as with women, the discontinuous system is preferable to continuous night work.

There is no reason to think that the nightly output need be much, if at all, inferior to the output by day in the case of a discontinuous system, and there is evidence that the timekeeping by night is rather better than by day. The contrast between permanent night shifts and permanent day shifts is, however, less striking than in the case of women. On the whole, it appears that the rate of output may be less and the loss of time greater than in the discontinuous system. This result is what might be expected, if the surmise regarding the cause of the inferiority seen among women were correct. Men do not naturally take so much part in domestic work as women, and the temptation to burn the candle at both ends is, from this point of view, smaller. On the other hand, the incitement to devote the time which should be given to sleep to amusement is certainly as intense among men as among women, so that some inferiority might be anticipated.

The practical conclusion seems to be, therefore, that, equally with women, *men can more profitably be organised under the discontinuous than under the continuous system of night work"*

The following recommendations were made in the Final Report 1918 of the British Health of Munition Workers Committee in regard to night work in England:

"Even for men night work is open to serious objection. It is uneconomical owing to the higher charges for wages, lighting and heating. Lighting is generally inferior and supervision more difficult. Adequate sleep by day is difficult owing to dislocation of ordinary habits or from social causes. Social intercourse and recreation can hardly be obtained except by an undue curtailment of sleep. Continuance of education is generally impracticable. Finally it is unnatural to turn night into day.

Night work for women and girls has been illegal for over 50 years. Although inevitable for adult women under existing conditions it should be stopped as soon as it ceases to be essential. Night work for girls under 16 has now been entirely stopped; for girls between 16 and 18 it has been largely curtailed and should be ended as soon as possible.

Night work for boys is only legal in certain continuous processes. It has already been curtailed for boys under 16, and should be altogether stopped. The Committee fully endorse the arguments against the employment of any boys under 18 at night which were put forward in the Report of the Department Committee on the 'Night Employment of Male Young Persons in Factories and Workshops'.

There is no uniformity of practice as to how long a worker should remain on the night shift at any one time. A week is the commonest period but much depends on the social conditions under which he lives. Investigations suggest that continuous night work is productive of less output than the system under which a worker is engaged on day and night shifts alternately. There is no evidence that the output of a continuous day shift balances this inferiority."

Advantages of Night Work. Except in the matter of reducing fixed charges per unit of output, the advantages of night work are more apparent than real. Where a considerable part of the worker's fatigue is due to heat, some real advantage may be gained from working at night especially in summer weather; if, however, this involves sleeping in a hot room, lack of rest may counterbalance the saving in fatigue, and the advantages will be lost.

With some steel making operations, and on excavation work with steam shovels and dragline machines, the output of the night shift is often greater than that of the day shift. This should not be interpreted as due to added efficiency, for it will generally be found that the day shift is obliged to do various repair and service jobs that are neglected at night. The night men are freed from many distractions and can devote themselves entirely to production.

Other Objections to Night Work are discussed in the following paragraphs:

Loss of Sleep is the most serious consequence due to night work. Recuperation from fatigue and exhaustion takes place almost entirely during sleep, which is difficult to secure in the day time even under the best of conditions; and the conditions under which industrial workers live are often not the best. Laborers' dwellings are often small and noisy; indeed, under city conditions, a whole family frequently live in one room in which the night worker must try to sleep while the regular activities of the home are going on. Under these conditions, complete rest is quite impossible.

Lack of Sunlight impoverishes the blood and favors the growth of bacteria. The blood of night workers shows a marked decrease in red coloring matter, sufficient at times to result in chronic impoverishment.

Effect Upon Eyesight. Night work often results in injury to the eyes. The danger of eye strain from close application to work is intensified at night by insufficient and improper lighting. It is very difficult to adjust the illumination of an entire factory so that there will be a sufficiency of light on each person's work without glare in some direction, so that even with the best of lighting some of the workers will suffer. Moreover there is no chance at night to rest the eyes by a momentary glance at some outside distant point; and by being held continuously on the work it is probable that the eyes suffer additional strain.

Effect on General Health. The digestive system undergoes functional changes owing to irregularity of meals incident to night work. The incompleteness of the change in the temperature cycle probably requires a greater expenditure of nervous energy to drive the muscles to a given amount of work. The procreative power of men is diminished or impaired, and the effect on the female generative organs is also injurious.

Effect on Family Life and Morals. The number of meals in the family budget is increased, extra cooking must be done and thus the family order and system are disjointed. A lower moral standard is established for the night worker, as his manner of living makes it more difficult for him to have a family.

Effect on Education. Night work and late overtime hours prevent the worker from taking advantage of the educational opportunities afforded by enlightened communities such as evening schools, public libraries, lectures, radio programs, etc.

The Introduction of Night Work at a plant, on an admirable working schedule for changing shifts from night to day, was described by C. A. Hubbell in American Machinist, May 3, 1917 as follows:

The first step consisted in training men to handle the machinery (automatic screw machines, milling machines, and lathes). Each shift was provided with a man who thoroughly understood the setting up of the machines and who could make any required adjustment immediately. Automatic screw machines gave no trouble in changing from one shift to another as the work was continuous and one man could pick up the operation where another left off. With other machines, requiring more adjustment, difficulty was encountered as each operator thought his way of working was best and complained at the adjustment and condition of tools left him by the man he relieved. These objections were overcome by patiently training the men to work together. Finally, in the tool room, it was found advisable to have the more intricate work finished by one man even though it remained in place and occupied his machine for the two intervening shifts. Simpler work could be removed from the machines or finished by the succeeding men.

Schedule of Shifts. Work started at 11 P. M. Sunday night and was continued through the week until 11 P. M. Saturday night, the shop standing idle during the next twenty-four hours. Shifts were from: 11 P. M to 7 A. M.; 7 A. M to 3 P. M.; and from 3 P. M. to 11 P. M.

They were changed every week, so that no one worked continuously at night. The shift finishing work at 11 P. M. Saturday night went on duty at 7 A. M. Monday, that finishing at 3 P. M. Saturday went to work at 11 P. M. Sunday, while the shift finishing at 3 P. M. Saturday did not go to work until 3 P. M. Monday. A diagram showing the arrangement of the shifts is given in Fig. 24.

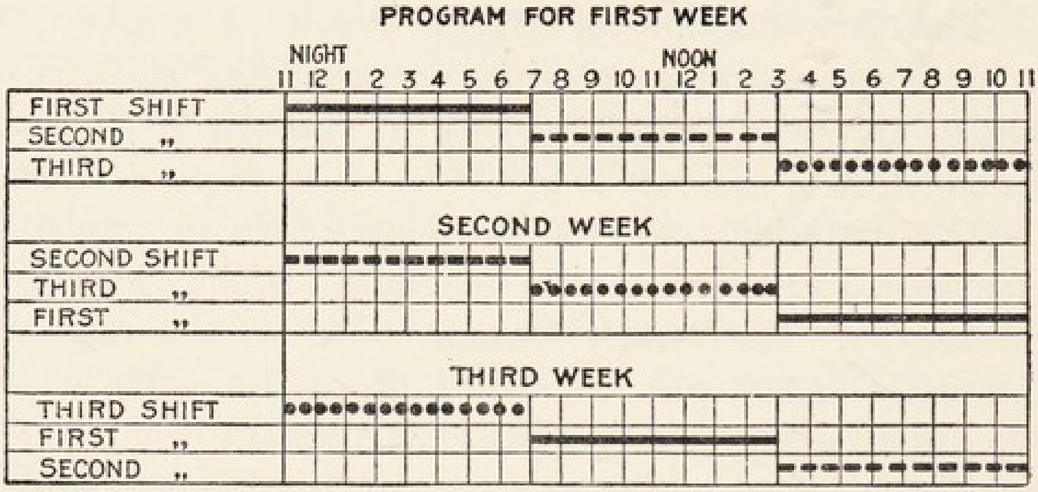


Fig. 24—Schedule for Changing Three Shifts from Night to Day Work

It was considered desirable to have the foreman change shifts at a different time than the workers so that the former would be on hand to insure smoothness and promptness when one worker was taking the place of another at the machine.

The Number of Working Days Per Week. It may be stated as a general rule that, in this country, six days constitute the week's work. In many industrial plants, the men work half a day on Saturday, or five and one half days per week and in one or two instances, notably at the Ford automobile works, a five-day week has been adopted tentatively with apparent success. Some few plants, however, are obliged to run continuously for a month or a similar period, because the furnaces, or other units, cannot be shut down until a certain amount of work has been done. In such plants the seven-day week, as well as the 24-hour day, is necessary.

The plants that do not have to run furnaces continuously from week to week have practically all adopted the shorter week. In doing this they have gained, just as those that have reduced the long working day have gained. The effects of cumulative fatigue on the part of the workers are not to be avoided except by allowing them the needed rest in which to recuperate.

Sunday Labor is absolutely necessary in some industries and at certain times in nearly all industries, particularly in the case of railroads, steamships, etc.; but for the vast majority of conditions Sunday labor is neither necessary nor economically desirable. The objections to Sunday labor as expressed in the November 1915 Report of the Health of Munition Workers Committee to the British Ministry of Munitions were principally the following:

Administrative. Supervision was difficult and imposed a severe strain on the foremen; yet deputies were not easy to obtain.

Economic. Sunday labor meant high wages often coupled with increased cost of running the Works. Though attendance on Sundays was generally good it was not, for various reasons, always accompanied by a satisfactory individual output. Moreover, Sunday labor was frequently accompanied by bad time keeping on other days of the week.

Religious and Social. There was a considerable feeling that the seventh day, as a period of rest, is good for body and mind.

The evidence before the Committee led them strongly to hold that if the maximum output was to be secured and maintained for any length of time, a weekly period of rest should be allowed. Except for quite short periods, continuous work, in their view, was a profound mistake and did not pay—output was not increased. On economic and social grounds alike this weekly period of rest was best provided on Sunday, and the Committee were strongly of opinion that Sunday work should be confined:

1. To sudden emergencies, including the occasional making up of arrears in particular Sections; and
2. To repairs, tending furnaces, &c., (the men so employed being given a corresponding period of rest during some other part of the week).

The Committee also suggested various methods for improving the conditions of Sunday work as follows:

1. Where two shifts (one for day and one for night) are worked, discontinuing the practice whereby the change from one shift to the other requires the men to work continuously for a period and a half.
2. Where three 8-hour shifts are worked by omitting one or two shifts on Sunday.
3. Where workers are employed only during the day with overtime, by reducing so far as possible the hours of work on Sunday.
4. By giving all workers alternate Sundays off, or at the very least a Sunday off at frequent intervals:

   (a) Allowing a certain number to get off each Sunday,

   (b) Closing completely, say, one Sunday in every two or three,

   (c) Closing alternately in particular Departments,

   (d) Giving another day off in place of Sunday, or, at any rate, letting workers on long hours off early on Saturdays or at other times,
5. By increasing the employment of relief gangs where this can be satisfactorily arranged for, obtaining either:

   (a) Relief workers among the ordinary staff; or

(b) Relief week-end shifts of volunteers.

Influence of Sunday Labor on Output. The following summary of a report by Dr. Vernon for the Health of Munition Workers Committee (Memo. No. 18, London, 1916, Appendix to Memo. No. 5) gives the results of an investigation to determine the influence of Sunday Labor on output. This report considers the following:

1. Women engaged in moderately heavy labor.
2. Women engaged in light labor.
3. Men engaged in heavy labor.
4. Youths engaged in light labor.

While the investigations described in this Report are, perhaps, too limited in the types of labor investigated to permit of final deduction being drawn from them, the writer was not aware of the existence of any exceptional conditions which would render such deductions inapplicable to other processes and industries. For convenience, he attached the following provisional summary of the results of his investigations:

(*a*) Observations extending over a period of 13½ months upon the output of workers employed in making fuses showed that a reduction of working hours was associated with an increase of production both relative and absolute. The rate of production changed gradually, and did not reach an equilibrium value before the expiration of four months. Thereafter it remained steady during the period of 3½-5 months during which it was observed. The *gradual* change negatives the suggestion that the effect was a mere consequence of the desire to earn the same weekly wage as before the hours were shortened.

(*b*) Owing to the reduction of the working time, first by a change from a 12-hour day to a 10-hour day, and subsequently by the abolition of Sunday labor, it was possible to compare output under three conditions. The group of women (numbering from 80 to 100) engaged in the moderately heavy labor of turning aluminum fuse bodies provided the following comparative results:

(i) When actually working 66.2 hours a week and nominally 74.8 hours, their relative hourly production was 100 and their relative gross production 100.

(ii) When actually working 54.8 hours and nominally working 58.5 to 66 hours, their hourly production was 134 and their gross production 111.

(iii) When actually working 45.6 hours and nominally working from 49.5 to 58.5 hours, their hourly production was 158 and their gross production 109.

It is therefore to be inferred that had these women been working uniformly a nominal 50-hour week their gross output would have been as large as when they were working a nominal 66-hour week, and considerably greater than when they were working a 77-hour week. In other words, a considerable addition to the leisure time of the operatives would have substantially improved the total output of the factory.

(*c*) A group of 40 women engaged in the light labor of milling a screw thread on the fuse bodies improved their gross output by 2% when actually working 54.8 hours a week, the standard being their gross output when working 64.9 hours per week. A further reduction of actual working hours to 48.1 resulted in such an improvement of hourly output that the gross output was only 1% less than when the actual working time was 16.8 hours more.

(*d*) A group of 56 men engaged in the heavy labor of sizing the fuse bodies improved their hourly output by 37% and their gross output by 21% when actually working 51.2 hours, the standards being the hourly and gross outputs observed when the actual weekly hours were 58.2.

(*e*) Fifteen youths engaged in the light labor of boring top caps by means of automatic machines produced only 3% less output when their actual weekly hours of work were 54.5 hours than when they were 72.5 hours.

(*f*) In none of the operations studied was there any change either in the nature of the operation or of the type of machinery during the period under notice. The data were also so chosen as to eliminate any possible disturbances due to increasing skill.

(*g*) A part of the improvement in output was due to the workers starting work more promptly when on shorter hours. At one period the women engaged in turning fuse bodies lost on the average 37 minutes daily by starting work after, and stopping before, the nominal time. Nine months later, when their hourly output was 25% better they lost only 26.5 minutes daily in these ways.

(*h*) A rest from work on Sunday is followed by a relatively low output on Monday, and this output steadily rises in the course of the week, owing to the increased efficiency produced by practice. Generally the cumulative effects of fatigue neutralise and overpower this increased efficiency, and the output may fall after the second day (or night) of the working week if the hours are long and the work laborious, or not till after the third, fourth, or even fifth day, if the hours are shorter. In the absence of a Sunday rest, the fatigued worker has no opportunity for complete recuperation, and his output, though more uniform, remains permanently at a lower level than that shown on Monday by a worker who has rested on Sunday.

(*i*) When the hourly outputs of individuals are plotted on a diagram, the distribution in the majority of operations is roughly symmetrical, persons who exceed the value reached by the largest group being about as numerous as those who fall short of it. In certain operations ("drawing" and "rectifying" cartridge cases) where the machine itself places an upper limit upon the possible speed of production, the shape of the diagram was different, the number that exceeded the output most frequently attained

—what may be termed the fashionable or "modal" value—being much smaller than that which fell short of it. A corresponding result was obtained for women sorting cartridge cases, when paid at time rates, but for similar operatives when paid at piece rates the symmetrical distribution was once more observed. It is accordingly contended that the form of distribution, whether approximately symmetrical or asymmetrical, may be a useful test as to the existence of limitation of output, and that in the majority of the operations here studied no such limitation occurred.

The Final Report, 1918, of the British Health of Munitions Workers Committee gave the following conclusions:

1. At the commencement of the war Sunday labor, especially for men, was widely adopted in the hope of increasing output. The evidence, however, proves conclusively that Sunday labor is unpopular, uneconomical and not productive of increased output.
2. In accordance with an early recommendation of the Committee Sunday labor is now almost entirely confined to sudden emergencies, repairs, attending furnaces, and certain continuous processes. Constant scrutiny is, however, necessary in order to secure that such exceptions as continue are confined within the narrowest limits. Where Sunday labor becomes necessary, arrangements should be made by a system of relief shifts so that no individual worker is employed more than six days in the week.

Overtime. The subject of overtime has been brought up in various ways in a number of places in this book. Continual overtime work is the same as long shifts. Calling it overtime is just another way of expressing it. The fatiguing effects of continuous overtime are the same as the fatiguing effects of long hours.

We have demonstrated that the human machine is capable of "spurts," and that it can be strained beyond its normal capacity for short periods with no ill effects, provided it be given sufficient rest amid favorable surroundings. Overtime work to be economic should be arranged to conform to these requirements. Overtime work that does not conform to these requirements should not be considered as overtime. If the plant has to run longer hours in order to produce more units, an extra shift should be arranged.

A clear distinction should be drawn between overtime when the hours of work are approximately equal to the hours of duty and the so-called overtime that the men want to work in order to draw overtime pay when, as in many railroad operations, the actual work is so light as to permit such longer hours without overstrain or other injury to the workers. The American public has been considerably imposed on in the past by failure clearly to appreciate this distinction.

Objections to Overtime are most admirably stated by the British Health of Munition Workers Report (Memorandum No. 5) "Hours of Work," London, 1917, as follows:

> Overtime is commonly justified on the ground that no other arrangement is possible owing to the dearth of workers and to the difficulties of increasing plant, and it is contended that, though the output per hour may not be maintained, the system does result in increased production. It should be noted that as the most highly skilled workers (tool and gauge makers, tool-setters, &c.) are the most difficult to obtain, they have been most generally employed on overtime, and have frequently had to work exceedingly long hours. At one time cases of men working as much as 90 hours per week were common; more recently there has been a tendency to reduce hours, but even so weekly totals of 70 to 80 hours are still frequent. Some overtime amongst this class is no doubt inevitable, but the Committee

are satisfied that hours such as these cannot be worked with impunity, and they most strongly urge that every effort should be made, either by "dilution" of labor or otherwise, to extend the shift system to this branch of the industry as rapidly as possible.

The objections to overtime may be briefly stated as follows:

(1) It is liable to impose too severe a strain on the workers. Many witnesses assert that while for an emergency overtime is effective, after a period the rate of production tends to decrease and the extra hours to produce little or no additional output. Moreover the quality of the output may be adversely affected during the whole period of work and not only during the hours of overtime.

(2) It frequently results in a large amount of lost time. In part this is to be attributed to the workers becoming exhausted and taking a rest, and also to sickness, noticeable chiefly amongst the older men and those of weak constitution.

(3) It imposes a very serious strain upon the management, the executive staff, and the foremen, both on account of the actual length of the hours worked and the increased worry and anxiety to maintain output and quality of work. These men cannot take days off duty like the ordinary workers.

(4) It is liable to curtail unduly the period of rest and sleep available for those who have to travel long distances to and from their work, a matter of special importance in the case of young persons.

(5) The fatigue entailed increases the temptation to men to indulge in the consumption of alcohol; they are too tired to eat, and seek a stimulant.

Conclusions. The output of productive labor increases with the number of hours employed, but, as the rate of output decreases at the same time because of fatigue, and as fatigue is cumulative, affecting not only the end of one day but also the beginning of the next, it follows that these two dependent variables are equally vital in determining quantity. It is also true that quantitative determinations, depending upon such variables, are not easily made. This chapter is the result of a general survey of the problem which has led to the following conclusions:

1. The human machine will put forth its greatest output if its time be divided between work and rest in definite proportions.

2. The optimum number of hours from a standpoint of output is different for different tasks, for different types of workers and also for different individuals. It varies between wide limits from less than five to more than ten hours per day.

3. Habit and usage largely determine the length of the working day and legislation attempts to protect workers from excessively long hours.

4. The eight-hour day is widely accepted as correct for many industrial plants and is legal in many States for many kinds of work. There is much sentiment in its favor, especially where it has recently superseded a longer day. It is, however, probably not the most efficient length of day for the majority of work.

5. Although the selection of working hours may be restricted by custom and law, it is nevertheless of great advantage to any industry to know what hours will give it the greatest output.

6. Instances of increased output on reduction of hours from ten or more, to eight or nine, per day are so numerous as to merit the earnest consideration of every plant that is still working long hours.

7. A determination of the most effective hours can only be had as the result of experiment. Experiments must be carefully conducted, without personal bias, and

must extend over a long period. Four or five months may be required to eliminate the fatigue due to long hours and to habituate the workers to more rapid work in shorter hours.

8. It is economical to postpone the adjustment of working hours until after fatigue-causing conditions surrounding the work, such as heat, dust, poor lighting, etc. have been remedied as far as possible.

9. The human machine does not work as well by night as by day, principally because it cannot rest as well by day as by night.

10. Where night work is necessary it should not be continuous, but the shifts should be changed about so that each will get its turn of day work and night rest.

11. In changing shifts from night to day work, the periods of each should not be less than two weeks, nor more than four weeks. It will take some men fully a week to adjust themselves to the change, and if their working hours are changed as often as that they will be constantly upset. On the other hand more than four weeks of night work may produce undue fatigue and deprive a man of recreational advantages through a great part of a season.

12. Sunday work should be avoided. Complete recovery from fatigue requires an occasional day off, as well as diurnal rest, so the total number of hours to be worked should be allotted to six days of the week or perhaps less. The sense of staleness that comes from working continuously through Sunday after Sunday is even more harmful than the fatigue produced.

13. Sunday labor is justifiable only for repair and emergency work, and for operations that must be continuous. The workers engaged should have some other day off.

14. Overtime, in general, is merely another name for long hours and will not be effective if added to a working

day of economic length. It may be effectively used in three ways.

(*a*) As a brief spurt to be made up for by extra hours of rest later.

(*b*) As a correction to an artificially shortened day. If the effective hours for an industry are 9 per day and state laws or labor unions hold it to eight then an hour of overtime will result in increased production.

(*c*) As a means of employing the reserve strength of certain individuals. It is not practical to adjust the length of the working day to the most capable workmen, because there would not be enough of them; but it must be adjusted to the best grade that will furnish an adequate number of workers, and, therefore, there will always be a few who can stand longer hours without undue fatigue. These, if they be known, may be employed on overtime work without harmful results.

CHAPTER VII

RELATIVE EFFICIENCIES OF MEN AND WOMEN

Until the Great War it was quite generally assumed that men could do everything in the nature of industrial work that women could, and do it better; but that for such light tasks as teaching school and pounding a typewriter women could function well enough for practical purposes, and that their employment was economical because of their lower rates of pay. This tacit assumption came about quite naturally from social causes, and seems to have been accepted without any definite attempt at real investigation until the War.

It was then very clearly shown that many classes of work which formerly had been considered closed to women could be handled by them better and more efficiently than by men. Under war conditions, and urged to maximum efforts by patriotism, women were successful in tasks that ordinarily are unsuited to them and at which their economic superiority over men is much more apparent in war times than in peace. When there is a great shortage of labor, and particularly when a great national exigency supplies an incentive far beyond that of money alone, experimental investigations may easily lead to conclusions perfectly sound in themselves but which should be applied with due caution under conditions of less emotional stress. This is not by way of deprecating the admirable investigations described below, but to urge the importance, in applying these figures to the peace time problems of industry, of certain characteristics wherein men and women differ radically, and whose effects are extremely difficult, if not quite impossible, to measure or express in cold figures. Women as compared to men are generally more emotional, gregarious, impressionable and sympathetic; they are less agressive, energetic, ingenious and dominant, to mention only a few of their mental and none of their physical differences. Therefore it stands to reason that persons of opposite sexes cannot be of equal efficiency in the various simple functions of industry, and that even more radical contrasts of efficiency must obtain in the process of coördinating the various functions that make up the operations of industry. Moreover it is to be expected that where the one sex shows a superiority over the other under war conditions, that superiority may be intensified, decreased or reversed under conditions of peace. The data of this chapter throw an interesting and valuable light upon this general problem, in viewing which the above facts should be kept in mind. For the solution of a radical and specific problem of procedure the data here given should be supplemented by thorough experimental investigation under as many as possible of the actual conditions of operation.

The opportunities for increasing industrial efficiency in specific cases by applying more intensive scientific methods to the allocation of tasks between men and women would seem to be very good, since much has already been accomplished, and the scientific part of the subject is only just beginning.

Comparison of Men and Women in Industry. The Cleveland Chamber of Commerce conducted an investigation which was reported in Iron Age, August 1, 1917. Production and employment managers in the metal industries in that city were asked to report on this question in respect to production, attendance, tardiness, and ease of transference. The report, which is based on the number of replies received, and not on the number of workers involved, is summarized in Table 25.

The marked superiority of women in production indicated that instead of substituting on men's work, they were in reality doing women's work that had been allotted to men by mistake in the past. The committee collecting the foregoing data recommended equal pay for equal work. They found, however, that women were seldom employed on exactly the same work as men, and that women were handicapped by the limitations of law and even more of custom. Overhead and maintenance charges and supervision were greater in the case of women than they were for men. Money and time spent in training women brought less return than that spent on men because marriage ended their productiveness and also because promotions were not possible when they involved supervision over men.

