A.P. 1269B
(2nd Edition)

AIR MINISTRY

HANDBOOK
OF
PREVENTIVE MEDICINE

LONDON
HER MAJESTY'S STATIONERY OFFICE
PRICE £2. 0s. 0d. NET

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AIR MINISTRY

MAY, 1957

FOREWORD TO FIRST EDITION

THE aim of preventive medicine is to preserve and improve health by the interception or removal of all factors which may exert an adverse influence on individual well-being.

In the Royal Air Force emphasis is placed on the ultimate responsibility of commanders for the health of their men. An equally great responsibility rests on medical officers to advise their commanders of the measures necessary to protect the personnel under their care, as far as possible, against communicable disease and any defects of habit or environment which may impair their vitality, as well as measures to improve their efficiency even beyond what is accepted as normal.

It is of the utmost importance not only that loss of man hours through sickness should be kept to a minimum, but that all personnel on duty should be at the peak of their efficiency. That outmoded word debility has a real meaning when applied to an individual whose physical and mental vigour has been sapped by sub-clinical malaria or a diet lacking in vitamin B.

In all wars disease has been responsible for many more admissions to hospital than has enemy action. In Macedonia, during the war of 1914-18, 27 cases of disease, chiefly malaria, were admitted to hospital for every wounded patient; while in East Africa, where dysentery was the principal foe, the ratio was a high as 33 to 1. The Serbian Army was defeated by typhus, not by the Bulgars. In 1943 the incidence of malaria in certain islands in the South-West Pacific rose to 80 per 1,000 a week (over 4,000 per 1,000 per annum), while a similar incidence for dysentery was encountered in parts of Burma.

Medical recommendations may clash with strategical and tactical considerations and may therefore be impossible to fulfil. The ruthless removal of a native village from the outskirts of a military camp, however desirable from the viewpoint of the hygienist, may have to be renounced for political reasons. The only suitable ground for a landing strip may be alongside a malarial marsh. Compromise is often inevitable. It may not be possible to ensure an absolute minimum of avoidable disease, but the most strenuous efforts must always be made to reduce ill-health, and sub-health, to the lowest possible level, by applying the principles of preventive medicine which are set out in this publication.

H. E. WHITTINGHAM

Director-General of Medical Services
Royal Air Force

FEBRUARY, 1946

FOREWORD TO SECOND EDITION

SINCE the first edition of this publication was issued eleven years have passed. The aims of those practising preventive medicine remain unchanged, and the need for Royal Air Force doctors to maintain a high standard of knowledge and effort in this field is as great as ever.

This edition, like its predecessor, is an original compilation by medical staff of the Royal Air Force, entirely from their own experience or from the original work of others. The latter sources of information are gratefully acknowledged, and are listed on later pages. The form of layout is little changed and the contents of the first edition, revised where necessary, are largely contained in the first twelve chapters. New features include an introduction intended to give the station medical officer, for whom the book is primarily written, a clear indication of the organization for disease prevention in the Royal Air Force, and the relative duties of those concerned in its practice. Additional chapters have been added on mental health; occupational health, including that of aircrew; toxic substances; medical statistics; and the risks in handling radioactive substances, thereby giving an indication of the widening scope of Air Force medicine.

A number of appendices have been added, some of which contain data of relatively short-term application. The loose-leaf system will permit easy amendment.

Success in preventive medicine lies not only in reducing sickness rates but in the ability to improve mental and bodily function and maintain it at a high level of efficiency. This means that the medical officer should have a good knowledge of nutrition, environmental conditions, the value of exercise, and many other subjects which the average person does not often discuss with his doctor. In this publication there is much which will help the latter to make reasonable recommendations, although he must bear in mind that the successful preventive medicine practitioner does not merely apply regulations to a problem but ensures that advice he gives is practical and economical in the circumstances. Only by so doing will he achieve results, for his opinion will be respected, and therefore sought.

P. B. LEE-POTTER
Director-General of Medical Services
Royal Air Force

MAY, 1957

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INTRODUCTION

GENERAL

1. Preventive medicine is a subject with which the majority of Royal Air Force medical officers are closely concerned throughout their careers, but its range is such that few can be completely familiar with all its facets. Medical opinion is freely sought and advice must be given on a wide variety of problems: these may be elementary or may be intricate. The need to turn to a book of reference is not infrequent, but few, if any, standard public health textbooks cover the necessary range of problems in detail. Evidence of this is given by the list of sources from which material for this book has been collected. There are also problems peculiar to the Royal Air Force that have no published literature.

2. The object of this book is to provide a work of reference not only for unit medical officers but also for those holding more senior appointments. It has been the aim to include sufficient detail to cover both simple and advanced service hygiene subjects. As an introduction to these it is necessary to outline the basic concept and organization of R.A.F. preventive medicine.

R.A.F. PREVENTIVE MEDICINE

Concept of R.A.F. Preventive Medicine

3. The concept of R.A.F. preventive medicine is based on three principles:—

(*a*) A good preventive medicine programme is essential to the effectiveness of an air force.

(*b*) The ultimate responsibility for the health of his men lies with the commanding officer.

(*c*) The doctor is his commanding officer's medical adviser.

4. It follows that, if preventive medicine is to be successful, it calls for close teamwork between those in executive authority and their medical advisers. Disciplinary powers, on the one side, and expert knowledge on the other, are complementary.

Commanding Officers' Responsibilities

5. The commander of a force is required to pay particular attention to the health of his men (Q.R. 46). Commanding officers are responsible for the health and sanitary state of their stations; they are liable to incur grave responsibility if they ignore the advice of their medical officers on any medical or sanitary matter (Q.R. 62).

6. A commanding officer has powers of delegation (Q.R. 57). Under these he normally charges his senior administrative officer with the routine executive duties concerned with promoting health and preventing disease. In the main it will be with this officer that the unit medical officer deals, but he has the right of direct access to the commanding officer.

Medical Responsibilities

7. The medical officer is adviser to the commanding officer in all matters affecting health (Q.R. 1474). This provides wide scope, for there are few R.A.F. activities that have no health implications.

8. The medical officer bears full personal responsibility for the medical care of the sick or injured, but he has no executive powers outside his own section (except on a medical unit). He is, however, responsible to the commanding officer for the correct administration of his section.

9. The lack of executive powers by the medical officer is matched by the lack of medical knowledge on the part of those in executive authority. But since the latter carry the burden of responsibility, the medical officer is in duty bound to ensure that the advice he gives them is of high quality. The measure of his success will be the frequency with which his opinion is sought, and the confidence with which his advice is accepted and enforced.

ORGANIZATION

Chain of Administration

10. The Directorate of Hygiene and Research, on behalf of the Directorate General of Medical Services, Air Ministry, is responsible for the central administration of R.A.F. preventive medicine. Its broad functions are:—

(*a*) To advise other authorities within the Air Ministry on the health implications of R.A.F. policy.

(*b*) To formulate medical policy concerning the promotion of health and the prevention of disease within the Royal Air Force.

(*c*) To provide professional assistance in the implementation of such policy.

11. At command headquarters the principal medical officer is inter alia responsible, personally or through his deputy principal medical officer (hygiene), for:—

(*a*) Advising the air officer commanding-in-chief on all matters concerning the promotion of health and the prevention of disease within the command.

(*b*) Implementing Air Ministry medical policy on such matters, in the light of circumstances within the command.

(*c*) Providing professional assistance in the implementing of such policy.

12. At group headquarters, the senior medical officer's duties include:—

(*a*) Advising the air officer commanding on all health matters.

(*b*) Providing professional assistance in the implementing of command preventive medical policy.

13. The role of the unit medical officer has already been outlined. During the course of his duties he will have to make inspections and reports. He will have dealings with the hygiene detachment, hygienists, and the Air Ministry Works Directorate. He may require specialist help from, for example, the R.A.F. Institute of Pathology and Tropical Medicine, or from the School of Hygiene, M.T.E.

Inspections

14. The inspecting duties of principal medical officers are detailed in Q.Rs. 1455 and 1766.

15. In accordance with Q.R. 1482, the unit medical officer is required to inspect the station periodically. His findings have to be entered in a hygiene diary, which should also contain his recommendations for the correction of faults. This diary is passed to the commanding officer and provides him with regular information on the sanitary state of the station. Additional verbal or written reports may be made to the commanding officer when necessary. A schedule for station inspections and a specimen layout for the hygiene diary are in Appendix "A".

Reports

16. Each year the medical officer is required to prepare a report on the hygiene of his station. This is forwarded, through group, to command headquarters. Here all unit reports are consolidated and forwarded to the Air Ministry in accordance with Q.R. 1465. These reports are drawn up in a form notified by the Air Ministry each year.

17. Other reports may be specially called for, or may be initiated by medical officers when some event of especial epidemiological or other interest occurs. The attention of medical officers is drawn to A.P. 3184 (Manual of Service Writing and Office Management) as a guide on the preparation of reports.

Hygiene Detachment

18. A number of men, in proportion to the size of the station, are established as a sanitary detachment. They may be service personnel or civilians. This detachment carries out the routine work of keeping the station in a sanitary condition. The detachment is under the control of the commanding officer (Q.R. 1482), through the station warrant officer. The medical officer is responsible for advising in connection with the detachment's duties and for pointing out the fact when the standard of these is unsatisfactory.

Hygienists

19. Hygienists are the equivalent within the Royal Air Force of the civilian public health inspector. They are usually held on the establishments of commands and groups. They may carry out sanitary inspections of stations on the instructions of principal or senior medical officers; but a medical officer faced with a difficult sanitary problem may ask his command or group for a hygienist to visit and advise.

Air Ministry Works Directorate

20. The responsibilities of the Air Ministry Works Directorate include the design, construction, and maintenance at stations of buildings, and other structures, of roads, and of water, gas, electrical, heating, drainage, and sewerage services (Q.R., Chap. 23). Many hygiene problems have a works service aspect, and it is always advisable for the medical officer to keep in close touch with A.M.W.D. He should make use of their experience and technical knowledge before making any works service recommendations. He should in return be prepared to advise them on the medical aspects of building plans locally drawn up and of services such as water supply or sewage disposal.

15. In accordance with O.R. 1482, the unit medical officer is required to inspect the station periodically. His findings are to be entered in a hygiene diary, which should also contain his recommendations for the correction of faults. This diary is passed to the commanding officer and provides him with regular information on the sanitary state of the station. Additional verbal or written reports may be made to the commanding officer when necessary. A schedule for station inspection and a suggested layout for the hygiene diary are in Appendix "A".

Reports

16. Each year the medical officer is required to prepare a report on the hygiene of his station. This is forwarded, through group, to command headquarters. Here all unit reports are consolidated and forwarded to the Air Ministry in accordance with O.R. 1485. These returns are drawn up in a form notified by the Air Ministry each year.

17. Other reports may be specially called for or may be initiated by medical officers when some event of special epidemiological or other interest occurs. The attention of medical officers is drawn to A.P. 3164 (Manual of Service Writing and Office Management) as a guide on the preparation of reports.

Hygiene Detachment

18. A number of men, in proportion to the size of the station, are established as a sanitary detachment. They may be service personnel or civilians. This detachment carries out the routine work of keeping the station in a sanitary condition. The detachment is under the control of the commanding officer (O.R. 1482), through the station warrant officer. The medical officer is responsible for advising in connection with the detachment's duties and for pointing out the fact when the standard of these is unsatisfactory.

Hygienists

19. Hygienists are the equivalent within the Royal Air Force of the civilian public health inspector. They are usually held on the establishments of commands and groups. They may carry out sanitary inspections of stations on the instructions of principal or senior medical officers, but a medical officer faced with a difficult sanitary problem may ask his command or group for a hygienist to visit and advise.

Air Ministry Works Directorate

20. The responsibilities of the Air Ministry Works Directorate include the design, construction, and maintenance of all forms of buildings and other structures, of roads, and of water, gas, electrical, heating, drainage, and sewerage services (O.R. Chap. 32). Many hygiene problems have a works service aspect, and it is always advisable for the medical officer to keep in close touch with A.M.W.D. He should make use of their experience and technical knowledge before making any works service recommendations. He should in return be prepared to advise them on the medical aspects of building plans locally drawn up and of services such as water supply or sewage disposal.

CHAPTER 1

PERSONAL HYGIENE

INTRODUCTION

1. Personal hygiene aims at the formation of habits which will assist the body to function effectively. Most people realize the fundamental importance of cleanliness, fresh air, exercise, and regular habits, but a proportion fail to put their knowledge into practice. Lack of personal discipline, the root of which is often poor morale rather than ignorance, is more usually the cause of such neglect. However, there are people ignorant of the most elementary facts of personal health. Although the ideal is the inculcation of the right habits from an early age, health supervision and education remain essential to stimulate the lazy and instruct the ignorant of all ages.

PERSONAL CLEANLINESS

The Skin

2. Care of the skin is important in all climates, but particularly in the tropics. Surface accumulations of dirt and of natural secretions impair the natural functions of the skin and predispose to infection. They inhibit the natural bactericidal power of the skin, which, macerated by sweat, loses its specific barrier properties and eventually becomes a medium for the multiplication of fungi and bacteria.

3. Those serving in temperate climates should be advised to have a hot bath or shower at least twice each week, when the whole body should be washed thoroughly with soap. In hot climates a shower or bath should be taken at least morning and evening. Particular care should be taken in cleansing the armpits, crutch, cleft of buttocks, and toes, where skin diseases are so apt to start. Careful drying of these areas is also important, and the use of a dusting powder will help, especially in the tropics.

The Hair

4. The hair should be kept short and washed weekly. It should be brushed and combed thoroughly twice a day, to remove loose hair and dirt and to stimulate the scalp. Regular washing, brushing and combing discourage head lice, which thrive best when undisturbed. For this reason, women should be discouraged from adopting complicated coiffures likely to be spoiled by these measures and expensive to reconstruct.

The Teeth

5. The teeth should be cleaned at least night and morning, but ideally after every meal. A small brush with bristles of moderate stiffness is best. Brushing the teeth from side to side harms them and also the gums. The correct method is to brush in one direction only, over the gums towards the tips of the teeth at least six times. This enables the bristles to enter the spaces between the teeth and remove food particles. The gums also benefit by stimulation from the massage effect. Tooth paste is not essential; a mixture of equal parts common salt and bicarbonate of soda is as good.

PERSONAL HABITS

6. One aim of health education is to encourage the cultivation of good personal habits and to eradicate the bad. In advising men on this subject the first emphasis should be on regular sleep, regular meals and regular exercise. The wise use of leisure is another important factor.

7. For active young men seven to eight hours of sleep are necessary. This means going to bed at a reasonable time, as reveille is not variable. Full advantage should be taken of the food provided at meals. Indiscriminate eating between meals ruins the nutritional balance of any diet. The need for an adequate fluid and salt intake, especially abroad, is also important. The benefits of exercise require emphasis, as does the importance of developing the physiological habit of regular bowel movement. The reasons why it is important to wash the hands after going to the lavatory require explanation. This is of especial importance among food handlers, who should be the target of much propaganda on this subject. It is generally accepted that in moderation alcohol and tobacco do little harm.

EXERCISE

8. Exercise maintains good muscular tone and, by encouraging blood flow, stimulates the efficiency of all the organs of the body. The amount required depends on the age and physique of the individual. The virtue of exercise is not measured by quantity or violence. Sudden violent or prolonged exertion can be harmful to untrained persons but, moderated to suit personal needs and tastes, it is of the greatest value, physically and psychologically.

Organized Games

9. Organized team games are an integral part of service life. Everyone who can, should be encouraged to take part, but this alone will not meet the needs of all. There will be further scope for some of the remainder in the more individual type of game and in cycling or walking; for others alternative means of exercising must be arranged.

Other Forms of Activity

10. Drill and marching provide a modicum of exertion for most persons on a unit. There are also the compulsory and voluntary periods of physical fitness training, held under physical fitness instructors in the gymnasium or out of doors. As a last resort men can be taken out for a cross-country run, a run and walk exercise along a road, or even a route march.

11. The more men enjoy exercise the more benefit they will gain from it; compulsory participation should not, therefore, normally be enforced. Encouragement and opportunity will pay better dividends. The full value of exercise, especially the subsequent sense of well-being, will be lost unless it is followed by a bath, or shower and a rub-down. Time and facilities for this must be afforded, and exercise without changing into sports kit should be discouraged.

12. The medical officer and the physical fitness officer should work together to ensure that the right kind of exercise is available for men of varying physical ability and fitness. It is of the greatest value to a unit if the medical officer takes an active part in sport himself, so emphasizing precept by practice. In this way, too, he can observe the effects of different types of exertion on different individuals and so be in a better position to give sound advice.

CLOTHING AND BEDDING

Clothing

13. Two of the functions of clothing are insulation and protection. It must consequently be kept in good repair and clean. Airmen are issued with an adequate scale of clothing, which they are expected to keep in good repair by mending or replacement. For this purpose they receive a cash allowance. They are entitled to send to the laundry each week, at public expense, a bundle containing a fixed number of items of personal clothing. They may also have their uniforms and greatcoats dry cleaned free of cost from time to time. It is the duty of the executive to make sure that airmen take proper advantage of these facilities, but the medical officer should be prepared to advise if he considers that clothing is not being maintained at a proper standard of cleanliness and repair.

Bedding

14. Airmen are issued with pillow or bolster slips, sheets, counterpanes, blankets, and mattresses. The number of blankets allowed in temperate climates is five. This number can be increased in the interests of health, on the recommendation of a medical officer. Beds should be stripped daily and bedding aired. Medical officers should draw the attention of the executive to any neglect of this practice.

15. The frequency with which various items of bedding may be laundered at public expense is set out in A.P. 830, Vol. 1, Part 2, Leaflet B.24/2. It should be noted that, if the medical officer certifies it essential, more frequent laundering may be arranged. In addition, blankets should be steam disinfected on interchange between personnel (when sheets are not issued), on return to store, or when considered necessary by the medical officer. For details of service arrangements for disinfection, reference should be made to A.P.830, Vol. 1, Part 2, Leaflet B.24/5.

MEASURES FOR THE REDUCTION OF SKIN DISEASE

Incidence

16. Skin disease causes incapacity and loss of manpower quite out of proportion to its severity. This is especially so abroad, where the prevalence ranks high among diseases of all kinds.

Factors Encouraging Spread

17. Factors which encourage skin disease include lack of personal cleanliness, poor sanitary facilities, indifferent condition of clothing and facilities for laundry, overcrowding, promiscuity, climatic conditions, and lack of general bodily resistance. The majority of these are amenable to improvement by obvious administrative measures.

Control

18. **Early Diagnosis.** Early diagnosis is the best means of preventing spread from an infected case. To ensure this, frequent skin inspections are necessary and men should be instructed to report sick as early as possible when skin infections have been contracted.

19. **Admission.** Admission to sick quarters for any but the most severe skin infections may appear drastic. However, this step reduces the chance of spread to others and usually produces quicker results than ambulatory treatment. Although isolation is not recommended as a routine measure, there are occasions when it must be considered.

20. **Other Steps to Prevent Spread.** Every effort must be made to prevent spread by ensuring that men with infective skin diseases do not play games, use other people's towels or washing gear, and realize that they are, in fact, infectious. The use of roller towels should be discouraged. Duck boards in showers and the floors of ablutions should be scrubbed daily with a solution of sodium hypochlorite. The common use of unlaundered sports gear must be prohibited. The hygiene of barber shops requires supervision.

Climate

21. The most important action in reducing skin disease abroad is the selection only of men with healthy skins for service in tropical and subtropical climates. Once abroad it is important that due attention should be paid to acclimatization. Thereafter all should be done to make the environment comfortably cool by any means practicable. Personal hygiene is of particular importance in hot and humid climates.

SPECIFIC INFESTATIONS AND INFECTIONS

Pediculosis

22. Man may be infested by the body louse, head louse, or crab louse. These and their habits are described in Chapter 11. Excoriation of the skin may result from the scratching of irritating louse bites. This leads to secondary infection, louse rash, and adenitis.

23. **Body Lice.** Adults live three to five weeks, their habitat being the folds and seams of clothing; they pass to the body only to feed. Eggs are also laid in these places, being fastened to the fibres of the clothing by a chitinous cement. After hatching, the nit case remains as evidence of infestation.

24. **Head Lice.** Head lice closely resemble body lice, but live in the hair of the head. The occiput is most usually infested and cervical adenitis is a common sign of this. The eyebrows are sometimes affected. The eggs are attached to the hair in the same way as to clothing fibres. Head infestations are commoner in women than men: men's hair is usually shorter and so easier to comb, brush, and wash.

25. **Crab Lice.** These are usually found in the hair of the pubic and perianal regions, less commonly on the abdomen, chest, and eyebrows. The bite of this species leaves a bluish black macule. Transmission, as for the other types of louse, is by personal contact or the use of verminous clothing or bedding.

26. **Prevention.** Personal cleanliness, early diagnosis and treatment, disinfestation of clothing and bedding and discouragement of promiscuity are the main lines of prevention.

Scabies

27. Scabies is caused by the itch mite, *Sarcoptes scabei*, the female of which burrows into the horny layer of the skin to lay her eggs. Burrowing may be at a speed of up to five millimetres a day, two or three eggs

being laid daily in the burrow for up to two months. The eggs hatch in three to four days. Fortunately under ten per cent. of eggs laid reach the adult stage.

28. The diagnosis of scabies is based on the typical distribution of the lesions, itching, especially at night, and the finding of burrows; it can be confirmed by digging out a mite from the end of a burrow with a needle. The spread of scabies is often difficult to trace because from the time of infestation up to two months may elapse before symptoms occur, and during this time the individual is himself infectious. Little spread of scabies occurs in the Service; it is essentially a domestic disease and is mainly imported from the home or other civilian source. The incidence of scabies appears higher among service personnel because frequent skin inspections and awareness of the disease result in a higher rate of diagnosis.

29. Theories on the method of its spread have blamed bedding, communal towels, infected clothing, and other inanimate objects. Bedding can transmit scabies, but the occupation of a bed slept in the previous night by an infected person results only in a risk of 1 in 200 of infection. The number of mites in the great majority of infections is small. They are highly susceptible to temperatures below that of the skin and are immobilized at normal room temperatures, so they are not likely to migrate to fomites in any numbers and to survive there. Mellanby concludes that nearly all transmission is by personal contact. In young adults a high proportion of cases are contracted venereally, more often than not the relationship being marital. Often it is children who first introduce the infection into households and pass it on to their mothers. Transmission is also encouraged by any other prolonged skin contact, where warmth promotes the activity of the mite, such as dancing or holding hands. Routine disinfection of bedding and clothing is consequently not essential, but may be advisable for psychological reasons when steam disinfection is the method of choice. The mite will also die in two days under normal drying cupboard conditions and ordinary laundering will kill it.

30. **Prevention.** There is little the individual himself can do to avoid scabies. It occurs among those with the highest standards of cleanliness and in the best regulated homes. Early diagnosis and treatment are of first importance. If there is a case in a household, the whole family should be treated. Although symptomless, other members may be in the silent but infectious stage. Men should be educated to report as soon as they suspect they have scabies or any other skin disease, and even in spite of the difficulties, efforts should be made to establish and, if possible, treat personal contacts.

Impetigo

31. All the various types of impetigo are troublesome in a service community. One example is the high incidence of adult bullous or tropical impetigo among troops in the Far East during the Second World War. Another is that cases may be resistant to treatment and cause considerable wastage of manpower. Unless adequate measures are taken the disease can become widespread, causing much inconvenience and unpleasantness. Prevention follows the general control measures already mentioned.

32. **Adult Bullous or Tropical Impetigo.** This condition is characterized by superficial blebs with little or no surrounding inflammation or lymphadenitis. Lesions are common in the axilla, rare on the face. The causal organism is a coagulase positive *Staphylococcus aureus*. Secondary infection by streptococci follows. The underlying cause is loss of skin resistance due to maceration by persistent sweating. The infecting strains of staphylococci are not those normally found on the skin or in the nose, and appear to have epidemic characteristics. Spread is from case to case.

33. **Impetigo Contagiosa.** Impetigo may be due to infection by haemolytic streptococci initially, followed by secondary staphylococcal infection, or may be due from the beginning to staphylococci. The haemolytic streptococci concerned belong to Lancefield Group A and cause lesions on the face and scalp. The lesions consist of thick, yellow, sticky crusts, surrounded by a zone of erythema and associated with lymphadenitis. In children, especially abroad, lesions may also occur on the legs in the form of crusted ulcers. The disease is highly contagious, spread being from case to case. Infection by *Staphylococcus aureus* results in a more persistent type of vesicular lesion, with some flat varnish-like crust formation. The periphery extends as the centre heals giving a circinate appearance. There is little surrounding erythema or lymphadenitis. The condition is even more contagious than streptococcal impetigo. Staphylococci may also cause a superficial pustular folliculitis, known as Bockhart's impetigo. Staphylococcal impetigo is commoner in adults than in children and is particularly prevalent in hot dry summers. The predisposing factor is irritation of the skin of the face by the sun and by shaving. It is thus common in unacclimatized troops abroad. Seborrhoea may also contribute to a lowered skin resistance. It is possibly an autogenous infection by staphylococci carried in the nose. There is enough serological evidence that sycosis barbae is a similar autogenous infection, hence the importance of treating the nasal carrier state. In spite of its largely autogenous nature, the disease can be spread from case to case.

Tinea

34. The commonest skin disease among troops is tinea in one form or another. In the tropics constant sweating causes maceration of the skin, which increases the prevalence of this complaint. Tinea pedis, tinea cruris, tinea corporis, and tinea of the hands occur in that order of frequency.

35. **Tinea Pedis.** The lesions are localized to the area of the foot having no hair follicles or sebaceous glands, and thus devoid of fatty acid secretions. The infection can be caused by several types of fungi and carriers of these are found having no clinical signs of infection. Conversely, in conditions clinically identical with tinea pedis, sometimes no fungi are found. Cases may be due to saprophytic infection when general host resistance is low, but infections may be followed by temporary local immunity, the waning of which is followed by relapse. On the other hand, infections may be exogeneous encouraged by maceration of the skin due to sweating, frequent swimming, and a humid climate. Other predisposing factors are the wearing of heavy impermeable footwear and dirty socks. The role of bath mats, the floors of showers and swimming baths in spreading infection is not accepted as important by all. It is nevertheless advisable to take steps to check this potential route of

infection. The most effective measures are, however, early diagnosis and treatment, the encouragement of healthy feet by cleanliness, frequent change of socks and, so far as possible, the avoidance of excessive sweating.

36. **Other Tineas.** Although tinea corporis and tinea cruris are caused by a number of fungi different from those of tinea pedis, infection may be autogenous and secondary to the latter, mutation of the fungi occurring. However, exogenous infection also occurs. The predisposing factors and the means of prevention are closely parallel to those of tinea pedis.

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CHAPTER 2

WATER

ADMINISTRATIVE ASPECTS OF WATER SUPPLIES

Responsibility for Water Supplies

1. The Ministry of Public Building and Works (M.P.B.W.) is responsible for the design, construction, and maintenance of water services on R.A.F. stations (Q.R. 1743). At units M.P.B.W. representatives undertake the operation of water supply and storage plant (Q.R. 1775).

2. The commanding officer is responsible for economy in the use of water and for precautions in the event of frost. For these purposes the clerk of works is required to provide him with a complete plan of the water system (Q.R. 1774).

3. Before water is introduced from a hitherto unused source of supply, the command works adviser is to inform the principal medical officer, who should arrange sampling and analysis to determine its fitness for use (Q.R. 1774).

Responsibility for Purity of Water Supplies

4. The ultimate responsibility for the purity of the water supply lies with the commanding officer, under the terms of Q.R. 62, but it is the duty of the medical officer to satisfy himself that the quality of the drinking water is satisfactory and that the measures to prevent contamination at all stages of delivery and storage are adequate (Q.R. 1484).

Sampling of Water Supplies

5. The medical officer is required to arrange for periodical samples of the unit water supply to be taken as follows :—

(*a*) Water from public supply companies or undertakings—annually.

(*b*) Water from Ministry of Defence wells, boreholes, or other sources—quarterly.

6. These samples are to be sent to the R.A.F. Institute of Hygiene for bacteriological analysis. The regulations concerning sampling technique and dispatch are described later in this chapter (paras. 77 to 88).

7. Special analyses are likely to be necessary in the event of :—

(*a*) An outbreak of illness, possibly due to water-borne infection.

(*b*) Suspicion of possible contamination, if faults in storage tanks or piping are detected.

(*c*) The installation of new pipework or storage tanks or repairs to existing installations.

(*d*) The addition of water from a new source to existing supplies.

8. Chemical analysis may be required for new supplies, and will be necessary if there is suspicion of contamination by harmful inorganic matter, for example, by lead.

9. The medical officer should keep in close touch with the M.P.B.W. staff, to ensure that tests are carried out in accordance with their regulations on the levels of residual free chlorine in the water, and that these levels are satisfactory.

WATER SUPPLIES IN GENERAL

Introduction

10. A good water supply should provide water in sufficient quantity and of wholesome quality; the qualitative aspect is of overriding importance for health. Cholera became epidemic in England in 1831, and outbreaks occurred in London from 1848 to 1865. During this time Doctor John Snow evolved the theory of water-borne disease. The removal of the handle of the Broad Street pump cut short one outbreak and confirmed his views, but the bacteriology of water-borne infection was not understood until the subsequent discoveries of Pasteur, Koch, and others.

11. In England cholera is now unknown, but typhoid fever is still a potential threat as a water-borne infection. It is also possible that poliomyelitis can be water-borne. Abroad, however, cholera, dysentry, enteric, protozoal, and helminthic infections are all significant risks if the purity of water supplies is neglected. Ignorance or neglect of this risk has resulted in epidemics of disastrous proportions in military campaigns which might otherwise have been successful. It is, therefore, an essential precaution to regard all water supplies as unsafe unless adequately treated.

12. The problems of quantity, purity and distribution of water differ to some extent on permanent stations, and in the field. The basic principles, however, are of general application, so are described in relation to permanent or semi-permanent stations. The details of their application in the field are treated separately (paras. 60 to 76).

Amount of Water Required

13. Besides drinking water, supplies are needed for ablutions, laundry, cooking, the washing down of vehicles and the replenishment of their radiators, for sanitary purposes, including the flushing of closets and urinals, as well as for other technical and industrial purposes. Compared with the average volume for all purposes per head per day of 45 gallons in an industrial town and 30 gallons in a rural area, the following are accepted for domestic purposes in the Royal Air Force at home :—

Stations with water-borne sewerage	— 30 gallons
Stations without water-borne sewerage	— 10 gallons
Hospitals	— 50 gallons
Temporary camps	— 5 gallons
Temporary camps (drinking and cooking purposes only)	— 1 gallon

Sources of Supply (Fig. 1)

14. At the majority of R.A.F. stations, the water supply is from local authority mains or from Ministry of Defence boreholes. Occasionally other sources such as springs, wells, or rivers are used, particularly for small dispersed units or sites.

15. **Surface Sources.** Stream or river water in uninhabited country may be safe but if the country is populated pollution soon occurs. Sewage and other forms of pollution from villages and towns, through which they flow, render the water of streams and rivers unfit for domestic use without treatment, irrespective of appearance ; contaminated water may be discoloured and turbid or bright and sparkling. The quality of the water of lakes approximates to that of the streams or rivers flowing through

(A.L.4, Jan. 66)

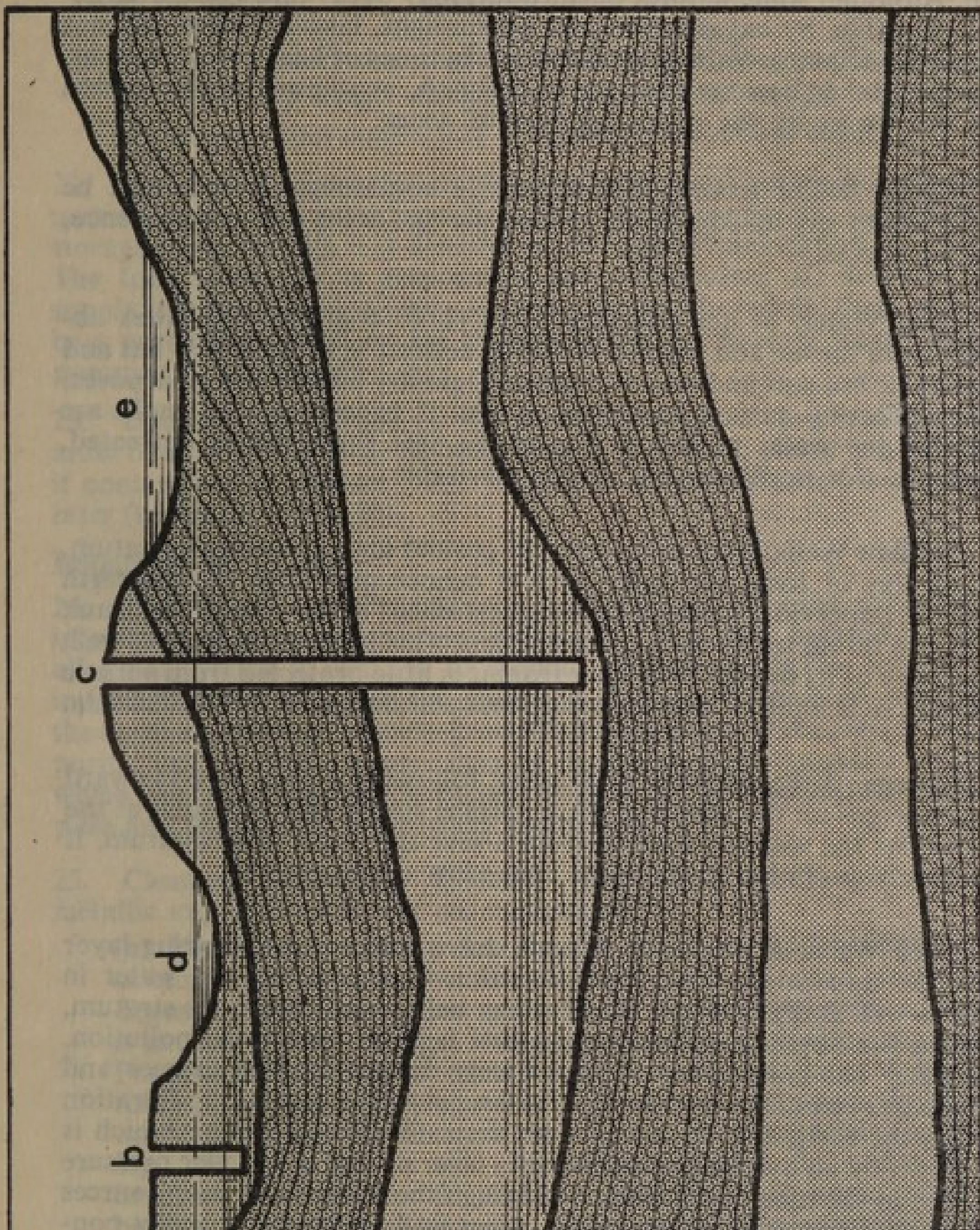


FIG. 1. WATER SOURCES

a—Spring
b—Shallow well
c—Deep well
d—Stream
e—Lake
f—Permeable strata
g—Impermeable strata

them. Although some natural purification may occur through the settlement of solids, by oxygenation and by sunlight, lake water should not be used for drinking without sterilization. In times of heavy rain, streams, rivers and lakes become even more polluted, as impurities are washed from the banks by the increased flow of water.

16. **Ponds.** Water from ponds is heavily contaminated and must be treated. Many dry up completely in summer and are not, in consequence, reliable sources.

17. **Rain Water.** Water collected from roofs contains impurities absorbed from the air and washed from the collecting surface. It is flat and unpalatable but soft and very suitable for laundry and washing purposes. If the collecting surface is protected and if proper storage tanks are provided, the water would, in theory, be safe for drinking untreated. But in practice sterilization is always advisable.

18. **Shallow Wells.** Rain soaks into the ground until it reaches a stratum, such as clay or rock, through which it cannot pass. The porous earth above the impervious stratum becomes saturated with water; a well sunk into it will fill up to the level of saturation. This is called a shallow well, irrespective of its depth. The water from it is little protected from surface pollution, so is unfit for domestic purposes without previous sterilization.

19. **Springs.** If the impervious stratum, following a level or downward trend, emerges on the side of a hill, a surface spring may be found at the outcrop. As the water is derived from above the impervious stratum, it is subject to pollution in the same way as in a shallow well.

20. **Deep Wells.** A deep well extends down into a water-bearing layer below the uppermost impervious stratum. Consequently the water in the deep well is drawn from that flowing below an impervious stratum, which in the absence of fissures protects it from immediate pollution. This water has come from comparatively distant surface sources and any possible remote contamination will have been removed by filtration through the earth and by storage. An artesian well taps water which is held down by an overhead impermeable layer so that it is under pressure and rises in the tube of the well. Although the water from deep sources may be safe for drinking purposes, deep wells must be properly constructed and maintained to exclude contamination. The bore should have a watertight lining, extending from about a foot above the surface of the ground to the first impervious stratum. The ground, for six feet around the well, should be concreted to exclude polluted surface water. A watertight and dustproof cover is necessary and should always be kept locked. Water should be drawn from the well by means of a pump, the suction pipe of which is a permanent fixture. Use of the old oaken bucket (or any bucket) is a method certain to cause contamination sooner or later. An area around the head of the well should be fenced off to prevent the entry of animals. No possible source of contamination, such as a manure heap or a cesspool, should be allowed within 100 feet of a well.

Distribution of Water

21. Water is brought from the source of supply to the household tap by the distribution system, which is made up of :—

(*a*) Trunk mains conveying water from the source to the waterworks for purification.

(*b*) Service reservoirs where water is stored after purification.

(*c*) Secondary mains distributing water from service reservoirs.

(*d*) Service pipes connecting premises to secondary mains.

22. On stations where the supply is from the local authority, secondary mains convey the water, usually from service reservoirs, to high-level storage tanks whence it is distributed throughout the station by gravity. The local authority is responsible for purification. If, however, the supply is from an Air Ministry source, such as a borehole, there will also be a purification plant on the station, where the water is treated before pumping to the storage tanks.

23. Detailed information on the water distribution system of a station must be readily available in order that a systematic check can be made if contamination occurs. The technique of such a check is described later (see paras. 43 to 50).

Impurities in Water

24. Pure water rarely occurs in nature. Rain absorbs atmospheric impurities; surface water collects bacteria, dust and organic matter of all kinds, which it conveys to streams, rivers and lakes; sewage and industrial effluents add to the pollution. Prolonged percolation through the earth and storage in underground water-bearing strata tend to restore purity, but inorganic matter may be dissolved from the strata through which the water passes. Consequently it is not safe to regard water as pure and wholesome until it has been treated.

25. **Chemical Impurities.** Chemical impurities consist of hardness, metallic impurities and war gas contaminants.

(*a*) Hardness is mainly due to the sulphates and carbonates of calcium and magnesium. It causes wastage of soap and forms deposits in hot water pipes and boilers. Temporary hardness, which is caused by bicarbonate, is readily removed by boiling the water. Permanent hardness is caused by sulphates and cannot be thus removed. Water softening on a large scale is not normally carried out in the Royal Air Force if the water is intended solely for drinking, but small plants are sometimes supplied for reducing the hardness of water used for cookhouse appliances, engine radiators, boilers, and hot water systems. Alternatively, to prevent deposits in pipes and boilers the water may be treated with sodium hexametaphosphate (Calgon).

(*b*) Lead may be dissolved out from lead pipes and cisterns if the water contains dilute acid, as is common in soft, peaty water supplies. Water containing more than 0·1 p.p.m. of lead is generally considered to be unsafe for human consumption.

(*c*) Zinc may be dissolved out from galvanized pipes but does not constitute a danger in the small quantities that usually appear in solution.

(*d*) Iron in solution in the water in small quantities may lead to the incrustation of pipes. Larger quantities will make the water unpalatable.

(*e*) Copper is now sometimes employed for water pipes and this metal may be taken into solution, with resultant green staining of basins, baths, and washing materials if an alkaline soap is used The permissible limit is 1·4 p.p.m.

PURIFICATION OF WATER SUPPLIES

26. The following are the stages of large-scale water purification :—

(*a*) Storage.

(*b*) Sedimentation.

(*c*) Filtration.

(*d*) Sterilization.

Storage and Sedimentation

27. By storage in reservoirs or lakes, gross turbidity is removed and colour improved. In addition, abrupt changes in quality are prevented and the bacterial flora inhibited. For example, in stored water S. typhi are heavily reduced in numbers in one week and eliminated in from six to eight weeks. Storage thus greatly reduces the load on the later steps in purification.

28. Subsequent clarification of water by sedimentation in settling tanks reduces the suspended solid and bacterial content yet further. This is effected by the addition of a clarifying powder, such as aluminium sulphate or aluminoferric, which forms a heavy flocculent precipitate that carries suspended matter with it to the bottom of the tank.

Filtration

29. Filtration may be carried out by the slow sand or rapid sand methods, but mechanical filtration is now more usual.

(*a*) *Slow Sand Filtration*. Purification is a biological process. A zooglial film, which grows on the surface of the sand filter, arrests suspended solids and many of the bacteria in the water. This is an efficient method, but the filter beds occupy a considerable area and renovating the filter medium takes time and labour; the beds tend to freeze up in cold weather and the rate of filtration is slow (50 gallons per square foot per day).

(*b*) *Rapid Sand Filtration*. A coagulant such as aluminium sulphate is added to the water, which is then forced under pressure through the filter medium. The coagulant, after combining with the alkali content of the water, forms a gelatinous colloidal film which enmeshes suspended solids and bacteria. The filtration is thus chemical, not biological. It has none of the disadvantages of the slow sand method, but the pH of the water may require adjustment to ensure proper coagulation. The rate of filtration may be up to 130,000 gallons per square foot per day.

(*c*) *Mechanical Filtration* (Fig. 2). This is a development of the rapid sand method. The filter consists of a candle, constructed of metal washers, kept separate by small bosses on their surfaces, or of spirally wound metal wire, on a hollow core. To the water is added diatomaceous earth (kieselguhr) which, as the water is forced through the candle, is deposited on its surface as a highly effective filtering layer. The candles are mounted in batteries, the number being according to the amount of water and rate of filtration required.

Sterilization

30. Nearly all suspended solids are removed by storage, sedimentation, and filtration. The water will still, however, contain bacteria, which in bulk water supplies must be destroyed by chemical treatment. For the Royal Air Force the most suitable method is chlorination, of which there are several forms.

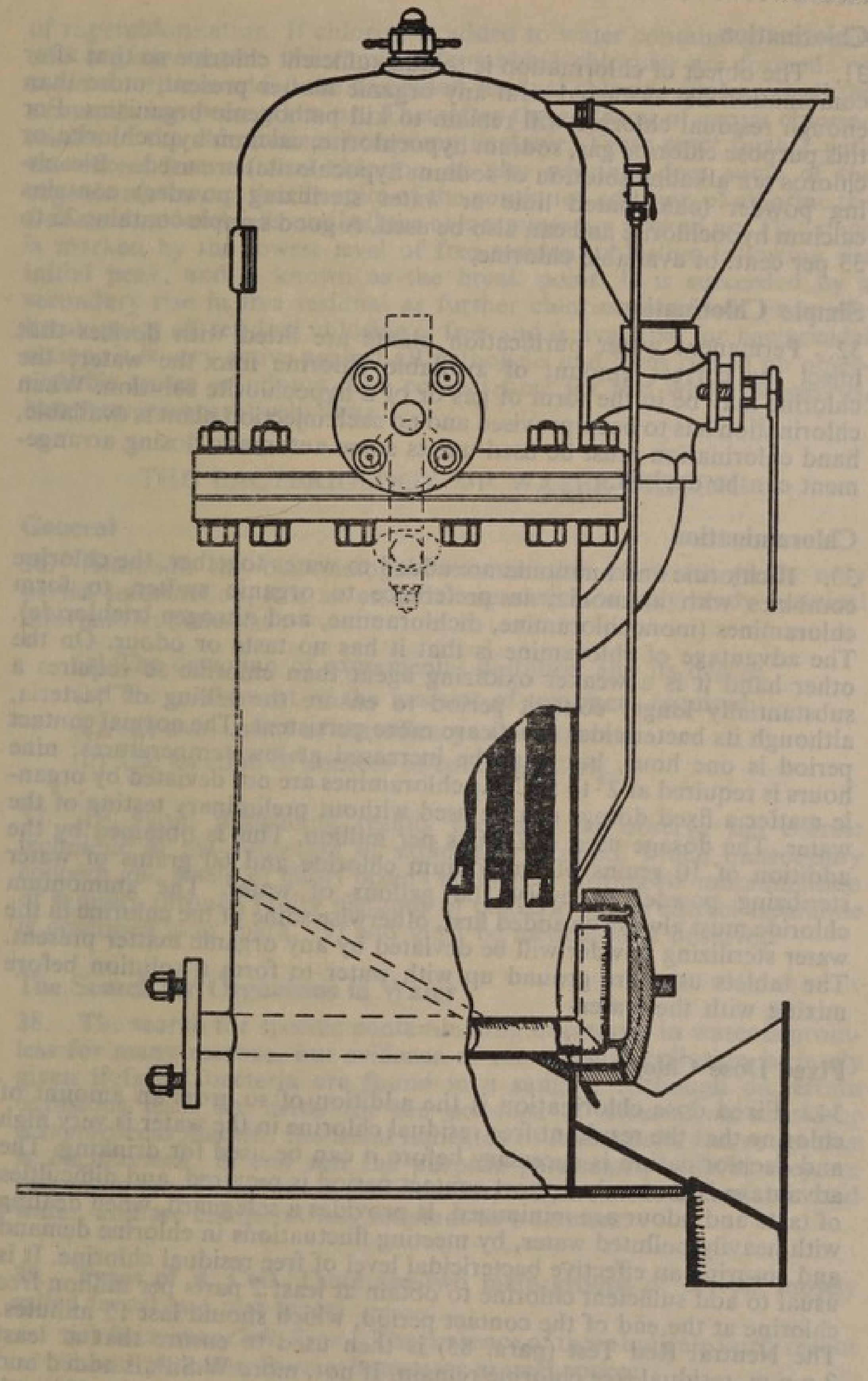


FIG. 2. MECHANICAL FILTRATION

THE METAFILTER

(Sectional Elevation)

Chlorination

31. The object of chlorination is to add sufficient chlorine so that after combination has occurred with any organic matter present, more than enough residual chlorine will remain to kill pathogenic organisms. For this purpose chlorine gas, sodium hypochlorite, calcium hypochlorite, or chloros (an alkaline solution of sodium hypochlorite) are used. Bleaching powder (chlorinated lime or water sterilizing powder) contains calcium hypochlorite and can also be used. A good sample contains 25 to 33 per cent. of available chlorine.

Simple Chlorination

32. Permanent water purification plants are fitted with devices that inject the correct amount of available chlorine into the water; the chlorine may be in the form of gas or of a hypochlorite solution. When chlorination has to be improvised and no such injection plant is available, hand chlorination must be used unless some automatic dosing arrangement can be devised.

Chloramination

33. If chlorine and ammonia are added to water together, the chlorine combines with ammonia, in preference to organic matter, to form chloramines (monochloramine, dichloramine, and nitrogen trichloride). The advantage of chloramine is that it has no taste or odour. On the other hand it is a weaker oxidizing agent than chlorine so requires a substantially longer contact period to ensure the killing of bacteria, although its bactericidal effects are more persistent. The normal contact period is one hour, but must be increased at low temperatures; nine hours is required at 2° to 5°C. As chloramines are not deviated by organic matter a fixed dosage can be used without preliminary testing of the water. The dosage used is 2 parts per million. This is obtained by the addition of 10 grains of ammonium chloride and 60 grains of water sterilizing powder to every 100 gallons of water. The ammonium chloride must always be added first, otherwise some of the chlorine in the water sterilizing powder will be deviated by any organic matter present. The tablets used are ground up with water to form a solution before mixing with the water.

Fixed Dose Chlorination

34. Fixed dose chlorination is the addition of so great an amount of chlorine that the resultant free residual chlorine in the water is very high and dechlorination is necessary before it can be used for drinking. The advantage is that only a short contact period is required, and difficulties of taste and odour are minimized. It provides a safeguard, when dealing with heavily polluted water, by meeting fluctuations in chlorine demand and ensuring an effective bactericidal level of free residual chlorine. It is usual to add sufficient chlorine to obtain at least 2 parts per million free chlorine at the end of the contact period, which should last 15 minutes. The Neutral Red Test (para. 85) is then used to ensure that at least 2 p.p.m. residual free chlorine remain. If not, more W.S.P. is added and the test repeated. Once the minimum residual of 2 p.p.m. is achieved, the water is dechlorinated by adding 1 gramme of sodium thiosulphate per 100 gallons.

Break-Point Chlorination

35. Break-point chlorination is a more scientifically controlled method

of superchlorination. If chlorine is added to water containing ammonia and organic matter, chloramines (combined chlorine) are formed. As more chlorine is added the combined residual chlorine rises until all the ammonia has been taken up. Thereafter the addition of excess chlorine results in the chloramines becoming unstable. These react further with the excess free residual chlorine, as also possibly does some of the organic matter, so that in spite of the continued addition of chlorine the free residual level falls until all the chloramines are broken up. This stage is marked by the lowest level of free residual chlorine, following the initial peak, and is known as the break point. It is succeeded by a secondary rise in free residual as further chlorine is added. From the break point all residual chlorine is free and is available for bactericidal action; it is very active against all pathogens and gives rise to no objectionable tastes or odours. The contact time for this whole process is, however, comparatively long.

THE BACTERIOLOGY OF WATER TESTING

General

36. Although the bacteriological examination of water yields only partial information, it is an essential measure to supply ready practical information aimed at :—

(*a*) The detection of excremental pollution and its degree.

(*b*) The assessment of the amount of treatment required.

(*c*) The assessment of the efficacy of treatment.

(*d*) The location of sources of contamination.

37. To avoid misleading results the need to observe the correct technique of the collection of samples is stressed. Much unnecessary concern and waste of effort occurs every year, owing to contamination of samples through faulty methods of collection. The correct technique is described later (para. 79) and must be meticulously observed.

The Search for Organisms in Water

38. The search for specific contaminating organisms in water is profitless for many reasons, but evidence of excremental pollution is clearly given if faecal bacteria are found in a sample. Although on certain occasions tests are made for the presence of *Clostridium welchi* or *Streptococcus faecalis*, the usual indicator of faecal pollution sought for is *Bacillus coli*. *B. coli* suit the purpose particularly well as they are present in large numbers in the intestine, are persistent in contaminated water, and are comparatively resistant to treatment.

39. **Types of B. Coli.** There are two main groups of *B. coli*, loosely called faecal and non-faecal :—

(*a*) *Bacterium Coli, Type* 1. The presence of these indicate fairly recent faecal pollution from a human or animal source.

(*b*) *Intermediate-Aerogenes-Cloacae Group* (*I.A.C. Bacterium Coli*). These occur occasionally in human or animal intestines. More commonly they are derived from such sources as the packing of pipe joints, washers, or hessian. Their presence indicates inefficient chlorination, faults in the distribution system, or impending serious faecal pollution. If they are found the cause merits further investigation.

40. **Standards.** Theoretically every supply should have its own standard, based on the results of frequent previous examinations. The following criteria are, however, generally accepted :—

	Coli-Aerogenes Organisms per 100 *ml.*		
Class 1.	Highly satisfactory	—	Less than 1
Class 2.	Satisfactory	—	1 to 2
Class 3.	Suspicious	—	3 to 10
Class 4.	Unsatisfactory	—	10 or more.

41. Chlorinated water and unchlorinated water from deep wells should all qualify for Class 1. If they do not they must be regarded as unsatisfactory and the cause must be sought and remedied.

42. In sewage the *B. coli* count is approximately 10 millions per 100 ml. If the count in water is negative in 100 ml., faecal pollution must be less than 0·0000001 per cent.

ACTION IN THE EVENT OF BACTERIAL CONTAMINATION

43. Immediately contamination of a water supply is suspected for any reason, the commanding officer must be informed and the following recommendations made :—

(*a*) All water for drinking, teeth washing, food preparation (unless sterilized in the process), and the cleansing of crockery must be boiled. Extra chemical treatment should be delayed until investigations have been made.

(*b*) Alternative supplies must be considered. This may include the transport of water from a safe source by water vehicle.

44. At the same time the clerk of works should be informed and his help enlisted. The first requisite in tracing defects is the plan of the station water distribution system. If the supply is obtained from an outside undertaking, they too should be immediately consulted. The competent medical authority should also be notified.

45. **Pressure.** The pressure at suitable sluice valves should be checked to eliminate the possibility of fractured mains.

46. **Inspection.** All storage tanks should be inspected to see that none are potential sources of contamination. The station as a whole should also be surveyed, in conjunction with the water plan, to ascertain whether there is any likely point of contamination. In this connection a plan of the station sewage system should be scrutinized in relation to the water system.

47. **Sampling.** Sampling should then be carried out at suitable points:—

(*a*) To check suspected sites of contamination.

(*b*) To localize any so far undetected site of contamination.

48. **Where to Take Samples.** Points should be chosen from the plan, between the source or point of entry to the station, and the furthest tap supplied. These points should be such that uncontaminated branching mains and service pipes can be eliminated in turn and the site of contamination eventually identified. It will also be worth while first to check the residual chlorine figure at these points. Any comparatively major drop would indicate abnormal pollution and so concentrate the area of search.

49. Special precautions should remain in force until investigations are complete, remedial action taken, and bacteriologically satisfactory samples obtained.

Safety of New or Previously Contaminated Water Supplies

50. When a new water system has been constructed, an existing one repaired or extended, or when there has been contamination, some time will elapse before the resultant supply is safe. Potential or actual contamination must be eliminated by flushing the system, including storage tanks, with hyperchlorinated water containing 10 to 50 parts per million of chlorine. Such a supply must be run to waste until convincing bacteriological evidence of purity has been obtained.

SWIMMING BATHS

General

51. The provision of swimming and bathing facilities adds greatly to the amenities of a station, particularly abroad. In the interests of health the design and maintenance of swimming baths must be of a high standard; improvisations are to be discouraged. All swimming baths should:—

(*a*) Be constructed of smooth, light-coloured material that shows up any dirt and will be easy to clean.

(*b*) Have impervious surrounds from which water will not drain back into the bath.

(*c*) Have a scum channel at the correct height.

(*d*) Be provided with changing facilities including showers, foot baths, lavatories, and duckboards.

(*e*) Have a water purification plant.

(*f*) Be protected from access by dogs and rats.

Purification

52. The water of swimming baths becomes rapidly polluted by dirt and organisms from the bathers and the surrounds. The water of little-used pools in the open air may purify themselves naturally if there is a constant flow of water or if they are of such a size that dilution and storage can minimize contamination. Constant emptying and refilling with fresh water, if cleansing is carried out while the bath is empty, provides initially satisfactory conditions. However, the result is temporary. To keep bacterial contamination within bounds very frequent changes of water are required and this is expensive. Even hand chlorination, performed each night, has little delaying effect on the build-up of pollution. The only satisfactory means of purification is by continuous filtration, aeration, and chlorination.

Continuous Filtration Method

53. There are various forms of plant designed to purify swimming bath water by continuous filtration but the principles are similar for all.

54. **Filtration.** For efficient filtration the water must first be made alkaline; coagulants are then added and it is pumped continuously through a rapid sand filter. To obtain really clear water it is most important that the pH should be adjusted so that the coagulant functions with

the maximum efficiency. The optimum values rest between 7·2 and 8·0 To achieve this it may be necessary to add small quantities of soda ash or lime. The coagulant used is aluminium sulphate or aluminoferric at a dosage of 1 to 2 grains per gallon. Rapid sand filtration is carried out normally at a speed of 200 gallons per square foot of sand per hour. The size of the filters should be arranged to ensure that the turnover period for the bath contents does not exceed four hours.

55. **Aeration.** Aeration restores the oxygen content in the water, so improving its appearance and oxidizing properties; it is an adjunct to filtration. It is normally carried out by passing the water through a chamber into which air is blown by a compressor. In open-air swimming baths ornamental fountains or cascades are often substituted. In such cases chlorination should be carried out after aeration. In heated baths the water should be raised to a temperature of 72°F. by means of calorifiers. The injection of steam is undesirable.

56. **Chlorination.** Simple chlorination is normally used with a dosage that should aim at 0·2 parts per million free chlorine in all parts of the pool and not more than 0·5 parts per million at the inlet ducts in the shallow end.

Standards of Purity

57. When practical the chlorine level and the pH value of the water should be checked daily by the attendant. Periodic samples should also be taken for chemical and bacteriological analysis. These should be collected at least 15 minutes after the last bather has left the water. Analysis may be carried out every three months when the bathing load is heavy or if there are grounds to believe that the plant is not functioning efficiently. Accepted standards are:—

(*a*) The water should appear bright, clear, and colourless. The clarity should be such that a 19 S.W.G. platinum wire can be seen at a depth of six feet.

(*b*) On heating to 80°C. and shaking, the water should be odourless.

(*c*) The free chlorine content of the water issuing from the plant should be 0·2 to 0·5 parts per million.

(*d*) The water should be alkaline to methyl orange but not to phenolphthalein (pH approximately 7).

(*e*) Nitrates should be absent.

(*f*) Albuminoid ammonia should not exceed 0·2 to 0·25 parts per million and oxygen absorbed should not be more than 2·5 parts per million.

(*g*) Bacterial colonies should not exceed 200 on agar after incubating one c.c. of water at 37°C. for four hours.

(*h*) *B. coli* and *Cl. welchi* should be absent in 100 c.c. of water.

Algal Growths

58. Heavy growths of algae may occur in reservoirs, water tanks, and swimming baths, especially in summer. They are harmless but spoil the appearance of the water. They also impart a scented, earthy, or fishy flavour to the water. Chlorination will inhibit the growth of algae. Growth will also be prevented by dosing the water with copper sulphate at the rate of two to ten pounds per million gallons of water, depending on the time of year and the luxuriance of the growth.

Abnormal Tastes in Water

59. In slightly chlorinated water a flavour of iodoform or chlorophenol may develop. This is caused by the combination of chlorine and phenolic compounds, derived in towns from pollution by tar washings from roads and by the products of coal combustion, or in the country from salicylate containing plants. This can be prevented by using chloramination or super-chlorination followed by dechlorination as the method of water purification.

WATER SUPPLIES IN THE FIELD

General

60. It is sometimes necessary to use water from uncontrolled sources such as lakes and rivers, either to supplement permanent supplies or to provide the main supply under field conditions. All water obtained from such sources must be sterilized before use. When the sterilizing process is carried out either by chlorination or chloramination a residual respectively of 0·5 parts per million free or 2 parts per million combined chlorine is required before it may be declared fit for drinking.

61. In addition to sterilization, the organization of water supplies in the field involves selection of a source, the establishment of water points at the source and on the camp, as well as the transport and distribution of the requisite quantities.

Selection of Source

62. Water sources normally available in the field consist of lakes, rivers, streams, springs, and wells. Their characteristics are described in paras. 14 to 20. Although all water in the field must be sterilized, the degree of pollution of a potential source should be assessed and if there is a choice the least contaminated should be selected. Irrespective of purity, however, the capacity of the source to meet the essential water requirements may well be the overriding factor. The following points should be observed in selecting a source:—

(*a*) Proximity to camp site.

(*b*) Accessibility.

(*c*) Presence of animal life.

(*d*) Absence of possible sources of pollution in the form of agricultural land, industrial premises, sewage disposal works, or other field encampments.

Water Points

63. Water points are set up in the field at the selected sources; from them water is distributed after treatment. The selection of water points is governed by accessibility and relative freedom from local pollution. A survey of the area around the chosen sources must be made to ensure that in these respects the best point has been selected. When the point has been finally chosen it should be suitably signposted and fenced off to protect it from contamination by animals or unauthorized personnel. A well drained hard standing should be constructed for water vehicles, and adequate roads laid to the area when practicable. Personnel must be prohibited from bathing and washing themselves or their clothes anywhere near the source, particularly upstream when it is a river. Points must also be arranged in the camps for the issue of water for drinking and domestic purposes.

Distribution

64. In the field, water is transported and distributed by mobile tenders normally fitted with pumping and filtering equipment and by means of 8-gallon galvanized iron containers fitted with taps and lids. The latter are used for drinking water storage in small sections such as hospital wards and M.I. rooms. The mobile tenders are of 200- and 350-gallon capacity and may be supplemented by canvas tanks or improvised containers. They are described in paras. 92 to 105.

Purification

65. The method adopted for the purification of water in the field depends on the quantity required, the resources available, and the urgency with which it is needed. Treatment is carried out in two stages, first clarification and then sterilization. Clarification consists of sedimentation followed by filtration.

Sedimentation

66. Sedimentation may be natural or assisted by chemicals. Natural sedimentation is not normally of much value in the field owing to the time required for completion. Water must be stored in tanks for a minimum of four to five days for suspended solids to precipitate naturally. For complete sedimentation 30 to 60 days are required.

67. **Chemically Assisted Sedimentation.** This process is used when water is supplied in bulk from a turbid source. A storage tank is filled with water and in the centre a muslin bag containing clarifiying powder is suspended so that it is half-submerged. The powder consists of aluminium sulphate two parts and sodium carbonate one part; the dosage is three to five grains of powder per gallon. By rendering the water alkaline, the sodium carbonate ensures the formation of a floc consisting of aluminium hydroxide. The floc spreads outwards over the surface of the water in the tank until the whole is covered with a gelatinous film, which is heavier than water and sinks taking all suspended solids with it to the bottom. This process takes about four to five hours.

Filtration

68. **Sand Filter.** Slow sand filters can be effectively improvised. One method utilizes two barrels or drums of different sizes. The smaller drum has a perforated bottom and is set inside the larger drum on a bed of sand. The lower two-thirds of the space between the walls of the drums are filled with sand. The effectiveness of this sand as a filter is enhanced by placing a layer of clarifying powder on its surface. Water is poured into the space between the drums and percolates through the sand up into the centre drum. The filtered water may then be sterilized chemically in situ or may be drawn off into another tank for further treatment.

69. **Cloth Filter.** The Millbank individual filter is a green canvas bag pointed at the lower end; it can be folded and carried in a pocket. It provides a simple means by which an individual can filter his own supply of drinking water. The user collects the filtered water in his water bottle as it runs from the filter bag and then sterilizes it. Individual cloth filters can be improvised from a handkerchief or a piece of cloth and should be used in the same way.

70. **Mechanical Filter.** Mechanical methods using kieselguhr as the filter medium have been devised for field use. The basic principles of mechanical filtration are described in para. 29(*c*). The appliances concerned range from the single candle midget metafilter intended for use by small parties in the field, to mobile water tenders and purification plants with multiple candle filters. As a working guide approximately 100 gallons of water per hour can be passed through one square foot of mechanical filter surface.

Sterilization

71. **Fixed Dose Chlorination.** Sterilization of water supplies in the field, with the exception of drinking water in aircraft tanks, is carried out by means of fixed dose chlorination. This method, which is combined with the Neutral Red Test described in paras. 85 and 86 has the advantage that preliminary estimation of the required quantity of water sterilizing powder is not necessary. A fixed amount of powder is added to the water and left for the minimum contact period of 15 minutes. If after this period the amount of free chlorine has been sufficient to sterilize the water it will also bleach the dye from the Neutral Red Test reagent. If the amount of free chlorine has been insufficient further quantities of water sterilizing powder must be added and the test repeated until the water is shown to be fit to drink. A minimum contact period of 30 minutes is required to kill the cercariae of schistosomes.

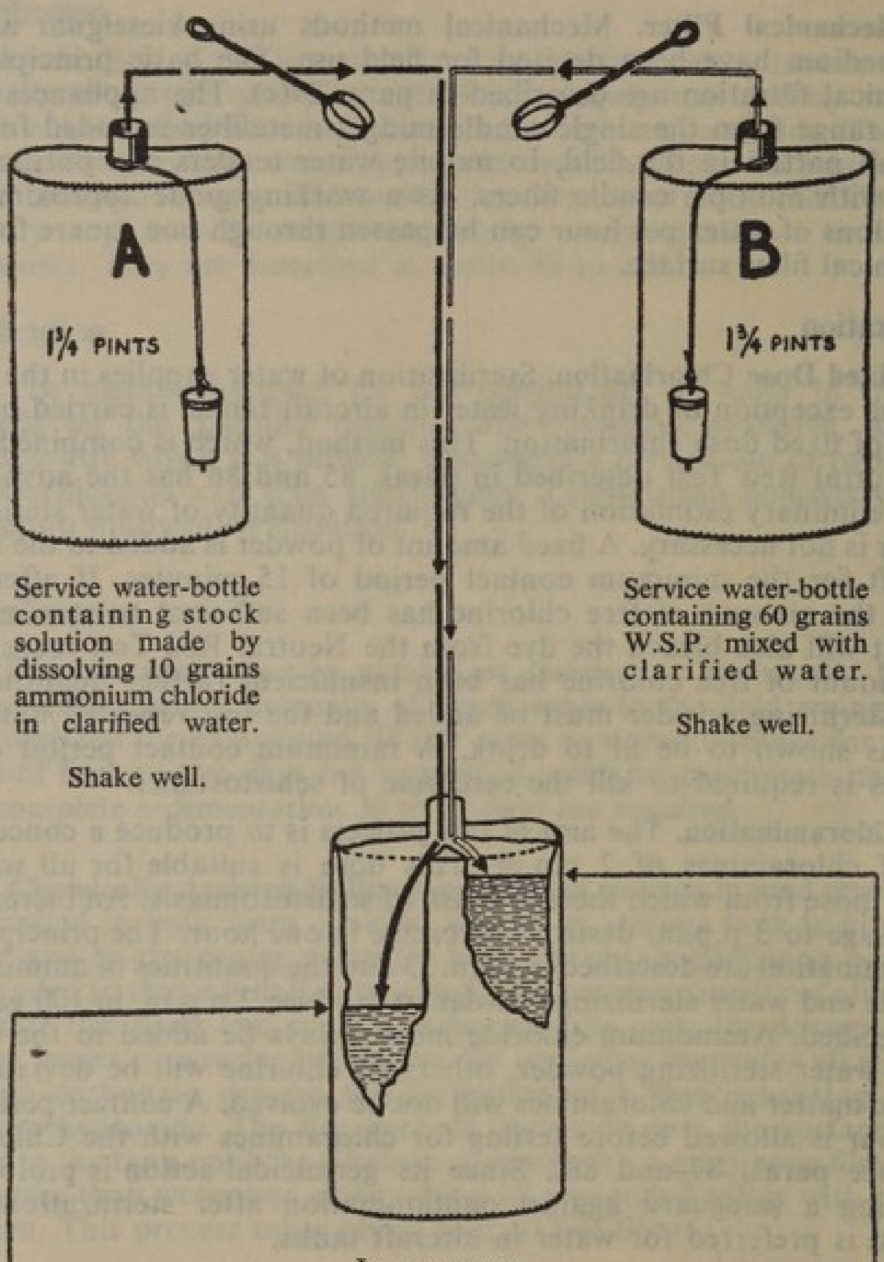
72. **Chloramination.** The aim of this process is to produce a concentration of chloramines of 2 p.p.m. This dose is suitable for all waters, except those from which there is a risk of schistosomiasis. An increase in the dosage to 3 p.p.m. destroys cercariae in one hour. The principles of chloramination are described in para. 33 and the quantities of ammonium chloride and water sterilizing powder to produce 2 p.p.m. in 100 gallons are specified. Ammonium chloride must always be added to the water before water sterilizing powder, otherwise chlorine will be deviated by organic matter and chloramines will not be evolved. A contact period of one hour is allowed before testing for chloramines with the Chlorotex Test (see paras. 87 and 88). Since its germicidal action is prolonged, providing a safeguard against contamination after sterilization, this method is preferred for water in aircraft tanks.

73. **Two-Tank Method.** The two-tank method of purification consists of sedimentation in the first tank and sterilization in the second tank. The sedimentation is assisted by a floc, the formation of which is described in para. 67. The water is siphoned into the second tank and sterilization carried out by any of the methods described in paras. 32 to 34.

74. **Boiling.** The sterilization of water by boiling is suitable only for small quantities. The water should be boiled for at least 10 minutes.

75. **Water-Bottle Chlorination.** The outfit consists of a small tin containing two bottles. In one are 50 water sterilizing tablets. The other contains sodium thiosulphate detasting tablets coloured blue. To sterilize the contents of a water bottle, which should if possible first be clarified, a white tablet is added and the bottle shaken vigorously. At the end of a contact period of 30 minutes a blue detasting tablet is added and after shaking to dissolve the tablet the water is fit for drinking.

76. **Two-Bottle Chloramination Method** (Fig. 3). Two water bottles labelled "A" and "B" are filled with clarified water. Into "A" are placed two 5-grain tablets of ammonium chloride and into "B" 60 grains of water sterilizing powder. The chemicals are dissolved in both bottles by thorough shaking. Each man half-fills his water bottle with clarified



INSTRUCTIONS

1. Half fill water-bottle with clarified water and add one scoop ammonium chloride solution A. Shake well.
2. After charging with ammonium chloride, fill up bottle with clarified water and add one scoop W.S.P. mixture B. Shake well.
3. Do not use sterilized water before one hour has elapsed.

FIG. 3. WATER STERILIZATION—TWO-BOTTLE METHOD

water and to it is added one scoopful (30 grains) of the ammonium chloride solution in water bottle "A". The bottle is then corked and well shaken. It is then filled to just below the neck with clarified water and one scoopful of the chlorine solution from the stock bottle "B" is added. The water bottle is then shaken thoroughly and allowed to stand for one hour. At the end of this period the water is fit for drinking. If there is any risk of schistosomiasis, 15 grains of ammonium chloride and 90 grains of water sterilizing powder should be added to bottles "A" and "B" respectively.

WATER SAMPLING

General

77. The occasions when water sampling is required are enumerated in paras. 5 to 8. It is stressed that trouble taken in using the correct technique of sampling will be repaid ; the investigation of apparent contamination, due to incorrect sampling, is very much more tedious in the long run. When a sample is to be taken the superintendent of works should be informed and his advice requested on suitable sampling points. His help should also be enlisted in obtaining the necessary information that must be sent to the laboratory with each sample. The arrangements for water sampling are to be supervised personally by the unit medical officer.

78. **Sample Bottles.** Water should be collected :—

(*a*) For chemical analysis in a Winchester Quart bottle.

(*b*) For bacteriological analysis in a sterilized 8-ounce bottle.

At home these bottles are supplied by the R.A.F. Institute of Hygiene, abroad by the appropriate laboratory. They may be sent on request or on the routine dates allotted by the Institute to various stations. If it is necessary in exceptional circumstances for bottles to be prepared at units, a Winchester Quart should be rinsed out with dilute sulphuric acid, then rinsed with the water to be sampled until all traces of acid are removed. Stoppers should be of glass or freshly boiled cork ; bottles that have contained ammonia must not be used. Eight-ounce bottles should be boiled for 30 minutes. A new cork, also boiled for 30 minutes, should be fitted, using sterile forceps. A crystal of sodium thiosulphate should be placed in the bottle before corking to neutralize the chlorine in the sample water.

79. **Sampling Technique.** If simultaneous samples are required for chemical and bacteriological examination, they must be taken from the same sampling point. Before filling, Winchester Quarts should be rinsed with the sample water. In the taking of samples for bacteriological examination, every precaution must be taken to avoid contamination of the mouth or cork of the eight-ounce bottle.

Samples from Piped Supplies

80. For routine examination, samples should be taken from the point where the water has run furthest in the pipes from the storage tanks. The selected tap is cleaned thoroughly, dirt from its mouth being removed with a plug of lint or gauze. The mouth is then flamed for one minute with a spirit lamp, and the water turned on to flow to waste for five minutes before the sample is taken. Taps with leaking joints should not be selected for sampling, as the water trickling over the outside may contaminate the contents of the sterile bottle. The cork and neck of the bottle should be flamed before the sample is taken.

Samples from a Well

81. When samples are taken from a well the pump should be operated for at least five minutes before the water is collected. The mouth of the pump or the delivery pipe should be cleaned and flamed in the same manner as a tap. When it is necessary to take a sample from the body of the well itself the technique described below should be followed.

Samples from Rivers, Reservoirs, and Lakes

82. To take a sample of water from any of these sources, a stout piece of string is secured tightly around the neck of the bottle in such a way as to leave a short and long end. The short end should be weighted to immerse the bottle below the surface of the water. The longer end should be several feet in length so that the operator can control the depth of the bottle. A second piece of string should be attached to the stopper so that it can be jerked out when the bottle is immersed. In this way contamination from surface scum can be excluded.

Dispatch of Samples for Analysis

83. All samples should be packed in the containers supplied and in the United Kingdom dispatched to :—

Officer Commanding,
Institute of Hygiene, Medical Training Establishment,
R.A.F., Halton
Aylesbury, Bucks.

These samples should be labelled "Water Sample, With Care, Urgent". Samples for chemical analysis should be sent by passenger train and labelled accordingly. Samples for bacteriological examination should be dispatched by unregistered parcel post ; when this cannot be arranged they should be packed in sawdust and ice and sent by passenger train. Samples should not be sent to the laboratory at the week-end.

84. **Information.** All samples must be accompanied by the following information which is required for analytical and record purposes :—

(*a*) Name of Station.
(*b*) Date and hour of collection.
(*c*) Source of supply (public, Ministry of Defence bore-hole, spring, river, well, etc.).
(*d*) Method of collection.
(*e*) Geological characteristics of soil or sub-soil.
(*f*) Nature and distance of evident or possible source of pollution.
(*g*) Rainfall during previous week (nil, small, moderate, or great).
(*h*) Any special treatment the water has received (boiling, chlorination, softening, or clarification).
(*j*) Reason for taking sample.
(*k*) Signature of officer sending the sample.

Neutral Red Test

85. **Apparatus.** The apparatus (Fig. 4) is called the Case, Water Testing and Sterilization, Neutral Red Method (Stores Ref. 9A-01210). It is a box containing :—

(*a*) Two white plastic cups (⅓ pint each).

(*b*) One bottle of Neutral Red Tablets.

(*c*) Five stirring rods in a wooden holder.

(*d*) Two brass scoops (30 grains each).

(*e*) One tin of Water Sterilizing Powder (W.S.P.).

(*f*) One bottle of detasting tablets.

(*g*) Instructions for use.

86. **Application.** The apparatus is used in the combined operation of fixed dose chlorination and neutral red testing. It is emphasized that the exact procedure detailed in the following sub-paras. must be observed.

(*a*) Add to the filtered water four scoopsful of W.S.P. for every 100 gallons.

(*b*) Mix thoroughly and leave for fifteen minutes.

(*c*) Turn on all delivery taps and allow the treated water to run to waste for fifteen seconds. Fill a white cup with the treated water.

(*d*) Place one neutral red tablet into the filled cup and crush it completely with a clean stirring rod.

(*e*) Allow to stand for five minutes.

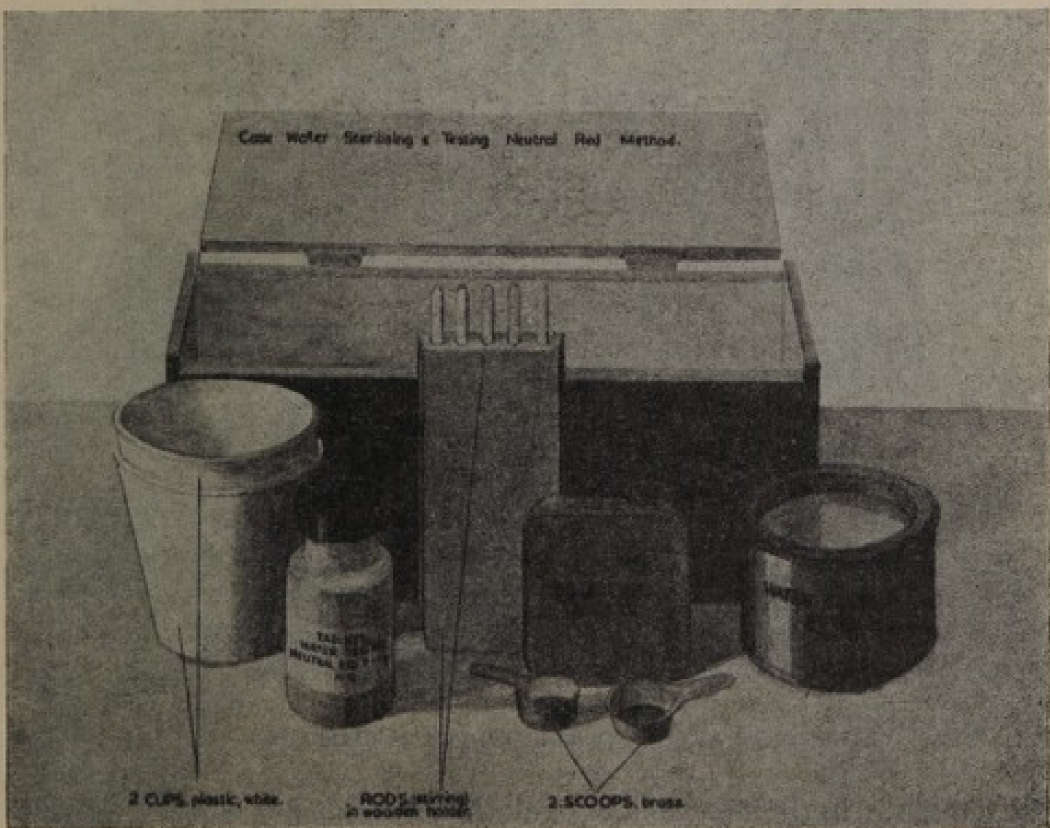


FIG. 4. CASE, WATER TESTING AND STERILIZATION—NEUTRAL RED METHOD

(*f*) If the water is colourless or yellow it is safe to drink. If the water is red it is unsafe to drink, therefore add another two scoopsful of W.S.P. for every 100 gallons of water in the tank and repeat stages as at sub-paras. (*b*) to (*e*). If the water turns red continue repeating the process until the test gives a colourless or yellow result.

(*g*) Immediately prior to issue crush and dissolve detasting tablets (four per 100 gallons), in a little of the purified water and pour the solution into the tank.

Chlorotex Test

87. The Chlorotex Test Case contains two 50 c.c. glass flasks, one bottle of reagent, a colour chart, a 5 c.c. pipette, and a stirring rod (Fig. 5). The test is used to determine the amount of residual free or combined chlorine in water and is the only satisfactory test after chloramination.

FIG. 5. WATER TESTING OUTFIT (CHLOROTEX)

88. To perform the test, 50 c.c. of sterilized water are placed in one o the glass flasks and 5 c.c. of reagent in the other. The water from the flask is then poured into the second, stirred, and allowed to stand for five minutes. The colour produced is then compared with the graduated colour chart and the amount of combined residual chlorine read off in parts per million. If a deep blue colour is obtained the amount of

chloramine is in excess of 1 p.p.m.; the extent is revealed by a further test made with 25 c.c. of the water to which 25 c.c. of water known to be free from chlorine has been added. Comparison with the chart will then give a reading which when doubled will give the amount of combined residual chlorine in that sample. Greater concentrations of chloramines can be detected by further suitable dilutions. The diluted reagent when mixed with water containing no residual chlorine produces a bluish efflorescence which should not be confused with a true colour reaction.

Orthotolidine Test

89. The object of the orthotolidine test is to detect the presence of residual chlorine. The reagent used is orthotolidine. About an inch of treated water is placed in each of two test tubes, one of which is for use as a control. One drop of orthotolidine solution is added to one tube only and well mixed. If residual chlorine is present a yellow reaction will occur. When the colour is faint it should be compared with the control test tube.

Lovibond Comparator

90. The Lovibond Comparator consists of a bakelite case, a brightness screen fitted in a holder, two 10 c.c. tubes, and a colour disc. When testing for free chlorine residual an "Orthotolidine Disc" is used. The test is for determining the amount of residual chlorine in treated water and as such is a refinement of the orthotolidine test. Ten c.c. of the water to be tested are placed in each of the test tubes supplied, which are then placed in the comparator (see Fig. 6). Three drops of orthotolidine solution are added

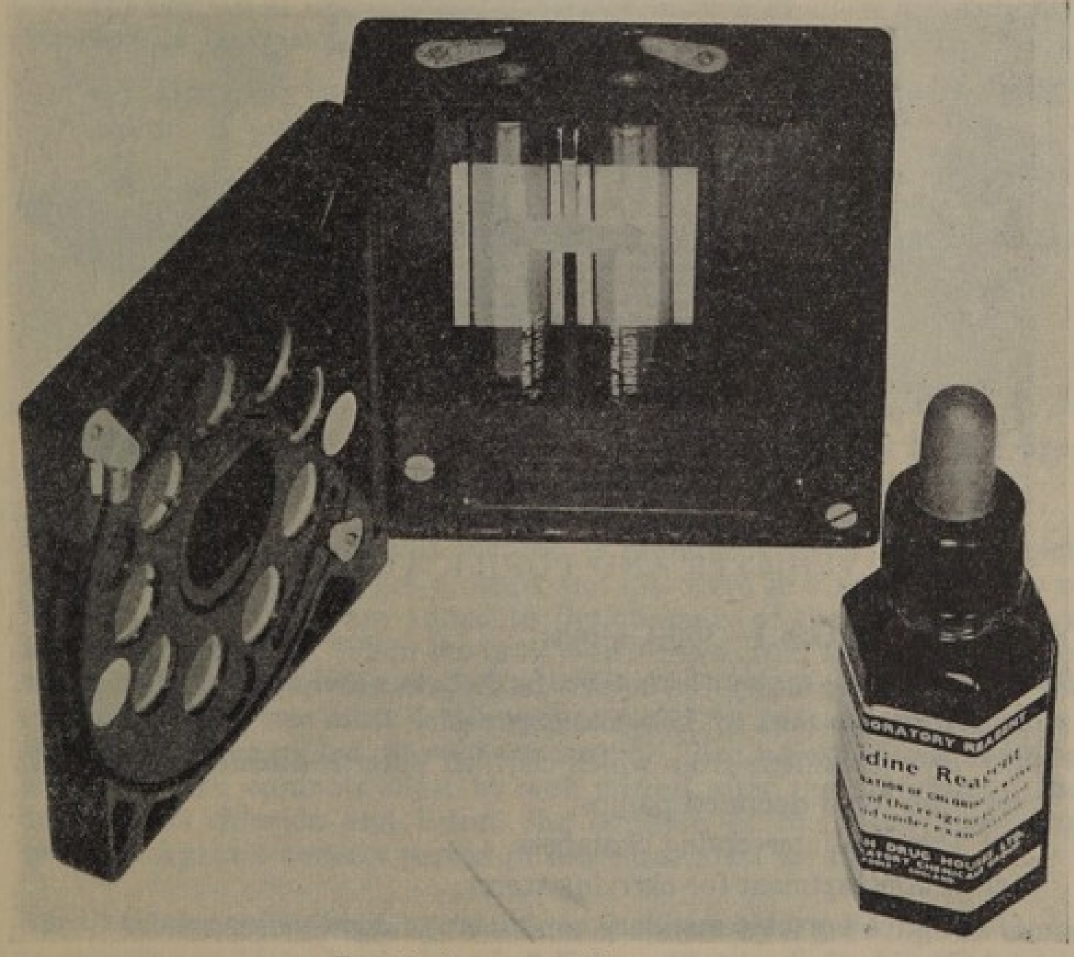


FIG. 6. LOVIBOND COMPARATOR

to the water in test tube No. 2. If residual chlorine is present, a yellow reaction will occur. The comparator is then closed and test tube No. 2 viewed through the aperture. The disc is rotated until the colours viewed through the apertures are identical, when the amount of residual chlorine in parts per million is shown in the lower right-hand corner of the front of the comparator. If the water contains nitrates a yellow reaction will occur even though residual chlorine may not be present.

Tests for Chemical Poisons in Water

91. An outfit known as Case Water Testing, Poisons (9a-C1220) is supplied for detecting chemical poisons which may be found in water supplies. A detailed list of procedures is contained in the case for the detection of certain more common heavy metals, cyanide, and chemical warfare agents (Fig. 7).

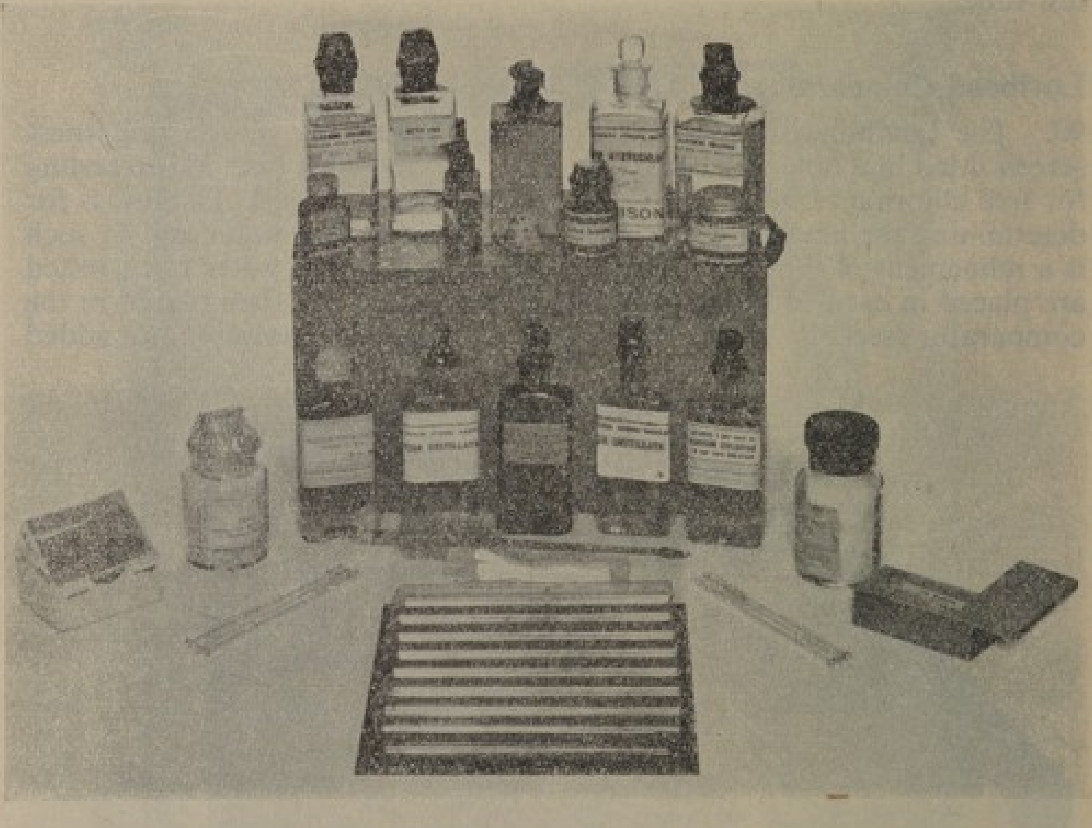


FIG. 7. CASE, WATER TESTING, POISONS

WATER VEHICLES AND PURIFICATION APPARATUS

Water Tender (G.S.)—350-Gallons

92. The plant is mounted on a Bedford chassis and consists of:—

- (*a*) A storage tank of 350-gallons capacity.
- (*b*) Two metafilters from which clarified water is directed to the tank.
- (*c*) Two hand-operated pumps.
- (*d*) Two grit-intercepting chambers.
- (*e*) A compartment for carrying stores.
- (*f*) Twelve portable auxiliary containers of eight gallons each.
- (*g*) Suction hose with filters and floats.

93. **Pumps.** The pumps are of the "Zwicky" double-acting type. On later models a power-operated pump has been installed. Each pump is arranged to feed its own filters and can be operated to backflush the opposite filter. Both pumps working together at a steady rate of 25 strokes a minute with raw water containing a fairly light suspension of solids will fill the tank in just over 1½ hours. The power-operated pump can fill the tank in about 40 minutes.

94. **Filters.** Two metafilters are fitted to this plant. The mode of operation is described in para. 29(*c*). The correct dosage of kieselguhr is six ounces. Four cups from the Neutral Red Test Case when filled to the brim equal six ounces of kieselguhr. The delivery pipes from the filters join together at a three-way control cock situated at the top of the tank and form one combined inlet of filtered water.

95. **Filtration.** To operate the filters the following procedure is carried out:—

(*a*) The suction hose is connected to the grit chamber.

(*b*) The strainers and cork floats are attached to the free end of the hose, which is anchored in the middle of the source of supply well clear of the bottom.

(*c*) The drainage cock under the grit chamber is closed.

(*d*) The near-side filter is isolated by adjusting the three-way cock at the top of the tank.

(*e*) The filter drainage cock is closed.

(*f*) The tap at the head of the filter is opened to allow first runnings to run to waste.

(*g*) The filter is charged with six ounces of kieselguhr in half a gallon of water.

(*h*) Pumping is started.

(*j*) When first runnings are clear the three-way cock is turned to pass the water into the tank.

(*k*) The filtrate running tap is closed.

(*l*) The procedure is repeated for the offside filter.

96. **Chlorination.** Sterilization of the water is carried out by the fixed dose method described in paras. 85 and 86.

97. **Chloramination.** If this method is preferred, seven 5-grain tablets of ammonium chloride are crushed and dissolved in a small quantity of filtered water. These are added to the contents of the tank when it is about one-third full. When the tank is two-thirds full, seven scoopfuls of water sterilizing powder are mixed into a thin paste and added to the contents. The water must be allowed to stand for at least one hour after the tank has been filled. Should the tank be filled before chloramination is started, the contents must be well stirred after the addition of the ammonium chloride and before the addition of the water sterilizing powder. Again a contact period of one hour must be allowed.

98. **Maintenance.** Clogging of a filter is shown by a growing resistance to pumping and later by the blowing of the pressure relief valve. When this

occurs the filter bed should be dropped and then re-formed in the following manner:—

(*a*) Pumping is stopped.

(*b*) The filter is isolated by adjusting the three-way control cock.

(*c*) The filtrate running tap is opened.

(*d*) The cock at the bottom of the filter is opened for a few seconds and then closed.

(*e*) An interval of two minutes must be allowed for the bed to fall from the packs.

(*f*) Pumping is restarted until the first runnings are clear.

(*g*) The three-way cock is turned to the tank.

(*h*) The filtrate running tap is closed.

99. **Removal of the Filter Bed and Flushing of the Packs.** If the procedure detailed above does not relieve the obstruction, the filter must be flushed as follows:—

(*a*) Pumping is stopped and the drainage plug to the filter is removed.

(*b*) The filter is completely drained.

(*c*) The three-way control cock is adjusted so that filtrate from the opposite filter is directed through the one being flushed.

(*d*) Pumping is resumed until first runnings are clear.

(*e*) The filter is recharged as in para. 94.

100. **Cleansing the Filter.** The filters should be cleaned daily. One filter is backflushed as in para. 99. The drain plug on the other filter is then removed and the contents allowed to run to waste. This filter is then backflushed before recharging. The filters should be dismantled once a month as follows:—

(*a*) The nuts on the filter head are removed.

(*b*) The filter head is taken out.

(*c*) Each pack is unscrewed and the rings loosened by slacking off the pack nuts.

(*d*) The rings are scoured by brushing.

(*e*) The pack nuts are tightened and the rings rescrewed into position.

(*f*) The filter head is reassembled and replaced.

200-Gallon Water Trailer

101. **Description.** The equipment is mounted on a one-ton, three-wheeled trailer chassis and consists of :—

(*a*) An insulated tank and pump compartment.

(*b*) A semi-rotary hand pump.

(*c*) A filter unit.

(*d*) Hose and piping.

(*e*) A feed gallery.

(*f*) Auxiliary equipment.

The semi-rotary pump is self-primed and delivers 6½ to 7 gallons per minute. The feed gallery is fitted with six taps which can be rotated on a horizontal axis so that they can be raised and locked within the compartment when not in use.

102. **Operation of Plant.** The plant is operated in the following manner:—

(*a*) The suction hose is fastened to the pump inlet and the free end placed in the source of supply.

(*b*) The cock at the outlet of the filter is turned to "first runnings".

(*c*) The cock at the bottom of the filter is turned to "shut".

(*d*) The filter is charged with one pound of kieselguhr in an equal quantity of water.

(*e*) Pumping is started.

(*f*) When the first runnings are clear the cock at the top of the filter is turned to the "into tank" position.

103. **Maintenance** Should the filter become clogged, the pump action stiffens through increased pressure and backflushing is necessary. To backflush:—

(*a*) The cock at the top of the filter is turned to "pressure".

(*b*) Pumping is continued until 100 pounds per square inch is recorded on the gauge.

(*c*) Pumping is stopped.

(*d*) The cock at the bottom of the filter is turned as quickly as possible to the backflushing position (*i.e.* open).

(*e*) When water has ceased to run the cock is turned to "shut".

200-Gallon Water Tender

104. This is a prime mover mounted on an Austin or Morris three-ton chassis. The technical equipment is identical with the trailer described in para. 101.