TABLE 25

RELATIVE EFFICIENCIES OF MEN AND WOMEN

Factor Considered	Percentage of Reports Stating That—			
	Women Excel	Equal Men	Doubtful	Men Excel
Production	64	24	12	0
Attendance	28	48	0	24
Promptness (Tardiness)	43	33	0	24
Ease of Transference	35	15	30	20

TABLE 26

ATTENDANCE OF WOMEN WORKERS COMPARED WITH ATTENDANCE OF MEN IN 115 ESTABLISHMENTS

(National Industrial Conference Board)

Total	Number	Per cent of Total	Number	Per cent of Total
Women's Attendance better than men's	44	38.3	10,481	27.2
Women's Attendance equal to men's	40	34.8	9,974	25.9
Women's Attendance worse than men's	31	26.9	18,045	46.9
Total	115	100.0	38,500	100.0

Attendance of Women Workers Compared with Attendance of Men. A more comprehensive survey of the metal trades was made by the National Industrial Conference Board, which reports the number of workers as well as the number of establishments involved (Report No. 8). Their findings are summarized in Table 26.

Analysis of the sources from which the women workers were recruited by these establishments did not disclose any reason for the variations in their attendance, nor did the differences appear to be explained by the type of work performed, since practically all operations on which women were engaged were represented among those establishments reporting poor attendance of women, as well as among those reporting it as good or better than that of men.

There was an apparent relation between the number of women employed and their attendance. In 27 of the 44 establishments where women's attendance was reported as better than men's, and in 20 of the 40 where it was equal, 100 women or less were employed, whereas of the 31 establishments reporting their attendance as worse, 26 employed a larger number. Although it cannot be determined from the data available, there is a probability that more individual adjustment and greater attention to health factors and to morale were possible where only a few women were employed.

While, therefore, the replies to the schedule of inquiry did not indicate a significant difference between the attendance of men and of women, when experience in other industries and other countries is considered, it appears that a higher average time lost because of absence must be counted among the unavoidable disadvantages connected with the employment of women.

Attendance of Married Women. Contrary to the rather generally expressed opinion, it appeared that the attendance of married women was fully equal to that of younger unmarried girls. Table No. 27 summarizes the information secured on this point.

Type of Work Satisfactorily Performed by Women. On all kinds of light work requiring manual dexterity, quickness of hand, eye or brain, which can be acquired after a comparatively short period of instruction, a woman generally learns more quickly than a man and eventually turns out more and better work. Women can effectively take the place of men at heavier work, provided that it be repetitive, as was amply proved in American and British munition factories during the war. They can perhaps less effectively do all kinds of manual labor provided that the working conditions are comfortable, and the work is within the scope of their strength and endurance. In emergencies women may be employed at a much wider range of tasks if the assistance they need can be efficiently provided.

TABLE 27

ATTENDANCE OF MARRIED WOMEN WORKERS AS COMPARED WITH SINGLE WOMEN IN 76 ESTABLISHMENTS

(National Industrial Conference Board)

	Number of establishments	Number of women	Number of married women	Percent of married women to total number of women
Women's attendance better than men's	33	4,965	575	11.6
Women's attendance equal to men's	23	3,488	723	20.7
Women's attendance worse than men's	20	7,213	924	12.8
Total	76	15,666	2,222	14.2

Thus women alone would not be suitable for driving trucks, as their lack of strength and mechanical skill would leave them helpless in case of accident, but they can operate a large part of a fleet of trucks if enough male chauffeurs be available to take care of possible emergencies.

Occupations Unsuited to Women. In general the woman worker is either excluded from, or is at a disadvantage in occupations requiring strength, endurance, control over others—particularly men—, willingness to work under disagreeable conditions, and long periods of apprenticeship. It is not practical to employ women on work requiring heavy lifting, and they have not been successful on such operations as chipping castings, and machine filing. On processes requiring special skill, as, for instance, lapping and brazing, they are not as capable as men. Whether technical training would make women the equal of men in work of higher character cannot be determined from available experience. At present their lack of training automatically excludes them from highly skilled mechanical work.

Women should not be employed on heavy work, or in processes exposing them to gases, fumes, unusually high temperatures, or to severe weather conditions. In general they do not like dirty work, and it is probable that, when they are obliged to do it, their dislike results in some inefficiency.

Methods for Improving the Output of Women Workers are referred to in the U. S. Monthly Labor Review in an account of war time conditions observed in French factories as follows:

> The necessity for intense production has led to the installation of automatic machinery and subdivision of labor, two conditions which are usually favorable to a good production on the part of women.
>
> At the lathes for 155-millimeter shells the women have been provided with pneumatic tackle, and for this reason get a "quarter less," while men have a higher wage because they handle the shells by hand. Yet the women succeeded in turning more shells in a day than the men. The women thus obliged to produce 125 pieces while the workmen produce only 100 force themselves continually. * * *

Extension of Women's Industrial Work as a Result of the War. The following list of occupations, from Iron Age, July 26, 1917, is an abridgment of findings by the National Gas Council. It is given in the form of replies to the general query: "Can women be employed in the undermentioned occupations and if so, to what extent?"

Coal Handling. Unloading ships and barges with grabs or skips worked by cranes.—Barges can be emptied by women, who can fill skips and wheel away. Handling grabs is not suitable work for women; but they can be employed as crane drivers.

Unloading of railroad cars.—Women are successfully employed in emptying railroad cars. Operating self-tippers and capstans might also possibly be done by women. Small shovels and suitable clothing are essential.

Weighing. Quite suitable, except where the position of the weighbridges makes it undesirable.

Pushing and tipping trucks.—Yes, in most cases.

Attendants on coal conveyors, elevators, and breakers.—Yes, in some cases.

Filling trucks by shovel.—Yes.

Coke Ovens. Handling of hot coke, quenching, and trimming.—No.

Attendants on coke conveying, elevating, and screening plants.—Yes, in some cases.

Coke Handling in Yard. Filling sacks from hoppers or with forks.—Yes.

Stacking sacks on vans.—Yes, if the sacks are not too heavy.

Filling trucks, carts or barrows.—Yes.

Weighing.—Yes.

Sack repairing.—Yes.

Coal picking and washing, and bagging.—Yes.

Wheeling from coke breakers.—Yes.

Coke-crushing machine.—Yes.

Screening and Packing Breeze. Yes, where the work is done by hand. Where it is done by machine, the man in charge is sometimes a "handy-man," capable of doing repairs, who could not be replaced by a woman.

Engine-room Attendants. Cleaning, and as assistants.—Yes. Not in charge.

Time Keeping. As assistants.—Not in charge, except in small works. Yes, as a rule; not where the "assistant" is responsible for the keeping of complicated wage records.

General Laboring. Such as sweeping-up, tarring and painting, cleaning firebricks and general cleaning.—Yes.

Cleaning windows by women is regarded as summer work only in some works.

Scraping, Tarring and Painting. Yes. Summer work only.

Lacquering and Polishing. Yes, with skilled male supervision.

Skilled Repair Staff. Bricklayers, carpenters, engine-fitters, etc.—No. As mates to above.—Yes, in many cases.

Workshops. Women can attend to drilling, planing, and shaping machines and lathes; also for simple work on vice. They have been successfully employed in munition factories, particularly where the work is of a repetitive character. Tool-setters and a skilled overlooker are, however, necessary. The suitability of the work for women would depend upon the kind of work being done; and this varies greatly between large and small works.

Works Testing. Routine tests.—Yes, under skilled supervision, and after a few months' preliminary training.

Storekeeping. Yes, to a large extent.

Driving Light Motor-Wagons, etc. Yes.

Other Work. Attending sulphate of ammonia plant.—Yes, as assistants and for bagging sulphate.

Concentrated ammonia plant. Yes, for watching gages and temperature to regulate steam.

Tar Distillery. Yes, for cleaning pitch bays and bagging methylene crystals.

That the employment of women in many of the foregoing occupations could be regarded only as an emergency measure, is indicated by the following abstract of a report by the New York Industrial Commission, published in the Monthly Labor Review for June, 1919:

> Next to administrative difficulties, heavy work was the most serious disqualifying cause, accounting for 440 discharges. These women seem to have been assigned without much consideration of their physical fitness for the occupations given them. The requirements of the work were often rather extreme.

In 10 of 51 plants, discontinuing some of their women replacing men, 440 women (6.5%) were unable to compete on equal terms with men because the work required was shoveling coal and coke, handling lumber, trucking bags of foodstuffs or other material from dock to storehouse or from storehouse to cars. * * * In one company where the work called for the trucking of freight from dock to storehouse and the tiering of sacks of coffee to the height of 9 feet, women were considered only 25% as efficient as the best men. * * * In yard work—shoveling of sand, coal, metal scrap into wheelbarrows, sorting of brick, cleaning of electrodes, stoking furnaces, and such work, one plant reckoned six women as equal to four men. In a plant where large truck loads of leather were handled women delivered 60% as much goods as men.

Employment of Women in the Metal Trades was discussed by the National Industrial Conference Board in its report No. 8, a summary of which is given in Iron Age, August 1, 1918.

The report summarized information obtained from one hundred and thirty-one establishments employing 335,015 men and 49,823 women, and treats of the comparative wages and output of men and women, the hours of work and numerous other matters of general interest.

The work done by women in the metal trades, at that time, embraced a great variety of processes from the operation of ordinary drill presses and lathes to coremaking, inspecting, and assembling mechanical parts, and many precise machine operations. In several, however, their work had been confined to the lighter processes in which rapidity and dexterity were more important than technical skill acquired by long training. The report emphasizes that work of a "repetitive" character is exceptionally well adapted to the utilization of female labor.

Comparative Output. The report shows that where men and women were employed on the same processes, 64 out of 97 establishments reporting found the output of women equal to, and frequently greater than that of men. In only 15 establishments was the output of women less than that of men on all operations on which both were employed. In the remaining 18 their production, although less in some operations, equaled or exceeded that of men in others. A highly favorable account of the efficiency of women had been received from an automobile plant where they were employed in 23 departments on assembling and inspecting materials and on many types of machine work. In this case the comparative output of women on identical processes was almost invariably greater than that of men and in some cases quite disproportionately so. This establishment reported an instance where a woman employed on a nut tapping machine produced at the end of her first week about double the output of the man working next to her. After endeavoring to equal her speed for a few days the man quit and was replaced by a woman who became very nearly equal to the first.

A gear manufacturing establishment where women did sandblasting, grinding, drilling, and broaching gave their output as from 15 to 25% higher than that of the men.

In a munition plant manufacturing fuses, women operatives on drill presses and milling machines were found to be from 25 to 50% more rapid than men. A manufacturer of small metal parts for munitions stated that women drill press operators finished 196 parts an hour on day work, while men on the night shift finished only 146 an hour.

Employers generally commended women as being more thorough and conscientious, as producing less spoiled work, and as being more careful with tools. Even where the quantity of work produced was less than that of men, the quality was frequently better. Women were also reported as more regular in production, and did not show the tendency to restrict output which is sometimes characteristic of men.

Output and Work of Women in Manufacture of Electrical Products. The report last quoted gave data from 18 establishments engaged in this line of work. A detailed tabulation of this information is also given in Electrical World, September 13, 1918.

The report shows that women's occupations included the following operations:

- Assembling
- Assembling, Coils
- Assembling, Meters
- Bench Lathe
- Bench Work, light
- Boxing
- Braiding
- Coils, form and pull
- Coil insulating
- Coil pressing
- Connecting
- Core building
- Drafting
- Drill press, light
- Elevator operator
- Grinding
- Hand Turret Lathe
- Inspecting
- Insulating
- Janitor
- Labeling
- Lamp repairing
- Machine taping
- Messenger
- Material Cutting
- Mica splitting
- Micarta and Composition work
- Milling machine
- Packing
- Painting
- Pasting mica
- Punch press
- Riveting
- Riveting machine
- Screw machine
- Sewing machine
- Shipping
- Soldering
- Sorting
- Spooling
- Stamping name plates
- Stock-room attendant
- Taping
- Testing
- Tool designing
- Tool-room attendant
- Weighing
- Winding
- Winding high tension coils
- Winding induction motor stator coils

Of the 18 establishments reporting, two found that women produced greater output in all operations. Six found men and women equal in all operations. Two found women greater in some and less in others and two found women equal in some and less in others. Two establishments found the output of women less than that of men in all operations. The four remaining did not report on output.

Five establishments reported rates of wages equal for men and women. Two reported piece rates equal for women and time rates less. Four reported both time and piece rates less for women.

The Employment of Women on Electric Railways in England and France is reviewed by F. W. Brooks in an address presented at the conference of the American Electric Railway Association, New York, October 9, 1917, and contained in the Electric Railway Journal of October 13, 1917, p. 659. The following paragraphs are especially noteworthy:

"The clearest expression of the British view is given by James Dalrymple, Glasgow, who writes us:

So far as conducting is concerned there is no difficulty whatever. Driving, however, is rather different and although the women manage it all right, I think that possibly the physical and mental strain would become rather too much for them. In fact, generally speaking, I do not think women are suited for this work. In driving a car they are quite cool, but when an accident occurs many of them collapse and are of no use for the remainder of the day. In conducting, however, they can manage the passengers just as well as the men could do. I think in normal times that there will be no difficulty at all in keeping women as conductors."

The Tramway & Railway World of London, however, is extremely conservative in its views on the success of women in the street railway business, stating that:

"When earlier in the war the necessity arose for employing women in the place of men as conductors we expressed the view that such a course could only be justified if it was absolutely unavoidable. It is probably not too much to say that there is not a tramway manager in the country who will not feel a sense of relief when, on the return of peace, it becomes practicable to release every woman conductor in his employ."

Objections to the Employment of Women as Street Car Conductors. The Monthly Review of the Bureau of Labor Statistics for May, 1918 calls attention to the irregularity of hours and the night work involved, and to the need for workers returning to their homes alone late at night. These considerations alone make the work unsuitable for women. The work itself involves considerable nervous strain resulting both from riding for hours at a time on a car that is constantly starting and stopping and from handling crowds at rush hours. On many cars the conductor is exposed to cold, damp, and draughts, even on the best type of inclosed-vestibule and center-door cars. On the closed-vestibule car there is added the strain of opening and closing the door at each stop. On the open summer car in such common use, the conductor is required to pass constantly along the running board, cling to a swaying car with one hand and collect fares with the other. Cars other than "pay as you enter" require often that the conductor force a way through the crowded car to collect fares. The danger of serious injury to a woman doing this work is by no means negligible.

From the facts brought out in this report it is evident that it is very difficult to make the conditions of street railway employment satisfactory for women.

Management and Supervision of Women is more difficult than that of men. Women expect closer personal contact with management and they require more tactful treatment in such contact. They seem unable to think of their work as apart from themselves for they look upon any criticism of it as personal, and are apt to be as resentful of deserved rebukes as of undeserved ones. They are less tolerant of small inconveniences and discomforts than men, and they may become more excited over minor matters of injustice.

In their final report for 1918 the British Health of Munition Workers Committee recommended the employment of forewomen, nurses, and welfare supervisors with definite lines of duty, so that each woman worker might have ready access to an officer of her own sex in case of difficulties with her work, her health, or the conditions under which she was employed. The following conclusions are from the committee's report:

Conclusions of the British H. of M. W. Report. In order to secure and hold the maximum output of which women are capable, the following essentials must be provided for:

(*a*) Short hours of work with suitable shifts, pauses, and intervals;

(*b*) Adequate medical supervision with rest rooms, etc., properly staffed;

(*c*) Careful selection of women for work within their capacity, the heavier work being allotted to the younger women;

(*d*) Good and sufficient food obtainable at convenient times; women appear to require food and refreshment more frequently than men, and always before commencing in the morning.

(*e*) Suitable factory environment: women are probably more susceptible then men to the benefits of effective ventilation, sanitary accommodation, etc.

(*f*) Sympathetic management and tactful supervision.

Working Standards for Women. As the basis for a program of reconstruction affecting women in industry the Woman in Industry Service of the Department of Labor issued standards based on experience in production during the war and recommended for the employment of women in times of peace. (U. S. Employment Service Bulletin No. 44, Vol. I, Dec. 17, 1918.)

The standards, as approved by Secretary of Labor Wilson, are as follows:

Hours of Labor. 1. Daily hours.—No women shall be employed or permitted to work more than eight hours in any one day or 48 hours in any one week. The time when the work of women employees shall begin and end and the time allowed for meals shall be posted in a conspicuous place in each work room and a record shall be kept of the overtime of each woman worker.

2. Half holiday on Saturday.—Observance of the half holiday should be the custom.

3. One day of rest in seven.—Every woman worker shall have one day of rest in every seven days.

4. Time for meals.—At least three-quarters of an hour shall be allowed for a meal.

5. Rest periods.—A rest period of ten minutes should be allowed in the middle of each working period without thereby increasing the length of the working days.

6. Night work.—No women shall be employed between the hours of 10 P. M. and 6 A. M.

Wages. 1. Equality with men's wages.—Women doing the same work as men shall receive the same wages with such proportionate increases as the men are receiving in the same industry. Slight changes made in the process or in the arrangement of work should not be regarded as justifying a lower wage for a woman than for a man unless statistics of production show that the output for the job in question is less when women are employed than when men are employed. If a difference in output is demonstrated, the difference in the wage rate should be based upon the difference in production for the job as a whole and not determined arbitrarily.

2. The basis of determination of wages.—Wages should be established on the basis of occupation and not on

the basis of sex. The minimum wage rate should cover the cost of living for dependents and not merely for the individual.

Working Conditions. 1. Comfort and sanitation.—State labor laws and industrial codes should be consulted with reference to provisions for comfort and sanitation. Washing facilities, with hot and cold water, soap, and individual towels, should be provided in sufficient number and in accessible locations to make washing before meals and at the close of the work day convenient. Toilets should be separate for men and women, clean and accessible. Their numbers should have a standard ratio to the number of workers employed. Workroom floors should be kept clean. Dressing rooms should be provided adjacent to washing facilities, making possible change of clothing outside the workrooms. Rest rooms should be provided. Lighting should be arranged that direct rays do not shine into the workers' eyes. Ventilation should be adequate and heat sufficient. Drinking water should be cool and accessible with individual drinking cups or bubble fountain provided. Provision should be made for the workers to secure a hot and nourishing meal eaten outside the workroom, and if no lunch rooms are accessible near the plant, a lunch room should be maintained in the establishment.

2. Posture at work.—Continuous standing and continuous sitting are both injurious. A seat should be provided for every woman employed and its use encouraged. It is possible and desirable to adjust the height of the chairs in relation to the height of machines or work tables, so that the worker may with equal convenience and efficiency stand or sit at her work. The seats should have backs. If the chair is high a foot rest should be provided.

3. Safety.—Risks from machinery, danger from fire and exposure to dust, fumes, or other occupational hazards should be scrupulously guarded against by observance of standards in State and Federal codes. First-aid equipment

should be provided. Fire drills and other forms of education of the workers in the observance of safety regulations should be instituted.

4. Selection of occupations for women.—In determining what occupations are suitable and safe for women, attention should be centered especially on the following conditions which would render the employment of women undesirable if changes are not made:

(*a*) Constant standing or other postures causing physical strain.

(*b*) Repeated lifting of weights of 25 pounds or over, or other abnormally fatiguing motions.

(*c*) Operation of mechanical devices requiring undue strength.

(*d*) Exposure to excessive heat—that is, over 80°, or excessive cold—that is, under 50°.

(*e*) Exposure to dust, fumes, or other occupational poisons without adequate safeguards against disease.

5. Prohibited occupations.—Women must not be employed in occupations involving the use of poisons which are proved to be more injurious to women than to men, such as certain processes in the lead industries.

6. Uniforms.—Uniforms with caps and comfortable shoes are desirable for health and safety in occupations for which machines are used or in which the processes are dusty.

Conclusions. There is a very considerable difference between men and women in industry, concerning both their abilities and requirements, and if they be employed together without regard for this difference confusion and inefficiency will result. If, on the other hand, it be given due consideration and the sexes employed accordingly, then each will help the other and there will be an increase in efficiency over that to be obtained if either be employed alone. Investigations of the extended work of women in industry enforced by the World War resulted in some important discoveries the chief of which are:

1. Women are superior to men on light repetitive work requiring manual dexterity and quickness of hand, eye, or brain. They learn to perform operations involving muscular coördination more rapidly than men.

2. Women are efficient on heavier repetitive operations provided they are supplied with mechanical means of lifting and handling their work.

3. Women can be effectively employed as helpers on a great variety of light work.

4. Women cannot be employed at work involving heavy lifting, or exposure to extremes of heat or cold. They should not be employed on work involving continuous standing or exposure to poisons.

5. Men are superior to women on all heavy work, on all work involving exposure to heat, cold, gases, and other poisons, and on all work requiring mechanical and technical skill and ability to plan.

6. Women workers require more comforts, better care, and closer and more tactful management than men.

CHAPTER VIII

OCCUPATIONAL AGE LIMITS

The age of the human machine is an important factor in determining its capacity for work. Presumably there is an optimum beyond which the worker's capacity decreases as he grows older. There is no doubt in cases where heavy physical labor is required, that a young man in the vigor of early maturity can be used to best advantage. Some kinds of hard work, however, require a certain cunning to be exercised wherein an older man who is physically fit is preferable to a stronger though less experienced young man. On less arduous work requiring technical skill and judgment the older man has a decided advantage.

There is little direct information on age limits in industry and practically none on the length of time a man may be expected to continue at work. For an extreme limit to this period we can turn to the tables of expectation of life compiled for the use of the Insurance Companies. Thus if a man is 30 years old he may be expected to live 35.65 years longer, and that is, of course, the ultimate limit of working years that may be counted upon for him. Actually the average working years remaining to any group of men 30 years old would be less than the average years of life remaining to their expectation of life and it seems probable that they would be very considerably less. Statistics are not available for the computation of tables of expectation of working years similar to the tables of expectation of life referred to. Certain deductions may be made from published reports giving the number of workers in each age group in an industry, but these are of limited application and are not usually based on large enough numbers to be even reasonably accurate.

An investigation of the economic status of the average man made by Joseph J. Devney, of Cleveland, Ohio, has some bearing on this subject. He found that there are dependent men at all ages, the least dependency being 5%, at the age of 35. At 45 it is 9% and it practically doubles each decade thereafter, being 18% at 55, 38% at 65, and 60% at 75. Turning again to the tables of Expectation of Life, we find that of 1000 men born, 659 are still living at 45; of these 9% or 59 will be dependent and 600 will be self-supporting; 567 are still alive at 55, of whom 18%, or 102 will be dependent. If the dependents die off at the same rate as the average, 39 of those dependent at 45 will still be living at 55, and 102 minus 39, or 63 more, will have become dependent. Thus more than 10% of the self supporting individuals at 45 become dependent within the next ten years. Dr. Devney's investigation covered only individuals known to banks and trust companies, and it is possible that different results might be obtained among industrial workers.

The Influence of Age at the Time of Employment Upon the Efficiency of Municipal Day Labor. A report by Messrs. Metcalf and Eddy, Consulting Engineers, abstracted by Engineering and Contracting, Sept. 1, 1909, contains the following:

The ages of the labor force of the Sewer Department of Boston at the time of the investigation are given in Table 28. Out of 715 men employed, there were nearly 100 over 60 years, 275 over 50 years and 535 over 40 years of age. Thus about three-quarters of the laborers were over 40 years old.