105. **Sterilization.** Chlorination and chloramination is carried out as described for the 350-gallon vehicles (paras. 96 and 97).

Ten-Gallon Water Sterilizer (Bell Sterilizer)

106. This apparatus (Fig. 8) is intended to provide sterilized water for small detached parties by means of hyper-chlorination, ensuring a sterile water after 30 minutes treatment. Ten gallons of water are dosed with chloros or with water sterlizing powder. After contact for 30 minutes the water is drawn off for use, through activated charcoal which absorbs excess chlorine. Unsterilized water must never be allowed to pass through this filter.

107. The apparatus packed in its wooden carrying case weighs 106 lbs. and is supplied complete with 50 ampoules of chloros (33C/616). It consists of a ten-gallon tank connected by a rubber hose to the filter, which consists of a metal cylinder containing activated charcoal (33C/617) and silverized grit (33C/897) and has a tap for draining off purified water at the lower end.

108. **Operation.** Instructions and a diagram are printed on the tank, inside the packing case, and also inside the chemical tin. The apparatus is assembled so that the bottom of the tank is supported at a height of two

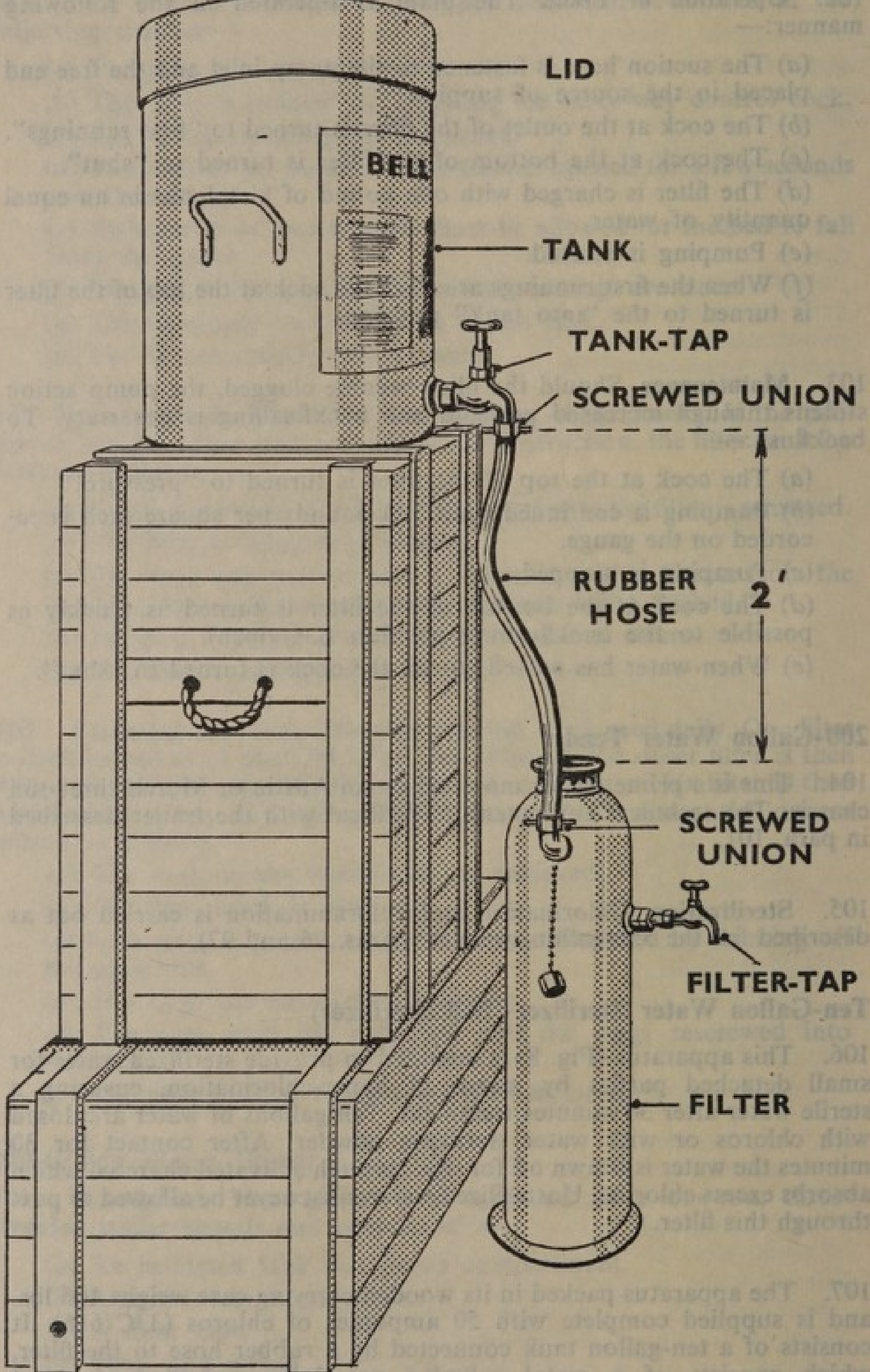


FIG. 8. ASSEMBLY OF STERILIZER, WATER, 10 GALLONS

feet above the top of the filter. The support must be firm, as the tank when filled weighs about one hundredweight. To operate, the following procedure is adopted:—

(*a*) One 2 c.c. ampoule of chloros is opened and mixed with one pint of water.

(*b*) The mixture is poured into the tank. One ampoule in 10 gallons of water produces 5 p.p.m. free chlorine.

(*c*) The tank is filled with water poured through the linen bag at the top.

(*d*) The water is allowed to stand for 30 minutes.

(*e*) The orthotolidine test is carried out.

(*f*) If the test shows no reaction the procedure described in sub-paras. (*a*) to (*e*) is repeated with a further ampoule.

(*g*) The upper tap on the filter is opened.

(*h*) The tap on the tank is opened.

109. **Maintenance of Filter.** The charcoal in the filter requires periodic freeing from chlorine. The tank is drained until it holds only two gallons of sterile water, in which the contents of the bottle of sodium carbonate (33C/179) are dissolved. This solution is then allowed to run through the filter. The expected life of one charge of charcoal is three months, but if before this period sodium carbonate fails to remove the chlorine the charcoal should be replaced. This is carried out in the following way :—

(*a*) The cap at the base of the filter is removed.

(*b*) The silverized grit is shaken out and retained.

(*c*) The filter cylinder is rinsed in a solution containing one ampoule of chloros to one gallon of water.

(*d*) Six pounds of fresh activated charcoal are placed in the filter.

(*e*) A new monal metal screen is inserted.

(*f*) Two and a half pounds of silverized grit are added.

(*g*) The cap is replaced.

110. If the flow through the filter becomes slow it indicates that the charcoal is becoming choked owing to excess turbidity of the water. It should be replaced or cleaned. Cleaning is carried out as follows:—

(*a*) The charcoal is removed as described in para. 109.

(*b*) It is placed in a cloth or bag and washed in the solution described in para. 109(*c*).

(*c*) The cylinder is rinsed with the same solution.

(*d*) One pint of water containing one ampoule of chloros is left inside.

(*e*) The charcoal is returned to the cylinder.

(*f*) The cylinder is flushed with sodium carbonate.

111. **Dosage.** Most waters can be sterilized by the addition of one ampoule of chloros to ten gallons of water. It should, however, be noted that the available chlorine content of chloros deteriorates after a year's storage. The date of manufacture is stamped on each ampoule. If ampoules are not available, water sterilizing powder may be used as the sterilizing agent—one half-scoopful of water sterilizing powder to ten gallons of water producing five parts per million of chlorine. The water sterilizing powder should be stirred to a cream with a little water and then further diluted before being added to the tank.

AIRCRAFT WATER SUPPLIES

General

112. On passenger transport aircraft water is carried for drinking, ablution, and galley purposes. The water may be loaded in containers such as vacuum flasks and urns, or carried in storage tanks which are an integral part of the aircraft structure.

Potability

113. All the water on a transport aircraft should be safe to drink, since it is difficult to prevent passengers using it in toilet compartments for drinking or cleaning their teeth. Unfortunately it is not always possible to guarantee safety and where any doubt exists all taps must be clearly labelled "unfit for drinking".

114. Aircraft water systems should be drained periodically, for example at major inspections, and should be flushed out with heavily chlorinated water. Tanks should be filled only from an approved source and preferably always with chlorinated water.

Quantities of Water Required

115. To obtain the maximum payload in transport aircraft, unnecessary weight has to be kept to a minimum. Only the smallest quantity of water necessary for in-flight use should be carried. No extra water should be added to aircraft storage tanks for survival requirements. This requirement is met by the survival packs designed for the purpose.

116. The quantity required may be planned on the basis of two-thirds of a pint of water per passenger per hour of flight. This amount may be sub-divided into one-sixth of a pint for drinking purposes and half a pint for toilet and galley use. For aircrew and for aeromedical evacuation cases the individual ration should be doubled.

Humidification

117. Many pressurized aircraft require a special supply of water for humidifying the dry air drawn into passenger and crew compartments from outside the aircraft for compression at high altitude.

118. The humidifying process is normally automatic, and the water required, although possibly contained in a common system, is usually inaccessible for any other purpose. Allowance for the humidification quotient of the water supply should however be made whenever there is an overall calculation of the water loading requirement.

CHAPTER 3

FOOD AND NUTRITION

INTRODUCTION

1. Good food is essential to the health and morale of a community. Primarily the diet must be nutritionally adequate; it must supply sufficient energy and promote growth, repair and general resistance to infection. These properties depend on the presence of the basic and accessory constituents of food, in the correct quantities and proportions. The description of the underlying principles of nutrition are left to the end of the chapter, for although they are fundamental, there are many factors, inattention to any one of which can completely destroy the benefits of the best planned diet.

2. The medical officer must therefore be able to advise not only on nutrition but on every aspect of feeding that may affect health directly or indirectly, from the time food is provisioned to the time it is eaten. It is necessary, in consequence, to consider catering organization, problems of communal feeding and some of its techniques, as well as food and kitchen hygiene, the prevention of alimentary infections and the health of food handlers.

CATERING

Definition

3. Catering includes the demanding, purchasing, storage, issue, cooking and serving of food, as well as the management of kitchen plant and appliances, the recovery of by-products and all relevant accounting (*see* A.P.3344, Manual of Catering).

Responsibility

4. The commanding officer is ultimately responsible that his men are properly fed and that the catering administration is efficient. The catering officer is directly responsible for implementing these aims. The medical officer's role is to ensure that the diet is nutritionally adequate, that the food is wholesome and that nothing in its preparation or serving will lead to risk of illness.

Rations

5. Ration scales are drawn up for the armed forces by mutual agreement to provide a properly balanced diet of adequate energy value within the financial limit permitted.

6. The cost of the complete ration scale represents a fixed cash entitlement, from which, at home, the various commodities are purchased. Basic foods such as meat, bread, flour, tea, sugar, salt, margarine, jam, cheese, and those tinned or dried fruits which are held in reserve and necessarily have a warranty life are obtained from the Royal Army Service Corps. The cash balance is used to complete the ration by purchasing other commodities from the N.A.A.F.I., unit farms, and unit market gardens. Abroad, practically the whole ration is supplied from service sources, small cash supplements sometimes being available for the purchase of items from the N.A.A.F.I.

7. There are in addition certain authorized supplements, *e.g.* for day flying, night flying, and for small units. Full details are given in A.P. 3344.

The Bill of Fare

8. The catering officer draws up a bill of fare based on the provisions he is likely to draw and purchase and will provide the medical officer with a copy of the daily menu. The medical officer should inspect the meals from time to time and comment, if necessary, to the station catering officer on the standard of nutrition.

Problems of Communal Feeding

9. The problem of communal feeding is to ensure that food is nutritious, palatable, and wholesome. A diet nutritionally perfect on paper is useless if the food served is unappetizing or causes illness. Preparation of meals from a limited selection of rations, bulk cooking, and the need for the rapid serving of large numbers give rise to acute difficulties. Nutritive value and palatability are sacrificed if food is kept hot for long periods in ovens or by simmering. Slow cooling of food for some hours enhances the risk of bacterial multiplication, should contamination have occurred. If food must be prepared a long time before it is needed, it should when ready be rapidly cooled, kept in refrigeration until required, and then reheated. The danger of contaminated food in communal feeding is emphasized, for a small focus of infection can affect large numbers under these circumstances.

Preservation of Nutritive Values

10. Destruction by heat and extraction by water are the chief causes of loss of vitamin content. For this reason, as well as to minimize the risk of infection, food should be served as soon as possible after cooking. Proper techniques in bulk cooking can help to preserve nutritive values.

11. **Potatoes.** Fresh good quality potatoes are a rich and often the main source of Vitamin C; they are also an important source of Vitamin B1. The vitamins and mineral salts of potatoes are best preserved if they are cooked in their jackets. They are destroyed by cooking twice (*e.g.* sauté potatoes). If mashed potatoes are left to keep hot the vitamin content deteriorates rapidly.

12. **Green Vegetables.** Greens are rich sources of mineral salts, the Vitamin B complex, and Vitamin C. The following measures help to preserve their nutrient content:—

(*a*) Obtain as fresh as possible and store in a cool place.

(*b*) Avoid crushing and bruising during transport, storage, and preparation.

(*c*) Clean by soaking in salt water for the shortest time practicable.

(*d*) Cook in the minimum quantity of salted water.

(*A.L.3, March 65*)

(*e*) Never add baking powder or washing soda, as alkalis rapidly destroy vitamins especially of the B complex, although they preserve the attractive green of these vegetables.

(*f*) Before cooking green vegetables, the water should be boiling vigorously. They must then be added gradually to prevent the water going off the boil.

(*g*) Stop cooking as soon as the vegetables are tender and serve as soon as possible.

(*h*) Use the remainder of the cooking water for soups and gravies as it is rich in minerals and vitamins.

13. **Other Foods.** The nutrients present in meat, fish, milk, cheese and eggs are not to any great extent destroyed by cooking. The Vitamin B1 content of flour is lost if baking powder is used instead of yeast in baking or making puddings. In addition, of course, yeast reinforces the Vitamin B content.

PREVENTION OF ALIMENTARY INFECTIONS

General

14 The alimentary infections concerned are the enteric fevers, dysentery, tuberculosis, undulant fever, certain worm infestations, and food poisoning. The epidemiology of food poisoning varies according to the causal organisms, which may be salmonellae, coagulase positive staphylococci, streptococci, Clostridium welchii, or Bacillus coli. Virus may also enter the body by the alimentary tract and be excreted in the faeces, as for example in poliomyelitis and infective hepatitis. In all these infections the source is a person or animal harbouring the causal organism; prevention must be directed at such sources and at blocking all routes by which the infection can reach food or drink.

15. Food and drink may be infected at source, for example milk from a tuberculous cow or salmonella-infected ducks eggs. They may be contaminated in transport or storage by vectors, such as flies, or by dust, but most commonly infection is conveyed during preparation by a food handler. The majority of causal organisms are transferred from the faeces or urine of the infective source; the route may be fingers, dust, flies, or contaminated water. Staphylococci and streptococci, however, are transmitted from the nose or throat by droplets, as well as by contaminated fingers and from septic skin lesions.

16. The development and severity of alimentary infections depends to an important degree on the dosage of the organism ingested. Some foods, especially if maintained at a temperature favourable to the organism, provide particularly effective media for bacterial multiplication. The result in certain circumstances is massive infection and severe illness.

17. Prevention of alimentary infections is in essence the provision of pure food and drink. Measures to ensure purity are:—

(*a*) Insistence on preparation and cooking techniques which prevent bacterial contamination and multiplication.

(*b*) Proper protection and storage of foodstuffs.

(*c*) Control of vectors.

(*d*) Adequate food inspection.

(*e*) Supervision of the health of food handlers and their education in hygienic habits.

Purity of Food and Drink

18. **Food.** Cooked food, with the exception of any containing preformed staphylococcal enterotoxins (which are thermostable), is safe if eaten while still hot and soon after cooking. It is emphasized that early preparation of food, especially milk products and those that form good bacterial media such as mock cream, custard and mayonnaise, with subsequent storage before consumption, must be discouraged as this increases the risk of alimentary infection. Fresh fruit, uncooked vegetables and salads are potentially dangerous unless disinfected. Theoretically they should not be eaten in the tropics but they may be essential to balance the diet. In these circumstances they must be thoroughly washed under a running tap and then immersed in bleach solution (30 grains to one gallon) for 30 minutes. This does not impair their flavour if subsequently they are thoroughly rinsed. Fruit and vegetables that must be skinned must be similarly treated before peeling. Potassium permanganate does not destroy the cysts of *Entamoeba histolytica*, so must not be used in place of bleach. Ice cream should be made by the hot-mix method and samples should from time to time be tested bacteriologically. It should be purchased ready made only from manufacturers of well-established reputation.

19. **Water.** All drinking water supplies should be chlorinated. Ice placed in contact with food or in drinks must only be made from drinking water and the containers must be scrupulously clean. In the tropics it is sound practice to refrain from putting ice in drinks. Mineral waters supplied for R.A.F. consumption should only be authorized when the place of manufacture has been inspected and approved, after samples have been tested.

20. **Milk.** Milk should be pasteurized or boiled. Most milk abroad is dried or tinned; it must not be reconstituted or the tins opened until a short time before use.

Storage of Food and Drink

21. All food and drink should be carefully protected from flies and dust and be stored in a cool place. Refrigeration does not kill contaminating bacteria but only reduces their rate of multiplication. If refrigerators are not thoroughly and regularly cleaned they taint the food and act as sources of contamination rather than instruments of hygiene.

Vectors

22. Flies and possibly cockroaches play an important part in the spread of many alimentary diseases, although the exact degree of their importance in particular infections is not completely known. The presence of large numbers of flies is obviously a serious risk to the purity of food, and also indicates a poor standard of hygiene. It is essential to keep premises for food storage and preparation free from rodents. Cats and dogs must be excluded from stores and kitchens.

Examination of Foodstuffs

23. However good the standard of food hygiene, its objects will be defeated if the raw material is not wholesome. Medical officers may be called upon to examine food of suspect quality and to give appropriate advice. In the United Kingdom the inspection of slaughtered animals is

of a high standard; it is rare to find diseased meat, and decomposition is likely to be the only problem. Abroad this may not be the case. The procedure required when foodstuffs are to be condemned is contained in Q.Rs. 2304 and 1704.

24. **Meat.** Good meat should be light red and uniform in colour, firm, not too moist, and should not pit on pressure. It should be marbled with fat and have no unpleasant odour. One side of the quarter should not be darker than the rest and it should not be bruised or bile-stained. Fat should constitute about 15 per cent. and bone 20 per cent. of the whole. Differentiation between beef from old cattle and horseflesh, by inspection alone is very difficult. If an opinion is essential, arrangements must be made for laboratory tests.

25. The odour of decomposing meat is characteristic; surface decomposition is quickly recognized by this and by discolouration. Deep-rooted decomposition can be detected, in its early stages, by the insertion of a skewer deep into the flesh, preferably near a large bone or joint. The skewer is withdrawn after a few seconds and, if deep decomposition is present, the smell is easily detected.

26. When expert opinion is not available, a medical officer should not hesitate to condemn meat which appears to be diseased or unwholesome. Any part of a carcase which shows evidence of tuberculosis in its substance, on its capsule, or in the associated lymph glands, must be condemned. It should be remembered that sheep do not suffer from tuberculosis. The presence of caseous lymphadenitis, a disease affecting mainly sheep, but found also in cattle, rabbits and fowl, demands condemnation of the part affected. The name describes the condition. Evidence of widespread, active tuberculosis or caseous lymphadenitis brands the entire carcase as unfit for consumption, irrespective of the wholesome appearance of particular parts. Parasitic infections and hydatid cysts generally require no more than condemnation of the part or organ affected, but when the small, cysticercal stages of tapeworm ("beef measles", "pork measles") are found it is advisable to condemn the whole carcase. The same applies to pork or pork products infested with *Trichinella spiralis* (trichinosis). The cysts are, however, invisible unless calcified, when they may be detected as small white specks in the diaphragm, the muscles of the tongue and throat, and the intercostal and abdominal muscles, particularly near their tendinous insertions. White moulds do not penetrate and only require removal by wiping with a damp cloth; "black spot" moulds may require excision, which should include any surrounding areas of putrefaction.

27. **Fish.** With the exception of certain fish of delicate flesh, only those that are firm and resiliant to the touch are fresh (haddock, codling and hake are among those with delicate flesh.) The gills should be bright red in colour, and the eyes clear and slightly prominent. When fish decomposes the smell becomes tainted and the flesh is limp and soft in parts. The gills may be a dark purple or purplish-brown colour; they may be dry or exude a dirty brownish fluid. The eyes are dull, sunken and the covering opaque. The flesh strips cleanly from the back-bone, which may be surrounded by a reddish discolouration. The strong smell of bad fish is sometimes due to decomposition of the surface slime and disappears when this is washed off. This possibility should be eliminated or confirmed by having the fish thoroughly rinsed in water before further inspection.

28. **Bread.** Bread should be well risen, with a good crust. It should have an elastic texture, be evenly aerated and free from large cavities. The crust should be thin and unbroken and a rich light brown in colour. The loaf should be sufficiently moist and soft to remain so for a reasonable time without becoming sour or musty. Stale loaves lose weight and tend to grow moulds.

29. **Milk.** Milk which has gone sour is obvious, but milk which has been adulterated with water may sometimes be difficult to detect without laboratory facilities. A useful guide is the specific gravity of cow's milk which varies between 1026 and 1036 degrees at 60° F. (There is an increase of 1 degree of specific gravity for every 10°F. of temperature below 60°F. and a similar decrease for every 10°F. above. (Milk as sold must contain not less than 3 per cent. milk fat or 8·5 per cent. solids other than fat. Estimates of these properties can only be made in a suitably equipped laboratory. If serious doubts arise in relation to the quality of the milk supplied in the United Kingdom, advice should be sought from the local medical officer of health (see also Appendix "A").

30. **Eggs.** Eggs when fresh sink in water and are translucent to candle-light. Preserved eggs show a purple stain when a drop of phenol phthalein is placed on the shell and their yolks on turning out are usually broken.

31. **Tinned Food.** The successful tinning of food depends on heating the contents of the can sufficiently to ensure sterilization and the subsequent exclusion of air. There is a reduced internal pressure as a result of the combined action of these two processes. All good tins of food should therefore be concave at both ends. Tins in which the contents have started to deteriorate contain gas and are hyper-resonant on percussion. These are usually swollen and become convex at both ends. They are then known as "blown" tins. The production of gas is usually due to either of two causes, depending on the contents. In solid-pack foods such as meat, fermentive micro-organisms produce gas and the contents sound sloppy on shaking; this indicates advanced decomposition and liquefaction. In hot climates, however, some solid-pack foods may sound sloppy, although quite fit for consumption. In tinned fruit the formation of gas is usually due to the action of the acid fruit-juice on the metal, with the production of hydrogen, causing hydrogen swell. In all cases a blown tin must be considered a bad tin and suspicion justifies rejection. Opening the tin will, in most cases, confirm the diagnosis. Any tins which are leaking, badly misshapen or severely rusted should be condemned.

Food Handlers

32. Alimentary infections are nearly always due to human negligence or ignorance. However carefully a kitchen is designed or however modern the equipment, outbreaks of such infections will occur if the staff are not healthy and educated in the need for personal cleanliness and hygienic habits.

33. **Definition.** The term "food handler" means anyone, including personal servants, employed in any capacity that may involve the handling of food, drink, cutlery, crockery or kitchen utensils in kitchens, messes, institutes, clubs, and similar places.

34. **Education.** Food handlers should be made the object of intensive education on the subject of their personal cleanliness and habits. They must be made to understand that the health of all personnel in their

units rests to a large degree literally in their hands. Lectures should be given by medical officers, if possible accompanied by suitable films or film strips. Suitable posters and notices may be displayed in all premises, especially in lavatories and changing rooms. Special attention should be paid to enlisting the co-operation in these educative efforts of all officers and non-commissioned officers upon whom the major responsibility for supervision devolves.

35. **Personal Cleanliness.** It is essential for food handlers to take a pride in their personal cleanliness and smartness. All should be made to wash their hands whenever they enter the kitchen premises and before attempting to handle food or any kitchen utsensils. This is especially important after visits to the lavatory. It is also essential that finger nails should be kept short as dirt collects under them when they are long and untended. The hair also should be kept short and clean; while at work it should be kept covered.

36. **Washing Facilities.** It is useless to insist on personal cleanliness unless adequate washing facilities are provided. There should be wash basins in all kitchen lavatories and also at least one within the kitchen near the entrance. The basins should be supplied with running hot and cold water, soap, nail brushes and towels, preferably paper towels if these are obtainable.

37. **Clothing.** Special white clothing is provided for cooks and consists of jackets, trousers, apron, and headgear. It must be worn, but not outside kitchen premises or preparation rooms. Adequate changing accommodation, preferably with clothes lockers, must be supplied and clothing must not be kept in any other part of the premises. Clothing must be washed frequently. Men working in vegetable preparation rooms, plate washes and tin rooms should be supplied with rubber boots and denim overalls; there should be arrangements for drying the latter after work.

38. **Personal Habits.** Certain habits are particularly undesirable in food handlers and must be discouraged. They should be taught not to finger the nose, pick spots, or scratch the head or the lower parts of the body; these habits contaminate the hands. They must also learn that they can contaminate food by coughing or sneezing over it or by failing to wash a spoon or fork used for tasting.

39. **Medical Supervision.** Medical officers must exercise close day-to-day supervision over the health of food handlers. It is most important that inquiry should be made at sick parade about the employment of all patients with particular reference to food handling. All those suffering from sore throats, septic cuts and other skin lesions or gastro-intestinal disorders must be suspended from food-handling duties, until permitted to resume by the medical officer.

40. Instructions should be issued that food handlers sustaining cuts or abrasions must report for medical treatment. This will reduce the risk of sepsis. If return to duty is permitted, a waterproof dressing must be applied. Working with rags or bandages applied to the fingers as first-aid should be forbidden.

41. **Venereal Disease.** Food handlers who contract venereal disease should be removed from their duties on diagnosis, but they may be re-employed after discharge from hospital or sick quarters on completion of the initial treatment for their condition.

42. **Special Measures.** Certain special safeguards must be imposed to prevent the spread of alimentary infections by human agency. Certain of them concern all infected persons but in the main they are applicable to food handlers. These safeguards are detailed in Appendix "C".

KITCHEN HYGIENE

Introduction

43. The danger of bacterial contamination and multiplication in communal feeding has already been mentioned. The importance, in combatting this risk, of insisting on the highest standards of hygiene in kitchen premises and among food handlers cannot be over-emphasized. The governing factor, at every point, is to keep food free from pathogenic organisms.

Kitchen Hygiene—General

44. Kitchen hygiene concerns the state of the premises and equipment, the techniques of food storage, preparation and handling, the correct disposal of waste products, the cleaning of utensils, the health of food handlers and their habits.

45. **Premises.** The layout should, ideally, be such that food passes one way from delivery, through storage, to preparation and consumption on the production line principle. Prepared food should not come in contact with raw material nor dirty utensils with clean ones. There should be no overcrowding of staff or equipment. Lighting and ventilation must be good, and floors must be of impermeable material easily cleaned and adequately drained. The structure and fittings must be kept in good repair and always scrupulously clean. Food preparation rooms and stores should be flyproof.

46. **Preparation and Handling of Food.** Food preparation must only take place in the rooms reserved and equipped for the purpose, only clean and appropriate utensils being used. The manipulation of food with the hands should be reduced to the minimum practicable. Food should be prepared as late as possible before the mealtime on the day it is to be consumed. If this is impossible, it must be cooled as rapidly as possible in a room set aside for the purpose. The speed of cooling in the kitchen itself will not be fast enough. It should then be placed in refrigeration until required. Reheating of liquids should be by simmering for 15 minutes, of solids by full heating in the oven. The risk from dishes made up from left-overs is that slow cooling, after they were first cooked, allows bacterial multiplication. In the opinion of many authorities the swift cooling and subsequent refrigeration of pre-cooked food is one of the most important factors in preventing food-borne infections.

47. **Waste Products.** Kitchen waste consists of dry refuse and swill. Swill is the food and scraps left over from plates, utensils and preparation, except for bones and tea leaves. Dry refuse and swill must be kept in separate bins. Suitable bins must be available within the kitchen into which waste can be thrown. These bins must be frequently emptied into others outside the kitchen. Bins must be kept in good repair, clean, and have well-fitting lids. Any which leak, are over-full or have badly fitting lids attract flies and vermin. In the swill compound outside the kitchen the bins should stand on a raised concrete plinth and adequate drainage must be provided in its vicinity to facilitate cleaning.

48. **Cleaning of Utensils.** It has been demonstrated that bacterial contamination of cooking utensils, crockery and other eating implements occurs, but there is little direct evidence that this is a way in which disease is commonly transmitted. It is however a potential route of spread, so must be eliminated. The aim is to remove not only grease and dirt but also organisms. Steps must also be taken to prevent recontamination by, for example, the use of dirty dish cloths, the placing of clean utensils on a sodden wooden surface, and by failure to provide adequate clean and dust-free storage space.

Dishwashing

49. The Catering Trade Working Party, reporting on hygiene in catering establishments in 1951, laid considerable stress on the cleansing of utensils, crockery, and tableware. They therefore carefully examined the techniques of hand and mechanical dishwashing and the use of detergents.

50. **Washing by Hand.** The two-sink method is carried out as follows:—

(*a*) The dishes are scraped as clean as possible.

(*b*) They are then placed in the first sink, containing water at 100° to 112°F. (which is as hot as the hand can comfortably bear) to which detergent has been added. The dishes are washed individually and placed in metal racks.

(*c*) The racks are plunged into the second sink, containing plain water of at least 170°F., and are kept there for at least 30 seconds and preferably for two minutes.

(*d*) The racks are removed and the plates allowed to dry in them without towelling; if plastic plates are used they must be dried with a cloth as they do not retain heat sufficiently long to dry by themselves.

51. It is important that the temperatures mentioned should not be allowed gradually to fall; suitable sink thermometers are therefore advisable. Extra detergent should be added periodically to maintain the concentration.

52. An alternative system is to rinse the dishes in a second sink in water at a lower temperature containing enough hypochlorite to give 50 to 100 parts per million available chlorine. Subsequent drying with towels is necessary.

53. **Mechanical Washing.** There are three main types of dishwashing machinery:—

(*a*) In the first type, dishes are placed individually between revolving brushes in a compartment containing hot water with detergent and are then rinsed in water of a higher temperture before self-drying.

(*b*) In another type, dishes pass through two or more compartments. In the first, strong jets of hot water, with detergent play on the dishes and clean them; in the second and third, jets of lesser force of very hot water rinse them and they are then allowed to dry. The rinse may be automatic or hand operated. The plates are passed through the machine in racks, which may move along on an automatic conveyer belt or be pushed through manually as successive racks are fed into the machine.

(*c*) The third type is the turbulence or deluge washer.

54. **Temperature.** The water from the washing jets should be at 140°F. Higher temperatures are inadvisable as they may coagulate proteins on to the surfaces of the plates. The rinse water should be 170°F. to 190°F. It is most important that washing machines should be fitted with temperature gauges and the heat regulated so that these temperatures are maintained.

55. **Detergent.** Usually detergent is fed into the wash water by hand. The dosage varies with the strength of the detergent used. As the process goes on it is usually necessary to add more to make good dilution or wastage. Operators should be instructed on this point. The theoretical optimum concentration is given by 1 to 5 ounces per 10 gallons. In some machines dosage is automatic, and in the most modern it is electronically controlled.

56. A liquid detergent is preferable to a powder as dosage can be more accurately measured. The types least affected by the hardness of water are the higher alkyl sulphates. Detergents usually consist of a solution of the active constituent of 20 to 40 per cent. and the dosage required should aim at a dilution of 0·02 to 0·07 per cent. of active constituent in the washing water. For the washing of glasses in bars the quaternary ammonium sulphate detergents are best.

57. **Operators.** Personnel employed in dishwashing are seldom skilled men; they rarely receive adequate instruction and they do not continue regularly at this type of work. It is essential, therefore, that members of the catering staff are familiar with the correct operation of washing machines, and they should instruct and supervise those detailed for dishwashing.

NUTRITION

General

58. The constituents of a diet must be sufficient to sustain all vital processes; besides energy these processes require certain essential elements, *e.g.* amino-acids and vitamins. To provide these elements, the food consumed must be satisfactory not only in quantity but in quality also. It is emphasized, however, that dietetic science cannot compensate for shortcomings in the cooking and serving of food. Men eat their food because it is appetizing, and not because of its calorific value.

59. There are six recognized components of an adequate diet: protein, fat, carbohydrate, minerals, vitamins, and water. The human need for most of these substances is fairly accurately known, but knowledge concerning the amounts required of some of the vitamins and their distribution in foods is still incomplete. It is probable that numerous accessory food factors still remain to be identified.

60. The fuel requirements of the human body are described in terms of calories, *i.e.* units of heat produced by the combustion of specified weights of foodstuff. A Calorie (or 1 kilocalorie) is the amount of heat necessary to raise the temperature of 1 kilogram of water by 1°C. A 3,000 Calorie diet, if absorbed and metabolized completely, would produce sufficient heat to raise the temperature of 3,000 kilograms of water by 1°C. or 30 kilograms (about 7 gallons) of ice water to boiling point.

61. The gross energy value of the foodstuff necessary to yield the daily dietary requirement of the average airman has been estimated at about 3,800 Calories and for the airwoman 3,400 Calories. An allowance of about 10 per cent. is made for wastage; this gives net daily values of about 3,400 and 3,000 Calories. The calorie values quoted in the tables in this chapter are net figures, *i.e.* calculated on the edible portions of the various foods; hence when applied to ration scales they give the net energy value of the daily diet. Ration scales should provide a reasonable margin and should include alternative items to ensure that the energy value is not reduced below the required standard owing to local deficiencies or distribution difficulties. Occasional calculation of the energy value of the rations, as received at the kitchens, forms part of the medical officer's duties.

Assessment of Requirements for the Airman

62. The figure of 3,800 Calories per day is an estimate of the gross requirement for the average airman of 17 to 25 years of age, whose occupation does not involve extreme physical effort. This figure is derived as follows:—

(*a*) Calorie requirement to maintain life: heart beat, respiration, maintenance of body temperature and digestion over 24 hours (basal metabolism), at approximately 78 Calories per hour	1,900 Calories
(*b*) Work period of 8 hours; moderate work	850 Calories
(*c*) Off-duty 8 hours; sitting, standing, walking, and other activities associated with leisure hours apart from active exercise	400 Calories
(*d*) Active exercise; daily average	250 Calories
Total	3,400 Calories

63. The net requirement is thus 3,400 Calories. It is necessary to add approximately 10 per cent. to cover wastage in preparation, and to allow for inedible parts. The quantity of food obtained in bulk on this basis allows for differences in appetites, occupation, and age of the service community.

Balanced Diet

64. A normal diet that supplies the necessary energy value will usually contain sufficient and proportionate amounts of the necessary individual nutrients, including minerals and vitamins. It will be a balanced diet. Iron, calcium and vitamins B.1 and C are the elements most likely to be deficient in the modern diet. When it is suspected that essential nutrients are lacking, it is preferable to ensure that the best quality foodstuffs available are included in the rations, rather than to resort to synthetic supplements such as vitamin pills. Full use should be made of milk, fruits and vegetables, including potatoes. Dried vegetables contain vitamins and are of value in the absence of fresh varieties. The nutritive value of dried pulses (dried peas and beans), soya and peanuts is high.

Special Requirements

65. **Heavy Muscular Work.** Appetite is automatically increased by heavy muscular work and should be satisfied with additional carbohydrate and fat. Extra protein is not essential, but bacon, ham and wholemeal bread are useful supplements owing to their vitamin B.1 content, which is needed to assist the breakdown of the additional carbohydrate. Fatigue will develop more readily if vitamin B.1 is lacking.

66. **Athletic Contests.** Training should be carried out on a full but simple diet. Plenty of carbohydrate should be taken for a day or two before the contest, in order to build up a good reserve of glycogen in the liver. During this period only light exercise should be taken. Some sugar or glucose immediately before the contest is to be recommended.

67. **Mental Work.** Small, rather frequent, easily digested meals are best and protein should predominate relatively over carbohydrate and fat. "There is no special brain food." (R. Hutchinson, and W. H. Mottram, Food and Dietetics).

68. **Hot Climates.** Fluid intake should be greatly increased in order to promote sweating and consequently cooling. Additional salt is needed to offset that lost in the sweat. According to climate and activity, ½ to 1 ounce (14 to 28 grams) of extra salt each day may be required. Since there is but little lowering of the basal metabolism in the tropics, the dietary energy demanded will be much the same as that for similar activity in a temperate climate. The cooling effect of iced drinks is largely illusory. Two pints of iced water will take up only about 40 Calories from the body, while an equal quantity of hot fluid at 45°C. will add only 8 Calories; such amounts will have only a very transient effect on the body temperature.

69. **Cold Climates.** The body temperature can be maintained in moderate cold by clothing which decreases heat loss. With a further fall in external temperature heat production must be augmented by increased food consumption. Fat produces most calories for least bulk and theoretically should be the chief source of extra heat production. But in practice extra quantities of the usual diet will be accepted much more readily than unusual items. An extra 300 Calories a day for each 9°F. drop in temperature is advisable.

Protein

70. By far the greatest part of the organic matter of the body consists of protein, which as a nutrient is the chief source of nitrogen and sulphur. Protein is required for growth, tissue repair, and replacement, besides the synthesis of enzymes, hormones, and other secretions. Deficiency may lead to anaemia and liability to infection, while plasma protein concentration and consequently the colloid osmotic pressure are diminished, resulting in oedema if the deficiency is severe.

71. The nutritional value of any protein depends on the nature and relative proportions of its constituent amino-acids. Certain of the latter cannot be synthesized by the body, so are termed essential amino-acids. Animal proteins, which resemble body proteins, *e.g.* those in meat, milk, eggs, and fish, supply all essential amino-acids and are capable of supporting life even if they are the sole dietetic source of nitrogen. In contrast the amino-acids of plant proteins are mostly non-essential. Nevertheless, a vegetable diet composed of a suitable combination of varieties can

supply an adequate essential amino-acid pattern. It is recommended that at least one-third of the required protein intake (100 grams daily) should be derived from animal protein. Among the best of the vegetable proteins are those contained in peas, beans, and other legumes. Any protein in excess of that required for repair, synthesis and other physiological processes, is used as a source of energy; one gram of protein gives 4·1 Calories.

72. Protein has a specific dynamic action and in consequence its consumption greatly increases heat production, thus raising the metabolic rate. It is therefore important that carbohydrate and fat should be consumed with protein, to compensate by increasing the energy intake. There are thus sound physiological grounds for taking potatoes with meat.

Fat

73. Fat is particularly necessary in the diet when energy expenditure is high, owing either to heavy work or exposure to cold. It is also important as the vehicle of fat-soluble vitamins. Although the Inter-Allied Food Commission adopted 57 grams of fat as the daily minimum ration during the First World War, it is now considered that for Calorie intakes below 3,000 fat should supply about 25 per cent. of the total, but about 30 per cent. when the intake exceeds 3,000. The daily intake recommended is 100 grams. One gram of fat gives 9·3 Calories.

Carbohydrates

74. Carbohydrates are cheap, easily obtained, and provide more than half the energy content of the average diet. They assist in the oxidation of fats and ketosis results when a diet too high in fat and too low in carbohydrate is consumed. Ketosis also occurs in starvation when the body derives its energy from the combustion of body fat. The normal daily diet should provide about 500 grams of carbohydrate, one gram of which gives 4·1 Calories.

Minerals

75. **Calcium.** Calcium is required for ossification of bone, the regulation of nerve excitability, contraction of heart and skeletal muscle, clotting of blood, and the maintenance of capillary endothelium. It is particularly necessary in childhood, pregnancy, and lactation, when it is best provided by giving at least one pint of milk daily. The chief sources are milk, cheese and green vegetables. Absorption is defective if there is lack of vitamin D and if the ratio of calcium to phosphorus in the diet varies much from the optimum of 1 to 1·5. The average adult daily requirement is 700 milligrams.

76. **Phosphorus.** Phosphorus forms an integral part of most cells. It is concerned with tissue oxidation and in the formation of bones and teeth. The chief sources of phosphorus, in the form of phosphates, are milk, eggs, meat, and vegetables. The vitamin D and calcium intake influence its absorption. The daily adult requirement is about 1 gram, but more is needed during pregnancy and lactation.

77. **Iron.** Iron and traces of copper are necessary for the synthesis of haemoglobin. Iron is provided chiefly by wholemeal bread and animal tissues, particularly liver and kidney. Green vegetables, especially spinach, are also good sources. The approximate adult daily requirements are 15 milligrams of iron and 2 milligrams of copper.

78. **Iodine.** Iodine is contained in thyroxine, the active principle of the thyroid gland, and is required for its synthesis. The usual source is drinking water, but in many parts of the world this is deficient in iodine so that simple goitre is endemic. In such circumstances iodized table salt may be used. Sea fish are also a rich source of iodine, the daily requirement of which is 0·15 milligrams.

79. **Other Minerals.** Sodium, potassium, magnesium, sulphur, and chlorine are all needed by the body tissues, but deficiencies seldom occur under normal conditions of diet, health and climate. Salt deficiency can occur in hot climates owing to chloride loss in the sweat, so that the salt intake under these circumstances must be carefully watched.

80. **Trace Minerals.** Many other minerals are required in small amounts and are called trace minerals. These include cobalt, which is present in vitamin B.12, and zinc which is present in enzymes. Diets are generally adequately supplied with these minerals.

Vitamins

81. **Vitamin A.** Vitamin A is stored predominantly in the liver and to a lesser degree in the body fat. It may be ingested ready-made from animal sources or as a precursor or pro-vitamin in the form of carotene from vegetable sources. Carotene is converted into vitamin A by the enzyme carotinase in the intestinal mucosa and probably also in the liver. Vitamin A deficiency may occur because of poor intake, poor absorption, or failure to convert the precursor. Absorption is impaired when there is interference with the fat metabolism as in coeliac disease and sprue or may be prevented by the presence of an unassimilable oil such as liquid paraffin. Bile is necessary for the absorption of carotene but not of vitamin A. The chief sources of the vitamin are fats of animal origin, especially milk, butter, cream and eggs. Vitaminized margarine also provides it, while particularly rich sources are fish liver oils as well as fat sea fish such as herrings, sardines, and salmon. The precursor, carotene, is obtained from green vegetables, carrots, and some fruits such as apricots and bananas. The vitamin is essentially heat stable, and is little affected by the ordinary processes of cooking, preserving and canning. The earliest signs of deficiency are changes in the skin and poor dark adaptation. A dry, rough skin, often associated with papular eruptions, more common in children and native races on inadequate diets, is typical. This follicular hyperkeratosis is often referred to locally as "toad skin" or "shark skin". Keratinization of the cornea and conjunctivitis may also occur; the former may progress to complete destruction of the cornea. Structural changes in epithelial linings may develop, especially of the respiratory and gastro-intestinal mucosa, which become prone to secondary infection with results such as broncho-pneumonia and enteritis. Vitamin A combines with protein to form visual purple, a retinal pigment essential for night vision. Augmentation of the vitamin A intake can only improve night visual acuity in individuals whose diet is lacking in this substance. It should be given in capsular form to night flying personnel only when needed to ensure that their intake of the vitamin does not fall below the minimum requirement. The approximate daily dietary requirement is 4,000 I.U.

82. **Vitamin B Complex.** Vitamin B is a complex consisting of a number of factive principles. The chief sources are wheat germ, wholemeal cereals, milk, meat offals, vegetables, yeast, yeast extracts, pulses, and peanuts.

(*a*) *Vitamin B.1* (*Synonyms: Thiamine and Aneurin*). This vitamin is heat labile, but withstands moderate heat including short periods of boiling. It is destroyed by the high temperature of canning processes, and in the presence of alkalies or sulphites. The action of thiamine is due to its pyrophosphate, co-carboxylase, which is concerned in the metabolism of pyruvic acid, an intermediate product of carbohydrate metabolism. In vitamin B.1 deficiency pyruvic acid accumulates in the body tissues and fluids. Deficiency eventually results in beri-beri, which is preceded by fatigue, headache, loss of appetite, dyspepsia, dizziness, and slow pulse. The three classical symptom groups of beri-beri are peripheral neuritis, cardiac failure, and oedema. Of these oedema and cardiac failure have never been produced experimentally in man by thiamine deprivation alone. It is possible that they result from the combined deficiencies of several vitamins of the B complex. Yeast and the germ of cereals are rich in thiamine. It occurs to a lesser extent in liver, eggs, vegetables, pulses, meat and milk.

(*b*) *Riboflavin.* Riboflavin is reasonably heat stable and not destroyed by ordinary cooking processes, except in the presence of alkalies. Deficiency (ariboflavinosis) results in angular stomatitis, glossitis, a seborrhoeic type of dermatitis, and eye changes. The latter are associated with photophobia, burning and itching, which respond readily to riboflavin by mouth. Slit lamp examination of the eye shows early typical vascularization by invading capillary loops. This vitamin is found in several enzymes concerned with tissue oxidation. Among the best sources are yeast, milk, eggs, fish roe, and liver. The vitamin is also found in vegetables, especially the leafy parts.