Trenching and pipe laying for sewers requires physically capable men, and a contractor who is free to use his own judgment selects young and vigorous men for such duty. When this type of work is done under municipal management, various things hinder a choice of laborers and there is always a considerable number of men in the

TABLE 28

I.—LABOR EMPLOYED BY SEWER DEPT., BOSTON, CLASSIFIED ACCORDING TO AGE

Present age	Number of men	Per cent of force	Number and per cent of men above ages designated			Term of service (years)		
			Age	Number	Per cent	Average	Maximum	Minimum
Below 20	1	0.1	......	....	....	2	2	2
20-24	5	0.7	20	714	99.9	3.2	9	0
25-29	19	2.7	25	709	99.2	3.8	12	0
30-34	53	7.4	30	690	96.5	6.1	15	0
35-39	101	14.1	35	637	89.1	7.5	18	0
40-44	127	17.7	40	536	75.0	9.9	22	0
45-49	136	19.1	45	409	57.3	13.0	28	0
50-54	95	13.3	50	273	38.2	12.7	32	0
55-59	81	11.3	55	178	24.9	15.3	33	2
60-64	65	9.1	60	97	13.6	14.8	35	1
65-69	21	2.9	65	32	4.5	13.6	21	1
70-74	9	1.3	70	11	1.6	17.3	23	11
75-79	2	0.3	75	2	0.3	32.0	40	24

II.—CLASSIFICATION OF LABOR BY TERM OF SERVIC AND AGE

Present Age	Years of Service									Total
	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 to 44	
19 years	1	......	......	......	......	......	......	......	......	1
20 to 24 years	3	2	......	......	......	......	......	......	......	5
25 to 29 years	10	8	1	......	......	......	......	......	......	19
30 to 34 years	19	25	8	1	......	......	......	......	......	53
35 to 39 years	28	28	38	7	......	......	......	......	......	101
40 to 44 years	26	26	41	30	4	......	......	......	......	127
45 to 49 years	8	20	52	43	9	4	......	......	......	136
50 to 54 years	7	21	26	31	7	2	1	......	......	95
55 to 59 years	2	11	18	34	11	2	3	......	......	81
60 to 64 years	4	6	20	28	3	......	2	2	......	65
65 to 69 years	2	2	6	5	6	......	......	......	......	21
70 to 74 years	......	......	2	4	3	......	......	......	......	9
75 to 79 years	......	......	......	......	1	......	......	......	1	2
Total	110	149	212	183	44	8	6	2	1	715

trenching and pipe laying gangs who are too old for arduous labor. They reduce efficiency not only through their own inability, but also by setting a pace for the more capable men. Other work of a Sewer Department requires the service of various mechanics and is not so strenuous as the trenching. There are also positions which may be satisfactorily filled by laborers who are no longer physically able to perform hard manual labor.

These easier positions may well be filled by men who have grown old in the department, and this can easily be done if only young men are hired. The problem before the investigators in this case was to set a practical age limit above which no men should be employed.

The number of men who had served the city for each of a number of designated terms appears in Table 28, which also shows the present, average, maximum and minimum ages of the men in the respective groups. There did not appear to be an increase in age corresponding to the increase in term of service. Thus the men who had served 25 to 30 years averaged only 51.4 years of age while those whose terms of service were between 10 and 15 years averaged 47.3 years old; 222 of the 715 laborers on the force had been appointed when over 40 years old.

As a result of their investigation, Messrs. Metcalf and Eddy recommended that the age limit for hiring laborers be made 40 years.

Age Distribution Among Various Nationalities. There is a great difference as regards age distrbution between the various races and nationalities. This is clearly shown in Table 29, compiled from the reports of the Immigration Commission, which shows, by race and nativity, the percentage of employees in each age group.

Age Distribution in the Steel Industry. The labor force of the steel industry is made up largely of men in the prime of life—between 20 and 44 years of age. Very

TABLE 29
PER CENT OF MALE EMPLOYES WITHIN EACH AGE GROUP, BY GENERAL NATIVITY AND RACE

General nativity and race	Number reporting complete data	Per cent within each specified age group						
		14 to 19 years	20 to 24 years	25 to 29 years	30 to 34 years	35 to 44 years	45 to 54 years	55 years and over
Native born of native father:								
White	20,801	11.6	20.4	19.1	15.1	19.4	9.7	4.7
Negro	4,066	6.2	22.7	22.1	14.5	19.7	11.6	3.1
Native born of foreign father, by country of birth of father:								
England	1,610	17.0	22.9	18.1	12.4	17.8	8.2	3.7
Germany	4,265	15.9	20.0	16.9	13.6	19.1	11.3	3.0
Ireland	3,032	12.6	18.3	15.1	14.9	23.3	12.2	3.6
Foreign born, by race:								
Croatian	4,003	5.4	34.4	25.4	15.0	16.5	3.0	.3
English	2,340	2.9	8.7	12.5	15.5	30.1	19.1	11.2
German	4,426	2.2	9.4	14.2	13.1	26.6	20.9	13.6
Irish	2,448	.7	5.3	12.2	12.5	32.9	22.3	14.1
Italian, North	1,157	6.6	28.7	23.2	18.8	17.0	4.6	1.2
Italian, South	1,793	6.8	26.8	23.1	16.2	19.0	6.7	1.3
Magyar	4,675	4.4	20.9	24.6	20.2	23.5	5.5	.9
Polish	7,897	2.3	23.4	28.0	17.8	20.7	6.7	1.2
Russian	1,372	3.9	27.1	28.6	20.0	17.7	2.5	.2
Servian	1,046	4.0	36.4	27.6	14.3	14.8	2.7	.1
Slovak	9,029	5.0	23.2	23.7	18.4	23.0	6.1	.6
Slovenian	1,359	4.4	25.0	25.9	19.4	20.2	4.5	.6
Swedish	1,072	.8	12.4	16.3	16.2	31.7	17.3	5.2
Welsh	1,237	4.7	8.2	9.3	14.6	32.8	19.7	10.7
Grand total	86 089	7.7	21.1	20.9	15 8	21.2	9 5	3.8
Total native born of foreign father	11,542	17.6	21.1	16.5	13.0	18.9	9.8	3.0
Total native born	36,409	12.9	20.9	18.6	14.4	19.3	10.0	4.0
Total foreign born	49,680	3.9	21.2	22.6	16.9	22.6	9.2	3.7

little work can be done by child labor and comparatively little, at least in the production departments, can be done by men past the age for strenuous physical labor. Positions such as that of watchman and policeman, as well as various semi-clerical positions are frequently reserved for employees who have grown too old for more arduous work. The number of these positions, however, is small, so that they do not greatly affect the labor force as a whole. This is also true of the few exceptional individuals who retain their vigor long past the average. There are not enough of them to materially affect the records.

For these reasons, and because there is a comparatively rigid selection of only the younger and more vigorous men at the time of their employment, the ages of the workers at a large steel plant should reflect the depletion made in the ranks of labor by advancing age.

Table 30 gives the age distribution of the employees in a large steel plant. It is reasonable to assume that these figures represent average and fairly continuous conditions of the working force, and if they hold true year after year, they may be taken, not only as a record of existing ages, but as an indication of the number of years of work remaining to each age group.

From such a table a very rough approximation of expectation of employment may be made. The following method of figuring is not strictly correct, but it is simple, and will give results within the degree of accuracy warranted by the limited data on hand and by the assumptions necessary to make up for its deficiencies.

Consider the number of employees reaching its maximum with the age group 25 years old and under 30, when it is 1263; assume that no new men over 30 are employed, so that the decreasing numbers in the older age groups represent the total falling off in employment. There are then 1263 men 25 and under 30, of whom 1263-1008, or 255, will drop out in the next five years and may be counted

TABLE 30

AGE DISTRIBUTION OF EMPLOYEES IN A LARGE STEEL PLANT, BY DEPARTMENTS

NUMBER OF EMPLOYEES

Departments	Total	Employees in each age group: Under 16	16 and under 18	18 and under 20	20 and under 25	25 and under 30	30 and under 35	35 and under 40	40 and under 45	45 and under 50	50 and under 60	60 and over
Production force:												
Blast furnaces	699	......	1	29	163	156	120	113	56	33	25	3
Open-hearth furnaces	[1]1,161	......	53	69	208	227	197	179	114	71	40	2
Blooming and slabbing mills	477	......	17	18	82	80	58	67	58	42	43	12
Structural mills	283	......	6	14	35	53	46	46	38	22	19	4
Plate mills	[2]668	1	10	29	107	139	131	100	76	39	28	6
Merchant mills	53	......	......	......	6	12	11	10	6	3	3	2
Total	[3]3,341	1	87	159	601	667	563	515	348	210	158	29
Mechanical force:												
Steam	[1]275	......	......	4	32	50	43	54	17	31	30	13
Electric light and power	203	1	4	6	47	61	37	22	12	3	7	3
Transportation	[1]396	......	......	10	100	91	58	72	28	16	16	4
Shops	[1]1,085	1	16	49	222	207	168	144	104	70	83	20
Foundry	83	......	2	3	14	11	15	14	5	8	7	4
Shipping and mill yards	376	......	17	25	69	81	41	63	37	29	10	4
General yard labor	[1]613	2	19	36	102	95	83	86	58	57	49	25
Total	[4]3,031	4	58	133	586	596	445	455	261	214	202	73
Grand total	[5]6,372	5	145	292	1,187	1,263	1,008	970	609	424	360	102
PER CENT OF EMPLOYEES IN EACH AGE GROUP												
Production force	[3]100.0	(6)	2.6	4.8	18.0	20.0	16.9	15.4	10.4	6.3	4.7	0.9
Mechanical force	[4]100.0	0.1	1.9	4.4	19.4	19.7	14.7	15.0	8.6	7.1	6.7	2.4
Total	[5]100.0	.1	2.3	4.6	18.7	19.8	15.8	15.2	9.6	6.7	5.7	1.6

[1] Including 1, age not reported

[2] Including 2, ages not reported

[3] Including 3, ages not reported

[4] Including 4, ages not reported

[5] Including 7, ages not reported

[6] Less than one-tenth of 1 per cent

AGE DISTRIBUTION OF OFFICIALS AND CLERICAL FORCE IN A LARGE STEEL PLANT

Occupations	Total	Employees in each age group									
		under 16	16 and under 18	18 and under 20	20 and under 25	25 and under 30	30 and under 35	35 and under 40	40 and under 45	45 and under 50	50 and under 60	60 and over
Superintendent, assistant superintendent, etc.	46	......	......	......	......	......	5	17	13	7	3	1
Foremen	232	......	......	......	11	24	38	58	40	32	22	7
Recorders, weightmasters, etc.	[1]116	......	3	12	36	25	17	6	6	1	8	1
Clerks, stenographers, etc.	[1]353	1	8	38	82	66	47	40	26	14	23	7
Messengers	76	32	38	4	......	1	......	1	......	......	......	......
Chemist's helpers	115	......	7	17	34	23	17	6	5	3	2	1
Police	62	......	......	......	1	3	9	10	9	12	13	5
Janitors, storemen, etc.	34	......	......	......	4	1	4	6	8	3	5	3
Total	[2]1,034	33	56	71	168	143	137	144	107	72	76	25

[1] Including 1, age not reported

[2] Including 2, ages not reported

on to work from 0 to 5 years, an average of two and one-half years longer. The computation may be tabulated as follows:

No. of Men of 25 and under 30 years	No. of Years of Work Remaining	Average Years of Work Remaining	Total Man Years of Work Remaining, Average
255	0 to 5	2.5	637.5
38	5 to 10	7.5	285
361	10 to 15	12.5	4,512.5
185	15 to 20	17.5	3,237.5
64	20 to 25	22.5	1,440
258	25 to 35	30	7,740
102	35 or more	35 (assume)	3,570
1,263 Total No. of Men	×	17 (nearly) =	21,422.5

For the 1008 men in the next age group, who are 30 and under 35 years of age the computation would be as follows:

No. of Men of 30 and under 35 years	No. of Years of Work Remaining	Average Years of Work Remaining	Total Man Years of Work Remaining, Average
38	0 to 5	2.5	95
361	5 to 10	7.5	2,707.5
185	10 to 15	12.5	2,312.5
64	15 to 20	17.5	1,120
258	20 to 30	25	6,450
102	30 or more	30 (assume)	3,060
1,008 Total No. of Men	×	15.62 =	15,745

17 and 15.62 years would represent the average expectation of employment for these respective sets of figures.

In like manner results have been calculated for the remaining age groups and are compared with expectation of life in Table 31. These results do not indicate expectation of working years, for many men will find other employment when the work in the steel plant gets too heavy for them. What they do indicate is the length of service that the plant may expect from its employees.

The figures on expectation of life are from tables for white males in the United States, based on the 1911 census. They would be lower if negroes were included.

These figures have been given merely to illustrate a method of approaching the subject. They are too high, for they are based on the assumption that no new men beyond 30 are hired into the age groups, when in reality the mechanical force shows more men between 35 and 40 than between 30 and 35. No data are available, however, for taking labor turnover into account. Proceeding along similar lines, any well organized industry with a steadily employed force, by taking an age census of its workers, can find out how much further service is to be expected of them. This should have an important bearing on hiring men of different ages.

TABLE 31

EXPECTATION OF SERVICE FROM EMPLOYEES OF A STEEL PLANT COMPARED TO THEIR EXPECTATION OF LIFE

(Based on table of Age Distribution of Employees in a Steel Plant; Document No. 110, U. S. Department of Industry.)

Age Group	Expectation of Service Years	Expectation of Life, Years Maximum	Minimum
25 and under 30	17	38.79	35.65
30 and under 35	15.6	34.87	31.82
35 and under 40	11.1	31.08	28.16
40 and under 45	11.2	27.43	24.56
45 and under 50	10.1	23.86	21.08
50 and under 60	6.4	20.39	14.57

Turning again to the table of distribution of men in age groups, it is noticeable that a larger proportion of older men are in the mechanical than in the production force.

For example, 16.2% of the mechanical force are 45 years of age or more, while only 11.9% of the production force are as old as 45 years. There is, furthermore, three times as large a proportion of men 60 years and over in the mechanical force as in the production force. In making these comparisons it should be noted that the police, janitors, and other occupations in which there is an unusually large proportion of older men have been purposely transferred from the mechanical force to appear with the officials and the clerical force.

Occupational Age Limits for Women. On this subject there is even less information than on that of men. Their ranks are thinned, not only by age, but by voluntary retirement and by marriage, and the matter is further complicated by the fact that many older married women return to industry. Moreover, women do not like to tell their ages, so that a census of any but the younger workers will give questionable results.

Marriage is by far the most important factor leading to the retirement of women workers and in some industries may be the only one worth considering. In such cases age figures, free from other complications, may be compiled and will be of value, for while the age of marriage is in no sense an occupational age limit, it marks the limit of the worker's direct service to industry.

The Age of Female Workers by Industries. Table 32, which is from Document No. 175, United States Department of Labor, shows the number and proportion of women employed in each of several age groups for a number of industries.

A striking feature of this table is the low age level prevailing almost without exception throughout these industries. Only five of them show as many as one-third of their workers in the group aged 25 years and over, and only one shows as many as two-fifths in this group. In the case of the oyster canning industry, by far the greater pro-

TABLE 32

PER CENT OF TOTAL FEMALE EMPLOYEES IN SPECIFIED AGE GROUPS, BY INDUSTRY

Industry	Total number of employees	Total number of female employees	Per cent of female employees	Per cent of female employees reporting age— Under 16	16 and 17	18 and 19	20 to 24	25 and over
Canning and preserving, fruits and vegetables	1,063	684	64.3	6.6	27.0	17.6	24.8	24.0
Canning and preserving, oysters	485	229	47.2	13.7	8.7	14.1	14.1	49.4
Cans and boxes, tin	1,671	425	25.4	9.5	18.4	23.7	33.2	15.1
Cigar boxes	982	519	52.9	9.4	21.5	14.4	30.7	24.0
Cigarettes	1,985	1,436	72.3	5.0	19.6	21.8	27.6	26.0
Cigars	15,782	10,591	67.1	9.6	21.7	22.5	25.9	20.2
Clocks and watches	3,239	1,010	31.2	2.2	13.7	19.6	33.3	31.1
Confectionery	5,969	3,640	61.0	15.8	28.5	19.4	21.2	15.1
Core making	4,498	387	8.6	....	17.2	35.7	37.0	10.1
Corsets	4,857	4,084	84.1	8.3	16.3	16.2	23.6	35.7
Crackers and biscuits	3,898	2,170	55.7	11.2	26.8	23.2	24.6	14.2
Hardware, etc.	4,376	1,192	27.3	6.3	18.5	25.7	27.5	22.0
Hosiery and knit goods	16,951	12,475	73.6	10.5	19.0	18.1	28.1	24.3
Jewelry	637	242	38.0	9.8	19.7	16.4	29.0	25.1
Needles and pins	1,459	637	43.7	10.1	21.2	18.3	30.0	20.5
Nuts, bolts and screws	2,616	664	25.4	12.4	19.5	27.0	26.9	14.2
Paper boxes	5,387	4,156	77.1	14.8	25.7	17.9	21.9	19.7
Pottery	2,377	644	27.1	6.2	15.2	16.4	23.4	38.8
Rubber and elastic goods	869	283	32.5	3.6	12.6	14.4	29.9	39.5
Shirts, overalls and underwear	4,191	3,551	84.8	10.2	18.7	17.5	29.6	24.1
Stamped and enameled ware	6,331	1,539	24.3	5.8	25.5	26.8	28.5	13.4
Tobacco and snuff	9,975	5,056	50.7	5.6	12.2	20.4	26.1	35.7
Woolen and worsted goods	12,724	5,914	46.5	8.9	18.5	22.2	22.1	28.3
Total	112,322	61,528	54.9	9.1	20.6	20.2	25.8	24.3

portion of the workers are in the very youngest and oldest groups. This may be due to the fact that the work is so simple that both the young and the old can do it, and that it is so unpleasant that those whose age and circumstances will permit them to do other work, are not likely to undertake it. Any one who has practiced the art of opening oysters, however, might conclude that only the younger women have the temerity to attempt it and only the oldest survive the instruction period.

Duration of Industrial Life of Women. The age distribution of these women has some bearing upon the question of how long women are apt to remain in the industrial field and at what age the majority leave. In this study, women as young as 8 years and as old as 70 were found, but only 3.9% (2,160) of the group were under 15, so it is evident that only a relatively small number enter industrial pursuits before they are 15 years old.

TABLE 33

NUMBER AND PER CENT OF FEMALE WORKERS OF EACH SPECIFIED AGE

(Based on records of 55,328 female employees whose exact age was learned)

Age Group	Number	Per Cent
Under 15	2,160	3.9
15 years	3,158	5.7
16 years	5,370	9.7
17 years	5,741	10.4
18 years	6,224	11.3
19 years	4,933	8.9
20 years	4,409	8.0
21 years	3,176	5.7
22 years	2,701	4.9
23 years	2,164	3.9
24 years	1,828	3.3
25 to 29 years	5,553	10.0
30 years and over	7,911	14.3
Total	55,328	100.0

The real rush into industrial employment, however, seems to begin at 16, at which age nearly one-tenth of the whole group was found. For two years more the number entering exceeds that of going out, the number in any one year age group reaching its maximum at 18, where 6,224 were found. At 19 the number has fallen off by more than 1,200, and thenceforth the decrease is rapid. Table 33 shows the number and proportion of the female workers at specified ages.

So far as this group of workers can be taken as typical, it appears that about 1 in 10 begins her industrial life before she is 16, less than 1 in 4 continues it after she is 25, and only 1 in 7 keeps on after 30. For the great majority the period of industrial life falls between 15 and 25 years of age.

The above figures cannot be taken as applying to all women in industry. This group was made up for the most part of unskilled workers in occupations which gave them little chance of advancement and which were not in themselves sufficiently attractive and interesting to hold women longer than financial stress rendered their employment necessary. Moreover, even for these industries the investigation was not exhaustive, and since the purpose was to study the employment of women and children it is quite possible that the industries selected show a lower age level than that prevailing in the industrial world as a whole. Even in this group, while the great majority are young, it must not be forgotten that one-seventh of the whole number have reached or passed 30 years of age.

Proportion of Older Women in Industries Studied. The proportion of women aged 30 or over in the various industries differs widely. Four industries—hardware and metal specialties, jewelry, needles and pins, and rubber goods—were studied in only one State, so that the local circumstances may have determined the age grouping. Omitting these four, the number and proportion of women aged 30 years or more in each industry were as given in Table 34.

Clearly the proportion of older workers in an industry is not necessarily an indication of the skilled character of its work. Apparently women who have acquired a skilled occupation may remain in the industry in which they can practice it until after 30, or women over 30, who find wage earning a necessity, may enter an industry in which they find work so unskilled and simple that their lack of industrial training and even their lack of the speed of the more youthful workers will not debar them. The five industries showing the largest proportion of these older

TABLE 34

NUMBER AND PER CENT OF FEMALE WORKERS 30 YEARS OF AGE AND OVER IN EACH SPECIFIED INDUSTRY

Industry	Number	Per cent
Canning and preserving, fruits and vegetables	99	14.54
Canning and preserving, oysters	101	41.91
Cans and boxes, tin	36	10.06
Cigar boxes	67	13.45
Cigarettes	213	14.95
Cigars	1,033	11.64
Clocks and watches	135	15.84
Confectionery	282	7.97
Core making	10	2.64
Corsets	959	24.60
Crackers and biscuits	144	6.89
Hosiery and knit goods	1,367	13.14
Nuts, bolts and screws	45	6.86
Paper boxes	383	10.21
Pottery	165	25.70
Shirts, overalls, and underwear	412	12.28
Stamped and enameled ware	95	6.40
Tobacco (smoking and chewing) and snuff	1,076	23.53
Woolen and worsted goods	983	17.99

workers illustrate this difference. Oyster canning, pottery making, and the manufacture of smoking and chewing tobacco and snuff all showed women of 30 years and over engaged in unskilled labor of a particularly rough, dirty, and unattractive kind. These three industries also showed an unusually large proportion of married women among the workers.

In the manufacture of clocks and watches, women perform operations requiring judgment and accuracy, and it is difficult not to suspect a connection between this fact and the relatively high proportion of women 30 years of age and over in the industry. Apparently many older women may be found in an industry because its occupations require skill and training, or because they require neither; only a study of the individual industry will show which reason is operative in its particular case.

Relation of Age of Workers to Fatigue. An examination made by Miss Janet Campbell, of 210 women and girls in one factory in England, where the hours were rather long, gave results, described in an Appendix to a report made in 1916 by the Health of Munition Workers Committee, as follows:

A table, No. 35, follows showing the relation of the age of the workers to the amount of fatigue experienced. It will be seen that 44% of the workers aged 14 were suffering from slight or marked fatigue when medically examined, although the majority had been employed under four months and some of them for a much shorter period. Among the workers aged 16 to 20 about 55% found the long hours tiring. The heaviest proportion of those suffering marked fatigue occurred in the age group 30 to 40, but here it should be remembered that these numbers include a proportion of married women in whose case conditions of home work aggravated the strain of factory life.

A decline in signs of fatigue is noticed in the age group 40 and upwards, among whom were several elderly women of a wiry type.

A second medical inspection of 116 of these workers six months later revealed that on the whole the young workers (aged 14 or 15) showed improvement in health since the previous examination. Of 39 girls, 20 were quite healthy, 7 showed slight signs of fatigue, and 12 were no longer at the factory. Those who had left had usually been removed by their parents on account of long hours or dislike of night work. The ventilation of the main shop had been improved and defects due to faulty temperature were no longer marked; on the other hand the July inquiry showed a rise of 10% in the number of cases suffering from marked fatigue (possibly in part due to unsuitable arrangements for feeding.)

TABLE 35

RELATION OF AGE OF WOMEN WORKERS TO FATIGUE

Age	Number of workers examined	Fatigue		
		No obvious signs %	Slight %	Marked %
14	25	56	28	16
15	15	73	20	7
16-20	65	45	43	12
20-30	63	49	40	11
30-40	30	40	30	30
40 and over	12	58	25	16
Total	210			

Conclusions. The capacity of the human machine for work decreases after a certain age until for all practical purposes it vanishes altogether. Its value therefore depends on its state of decline and upon its remaining years of usefulness. These matters have an important bearing in gauging the performance of a group of workers, and they are of especial importance in problems of hiring and training people for work. It always costs money to hire a man and it frequently costs a great deal more to train him. The recovery of amounts so expended must be spread over his period of usefulness. Also, where retirement funds or old age pensions are provided it is essential to know if the workers hired can serve long enough to merit them. While there is no precise information on the subject the following facts are evident:

1. The occupational age limit of a worker depends first of all on his individual physical endowments.

2. The age limit depends further on the nature of a man's work and his fitness for it.

3. Records indicate that the Irish, German, English, and Welsh in the order named outlast other nationalities to a marked degree.

4. Decrease in productive capacity with advancing age is manifested in two ways. On efficient, well organized work, done under considerable pressure the worker stands the pace as long as he can and then drops out to find lighter work elsewhere. Examples of such procedure may be found in the iron and steel industries. However, on municipal and other work where the worker is protected in his position he remains as long as he can, gradually slowing up production to keep pace with his declining ability.

5. It is possible to figure tables of expectation of service from an age census of a single large plant. As each industry and district has age conditions peculiar to itself these may be as valuable as the results of a much wider survey.

6. The service of women in industry is limited more often by marriage than by age. Where this is the only factor involved the expectation of service from any group of workers may be figured. Due to the fact that older married women return to work in many industries to an extent that will vary with the general prosperity, it will be difficult to get reliable figures on age limits.

7. The average length of service of women in industry is very much less than that of men.

CHAPTER IX

INDUSTRIAL DISEASES

The term industrial disease is loosely applied to two widely different types of ailments. The first includes diseases which are not truly industrial, as they afflict all humanity, and which are far more prevalent in some industries than in others. Unusual susceptibility of industrial workers to any of these diseases is due to conditions of work within the industry. The second type of ailment includes conditions that are not truly diseases but result from poisoning from materials handled or fumes inhaled in industrial processes.

The fact that a man's employment in some line of work predisposes him to sickness or poisoning is of such vital human interest that a voluminous literature surrounds it. The importance and numerous ramifications of the subject justify more extensive treatment than will be possible in this volume; and therefore, instead of attempting to present a synopsis of present day knowledge, this chapter will be devoted to an outline of the problem of occupational disease, as it affects the human machine.

In order to connect disease with an industry, it is necessary to show that it is more prevalent among, or more fatal to the workers of that industry than it is to the average of all industrial workers, and also to show that no other cause than the conditions existing in the industry can be ascribed to its added prevalence. Thus the death rate from pulmonary tuberculosis is very high among stenographers, both men and women. It would seem, however, that this is due to selection and not to any condition inherent to the work, for only the least robust of the men will take up stenography and many of the more robust of the women will marry and will not be classified as stenographers in mortal statistics. Tuberculosis therefore, should not be classified as an industrial disease in this connection.

Among the diseases whose extra prevalence has been noted in various occupations are the following, which are listed by Dr. E. R. Hayhurst in a report to the Ohio State Board of Health. In this list there is necessarily some overlapping. Many poisons like lead produce complex symptoms, or more than one disease, whereas many varieties of irritants are productive of the same type of malady.

1. Diseases of the Respiratory System:
    (a) Due to hard inorganic dusts: bronchitis, swelling due to gas in the cellular tissues (emphysema,) a hardening and contraction due to excessive formation of connective tissue in the lungs (cirrhosis of the lungs.)
    (*b*) Due to soft organic dusts; inflammation of the nose (rhinitis), nasal catarrh (coryza), inflammation of the larynx (laryngitis), acute and chronic bronchitis, asthma, lung abscess.
    (*c*) Associated diseases; tuberculosis, pneumonia, pleurisy.
2. Diseases of the Circulatory System:
    Excessive development or swelling of the heart (hypertrophy), soft, pulsating, arterial tumors containing blood (aneurism), varicose veins, a deficiency in the blood or its constituents (anemia).
3. Diseases of the Kidneys:
    Chronic inflammation of the kidneys (Bright's Disease).
4. Diseases of the Alimentary System:
    Chronic dyspepsia, chronic gastritis, gastric ulcer, chronic constipation, chronic inflammation of the intestines (enteritis).

5. Diseases of the Skin:
   Inflammation of the skin (dermatitis). Ulcers, eczema, chronic fissures, growths such as cancers (epithelioma), etc.
6. Diseases of the Nerves and Muscles:
   Paralysis, twitching (tic), tremors, cramp, pain, inflammation of a nerve or nerves (neuritis), neuralgia, sciatica, wasting of muscles, (muscular atrophy), insomnia, headache.
7. Diseases of the Eye and Ear:
   Inflammation of the mucous membrane that lines the eyelid (conjunctivitis), inflammation of the retina (retinitis), inflammation of the optic nerves (optic neuritis), deafness, etc.
8. Diseases of the Bones:
   Mortification or gangrene (necrosis) of the jaw, and partition between the right and left nasal cavities (nasal septum).

Causes of Illness are listed in the final report for 1918 of the British Health of Munition Workers Committee from which the following paragraphs have been abstracted:

Sickness due directly or indirectly to industrial occupations takes various forms and degrees, from the passing headache to serious organic disease of fatal issue. The lungs, the heart, the digestive organs, the nervous system, the muscular system—each or all may be affected with results harmful both to industrial efficiency and output, and also to personal health and expectation of life. Moreover, it must be remembered that an undue proportion of sickness in any group of workers usually represents, among those not actually sick, lessened vigor and activity which cannot fail to reduce output. Disabling conditions or influences which injure some have a tendency to mark all. Employers and their work-people should therefore have a general appreciation of these injurious conditions, if they are to be on the lookout to guard against or mitigate their evil effect. Speaking generally, attention should be given to the following points :

1. Excessively long hours of work, particularly at night, if continued, produce fatigue, irritation, and sickness. "You will find," writes Sir James Paget, "that fatigue has a larger share in the promotion or transmission of disease than any other single causal condition you can name."

2. Cramped and constrained attitudes or postures during work which prevent the healthy action of the heart and lungs.

3. Prolonged and excessive muscular strain, e. g., the lifting of heavy weights, or prolonged standing, may produce rupture or varicose veins.

4. Machinery accidents.

5. Working in unventilated or insufficiently ventilated shops predisposes to disease and interferes with individual energy.

6. While poor ventilation generally means overheated air (air of insufficient cooling power) other extremes are also harmful. Air may be too cold, too humid, or too dry.

7. Imperfect lighting, whether by day or night, is conducive to eye strain and headache.

8. Working in the presence of gases, vapors, poisons, or other irritating substances predisposes to disease and may lead to direct poisoning.

9. Dust from certain industries may produce lung disease.

In considering the physical capacity of a woman for industrial employment, it must be remembered that her body is physiologically different and is less strongly built than that of a man. She is particularly liable to certain ailments and forms of physical disability which may be caused by or result in the following conditions:

1. Disturbances of digestion due to unsuitable food, irregular and hurried meals, or to fatigue.
2. Anæmia, with possibly associated diseases of the heart and circulatory system.
3. Headache.
4. Nervous exhaustion.
5. Muscular pain and weakness, flat feet, etc.
6. Derangement of special physiological functions.

Though these conditions may not in all cases be immediately incapacitating, they freqently tend to become chronic in nature and far reaching in effect, and they lead directly to malnutrition, and to reduction of bodily energy. If allowed to persist they invariably lay the foundation of ill-health and disease in later years.

At least as important as any of these occupational influences, but inseparable from them, is the predisposition to disease arising from the absence of personal hygiene. The necessities of individual health are few and simple, but they are essential. Suitable and sufficient food, fresh air, warmth, moderation, cleanliness in ways and habits of life, the proper interrelation of work, repose, and recreation of mind and body, are laws of hygiene; facilities for these elements of vital importance must be provided if the maximum output of the individual is to be secured and maintained. It is necessary for the management to consider these matters just as seriously as healthy supervision of the external circumstances of a factory and its technical processes.

Physical Condition of Women Workers. A medical examination undertaken in the British munition factories during the war showed that the ailments most frequently observed were indigestion, serious dental decay, nervous irritability, headache, anæmia and disorders of menstruation. About a quarter of the women examined failed in one respect or another; 7% had throat trouble; 8% sufferered from eye strain; and 9% from swollen feet.

Indications of Sickness. In addition to the clinical signs and symptoms of ill-health and disease, there are three general indications of sickness in a factory which can be gauged by the Management:

1. Absence, broken time, irregular time-keeping, or diminished output of the individual worker.
2. Sickness register.
3. Death certificates. These, though few in number, form important indications of the health of the workers as a whole.

Every case of lost time or absence calls for inquiry. It should be properly recorded. The study of such records is certain to disclose the existence of adverse influences or circumstances previously unsuspected which may denote the beginning of a sickness.

Professor Loveday, in his memorandum on "The Causes and Conditions of Lost Time," which is included in the Committee's Interim Report on "Industrial Efficiency and Fatigue," sets out the results of a series of investigations which he made on behalf of the Committee into Lost Time. He concludes that nearly all records under-state, and most records under-state greatly, the proportion of lost time due to sickness and other unavoidable causes. This is partly due to the difficulty in regard to medical certificates and partly to the fact that many absences for which no medical certificates are or can be forthcoming are attributable to fatigue, colds or other minor ailments. While such absences may in a sense have been avoidable, they frequently serve to prevent future breakdown. He gives reasons in support of the view that except where there is an undue degree of slackness more than half of the time lost is lost through unavoidable causes. Various methods are suggested for testing the accuracy of sickness records:

1. If the returns of bad time keeping and sickness coincide in direction.

2. If the number of whole weeks lost through sickness be abnormally high when compared with the shorter periods similarly lost.
3. If the number of days lost through sickness be abnormally high when compared with the number of "quarters" similarly lost.

An affirmative answer to any of these questions, unless explicable otherwise, gives good reason for supposing the rate of sickness to be under-stated. While no doubt in some places and in some trades time-keeping has really been slack, there seems little doubt that the under-estimate of sickness and unavoidable absence generally has led to many misinformed and unjust statements about the lethargy and irregularity of the whole body of workers in controlled factories.

In scrutinising sickness returns and in studying their rise and fall, account must be taken of various causes of fluctuation:

1. Climatic Conditions.—It may be assumed that the rate of sickness will be above the average in January, February, March, April and occasionally in November. In the remaining months it will ordinarily be below the normal. If the sickness rate does not respond to considerable changes in weather, or fluctuates independently of them, other causes of fluctuation must be operative and should be determined.

2. The approach of a holiday.—A worker, though feeling unwell, may hold on if a holiday is approaching, and a reduction in the sickness rate may accordingly result.

3. A holiday just past.—If the sickness curve fails to respond to a holiday, and especially to a break of several days, or if its steadiness or rise cannot be attributed to worsened climatic conditions, epidemics or the like, there is reason for receiving statements as to sickness with caution and sometimes with suspicion.

4. Patriotic enthusiasm.—Many workers will keep at work when they are convinced of its urgency and national importance even though they may be unwell and need rest. Consequently when a period of relaxation occurs the rate of lost time and also of sickness may rise substantially.

Industrial Health Hazards. A more complete list than that previously given includes the following agencies and conditions; some of these are more harmful than others, but all of them are productive of disease:

1. Compressed Air.
2. Dampness.
3. Darkness.
4. Dirt.
5. Dryness.
6. Dust.
7. Excessive Cold.
8. Extreme Heat.
9. Fatigue.
10. Germs and Infections.
11. Glaring Light.
12. Infective Materials.
13. Injuries.
14. Overheated rooms (poor ventilation.)
15. Poisons, both materials handled and vapors, gases and fumes inhaled.

Compressed Air affects caisson workers and divers. It has been discussed to some extent in Chapter III in connection with pressure. The injury produced is mechanical and arises from the liberation of minute bubbles of nitrogen which are dissolved in the blood under pressure and are freed again as a consequence of decompression. These bubbles may form in any part of the tissues and the results are painful, and even fatal, depending on their extent and location. The remedy for this condition is immediate recompression followed by very slow decompression.

Dampness. Humid air maintained in workrooms as an aid to some industrial processes is harmful chiefly through its lack of cooling power. It is also more favorable than dry air to bacterial growth. Miners and tunnel men who work continuously in wet surroundings, often with wet clothing, suffer therefrom. They should have rubber boots and rubber clothing and should be provided with lockers for their street clothes and a drying room for work clothes. Shower baths with ample hot water are also advisable. No one should be required to do sedentary work in damp cold air.

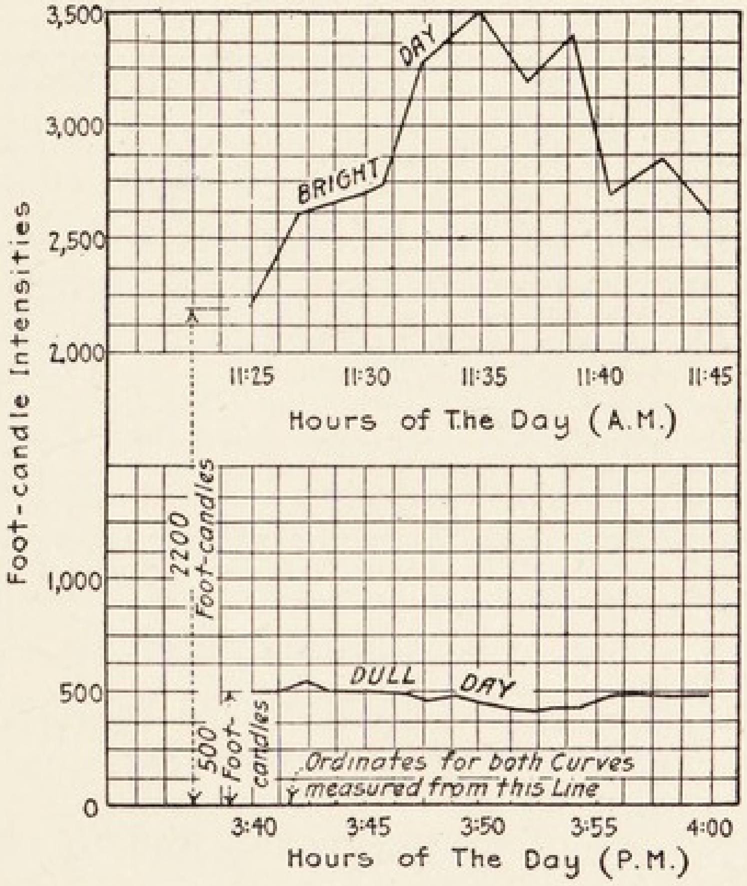


Fig. 25—Variation in Measured Illumination Intensities Under Open Sky in March

Darkness. Continual subjection to darkness whitens the skin and produces a condition of impoverishment to the blood, or anæmia. Actual darkness is rare but its effects will be produced by a lack of daylight and to some extent by a lack of direct sunlight. Inadequate light, whether natural or artificial, is always productive of eye strain. Too much light, and light shining into the eyes instead of on the work are also harmful. A flickering light or a dim light can be just as fatiguing, through its effects on the human eye, as the most laborious work. The eye also suffers from contrasts of light and shadows, as may be seen particularly in rooms where furnace glares are mostly depended upon for lighting. Such conditions produce inaccuracies of execution, and lead to accidents as well as to loss of production. Nystagmus, or dancing pupils, an affliction of the eyes among coal miners, is due essentially to poor lighting.

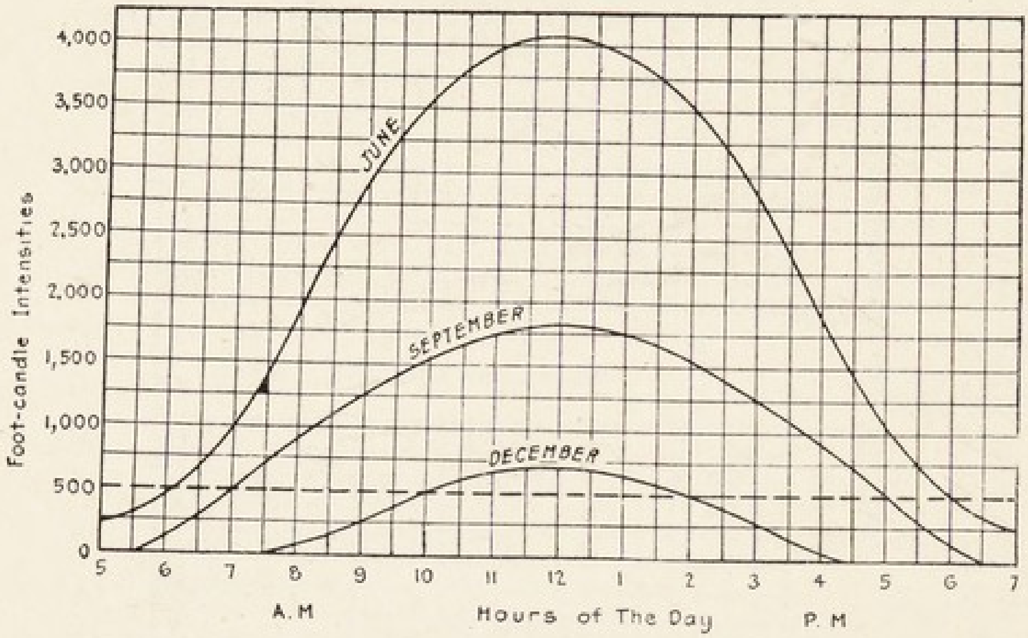


Fig. 26—Approximate Variations in Daylight Illumination Intensities Under Open Sky

By far the best source of illumination for any kind of work is daylight, and even this is not always adequate. According to an article by C. E. Clewell in Electrical World, June 16, 1917, factories which depend on side windows only may have spaces where the ratio of interior to exterior light is as low as 0.2%. In such a case, a factory space, under the conditions of exterior daylight shown in Fig. 26, will have less than one foot-candle of natural illumination.

Dirt is always favorable to the development of disease. Accumulations of refuse from manufacturing processes in unused corners invite expectoration and further dumping of refuse. The material dries out and, when it is finally removed, dust is stirred up that may or may not be poisonous or infected but is sure to be irritating. Dirt also has a considerable psychological effect. In the first place it produces a feeling of distaste and in so doing lowers morale. Besides this the sight of disorderly accumulations of materials, whether of refuse or of goods in course of manufacture, is subconsciously confusing to the mind and hinders the workers' ability to concentrate and hence to produce.

Dryness. The great majority of workshops and factories during the months of artificial heating have a relative humidity very much below the desirable range of from 60% to 70%. This is inevitable in all steamheated, hot water heated, or hot air heated quarters, unless special provision is made for supplying the air with moisture as its temperature is raised. Thus when the outdoor temperature is 20 degrees F., it can contain at the most about .15 grams of moisture per pound. This is only about 16% of the moisture that air can carry at 68 degrees, and corresponds to a relative humidity of 16%, which is too dry for human health. The dryness of the air is first evinced by an irritation of the nose and throat, the glands of which are forced to produce extra moisture in order to enable these parts to perform their functions. In time, acute colds and contagions are easily acquired. These are followed by chronic coughs and from then on a large variety of diseased conditions is possible.

Dust is one of the greatest of all health hazards and it is always present to some degree even in the purest and cleanest of air. Its contents may vary in size from particles so minute that their presence can be detected only by special laboratory apparatus, up to fragments that can remain suspended only at high air velocities. The number of particles varies enormously. One count gives 10,000 of them, with a combined weight of 0.001 milligrams per cubic foot in country air after a rain, 100,000 per cu. ft. in ordinary room air, and 160,000 particles, with a combined weight of 7.805 milligrams per cubic foot, in the air of an abrasive factory. The finer particles of dust, such as are always present, are harmless, but the coarser particles thrown into the air by industrial processes or stirred up by the wind are irritating to all the respiratory passages and to the eyes and skin. The breathing of dust-laden air day after day is a most productive cause of dust diseases of the lungs. Fibrous tissue is formed around the particles of foreign matter, destroying the function of respiration locally, and in the end resulting in a condition called phthisis. Almost always tuberculosis sets in before these conditions prove fatal, and is thus the direct cause of death. Dust conditions occur in many industries and greatly add to the prevalence of tuberculosis, making it one of the most destructive of industrial diseases.

Dusts may arise from soluble or insoluble inorganic substances or from organic substances. All of these are mechanically harmful in different degrees, and soluble dusts may in addition prove poisonous both by inhalation and ingestion. The least harmful dust is said to be that arising from the earth itself, such as the farmer enjoys. His immunity, however, may be due to the fact that his exposure is intermittent and is usually followed by much time in clean air. White flour and starch appear to be practically harmless to the normal person, soapstone and talc may be placed next in order, but a person inclined to tuberculosis, and at the same time subjected to these dusts, is almost certain to see an increment in the disease, if they promote coughing. Next in order of harmfulness, according to Dr. Hayhurst, are wood dust, bran dust, coal dust, clay dust, ore dust, mineral dust, and stone dust. The organic dusts are least harmful. Probably the most harmful of all, with the exception of poisons, is emery dust, which is composed of exceedingly hard, crystalline, sharp particles; next to this comes sand or sandstone dust, to which workers are subjected in surfacing, polishing and crushing stone and in sand blasting.

Dust may be removed by mechanical means or avoided by wet processes. Failing these, respirators should be worn by every exposed workman. Dry sweeping should never be done during working hours nor at any time, unless a current of air is immediately available to blow the dust outdoors. Vacuum cleaners should be used on all floor coverings and for getting into inaccessible corners. Wood floors of workrooms should be kept oiled.

Excessive Cold. There is practically no industry in which the workers are subjected to a harmful degree of cold, but there are a number of operations in which they are obliged to alternate between excessively hot working places and outside winter weather. Exposure to cold under these conditions is of course harmful. Sedentary workers are susceptible to small degrees of cold. Continuous work in even slightly underheated rooms, particularly when they are damp, lowers their vitality and makes them subject to infection.

Extreme Heat. Exposure to excessive heat is common among stokers and firemen, smelters, puddlers, blast and electric furnace men, steel mill and foundry workers, blacksmiths, glass blowers, kiln and pottery men, bakers, cooks, miners, tunnel workers and maltsters. Heat combined with humidity affects workers in breweries, laundries, kitchens, hot houses, tanneries, canneries, sugar refineries, and paper mills. The degree of heat encountered in some of these callings is astonishing, iron puddlers sometimes exposing themselves momentarily to dry bulb temperatures above the boiling point.

Exposure to heat is a formidable health hazard. It produces prostration, heat exhaustion, muscular cramps, and acute colic when the effects are extreme. Continued exposure produces anæmia, catarrh, rheumatism, Bright's disease, skin eruptions, cataract, and premature old age. The immediate effects of exposure to heat have been investigated in still and moving air, with the temperature and humidity carefully controlled, by the Research Laboratory of the American Society of Heating and Ventilating Engineers at the Pittsburgh Laboratory of the U. S. Bureau of Mines. The results of these investigations, appearing in the publications of the society during the years 1923, 1924, 1925, and 1926, are an important contribution to our knowledge of this subject. Working with still air, the investigators found, among other things, that;

1. There is an inability of the body at rest and in still air to compensate for saturated atmospheric conditions exceeding 90 degrees F.

2. The physiological effects resulting from exposure to high temperatures and humidities depend upon both the wet and dry bulb temperature readings.

3. The exhaustion and weakness following subjection of human beings to a very high temperature and humidity for a short period is not so severe as subjection to a moderately high temperature and humidity for a longer period.

4. The highest dry and wet bulb temperatures attained and length of time endured in the experiments are as follows*:

Dry Bulb	Wet Bulb	Relative Humidity	Time, Minutes
112.5	112.5	100	35
120.2	104.02	60	40
147	108.4	30	45
157	100.43	15	45

---

*Copyright 1926, Am. Soc. Heat & Vent. Engrs., Published by Permission.

5. The pulse-rate, rather than the rise in body temperature, apparently determines the extent of the discomfort experienced by the subject. Subjects became very uncomfortable after the pulse-rate exceeded 135 pulsations per minute and complained of unbearable and distressing symptoms when the pulse exceeded 160 per minute. The highest pulse rate recorded was 184 per minute.

6. The systolic and diastolic blood pressure fell with moderate increase in temperature and humidity, and the systolic rose and the diastolic fell, thus increasing the pulse pressure, in high temperatures and humidities.

The subjects of the tests who, frequently, on entering the test chamber were in a happy mood and of a joking disposition, soon became restless and irritable. They complained of a headache and palpitation of the heart. The headache soon became throbbing in nature, and the palpitation distressing. Great thirst was experienced. The eyes became inflamed and sore. A feeling as of a weight on the chest was noticed. The voice suffered somewhat in that it became an effort to speak. Dizziness and confusion followed. After leaving the chamber it was necessary to sit down and rest for five or ten minutes before taking a shower. Weakness and a dragged-out feeling continued for some time, depending upon the severity of the test. A metallic taste was a noticeable symptom, and persisted for one or two hours following the high temperature experiments.

It was found that if a small drop of sweat fell into the eye the conjunctiva became inflamed almost immediately, making the eye sore. Sweatbands worn on the forehead during subsequent experiments obviated this effect.

In all of these experiments the subjects remained in the test chamber about as long as they could, often having to be helped out at the end of the test. The results therefore represent the maximum safe endurance of men at rest when subjected to extreme heat. Fig. 27 shows the average endurance of subjects in a later series of tests made with still and moving air.

Experiments with still and moving air reported by W. J. McConnell, F. C. Houghten, and C. P. Yaglou in the Journal of American Society of Heating and Ventilating Engineers, March 1924, led to the following conclusions:

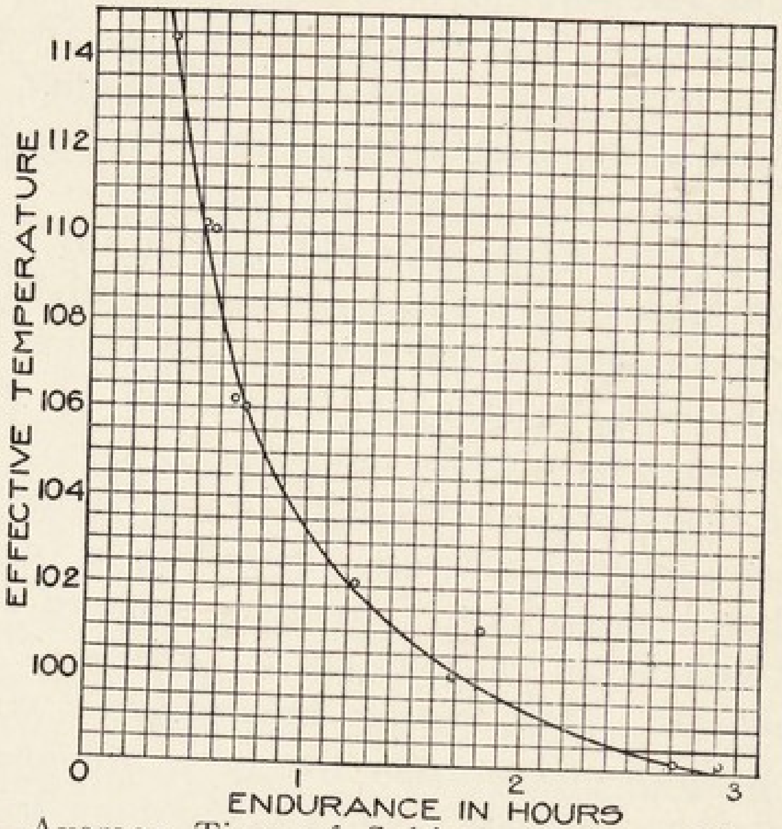


Fig. 27—Average Time of Subjects in Test Chamber for Temperatures Above Body Temperature*

1. Air motion exerts a cooling effect on the human body in atmospheres where the temperature is less than that of the body; in temperatures above that of the body air motion increases the discomfort, but the rate of change in reactions cannot be doubled by doubling the velocity of the air.