(*c*) *Nicotinic Acid.* This is one of the most stable of all vitamins, being unaffected by heat even under pressure or in the presence of alkalies. The benefits of nicotinic acid administered in the presence of deficiency are due to its conversion to nicotinamide, which is absorbed into enzyme systems involving coenzymes I and II. These are nucleotides concerned with oxidation and reduction processes in the living cell. Nicotinic acid is present in all tissues but chiefly in the liver as coenzyme. The blood level is not greatly reduced even when deficiency symptoms are present. As the circumstances in which deficiency occurs are those where there is also a lack of other B complex factors, it is difficult to assign particular symptoms to nicotinic acid deficiency alone. The syndrome of pellagra, which responds well to nicotinic acid therapy, is however mainly due to its lack, although B.1 and riboflavin deficiency in particular also play a part. There is initial general ill health, irritability, depression, weakness, loss of weight and anorexia; these symptoms are common to other B complex deficiencies. Symptoms generally attributed to nicotinic acid deficiency are desquamative dermatitis, pigmented on those parts of the body exposed to the sun, glossitis (unresponsive to riboflavin), intractable diarrhoea with sprue-like stools, and mental changes progessing in some cases to dementia. Sprue, pellagra, idiopathic steatorrhoea, the Plummer-Vinson syndrome and sulphonamide intolerance all present similar clinical features, which *post hoc* or *propter hoc* may be linked with a B complex deficiency and are alleviated by administration of one or more of

TABLE 1

THE COMPOSITION OF FOOD†

All values are per oz. of edible portion

	Waste	Calories	Protein	Fat	Carbohydrate	Calcium	Iron	Vitamin A	Vitamin B_1	Riboflavin	Nicotinic acid	Vitamin C	Vitamin D
	Per cent.		g.	g.	g.	mg.	mg.	i.u.	mg.	mg.	mg.	mg.	i.u.
1. Cereals :													
Barley, pearl ..	0	97	2·2	0·5	20·8	3	0·2	0	0·03	0·01	0·7	0	0
Biscuits—													
plain ..	0	116	2·9	2·1	20·8	8	0·4	0	0·08	0·03	0·3	0	0
sweet ..	0	126	1·9	3·9	20·0	3	0·4	0	0·07	0·03	0·3	0	0
Bread—													
white 70-72% extraction ..	0	73	2·3	0·2	15·6	4	0·2	0	0·01	0·01	0·2	0	0
National 85% extraction ..	0	72	2·4	0·4	14·6	4*(16)	0·5	0	0·05	0·03	0·3	0	0
wholemeal 92% extraction ..	0	65	3·1	0·6	11·2	7	0·7	0	0·09	0·05	0·6	0	0
Flour—													
white ..	0	98	2·3	0·3	21·6	5	0·4	0	0·02	0·01	0·3	0	0
National ..	0	97	2·5	0·4	20·9	6*(25)	0·7	0	0·07	0·04	0·4	0	0
wholemeal ..	0	95	4·3	0·9	17·4	10	1·0	0	0·13	0·06	0·8	0	0
Oatmeal ..	0	111	3·4	2·5	18·6	16	1·2	0	0·13	0·04	0·3	0	0
Rice ..	0	99	1·8	0·3	22·2	1	0·1	0	0·02	0·02	0·3	0	0
Wheatflakes, shredded wheat ..	0	97	3·9	0·7	18·7	10	1·4	0	0·01	0·02	0·3	0	0
2. Dairy products:													
Butter ..	0	211	0·1	23·4	0	4	0	1,140	0	0	0	0	17
Cheese ..	5 (rind)	117	7·1	9·8	0	230	0·2	370	0·01	0·14	0·1	0	10
Egg—													
fresh ..	12 (shell)	45	3·5	3·3	0·3	17	0·8	280	0·04	0·11	0	0	17
dried ..	0	163	13·0	11·9	0·9	62	3·1	850	0·11	0·37	0·1	0	68

†By courtesy of the Ministry of Food (*Manual of Nutrition*, 1945, 63-64).

*The figures in brackets show the calcium content after the addition of chalk to the flour.

Milk—													
whole	0	17	0·9	1·0	1·2	34	0	30	0·01	0·04	0	0·3	0·3
evaporated (condensed unsweetened)	0	40	2·0	2·3	2·7	69	0·1	90	0·01	0·10	0·1	0	1
condensed, sweetened	0	89	2·3	2·6	14·1	82	0·1	105	0·03	0·10	0·1	1	1
dried, whole	0	138	7·3	7·6	10·1	254	0·2	300	0·08	0·33	0·2	0	3
dried, skim	0	97	10·2	0·2	13·6	348	0·3	9	0·11	0·45	0·3	0	0
3. Fats:													
Cooking fat, lard, etc.	0	253	0	28·1	0	0	0	0	0	0	0	0	0
Margarine	0	218	0	24·1	0	1	0·1	450	0	0	0	0	56
4. Fish:													
Dried fish	35	52	11·9	0·4	0	18	0·7	0	0·02	0·12	1·8	0	0
White fish, cod, etc.	45	21	4·5	0·3	0	7	0·3	0	0·02	0·04	0·6	0	0
Fried fish		62	5·2	4·0	0	7	0·4	0	0·02	0·08	0·5	0	0
Fish paste	0	47	3·8	2·5	2·2	41	1·7	0	0·01	0·02	0·3	0	0
Herring	30	47	4·5	3·3	0	28	0·4	42	0	0·08	1·0	0	240
Salmon—canned	0	48	5·7	2·8	0	85	0·4	71	0·01	0·06	1·8	0	170
Sardine—canned	0	84	5·7	6·8	0	114	1·1	77	0·01	0·08	1·3	0	280
5. Meat:													
Bacon	12	128	3·1	12·8	0	3	0·3	0	0·17	0·06	1·2	0	0
Beef—													
corned	0	69	7·1	4·5	0	3	3·1	0	0	0·04	0·5	0	0
fresh, average good quality	17	89	4·2	8·0	0	3	1·1	14	0·02	0·07	1·3	0	0
stewing	25	60	4·8	4·5	0	3	1·1	14	0·02	0·07	1·3	0	0
Kidney	0	36	4·5	2·0	0	3	3·8	280	0·07	0·37	3·8	0	0
Liver-ox	0	40	4·8	1·7	1·4	3	3·9	4,260	0·11	0·85	3·8	0	0
Meat pie	0	103	3·1	6·5	8·0	4	0·6	0	0·03	0·03	0·5	0	0
Meat paste	0	45	3·4	2·3	2·6	7	1·0	0	0·01	0·03	0·6	0	0
Mutton	17	94	3·7	8·8	0	3	0·6	14	0·04	0·05	1·2	0	0
"Points" meat, spam, etc.	0	75	4·3	7·5	0	0	0·6	0	0·13	0·04	0·7	0	0
Pork	15	116	3·4	11·4	0	3	0·3	0	0·20	0·06	1·7	0	0
Sausage, pork	0	73	3·0	5·1	3·7	9	0·3	0	0·05	0·02	0·5	0	0
Shepherd's pie, etc.	0	78	2·8	5·0	5·5	8	0·2	0	0·02	0	0·2	0	0

THE COMPOSITION OF FOOD†—*continued*

All values are per oz. of edible portion

	Waste	Calories	Protein	Fat	Carbohydrate	Calcium	Iron	Vitamin A	Vitamin B_1	Riboflavin	Nicotinic acid	Vitamin C	Vitamin D
6. Vegetables:	Per cent.		g.	g.	g.	mg.	mg.	i.u.	mg.	mg.	mg.	mg.	i.u.
Beans—													
baked, canned	0	25	1·7	0	4·5	16	0·7	47	0·02	0·01	0·2	0	0
haricot	0	71	6·1	0	11·6	51	1·9	0	0·13	0·08	0·6	0	0
soya, dried whole	0	114	8·5	4·3	9·4	67	2·6	25	0·24	0·06	1·2	0	0
Cabbage	30	7	0·4	0	1·4	18	0·3	85	0·02	0·02	0·1	20	0
Carrot	5-20	6	0·2	0	1·4	14	0·2	1,730	0·02	0·01	0·2	3	0
Cauliflower	30	6	0·7	0	0·8	14	0·2	0	0·02	0·02	0·2	20	0
Lentil	0	82	6·8	0	13·6	11	2·2	5	0·13	0·02	0·9	0	0
Lettuce	20	3	0·3	0	0·5	7	0·2	380	0·02	0·02	0·1	4	0
Onion	5	6	0·3	0	1·3	9	0·1	0	0·01	0·01	0	3	0
Peas—													
green	60	17	1·6	0	2·7	4	0·5	47	0·12	0·03	0·2	8	0
dried	0	85	7·0	0	14·2	17	1·3	19	0·13	0·08	0·6	0	0
Potato—													
fresh	7-25	21	0·6	0	4·6	2	0·2	0	0·03	0·02	0·3	2-8	0
chips	0	66	1·1	2·6	9·5	4	0·4	0	0·03	0·02	0·3	2	0
Spinach	25	6	0·8	0	0·7	20	0·9	1,230	0·03	0·06	0·1	18	0
Tomato	15	4	0·3	0	0·7	4	0·1	280	0·02	0·01	0·1	7	0
Turnip	35	5	0·2	0	1·0	17	0·1	0	0·01	0·01	0·3	7	0
Watercress	15	4	0·8	0	0·2	63	0·4	475	0·03	0·02	0·5	17	0
7. Fruit:													
Apple—													
fresh	20	12	0·1	0	3·0	1	0·1	4	0·01	0	0·1	1	0
dried	0	52	0·6	0	12·5	8	0·6	8	0	0·01	0·4	0	0
Apricot—													
fresh	8	7	0·2	0	2·0	5	0·1	71	0·01	0·21	0·1	3	0
canned	0	14	0·1	0	3·5	4	0·1	47	0	0·02	0·1	1	0
dried	0	50	1·4	0	11·1	26	1·2	473	0	0·12	0·6	0	0

Banana	40	21	0·3	0	4·9	2	0·1	8	0·01	0·01	0·2	3	0
Blackcurrant	0	8	0·3	0	1·7	17	0·4	9	0·01	0·01	0·1	57	0
Date	14	68	0·6	0	16·3	19	0·4	9	0	0·01	0·1	0	0
Fig—dried	0	58	1·0	0	13·5	81	1·2	9	0	0·08	0·5	0	0
Lemon	30	5	0·2	0	0·8	20	0·1	0	0·01	0	0	12	0
Melon	45	6	0·2	0	1·3	4	0·1	8	0·01	0·01	0·2	3	0
Orange	25	10	0·2	0	2·2	12	0·1	28	0·02	0·01	0·1	16	0
Peach—canned	0	16	0·1	0	3·9	2	0·2	47	0	0	0	1	0
Pear	25	11	0·1	0	2·7	2	0·1	1	0·01	0·01	0·1	1	0
Pineapple—canned	0	20	0·1	0	4·9	3	0·2	6	0·01	0·02	0	3	0
Plum	6	7	0·2	0	1·6	4	0·1	38	0·01	0·01	0·02	1	0
Prune—dried	17	44	0·7	0	10·3	11	0·8	237	0	0·04	0·6	0	0
Raisin	8	67	0·3	0	16·5	17	0·5	5	0	0·01	0·1	0	0
8. Nuts:													
Coconut	30	100	1·1	10·2	0·9	4	0·6	0	0·01	0·03	0·1	0	0
Peanut	30	166	8·0	13·9	2·2	17	0·7	0	0·25	0·08	2·6	0	0
9. Preserves, etc.:													
Chocolate—plain	0	148	1·3	9·2	15·0	7	0·9	7	0·03	0·07	0·3	0	0
Jam	0	71	0·1	0	17·6	3	0·3	2	0	0	0	3	0
Sugar	0	108	0	0	27·0	0	0	0	0	0	0	0	0
Syrup	0	81	0·1	0	20·2	7	0·4	0	0	0	0	0	0
10. Beverages:													
Beer—mild	0	10	0·1	0	1·5	3	0	0	0	0·01	0·4	0	0
Cocoa—as drunk with milk and sugar	0	6	0·2	0·2	0·9	3	0	3	0	0	0	0	0
powder	0	125	5·8	7·3	8·9	14	4·1	14	0·03	0·08	0·3	0	0
Tea—as drunk with milk and sugar	0	5	0·1	0·1	0·8	3	0	4	0	0·01	0	0	0
11. Cakes and puddings:													
Cakes, plain	0	89	2·8	1·4	16·2	14	0·6	85	0·03	0·01	0·1	0	0
Bun	0	85	2·3	2·2	13·9	10	0·6	0	0·04	0·03	0·3	0	0
Custard	0	33	0·9	1·1	5·0	35	0	20	0·01	0·02	0	0	0
Rice pudding	0	40	1·1	1·6	5·3	35	0	23	0·01	0·01	0	0	0
Steamed pudding	0	86	1·1	4·4	0·6	15	0·2	0	0·02	0·01	0	0	0
Yorkshire pudding	0	62	2·0	2·7	7·5	28	0·2	0	0·02	0·01	0·1	0	0

TABLE 2

DAILY CALORIE REQUIREMENT FOR ADULT MALES
(allowing for wastage in cooking)

Sedentary work	2,900 Calories
Light work	3,100 ,,
Moderate work	3,500 ,,
Heavy work	4,000 ,,
Very heavy work	5,000 ,,

TABLE 3

AVERAGE DAILY REQUIREMENTS FOR A BALANCED DIET

Protein ..	100	Grammes	410	Calories
Fat	100	,,	930	,,
Carbohydrate ..	500	,,	2,050	,,
		Total ..	3,390	,,

Vitamin A	4,000	international units
Vitamin B.1 (thiamine)	1·5	milligrams
Riboflavin	2·0	,,
Nicotinic acid ..	20·0	,,
Vitamin C ..	50·0	,,
Calcium	700·0	,,
Iron	15·0	,,
Iodine	0·15	,,

the B factors. Unpleasant side effects are often produced when nicotinic acid is given, owing to its vaso-dilator effect. Nicotinamide given in the same dosage is equally effective and causes no disagreeable symptoms. Although the symptoms of pellagra are easily relieved, they are rarely completely cured. Sources of nicotinic acid include liver, yeast, meat, and wholemeal flour.

(*d*) *Other Members of the B Complex.* The remaining members of the vitamin B complex are generally adequately supplied by a good diet. In special circumstances deficiencies may occur; for example, an outbreak of pyridoxine deficiency occurred in the United States among babies fed on processed milk in which this factor had been destroyed. Tropical macrocytic anaemia is endemic in India and elsewhere; it is due to dietary deficiency of folic acid and vitamin B.12. Pernicious anaemia is essentially caused by failure to absorb the dietary vitamin B.12 because of deficiency in intrinsic factor, which is secreted by the normal stomach but not by the stomachs of those suffering from pernicious anaemia. The following are the present known components of the B complex:—

Thiamine (B.1)	Pantothenic acid	Vitamin B.12
Riboflavin	Biotin	Para-aminobenzoic acid
Nicotinic acid	Folic acid	Choline
Pyridoxine (B.6)		

83. **Vitamin C.** Vitamin C, or ascorbic acid, is the anti-scurvy vitamin. Pure ascorbic acid is a white crystalline solid, freely soluble in water, with a pleasant acid taste; it is a powerful reducing substance. It is present in all body fluids and tissues. Black currants, hips and haws are excellent sources, and to a lesser extent citrus fruits, gooseberries, strawberries, and raspberries. The autumn fruits (apples, pears and plums) are comparatively poor in vitamin C. Among vegetables, cabbage, cauliflower and brussels sprouts provide a large quantity, especially if eaten raw; they deserve more popularity as constituents of salads. Celery, lettuce and cucumber contain disappointingly small amounts. Potatoes are an important source; new potatoes are particularly rich, but storage causes a diminution of the vitamin content; nevertheless a good quantity is provided even by old potatoes. The stability of the vitamin is affected by pH, temperature, oxidation, and traces of metal. Prolonged cooking of vegetables, including potatoes, and keeping them hot after cooking are equally destructive of the vitamin. Much of the vitamin present in green vegetables is leached out during cooking and is lost if the cooking water is discarded. The bruising or fine chopping of vegetables before cooking aids vitamin destruction by oxidation, as ascorbic acid oxidase is thus released. The loss of vitamins by leaching during the boiling of potatoes is less serious. Potatoes cooked in fat retain most of their vitamin C. Canned foods are often good sources, and, indeed, better than carelessly cooked fresh food. Dehydrated vegetables retain the bulk of the vitamin. The metabolic role of ascorbic acid is not clear, but the pathological results which follow deficiency are due to impairment of the collagen matrix in connective tissue. This causes malformation of growing bone and cartilege, delayed healing of fractures, maldevelopment of the teeth, and defective wound repair. In addition, scurvy results on account of the absence of cement substances in capillary linings. In scurvy, after a period of general ill health, weakness, tiredness and dyspnoea, haemorrhages occur either subcutaneously or internally, for example into the joints and below the periosteum; there is also gingivitis. The phenomenon of capillary fragility may not be entirely due to lack of ascorbic acid; another factor associated with vitamin C and known as vitamin P may also be concerned, but its role is not fully established.

84. **Vitamin D.** Vitamin D is the anti-rachitic or calcifying vitamin and is heat stable. It is formed in the skin by the action of the sun on the animal sterol, 7-dehydrocholesterol, or can be prepared artificially by the irradiation of the vegetable sterol, ergosterol. In the latter form it is known as claciferol. An important source of vitamin D for man is sunlight, which produces the vitamin by its activating effect on sterols in the skin. Ultra-violet radiation is equally effective. The chief dietary sources are dairy products, such as milk, eggs, and butter, and the fat sea fish such as cod, halibut, herring, pilchards, sardines, and salmon. The vitamin D content of certain foods may be reinforced artificially by the addition of calciferol or by irradiation. In the United Kingdom, margarine must now be fortified with vitamin D. Milk may be reinforced by irradiation or the addition of calciferol; alternatively the cow may be irradiated or have vitamin D added to its food. The effects of vitamin D deficiency are probably on the phosphorus metabolism, the influence on calcium being secondary. Deficiency in children causes rickets, characterized by deformities resulting from the bending, under the weight of the body, of bones which are soft from deficient deposition of calcium and phosphorus. The teeth may also be adversely affected, although in this, vitamins A and C play a more important role. When both the calcium and vitamin D content of the diet is low, tetany may develop as a complication of rickets. In the adult the deficiency results in osteomalacia, which particularly affects the pelvis.

85. **Vitamin E.** Vitamin E or tocopherol is found chiefly in wheat germ oil and green leafy vegetables. In vitro it is an antioxidant, protecting vitamin A and carotene from oxidation and delaying rancidity in fats. In the process vitamin E itself is oxidized and becomes inactive. It has been used in the treatment of habitual or recurrent abortion and in the muscular dystrophies. There is little evidence of a vitamin E deficiency state in man and its relationship to sterility is doubtful.

86. **Vitamin K.** Vitamin K is a generic term applied to a group of naturally occurring substances, some existing in green plants, others being synthesized by micro-organisms. Lack of vitamin K impairs the coagulability of the blood and a haemorrhagic tendency results. Green plants, especially lucerne and spinach, are rich sources of this vitamin, which is also found in cauliflower, cabbage, carrot tops, soya beans, seaweed, tomatoes, bran, and orange peel. Most putrefying animal or vegetable matter contains large amounts, while it can be synthesized by the bacterial flora of the intestine. Owing to this last source, it is improbable that vitamin K lack due to dietary deficiency causes impaired blood coagulation in man. Failure to absorb the vitamin, however, results in hypoprothrombinaemia, which may be latent. The action of the vitamin is either as an element in the formation of prothrombin or as a stimulant of the liver in prothrombin production. In the latent type of hypoprothrombinaemia, operation wounds begin to ooze or the gums bleed easily when the teeth are brushed. The spontaneous type is seen in the new born, in idiopathic steatorrhoea, obstructive jaundice, or severe parenchymatous liver disease; it is characterized by large haematomata haematemesis, haemarthrosis, haematuria, epistaxis or melaena. The

blood coagulation time is prolonged but the capillary fragility is unaltered. Since vitamin K is fat soluble, its absorption is impaired when liver damage results in reduction or absence of bile salts, or when fat absorption from the intestines is defective. Additionally, in new-born infants the supply of vitamin K from the maternal blood may be scanty. Hence it is only under such circumstances that vitamin K therapy is of use ; it is valueless if there is extensive liver damage, in haemophilia, purpura, diseases of the blood-forming organs, or for the control of haemorrhage in the normal individual. In large doses it acts as a respiratory depressant and produces acute vascular congestion.

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CHAPTER 4

CONSERVANCY

INTRODUCTION

1. Arrangements for sound conservancy are essential for the protection of the health of a community and are complementary to safe food and water supplies. The term conservancy covers the disposal of excreta, sullage water, and refuse. This chapter refers to sewage and refuse disposal on permanent stations.

SEWAGE DISPOSAL

Administration

2. The responsibility for the provision, maintenance, and technical efficiency of all drainage and sewage disposal works at R.A.F. stations rests with A.M.W.D. (Q.Rs. 1743 and 1775). The medical officer must be able to advise the commanding officer on the efficiency of the station sewage disposal arrangements and should take periodic samples of effluent in accordance with Q.R. 1461 (see paras. 19 to 21 of this chapter). Instructions on the management of sewage disposal plants are contained in R.A.F. Form 724, a copy of which must be posted in each works. A detailed account of sewage treatment is contained in A.P. 3129B (Handbook of Sewage Treatment, 1947) which describes the code of practice adopted by A.M.W.D. in the operation and maintenance of sewage purification plants.

3. The clerk of works is responsible for the supervision of sewage disposal on a station. He has a knowledge of the principles of sewage treatment and the operation of sewage plants, of which he carries out frequent inspections. There is normally a civilian attendant in charge of the plant who maintains its technical efficiency and the cleanliness of the plant and its surrounds. The attendant is required to take daily samples of effluent which must be kept for a week before disposal (see para. 21).

Water Carriage System

4. On nearly all permanent stations sewage disposal is by the water carriage system. In this system liquid wastes and excreta are conveyed to the disposal plant by drains and sewers. Drains, which are defined as pipes receiving drainage from one house or curtilage, are fed by soil and waste pipes. A sewer is a pipe receiving wastes from the drains of a number of houses or curtilages. Soil pipes receive excretal wastes, waste pipes all other types of water.

5. **Drains.** Drains are made of glazed stoneware or cast iron. They must be laid in a straight line between points of access, which must be provided in the form of inspection chambers or man-holes, at all junctions, changes in direction, or places where blockage may occur. They must also be laid at such a gradient or fall that solids in the sewage will float down the drain. The drainage system must be ventilated to prevent the accumulation of foul air and the breaking of water seals in traps by siphonage or air pressure. A trap is a pipe bent on itself so that a certain amount of water is retained as a seal to prevent the passage of gases. Ventilation is provided by carrying the upper ends of soil pipes above the eaves of the house and leaving them open.

6. **Sewers.** At the junction of drains and sewers, ventilated inspection chambers must be provided. Sewers vary in diameter from 6 inches to 10 feet, the smaller being made of concrete, the larger built of brickwork. Those up to 2 feet in diameter are circular in cross section ; above that size they may be egg-shaped to increase the depth and velocity of flow. For the sewer to be self-cleaning the flow should be 2 to 3 feet per second.

Sewage

7. Besides faecal matter sewage contains other putrescible material such as food scraps and soap, oil and other industrial wastes from workshops, chemicals from laboratories, and detritus. In some systems, sub-soil and surface drains are connected to sewers so that storm water and surface washings also enter the sewage. Some of the solids dissolve, some remain in gross form, but most become suspended solids of varying particle size. On an average there is 1 pound of solid matter in 100 gallons of fluid, at least half the solid matter being in suspended form. Thus in raw sewage suspended solids constitute approximately 50 parts per 100,000. If, however, surface and sub-soil drains discharge into the sewers the dilution is much greater, especially after heavy rainfall. The average amount of sewage at stations is 20 to 30 gallons each day per head. Quantities in excess of these indicate abnormal usage of water on the camp, or entry of sub-soil or surface water to the sewerage system.

Disposal

8. Except in coastal areas where crude or screened sewage may be discharged directly into the sea, the effluent from disposal plants is usually discharged into ditches, streams, or rivers. The treatment of sewage aims at the production of an innocuous effluent, which will not cause river pollution and endanger fish life, plant life, or health.

Principles of Purification

9. The biological treatment of sewage is carried out in plants designed to produce conditions in which anaerobic and aerobic bacteria can break down the nitrogenous contents to ammonia, nitrites and nitrates. Besides the chemical breakdown products an inert residue remains, as well as small quantities of organic matter. The treated sewage eventually becomes sludge, humus, and effluent. The essential steps in this process are:—

(*a*) Screening to remove gross solids.

(*b*) Reduction of the rate of flow to allow sedimentation and anaerobic action.

(*c*) Filtration to permit oxygenation and the action of aerobic bacteria.

(*d*) Removal of excess organic biological residues and final disposal of effluent and sludge.

10. The final effluent must conform with certain standards depending on the degree of dilution it receives from the river or stream into which it is discharged. These standards are physical and chemical. Bacterial standards are not applicable, as the purification system is not intended to render the effluent sterile, unless special chemical treatment is carried out in addition.

STANDARD SEWAGE DISPOSAL PLANT

Screening Chamber

11. Crude sewage first passes through a screening chamber, sometimes called a grit chamber or detritus tank. This is so constructed that heavy particles such as grit and stones fall to the bottom, but lighter and more bulky objects such as large faecal masses, lumps of paper and twigs are withheld by a screen of iron bars, placed about 1 to 1½ inches apart. The screens should be raked twice daily and sludge removed from the chamber weekly. Rakings and deposits should be buried.

Sedimentation Tank

12. After screening, the crude sewage passes to primary sedimentation tanks where much of the solid matter settles to the bottom as sludge and a surface scum forms. Beneath the scum, the anaerobic bacteria multiply and convert some of the remaining suspended solids into liquid and gas. Two main types of sedimentation tanks are used in the Royal Air Force: in one the flow is horizontal and in the other vertical. The object of both is to slow down the flow sufficiently for sedimentation and anaerobic action to take place. The effluent from sedimentation tanks should not contain more than 10 to 15 parts suspended solids per 100,000.

13. **Horizontal Flow.** The tanks are rectangular in shape (Fig. 9) and are usually installed in duplicate. Screened sewage passes over a weir extending across the whole breadth of the tank and flows out over a similar weir at the other end. Vertical baffles or scum boards are fixed a few inches from each weir and extend 18 inches below the surface of the liquid to retain floating solids. The floor of the tank slopes towards the inlet and a pipe is provided at the lowest point for drawing off the sludge. Efficient function depends upon liquids passing through the tank with a steady flow and low velocity; each tank should be of sufficient capacity to hold 8 to 12 hours' flow of sewage. Rapid flow through the tanks does not allow proper sedimentation and stirs up the sludge which will then choke the percolating filter. Too slow a flow will allow the sewage to putrefy. Under normal conditions, sludge should be removed and the tanks cleaned once a month. If the plant is overloaded, weekly removal may be necessary. If the surface scum forms rapidly it should be removed at intervals of about three days ; but since disturbance of the tank contents is undesirable the scum should normally be two inches thick before removal is attempted. It should be buried, not deposited on the sludge beds.

14. **Vertical Flow.** The vertical flow tank is constructed in the form of an inverted pyramid and is much deeper than the horizontal flow tank (Fig. 10). The inlet is in the centre of the tank near the surface and is surrounded by a baffle extending to a depth of 5 to 6 feet. The sewage passes down under this baffle, then upwards outside it, depositing the solids on the way. It then flows under scum boards which retain any floating debris, and over a weir to the outlet channel and percolating filter. It is usually best to remove sludge in two or three successive stages without allowing the water level to drop too far. This will allow settling of the sludge in the intervals and its removal with the minimum loss of liquid. Scum should be removed only when the level of the liquid has been lowered during sludge removal.

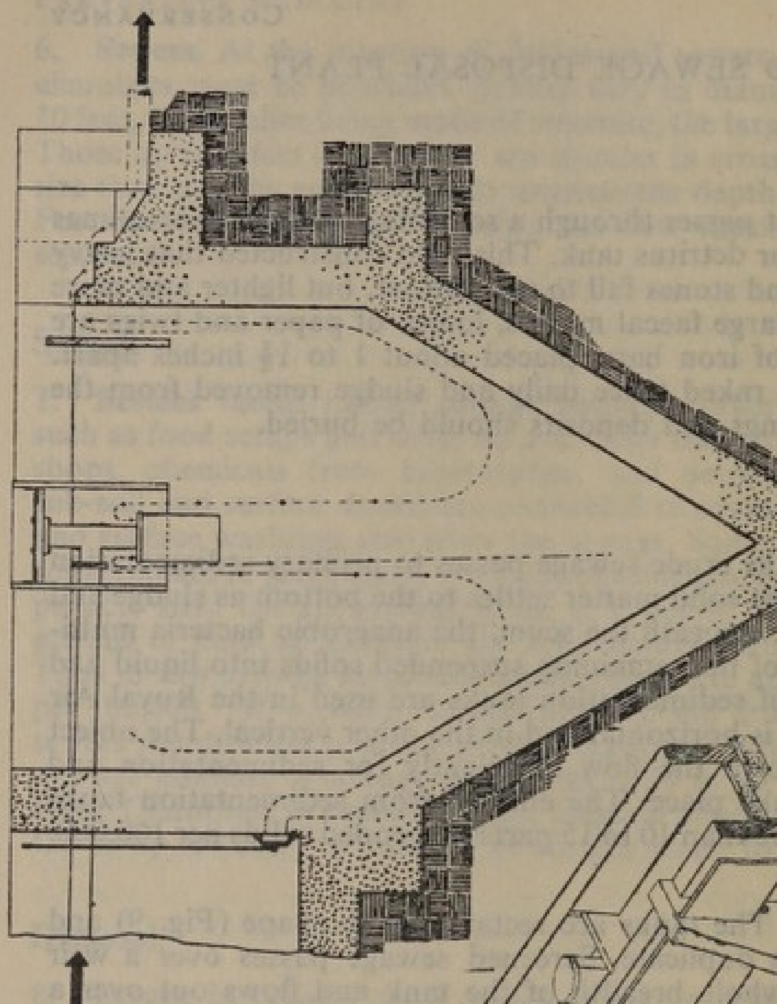


FIG. 10. SEDIMENTATION TANK—VERTICAL FLOW

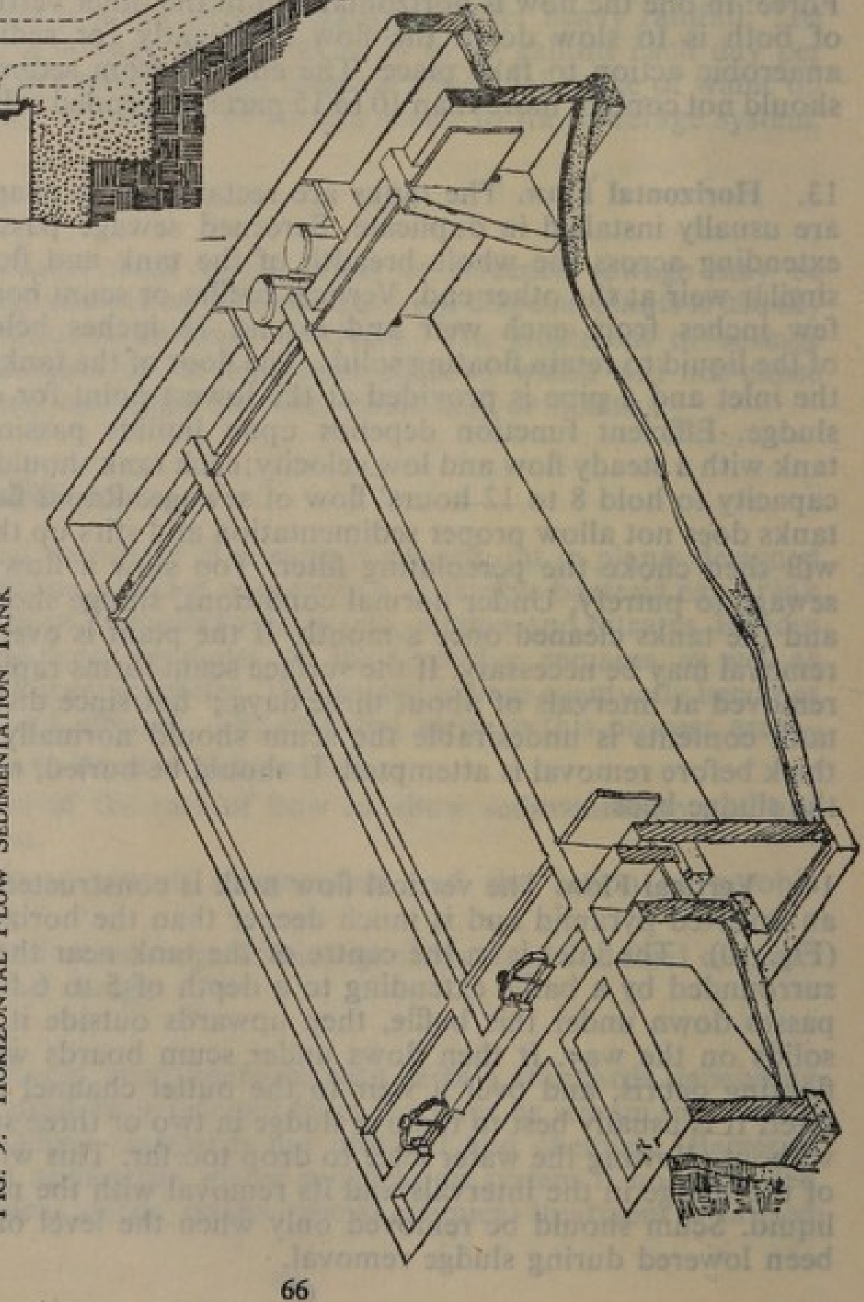


FIG. 9. HORIZONTAL FLOW SEDIMENTATION TANK

Percolating Filters

15. After sedimentation the sewage passes through percolating filters. These are not intended further to separate solids by filtration, but to provide aeration beds with a large surface area where ample oxygenation will enable aerobic organisms to break down colloidal and very finely suspended matter. These aerobes exist in a gelatinous bacterial film which forms when sewage is passed over the filter medium.

16. The filter is usually 4 to 6 feet deep and consists of a medium which must be hard, durable, and have a rough texture to ensure film adhesion. Clinkers, which are mainly composed of ash, or other materials which rapidly disintegrate are useless. The bed should be graded from about $\frac{3}{4}$-inch material in the top layer to $2\frac{1}{2}$-inch material in the lower layers. Larger pieces, 4 to 6 inches in size, are placed on the bottom of the bed surrounding the drainage pipes which lead to the outlet.

17. Effluent from the sedimentation tanks passes into a dosing tank from which it is discharged at intervals by an automatic siphon. Liquid is distributed over the surface of the filter by rotating perforated arms into which it flows from a central hollow pillar fed from below. If the effluent from the sedimentation tanks contains an excess of suspended solids or is flowing too fast, the top layers of the filter become clogged and ponds form on the surface. When extensive ponding occurs, it may be necessary to rake or fork the surface gently, The rate of percolation should be approximately 80 gallons per day per cubic yard when the sewage is weak, 60 gallons when it is medium, and 48 gallons when strong. Sewage from stations where the water consumption is 30 to 35 gallons per head per day is normally of medium strength.

Humus Tanks

18. The effluent from the filters contains fine dark-coloured suspended matter known as humus, which consists of the bodies of organisms, fragments of film, and particles of medium. Humus has a high water content and, while not entirely inert, is virtually not putrescible. Final settling tanks, known as humus tanks, are provided for its removal; they may be of either the horizontal or vertical flow type but are considerably smaller in size than a primary sedimentation tank. Horizontal flow types should be cleaned out weekly, but the vertical flow type require cleaning every four or five days. If humus is seen passing over the outlet weir, more frequent cleaning is necessary. Humus may be disposed of on land, in sludge beds, or by burial.

Sampling of Sewage Effluents

19. **Laboratory Samples.** The sewage effluent, from all R.A.F. stations that have their own sewage purification works, is examined by a laboratory at least once a year. In the United Kingdom bottles will be supplied from the Royal Air Force Institute of Pathology and Tropical Medicine, Halton, Bucks., and should be returned in the same manner as water samples (see Chapter 2). The effluent should be collected in a Winchester quart bottle from the pipe or channel which discharges from the humus tank. The loading of sewage plant is not uniform, since the amount of faecal matter and the quantity of sullage water from kitchens and ablutions vary according to the time of day or night. Unless hourly samples are taken over a period of 12 to 24 hours and mixed thoroughly, a representative sample will not be obtained. Spot samples are, however, normally acceptable.

20. The following information is required to help the analyst in formulating his report:—

(*a*) Site of sewage disposal works.

(*b*) Date and hour of collection.

(*c*) Type of treatment plant:—

(i) Sedimentation or septic tank.

(ii) Sedimentation and filtration only.

(iii) Sedimentation, filtration, and humus settlement.

(iv) Activated sludge (Simplex Process).

(*d*) Method of effluent disposal:—

(i) To ditch or stream.

(ii) Surface irrigation.

(iii) Soakaways.

(*e*) Approximate estimate of the relative volumes of the effluent and receiving stream, where discharge is to the latter.

(*f*) Rainfall during week preceding collection of samples, *e.g.* nil, slight, moderate, or great.

(*g*) Point of collection of sample, *e.g.* at humus tank, at entry to stream, at boundary of Air Ministry property.

(*h*) Other information, *e.g.* use of chemicals for treatment, chlorination of effluent, entry of surface water to foul drainage system.

(*j*) Reason for desiring analysis.

(*k*) Signature of officer sending the sample.

21. **Field Tests.** Daily samples should be taken by the sewage plant operator. If kept for a week these should be the colour of rain water, have no turbidity and little sediment. They should not decompose or have a faecal odour.

Qualities of a Satisfactory Effluent

22. The qualities of an effluent are not judged by its bacterial content. Effluents from sewage works are never sterile unless chlorinated. The characteristics of an effluent are judged by its suspended solids content, nitrate content, and biological oxygen demand. Accepted standards, when dilution by the receiving stream is 150 to 1 or less, are:—

(*a*) Suspended solids (S.S.) must not exceed 3 parts per 100,000.

(*b*) Biological oxygen demand (B.O.D.) must not exceed 2 parts per 100,000.

(*c*) Nitrates must be not less than 0·5 parts per 100,000.

When the stream is from 150 to 300 times the volume of the effluent, B.O.D. may be neglected, but the suspended solids should not exceed 6 parts per 100,000. When the stream is from 300 to 500 times the volume of the effluent, the suspended solids should not exceed 15 parts per 100,000.

23. **Suspended Solids.** The total solids in sewage consist of all faecal and inorganic matter contained in it. Some of these solids are insoluble floating particles. The gross solids are removed by screening, the large particles by sedimentation. The remaining suspended solids can be removed only by bacterial action. Excess suspended solids in the effluent show that insufficient bacterial action has taken place.

24. **Biological Oxygen Demand.** The presence of organic matter and bacteria in water creates an increased oxygen demand. If there is an excess of oxidizable constituents in the effluent, effective purification is not taking place in the plant. Thus a high B.O.D. shows that either sedimentation is ineffective or bacteriological action is poor, or both.

25. **Nitrates.** The oxidization and breakdown by bacteria of nitrogenous matter produces nitrates. Absence of nitrates in the effluent indicates that this process is not occurring. This may be due to excess demands on available oxygen, which is thus a corollary to a high B.O.D. or it may be caused by inefficient aeration in the percolating filters.

VARIATIONS FROM STANDARD PLANTS

Activated Sludge (Simplex) Process

26. In the Simplex process screened sewage, free from detritus, is agitated with specially ripened or activated sludge. The process is partly physical and partly biochemical. Activated sludge is made by aerating for some days sludge obtained from contact beds or percolating filters. In practice, sewage, after being screened and passed through detritus tanks, is aerated for a period of two to four hours in the presence of 7 to 10 per cent. of activated sludge as it flows continuously through an aerating tank. Aeration may be carried out either by exposing the liquids to atmospheric conditions or by the injection of compressed air. This is followed by passage through settlement tanks for another two to four hours. The sludge deposited in the settlement tanks is returned in part to mix with the sewage as it enters the aeration tanks and the rest is run off to sludge-drying beds.

Cesspool

27. The cesspool is a watertight pit which acts as a reservoir for sewage. The amount of solid deposit left after prolonged use is small. The liquefaction and disappearance of the solid constituents of the sewage is due to the action of anaerobic bacteria. Cesspools can only deal with sewage from a small number of people and are therefore most commonly found serving individual houses in isolated communities. Frequent emptying is necessary to prevent the liquid contents overflowing. There is always the risk that there may be leakage from the pit which may contaminate water supplies. Cesspools must be constructed so that they are watertight and adequately ventilated.

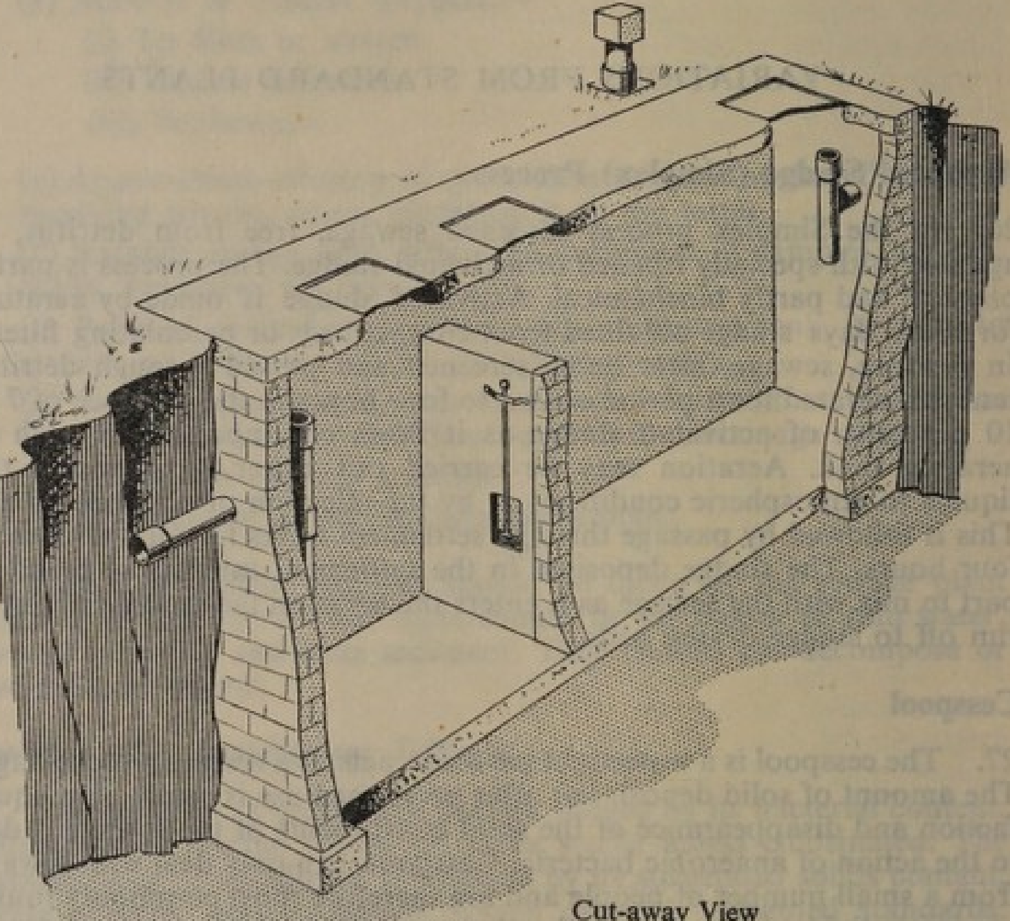
Septic Tank

28. Septic tanks (Fig. 11) are sealed underground receptacles into which sewage flows at such a rate that it remains about six hours in the tank before flowing away through an elbow pipe beneath the surface of the liquid. About 50 per cent. of the solids deposited in the tank are converted into gas and soluble substances by anaerobic action. The sludge remaining must be cleaned out at intervals or it will be washed into and choke the drainage system. A well-designed tank of sufficient capacity may be left for three years without sludge removal. A septic tank is limited in capacity and can only deal with sewage from a large house or institution. The passage of sewage through the tank does not alone give a satisfactory effluent and should be followed when possible by aeration.

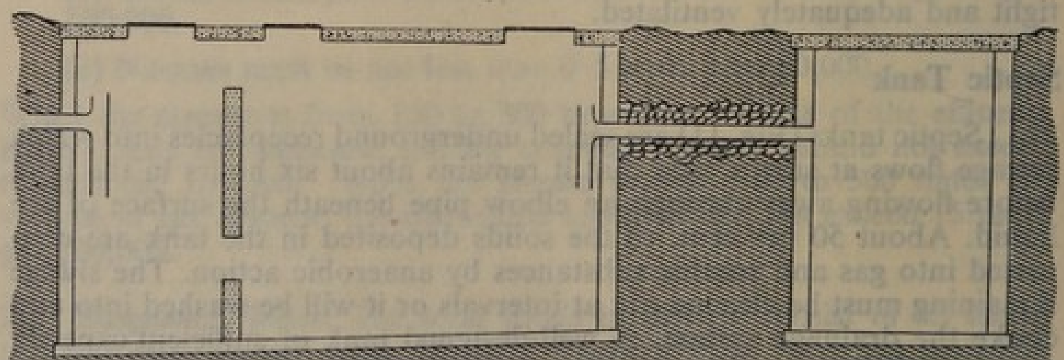
REFUSE DISPOSAL

General

29. The composition of refuse varies with the seasons both in quality and quantity. During the winter months the high consumption of solid fuel greatly increases the quantity and the proportion of ash or clinker. Refuse is classified as either combustible or non-combustible and on a station will on the average be made up in the following proportions.



Cut-away View



Section

FIG. 11. SEPTIC TANK

30. Non-Combustible Refuse.

		Per Cent.
(*a*)	Fine dust and clinker	50·8
(*b*)	Brick, pots, slate, etc.	8·6
(*c*)	Tins, drums, etc.	7·2
(*d*)	Glass	0·3
(*e*)	Scrap-iron	0·3
		67·2

31. Combustible Refuse.

(*a*)	Cinders	30·9
(*b*)	Rags	0·4
(*c*)	Waste paper, cardboard, etc.	0·2
(*d*)	Vegetable matter	1·3
		32·8

32. Wet and dry swill is also classified as refuse, but is kept separate and disposed of either to the unit farm or by local contract. A certain percentage of refuse is salvaged and stations have an organization which collects and disposes of all material of salvage value (A.P. 3045 refers). The approximate daily yield of refuse from a community may be computed as follows:—

$$\frac{\text{Thousands of population}}{4} \times 3 = \text{Yield in tons per day.}$$

Organization of Refuse Disposal

33. The collection and disposal of refuse may be carried out by local authorities, by station labour and transport, or by a contractor. Details are given in A.P. 830, Vol. 1, Part 2, Leaflet B. 28/4. The services provided by local authorities vary from the collection of refuse from married quarters only to collection from the entire station. The station may thus have to supplement the local authorities' services and carry out the balance of scavenging work in accordance with Q.Rs. 1462 and 1846. Only if it is impossible to organize an adequate refuse disposal service from the resources of the local authority and station labour is a contract normally authorized.

34. Irrespective of the type of scavenging service, it requires systematic planning. At messes, cookhouses, and institutes the frequency of collections should be as circumstances dictate, but daily collections are to be preferred. From all other buildings a weekly collection is normally sufficient, but this may be increased if certified by the unit medical officer or a command hygienist to be necessary in the interests of satisfactory sanitation.

35. If a station is so large that collection cannot economically be achieved in one day, it should be divided into areas, each to be cleared on a specific day each week. Time and labour are saved by allocating central collecting points to areas; to these the refuse bins are carried for clearance by the refuse vehicle on its rounds. Arrangements are also necessary for the bins to be returned to the appropriate place after emptying.