2. Within the range of the experiments no appreciable change in the period of endurance resulted from air motion as indicated by the series of tests in still and in moving air.

---

*Copyright 1924, Am. Soc. Heat & Vent. Engrs., Published by Permission.

3. The pulse-rate appears to be the best index to the severity of the discomfort.

4. The correlation between the pulse frequency and body temperature is not constant.

5. The systolic blood pressure increases on exposure to high temperatures, while the diastolic pressure decreases, and frequently becomes a negative quantity.

6. The peripheral blood vessels dilate on exposure to high temperatures.

7. Respirations are increased in rate and depth after removal from a hot atmosphere to a cooler one.

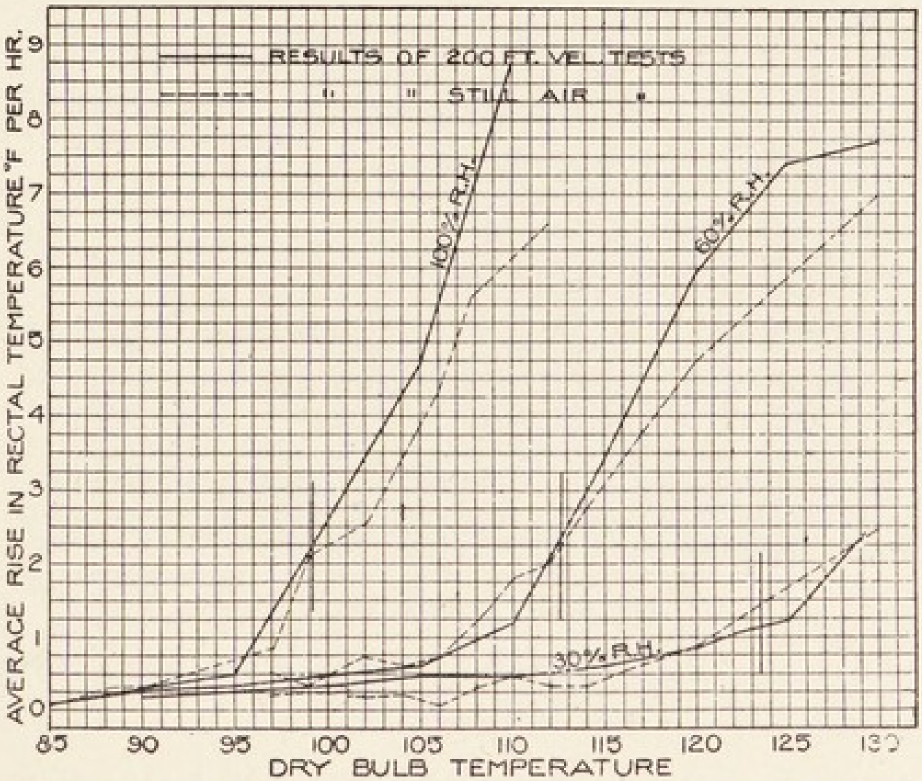


Fig. 28—Average Increase in Pulse Rate in the 200-foot Velocity Tests*

8. The loss in weight which occurs after exposure to high temperatures is not permanent.

9. Exposure to high temperatures did not cause albuminuria in any of the subjects of these experiments.

There are means of combating and lessening the ef-

---

*Copyright 1924, Am. Soc. Heat & Vent. Engrs., Published by Permission.

fects of heat which are available to practically every trade. The adoption of appliances for handling and transporting materials has done much toward solving the problem in the metal industries. Shields and asbestos coverings are used to advantage, and air blasts are particularly effective. They may be strong enough to blow back the hot air or may be used merely to blow upon the exposed workmen. Fans of all kinds and water sprays are useful for the amelioration of excessively hot working conditions. Finally, short working days and frequent short rest pauses enable the workmen to recover from periods of severe heat exposure.

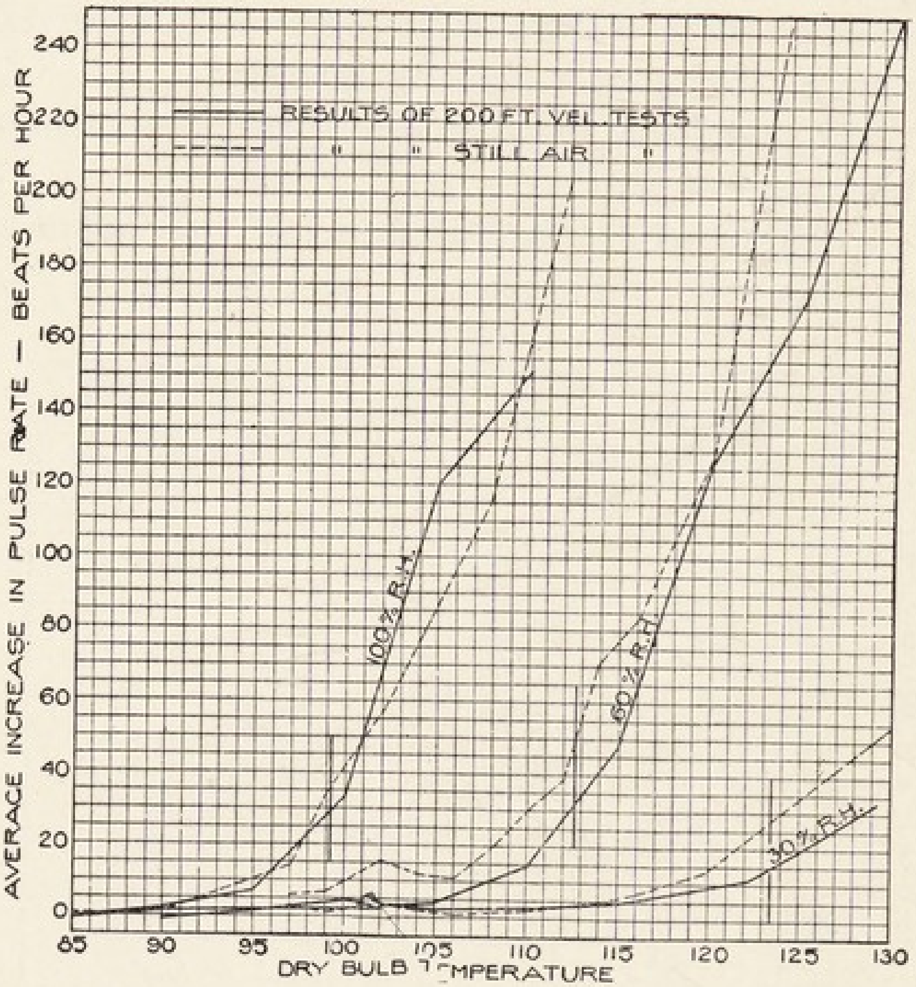


Fig. 29—Average Rise in Rectal Temperature in the 200-foot Velocity Tests*

Fatigue lowers the vitality and renders the individual

---

*Copyright 1924, Am. Soc. Heat & Vent. Engrs., Published by Permission.

susceptible to all forms of disease. The subject is covered at greater length in Chapter IV.

Germs and Infections form an industrial health hazard only in so far as workers are subjected to unsanitary conditions and to crowding. Besides crowding, ordinary causes of infection are the common use of towels, cups, wash basins, etc., improper closets, spitting upon floors, dry sweeping, and the handling of infectious materials from one workman to another. Such diseases as diphtheria, colds, tonsilitis, pneumonia, consumption, syphilis, and trachoma can be spread in this way. These are not peculiar to industry but will run rife in any crowd of persons assembled without adequate regard for sanitation, whether it be the personnel of a factory, an army, or a crusade. There is no reason why the workers in a properly equipped modern factory need be more subject to germs and infections than individuals in any other walk of life.

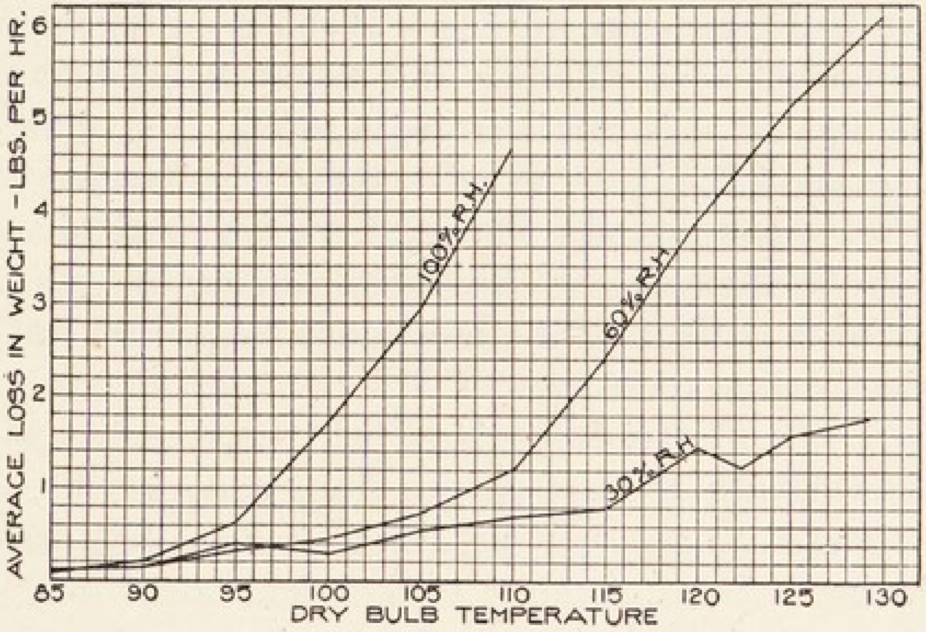


Fig. 30—Average Loss in Weight per Hour in the 200-foot Velocity Tests*

Glaring Light has greatly increased with the increased use of the vacuum and nitrogen filled tungsten lamps. It is difficult to locate these for the benefit of some workmen

---

*Copyright 1924, Am. Soc. Heat & Vent. Engrs., Published by Permission.

without putting them where they will shine in the eyes of others. The result is eye strain, headache, fatigue, and impaired vision. Welders using the acetylene torch or the electric arc have their eyes protected with screens and colored goggles. Their fellow workers, who must look upon the flame from only a slightly greater distance, generally with no protection at all may in time suffer materially from its effects. Welding and work with molten metals should be screened from the sight of everyone but the operators, who may wear adequate protective masks and glasses. Factory illumination should be individual, ample light being provided on each man's work at the most suitable angle for his convenience. Besides this there should be as little general lighting as is consistent with safety. On night work bright general lighting can advantageously be used as the signal for a rest period. The workers can move about and rest their eyes on distant objects. Dimming the general illumination and lighting the individual lamps can call their attention back to their work.

Infective Materials. Hides, hair, rags, and wool may be infected with the anthrax bacillus, and thus become a health hazard to those who have to handle them prior to sterilization. Used clothing, papers, and books may carry the germs of tuberculosis as well as various pus-forming organisms, and thus are a source of risk to laundry workers and librarians. Gloves are a valuable means of protection in these cases.

Injuries may be of two sorts: First, the more or less serious accidents, such as happen to men in all walks of life but which are more prevalent in some sports and occupations than in others. These are a serious menace to the workers of some trades, and much has been written on the subject of their cause and prevention. This subject, however, except in so far as frequent accidents are the direct outcome of illness and fatigue, is beyond the scope of the present volume. A second sort of injury includes minor cuts and abrasions that are of no consequence in themselves but which become lodging places for dirt and infection. Poisonous substances, as well as disease, find entry into the body in this manner. The risk of tetanus, or "lock-jaw," is much greater in the neighborhood of large cities than in the country, and no injury should be considered too trivial for first aid treatment. Injuries to the eyes are particularly liable to serious results if infection is given a start either through neglect or unskilful treatment.

Overheated Rooms are an invariable accompaniment of poor ventilation. If the cooling requirements of the human machine (See Chapter III) are lacking, its output will be restricted and its usefulness will soon be impaired.

Industrial poisons are alike harmful in themselves and favorable to the development of many diseases. Their number is large and their effects are manifested in many ways. The subject is treated later in this chapter.

Occupational Longevity. The following table, taken from the famous Massachusetts mortality statistics, including 229,897 deaths which occurred in 42 years in that state and including all working persons of 25 years of age or

TABLE 36

MORTALITY BY OCCUPATIONS

		No. of Persons	Average age at Death
1.	Females in trades	7,387	39.10
2.	Trainmen, teamsters, soldiers, etc.	10,776	39.36
3.	Indoor sedentary workers	28,459	45.43
4.	Indoor active workers	28,208	48.80
5.	Sailors, etc., on the ocean	12,394	48.57
6.	No special trades	43,716	49.06
7.	Business men (indoors)	27,098	49.60
8.	Outdoor and active workers	17,371	51.34
9.	Professional men	8,306	52.13
10.	Cultivators of the earth	46,182	66.29
		229,897	51.82

over, was published in the report by Dr. E. R. Hayhurst to the Ohio State Board of Health in 1913.

Causes of Death, by Occupation. Based upon the report of 94,269 deaths of male and 102,467 deaths of female industrial policy holders, 15 years of age and over, as recorded in 1911, 1912, and 1913, by the Metropolitan Life Insurance Company, and quoted in the Monthly Labor Review, Vol IV, No. 6.

Tuberculosis caused the death of 20.5% of the former and 14.4% of the latter, while organic diseases of the heart were responsible for 12% of the deaths of males and 14.8% of the deaths of females. The average age of men dying from tuberculosis was 37.1 years and of women, 34.1 years. Of males the lowest average age at death, 31.1 years, was among those who died from typhoid fever, and of females the lowest average age at death, 29 years, was among those who died at childbirth. By occupation, the lowest average age at death was 36.5 years among bookkeepers and office assistants and the highest average age was 58.5 years among farmers and farm laborers.

Tuberculosis was responsible for the largest number of deaths among clerks, bookkeepers and office assistants, 35%; compositors and printers, 34.1%; gas fitters and steam fitters, 31.6%; longshoremen and stevedores, 29.2%; teamsters, drivers, and chauffeurs, 28.2%; saloonkeepers and bartenders, 26%; machinists, 25%; cigar makers and tobacco workers, 24.1%; textile mill workers, 22%; iron molders, 21.9%; painters, paper hangers, and varnishers, 21.9%; masons and bricklayers, 19%; bakers, 18.8%; laborers, 16.4%; blacksmiths, 14%. Accidental violence was responsible for the largest number of deaths among railway enginemen and trainmen, 42.3%; railway track and yard workers, 20.8%; and coal miners, 20.4%; while the largest number of farmers' and farm laborers, 16.4%, died from organic diseases of the heart, due to the facts that the prevalence of these diseases increases with age and that the average age at death of those in this group is higher than in any other.

Similarly, among women the largest number of housewives and housekeepers, 15.2% died from organic diseases of the heart for the same reasons stated above, while tuberculosis took the largest proportion of clerks, bookkeepers and office assistants, 42.4%; clerks and saleswomen, 38.7%; textile mill workers, 35.5%; dressmakers and garment workers, 27.8%; and domestic servants, 15.9%. The average age at death was 26.1 years among clerks, bookkeepers, and office assistants, and 53.3 years among housewives and housekeepers.

Tuberculosis as an Industrial Disease. The following table was compiled from mortality statistics of the United States Census Bureau by Dr. Hayhurst.

TABLE 37

DEATHS FROM TUBERCULOSIS IN AMERICAN OCCUPATIONS

SUMMARY

Occupied Persons	Total deaths reported	Tuberculosis Number	Tuberculosis Per Cent
Males	210,507	31,059	14.8
Females	27,459	5,764	21.0
Total	237,966	36,823	15.4

ANALYSIS

Per cent of Deaths from Pulmonary Tuberculosis	Occupations (Males unless otherwise indicated)	Ascending Numerical Order
10.4	Agents	21
8.7	Agricultural pursuits combined	13
8.6	(female)	10
18.6	Bakers	44
5.9	Bankers and brokers	1
23.9	Barbers and hairdressers	66
27.9	Bartenders	75
11.4	Blacksmiths	25
19.6	Boilermakers (steam)	52

Tuberculosis Per cent of Deaths from Pulmonary	(Males unless otherwise indicated) Occupations	Order Ascending Numerical
22.5	Bookkeepers and accountants	62
35.7	(female)	90
13.4	Boot and shoemakers and repairers	28
31.8	Boot and shoe operatives (female)	87
31.3	Brass workers	86
12.0	Brick and tile makers	26
16.2	Butchers	37
10.9	Cabinet makers	23
10.1	Carpenters and joiners	20
6.6	Clergymen	4
28.3	Clerks and copyists	78
31.9	Clerks and copyists (female)	88
20.1	Clock and watch makers and repairers	55
13.7	Coopers	29
21.1	Cotton mill operatives	58
9.3	Dentists	17
18.6	Domestic and personal service (female)	43
19.2	Dressmakers (female)	50
24.1	Electricians	69
12.6	Engineers and firemen (not locomotive)	27
6.6	Farmers, planters and overseers	5
7.9	Farmers, planters and overseers (female)	9
8.7	Foremen and overseers (manufacturing)	14
31.1	Glassworkers	85
20.6	Hostlers	56
9.3	Hotel keepers	16
18.3	Hucksters and peddlers	41
16.3	Iron and steel workers	38
13.9	Janitors and sextons	30
19.9	Laborers (not specified)	54
26.5	Launderers	72
18.5	Laundresses	42
7.5	Lawyers	8
18.3	Machinists	40
6.3	Manufacturers and officials, etc.	2
28.6	Marble and stone cutters	80
13.9	Masons (brick and stone)	31
15.5	Mechanical and manufacturing pursuits	34
27.4	Mechanical and manufacturing pursuits (female)	73

Per cent of Deaths from Pulmonary Tuberculosis	Occupations (Males unless otherwise indicated)	Ascending Numerical Order
9.9	Merchants and dealers (not wholesale)	18
7.0	Millers	7
20.6	Milliners (female)	57
8.8	Miners and quarrymen	15
23.4	Musicians and teachers of music	63
11.1	Nurses and midwives	24
8.6	Officials (government)	11
29.2	Packers and shippers	82
18.9	Painters, glaziers and varnishers	46
23.9	Paper hangers	65
6.6	Physicians and surgeons	3
17.6	Plasterers	39
29.2	Plumbers, gas and steam fitters	81
28.3	Porters and helpers in stores	79
34.6	Potters	89
29.2	Printers, lithographs and pressmen	83
19.0	Roofers and slaters	49
27.9	Rubber factory operatives	76
10.4	Sailors and boatmen	22
15.8	Salesmen (in stores)	36
31.1	Saleswomen (in stores)	84
15.5	Saloonkeepers (proprietors)	35
24.2	Seamstresses	70
7.0	Steam railway employees	6
37.0	Stenographers and typewriters	91
38.8	Stenographers and typewriters (female)	92
18.9	Street railway employees	45
19.0	Tailors	48
24.0	Tailoresses	68
15.2	Tanners and leather curriers	33
15.0	Teachers, college professors, etc.	32
21.5	Teachers, college professors, etc., (female)	59
23.4	Teamsters, etc.	64
28.1	Telegraph and telephone operators	77
43.0	Telegraph and telephone operators (female)	94
18.9	Tin plate and tinware makers	47
24.3	Tobacco and cigar factory operatives	71
40.5	Tobacco and cigar factory operatives (female)	93
24.0	Tool and cutlery makers	67

Tuberculosis Per cent of Deaths from Pulmonary	(Males unless otherwise indicated) Occupations	Order Ascending Numerical
10.0	Travelers (commercial)	19
19.8	Upholsterers	53
21.7	U. S. soldiers and sailors	60
27.6	Waiters and servants	74
19.5	Waitresses and servants (female)	51
8.7	Watchmen, policemen, firemen, etc.	12
22.2	Woolen mill operatives	61

It is surprising to note that certain trades and callings are listed as below the general average, but this is because tuberculosis has strong competitors in certain avocations; for instance, 53.4% of deaths among Steam Railway Employes were the result of accidents and injuries, and 38.8% of miners and quarrymen died from like causes.

Defective Vision may be caused or aggravated by industrial conditions. Many workers, without knowing it, have poor eyesight when they first enter a factory. They suffer eye strain from work that is performed without fatigue by normal eyes, and through the eye strain their vision is further impaired. Their output decreases, their work suffers in quality, and they become readily subject to minor accidents. A man who doesn't see a step clearly trips over it; or perhaps in reaching hurriedly to stop a machine he misjudges the distance and sticks his fingers between the gears. If he is handling moving machinery, such as locomotive cranes or traveling hoists, he becomes a menace to his fellow workmen.

Close work is extremely trying to the eyes and adds to the risk of visual impairment. Individuals suffering from myopia are particularly susceptible to damage from this cause and should not be hired where such work is to be done.

Poor eyesight is such an important cause of accidents and defective work that every employee's eyes should be examined at the time he is hired, for in no other way can the management learn what the man does not know himself. Students and clerical workers with sub-normal vision must have it corrected by glasses if they are to get along at all. Workers in foundries and machine shops, on the other hand, can get along with their work in a slovenly way, and, unless they are of a studious disposition, may never know that their sight is defective until it traps them into some accident. It is for this type of worker that an examination by an optometrist is of greatest importance as a prerequisite of employment, for the close worker is likely to have discovered and remedied his defects for himself.

Industrial Poisons. The extent to which poisonous substances are handled in industry is enormous. They are widely used for themselves and are indispensable re-agents in many processes that are required to fill the needs of modern civilization. Except for a few special substances, there can be no question of discontinuing the use of poisons. Efforts therefore must be directed toward minimizing exposure by mechanical means and toward proper selection, instruction, and care of the workers who have to handle them. It must be borne in mind that men do not get used to these poisons. They cannot be absorbed by the human system without damage. Some human beings are more tolerant than others, but none can become habituated. Those who are not intelligent enough to understand this will in time become contemptuous of danger and will neglect necessary precautions. An increase in fatigue or a decline in general health will render them as liable to poisoning as the most susceptible, and their names will be added to the list of victims of industry.

Apparently the most difficult precaution of all for men to adhere to is the avoidance of taking poison into the mouth. They will handle food or tobacco with dirty hands and will place it in the month when it therefore must carry poisonous dust. Even a man wearing a respirator will lick his lips and in this way absorb small amounts of noxious substances. It would seem that, in order to take the least risks in work of this kind, a man needs both intelligence and character.