36. Refuse must not be allowed to overflow onto the ground, but must be kept covered in bins with well fitting lids until collected. The bins supplied are of a standard type conforming to British Standard Specification No. 793—1940. It is important to ensure that sufficient bins are provided to hold the normal volume of station refuse. Reasonable care is required in handling bins to prevent them becoming leaky and so distorted that the lids no longer fit.

37. Whenever possible arrangements should be made to dump refuse off the station, either on a local authority tip or on private land. All tipping must be controlled as described below and any local authority requirements must be observed. Tips within station boundaries must be sited well away from domestic or technical accommodation. If difficulty occurs in their control they should be sealed and abandoned.

Method of Disposal

38. The disposal of refuse is carried out in various ways depending among other things upon the physical characteristics of the district, the situation of the disposal site, the quantity and quality of the refuse, and the method of collection. The normal methods are incineration or controlled tipping.

Incineration

39. Incineration alone is not sufficient for complete disposal and is usually co-ordinated with a system of tipping. Besides all combustible material, food tins must be burnt before tipping takes place to prevent infestation of the tip by pests. Dry refuse is easily reduced to a small volume of ash, by burning, but it is necessary to add fuel to wet refuse to assist evaporation of moisture and combustion. Various forms of incinerators are in use and the choice of type depends on materials available, the quantity of refuse for disposal, and the length of time for which the incinerator is required. Field incinerators are described in Chapter 5. The incinerators described below are those normally used on permanent stations in the United Kingdom. They should be sited away from living quarters and as near to the refuse dump as possible. Ideally they should be surrounded by a properly constructed incinerator compound. The floor of this compound should be made of concrete surrounded by a brick wall six feet high. There should be two covered-in sheds, one to contain dry refuse for combustion, the other to contain fuel for starting the fire and for keeping the necessary tools. There should be a properly constructed road to the compound with room for vehicles to turn.

40. **Horsfall Incinerator** (Fig. 12). This incinerator is supplied from the manufacturer in metal sections. The inside is lined with fire bricks. A baffle arch within the destructor directs the smoke and fumes through the hottest part of the fire before emission through the flue ; this ensures complete combustion and reduces smoke. The chimney should be long enough to discharge the smoke above the walls of the compound. Horsfall incinerators are supplied in various sizes. A large one, if properly maintained and stoked, can destroy 1 to 1½ tons of combustible refuse per day.

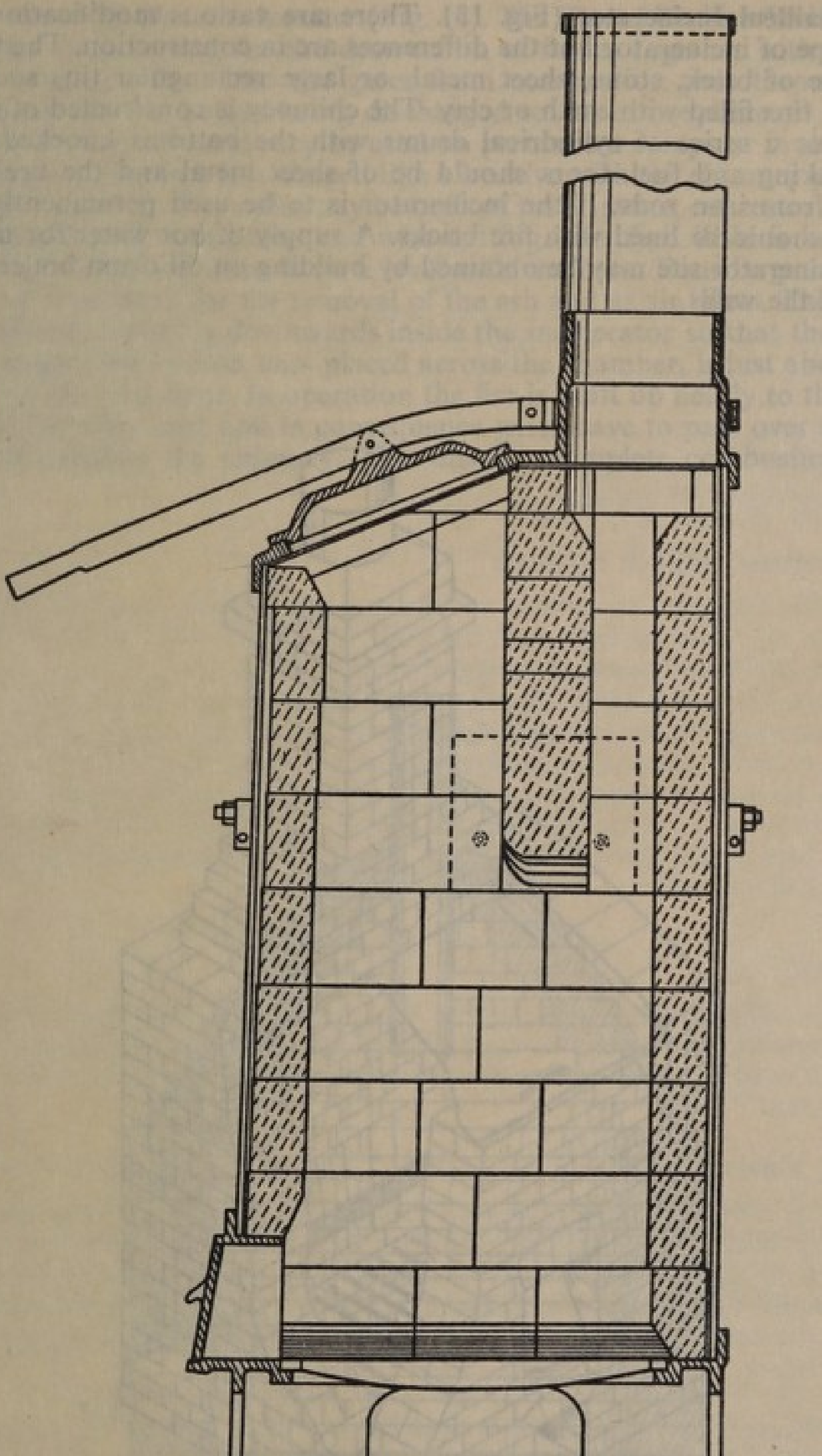


FIG. 12. HORSFALL DESTRUCTOR

41. **Bailleul Incinerator** (Fig. 13). There are various modifications of this type of incinerator but the differences are in construction. The walls may be of brick, stone, sheet metal, or large rectangular tins such as biscuit tins filled with earth or clay. The chimney is constructed of sheet metal or a series of cylindrical drums with the bottoms knocked out. The raking and fuel doors should be of sheet metal and the fire bars made from iron rods. If the incinerator is to be used permanently the inside should be lined with fire bricks. A supply of hot water for use at the incinerator site may be obtained by building an oil drum boiler into one of the walls.

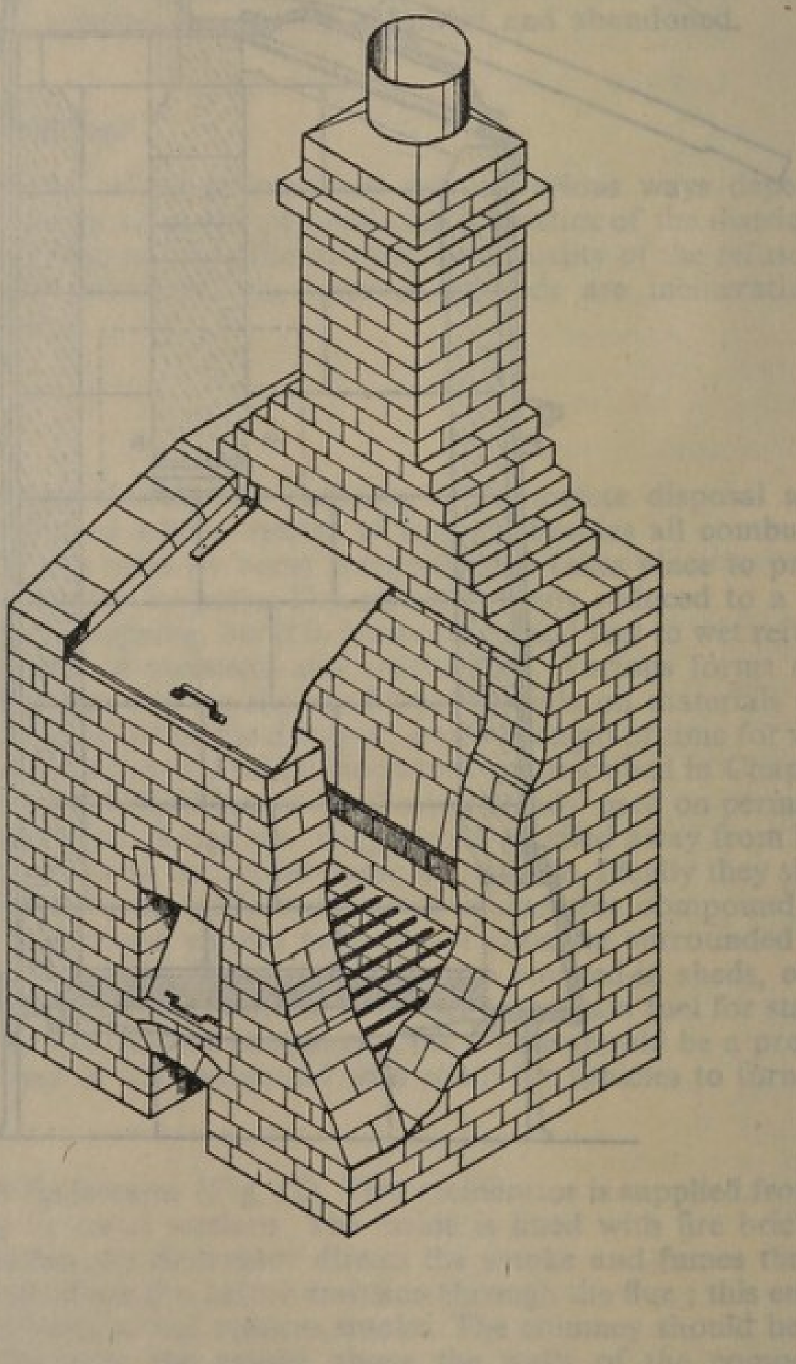


FIG. 13. BAILLEUL INCINERATOR

42. **Closed Beehive Incinerator** (Fig. 14). The Closed Beehive Incinerator is often used abroad for the destruction of faeces together with refuse. It is constructed so that the gases from combustion pass through the centre of the fire before being discharged to the atmosphere. It can be constructed locally and may be used on permanent camps or in the field. As its name implies, it is shaped like a beehive with the chimney projecting from the top. The walls may be built of brick, stone, concrete, or mud reinforced with metal bars and wire netting. The feed door is near the top and the raking door is on a level with the bars. Four large holes at ground level serve for the removal of the ash and as air inlets. The chimney extends centrally downwards inside the incinerator so that the lower end, supported by iron bars placed across the chamber, is just above the level of the feed door. In operation the fire is built up nearly to the level of the chimney inlet and in consequence gases have to pass over the fire before entering the chimney. This ensures complete combustion.

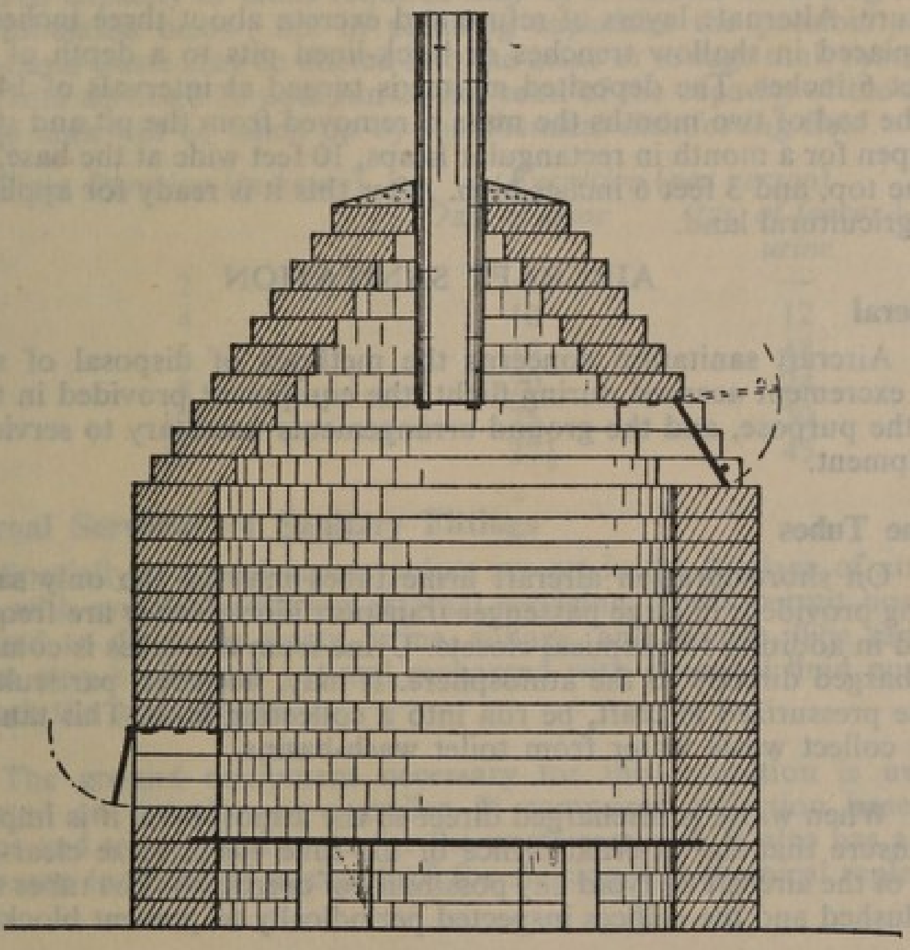


FIG. 14. CLOSED BEEHIVE INCINERATOR

Controlled Tipping

43. The term "Controlled Tipping" describes the disposal of refuse by dumping in a methodical as distinct from an indiscriminate manner. Disused excavations, such as quarries, or low-lying sites free from water, are chosen for this purpose. Refuse is deposited in layers approximately six feet in depth, in strips 15 feet wide. Tipping is carried out progressively from the ends of the strips, the sides being kept properly trimmed, sloped, and covered with earth. Paper, cardboard, and combustibles are raked out, flattened, and laid at the bottom. Tins and receptacles of all kinds are either flattened or laid mouth upwards and filled with refuse. Ashes and putrescible material are put on top of the paper, larger articles of refuse are placed at the bottom, and the smaller refuse forms the upper layer. Each layer is covered with earth about one foot in depth. By careful packing in this way and by compression, air space is reduced to a minimum, spontaneous combustion is prevented, and rats, mice and flies are denied a breeding ground.

Composting (Indore System)

44. The compost process is used abroad, primarily where the organic content of refuse is high and there is need to dispose of excreta from bucket latrines. The aim is to convert these wastes to humus of value as manure. Alternate layers of refuse and excreta about three inches deep are placed in shallow trenches or brick-lined pits to a depth of about 2 feet 6 inches. The deposited matter is turned at intervals of 14 days. At the end of two months the mass is removed from the pit and stacked to ripen for a month in rectangular heaps, 10 feet wide at the base, 9 feet at the top, and 3 feet 6 inches high. After this it is ready for application to agricultural land.

AIRCRAFT SANITATION

General

45. Aircraft sanitation concerns the methods of disposal of sullage and excrement accrued during flight, the equipment provided in the air for the purpose, and the ground arrangements necessary to service this equipment.

Urine Tubes

46. On short-duration aircraft urine tubes may be the only sanitary fitting provided; in large passenger transport aircraft they are frequently fitted in addition to chemical closets. Urine from the tubes is commonly discharged directly to the atmosphere. It may, however, particularly in some pressurized aircraft, be run into a collecting tank. This tank may also collect waste water from toilet wash-basins.

47. When waste is discharged direct to the atmosphere, it is important to ensure that the external orifice of the tube ejects urine clear of the side of the aircraft to avoid any possibility of corrosion. The tubes should be flushed and the orifices inspected periodically to prevent blockage.

Chemical Closets—Bucket Type

48. Chemical closets are fitted in passenger transport aircraft instead of, or in addition to, urine tubes. Firm attachment to the floor, a reflected rim to guard against splash and a cover are necessary features of their design. Removal, cleansing, and replenishment should be undertaken on a daily basis by a special department of the servicing organization at base or staging points.

Chemical Closets—Flush Type

49. Closets of the flush type have a pan connected to a separate sewage tank containing a deodorizing disinfectant fluid. By operation of a lever, which may be the closet lid, the fluid is circulated between the pan and the tank, to act as a flush.

50. Closets with a fitted reservoir as part of their structure may be completely removed from the aircraft for cleansing and replenishment of fluid. Most commonly, however, closets are permanent aircraft fittings, draining, either as single or multiple units, to a common sewage tank. This system requires special airfield equipment to provide servicing.

Lavatory Accommodation

51. Closets should be provided in aircraft on the basis of one for every 25 persons, including crew, that the aircraft is designed to carry. Each lavatory should preferably be equipped with a urine tube as well as a closet, to restrict dilution of the chemical closet fluid.

Urine and Sewage Tank Capacity

52. The capacity of tanks required may be estimated according to the data tabulated below; but in planning capacities the possibility that wash-basin waste may be ducted into the urine or sewage tank should be taken into account. In addition 20 per cent. of the capacity of the closet sewage tank will be taken up by the chemical disinfecting fluid.

Flight Duration (*in hours*)	*Excretion* (*per person*)	
	Ozs. of urine	*Ozs. of faeces + urine*
2	5	—
4	10	12
6	15	18
8	20	24
10	25	30
15	37½	45

External Servicing of Sanitary Fittings

53. Specially designed access points are set in the fuselage of aircraft fitted with systems requiring external servicing. These permit hoses to be fitted to discharge waste, urine, sullage, and sewage. The sanitary system may be flushed out and recharged with chemical fluid pumped through the same hoses.

54. The ground equipment necessary for this operation is usually mounted on a trolley or a trailer. It comprises collection hoses for sullage and sewage and tanks for the waste removed; it also has a tank and pump (manual or mechanical) for sluicing and chemical replenishment.

Disposal of Chemical Closet Waste

55. Water-borne sewage systems may be utilized where a dilution of chemical can be assured that will prevent damage to sewage farm filter beds or contamination of watercourses receiving the final effluent. If there are objections to the use of water-borne systems for this purpose, or in places where no such system exists, disposal should be to Otway pits.

Chemical Closets—Flush Type

49. Closets of the flush type have a pan connected to a separate sewage tank containing a deodorizing disinfectant fluid. By operation of a lever, which may be the closet lid, the fluid is circulated between the pan and the tank to act as a flush.

50. Closets with a fitted reservoir as part of their assembly can be completely removed from the aircraft for cleaning and replenishment of fluid. Most commonly, however, closets are permanent aircraft fittings, draining, either as single or multiple units, to a common sewage tank. This system requires special airfield equipment to provide servicing.

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51. Closets should be provided in aircraft on the basis of one for every 25 persons, including crew, that the aircraft is designed to carry. Each lavatory should preferably be equipped with a urine tube as well as a closet, to restrict dilution of the chemical closet fluid.

Urine and Sewage Tank Capacity

52. The capacity of tanks required may be estimated according to the data tabulated below; but in planning capacities the possibility that wash-basin waste may be drained into the urine or sewage tanks should be taken into account. In addition, 20 per cent of the capacity of the closet sewage tank will be taken up by the chemical disinfecting fluid.

Flight Duration (in hours)

External Servicing of Sanitary Fittings

53. Specially designed couplings are set in the fuselage of aircraft fitted with systems requiring external servicing. These permit hoses to be fitted to discharge waste, urine, sullage and sewage. The sanitary system may be flushed out and recharged with chemical fluid pumped through the same hoses.

54. The ground equipment necessary for this operation is usually mounted on a trolley or a trailer. It comprises collection hoses for sullage and sewage and tanks for the waste removed; it also has a tank and pump (manual or mechanical) for flushing and chemical replenishment.

Disposal of Chemical Closet Wastes

55. Water-borne sewage systems may be utilized where a dilution of chemical salt will prevent damage to sewage farm filter beds or contamination of watercourses receiving the final effluent. If there are objections to the use of water-borne systems for this purpose, or in places where no such system exists, disposal should be to Otway pits.

CHAPTER 5

FIELD HYGIENE

INTRODUCTION

1. The main problems of living under field conditions concern the provision of adequate shelter in an orderly camp, sufficient wholesome food and water supplies, facilities for personal hygiene, and the disposal of excreta and refuse. The basic principles of hygiene are no different from those applicable in permanent camps, but for obvious reasons their observation in the field has added importance. Sound planning and the provision of adequate facilities alone are insufficient; close and continuous supervision is essential to ensure a high standard of field hygiene. Finally, it is not essential for camp life to be too hard and austere; a little skill and ingenuity can provide a reasonable degree of comfort.

TENTED CAMPS

Siting

2. A medical officer should always be included in a camp siting party so that he may advise on the essential medical aspects. Although selection depends to a great extent on the availability of water supplies and on general accessibility, the ideal site for a tented camp is on high ground with a gentle slope, good grass covering, well drained sub-soil, and an aspect facing the morning sun. It is rarely possible, often for tactical reasons, to combine all these requisites, but certain localities should be avoided; low meadows, river beds, impervious soils and the base of hills are unsuitable owing to the risk of flooding. Steep bare slopes can become rivers in heavy rain. The tops of hills may be exposed to strong winds. Ground close to villages or graveyards and camp sites, which have recently been abandoned, may be fouled and infected. Ploughed fields or lately turned soil will not stand up to the passage of troops or transport. Sites adjacent to breeding grounds of vectors or reservoirs of infection are obviously undesirable.

Layout

3. The layout of a camp is governed by the topography of the site. Dispersal should be avoided unless a tactical necessity. Domestic and sleeping accommodation should be to the front of the camp, which should face the prevailing wind; cooking and messing facilities should be to one side, with the conservancy area to leeward and sited so that it will not contaminate the water supply. The ablution area should be on the opposite perimeter to that of the kitchen and food preparation area. Roads and paths should be planned and marked out, not allowed to develop at random. They should be reduced to a minimum and always pass to leeward of those places where dust is particularly undesirable, for example messes.

Camp Routine

4. Effective camp hygiene demands a fixed sanitary routine. All refuse buckets, swill bins, latrine and urinal pails, must be emptied and cleaned at least daily. The grease traps and strainers constructed for ablution and wash-up benches must be cleaned or replaced frequently. Tent flies must be looped up all round each morning in fine weather and on the leeward side when it is wet or stormy. Blankets and bedding should be aired daily, if weather permits, while care must be taken to slacken off guy ropes in the wet.

URINALS

General

5. On the average 100 men produce 30 gallons of urine per day. To prevent fouling of the ground, urinals must be erected which will either collect the urine for ultimate removal or dispose of it directly below ground. Urinals must be accessible, otherwise they will not be used. Some should be sited for the use of the staff at a reasonable distance from kitchens or the food preparation area. There should also be others adjacent to latrines; this to some extent lightens the load on latrines and may obviate the need for separate screens and paths. Night urinals must be placed near sleeping quarters and be emptied daily.

Shallow Trench Urinal

6. A trench 10 feet long by 3 feet wide and 6 inches deep with the excavated earth banked up on three sides is sufficient for 250 men for 24 hours. The floor of the trench should be forked over to assist soakage. At the end of the 24 hours the trench should be refilled and the turf replaced. A urinal of this type should only be used for short halts and temporary camps.

Funnel Urinal

7. Urinal tubes improvised from scrap metal are built into each corner of a soakage pit at an angle of about 60° to the ground. The lower ends of the tubes should discharge about two feet below the surface and near the centre of the pit, to avoid earth being washed from the sides and clogging the tube. The funnels should be tapered from 12 inches diameter at the top to 2 inches at the bottom. A detachable wire or perforated metal strainer should be inserted about 6 inches from the top of each funnel (Fig. 15). There are many equally effective variations of this basic pattern (Figs. 16 and 17).

Trough Urinal

8. A trough 8 feet long is sufficient for the use of 100 men. It should discharge into a soakage pit of standard size and be moved when this ceases to function, which will depend on the porosity of the ground. It may be made from a sheet of corrugated iron or other suitable scrap metal; Fig. 18 shows a trough made from six oil drums, the joints being lapped one inch and soldered. The metal is carried up to form a back to the trough and the whole is supported by timber uprights and brackets. The trough should stand 2 feet 3 inches above ground level and have a fall of 6 inches towards the outlet, which is connected by a pipe, 2 to 3 inches in diameter, to a soakage pit. This pipe may be improvised from sheet metal with a seamed joint or from small tins with their ends removed. A strainer must be provided at the head of the outlet pipe.

Pail Urinals

9. Where urinals which require soakage pits are not practical, pail urinals must be used. The pail must be wide at the top, made of impervious material, have a handle and preferably a lip for easy emptying. Improvised containers should also be wide-topped or fitted with a funnel

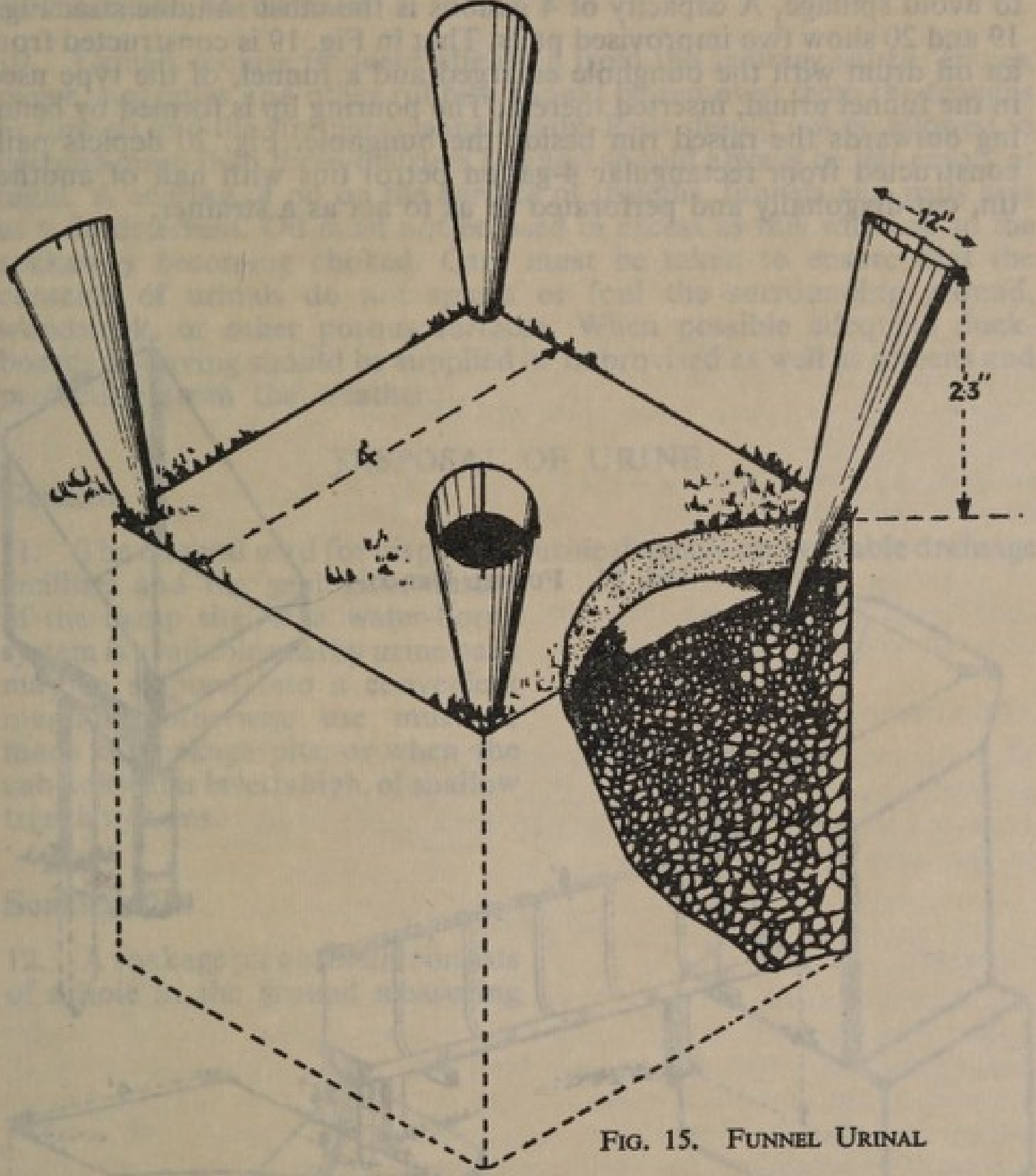


FIG. 15. FUNNEL URINAL

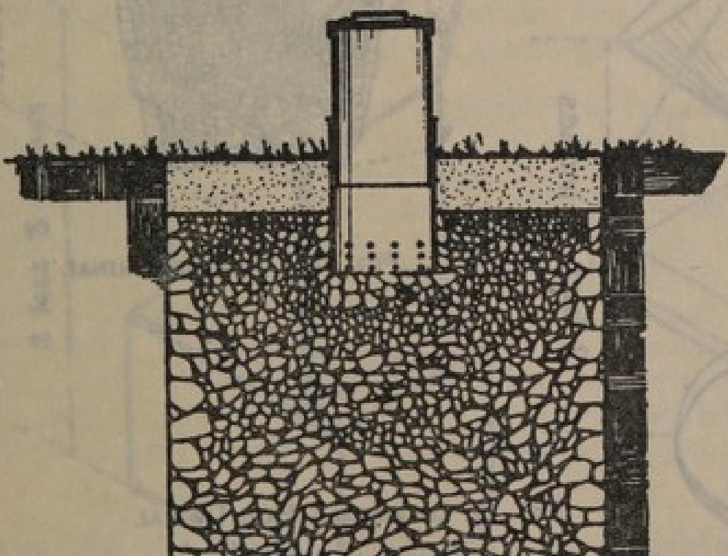


FIG. 16.
FUNNEL URINAL
(Soakage Pit)

to avoid spillage. A capacity of 4 gallons is the most suitable size. Figs. 19 and 20 show two improvised pails. That in Fig. 19 is constructed from an oil drum with the bunghole enlarged and a funnel, of the type used in the funnel urinal, inserted therein. The pouring lip is formed by bending outwards the raised rim beside the bunghole. Fig. 20 depicts pails constructed from rectangular 4-gallon petrol tins with half of another tin, cut diagonally and perforated so as to act as a strainer.

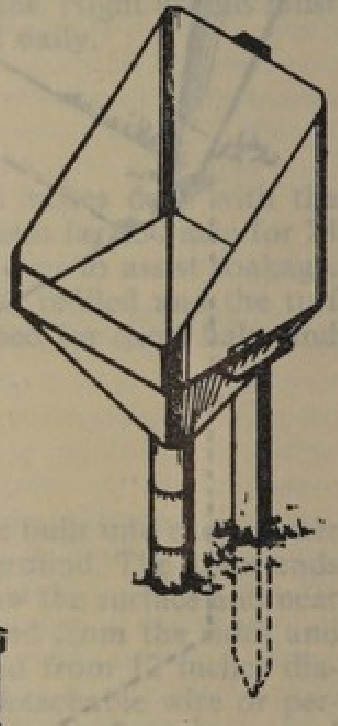


FIG. 17. FUNNEL URINAL

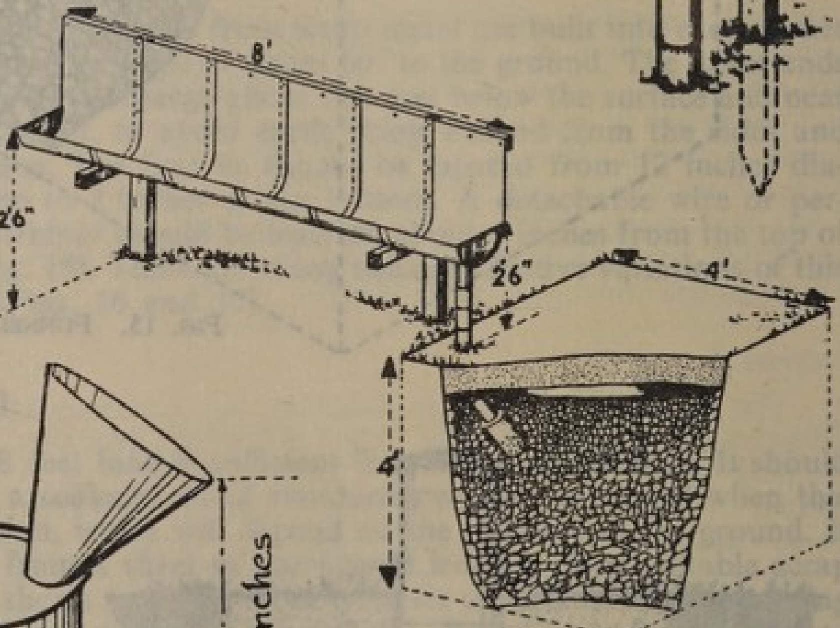


FIG. 18. TROUGH URINAL

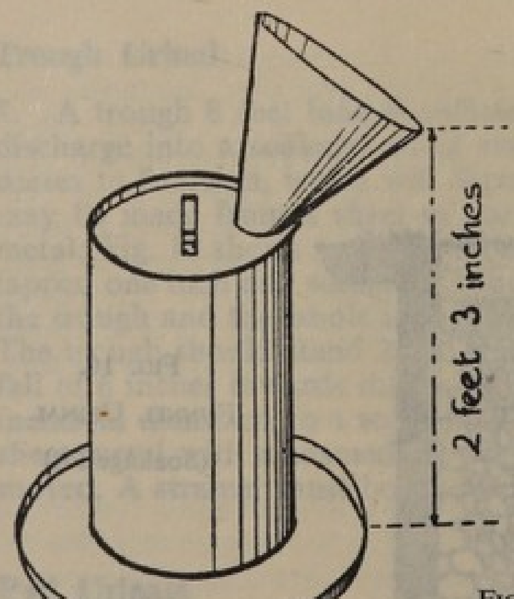


FIG. 19. IMPROVISED PAIL URINAL
(From an Oil Drum)

Maintenance of Urinals

10. Urinals require frequent attention from the sanitary squad; leaves, paper, cigarettes and other rubbish should be removed from the troughs or funnels and the strainers cleaned daily. Pails should not be allowed to become more than three-quarters full and should always be left empty at night. A coating of oil on the surface of troughs, funnels and pails acts as a fly deterrent. Oil must not be used in excess as this will lead to the soakaway becoming choked. Care must be taken to ensure that the contents of urinals do not splash or foul the surrounding ground, woodwork, or other porous surfaces. When possible adequate duck-boards or paving should be supplied or improvised as well as screens and protection from the weather.

DISPOSAL OF URINE

General

11. The method used for disposal of urine depends on available drainage facilities and the geological nature of the camp site. If a water-borne system is available nearby urine pails may be emptied into a convenient manhole; otherwise use must be made of soakage pits, or when the sub-soil water level is high, of shallow trench systems.

Soakage Pit

12. A soakage pit normally consists of a hole in the ground measuring

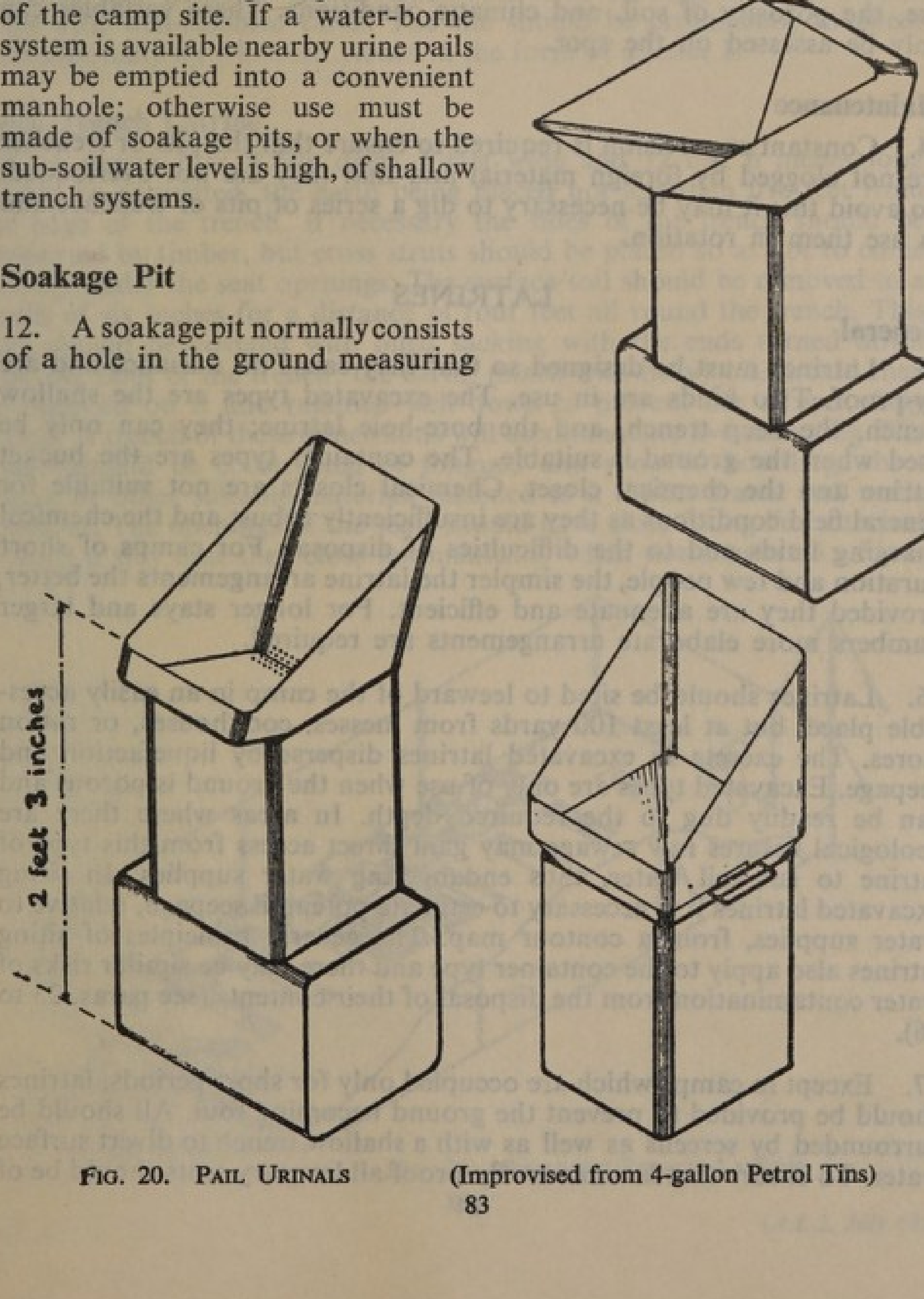


FIG. 20. PAIL URINALS (Improvised from 4-gallon Petrol Tins)

4 feet by 4 feet by 4 feet, giving an absorption area of 80 square feet. The duration of use depends on the depth of the sub-soil water and the porosity of the surrounding ground. The pit is filled to within six inches of ground level with stones, rubble, or perforated tins. The larger, coarser material is placed near the side and bottom. The whole is covered with a layer of oiled sacking and earth replaced on top. The funnels should discharge into the soakage pit near the centre to avoid clogging by earth washed from the sides (see Figs. 15, 16, and 18).

Shallow Trench

13. If the sub-soil water level is too high to dig a pit 4 feet deep, a system of shallow trenches can be used to dispose of urine. The trenches should be dug as deep as possible and filled to within six inches of the surface with material similar to that used in soakage pits. They are then covered with oiled sacking and earth. Suitable dimensions for the trench are 10 to 20 feet long and 3 feet wide. Urine is emptied into the trenches through funnels like those used for soakage pits. The number of trenches required and their duration of use depends on the extent of use, the porosity of soil, and climatic conditions. These variables can only be assessed on the spot.

Maintenance

14. Constant supervision is required to ensure that the pits or trenches are not clogged by foreign material and that they are not overloaded. To avoid this it may be necessary to dig a series of pits or trenches and to use them in rotation.

LATRINES

General

15. Latrines must be designed so that they cause no nuisance and are fly-proof. Two kinds are in use. The excavated types are the shallow trench, the deep trench, and the bore-hole latrine; they can only be used when the ground is suitable. The container types are the bucket latrine and the chemical closet. Chemical closets are not suitable for general field conditions as they are insufficiently robust and the chemical charging fluids add to the difficulties of disposal. For camps of short duration and few people, the simpler the latrine arrangements the better, provided they are adequate and efficient. For longer stays and larger numbers more elaborate arrangements are required.

16. Latrines should be sited to leeward of the camp in an easily accessible place, but at least 100 yards from messes, cookhouses, or ration stores. The excreta in excavated latrines disperse by liquefaction and seepage. Excavated types are only of use when the ground is porous and can be readily dug to the required depth. In areas where there are geological fissures raw sewage may gain direct access from this type of latrine to sub-soil water, thus endangering water supplies. In siting excavated latrines it is necessary to estimate potential seepage, relative to water supplies, from a contour map. The general principles of siting latrines also apply to the container type and there may be similar risks of water contamination from the disposal of their contents (see paras. 23 to 26).

17. Except in camps which are occupied only for short periods, latrines should be provided to prevent the ground becoming foul. All should be surrounded by screens as well as with a shallow trench to divert surface water. To ensure that latrines are fly-proof all lavatory seats should be of

the self-closing pattern; for the same reason it is also particularly important that the seats of bucket latrines fit securely. Shallow trench latrines must be used correctly while deep trench and bore-hole latrines must be properly constructed, if fly breeding is to be avoided. Facilities should be provided where practicable for washing hands after using latrines.

Shallow Trench Latrine

18. For short halts and temporary camps of not more than three days' duration the shallow trench latrine may be used. It consists of a row of trenches two feet apart, each trench being 3 feet long by 1 foot wide and 2 feet deep (Fig. 21). The turf from the top of the trenches should be rolled up and piled at one end with the excavated soil. The sides of the trench should be dressed. The latrine is used by squatting astride the trench, each man covering his excreta with excavated earth using a scoop made of tin or a piece of board. Five trenches are sufficient for 100 men, three more trenches being required for each additional hundred. When the trench becomes filled to within six inches of the top or is no longer required, the contents are covered with oiled sacking and the trench filled with well-rammed earth. The site should be prominently labelled, conventionally by whitened stones in the form of a letter L.

Deep Trench Latrine

19. A trench 6 to 8 feet deep, 3 feet wide and 12 feet 6 inches long should be excavated, the earth being placed not less than five feet from the edge of the trench. If necessary the sides of the trench should be supported by timber, but cross struts should be placed so as not to come directly under the seat openings. The surface soil should be removed to a depth of six inches for a distance of four feet all round the trench. This area should be covered with oiled sacking with the ends turned down over the sides of the trench; the earth, mixed with heavy oil, should then be replaced on it and rammed well down to prevent the escape of fly larvae. A trench of these dimensions will accommodate five seats (Fig. 22). These should be constructed of tongued and grooved boarding, sheet metal, or other suitable material, fastened to a timber frame and made fly-proof. The openings of the seats should have close-fitting lids attached in such a way that they close automatically when not supported; this is

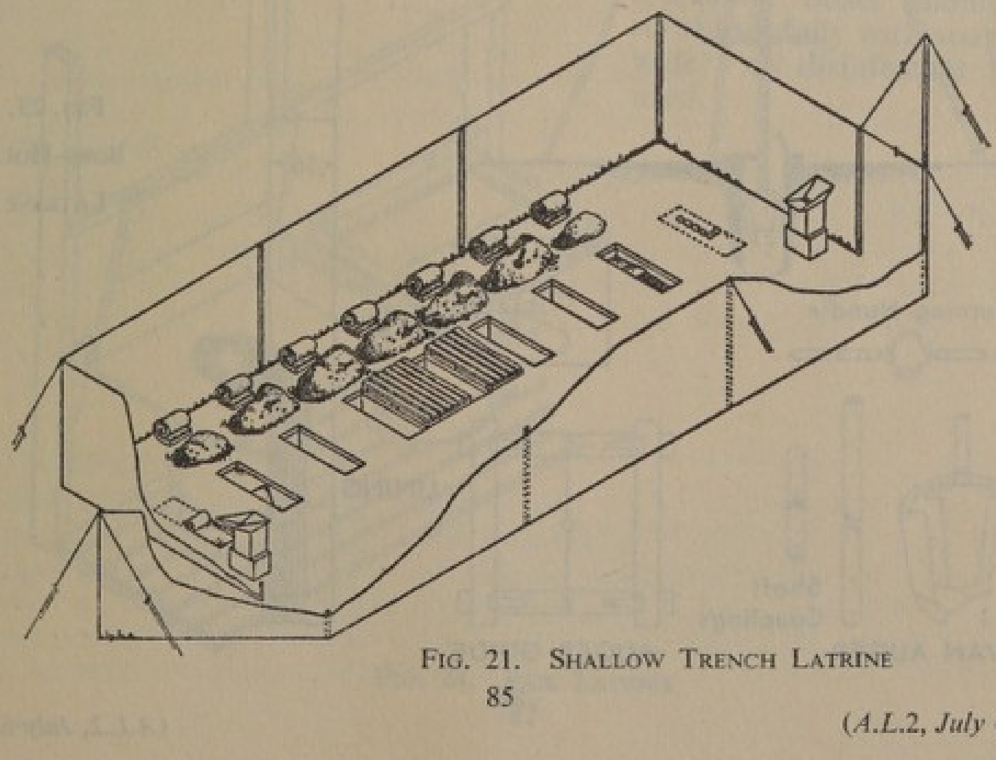


FIG. 21. SHALLOW TRENCH LATRINE

effected by a bar at the back arranged to arrest the lid before it reaches the vertical position. The openings should be arranged above the centre of the trench and a piece of sheet metal should be placed below and in front of each opening to deflect urine and prevent it fouling the sides of the trench. The whole should be surrounded by screens and roofed. When the trench becomes filled to within two feet of the surface the seats, duck boards and screens should be removed. The contents are then covered with earth, which is well rammed, the turf replaced, and the whole permanently labelled.

Bore-Hole Latrine

20. This is a vertical boring usually 16 inches in diameter sunk 20 feet deep or to the level of the deep sub-soil water. The bore is sunk by a hand-operated auger, the shaft of which is made in sections for easy transport and to allow lengths to be added as work proceeds (Fig. 23).

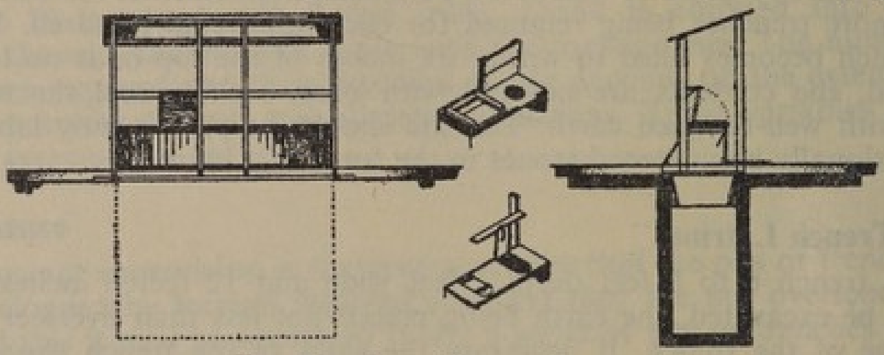


FIG. 22. DEEP TRENCH LATRINE

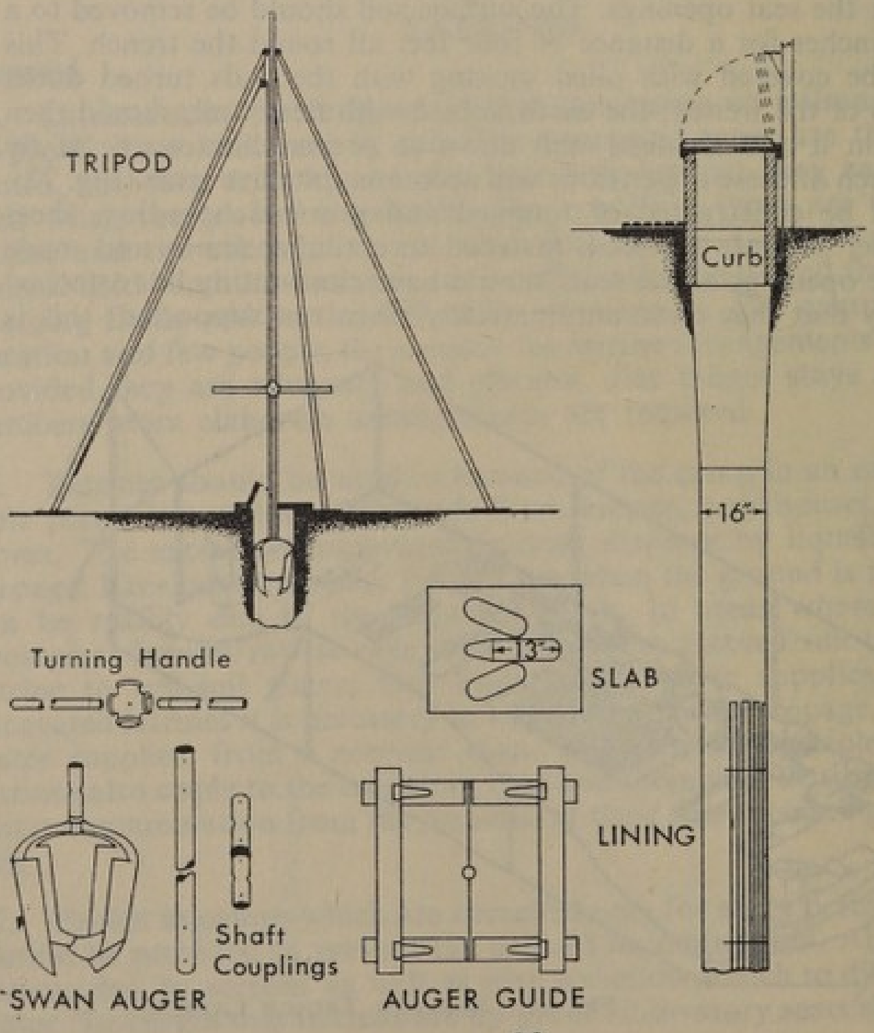


FIG. 23. BORE-HOLE LATRINE

(*A.L.2, July 62*)

Shear legs are erected over the site of the boring to guide the upper end of the shaft and to support a pully-block for withdrawing the auger from the ground. A flat piece of wood or metal is fastened over the top of the bore to act as another guide to the lower end of the shaft. In exceptionally loose soils it may be necessary to line the whole or part of the boring to prevent it caving in. Suitable linings may be made of galvanized iron sheets pierced with holes, wood, concrete, or basket work. However, when such measures are necessary, conditions are not really suitable for bore-hole latrines. A well constructed bore-hole latrine will last for many years. It is not, however, suitable for large numbers of men.

Bucket Latrine

21. A bucket latrine consists of a bucket with a capacity of about one cubic foot surmounted by a wooden seat with a fly-proof, self-closing lid. The top of the bucket must be flat to fit tightly against the seat and keep out flies (Fig. 24). Buckets of less than one cubic foot require too frequent emptying and larger ones are too heavy to handle when full. When standard patterns are unobtainable buckets must be improvised from oil drums and other metal containers. Buckets should be placed in suitably screened compartments. They should be emptied daily and should be sufficient in number to prevent any individual bucket becoming more than three-quarters full.

22. Disposal of the bucket contents is either into a sewer, the screening chamber of a sewage works, an Otway pit, by burial, or by incineration, according to circumstances. After emptying, the buckets should be scrubbed with a solution of cresol (2·5 per cent.) and the interior coated with thick oil as a fly deterrent. A very small amount of disinfectant left in the bottom helps cleansing. Seats should be scrubbed daily with soap and water, no disinfectant being used.

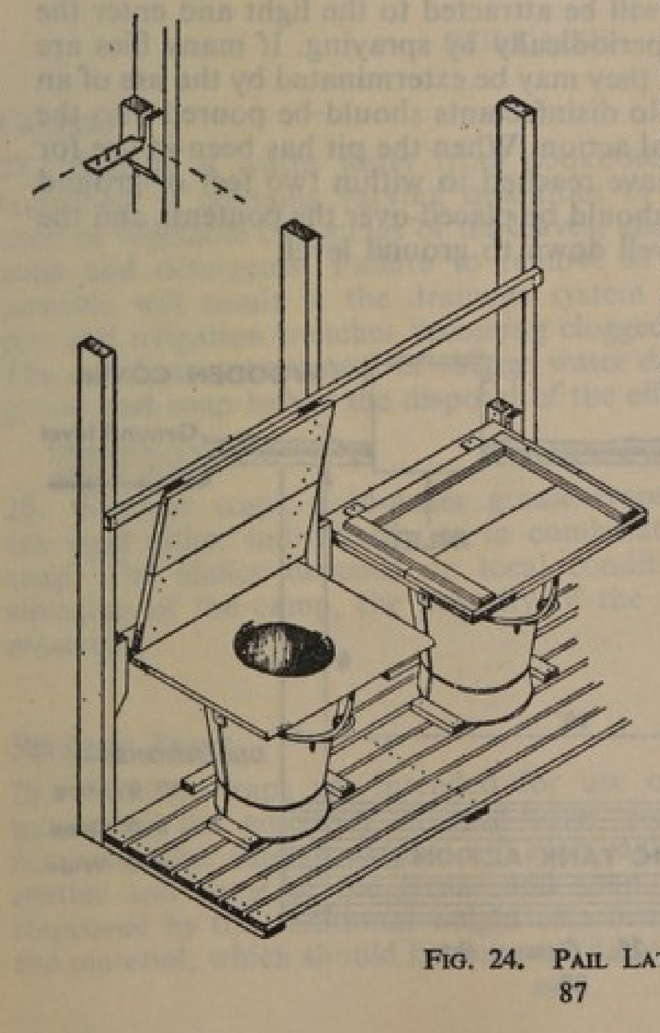


FIG. 24. PAIL LATRINE

DISPOSAL OF FAECES

The Otway Pit

23. The Otway pit is a simple form of septic tank suitable for the disposal of the contents of latrine pails. It consists of a pit dug in porous ground and protected by a fly-proof cover ; the bottom of the pit must be kept water-logged so that the contents remain covered with a layer of liquid (Fig. 25). It may be necessary to add water periodically for this purpose. Sewage and other wastes emptied into the pit decompose, a thick scum forming on the surface and excluding the air so that anaerobic liquefaction follows. The resultant liquid soaks away through the walls of the pit as the level rises. The amount of residual solid matter is not great and the pit will last for a long time before becoming full.

24. A suitable size for the pit is 10 feet long by 3 feet wide and 6 feet to 8 feet deep, although the condition of the ground may make it necessary to use other dimensions. In loose soils the walls of the pit may need shoring up. To prevent the emergence of fly larvae the ground around the pit should be excavated to a depth of six inches for a distance of four feet and covered with a layer of oiled sacking, the edges being turned down into the pit to a depth of two feet. The excavated earth mixed with heavy oil should then be replaced over the sacking to the edge of the cover and rammed firm. The cover of the pit is made of timber, covered with oiled sacking to make it fly-proof. The inlet is formed by an oil drum or other suitable container, with the bottom removed, fixed over a hole at one end of the pit. This inlet should have a close-fitting lid which must always be kept in place except when pails are emptied. A hole is left in the cover at the end opposite to the inlet and a fly trap placed over it, so that any flies in the pit will be attracted to the light and enter the trap. The flies are destroyed periodically by spraying. If many flies are found to be breeding in the pit they may be exterminated by the use of an insecticidal spray or smoke. No disinfectants should be poured into the pit as this will impede bacterial action. When the pit has been in use for some time and the contents have reached to within two feet of ground level, a layer of oiled sacking should be placed over the contents and the earth replaced and rammed well down to ground level.

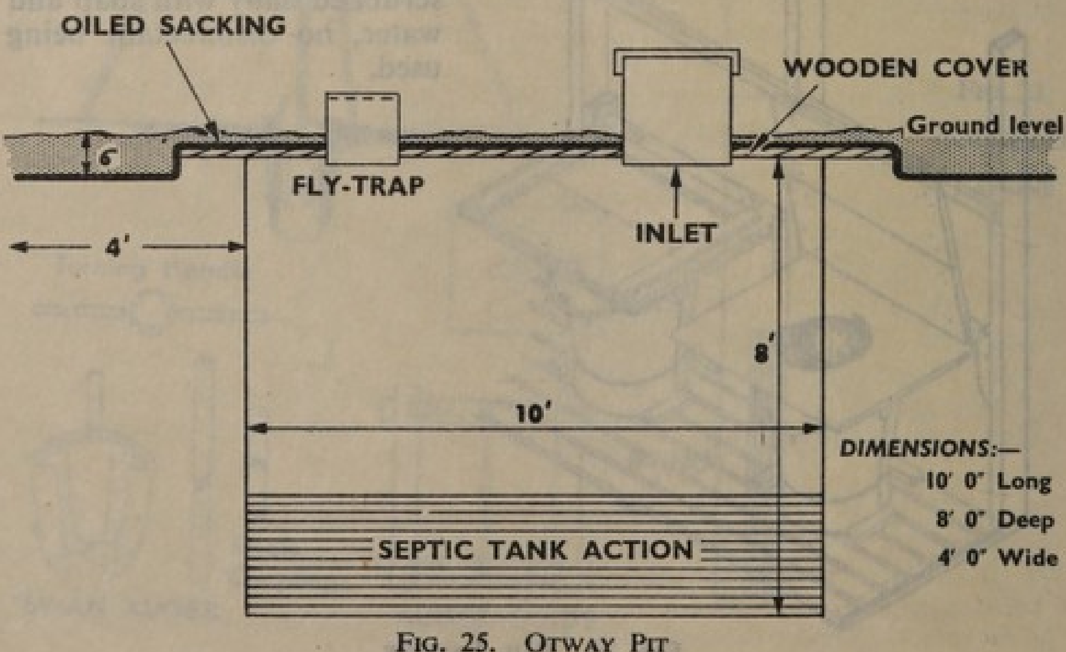


FIG. 25. OTWAY PIT

Incineration

25. Faeces can be burnt, but this is not a satisfactory method of disposal, as urine must be drained off to a soakage pit and a large quantity of combustible material added. Suitable incinerators are the Horsfall, Bailleul, Beehive, A.S.H. minor faeces destructor, or No. 2 Drycinerator. Open incinerators should not be used. The incinerators should be situated as near the latrines as possible. A concrete platform suitably drained for cleaning buckets must be adjacent. There must also be a dry store for combustible material and a soakage pit for decanted urine. Sufficient incinerators must be available for the destruction of each day's excreta. Faeces must not be stacked to await burning or fly breeding will take place.

Burial

26. Burial of faeces is preferable to incineration. The trenching ground should be at least one mile from the camp. The trenches should be 2 feet wide and 2 feet deep. The length is immaterial, but 20 feet is suitable. Faeces should be deposited in the trench to a depth of nine inches with an inch of lime on top and then covered to ground level with well-rammed earth. If lime is not available the depth of the trench should be increased to three or four feet, and the faeces covered with a minimum of two feet of earth. Faeces must be left uncovered for the minimum of time possible during the filling of the trench; the section of the trench receiving each load of faeces should be properly filled in before a new load is deposited.

SULLAGE

General

27. Sullage is waste water from cookhouses, messes, ablutions, and laundries. It contains varying quantities of grease, soap, solid matter such as vegetable trimmings or tea leaves, and chemicals such as washing soda and detergents. Failure to remove as much grease and soap as possible will result in the drainage system becoming choked, soakage pits and irrigation trenches becoming clogged, and water courses fouled. The satisfactory treatment of sullage water depends on the separation of grease and soap before the disposal of the effluent and remaining solids.

28. Strainer traps, cold-water grease traps or chemical precipitation are used either individually or in combination to separate grease and soap. The choice depends on local conditions such as the type and situation of the camp, the porosity of the soil, and the availability of materials.

Strainer Traps

29. Strainer traps are intended for use on temporary camps or for increasing the efficiency of cold-water grease traps. Grass, bracken, furze, or other similar material will keep back gross particles of suspended matter and some of the grease and soap. The strainer action can be improved by the additional weight of a few stones placed on the top of the material, which should be removed daily and either burned or buried.

Cold-Water Grease Traps

30. Cold-water grease traps if properly constructed are far more effective than strainer traps and are in general use on semi-permanent and permanent stations. They work on the principle that if warm water containing grease is added to an adequate amount of cold water, the grease will solidify and float to the surface. Constructional details of these traps vary according to circumstances. Those built of concrete and brickwork are best, and are usually built by the Air Ministry Works Department. Improvised traps constructed from packing cases, metal tanks or oil drums can however be used (Fig. 26).

31. Whether permanent or improvised, the traps must be of adequate size, watertight, easy to clean, provided with fly-proof covers, and simple in design and construction. The smallest traps should hold 50 gallons of water and the largest not more than 250 gallons. The capacity should be at least five times the amount of hot greasy water entering at one discharge. When the maximum flow demands a capacity of more than 250 gallons, two traps can be arranged in series. Two traps of reasonable size are more efficient than a single large one. When there are large quantities of hot greasy water, preliminary cooling may be obtained by constructing a gully drain of 10 to 15 feet between the outfall and the grease trap. Before passing down the drain, the water must be strained to remove large solid matter and prevent blockage.

32. Suitable dimensions for a 50-gallon trap are 3 feet long by 1 foot 6 inches wide by 2 feet deep. The length of a trap should always be about three times the width, and the depth should always exceed the width.

33. Two detachable baffles should be fitted to slow down the rate of flow of sullage through the trap. This allows grease to rise, prevents undue disturbance of solidified grease, and checks any tendency for the surface layer to break up. The baffles should be fitted not more than six inches from each end and the space between them should be as great as possible. Each should extend downwards for three-quarters of the depth of the trap.

34. Grease traps are usually constructed below the surface of the ground. The level is governed by the layout of the water carriage system of drainage when such is concerned. In other circumstances the trap

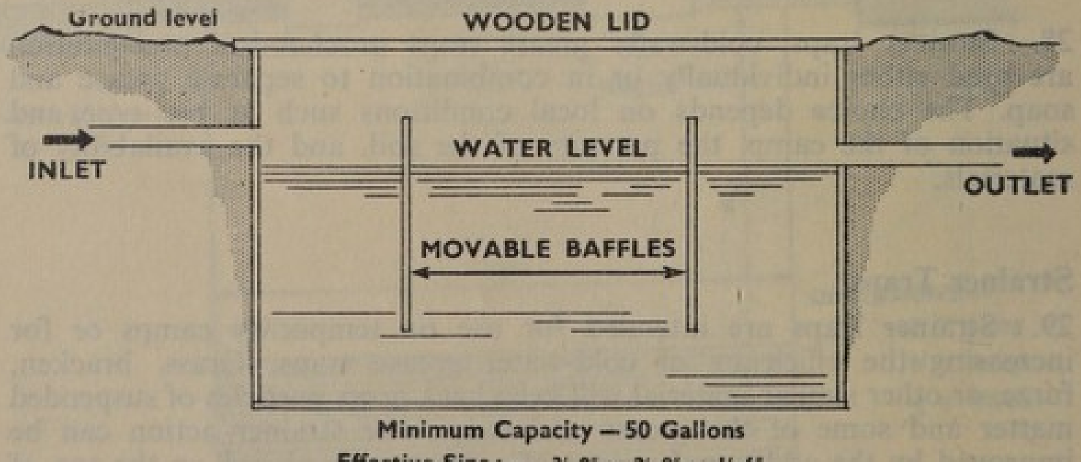


FIG. 26. COLD-WATER GREASE TRAP

should be embedded so that the cover is just above the ground level. Preliminary straining to remove large particles of food debris and gross refuse is usually necessary. Where permanent drainage systems exist the iron grids over standard gullies are sufficient. When these are absent, wire strainers may be improvised. Such strainers should be placed as near as possible to the outfall of the water from the kitchen, mess, or ablution. In the absence of detergents, solidified grease should be removed at least every other day and burnt or buried. Any sediment at the bottom of the trap should be removed at least twice weekly (Fig. 27).

Chemical Precipitation

35. Chemical precipitation almost completely removes grease and soap from water. One method is to add lime to the sullage in sufficient quantity to produce a pink reaction with phenolphthalein; this requires usually about 40 grains per gallon but varies with the nature of the water. Ferrous sulphate is then added at the rate of 30 grains per gallon. This produces a floc which carries down grease and suspended particles as it settles. For this treatment sullage is collected in tanks which are usually constructed in pairs so that they can be used alternately. The chemicals are added and after agitation the contents are left for at least one hour. Drying beds are necessary for the disposal of the sludge which accumulates in the bottom of the tank. These should be constructed of hard clinker, about 1½ to 2 feet in depth. The crude sludge should not cover the drying beds to a greater depth than nine inches. The sludge when dried should be buried as it has no value as a fertilizer.

Disposal of Sullage Effluent

36. The effluent from grease traps or chemical precipitation tanks may be disposed of by soakage pits, herring-bone drainage, or evaporation pans, depending on the nature of the ground and climatic conditions. None of these methods will function satisfactorily if the grease trap system is ineffective. If it has been chemically clarified the effluent may be led directly into a convenient water course.

37. **Soakage Pit.** The dimensions and construction of soakage pits for the disposal of sullage water are identical with those for the disposal of urine. (See page 84, para. 12.)

38. **Herring-Bone Drainage.** This method is of service when the level of the sub-soil water is too high to permit the use of soakage pits. A series of connecting channels, 1 foot wide and 1 foot deep, are dug in a herring-bone pattern. Different sections of the channels are used alternately. Both soakage and evaporation take place. To facilitate the former the sides of the channels should be kept clean and the earth at the bottom periodically loosened.

39. **Evaporating Pans.** Evaporating pans are effective only when air temperatures are high and humidity low. A series of level pans, each measuring about 30 feet by 30 feet, are constructed by building up low walls to a height of about one foot. The pans are used in rotation for each day's flow of sullage and a sufficient number must be constructed to deal with the maximum requirements. Six pans will generally be found sufficient for 300 to 400 men. The depth of water must never be allowed to exceed nine inches at any point in a pan. Each pan must be shut off when this level is reached or at the end of the day's flow, whichever is the first to occur. Evaporation and a varying amount of soakage through the

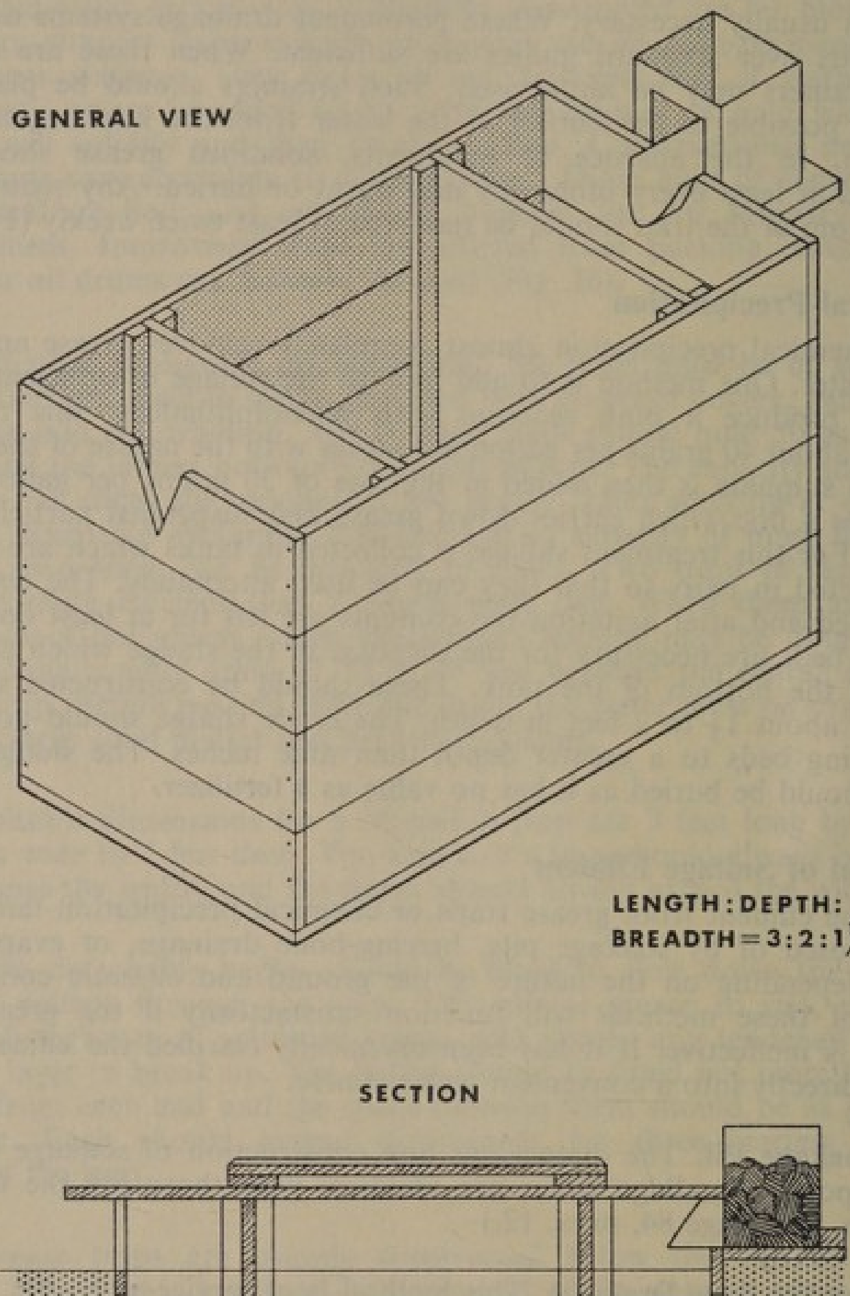


FIG. 27. GREASE TRAP AND STRAINER

underlying soil generally dry the pans in from two to five days. A grey flaky deposit is left. This should be removed with a scraper and burnt or buried. The top layer of soil to a depth of one inch, should be scraped off every two to three months. There is little nuisance from smell, but the pans should be sited not less than 300 yards downwind from the camp. Sullage water should be led to them in pipes or open cement gullies. Simple earth ditches may be used as an improvisation, but these become rapidly clogged with an offensive slime. There is no associated risk of fly or mosquito breeding. The planting around pans of canna lilies or the cultivation of maize and vegetables will accelerate the soakage of the sullage water and can be made a source of income to unit funds.

REFUSE DISPOSAL

General

40. In the field, the principles of refuse collection and disposal are the same as on a permanent station. The aim is to prevent fly breeding, rodent infestation and, in the tropics, the breeding of mosquitoes. The two main methods of disposal are incineration and burial. For both methods it is best to keep dry refuse segregated from wet at the place of collection.

Incineration

41. Dry refuse burns readily without adding fuel, which must however be used to evaporate moisture and help the combustion of wet refuse. Various forms of incinerator may be used; the choice depends on the quantity of refuse to be burned, the length of time the incinerator will be required, and the material available if improvisation is necessary. The essence of a good incinerator is complete combustion with the minimum of smoke. The following types are easily constructed and function efficiently.

42. **Open Circular Incinerator** (Fig. 28). The walls of the open circular incinerator are built to a height of 4 feet 6 inches; stones laid dry or pieces of turf 9 inches wide may be used. Four draught holes are left at the base of the walls, and iron fire-bars two inches apart are built in nine inches from the ground.

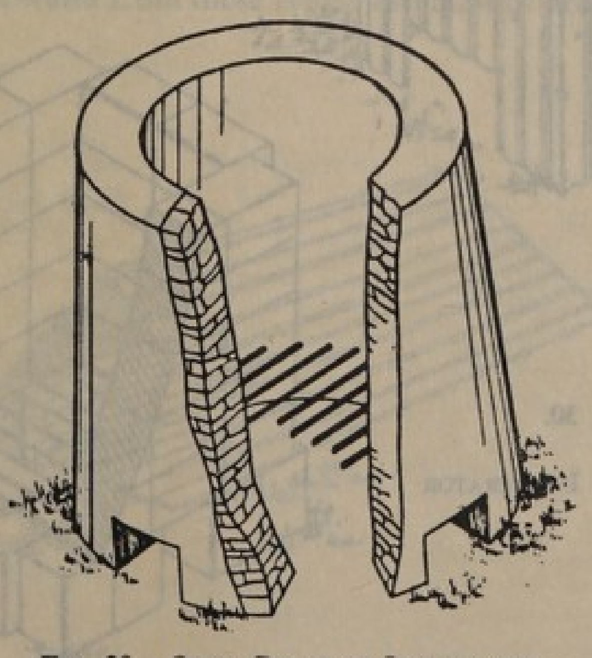


FIG. 28. OPEN CIRCULAR INCINERATOR

43. **Portable Corrugated-Iron Incinerator** (Fig. 29). This incinerator is constructed from sheets of corrugated iron, a dozen bars, and 20 feet of strong iron wire. Air inlets 12 inches long and 9 inches high are cut from the base of each iron sheet; slots for the fire-bars are made with a cold chisel in two of the sheets, and an opening for a raking door cut in one of them just above the fire-bar slots. Air inlet holes are punched in each sheet on a level with the raking door. The four sheets are then wired together at the edges to form a rectangular box and the fire-bars inserted. A raking door of corrugated iron is made and hinged into position. A drying shelf of iron bars, formed across the incinerator about three feet above the fire-bars, will break the fall of refuse and prevent it smothering the fire during stoking. When assembled for use, the feet of the incinerator should be anchored down. A cowl may be made from a piece of sheet metal to prevent damping of the fire by heavy rain. This incinerator is easily dismantled and transportable.

44. **Open Square Incinerator** (Fig. 30). This incinerator can be constructed of rectangular tins, filled with clay or sand, wired together and reinforced with iron bars. As before, openings in the base of the walls serve as air inlets and raking doors for the removal of ashes. Iron fire-bars are built in nine inches from the ground.

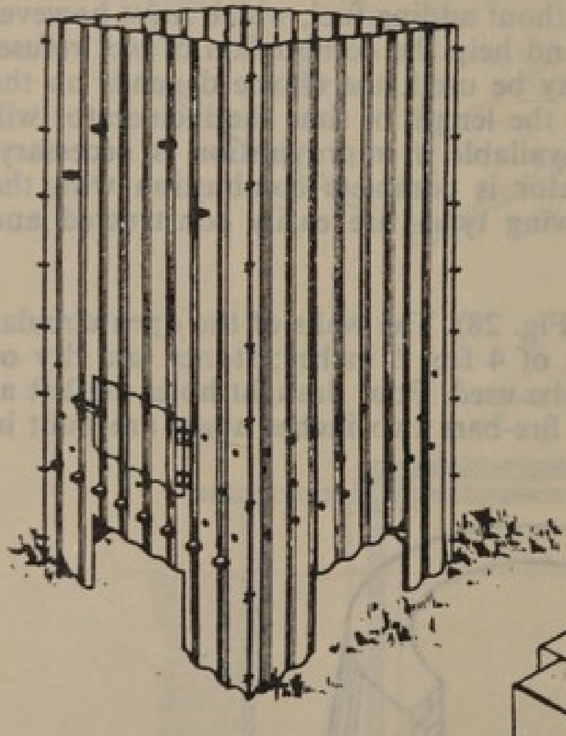


FIG. 29.

PORTABLE CORRUGATED-IRON INCINERATOR

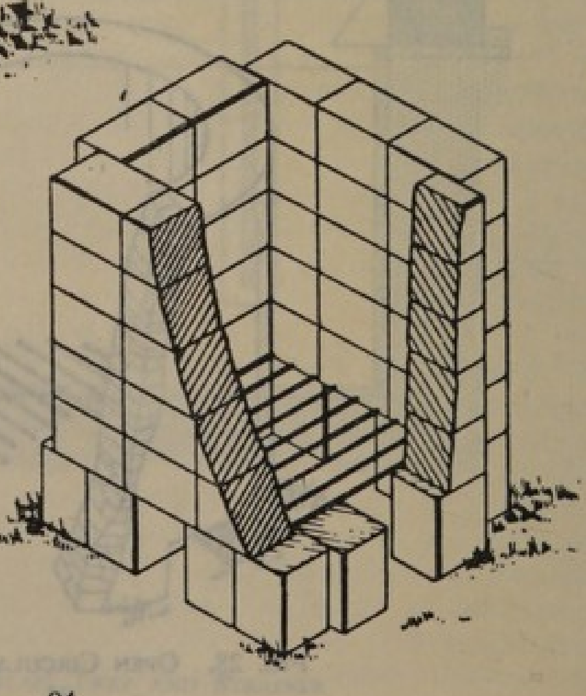


FIG. 30.

OPEN SQUARE INCINERATOR

45. **Inclined Plane Incinerator** (Fig. 31). The inclined plane incinerator is made from three sheets of corrugated iron fixed together by wire and raised at one end by iron supports. V-shaped cuts are made at intervals in the lower sheet of iron forming the base of the incinerator, and the metal turned up to form projections. These projections prevent refuse slipping down to the other end of the incinerator too rapidly. Refuse is fed in at the raised end, the lower end being placed to face the direction of the wind. It is easily dismantled and transportable.

Burial

46. Burial is the method of choice for refuse disposal on camps of short duration. Although it has the advantage of simplicity, careful control is essential to prevent fly breeding and the attraction of rats. In addition, large heaps of poorly controlled refuse may catch fire by spontaneous combustion, while liquid drainage from the heap may find its way into water supplies.

47. Trenches should be dug in a well drained site; they should be two or three feet wide and three or four feet deep. The length or number of trenches should be sufficient for two or three days' refuse, to prevent accumulation. Refuse should be put in the trenches as soon as it is brought to the site. If it is possible to segregate them, wet and offensive material should be placed at the bottom of the trench, dry material on top. Tins should be crushed flat or perforated before being buried, to prevent them accumulating water. When the refuse is two feet from the ground level the trench should be filled with earth, which must be rammed well down. At the end of each day no refuse should be left uncovered. Existing excavations may be used instead of trenches, but refuse should not be deposited to a depth of over five feet, for fear of spontaneous combustion. It must be covered with two feet of earth, as above.

ABLUTIONS

48. Adequate washing facilities and showers must be provided in the field in the interests of personal hygiene. Suitable arrangements for the disposal of sullage water from these is also essential to prevent fouling of the ground.

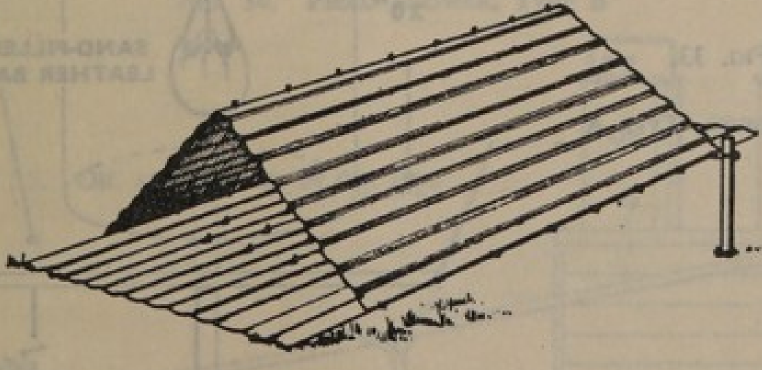


FIG. 31. INCLINED PLANE INCINERATOR

Ablution Benches

49. Ablution benches should be constructed on a scale of one 8-foot double-sided bench for every 100 men. Fig. 32 shows a typical example. The centre trough is constructed of corrugated iron or oil drums. Metal wash-basins must be supplied. The disposal of sullage water should be through a grease trap to a soakage pit or herring-bone drainage system.

Showers

50. Improvised showers are illustrated in Figs. 33 and 34. The first consists of a five-gallon oil drum mounted on a stand. A funnel inlet is fitted in the top and an outlet in the centre of the bottom leading to a

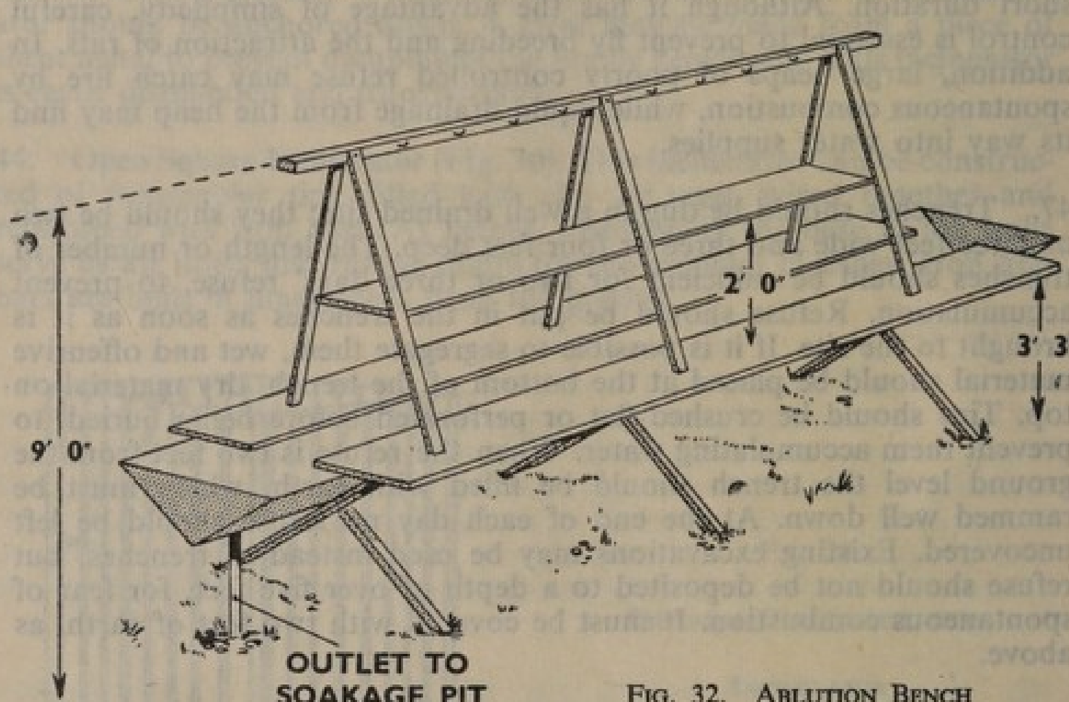


FIG. 32. ABLUTION BENCH

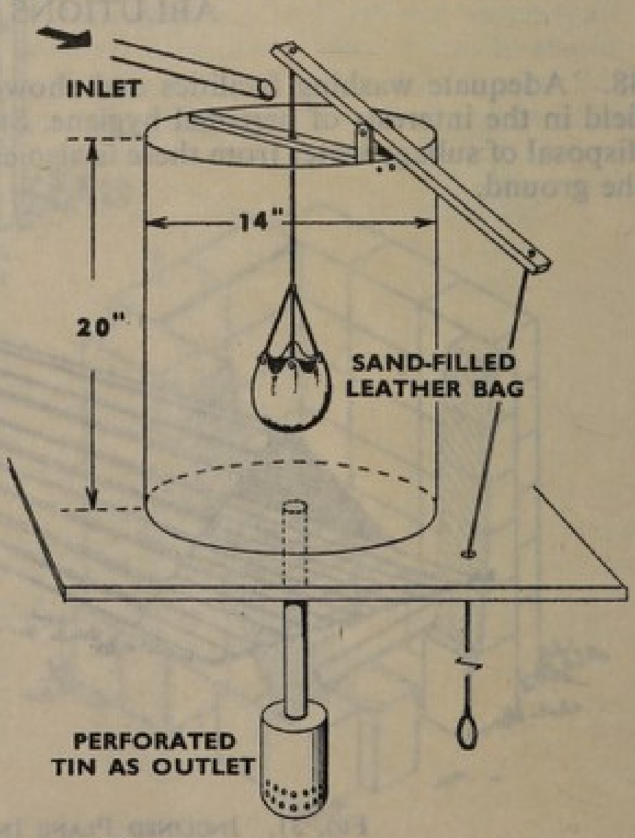


FIG. 33.

FIELD SHOWER, TYPE A

rose made from a small perforated tin. The outlet is plugged inside with a bag of sand which is raised by a lever fitted to the upper edge of the drum. Hot water is poured into the oil drum and the shower operated by pulling a cord attached to the lever.

51. The design for another type of shower is shown in Fig. 34. A small oil drum is required from which one end is removed. Lugs are fitted at one-third of the depth from the open end. The drum is then filled to the level of the lugs and suspended by them from a suitable stand. The weight of water will keep it vertical. Holes are punched in one side of the drum above the level of the lugs and a piece of wire is attached to the rim of the drum immediately above the holes. By pulling the wire the drum is tilted towards the holes, which act as a rose and allow the water to run out as a spray.

Hot-Water Supplies

52. The provision of hot water under field conditions is a great asset to health and comfort; every endeavour should be made to provide an adequate supply. Three methods of heating water are described below.

53. **Oil and Water Flash Fire.** This consists of two five-gallon drums, one containing water and the other oil (Fig. 35). These are placed on a stand

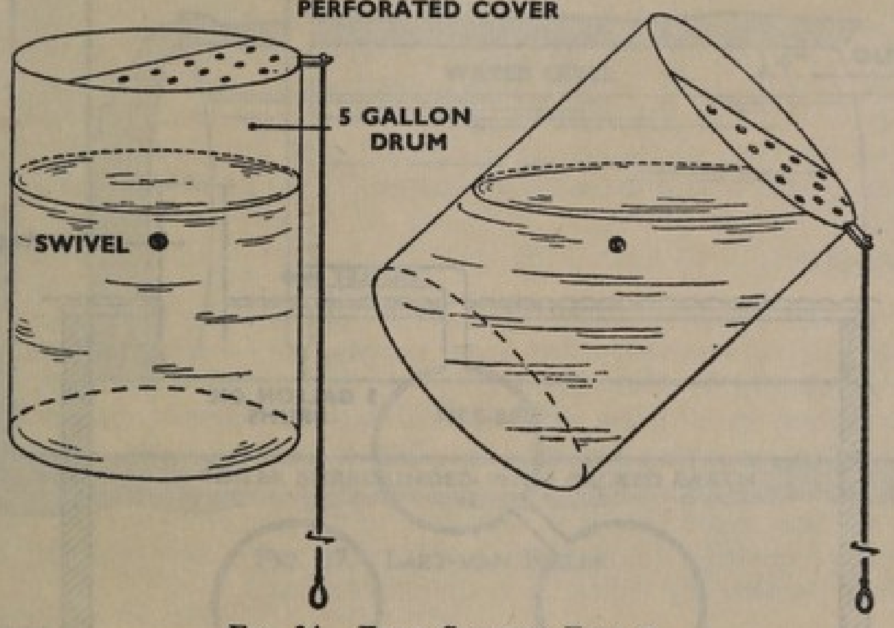


FIG. 34. FIELD SHOWER, TYPE B

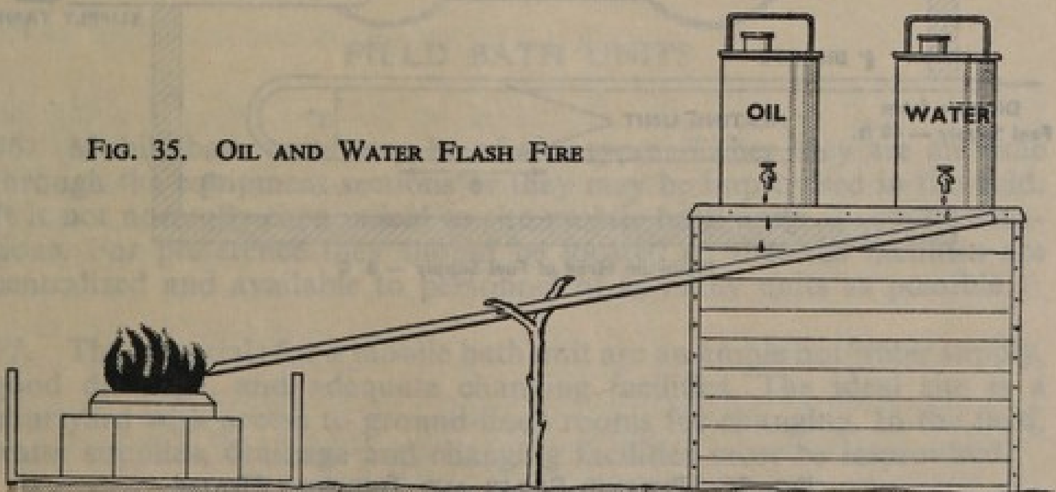


FIG. 35. OIL AND WATER FLASH FIRE

and a nailhole is made in the side of each, near to the bottom, a piece of wood or a nail being inserted to act as a bung and to regulate flow to three drops of water to one of oil. The oil and water drip into a channel made of iron or similar material and run down to a burning pan. This is a shallow dish-shaped metal container. To ignite the fire the flow is started and a piece of burning rag is placed in the pan. The ignition of the oil and water mixture gives a hot, smoky flame.

54. **Trombone Heater.** This heater is illustrated in Fig. 36. A tank containing fuel oil is mounted on a stand 8 to 10 feet above ground level. A feed pipe of wrought iron or steel tubing with an internal diameter of one inch connects the tank to the burners. The burner resembles the slide of a trombone and is constructed of three-quarter inch wrought iron or steel tubing. It is fitted with a screw-down control valve and the end is closed by a cap. Three burner holes are drilled at eight inches, 16 inches, and 24 inches from this cap. They should be $\frac{3}{64}$ths of an inch in diameter. To avoid back burning, the length of pipe from the tank to the first burner should be not less than 40 feet or there should be a U-shaped trap. Diesel oil is used as fuel, the average consumption for one burner being 11 pints per hour. The heater is ignited by turning on the control valve and placing a piece of burning rag by the burner holes. After the rag has been burning for a while, the outcoming oil is vapourized and a good, almost smokeless, flame is obtained.

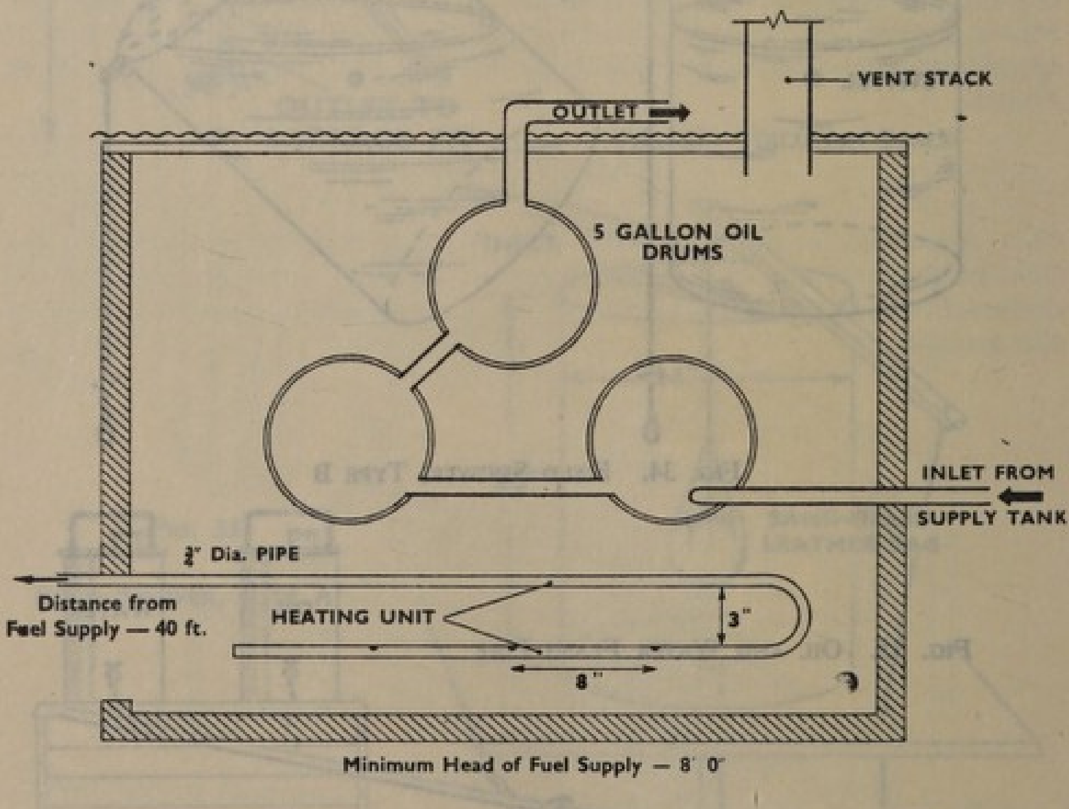


FIG. 36. PYRAMID BOILER AND TROMBONE HEATER

55. **Lazy-Man Boiler.** This boiler is simple to make and is illustrated in Fig. 37. A 40-gallon oil drum is suitable, but one of any capacity may be used. The boiler may be placed over the heat source on its side or end. The former gives a greater heating area. It may also be lagged with turf or clay to improve efficiency. If the boiler is to be used horizontally, an inlet pipe with a funnel should be fitted into the uppermost side near one end to reach within six inches of the lower side opposite. At the required water level an outlet pipe is fitted horizontally into the end of the drum. No other openings should be made. There is no chance of explosion with this boiler, as even if the outlet pipe becomes choked the inlet will act as a safety valve. Hot water is obtained by pouring cold water into the inlet funnel to displace an equivalent amount through the outlet by constant replacement. This also prevents the water being drained off and the boiler being burned out.