The number of poisonous substances in use is very large and is constantly being augmented by new inventions. This is not as unfortunate as it may seem, for science is often able to replace some highly injurious substance or process with a less harmful one. In a report by Somerfield and Fischer translanted by Dr. Wm. H. Rand, and published by the Ohio State Board of Health, 1914, an abridged list of industrial poisons, and other substances injurious to health found in industrial processes, is given as follows:

TABLE 38

PARTIAL LIST OF INDUSTRIAL POISONS

Designation of Substance	Mode of Entrance into the Body
Acetaldehyde (CH_3COH)	Through respiratory organs and mucous membranes
Acridien ($C_{13}H_9N$)	Affects skin and mucous membranes
Acrolein (C_2H_3COH)	Respiratory organs and mucous membranes
Ammonia (NH_3)	Respiratory organs, affects the eyes
Amyl Acetate ($C_5H_{11}CH_3CO_2$)	Respiratory organs, in form of vapor
Amyl Alcohol ($C_5H_{11}OH$)	Respiratory organs, in form of vapor
Aniline ($C_6H_5NH_2$)	Absorption through the skin, by direct contact or by saturation of the clothing
Aniline Dye-stuffs	Respiratory organs in form of vapor; irgestive organs, affects the skin
Antimony Compounds	Respiratory organs in from of vapor; irritation of the skin; in form of dust
Arsenic Compounds	Respiratory organs, in form of dust and vapor and through mucous membranes, the stomach and intestinal canal
Arseniureted Hydrogen (AsH_3)	Respiratory organs, in form of gas
Benzine	Respiratory organs, in form of vapor
Benzol (C_6H_6)	Respiratory organs, in form of vapor; reabsorption through the skin
Carbon Dioxide (CO_2)	Respiratory organs, in form of gas
Carbon Disulphide (CS_2)	Respiratory organs, in form of vapor or dust. In fluid form through the skin
Carbon Monoxide (CO)	Respiratory organs, in form of gas
Chloride of Lime ($Ca\ OCL_2$)	Respiratory organs in form of vapor or dust. Affects the skin
Chlorine (CL)	Respiratory organs, in form of gas

Chromium Compounds	Respiratory organs, in form of dust; absorption through the skin and mucous membranes
Cyanogen Compounds	Respiratory organs, in form of gas
Diazomethane (CH_2NH_2)	Lungs, in form of gas; effect on skin
Dimethyl Sulphate $(CH_3)_2SO_4$	Respiratory organs, in form of gas. Affects skin
Dinitrobenzol or Binitrobenzol $C_6H_4(NO_2)_2$	
Formaldehyde CH_2O	Through respiratory organs and mucous membranes
Hydrochloric Acid HCL	Acts on skin and nasal mucous membranes; seldom in vaporous form, affecting the respiratory organs
Hydrofluoric Acid or Fluoric Acid HF	Respiratory organs, in form of gas
Lead Pb	Respiratory organs, in form of vapor and dust. Digestive tract by means of contaminated food and drinks; also as dust
Manganese Dioxide MnO_2	Respiratory organs, in form of dust
Mercury Hg	Through uninjured skin and in form of vapor and dust
Methyl Alcohol CH_3OH	Respiratory organs, digestive organs, and skin
Methyl Bromide CH_3Br.	Respiratory organs, in form of gas, and through the mucous membranes
Nitrobenzol $C_6H_5NO_2$	Absorption through the skin, respiratory organs, digestive organs
Nitroglycerin $C_3H_5O_3(NO_2)$	Respiratory organs, absorption through skin and mucous membranes
Nitrous Gases	Respiratory organs, in form of gas
Oxalic Acid $C_2H_2O_4$	Respiratory organs, in form of dust
Petroleum	Respiratory organs, in form of vapor. Affects the skin
Phenol C_6H_5OH	Action on the epidermis and digestive organs
Phenylhydrazine $C_6H_5NH.NH_2$	Absorption by the skin; action on the skin
Phosgene $COCL_2$	Respiratory organs, in form of vapor
Phosphorus P	Respiratory organs, in form of vapor, digestive canal; by the fingers; action on the skin
Phosphorus Sesquisulphide P_2S_3	Respiratory organs
Phosphureted Hydrogen PH_3	Respiratory organs, in form of gas
Picric Acid $C_6H_2(OH)(NO_2)_3$	Respiratory passages, in form of dust. Affects the skin
Pyridine, C_5H_5N	Respiratory organs, in form of vapor Affects skin when in fluid state
Sulphur Chloride S_2CI_2	Respiratory organs, in form of vapor
Sulphur Dioxide, Sulphurous Acid (H_2SO_3)	Respiratory organs, in form of gas
Sulphureted Hydrogen H_2S	Respiratory organs, in form of gas, admixture with other gases. Direct action on the conjunctiva
Sulphuric Acid H_2SO_4	Respiratory organs, in form of vapor
Tar	Respiratory organs, in form of vapor Acts on the skin
Turpentine Oil	In the form of vapor it acts upon the mucous membranes; in fluid state, acts on the skin

Measures for Protection Against the Dangers of Poison as listed by Industrial Councilor Dr. Fischer of Berlin are:

1. Properly adapted buildings, thick walls of separation for dangerous rooms, good lighting, facilities for keeping the workshops clean and for effective ventilation.

2. Apparatus adapted to its special purpose, and whenever possible, tightly closed in every part.

3. Appliances for accomplishing the arrest of gases and dust at their place of origin and their removal (by exhaust fans); appliances for rendering them innocuous or collecting them, thus preventing them from entering the nose and mouth..

4. As far as possible, avoidance of direct contact with poisonous materials or substances injurious to health in working with, transporting, or packing them.

5. The displacement of particularly dangerous labor methods and materials by the introduction of less dangerous labor processes and materials, as well as by the employment of materials satisfactorily pure chemically.

6. Instruction of workmen just entering upon an occupation concerning the properties of the poisonous substances extracted, manufactured, used, or otherwise evolved. Whenever possible, cautionary leaflets should be put into the hands of the workers.

7. The repetition of this instruction at frequent intervals.

8. Posting of precautionary regulations and warning placards containing admonitions for the exercise of special caution, and enjoining the observance of measures for insuring safety. Constant supervision of all dangerous employments by expert and responsible persons.

9. Employment of appropriate means for personal protection, as work clothes, caps, gloves, goggles, and, as necessary adjuncts, mouth and nose shields, respiratory masks and the like, in case the appliances named in rule 3 are inapplicable.

10. Practice of bodily cleanliness by the use of wash, bath, and dressing rooms, the use of special rooms for eating, separate wardrobes for street and work clothes, and frequent, nonhazardous cleansing of the clothing.

11. Immediate report of symptoms of indisposition, attention to wounds of the skin caused by the handling of corrosive materials, the speediest employment of an unexceptionable antidote giving promise of success, at the very first symptoms of poisoning, with the simultaneous summoning of a physician.

12. The installation of a healthy working force capable of withstanding exposure to the poison. Temporary or permanent exclusion of sick workmen from the dangerous departments of the industry. Medical examination of the workers in dangerous employments at suitable intervals. Under certain circumstances there should be a change of work in occupations giving rise to chronic poisoning.

13. The utmost possible reduction of the hours of labor in dangerous employments.

Poisonous Gases. The chief dangers arising from the manufacture and manipulation of poisonous gases are given as follows in the Final Report, 1918, of the British Health of Munition Workers Committee:

1. Poisoning by the lethal and lachrymatory gases;
2. Irritation of the skin, eyes and other exposed parts of the body, caused by the handling of raw materials or finished products;
3. Mechanical accidents; these, however slight in the first instance, may become serious, unless they receive prompt medical attention, on account of the poisonous character of the bodies handled or manufactured.

Apart from mechanical safeguards against accident, the principal measures necessary for prevention and treatment are:

1. The appointment of a medical officer for each factory;

2. The medical examination of all workers before engagement, and at frequent intervals during employment;
3. Suitably equipped ambulance stations in charge of a trained nurse and under the constant supervision of the medical officer;
4. Hospital accommodation for special cases;
5. Suitable protective clothing (including overalls, helmets, respirators, gloves, goggles and clogs); all such clothing must be worn only during the period of actual working. Overalls should be washed weekly.
6. Suitable cloakrooms;
7. Washing facilities sufficient to enable workers to wash thoroughly at the end of each period of work;
8. No food may be taken into a workplace;
9. Adequate facilities for obtaining food.

Common Industrial Poisons. Dr. E. R. Hayhurst states that in the State of Ohio the most common poisons in their order of frequency are : Lead, benzine and benzol (naphtha, petrol, gasoline, etc.), turpentine and similar dryers, brass or zinc in the form of fumes: acids, alkalis, wood alcohol, analin oil, carbon bisulphide, antimony and fuel gas, sulphinated hydrogen, arsenic, phosphorus, and mercury. It is his opinion that the most common and widespread forms of poison are those derived from lead and its derivatives and from carbon monoxide as exhausted by automobiles. The seriousness of the latter source of poisoning is probably not fully realized. Deaths from this cause, which are not infrequent, receive due attention, but a good deal of discomfort, if not danger, passes unnoticed in the garages throughout the country. A cumulative effect has not been established, but it is observable that there seem to be very few robust garage mechanics.

TABLE 39
DANGEROUS AND ENDURABLE CONCENTRATIONS OF NOXIOUS FACTORY GASES

(From the Journal of Industrial Hygiene, vol 7, opposite p. 140)

Designations of Volatile Poisons	Are quickly Fatal for Man and Animals	Concentrations Which Cause Illness Dangerous to Life in ½ to 1 Hour	Concentrations Which Are Endurable Without Serious Disturbances for ½ to 1 Hour	Cause Only Minimum Symptoms with Several Hours' Action
Hydrogen chloride (hydrochloric acid)	....	0.15-0.20%	0.005-0.01% at the most	0.001%
Sulphur dioxide	....	0.04-.05%	0.005-0.020%	0.002-0.003%
Hydrogen cyanide (hydrocyanic acid)	about 0.03%	0.012-.015%	0.005-0.006%	0.002-0.004%
Carbon dioxide	30%	about 6.0-8.0%	4.0-6.0%	2.0-3.0%
Ammonia	....	0.25-.45%	0.03%	0.01%
Chlorine and bromine	0.1%	0.004-0.006%	0.0004%	0.0001%
Iodine	....	....	0.0003%	0.00005-0.0001%
Phosphorus trichloride	3.5 mg.	0.3-0.5 mg.	0.01-0.02 mg.	0.004 mg.
Phosphine (phosphoretted hydrogen)	....	0.04-0.06%	0.01-0.02%	....
Hydrogen sulphide	0.1-0.2%	0.05-0.07%	0.02-0.03%	0.01-0.015%
Benzine	....	....	15-25 mg.	5-10 mg.
Benzol	....	....	10-15 mg.	about 5 mg.
Carbon disulphide	....	10-12 mg.	2-3 mg.	1-1.2 mg.
Carbon tetrachloride	300-400 mg.	about 150-200 mg in 1 liter	about 25-40 mg. in 1 liter	about 10 mg.
Chloroform	300-400 mg.	70 mg.	25-30 mg.	about 10 mg.
Carbon monoxide	....	0.2-0.3%	0.05-0.10%	.02%
Aniline and toluidine	....	....	0.4-0.6 mg.	0.1-0.25 mg.
Nitrobenzol	....	....	1.0 mg.	0.2-0.4 mg.

Carbon Monoxide must be kept below 0.1% to avoid poisoning. An ordinary gasoline motor running at moderate speed is said to be capable of emitting 2.5 cubic feet of carbon monoxide per minute, and about 2500 cubic feet of pure air per minute would be required to keep the concentration within safe limits while the gas is being emitted at this rate. It is, of course, much better to collect and exhaust the gas to the outside air than to attempt to dilute it after it has been freed in a workroom, so perhaps a more suitable way of visualizing the foregoing figures is to consider that one minute's operation of a motor will produce a harmful condition in a garage 15 by 20 by 8 feet. This gas is odorless, colorless, and tasteless, and its victims may never know that they have been poisoned.

Lead affects not only the workers who produce the metal in the smelters but all those who work with it and its compounds. Paint and color factories, storage battery works, ceramic and textile plants, all have the hazard of lead poisoning to contend with. Painters are susceptible to this form of poisoning whenever they handle lead paint.

Workers in this material who do not develop symptoms of acute or sub-acute lead poisoning may be considered as having superior eliminative capabilities. These individuals often continue in the trade for many years, but ultimately degenerative diseases are apt to set in. Chronic lead poisoning is manifested by a diseased condition of the gums; atrophy (particularly of the most used sets of muscles) and muscular incoördination, high blood pressure, and rheumatic pains.

Preventive Measures. Hand work can be largely eliminated by dipping and spraying. Rubbing down and dry sandpapering of painted surfaces should be avoided as the paint dust is particularly harmful. Sandpapering can be done without creating dust if a suitable mineral oil be used on the paint work. The wearing of wet sponge respirators is an additional precaution, but these will not in themselves prevent lead poisoning. To prevent lead entering the system through the digestive tract the following special steps were recommended by the British Health of Munition Workers Committee in their Final Report, 1918:

1. Smoking should be prohibited in all places where lead is manipulated.
2. No person should be allowed to take a meal or to remain during the time allowed for meals in any room where lead is used.
3. Special mess rooms or canteens should be provided where workers can take their meals. Good food is of special importance in helping a worker to resist poisoning. In particular, workers should not commence work without having taken food. Evidence shows that hungry and ill-fed workers succumb more readily than others, and excellent results have been obtained from supplying workers with at least half a pint of milk or cocoa before starting work in the morning.
4. Overalls should be provided and cloakrooms established, separate provision being made for the keeping of outdoor clothes and overalls respectively; they should never be allowed to come in contact with one another.
5. Special washing facilities should be provided, and should be sufficient to enable the workers not only to wash their hands, but also their faces, necks and arms. Such facilities will only be effective if a sufficient supply of hot and cold water, clean towels, soap and nail brushes is always available. In some processes the employment of women, boys and girls is forbidden.

Where their employment is allowed, boys and girls should be closely watched, because they are not so likely to observe the necessary precautions as grown-up people. Women should be especially careful as the injurious effect of lead in them seriously interferes with the health of their children. Only healthy and temperate persons should be employed.

Prevention, Remedy and Treatment of Industrial Diseases. At the foundation of any sound system of dealing with industrial disease lie two elementary principles: First, prevention is better than cure; and second, to be effective, treatment must deal with the beginnings of the disease. The preliminary safeguard should be to provide for the medical examination of all workers entering an establishment, in order to secure a reasonable degree of physical fitness and a knowledge of the abilities and failings of individuals. Such medical examinations, besides serving the purposes above stated, are valuable in affording convenient opportunity for the inculcation of sound doctrines as to personal hygiene, cleanliness, and health habits. Periodic re-examinations are essential in trades where the workers come in contact with poisonous substances, and might be profitably employed in much other work. Those who handle poisons should be required to have sound teeth and may advantageously be provided with inexpensive or free dental treatment.

Sanitary conditions should be made as good as it is possible to have them, and lighting, seating arrangements, material supply, hours of work, and rest periods should be such as to avoid undue fatigue.

Provision should be made for medical attention at any time. A large plant may employ a physician and a staff of assistants, a smaller one a nurse, or perhaps a member of the force skilled in First Aid may be assigned to this task. There should be some definite place and some special person to go to for the immediate treatment of all injuries.

Requirements for prevention and care of industrial disease may be summarized as follows: 1. Reduce the hazards incident to the work as far as it is possible to do so. 2. Provide as sanitary, comfortable, and convenient working quarters as it is feasible to get. 3. Select individuals who appear capable of standing up under the conditions fixed by the foregoing factors. 4. Watch the workers, by periodic examination, to see that they do stand up under the work. 5. Transfer any worker who shows signs of infection or poisoning to less hazardous work. 6. Provide equipment and competent personnel for immediate First Aid treatment of all injuries.

Conclusions. The operation of the human machine is adversely affected by its tendency to break down under unfavorable working conditions. The surroundings amid which work is done and the materials worked with are responsible for illness and poisoning that are generally referred to as industrial diseases. These are of vital concern to both labor and management, whose joint coöperation is needful if they are to be controlled. Some of the facts concerning industrial diseases and their possible elimination or remedy are as follows:

1. A worker's health may be ruined and his life shortened through the hazards encountered in some particular lines of industrial work. If he be more robust and resistant than the average individual, and if by the practice of certain precautions he be able to fill out his allotted span of life he will still suffer, for, being classed as one of a group engaged in a dangerous trade, he must pay higher rates for insurance.

2. An industry whose workers are short lived is at the disadvantage of having to break in new workers more often than the average. It also will have a greater number of workers who have passed their time of maximum production and are nearing the limit of their usefulness.

3. Absence from work because of disease or poisoning is always accompanied by considerable disability of a lesser degree. An increase in the number of workers who are temporarily off the payroll on this account means also

an increase in the number who are more or less disabled but contrive to stay on the payroll.

4. Contagious germ diseases should have no part in industry. They pass from one person to another, through the agency of unsanitary surroundings, when human vitality is lowered by undue fatigue. In a properly constructed, equipped, and operated factory the workers should run less risk of infection than in their own homes.

5. Some germ diseases, such as tuberculosis and pneumonia, that owe their beginnings to mechanical injuries in persons otherwise immune, are inseparable from some lines of work. Much can be done, however, to decrease their prevalence.

6. Dust is the greatest of all industrial health hazards in both the frequency with which it is encountered and the seriousness of its effects. It is the direct cause for making tuberculosis the foremost of industrial diseases.

7. Eyesight is of such vital importance to industrial work as well as to humanity that all workers should be subjected to examination at the time of their employment. They should be classified according to their visual ability, and their sight should be carefully safeguarded.

8. Some men are more tolerant of poisons than others and are apt to think that they are getting used to them. Their toleration also misleads their employers. The universal recognition of the fact that men cannot become habituated to poisons is vitally important to all concerned.

9. The control of poisonous processes is technical and requires expert supervision. Everything physically possible should be done to reduce the amount of dust fumes or vapor to which operators are exposed.

10. The selection of personnel is of almost equal importance to the control of the process. Only men who appear able to withstand the expected hazards should be employed.

11. The control of industrial disease in dangerous oc-

cupations is largely a matter of medical supervision. Periodic examinations should be provided and the examining physician should have authority to remove any man who shows signs of failing health.

12. The tremendous value of the invariable habit of thoroughly washing the hands immediately before eating is almost unknown among industrial workers. This should be impressed upon them by the Management in every possible way as a privilege as well as a duty to their fellows.

CHAPTER X

EFFECT OF STIMULANTS ON EFFICIENCY

It has previously been brought out that a beneficial stimulating effect may be given to the human machine by food. Wholesome and well balanced rations are necessary between working periods.

There are many mild stimulants, such as sugar (candy,) coffee, tea, cocoa, etc., which, if taken in temperate quantities both during and between meals, may prove helpful in lessening fatigue, and thereby increase productivity, whithout proving harmful to the system.

A temporary increase in vital activity may be effected by the use of alcohol or drugs. These agents, however, are toxic and generally harmful. Tobacco is a stimulant which, if used moderately, may not prove very harmful to the normal person.

Much has been said of the effects of alcohol when used as a beverage. There is no doubt that some alcohol is necessary to the human being, as it is formed in the body by natural processes. As a beverage, alcohol may be beneficial at the proper times and in the proper quantities. While it is hard to get conclusive evidence as to what is the correct usage of alcohol, there is no doubt that, in the vast majority of cases, its effects are positively harmful to a man's physiological condition and also to his muscular and mental productivity. There is no justification for the use of drugs except when given by a physician in the treatment of certain cases.

Effect of Intemperance on Attendance and Production. This is well illustrated by a chart, Fig. 31, from Coal Age, August 15, 1918, indicating the variation of the working force of six anthracite mines, on account of pay days and holidays.

The chart shows the variation in the force of men cutting and loading coal at the six mines. Circles call attention to the number of men reporting on the day after pay day. Sometimes, however, the chart cannot record the profundities of low output, and the circle has had to be omitted, a note being substituted.

In the months of July, August and December, 1917, there were three days, each of which followed a pay day, on which the force dropped to about 1100 men. This was approximately 500 men short of a normal force, namely 1600 men. Allotting 5 tons to each man, which is considered a fair day's work, there was on each of these days a loss of 2500 tons.

The Effect of Alcohol on Production is generally to reduce it. We are here considering the question entirely aside from its moral or sociological implications. The tremendous craving for alcoholic stimulation is a product of excessive fatigue, and from the earliest times men have gone to the bottle when they could find no other means of relief, temporary of course, from their troubles. This, when repeated often enough, leads to a ruinous habit, every period of indulgence in which requires time for recovery of normal working power, and time is our most precious commodity, daily becoming more rare and valuable.

Moderate drinking also takes time, for the alcohol imbibed must be eliminated from the body just as much as the poisons created by fatigue. Indeed, alcohol in small quantities may be likened to fatigue in its effect, for both require a period of rest for the body before it regains its normal abilities. This is true for any amount of drinking, however small. Drinking habits, too, are fatiguing. The German sits for weary hours in his beer house and the American stood (and still does,) half the night in the saloon. Either would soon succumb to fatigue unless sustained by stimulants, and both must recover from the double dose of fatigue and alcohol before they are again normal.

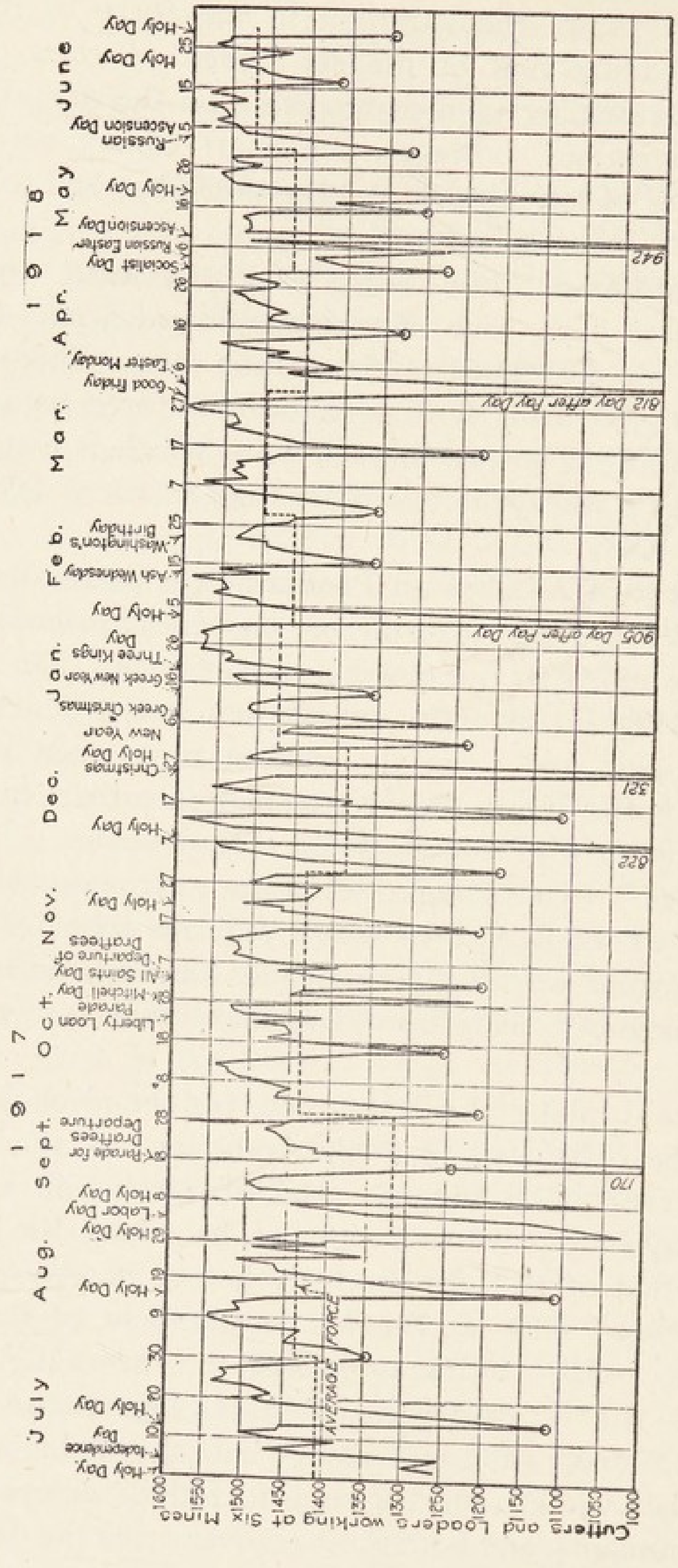


Fig. 31—Curve Showing Variation in Working Force at Six Coal Mines Owing to Paydays and Festivals

The fact that any amount of alcohol is similar to fatigue in its effect should not condemn it as a beverage, for the same is true of all forms of sport and exercise. The workman's Sunday automobile ride on traffic-laden metropolitan streets may be just as fatiguing as a reasonable amount of drinking, and, depending on the temperament of the man, it may not be as satisfactory a form of recreation.

It is of course impossible to say how much drinking constitutes a reasonable amount but where any drinking at all is done it is difficult to keep it within reason. The effects of heavy indulgence in alcohol over the week-end were investigated in a number of German industrial plants in 1898 and 1899 by Alfred H. Slehr, Doctor of Political Economy, Magdeburg, Germany, who came to the following conclusions:

1. Every kind of work, even that requiring only a minimum of intelligence, shows throughout the whole week the injurious influence of immoderate use of alcohol on Sunday.

2. The smaller product of Monday is not to be attributed solely to Sunday indulgence in alcohol; the physiological disinclination to begin work again and the loss of practice during the time of rest, diminished productivity in a small degree difficult to measure, and varying with the individual workman and kind of work. In order to determine exactly the damage through irrational pleasure, the factors of disinclination to resume work and loss of practice would have to be deducted. A clue to the size of these two factors is furnished us by the differences in the Zeiss workers (1.03%.)

3. The extent of the total damage resulting from Sunday indulgence may exceed 50% in alcohol addicts engaged in crude muscle work. With workmen designated as "average" and only given to what is called moderate use of alcohol, it may amount to from 2.5-13.3%.

With the Dresden bottle workers it was about 28.5% below the average of the rest of the week; with the umbrella workers of Cologne it varied from 2 to 23.9%.

4. The more the workman is accustomed to indulge only on Sunday in the immoderate use of alcohol, the more his efficiency curve shows a steady upward direction in the course of the week; in substance, it is the expression of disappearance of the alcohol intoxication.

5. The more rational a workman is in his enjoyments, the nearer his Tuesday's efficiency approaches the maximum of his output, which is oftenest reached on Thursday, and the more constant, as a rule, is his daily working ability.

The Effect of Alcohol on Industrial Accidents and Health was also reported on by Dr. Slehr who offers the statistics given in Table 40 as evidence that drinking during the week-end is responsible for an increase in accidents.

TABLE 40

ACCIDENTS OCCURRING IN GERMANY ON THE SEPARATE WEEK DAYS

		Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
1897	Average for the German Empire	17.57	16.71	15.72	15.72	15.14	17.00
1885-1898	North Austrian Bldg. Trades	18.70	15.60	15.60	16.20	16.60	16.20
1889-1899	Milling, General	16.70	15.90	14.90	14.60	15.90	17.30
1889-1893	Land & Forest Cultivation	16.80	15.90	16.00	14.70	15.60	15.50
1897	(40 weeks) Ship Building concern, Hamburg	19.20	16.90	16.30	14.90	15.20	17.50
1898	Lower Alsace—over the weekly average	Monday, 14 per cent				Friday, 10 per cent	

The frequency of accidents, on the average for the empire, reached its highest point on Monday, and steadily declined until Saturday, which was the usual pay day, when it quickly rose almost to the height of Monday. Other computations showed also, with few exceptions, that

Monday stood at the top of the danger scale with a corresponding increase at the end of the week. In the milling trade union, where Monday and Saturday have changed places, pay day fell usually on Friday. In Lower Alsace where Friday stood next to Monday in number of accidents, there were many trades in which Thursday was pay day.

The drinking of alcohol results in external symptoms of insufficient attention and diminished clearness of perception, just as does fatigue. It is also responsible for a tendency to inconsiderate and impulsive movements. There is a relaxation of a brain function that nature has provided for the better protection of the body, and the feeling of freedom from care, which otherwise comes only when no danger is present, gains the upper hand. A more advanced degree of drinking leads to a tendency to play with one's strength, to scuffle or fight, a tendency in which there is danger of bodily injury, arising from the diminished sense of responsibility that accompanies the lowered functional activity of the brain. All these effects of drinking are exactly the tendencies that lead to accidents.

Dr. Slehr compares accidents and assaults with the following comment:

"If we place side by side the average of accidents occurring on the separate days of the week and the corresponding distribution of convictions for assaults, according to the national statistics for the years 1898-1899, we find again a striking parallel not only in the highest and lowest points, but also in the same descending tendency up to Friday and the same sudden rise on Saturday to a level nearly equal to that of Monday, such as we found inversely in the efficiency of the separate days of the week.

	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
Accidents	17.57	16.70	15.72	15.72	15.14	17.00	—
Assauts	125.00	69.00	62.00	0.62	3.48	103.00	254

"Like effects lead to the supposition of like causes. In assaults the use of alcohol is an undisputed cause of the variations.

"If the workman's fatigue and not the effects of alcohol occupied the foreground on Monday, it would be shown in a clearly manifested disinclination for scuffling and scrambling, and assaults on Monday would stand lowest. That the opposite is the case indicates clearly that the fatigue theory, under which term I include those opinions which attribute the increase of accidents on Monday chiefly to sleepless nights, long sitting in the public-house, and excessive pursuit of pleasures, is untenable."

It is needless to go into further detailed statistics in order to connect accidents with the use of alcohol. Our nationwide campaign for safety, here in the United States, requires the utmost carefulness and alertness from every individual, and anything that tends to deaden these faculties is opposed to the purposes of the campaign.

From a standpoint of health alcohol should be regarded in the same light as any other poison. A man can absorb and recover from a quantity of it, provided his living conditions are as they should be and he has time for recovery, otherwise it will set up degenerative changes in the bodily organs and at the same time will increase the susceptibility to disease. Abstainers live longer and have a lower death rate than moderate drinkers who, in turn, have similar advantages over heavy drinkers. For this reason Dr. Slehr suggested that fraternal insurance organizations should give their abstaining members a more favorable rate than is accorded to drinking members, but he doubted that enough abstainers could be found in Germany in 1898 to furnish data for rate computation.

The Effect of Alcohol on Mental Work was experimentally investigated by Professor Kraepelin of Heidelberg, whose findings as described in a lecture by Dr. A. Smith are available in the publication of The American

Issue Publishing Company. Professor Kraepelin's experiments were undertaken with the idea of applying exact measurements to mental operations, in order to fix a standard by which they might be judged under varying conditions. At first they were only indirectly concerned with alcohol, it being merely one of several substances used to produce a mental condition. The results obtained with alcohol however were so unexpected that the experiments were repeated many times with many different subjects so that correct conclusions might be drawn from them.

In order to test memory Professor Kraepelin used one place figures. These were divided into groups of twelve, and the twelve figures were repeated until they could be re--produced once without error before the next series was taken up. Every repetition was recorded by a perpendicular pencil-stroke at the side of the group being memorized. Every five minutes an alarm clock gave a signal and a horizontal line was drawn under the last repetition record. When the signal sounded, if the series previously learned was not completely impressed upon the memory, it was quietly repeated again, and a perpendicular stroke was drawn under the last horizontal line.

The test proceeded continuously for half an hour. The work was estimated by counting up the numbers of figures learned in the five minute periods of the half hour, and noting also the relation of the number of figures learned to the number of repetitions, that is, the value of every repetition was ascertained.

In order to study the rapidity with which the person tested could recall the forms he had learned, Kraepelin introduced the addition of one-place figures. Employing the same series of figures that had previously been used for memorizing, every time the sum of two figures added amounted to more than nine, the left-hand figure was dropped and the right hand one only remained. Thus in adding seven plus eight, the resulting 15 was not written.

only the 5. The possible objection here that writing down the sums took time and made it more difficult to estimate the purely intellectual work, was shown, by control experiments, to be not valid, because when the numbers were dictated, considerably more could be written in the same time.

As in the memorizing exercises, a signal sounded every five minutes and was recorded by a horizontal stroke under the last number written, and the experiment lasted exactly half an hour.

The figures recorded show how *many* figures had been used within the time limit; also the *accuracy* of the adding. It was found, for instance, that various individuals showed a double influence under otherwise similar conditions. With one, the test would show a considerable slowing of mental work, while no change occurred in the number of errors; in others there would be no change in the quantity, while the number of errors would mount up to 40%. This is the kind of mental work that is termed "fickle," and is the result not of indolence but of fatigue.

Somewhat similar tests were made in reading, time estimating, speed of response to a signal, and association of ideas. Varying doses of alcohol were used, ranging from 7.5 grams to 60 grams, corresponding to the contents of from one-fifth of a liter (about six ounces) to one and one-half liters of beer.

With the smallest doses simple reactions were at first performed more easily. The acceleration however, lasted only a short time after which the work began to be more difficult and the reaction time lengthened. With doses larger than 7.5 grams the work was, as a rule, more difficult from the start. With quantities corresponding to half a liter (about one pint) of beer, impairment began at once with all of the persons investigated. The memory test of repeating numbers was carried on with more rapidity but less accuracy under the influence of alcohol. In all cases and on all tests the persons tested slowed down under the influence of a quantity of alcohol corresponding to a pint of beer.

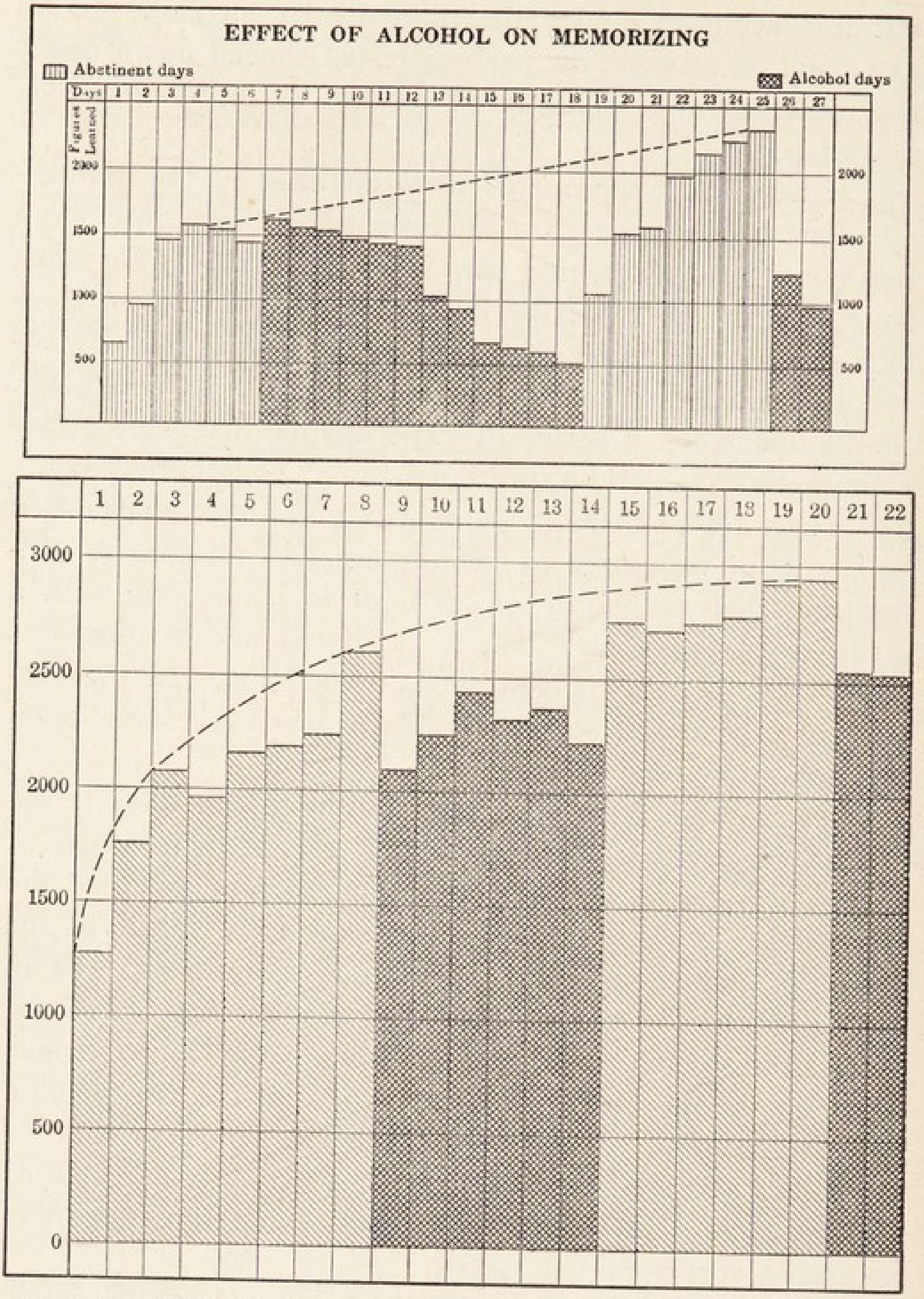
Kraepelin's experiments were confined to the immediate effect of the drug, from the time it was taken until about two hours afterward, and they show admirably what must have been the effect of the noon hour pail of beer so common in pre-prohibition times. In order to find out how alcohol affected the mind some time after it was taken, Dr. Smith undertook a series of experiments, after the Kraepelin method, which he continued for 27 consecutive days.

These tests started in the morning at nine o'clock when half an hour was given to memorizing, half an hour to adding, and then a quarter of an hour to connecting with a given word every idea that it suggested and writing this down—the method of continuous association. In the evening, at 7 o'clock, tests were made in word and association reaction, precisely timed.

After these tests had been continued five days to ascertain the normal working ability, the administration of alcohol was begun, directly after the morning work of the sixth day. Twenty grams of alcohol were taken in the morning, and again after the evening experiment. From the eighth to the twelfth day, this amount was increased to 30 grams, then up to the seventeenth day to 40 grams. Thus on the morning and evening of the first two alcohol days an amount was taken that corresponds to that of about half a liter of beer, so that these two days exemplified the effects of a liter (quart) of beer. The maximum was 80 grams, corresponding to two liters of beer.

From the eighteenth day to the twenty-fourth day alcohol was entirely withheld, then on the twenty-fifth and twenty-sixth days 80 grams were again taken.

The result of two of Dr. Smith's experiments are shown in Figs. 32 and 33, which represent the reactions



EFFECT OF ALCOHOL ON MEMORIZING

Fig. 32 and 33—Relative Memorizing Ability, With and Without Alcohol

The shaded columns represent the non-alcohol days; black columns the alcohol days.

The numbers at the top show the days of the experiment; those at the side the figures memorized.

The dotted line denotes the rate of gain from practice.

of a schoolmaster, who thought alcohol in moderate doses was practically indispensable for promoting physical and mental work and who would have been glad, had it been possible, to prove his opinion correct.

This man practiced total abstinence for four days before beginning the experiment. Then for eight successive days he worked without alcohol, then for six days under

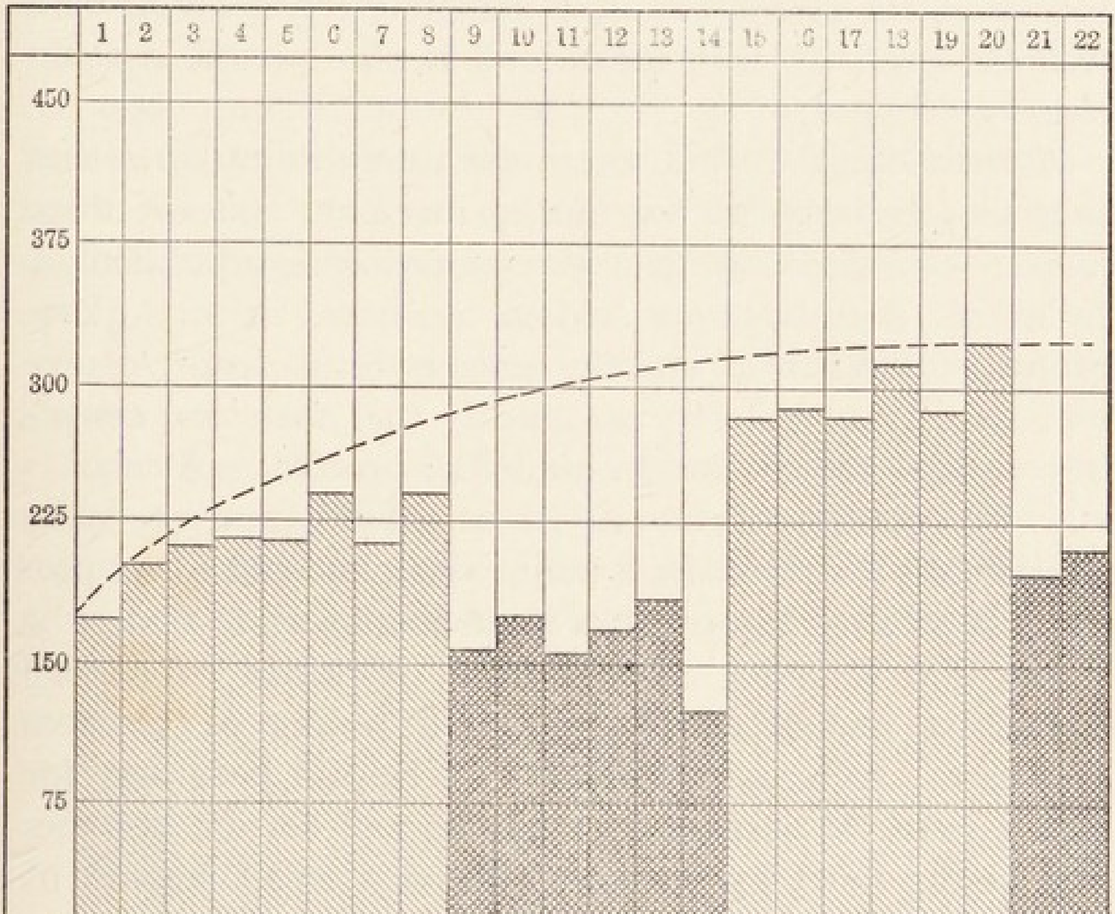


Fig. 34—Relative Adding Ability, With and Without Alcohol

The shaded columns represent the non-alcohol days; black columns the alcohol days.

The numbers at the top indicate the days of the experiment; those at the left, the figures added.

The dotted line denotes the grain from practice.

the influence of 80 gram doses of alcohol, so arranged that the work was done 20 hours after the alcohol was taken. Then there were six days without alcohol, followed by two days with it, at the close.

The curves for both memorizing and adding show that his working ability fell, for the first time, directly after the first alcohol was taken; that it rose again as suddenly in the following non-alcohol periods, forming, with the commencement curve, almost a complete continuation of a parabola; and that, with the second alcohol period, it again suddenly dropped.

Conclusions. While there are many stimulants that affect the efficiency of the human machine, none of them requires consideration in this connection except alcohol. The milder stimulants are seldom consumed in such quantities as to be harmful, and the more noxious drugs remove their users from industry so quickly that their use constitutes a social rather than an industrial problem. Alcohol is so widely used, so insidious in its effects, and so easily misused that it constitutes a major economic and social problem. It affects industry in a number of ways.

1. The drinking of moderate quantities of alcohol produces a mental relaxation and a feeling of freedom from care. At proper times it is a helpful beverage, for when a sense of harassment, anxiety, and tension becomes fixed in the mind by nervous fatigue, a small amount of the stimulant lessens the tension and is conducive to rest.

2. Alcohol, however, even in very small quantities, is a poison and must be eliminated from the body, for which purpose time and rest are required. The worker who lessens his mental tension with a stimulant must rest from the stimulant, as well as from his work. He is in somewhat the same position as one who relaxes from work by indulging in violent exercise.

3. Where there is always a tendency to drink too much alcohol, even within the limits of temperance, its immediate effects are equivalent to an added burden of fatigue, and tend to cut down production accordingly.

4. Because alcohol deadens the sense of responsibility, many people, when they drink at all, are intemperate. The free use of alcohol has, in the past, caused serious loss to industry, through the great number of absent and inefficient workmen after pay days and holidays.

5. Occasional small amounts of alcohol, from which the body can completely recover, are a hazard to health just as are equivalent amounts of fatigue. The continuous use of alcohol produces degenerative changes in the bodily organs and at the same time, decreases resistance to disease.

6. The use of alcohol in moderate quantities retards mental processes.

7. Regardless of the merits of the present controversy over prohibition, it is evident that a return to the general use of alcohol on the part of industrial labor would be accompanied by a material decrease in production.

CHPTER IXI

MORBIDITY

Morbidity is a term used to express the sick-rate existing in a community in the same way that mortality expresses the death rate. It may be defined as the proportion of sick persons to the total considered. Statistics on this subject for the United States are available only for recent years and are not yet comprehensive. It is evident, however, that the total time lost to industry on this account is enormous. One estimate, by Mr. C. E. Knoeppel, in a paper read before the Western Efficiency Society, May, 1917, places it at nine days a year for each year of 30,000,000 workers, or a total loss of 270,000,000 days a year. This he considered represented a monetary loss of $700,000,000 annually. Allowing for increases in population and wages, this last figure corresponds to about 1 2/3 billion dollars in 1926.

Estimates such as the above, and all morbidity statistics are based on the number of days absent from work because of sickness. No account is taken of the days that are virtually lost through the unwillingness of workers to give up and stay at home when ill. Many remain, and therefore, work at greatly reduced efficiency, because they do not wish to lose time, or because they are unwilling to indulge in needed rest. This is particularly true during epidemics of grippe and colds, in the winter and early spring, and is a further source of very considerable loss.

While a morbidity rate is inevitable in our present state of development, it can undoubtedly be reduced by organizations that take adequate steps for its control. Such steps include, first of all, a medical examination for the proper selection and placement of workers. Of equal importance are adequate, sanitary, and comfortable working places. and working hours that do not cause undue fatigue. Free or compulsory medical treatment will tend to shorten the periods of illness and lessen the spread of infectious diseases. It may, however, result in an apparent increase in morbidity. Adequate medical supervision together with health instruction will gradually get the workers into a habit of staying at home when they are ill, and taking care

TABLE 41

MORBIDITY RATES IN DIFFERENT DEPARTMENTS OF A WELL ORGANIZED IRON AND STEEL PLANT IN OHIO

(Considered to be the minimum that may be expected)

Departments	Average Number of Employees	Average Number Sick	Average Per cent Sick
Heat Exposed:			
Bessemer	393.3	33.	8.39
Open Hearth	145.3	7.	4.81
Rail and Shape Mill	500.	43.3	8.66
Blast Furances	261.	35.	13.41
Foundry	163.3	12.7	7.77
Shelf Mills	348.3	33.3	9.56
Pipe Mill	1,764.7	162.	9.18
Weather Exposed:			
Police	35.	2.7	7.62
Railroad (yards)	156.3	9.	5.76
Section Hands	110.	10.	9.09
Yard Labor	468.	28.7	6.13
Ore Docks	90.3	8.3	9.19
Bricklayers	72.7	2.7	3.66
Building Construction	106.3	9.7	9.07
Indoors (mostly):			
Mechanical	472.3	47.7	10.09
Electrical	181.3	4.3	2.37
Miscellaneous	351.6	11.3	3.21
Total	5,619.7	460.7	8.20

of themselves. The result will be that, instead of remaining more or less ineffectively on the pay roll, their names will be added to the morbidity lists. Both employer and employee will benefit, but, because of the impossibility of keeping track of the loss through sickness of those who remain at work, evidence of the benefit must be sought in output records and not in morbidity statistics.

The Average Morbidity to be Expected. The following data, from a report by Dr. E. R. Hayhurst, published in the Ohio Public Health Journal, 1915, refers to the employees of an iron and steel establishment which had the highest attainments in sanitation and hygiene of working quarters, and medical supervision of its working force. The figures given in Table 41 show which departments had the most, and which the least percentage of sickness, and hence indicate the types of work in which the greatest precautions are necessary. The figures given for a number of weather exposed groups are particularly interesting as they are not easy to obtain.

TABLE 42

PER CENT AND DURATION OF SICKNESS IN GERMAN SICKNESS INSURANCE SOCIETIES 1888–1907

		1888	1892	1903	1904	1905	1906	1907
Cases of sickness per year per 100 insured	Men	33.5	36.8	38.3	40.9	41.4	39.4	42.7
	Women	28.8	31.1	33.0	35.4	35.0	33.4	35.6
Average number of days of sickness per case	Men	16.6	17.0	18.1	18.7	18.7	18.5	18.5
	Women	17.7	18.3	21.9	23.2	23.5	24.1	23.4
Days of sickness per annum per 100 insured	Men	555.6	626.6	695.3	761.2	775.9	728.6	788.7
	Women	508.3	569.7	720.4	822.9	927.9	804.7	833.1

Table 41 shows a much higher rate of morbidity than the figures for German sickness insurance societies given by Miss Goldmark in "Fatigue and Efficiency,*" which are reproduced in Table 42.

The morbidity of women is generally much higher than that of men. The figures of Schuler and Burckhardt showed that in a Swiss cotton mill employing both sexes the relative morbidity of men and women was 100 to 128. Insurance societies published in Berne in 1907 the following statement:

"Among 100 insured men an average of 26.76 received sick relief, but among 100 women only 24.26. The men who received sick relief averaged 23.55 days of illness; the women averaged 32.46.

"The women, therefore, showed a lower percentage of relief but a longer average duration of sick time, and as a result of these two circumstances the average morbidity of the women is higher than that of the men—7.87 as against 6.30."

Rates and Cause of Industrial Morbidity. That women are a poorer health risk than men is well borne out by the very excellent statistics collected for the Edison Electric Illuminating Company of Boston and published by H. W. Moses in National Safety News for December, 1925, Vol. 13, pp. 13-16. Since February, 1913, every employee who entered the service of this company has been required to pass a physical examination. Rejections were made of applicants having defects of the heart, lungs, or kidneys, and of those having hernias. A liberal non-contributory disability benefit plan was in force under which the workers got full pay during disability. For this reason the records are not exactly comparable to those that apply where no sick benefit payments are made. They show "medical inadvisability to work" rather than actual inability as is most often the case where no sick pay is to be expected.

The following tables, 43 to 50, apply to the company's force, which averaged about 2300, with an average labor turn over of about 25%. The ages of the group ranged

---

*Published by Russell Sage Foundation.

from 16 to 79 years, and about 90% were American born. The proportion of females to males was about one to four, most of the women being single and a large percentage of the men married.