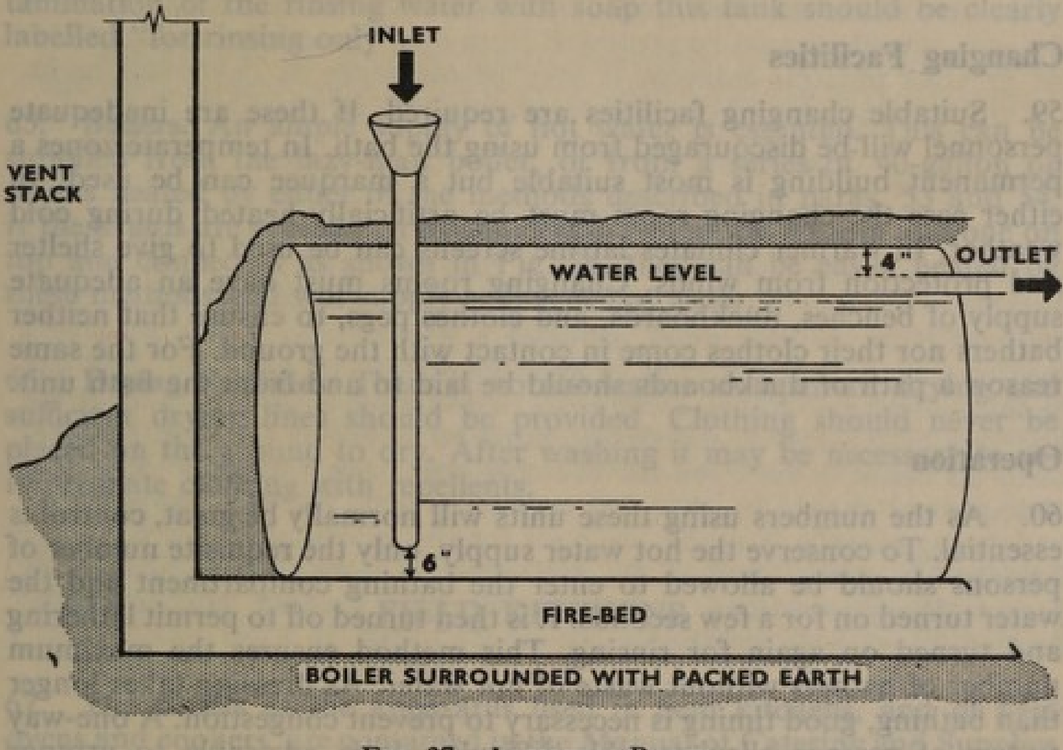


FIG. 37. LAZY-MAN BOILER

FIELD BATH UNITS

56. Mobile bath units may be of two types. Either they are an issue through the equipment sections or they may be improvised in the field. It is not normally economical to site mobile bath units at small formations. For preference they should be located so that the facilities are centralized and available to personnel of as many units as possible.

57. The essentials for a mobile bath unit are an ample hot water supply, good drainage, and adequate changing facilities. The ideal site is a courtyard with access to ground-floor rooms for changing. In the field, water supplies, drainage and changing facilities must be improvised.

Improvised Bath Unit

58. The improvised bath unit consists of hot and cold water supply tanks, heating boilers and sprinklers. Suitable water tanks, which may be of canvas or metal, are mounted on superstructures 10 to 15 feet above ground level. A 1-inch wrought iron pipe leads off the base of each tank. The pipe from the cold water supply passes direct to a mixer valve; that from the hot water passes via the boilers to the mixing valve. The water passes from the valve by pipes to six sprinklers which are constructed of perforated tins. The boilers for heating the water can be constructed from three 40-gallon oil drums arranged as shown in Fig. 36. The most effective source of heat is the trombone heater (see para. 54). Sullage water is disposed of into an adjacent sewer or through grease traps by any of the methods described in para. 27 *et seq.* Duckboards must be supplied for the bathers, who must not be allowed to stand on the bare ground. The boards should be scrubbed daily to reduce the risk of transmitting tinea pedis. The unit should be surrounded by latrine screens.

Changing Facilities

59. Suitable changing facilities are required. If these are inadequate personnel will be discouraged from using the bath. In temperate zones a permanent building is most suitable but a marquee can be used. In either case the changing room must be artificially heated during cold weather. In warmer climates latrine screens can be used to give shelter and protection from winds. Changing rooms must have an adequate supply of benches, duckboards, and clothes pegs, to ensure that neither bathers nor their clothes come in contact with the ground. For the same reason a path of duckboards should be laid to and from the bath unit.

Operation

60. As the numbers using these units will normally be great, control is essential. To conserve the hot water supply, only the requisite number of persons should be allowed to enter the bathing compartment and the water turned on for a few seconds. It is then turned off to permit lathering and turned on again for rinsing. This method ensures the maximum number of bathers without waste of hot water. As dressing takes longer than bathing, good timing is necessary to prevent congestion. A one-way system of passage alleviates this difficulty. It is advisable to arrange bathing parades by units on a time-table basis.

FIELD LAUNDRIES

61. Personal cleanliness is facilitated by the provision of ablutions, showers, and hot water ; but arrangements are also necessary for washing clothes. Should the camp be adjacent to a town or village, a local contract may be arranged or local labour employed. Alternatively a mobile laundry may be available. Under most circumstances it will be necessary to improvise facilities.

Improvised Laundry

62. Improvised laundry arrangements must incorporate washing benches, rinsing tanks, boilers, and drying arrangements, together with the means for re-impregnating clothing with repellents.

63. **Washing Benches.** A laundry bench can be improvised from timber and metal drums. A trestle is constructed 6 feet high and 7 feet long. The metal drums are then cut vertically in half, so that laid horizontally the sections form a trough. The joints of the drums are lapped and soldered. This trough is fitted into a wooden framework over which the edges of the drums are turned and nailed down into position. The frame is attached inside the trestle about three feet from the ground. In the bottom of one end of the trough, which should have a slight fall in that direction, a hole is made connecting with an outlet pipe 2 to 3 inches in diameter made from sheet metal or small tins, and leading to a grease trap and soakage pit. A shelf should be constructed two feet above the trough for carrying soap and other requirements, while the top of the trestle should have pegs for hanging clothes.

64. **Rinsing Tanks.** A duplicate of the washing bench can be used as a rinsing tank, which should also have its contents led through a grease trap before final disposal. To avoid confusion and prevent undue contamination of the rinsing water with soap this tank should be clearly labelled "for rinsing only".

65. **Boilers.** An ample supply of hot water is essential. This can be supplied from the lazy-man boiler, or from a series of 40-gallon oil drums heated by either of the methods described in paras. 53 and 54. If the drums are placed in a pyramid with two at the bottom and one on top and connected as shown in Fig. 36, they can be easily heated by these methods and will supply sufficient hot water.

66. **Drying Facilities.** There is no alternative to open-air drying and sufficient drying lines should be provided. Clothing should never be placed on the ground to dry. After washing it may be necessary to re-impregnate clothing with repellents.

FIELD KITCHENS

67. The details of the apparatus used in field kitchens, and of field ovens and cookers, are contained in the Manual of Catering and Supplies (A.P. 3263). Owing to the primitive conditions in field kitchens, food hygiene demands particular attention.

Siting and Construction

68. The field kitchen should be sited as described in para. 3 of this chapter. The kitchen, which should measure not less than 10 feet by 10 feet, and other preparation areas, should be screened on three sides with the open side facing downwind. They should be roofed as a protection against the weather with the roof sloping from front to rear. The floor should be covered with duckboards which can be removed for cleaning. If these are not available ashes provide a substitute and can be replaced when they become fouled. A water point, in the form of a tap, and static water tank or water tender must be placed adjacent to the kitchen to avoid fetching quantities of water from a distance. Washing facilities should be provided near the kitchen for the use of the staff and must be placed out of bounds to other personnel.

Food Storage

69. Too often food storage arrangements in field kitchens are haphazard. Everything possible must be done to keep food cool and to protect it from dust, flies, and rats. Fly covers, meat safes, and larder cupboards can be improvised from butter muslin or wooden frames and packing cases. Containers are required for flour, sugar, and vegetables; these commodities should not be left to deterioriate in sacks. Cereals and flour containers should be rat-proof. Although much food is likely to be provided in tins or as compo rations, there will also be perishables, the preservation of which will require special care.

Equipment and Utensils

70. It is impossible for cooks to prepare and cook food hygienically unless sufficient equipment and utensils are available. Preparation tables must be provided and these must be kept scrupulously clean by scrubbing. Utensils must be washed immediately after use and not left lying about inside or outside the cookhouse, otherwise they will attract flies. Once cleaned, utensils should be protected from dust. To achieve this and also the greatest possible tidiness, it may be necessary to improvise racks, lockers or cupboards from whatever material is available.

Washing-Up

71. Efficient cleansing of utensils, without fouling the surrounding ground, is possible only if attention is paid to washing arrangements. A suitable bench similar to that used for ablutions is required for scouring tins and pans. It must drain, through a strainer and grease trap, to a soakage pit. A two-sink type of wash-up should be provided. This can be made from oil drums. Detergents, if available should be used in the first sink. The water in the second must be as hot as possible. Another wash-up bench is required for draining and drying utensils. A similar arrangement should be provided near mess tents for washing-up plates and eating utensils. Suitable methods for the provision of hot water are described in paras. 52 to 54. All sullage water from washing-up must be passed through strainers and grease traps to soakage pits or similar devices. These are described in paras. 27 to 38.

Swill

72. Sufficient swill bins must be available to hold kitchen waste for 24 hours. It is advisable to keep swill in containers separate from refuse. These bins should be emptied daily. Disposal of swill and refuse is described in paras. 39 to 46. If it is necessary to improvise swill containers, well-fitting covers must be made from wood, sacking, or a combination of these. Bins should be placed on duckboards or on ground covered with ashes.

CHAPTER 6

CLIMATE*

INTRODUCTION

1. The Royal Air Force may be called upon to operate in any part of the world. The range of climates that may be met raises problems of human performance, hygiene, and control of environment. The solution of these problems demands an understanding of the world's climates and climatic behaviour.

2. Men can exist in almost any climate, if they are suitably equipped and fed, but climatic extremes limit human efficiency. Acclimatization to either intense cold or tropical heat can be acquired. Human performance is, however, lowered by prolonged exposure to either type of extreme. But much can be done to promote and extend efficiency by ensuring acclimatization and by environmental control.

3. Environmental control means provision of a modified physical environment with conditions for work, leisure and rest that are conducive to health, efficiency and comfort. The main problem is regulation of body heat loss; it involves the design of suitable clothing as well as the siting and style of buildings, which must be heated or cooled and ventilated as necessary.

4. The prevalence of certain diseases is related to climatic conditions which favour the pathogenic organisms, their vectors, and reservoirs of infection. Adverse climates may cause general poverty and periodic famines in certain regions, where as a result deficiency diseases may become prevalent, human resistance is sapped, and endemic infections become rife. There are also the pathological effects directly caused by exposure to extreme heat or cold.

5. This chapter contains text, maps, and tables which will enable an assessment to be made of the climate to be expected in any given place. In addition, more detailed climatic data are tabulated for a selection of representative places (Table 6).

THE NATURE OF CLIMATE

Effects on Life

6. Climate is the sum total of weather sequences occurring at a given place around the year and from year to year. Classification of climates, based on long-term averages and according to their usual effects on human, animal, and vegetable life is insufficient. Account must also be taken of the persistence of spells of weather, which may last a whole season, and of the commonly abrupt, day-to-day changes. There are in addition variations from year to year. In short, the effects of climate on human, animal, plant, insect, and bacterial life are due to:—

(*a*) The normal average values of such elements as temperature, humidity, and rainfall.

(*b*) The variations of these elements, including their extremes.

(*c*) The duration of conditions beyond certain threshold values.

*From material contributed by H. H. Lamb, M.A., Head of World Climatology Branch of Air Ministry Meteorological Office

Results of Variations

7. Climatic variations become apparent when the data for many years are studied. Unless the changes threaten existence, livelihood, or comfort, they are rarely important during the span of one human life. But there are exceptions. For example, a decade of dry years caused the "dust bowl erosion" in the Great Plains of the U.S.A. in the nineteen thirties. Much valuable agricultural soil was simply blown away.

8. In the main, however, climatic characteristics seem to have remained relatively constant over the historic centuries. The classics and recorded history describe climatic conditions in many parts of the world that accord reasonably with modern experience.

Solar Energy

9. Climate and weather are determined by the general circulation of the atmosphere. The source of the energy that drives the atmospheric circulation is the sun. The circulation is in addition influenced by the various types of terrain over which the air flows.

10. The heat of the sun is largely picked up by the air from the surface of the earth, after this has been warmed by the incoming solar radiation. The degree of surface heating varies according to latitude. In addition, the absorption and reflection of heat by different types of surface are unlike. In consequence the air is set in motion in an arrangement of convection currents on the grandest scale. Climatic zones are largely governed by the amounts of incoming solar radiation available to drive the atmospheric circulation.

Incoming Solar Radiation

11. Given complete transparency of the atmosphere, the amount of incoming solar energy at noon which would fall on a horizontal surface in different latitudes would be of the order shown in Table 4. However, the clouds and dust in the atmosphere scatter and reflect much solar energy before it reaches the ground.

TABLE 4

SOLAR ENERGY AT NOON WITH TRANSPARENT ATMOSPHERE

(Calories per minute per square centimetre of level surface)

Date	S. Pole	60°S.	40°S.	20°S.	Equator	20°N.	40°N.	60°N.	N. Pole
21 June	0	0·21	0·84	1·36	1·72	1·87	1·80	1·51	0·75
Equinoxes	0	0·97	1·49	1·82	1·94	1·82	1·49	0·97	0
21 Dec.	0·8	1·61	1·92	2·00	1·83	1·45	0·89	0·22	0

12. Under average conditions of vertical atmospheric transparency, the values in Table 4 would be at least halved in the tropics and reduced considerably more in the higher latitudes. In these latitudes the sun's rays are slanted at a low angle, so must traverse much greater distances through the atmosphere before reaching the earth's surface. Under the best conditions of atmospheric clarity met, half the incoming radiation at noon in summer would reach the ground at the poles and about three-quarters at the tropics.

13. Even under average transparency conditions, the heat received per square centimetre of level surface in the tropics may be more than one calorie a minute at noon at certain times of the year. This is an indication of the formidable heat load possible where conditions afford little aid to the body-cooling mechanism.

14. The total solar energy received each 24 hours, about the solstices and equinoxes in different latitudes, is shown in Fig. 38. These values differ less in summer than do the noon intensities of solar radiation at different latitudes (Table 4). This is because the hours of daylight, and hence of potential sunshine, increase as latitudes become higher. With extreme atmospheric transparency, the total daily solar energy received at the poles, about the summer solstice, may even for a time exceed that received at the tropics. However, on account of the influence of weather, far less sunshine than is theoretically possible actually reaches any given place.

15. The comparative uniformity in the total solar energy received in summer by different latitudes results in temperature gradients, between low and high latitudes, that are relatively less steep than during other seasons. Hence in summer the general horizontal atmospheric circulation is comparatively weak. However, during summer land surfaces become considerably heated, which results in great vertical convection of the air over them. Fierce wind squalls, associated with this strong local heating, and violent thunderstorms, occur in the warm season especially when the atmosphere is humid.

Radiation Loss

16. The heat gained from the sun is partially dissipated by outgoing radiation from the earth's surface. The effects of this are most obvious

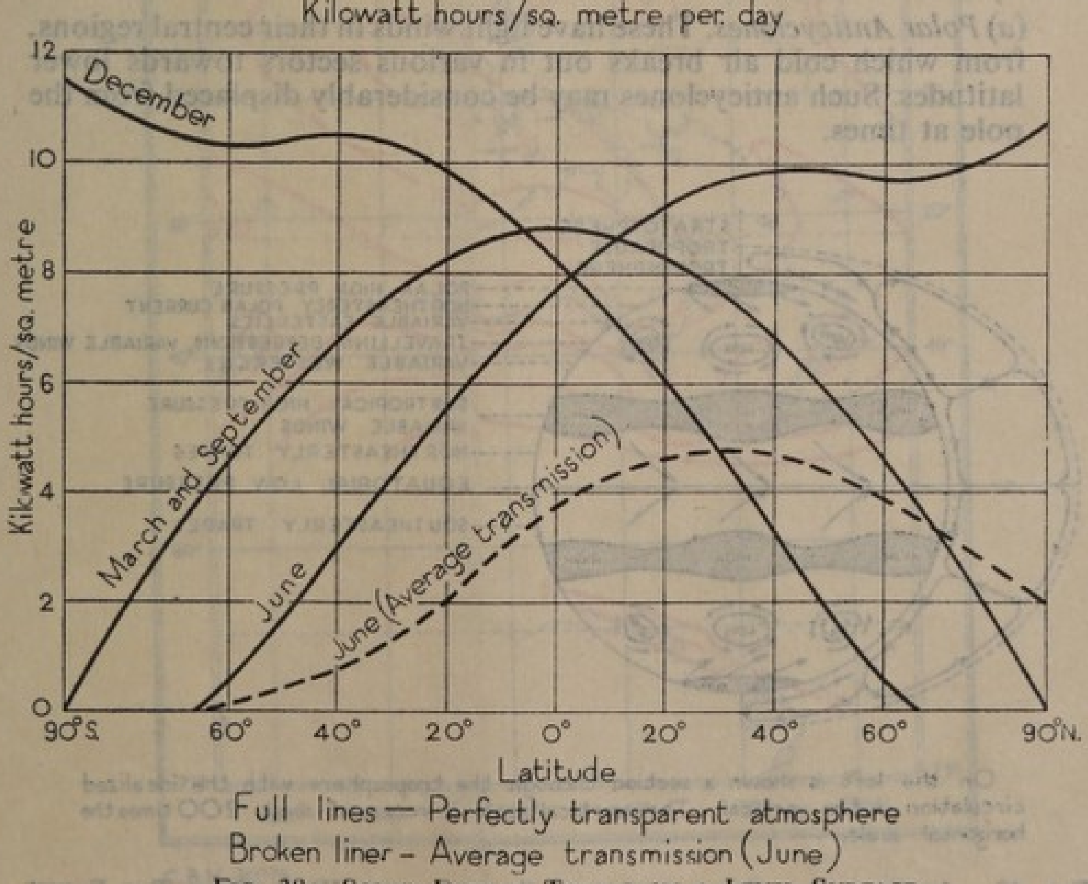


FIG. 38. SOLAR ENERGY TOTALS ON A LEVEL SURFACE

at night, when there is no incoming solar radiation. The radiant heat loss is greatest under clear skies and in conditions of high atmospheric transparency. The rate of loss is greatest when the temperature of the earth's surface is highest. The heat-glare from ground and walls in tropical countries shortly after the sun has set is sensible evidence of this.

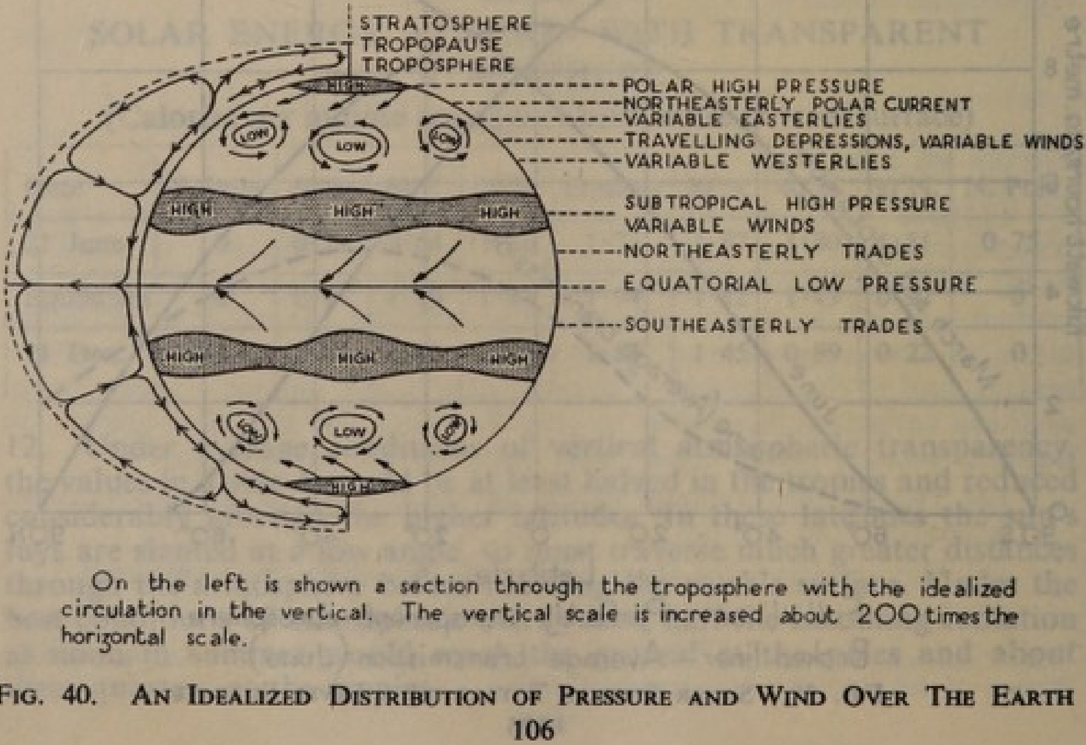
17. The greatest ranges of surface temperature, from day to night, are met in the deserts. Over seas and oceans the diurnal range of temperature is almost nil. There is markedly increased cooling at night from snow surfaces and dry ground, compared with vegetation, moist ground, and stretches of water.

18. Apart from heat loss by radiation, evaporation lowers the temperature of moist surfaces and of the air in contact with them. Dry winds encourage evaporation. In contrast, condensation releases warmth; it may add appreciably to the heat load in some climates where there are mild moist air streams and the weather is warm and close with much cloud. Föhn winds also derive much of their warmth from the condensation of moisture on the windward side of mountains.

Atmospheric Circulation

19. The picture of atmospheric circulation in Fig. 40 is a generalized one. The lack of uniformity in the earth's surface and the influence of travelling disturbances upset the general wind pattern. This pattern is fundamentally due to two factors. Air over the main areas of heated surface expands and rises, being replaced by colder denser air from adjacent regions. Secondly, air over cold surface areas contracts and forms downward currents. The interplay of these and other factors, for example the rotation of the earth, results in the following basic zones of atmospheric circulation.

(*a*) *Polar Anticyclones.* These have light winds in their central regions, from which cold air breaks out in various sectors towards lower latitudes. Such anticyclones may be considerably displaced from the pole at times.



On the left is shown a section through the troposphere with the idealized circulation in the vertical. The vertical scale is increased about 200 times the horizontal scale.

FIG. 40. AN IDEALIZED DISTRIBUTION OF PRESSURE AND WIND OVER THE EARTH

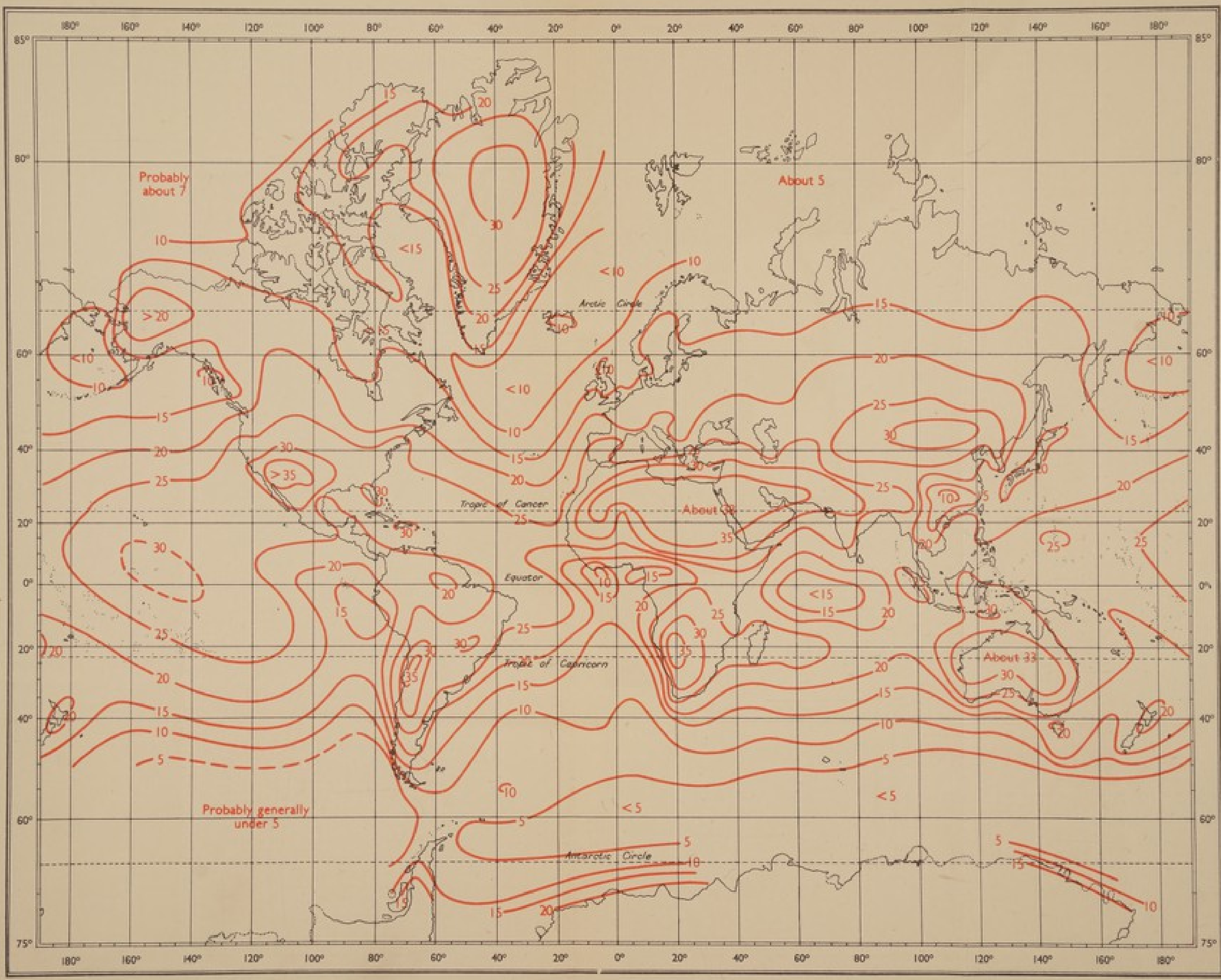


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FIG. 39. BRIGHT SUNSHINE
Average Yearly Numbers of Hours (Figures in Hundreds of Hours)

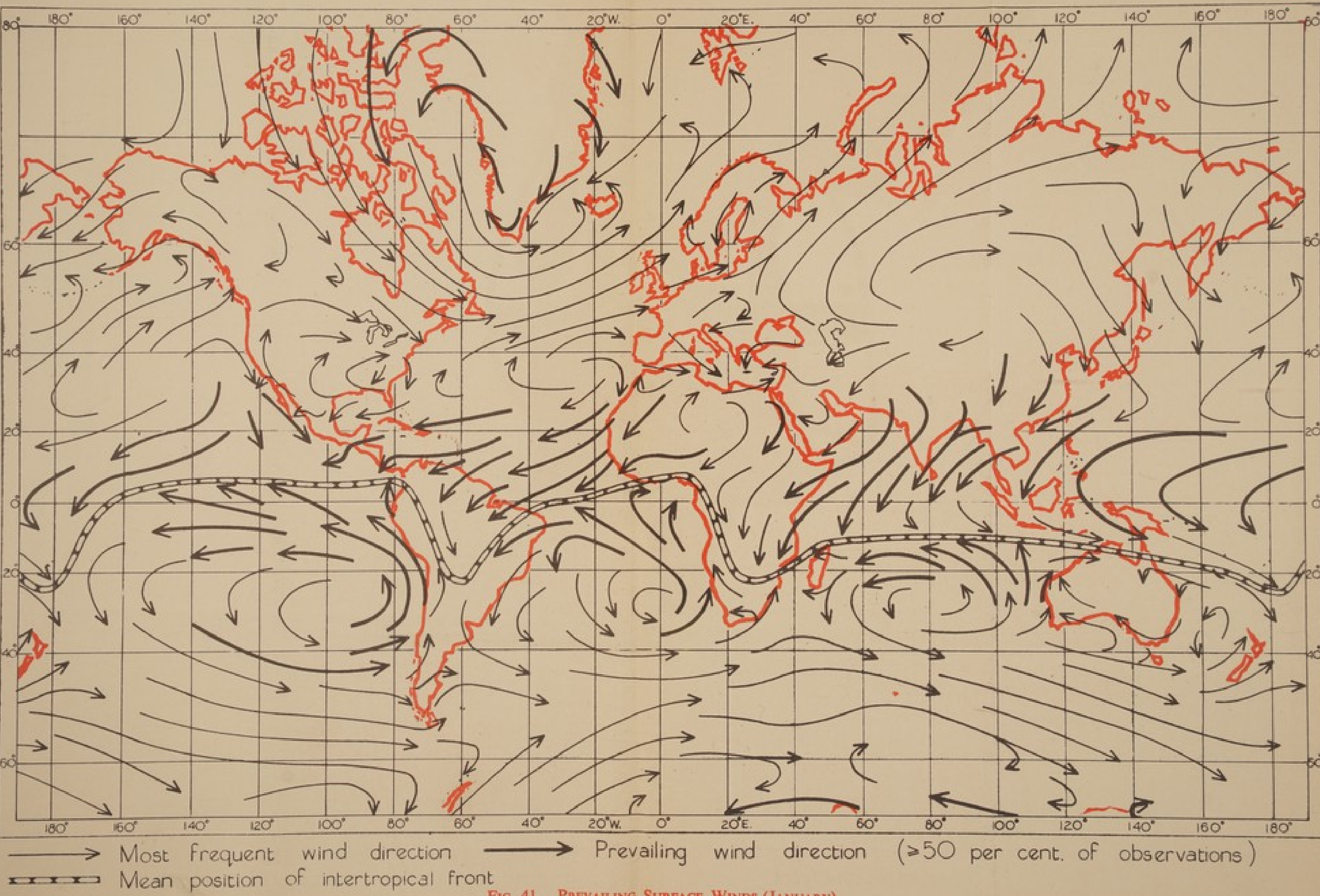

FIG. 41. PREVAILING SURFACE WINDS (JANUARY)

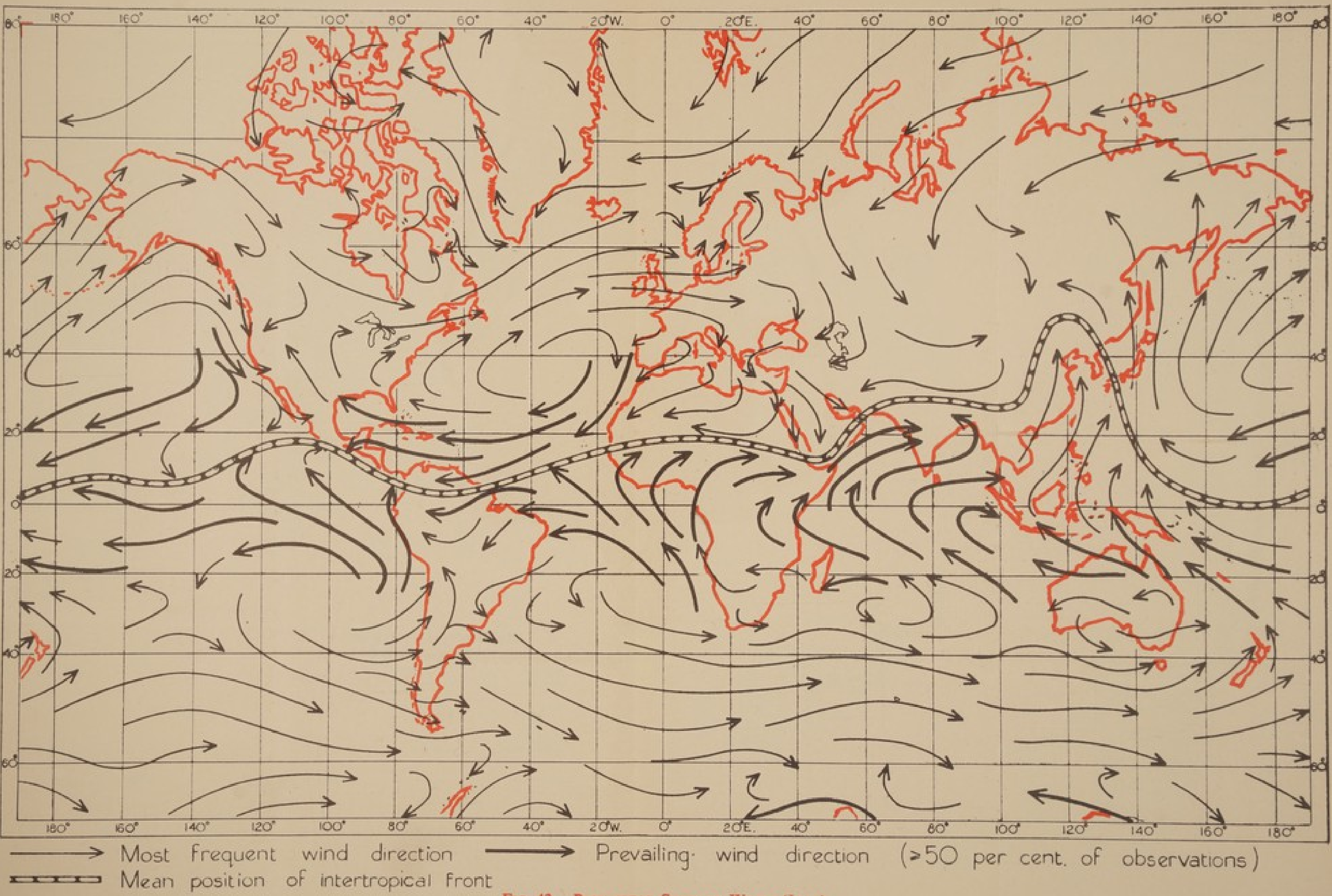

FIG. 42. PREVAILING SURFACE WINDS (JULY)

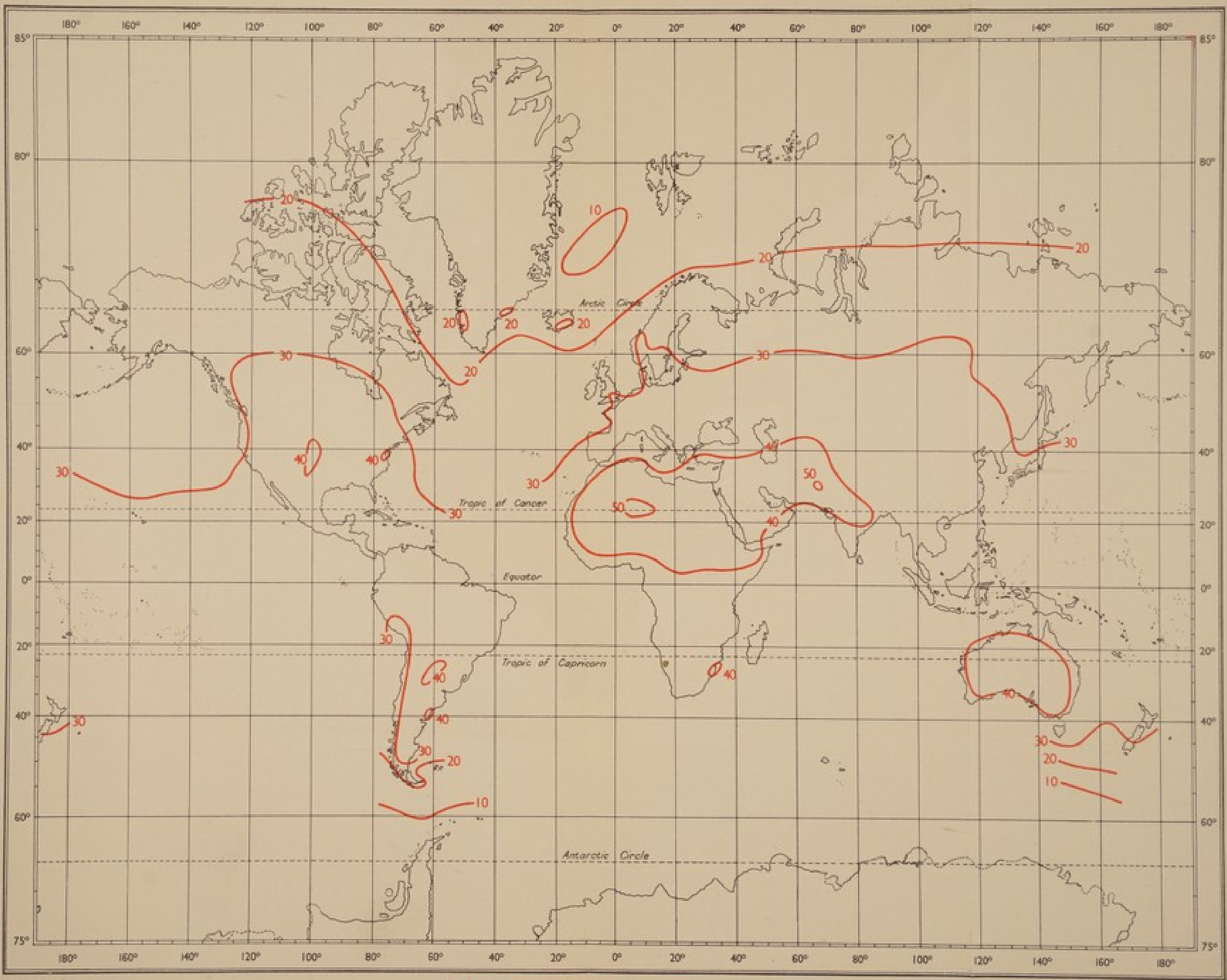

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FIG. 43. AVERAGE YEARLY MAXIMUM TEMPERATURE (°C.)

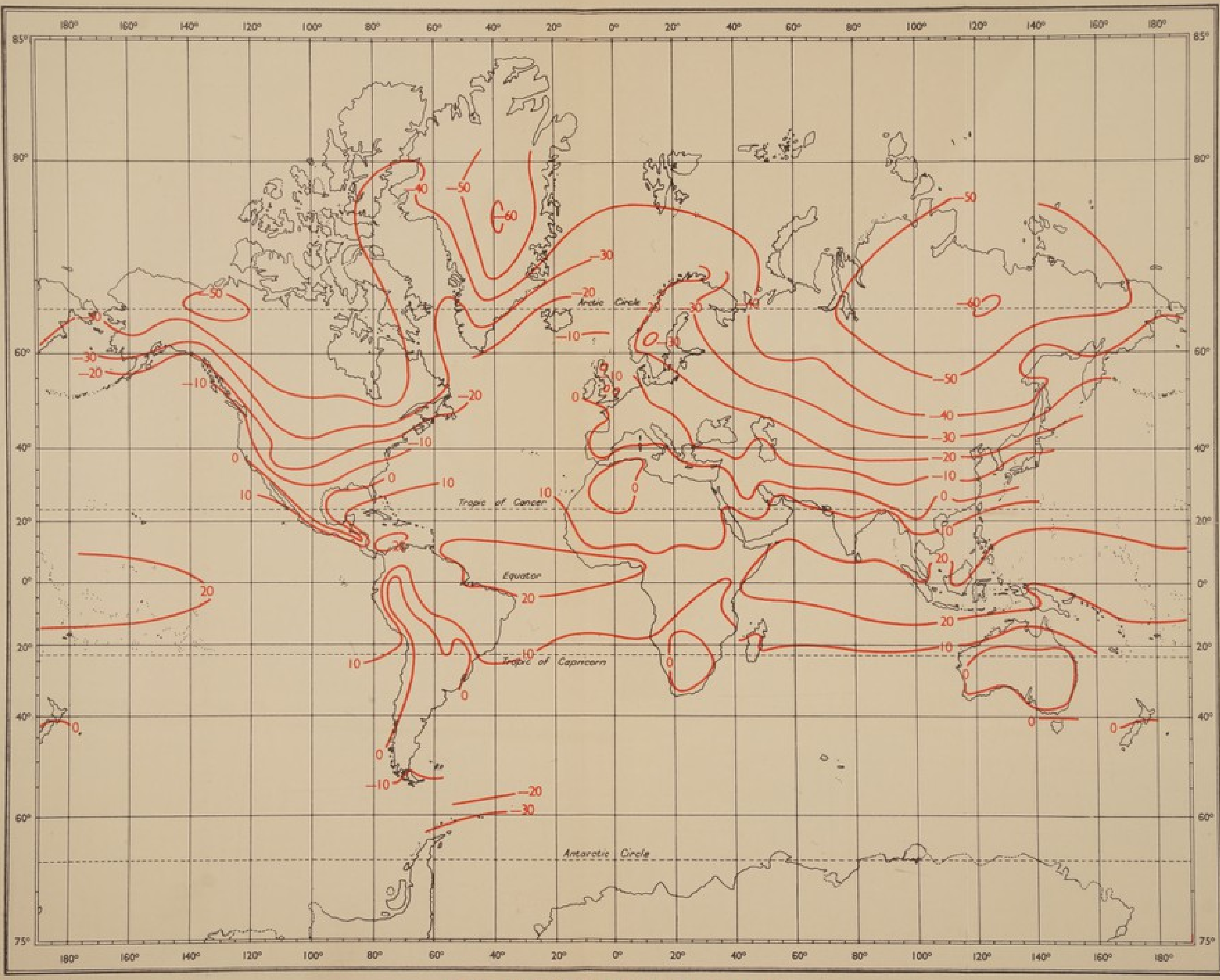

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FIG. 44. AVERAGE YEARLY MINIMUM TEMPERATURE (°C.)

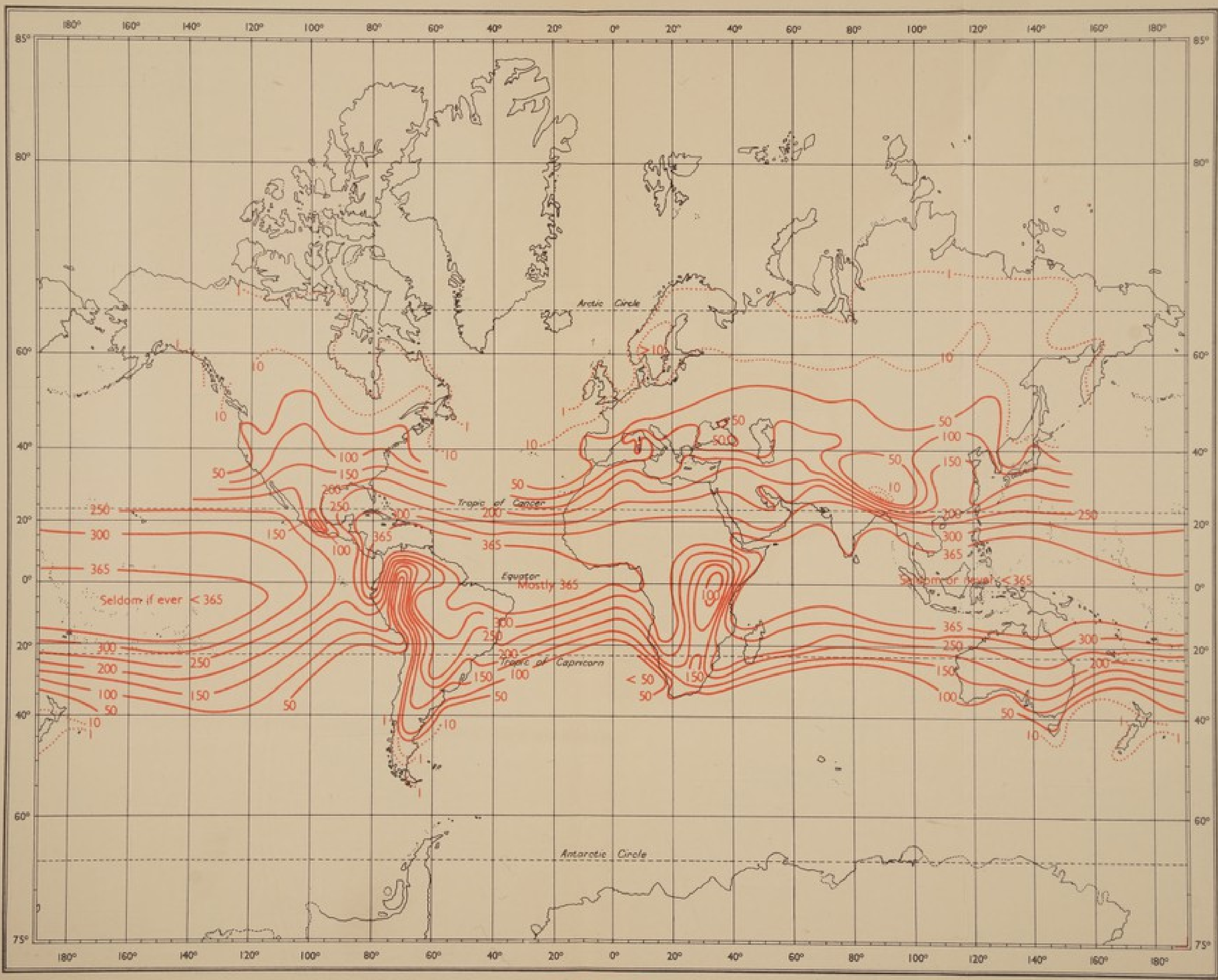

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Fig. 45. Hot Days
Average Yearly Number on Low Ground (Max. ⩾ 25°C.)