Colds occupy first place. Table 43 shows the number of cases, total rates and working days lost for the six highest diseases causing absence during 1918-1922. Common colds easily occupied first place, causing 34.3% of all absence, and showing the rate of 47 per 100 employees and an average loss of 3.2 days per case per year.

TABLE 43

NUMBER OF CASES, TOTAL RATES AND WORKING DAYS LOST FOR THE SIX HIGHEST DISEASES CAUSING ABSENTEEISM DURING 1918 to 1922

(Edison Electric Illuminating Company of Boston)

Disease	Number of Cases	Rate per 100 Employ's	Total Working Days Lost	Average Working Days Lost per Case
Common colds	5,328	47	16,983	3.2
Dysmenorrhea	683	32 (per 100 women)	1,486	2.1
Disease of stomach	1,246	11	2,647	2.1
Pharyngitis and tonsillitis	1,007	9	4,698	4.9
Functional nervous diseases	731	6	6,882	9.4
Rheumatism, arthritis and gout	651	6	4,781	7.4
All diseases	14,280	128	83,280	5.8

Table 44 gives the rates per 100 employees, by age groups, for the six highest diseases causing absence during 1918-1922. The rates for these diseases by age groups show a phenomenon contrary to that usually observed, there being a progressive decrease in rates as age increases, except in the classifications of rheumatism, arthritis and gout. In considering these statistics it must be borne in mind that this five year period, 1918 to 1922 inclusive, includes the influenza epidemic.

TABLE 44

RATES PER HUNDRED EMPLOYEES, BY AGE GROUPS, FOR THE SIX HIGHEST DISEASES CAUSING ABSENTEEISM DURING 1918 to 1922

(Edison Electric Illuminating Company of Boston)

Disease	Rates per 100 Employes in Age Groups						
	10-19	20-29	30-39	40-49	50-59	60	All Ages
Common colds	101	57	50	51	31	18	47
Diseases of stomach	23	15	11	10	6	3	11
Pharyngitis and tonsilitis	21	13	9	5	2	1	9
Functional nervous diseases	13	9	6	5	4	2	6
Dysmenorrhea per 100 women	30	42	20	12	4	0	32
Rheumatism, arthritis and gout	2	4	6	10	10	8	6
All other diseases	110	47	45	45	33	30	41
All diseases	285	158	132	128	88	61	128

Women poorer hygenic risks. Table 45 gives the number of cases, total rates and sex rates, per 100 em-

TABLE 45

NUMBER OF CASES, TOTAL RATES AND SEX RATES PER HUNDRED EMPLOYEES FOF THE SIX HIGHEST DISEASES CAUSING ABSENTEEISM DURING 1918 TO 1922

(Edison Electric Illuminating Company of Boston)

Disease	Number of Cases	Rate per 100 Employees	Rate per 100 Men	Rate per 100 Women
Common colds	5,328	47	41	76
Diseases of stomach	1,246	11	17	9
Pharyngitis and tonsilitis	1,007	9	6	19
Rheumatism, arthritis and gout	651	6	6	4
Dysmenorrhea	683	—	—	32
Functional nervous diseases	731	6	3	19
All other diseases	4,645	44	51	222
All diseases	14,280	128	157	683

ployees, for the six highest diseases causing absence during 1918-1922. This analysis shows a much higher rate for women for most of the diseases listed.

Table 46 shows disease absence, according to distribution by sex, during 1918-1922. Here the disease rates for female workers in all groupings are clearly shown to be higher than the rates for men.

TABLE 46

DISEASE ABSENTEEISM (according to duration) BY SEX DURING 1918 TO 1922

(Edison Electric Illuminating Company of Boston)

	Accidents			Home Accidents		
Absentee Group	Cases Male	Rate per 100 Males	Cases Female	Rate per 100 Females	Total Cases	Rate per 100 Employees
1 day	3,503	38	2,222	106	5,725	51
2 day	2,046	22	746	35	2,792	25
3 day	1,139	12	429	20	1,568	14
4 day	656	7	219	10	875	8
5 day	471	5	177	8	648	6
6 day	431	5	166	8	597	5
Over 10 days	882	10	374	18	1,256	11
All groups	9,409	103	4,871	230	14,280	128

TABLE 47

ACCIDENTS AND HOME ACCIDENTS ACCORDING TO AGE GROUPS DURING 1918 TO 1922

	Accidents		Home Accidents	
Age Group	Number of Cases	Rate per 100 in Age Group	Number of Cases	Rate per 100 in Age Group
10-19	30	0.3	39	0.3
20-29	289	3.1	191	1.7
30-39	255	2.8	118	1.0
40-49	147	1.6	61	0.5
50-59	37	0.4	31	0.2
60+	16	0.1	8	0.0
All Ages	774	8.5	448	4.0

Table 47 shows accidents and home accidents according to age groups during 1918-1922. The highest rates were among the 20-29 and 30-39 age groups, due no doubt to the greater exposure to hazards by the members of those groups.

Table 48 shows the case frequency, aggregate, and case time loss, and estimated cost per case, per employee, for all cases of disability during 1918-1922.

TABLE 48

CASE FREQUENCY, AGGREGATE AND CASE TIME LOSS , AND ESTIMATED COST PER CASE AND PER EMPLOYEE FOR ALL CAUSES OF DISABILITY DURING 1918-1922

(Edison Electric Illuminating Company of Boston)

Cause of Disability	Number of Cases	Total of Working Days Lost	Average No. of Working Days Lost per Case	Average No. of Working Days Lost per Employee	Average Case Cost	Average Cost per Employee*
Sickness	14,280	83,280	5.8	7.4	$19.40	$24.80
Accidents	744	13,221	17.1	1.1	38.00	26.30
Home Accidents	488	3,377	7.5	0.3	24.60	1.00
All causes	15,502	99,878	6.4	8.9	20.50	28.50

*Cost is here based solely on benefits paid and estimates of salaries paid out before tranference of benefit fund (on the fifteenth day of disability). Other items of expense are not included.

In comparing the experience of 1915-1917 with that of 1922-1924 it was found that among the men the frequency rates increased for some diseases and decreased for others, while among the women they increased in every case except in diseases of the stomach and in ill-defined conditions.

The frequency rates among the males increased in 1922-1924 as follows:

Industrial accidents	+11
Non-industrial accidents	+48
Influenza and grippe	+194
Colds and other disease of nasal fossae	+56
Bronchitis—acute and chronic	+298
Diseases of the digestive system	+41
Neuralgia and neuritis	+17
Neurasthenia, nervousness, etc.	+83
Diseases of the circulatory system	+18
Miscellaneous general disease	+21

The frequency rates among the males decreased in 1922-1924 as follows:

Tuberculosis of the respiratory system	—56
Pneumonia	—53
Rheumatism	—6
Diseases of the eyes	—40
Diseases of the genito-urinary system	—29
Epidemic and infectious diseases	—8
Purulent infection (blood poison)	—21
Ill-defined and unknown causes	—64

It is of considerable importance to note that there was more sickness among the men under 25 years of age than among those from 25 to 35.

Table 49 compares the frequency of disability lasting one, two and three calendar days, in the period days of disability per year, per person, for the ten-year period 1915-1924.

Table 50 indicates an average loss of 8.56 days per year, of which 7.06 days are due to sickness. This, according to Mr. Moses, is somewhat less than the experience of industrial workers as a whole. It will be noted that there is a progressive increase in the amount of time lost. That this may be due in part to the fact that the workers have gradually acquired the habit of staying at home and nurs-

TABLE 49

COMPARISON OF FREQUENCY OF DISABILITY LASTING ONE, TWO AND THREE CALENDAR DAYS IN THE PERIOD 1915-17 INCLUSIVE WITH 1922-24 INCLUSIVE

(Edison Electric Illuminating Company of Boston)

Period	No. of years of life exposed	No. of disabilities lasting 1, 2 and 3 calendar days	Calendar days of disability from such disabilities	Annual No. of 1-3 day disabilities per 1000 on payroll	Calendar days of disability per attack lasting 1-3 cal. days	Annual No. of cal. days of disabilities per 1000 on payroll
MALES						
1915-17 Inclusive	5,648	3,746	6,140	663	1.64	1,087
1922-24 Inclusive	6,039	4,509	7,790	747	1.73	1,290
%Change	——	——	——	+13	+5	+19
FEMALES						
1915-17 Inclusive	560	777	1,177	1,388	1.51	2,102
1922-24 Inclusive	1,519	2,750	4,217	1,810	1.53	2,776
%Change	——	——	——	+30	+1	+32

ing minor illnesses, is evidenced by a material decrease in the length of more serious cases while the number of shorter ones increased.

TABLE 50

DAYS OF DISABILITY PER YEAR PER PERSON ON THE PAYROLL FOR CAUSES SPECIFIED

(Edison Electric Illuminating Co. of Boston)

	Total disability	Sickness	Industrial accidents	Non-Industr'l accidents
1915-17 Inclusive	7.7	6.1	1.2	.4
1918-22 Inclusive	8.9	7.5	1.1	.3
1923-24 Inclusive	9.0	7.4	1.1	.5

The most striking feature of these statistics is the tremendous loss to both sexes and every age group by common colds.

The Control of Morbidity. Medical examinations at the time of employment are always advisable, and wherever sickness or old age benefits, or insurance plans are conducted, they are a matter of necessity. Cases are on record where industrial employees have attempted by fraudulent means to obtain benefits to which they were not entitled; against this form of dishonesty the employer has no better defense than his examining physician.

The examining physician's chief services, however, will comprise weeding out the unfit and classifying the remainder according to the work they are capable of handling. A considerable amount of unfitness exists, as shown by the Draft Board records quoted in the first chapter of this volume, and must be accepted if industry is to be manned. It is not practical to refuse to employ men with such ailments as heart trouble and poor eyesight, but, as the result of examination, they can be assigned to tasks in which their defects are of least detriment. A man with heart trouble should not be given a position where he is called upon to climb stairs, run, or do heavy lifting, and a man with poor eyesight should not be given work of precision. Both types will benefit as much as their employer from the correct assignment.

A medical examination can be of further service in aiding and encouraging a man to correct the physical defects that have been discovered.

There are many other services that a physician can perform for an industrial plant. He can maintain a hospital, or at least a dressing station, and supervise the treatment of injuries. He can make periodic examinations that will show the management the effect of working hours and conditions on the force. He, better than anyone else, can see that the sanitary utilities of a plant are properly maintained. The heating, lighting, and ventilation of buildings; the care of wash rooms and locker rooms; and the supply of drinking water, will all be better for his attention. Finally, a physician can maintain office hours and act as a general practitioner to the workers under his care. This may be his greatest service, for the human machine, like other machines, operates best and most economically when kept in good repair.

If the services of the physician can be extended to include the immediate families and the homes of the workers, his employment should be economically possible with forces of as few as 400 or even 300 workers. Where his attentions are confined to the workers themselves, a considerably larger force will be required to justfy the maintenance of a company doctor. Under these conditions, Dr. Otto P. Geier, writing in Industrial Management, October, 1917, estimates that a force of 750 workers is the minimum for which a full-time physician can profitably be employed. For smaller plants, down to almost the smallest a part time medical supervisor is economically essential. According to the United States Statistical Abstract, in 1920 there were 15,982,106 persons engaged in manufacturing and mechanical industries and transportation; there were 41,614,248 engaged in all gainful occupations, and 144,977 physicians and surgeons.

Nursing Service. A plant nurse can be employed to advantage when the working force is too small to justify the employment of a physician, and one or more nurses are needed to supplement the work of the physician in larger establishments. It is of great advantage to extend nursing service to the homes of the workers, if this can be done in a manner that will avoid the paternalism that such a service is apt to involve. A report issued by Dr. T. H.

Mullen, on Recommended Standard Practice on Medical Supervision in Detroit Plants, states that: "Out of a total of 378 patients cared for during the month of December, 1916, by the Visiting Nurse Association, there were 222 cases where the wage-earner was employed by a manufacturing firm. The Detroit Home Nursing Association made a survey of more than 10,000 homes of moderate means, including records of 2,000 cases of childbirth, 675 of which were where the wage-earner was employed by a manufacturing firm. In 653 cases of the 675, the husband acted as nurse at night. In 158 cases he stayed at home from work for from one to four days; in 31 cases he stayed at home one week and in four cases he stayed at home two weeks."

The Scope of an Adequate Health Department, according to an article by Dr. Otto P. Geier, in Industrial Management, June, 1917, should include the following:

1. Physical examination at the time of hiring and subsequently, as conditions indicate.
2. Advice to the employment department as to the proper placement of defectives.
3. Supervision and follow-up treatment of those defectives.
4. Facilities for the treatment of medical, surgical, dental, ocular, and other types of cases.
5. Investigation and, in many cases, nursing and medical treatment of home cases.
6. A system of benefits sufficiently adequate to tide over the disability period.

Cost of Health Supervision in Industrial Establishments. Table 51 gives the cost of health supervision, in 1916, at 99 industrial plants in the United States, as reported by Magnus W. Alexander, in "Modern Hospital" for May, 1919. The "total medical and surgical cost" listed includes salaries of physicians and nurses, cost of outside medical and surgical service, and cost of medical and surgical supplies, whether or not paid for by insurance companies as a part of the insurance contract; it includes compensation for injuries, overhead expenses, and wages paid to employees while off duty to have their injuries treated.

TABLE 51

COST OF HEALTH SUPERVISION IN VARIOUS INDUSTRIES IN 1916

Industry	Number of establishments represented	Total average number of employees supervised	Total cases of all kinds	Total medical and surgical cost	Average annual cost of medical and surgical supervision per employee
Metal trades	47	294,646	1,988,991	$541,771	$1.84
Rolling mills	7	49,317	358,574	137,047	2.78
Smelting and refining	1	1,270	2,832	6,932	5.46
Light and power	7	24,921	49,046	92,601	3.72
Transportation	5	35,795	81,591	69,633	1.95
Chemicals	6	10,572	78,744	34,797	3.29
Food	5	13,650	69,565	39,875	2.92
Rubber	5	27,462	234,069	76,089	2.77
Textiles	4	8,939	67,380	24,177	2.70
Paint	2	4,023	10,255	29,635	7.37
Leather	2	3,026	9,440	6,102	2.02
Publishing	2	3,358	6,742	3,473	1.03
Coal mining	1	2,454	2,842	4,637	1.89
Gold mining	1	2,500	62,126	35,590	14.24
Coal and iron mining	1	11,000	131,898	130,000	11.82
Miscellaneous	3	2,611	11,019	6,126	2.35
Total	99	495,544	3,165,114	1,238,485	2.50

"The purpose of this compilation was to inform employers of the actual cost of health supervision of employees in different industries. To this end the data were secured from plants engaged in many industries, in light, medium, and heavy work, in comparatively safe as well as hazardous operations, and in shops of various sizes and character, located in various parts of the United States. Some are situated in cities where hospitals and specialists are available, some in small places where such service can be secured only with difficulty.

"While the average cost per person, as indicated in the summary, is $2.50, it is not representative, as the total cost on which the average is based includes that of four plants which render unusual service, giving both medical and surgical attention to their employees at the plant and in their homes as well, besides assuming the medical care of employees' families. Omitting these four plants from consideration, the average cost for the 479,635 employees in the other 95 plants was $2.21.

The figures given in Table 51 should be multiplied by a factor of about 1.4 in order to bring them to 1926 levels, but, even if so corrected, they can only give a very rough idea of what such service should cost. Many of the factories reporting cared for injuries only, while others furnished complete medical service. It is evident, however, that in general the saving of one or two days' time per year for each employee would have paid for the service. This would be to the workers' advantage, in so far as it enabled them to recover more rapidly from sickness, and to the employers' advantage to the extent that sick and ineffective workers were kept home.

The Benefit Derived from an Industrial Medical Department may extend in several directions. This is admirably illustrated in an account given in Iron Age, January 23, 1913, as follows:

"The medical department of the Norton Company, Worcester, Mass., has collated the results of the year 1912 in their effect upon shop efficiency. They show that the systematic medical and surgical care of employees under intelligent, aggressive direction, coupled with organized sanitary inspection of works, is a direct source of financial profit, as well as a powerful influence on the physical health and the earning power of the workmen. The percentage of idle hours—the time that men are absent from their work—has been reduced from about 3 to 1½. The sick or injured workmen who receive treatment at the company's hospital average 19.2 hours less of lost time than those employees who do not avail themselves of the opportunity urged upon them, and instead go elsewhere for professional assistance, or, as often happens, receive no attention at all. The medical department's effort to reduce the loss of working time has been extended by the company to a radical curtailment in absences from the works because of personal reasons other than impaired health. Tuberculosis has been stamped out; the cases which were discovered, less than 10 all told, were taken in the incipient stage, and already some of the patients are back at work cured.

"A sigularly illuminating commentary on the value of prompt treatment of injuries is the fact that in all the 800 accident cases treated in the hospital since its establishment 20 months ago, only one case of septic poisoning has occurred, and that a trivial affair, due to the patient's removing the dressing. The influence of the system in making more cordial relations between workmen and owners has been made evident in many ways, and increases as the work is better understood.

"A crowning proof of the effectiveness of the department is that the liability insurance company has granted a premium rebate, which covers practically the entire cost of the medical and sanitary departments. In other words, the system is paying its way by the reduction effected in accident risk under the workmen's compensation act.

"The saving of idle hours is no mean item of economy. The Norton system applies to some 900 men. A reduction in lost time from 3% to 1½ means, roughly, a decrease from 70,000 to 35,000 hours. The production saved is the labor of 600 men for one week of 60 hours. The gain is greater than this, however, for the influence of absence from work may extend beyond the actual labor which the workman fails to perform. The loss from the idleness of certain highly skilled men may be serious in upsetting the balance of production. In such cases the medical department has the chance to coöperate directly with the head of the department, perhaps to tide the man over in his illness until certain necessary work has been completed.

"One revelation of the records is that a wide vari--ation exists between departments as to the number of idle hours due to reasons other than that of health. The personality of the foreman is involved, including his leniency as to requests for leave of absence, his degree of indulgence where men fail to appear for work, and his friendliness toward individuals. The rule has been made that a workman is dropped from the rolls automatically if he is absent for a period of more than seven days. Upon his return he must apply for work at the office of the superintendent and must be hired over again, even to the making out of a new card. This gives the superintendent the chance to watch his men and the foreman is eliminated as the judge of the case. The rule works against indulgence in an extra day or two of idleness at the expiration of a period of sickness, and the chronic idler is soon detected."

Conclusions. Most factories that operate a number of machines maintain a force of extra skilled mechanics whose duty it is to see that the machines are properly handled, properly adjusted, and kept in repair. These mechanics have a machine shop at their disposal wherein they can mend such breakages as occur. The human machines are worthy of equal consideration. Their skillful mechanics are the doctor and nurse, and their machine shop is the hospital. Like the mechanical machines they will work, if kept in good condition, until worn out, and as with them, if a breakdown occurs, there must be a period of idleness before work is resumed, and, even then, the repaired machine is never quite as good as it was before.

The human machine breaks down because of accidents and sickness, which must be expected in every line of work; but their rate of occurence, to which the term morbidity is applied, will vary with the type of work, the age and sex of the workers, the location and climate, and finally with the conditions under which the work is done, particularly in regard to fatigue. Present day knowledge of this subject is far from complete but a few generalizations are possible:

1. The accident rate will depend primarily on the nature of the work. Age is another cause of variation, young men being more prone to accidents than older ones.

2. Poor lighting and fatigue will increase the rate of accidents.

3. The sickness rate is greater among women than among men, both in the frequency and duration of illness.

4. There is a greater morbidity rate among heat-exposed and poison-exposed workers than among other indoor workers, or among weather exposed workers.

5. The compilation of sufficient statistics should establish a definite rate of morbidity for each line of industry. Morbidity in excess of this rate will indicate that something is wrong where it occurs. If the trouble cannot be ascribed to excessive fatigue or to poor ventilation or other unsanitary factory conditions it must be looked for in the workers' homes or in the community at large.

6. Common colds are the most prolific cause of morbidity not only in industry but in all walks of life. The total time lost on account of them is very great and the

discovery of better means for their control would be of immense benefit to humanity. The following rules for avoiding and curing common colds are partly from "Colds" by R. L. Cecil:

(*a*) Avoid spitters, coughers, and particularly sneezers.
(*b*) Avoid over-worry, over-work, and over-feeding.
(*c*) Look after your nasal passages, even if an operation be necessary.
(*d*) Get a maximum of fresh air, day and night.
(*e*) Get a maximum of sunlight, Winter and Summer.
(*f*) Breathe deep, as an exercise and as a habit.
(*g*) Exercise regularly and often, especially in Winter when you are likely not to.
(*h*) Wash a lot, especially your hands, and always before eating.
(*i*) Keep your hands away from your face; develop the habit.
(*j*) Use proper clothing and adapt it to the weather.
(*k*) Keep your feet dry, and drink lots of water.

Rules for Curing Colds.

(*a*) Rest in bed.
(*b*) Hot bath, hot drink, extra blankets.
(*c*) Check infection by local antiseptics.
(*d*) Eat less, and softer food.
(*e*) Blow your nose on paper napkins and burn them, —or
(f) Disinfect your handkerchiefs.

7. Besides the loss occasioned by absence due to sickness there is a very considerable loss due to the inefficiency of workers who do not consider themselves sick enough to stay at home. They are unable to work effectively themselves, they set a poor example to their fellow workers, and

their presence adds to the risk of infection of the entire force. No one but a physician is competent to say that such workers should be sent home.

8. The employment of an adequate medical staff is always advisable. Whenever the force is large enough, it will pay for itself in man-hours saved, and, in any event, it will promote smoother and more satisfactory operation on the part of the human machines under its charge.

INDEX

GRAPHIC CHARTS IN BUSINESS

HOW TO MAKE AND USE THEM

By

ALLAN C. HASKELL

With an Introductory Chapter by

RICHARD T. DANA

What is the first question that arises when you receive reports of your current month's income, expenses, output, collections, etc.?

Isn't it invariably—"What were they last month or last year?" In other words you desire comparisons. You want to know whether things are on the increase or decrease.

The next question is—"How much more or less?"

These questions can be answered more effectively by graphic charts than in any other way. If you make a graphic chart from two or more sets of figures that you want to analyze the graphic chart automatically shows you:

1. Whether the figures in one set are more or less than the figures in the other sets.
2. How much more or less they are, either in actual quantity or in percentage.
3. Whether the general tendency is to get closer together or further apart.
4. At just what point a transition from one set of conditions to another takes place.

A few moments' study of such charts will show an executive more about what his business is doing than hours of poring over figures and statistics. They give him quickly, concisely and clearly the information he needs for important decisions and effective control.

How these charts are made and their use in the advertising, accounting, sales, purchasing, etc., departments is fully explained in Graphic Charts in Business, $4.00, net, postpaid.

A request on your business letterhead will bring you the above book on 10 days' approval. No cost or obligation.

CODEX BOOK COMPANY, Inc.

461 EIGHTH AVE., NEW YORK, N. Y.

EARNING AND SPENDING

By

PROF. REID LAGE McCLUNG

Earning and Spending is the reprint of a series of radio talks on economics given by Dr. McClung through Station WJZ. The author has produced an exceptionally clear and simple description of the principles and method of operation of the Federal Reserve banking system. His treatment of the principles of market price making, the labor problem, the trust problem, the tariff, immigration, the railroad problem, taxation, price maintenance, social reform, etc., will add a great deal to one's information and in a most pleasant manner for the book is written in a very interesting style.

There are several charts—many in two and three colors—which give graphic pictures of economic trends, that are of great importance to every business man, such as cost of living changes, purchasing power of wages, wage earnings, immigration, etc.

208 pages—12 graphic charts

Price: $3.00, net, postpaid.

We shall be glad to send a copy for 10 days' free examination. There is no cost or obligation whatever. Just write the request on your business letterhead.

CODEX BOOK COMPANY, Inc.,

461 EIGHTH AVE. NEW YORK, N. Y.

INDUSTRIAL DEPRESSIONS

By

GEORGE H. HULL

Revised By

PROF. REID LAGE McCLUNG

"To assist business men in the application of these barometric facts to their own problems, to help to read the barometers and to interpret them in the light of sound economic theory, and to bring the various economic data up to date, are the main purposes of the present edition. It presents an analysis and solution of one of the main problems of economics, and offers an example of a method for the application of the barometers of industry to the problems of business."

340 pages—11 charts
Statistics of Pig Iron in U. S. from 1896 to 1925
Price: $5.00, net, postpaid

The best way to determine the value of this book to you is to go over it. We will gladly send you a copy without cost or obligation for a 10 days' examination if you will write a request on your business letterhead.

CODEX BOOK COMPANY, **Inc.**
461 EIGHTH AVE. NEW YORK, N. Y.