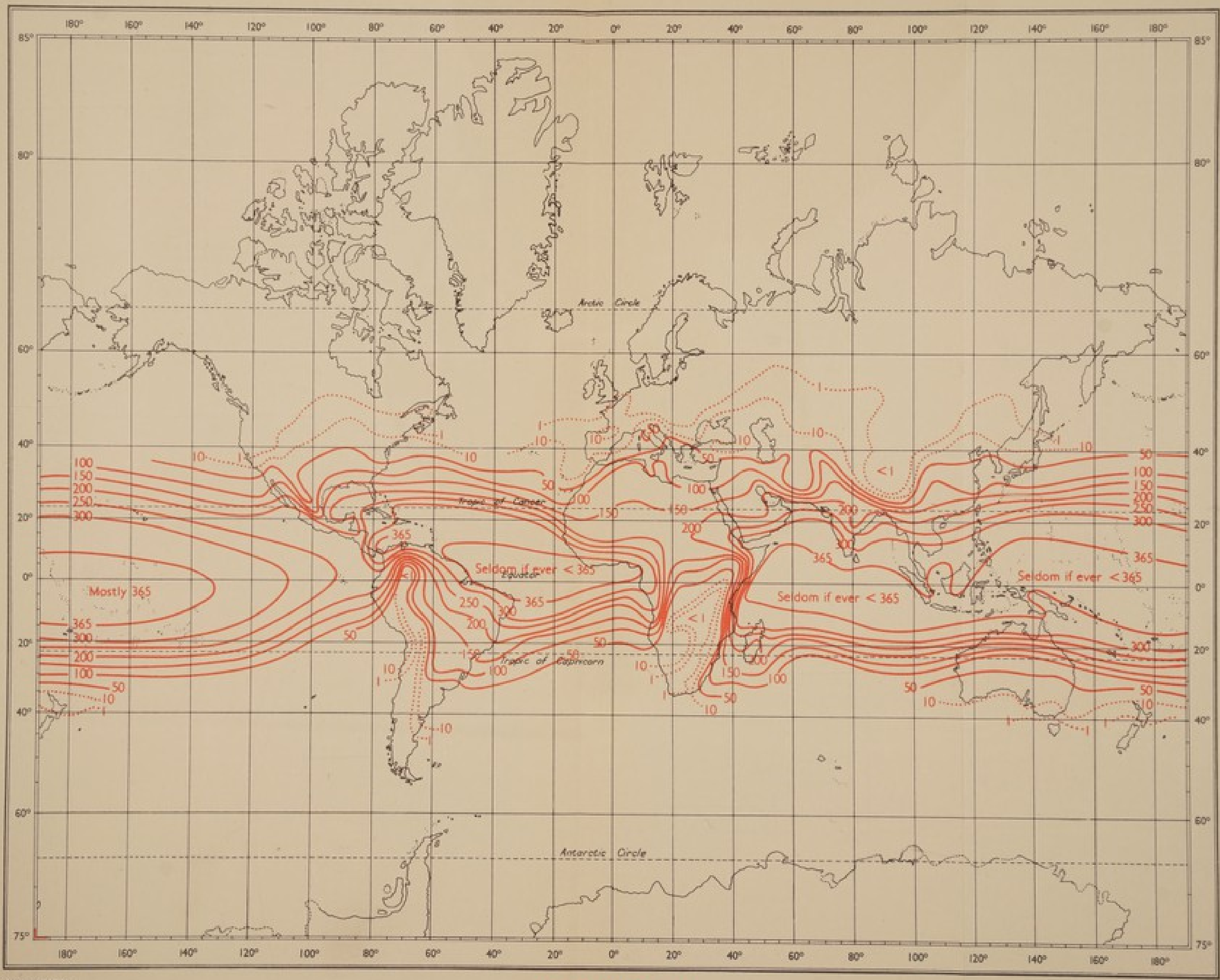

FIG. 46. WARM NIGHTS
Average Yearly Number on Low Ground (Min. ≥ 20° C.)

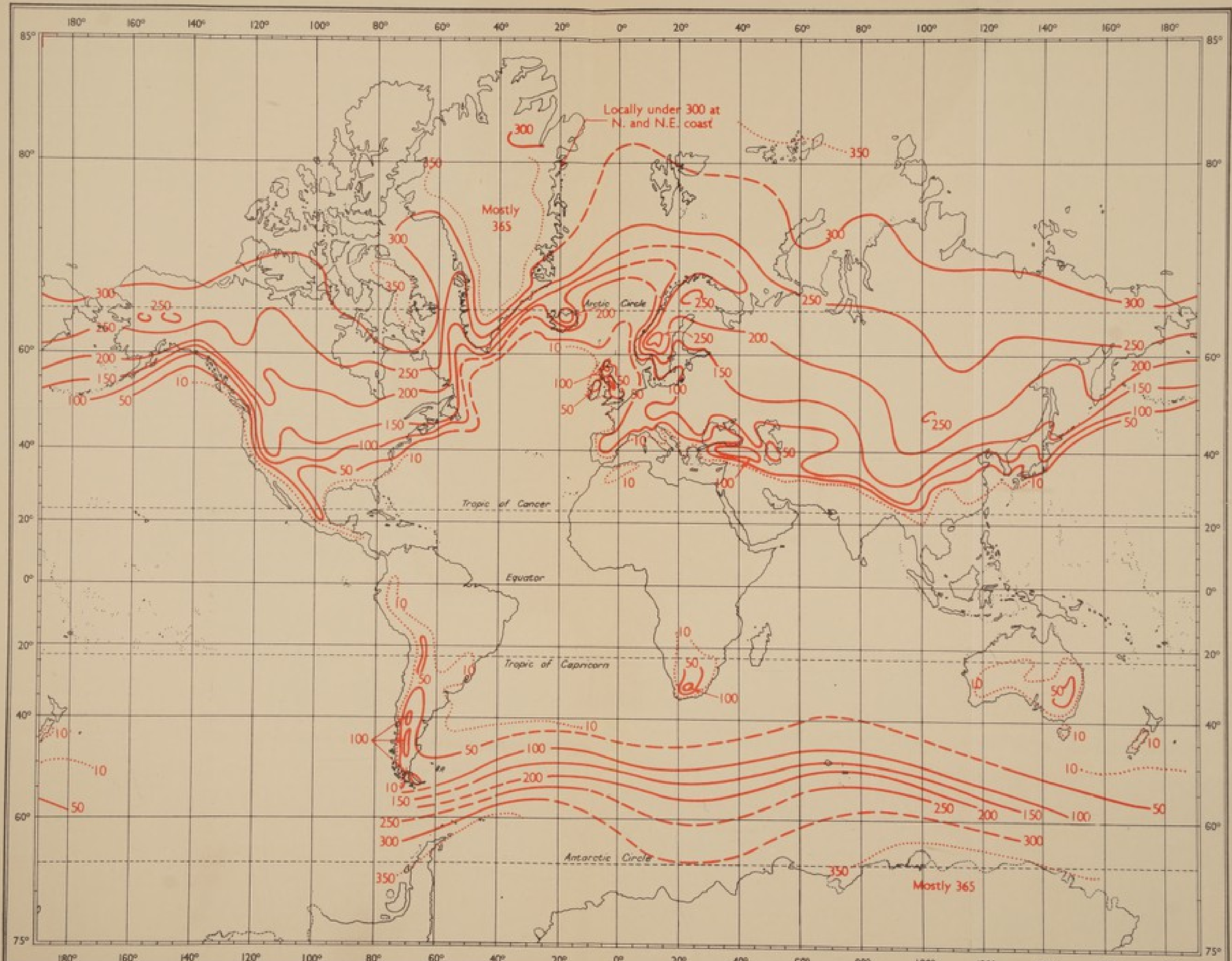

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FIG. 47. DAYS WITH FROST
Average Yearly Number (Min. < 0°C.)

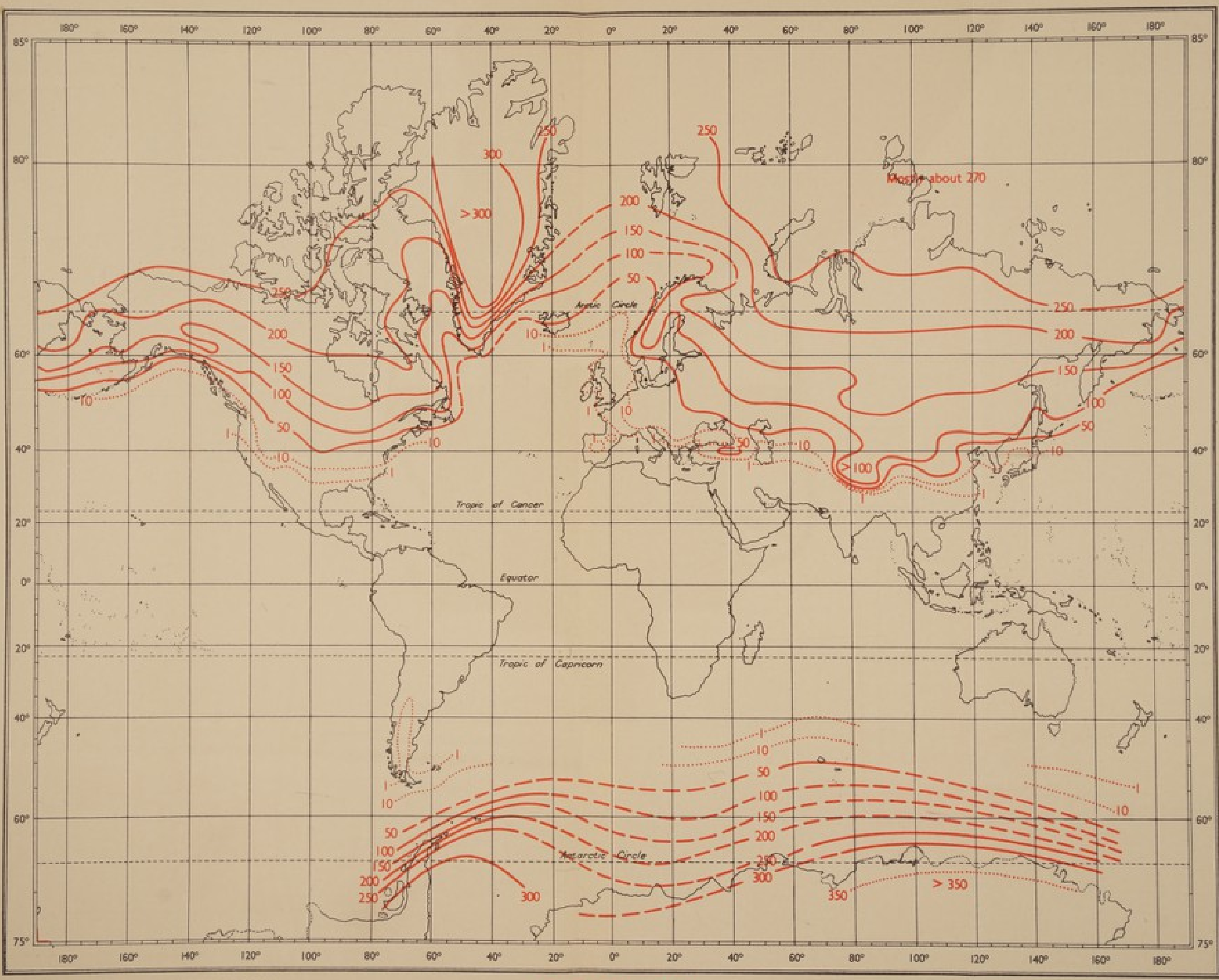

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Fig. 48. Freezing Days
Average Yearly Number (Max. ≤ 0°C.)

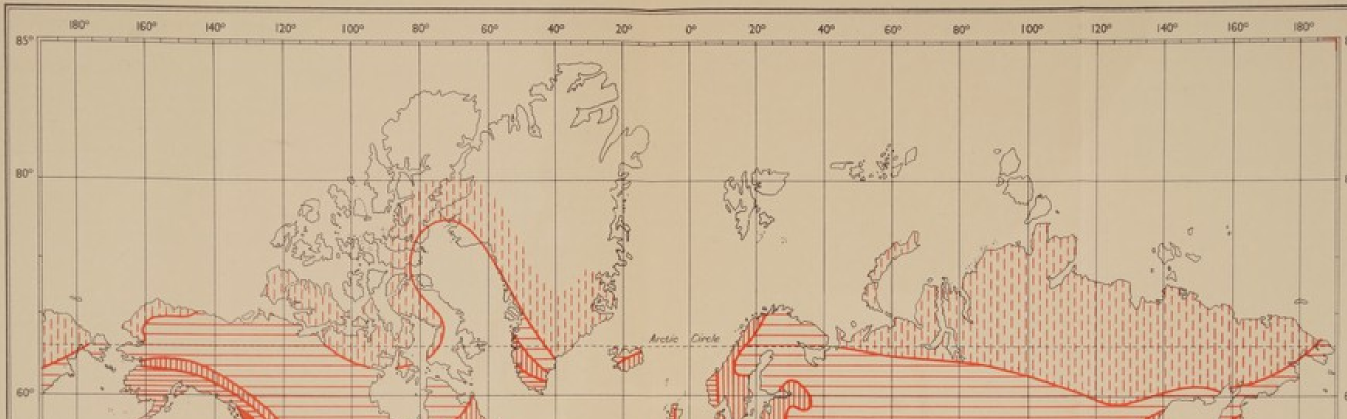

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FIG. 49. MEAN ANNUAL RAINFALL
(in inches)

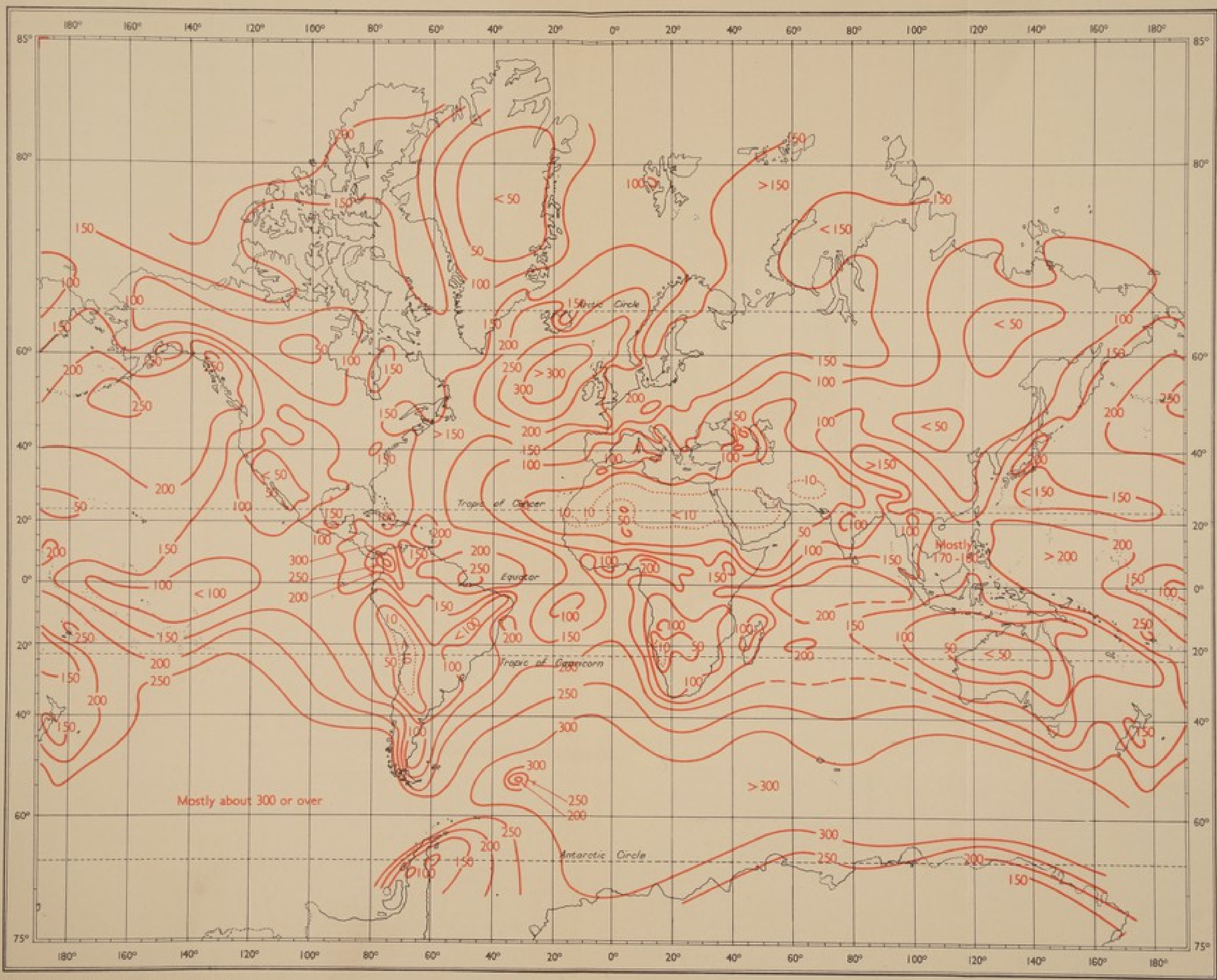

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FIG. 50. DAYS WITH PRECIPITATION
Approximate Average Yearly Number (≥ 0.1 mm. rain)

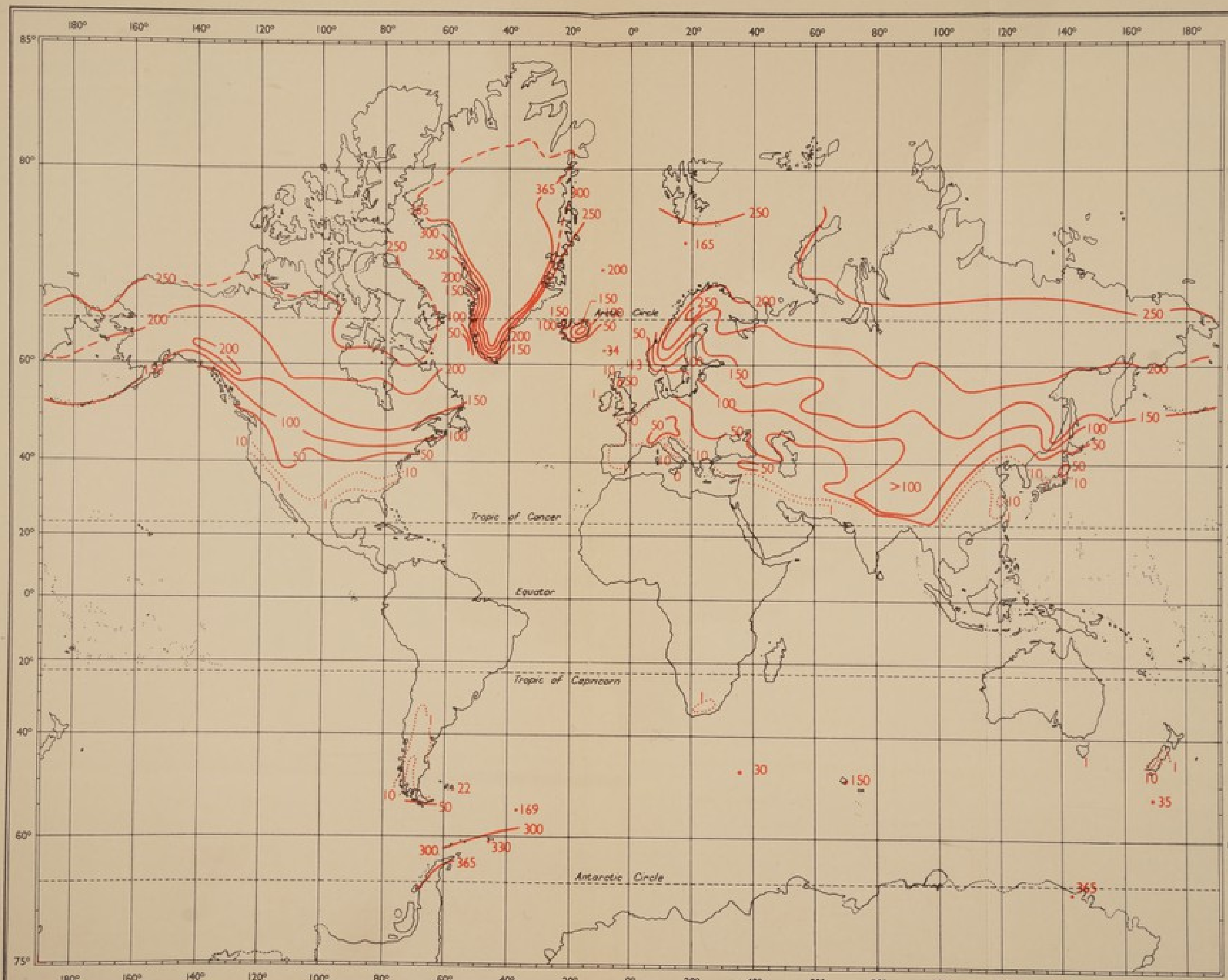

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FIG. 51. DAYS WITH SNOW LYING
Approximate Average Yearly Number on Low Ground

(*b*) *Zone of "Polar Front" Depressions*. Such depressions generally appear about latitude 55° to 70°, as a belt of low pressure on the mean map. Together with the front of the polar cold airstreams, they meet and undercut the milder, moister, and less dense prevailing westerly winds of middle latitudes.

(*c*) *Prevailing Westerly Winds of Middle Latitudes*. Components of these winds tend to move in a general direction towards the poles; but the travelling disturbances characteristic of the middle latitudes cause considerable variations, the winds swinging freely between S.W. and N.W. They appear as broad currents of relatively warm air. Where the colder winds of polar origin are met by these warmer air currents the latter are uplifted; the accompanying (adiabatic) expansion cooling produces widespread condensation, causing the clouds and rain of the polar-front depressions.

(*d*) *Subtropical High-Pressure Belts*. In general there are light winds and, on the whole, small amounts of cloud in these belts (the "horse" latitudes). From the anticyclones in these, well-defined currents of air circulate outwards towards both higher and lower latitudes. Their centres of highest pressure generally occur over the oceans. Over the land areas the surface is usually too strongly heated by the sun to allow normal anticyclonic development, which is therefore commonly shifted to a strip around the coast. Over the land in this zone, with cloudless skies, the highest temperatures in the world are produced.

(*e*) *Trade Winds*. These are driven towards lower latitudes, from the subtropical anticyclones in the northern and southern hemispheres, as N.E. and S.E. winds respectively. Disturbances are rare in this zone and the Trade Winds are the most persistent airstreams on the earth, rivalled for steadiness only by the cold winds draining off the Greenland and Antarctic ice-caps (see Figs. 41 and 42). The amounts and vertical growth of cloud in the Trade Wind zone increases towards the thermal equator, where the windstreams from both hemispheres converge.

(*f*) *Doldrums*. These are the intertropical convergence zone of relatively low pressure. It is a zone of mainly light surface winds and much vertical air motion, accompanied by great cloud growth and the well-known "equatorial rains". Where the equatorial air is forced up over mountains, and other factors causing instability coincide, torrential rains of up to 40 inches and more in a single day have been recorded.

20. The thermal equator, or intertropical convergence, and most of the other zones of atmospheric circulation shift north and south with the seasons and vary in intensity.

21. At any given time each zone is normally broken down longitudinally into a number of atmospheric circulation cells of limited size. The cell divisions are positions at which exchanges of air between different latitudes most easily take place, sometimes in the form of rather persistent "meridional" (northerly and southerly) airstreams. Each cell has a limited life and generally moves over shorter or longer distances on irregular tracks. A depression or anticyclone may migrate outside its proper zone and distort the general circulation for a time.

22. The pronounced seasonal heating and cooling of land surfaces tends to cause, over continents, persistent high pressure in winter and

low pressure in summer. This distorts the zonal arrangement of atmospheric circulation and sets up the monsoon systems, which produce a seasonal reversal of great windstreams in India, West Africa, and elsewhere (see Figs. 41 and 42). The summer monsoon depression over Asia draws the intertropical convergence of air streams north over India to about latitude 30° N. Thus the equatorial rain system is involved, producing the well-known rains of the S.W. monsoon in India and Burma and even further north in China. Similar events are involved in the rainy season in West Africa and the Amazon basin.

23. In addition to the fundamental zonal features of the atmospheric circulation and the great monsoons, two occasional or erratic features are of considerable importance:—

(*a*) *Tropical Hurricanes or Typhoons*. These fierce storms originate at certain points in the Trade Wind zone and travel westwards; they occasionally curve back later towards higher latitudes (on tracks towards N.E. or S.E. in the northern and southern hemispheres respectively). They cause great material damage close to the path of the centre, but few individual places feel the effects of more than one of these storms in any one year.

(*b*) *Cold-Pool Depressions*. These occur erratically in latitudes between 30° and the poles and are liable to bring the lowest temperatures to which the regions affected are ever exposed. Over the oceans in latitudes 30° to 40°, there are one or two regions specially prone to this type of disturbance in the colder half of the year (*e,g*. Azores-Madeira-Portuguese coast, several parts of the Mediterranean, and the ocean region near St. Helena). Here these depressions commonly remain centred in the same region for periods ranging from several days to a couple of weeks, bringing strong winds and often considerable rain and hail.

SURFACE INFLUENCES ON CLIMATE

24. Climate is modified by the characteristic effects on the atmosphere of differences in the earth's surface.

The Oceans

25. The response of the surface of the open sea to incoming and outgoing radiant heat is relatively sluggish. No great extremes of air temperature occur in oceanic climates and seasonal differences are not marked.

26. Strong, frequent winds are characteristic because they are unobstructed. They are usually mild in winter, cool in summer. Their rain content and humidity values are generally high especially near coasts and at the windward side of the first mountain range encountered.

27. As a result, coastal climates have more wind and less extreme temperatures than places inland. They also usually have a heavier rainfall. The warmest days are tempered by cool sea breezes, which spring up during the day and die down in the evening. Sea fogs tend to occur in spring and summer, when the sea remains cooler than the land.

The Continents

28. Places remote from maritime influences, or shielded from them by mountain ranges, are noted for extremes of temperature. Rainfall and the frequency of strong winds decrease sharply to the leeward of the first mountain range encountered by winds from the ocean.

29. The climates of inland places near lakes, rivers, and marshes are more humid than adjacent regions. Showers and thunderstorms in late summer and mists in autumn are liable to occur. At other times of the year lakeside places may be better off for clear skies and sunshine than the neighbouring countryside.

30. Inland forests are distinctive for shelter and light winds. Extremes of atmospheric dryness do not occur, rainfall and cloud being more prevalent over extensive forests than over bare ground. Trees provide protection from extremes of temperature on hot days and cold nights. However, radiation cooling may produce extremely low temperatures in clearings, which may act as the gathering ground for the coldest air draining off surrounding higher country.

Snow and Icefields

31. Passing air is chilled by snow and ice; its temperature is reduced to within a few degrees of freezing point, and condensation occurs. As a result, the passage of mild air over snow frequently leads to widespread fog and drizzle. At the worst all the damp and difficult features of a thaw are present.

32. At night under clear skies radiation cooling of ice or snow produces the extreme lowest surface temperatures occurring at any given place. As long as frost persists, a snow surface encourages the deposition of moisture from the air as rime rather than as fog. The relative comfort of dry cold is connected with this.

33. Chilling of the surface air also produces stable stratification of the lower atmosphere. Consequently vertical convectional turbulence and showery weather are rare over frozen ground, except near unfrozen seas and lakes. Slight snow flurries in light winds are common, but yield usually a very small snowfall.

Mountains

34. The air on the windward side of mountains is uplifted on a large scale. Here dense masses of cloud and copious rainfall are common. On the leeward side, the turbulent descent of the air brings clearing skies and low relative humidity.

35. Mountain ranges also cause a very rapid transition from oceanic to continental climates in winter. The warm air from the sea is forced up over the crest of the range; it then overrides the dense cold air to leeward, which it is too light to dislodge. Examples of this transition occur in Norway, the Alps, the Rocky Mountains, and to a lesser degree in the United Kingdom.

36. Altitude, aspect, and exposure in mountainous country give rise to wide local climatic variations. Temperature drops by about 3°F. per thousand feet as altitude increases. Hence snow lies all the year round on high mountains even in tropical countries, for example on Mount Kenya.

37. Valleys, though on the whole more sheltered than peaks, are liable to strong cold night winds. These are katabatic winds (see para. 122), consisting of cold dense air moving down slopes and draining out through the channels formed by the valleys. Funnelling of the wind through passes and straight valleys may also cause local gales much

stronger than on the tops. The small side valleys and places not in the main wind channel may escape, but the bottom of any valley is exposed to the drainage of the local cold air.

38. The aspect of mountain slopes is important to all forms of life. In the northern hemisphere lack of adequate sun makes slopes with a northern aspect climatically equivalent to flat, open sites in much higher latitudes. South and south-west slopes, facing the afternoon sun, receive warmth equivalent to lower latitudes. In mountain country the richness of crops or pastures, the presence of trees and the persistence of winter snow are all influenced by aspect.

THE COMPONENTS OF CLIMATE

Sunshine and Cloudiness

39. The normal world distribution of bright sunshine is shown in Fig. 39. The figures relate to the most extensive lowland or plateau in any region; they may be quite different on neighbouring peaks and mountain sides.

40. On account of cloudiness the sunshine received is less than the possible total, the difference being most marked in winter. For example, in Britain and Central Europe at low altitudes in winter only 15 to 20 per cent. of the possible sunshine is received. In summer the figure rises to 30 to 50 per cent. The reverse occurs on mountains covered with convection clouds in summer but above cloud in winter. Most of the world's deserts, parts of S.W. Africa, the southern Rockies and the Andes receive 80 per cent. or more of the possible sunshine.

41. The proportion of the possible sunshine received is an indication of the prevalence of cloudiness. For example, over desert regions receiving 80 per cent. of the possible sunshine, it follows that the mean cloudiness from sunrise to sunset is $\frac{2}{10}$ths. (20 per cent.) of the sky covered. In temperate latitudes the least sunshine is received at altitudes of 2,000 to 5,000 feet, where, especially in maritime climates, low cloud and hill fogs are persistent. The least sunny places in the world are the islands of the Southern Ocean, where overcast skies are the rule and virtually complete overcast may occur on 300 days in the year.

Temperature

42. The general distribution of extremes of temperature is shown in Figs. 43 and 44. Both the highest and lowest temperatures are found in inland regions, well away from open water. Actual extremes may only occur briefly, so they are not in all cases of great importance to life, including bacteria and vectors of disease. Greater influence is exerted by the duration and frequency of temperatures above and below certain critical thresholds.

43. An example will make this point clear. The minimum period for the development within the mosquito of *Plasmodium vivax* is, at 25°C., ten to eleven days. The corresponding minimum for *Plasmodium falciparum* is at temperatures about 28°C. With temperatures under 16°C. there is no appreciable development of either variety. On the other hand, malarial mosquitoes continue to infest regions in Turkey and Russia where extreme temperatures as low as −20° to −40°C. occur in winter. It is not this extreme that is important here but the duration in summer of temperatures favourable to plasmodial development.

44. The upper extremes of temperature in the year do not vary much with changes of height. At high altitudes, however, they occur only on rather few days when the air is still. Greater variations of maximum temperature are found near local moderating influences such as coasts or stretches of water. The lower extremes of temperature are even more susceptible to local influences, for example in mountainous country especially in the more enclosed valleys.

45. The world distribution of days with a maximum temperature of 77°F. (25°C.) or above is shown in Fig. 45. By European standards these are summer days when only light clothing is comfortable. Altitude has a greater influence on the frequency of such days than on absolute maximum temperatures (Fig. 43). For example, Darjeeling, India (7,000 ft.), on the average has no more than one such day in several years compared with other places at lower altitudes in the same latitude, which may have up to 365 in the year.

46. Such temperatures may reach very far north, being found occasionally even in western parts of Greenland away from the icesheet and well inland from the cold sea. The reason is that sunshine in the arctic summer is so prolonged that it can raise the temperature to 77°F. over tundra and rock that is free from snow.

47. The corresponding distribution of warm nights with minimum temperatures of 68°F. (20°C.) or above is given in Fig. 46. These temperatures cause sleeplessness, especially when winds are light and the sky overcast. Such conditions sap vitality and encourage mosquito breeding. The greatest number of warm nights occur near sea level and at places near the sea. For example, in an average year, Valetta gets 120 nights with minimum temperature of 68°F. (20°C.) or above. On the Malta plateau (600 to 800 feet) the number falls to 50 to 60. Similar contrasts due to altitude are to be found everywhere in the tropics and subtropics. The number reaches 365 at places like Singapore.

Frosts

48. The general yearly distribution of frosts is assessed according to the number of days on which the air temperature falls below 32°F. (0°C.) at any time (Fig. 47). The map applies to low-lying places in any region. In hot climates frosts occur in deserts remote from the sea and in the valleys and plateaux of mountainous country. Places near oceans or smaller areas of water that are warm for their latitude have far fewer frosts than inland.

49. "Freezing" days are those on which the temperature never rises above 32°F. (0°C.). The general yearly distribution of these is given in Fig. 48. Maritime and continental influences have the same effect on the number of freezing days as on the number of night frosts.

50. At places with appreciably more than 10 freezing days, there is usually a fairly long spell of dry cold each winter. Cold weather clothing for such places need not consequently be waterproof, as it must be to protect against cold-wet conditions.

Humidity

51. Air takes up moisture in the form of invisible vapour; its capacity to do this increases with temperature. Atmospheric air is never entirely free from moisture, but may often be saturated. Table 5 shows the amount of water vapour required to saturate air at various temperatures and normal pressure.

TABLE 5

WATER VAPOUR REQUIRED TO SATURATE AIR
(Grammes water per kilogram saturated air at normal pressure)

Temperature	40°C.	30°C.	20°C.	10°C.	0°C.	−10°C.
Moisture content at saturation	46·6	26·5	14·5	7·5	3·7	1·7

52. Humidity may be expressed in terms of the actual amount of evaporated moisture in the air. This is the absolute humidity, defined as the mass of water vapour in a given volume of air. Alternatively, relative humidity may be used; it is the proportion (per cent.) of the moisture present in comparison to that required to produce saturation at a given temperature.

53. Both the absolute and relative humidity of the atmosphere are higher near sources of moisture, especially when water surfaces are relatively warm. Sources of moisture include seas, lakes, rivers, and swamps. Aggregations of human, animal, and vegetable life may also act as sources. Industrial exhausts may, besides poisoning the atmosphere, contribute to its moisture.

54. When the saturation point of air is passed, condensation occurs. This may happen because too much moisture is passed into the air; but far more frequently the immediate cause is through the reduction by chilling of the air's capacity to hold moisture. Air is generally cooled either by passing over a colder surface or by reduction of pressure during ascent. This adiabatic expansion (see para. 106) is the principle of the refrigerator. Clouds and fog are, therefore, specially prevalent over cold seas and oceans as well as over hills and mountains where moist air is forced to ascend.

55. Descent of air is accompanied by increasing pressure (adiabatic compression) and rising temperature. This causes lowering of the relative humidity and evaporation of condensed moisture. The result is the bright, warm climate often found to leeward of mountain ranges. These are the conditions of the Alpine Föhn wind which brings warm weather (and avalanches in season) to the valleys of Switzerland, Austria, and Southern Germany. The Chinook wind of the Rockies is similar; even in midwinter it may cause thaws on the eastern slopes.

56. Prevailing relative humidities at low altitudes are highest in the coldest hours about dawn and lowest in the afternoons. The morning values in London average, summer and winter respectively, 80 and 90 per cent.; the corresponding afternoon values range from 55 to 60 per cent. and from 75 to 80 per cent. Afternoon values are higher near the Atlantic coast, where the cloud base is habitually lower in consequence and hill mist or drizzle are correspondingly frequent. The average afternoon figures, as an example, for S.W. Ireland and the Hebrides are 75 to over 80 per cent. Small islands show high humidity characteristics also; afternoon values for Valetta in summer are about 60 to 65 per cent.

57. By contrast the humidity on high mountains may be extremely low, especially during winter anticyclones. This occurs when the air is involved in large-scale vertical atmospheric circulation of downward direction. Relative humidities may fall below 10 per cent.; on one occasion the value was 6 per cent. on Ben Nevis.

Rainfall

58. The annual world distribution of rainfall is shown in Fig. 49. It includes the water equivalent of snow after melting. The map is largely representative of the lowlands; the variations due to mountains and lakes have been ignored in the interests of simplicity. Quantitative distinction between rainfalls of over 80 inches has not been made for the same reason.

59. Besides the quantity of rain that falls, its frequency and duration must be taken into account. The average number of days during which precipitation occurs each year is shown in Fig. 50.* At Cherrapunji (Assam) the annual rainfall is 436 inches and measurable rain falls on 160 days in the year. The days of precipitation in the drier parts of Europe are similar, but the rainfall is only 20 to 40 inches.

60. Types of rainfall are distinguished by their cause:—

(*a*) *Orographic*. This is due to the uplift of moist airstreams over mountain ranges. Characteristically there is prolonged rain on the windward side, dry weather on the leeward.

(*b*) *Frontal*. A warm moist airstream meeting the surface of a colder, denser body of air, overrides it. This uplift results generally in prolonged, gentle to moderate rather than heavy rainfall.

(*c*) *Cyclonic*. This is due to the general ascent of converging, moist air masses in a depression. Prolonged, sometimes intense, rainfall usually results.

(*d*) *Instability*. Instability rains are characteristically intense and often brief. They are due to adiabatic cooling and condensation in local, strong, vertical convection currents of air, unstable because of strong heating from below.

61. Combinations of these effects commonly occur, leading to more rain than would result from any one single cause. High air temperatures and warm areas of water, from which moisture is taken up, encourage heavy rainfall. Where the surface of the earth is cold, rain or snowfall is usually light but may be frequent and prolonged. Over hot countries, where the heat encourages instability rain (showers and thunderstorms), rainfall may be rare but is likely to be heavy when it does occur. Heavy and frequent rainfall is common over and near the warmest ocean regions.

62. Thunderstorms occur on over 100 days in the year over certain tropical islands, the narrow zone of Central America, and in two special zones in S. America and S. Africa, where they are due to repeated frontal activity. The greatest known frequency is over 200 days of thunderstorms in a year in the mountains of Java.

63. The frequency of rainfall depends primarily on aspect relative to the prevailing wind. It is also influenced by height above sea level. Great predominance of one wind direction may cause exceptional local

**Note*.—In Fig. 50, the value of the isopleth in approx. Lat. 23°N., Long. 180°, should read 150.

variations from the general distribution. For example, rain occurs on the windward side of St. Helena on 200 days in the year, compared with 41 days on the side sheltered from the S.E. Trade Winds.

Snow

64. The frequency with which ground has a covering of snow is shown in Fig. 51. The map relates to the relatively low ground in each area or terrain.

65. In the maritime climates on the west of the great continents and in South America, the number of days with snow lying exceeds freezing days by about 10 to 20. There is consequently frequent wet, thawing snow on the ground. The opposite occurs in the eastern parts of North America and Asia. In these eastern continental climates snowfall is usually light; much is evaporated or blown away by dry winds before it melts, and there is little trouble from thaw. Exceptions to this are found near the coasts and coastal mountain ranges where the snowfall is heavier. In addition, the spring thaw causes swollen rivers and flooding in any region where snow accumulates during a long winter.

66. Snowfall varies markedly from winter to winter in countries having on the average less than 50 days with snow on the ground. Winters with at least 20 to 30 days snow cover generally contain one main period of prolonged frost. Rain is then rare and people can adapt themselves to the cold dry conditions. More trying weather conditions occur in places up to about 500 miles outside the main snow areas. There is much wind, rain, sleet, and hail with treacherous alternations of frost and mild air. It is difficult to adapt to the frequent changes, which expose animal and plant life to repeated weather hazards.

Dust and Haze

67. Loose surfaces, such as desert sand, powder snow, and light dry soil, are stirred by fresh breezes. About the same wind strength is required as causes the first breaking waves on extensive water surfaces. Stronger winds carry dust far up into the atmosphere and may transport it long distances. While the dust-bearing wind lasts, deposits of dust penetrate everywhere. The yellow haze of desert sand is a familiar sight in many parts of Southern Europe. Blowing dust and powder snow is similarly met on the Russian Steppes, in the hinterland of China, and on the Great Plains of the U.S.A.

68. The white glare of the Mediterranean is due to suspended particles of dust and to minute droplets of moisture, resulting from condensation when the sea is warm. This slight haziness is characteristic of tropical and sub-tropical latitudes in general. It reduces the intensity of solar radiation, especially in the shorter wave lengths. Both the beneficial effects and the risk of sunburn from ultra-violet radiation are markedly higher when the air is abnormally clear. Ultra-violet penetration is at its greatest when the atmospheric transparency is outstanding, as in high altitude and arctic climates.

Winds and Gales

69. The temperate and sub-polar oceans have particularly stormy climates, especially in winter. Gales are reported on 90 to 120 days a year by weather ships in the eastern North Atlantic. The N.W. coast of Britain has 30 to 50 days of gale a year. The stormiest places around the Mediter-

ranean, the North Sea and the Baltic average 10 to 20 days. For some two months in summer strong winds are rare in the polar regions and for four months in the sub-tropical latitudes (approx. 20° to 35° N. and S.).

70. Strong winds in the tropics are mainly associated with thunder squalls or tornadoes, and at sea with waterspouts. They are short-lived. Typhoons or hurricanes cause gales once or twice a year at any given point in tropical oceans, coasts, and small islands.

71. The amount of wind increases near the coasts and at higher altitudes over the temperate land-masses. Gales are rare in the interior, unless associated with summer and autumn thunder squalls and tornadoes, as in the tropics. Mountain and valley winds may produce localized windy conditions.

72. Very fierce cold gales are notorious in some valleys, fjords, and mountainous parts of the coast in the Arctic and Antarctic. Constriction and channelling by the mountains of the flow of dense, cold air plays a part in these gales. Open exposures on extensive ice-sheets and out at sea may actually be less exposed to this climatic hazard.

Some Local Winds

73. **Bora.** This is a cold, gusty katabatic wind (see para. 122) in the valleys and coasts of the Adriatic, associated with cold air draining off the mountains. Sometimes it produces squalls of great force. It blows mostly in the colder season, especially at night.

74. **Mistral.** This is the cold katabatic wind of the Rhone Valley and Riviera in winter. It resembles the Bora.

75. **Harmattan.** Cold, dry, dusty winds from the desert in W. Africa during the northern winter go by this name.

76. **Föhn.** This is a warm, dry, gusty wind which often has a sudden onset. It occurs in the valleys to the leeward of the Alps, in Switzerland, Bavaria, and Austria. The warmth is due to condensation when the air crosses the mountains, having brought rain and cloud in its ascent on the windward side. The westerly Chinook of the Rocky Mountains, the Zonda of the Andes and the northerly Berg wind of the south coast of South Africa are similar and are also sometimes called Föhn winds. Other examples occur on a greater or smaller scale near most hills and mountains.

77. **Ghibli and Khamsin.** These names are applied respectively in Libya and Egypt to hot, dusty, dry southerly winds from the desert.

78. **Sirocco.** This name applies to the warm, moist southerly wind which reaches Southern Europe and Malta across the Mediterranean from Africa. It is notoriously enervating and deposits large amounts of moisture both as dew and as condensation inside buildings.

CLIMATIC ZONES

Administrative Definitions

79. The features of the atmospheric circulation, described in paras. 19 to 23, and the varying characteristics of the earth's surface are the main factors that determine the climatic zones. For service purposes it is, however, expedient to classify the zones simply as tropical, subtropical,

arctic and subarctic, everything remaining being temperate. The definitions that follow are necessary as an administrative convenience; they are far from being meteorologically precise.

80. **Tropical Climate.** Those areas that have a mean monthly temperature for the coolest month of the year of not less than 68°F. are defined as having a tropical climate. Humid tropics in addition are defined as having an average of 3 inches or more rain per month and a mean relative humidity of 70 per cent. or over for the driest month. In contrast, areas having an average rainfall of less than 3 inches a month and a relative humidity of 60 to 70 per cent. for the wettest month are defined as dry tropics.

81. **Subtropical Climate.** Areas are defined as having a subtropical climate if the mean monthly temperature for at least one month of the year is 68°F.

82. **Arctic Climate.** Areas where the mean temperature of the coldest month is below 14°F., and of the warmest month below 50°F., are defined as having arctic climates.

83. **Subarctic Climate.** Those areas where the average temperature of the coldest months is below 32°F., and the mean monthly temperature rises above 50°F. for less than 4 months in the year, are considered to have a subarctic climate.

Meteorological Classification

84. The above administrative definitions, being based almost entirely on temperature, give no indications of the variety of climatic conditions and of weather in general likely to be found in the various regions. A meteorological classification of climatic zones, with brief description of their characteristics, is necessary in addition.

Equatorial Rain Zone

85. This is the zone of hard-wood forests (jungle) and swamps. Wetter and drier seasons may generally be distinguished, although the difference is not very marked. The air is always warm and is usually very moist. (Examples: Malaya, Indonesia, the lowlands of Equatorial Africa, Amazon basin.)

Regions of Monsoonal Rains

86. In the rainy season these regions are merely an extension of the equatorial rain belt, but in the dry season, especially in the relatively higher latitudes a wider range of temperatures occurs, including some quite low minima inland. (Examples: India, China, Indo-China, much of tropical Africa, Northern Australia.)

Tropical and Equatorial Highlands

87. The rainfall seasons are similar to those of the lowlands in the same latitude, but the amount of rainfall tends to decrease away from the sea, especially in districts sheltered by mountain ranges and escarpments between them and the coast. There is increased rainfall on the windward side of mountain ranges. Temperatures are lower than in the lowlands by virtue of the height and may be on average the same as those in temperate or higher latitudes, but without the seasonal variation characteristic of these. (Examples of these highland climates: Kenya, Tanganyika, Rhodesia, Ethiopia, Mexico, the foothills and plateaux adjacent to the Andes and Himalayas.)

Trade-Wind Zone

88. This is a pleasant region of steady moderate breezes, characteristically accompanied by small amounts of cloud and plenty of sunshine. The zone is only well developed over the oceans, and the best known trade-wind climates are therefore on islands such as Hawaii, the islands of the South Seas (*i.e.* central Pacific), Mauritius, parts of the West Indies, Cape Verde, the Canaries, and for part of the year, Madeira. Occasional tropical cyclones rudely disturb the prevailing settled weather; their frequency is greatest in the Western Pacific S.E. of Japan and in the Mauritius and West Indies regions (in that order). The windward slopes and summits of the islands sometimes get prolonged cloudiness and drizzle, owing to the persistence of the wind in one direction.

Arid Zone

89. This is the zone of deserts in the great land masses. They lie mainly in subtropical latitudes, except that the dry regions extend to about latitude 50° in Eastern Asia and part of Patagonia, which are screened by mountain ranges from moisture-bearing winds. There is also a region in the central Pacific where the islands are largely desert. In the arid zone rainfall is limited to very rare thunderstorm downpours and to slightly less infrequent but virtually insignificant very light showers. Evaporation is rapid. Water courses in the sand or rock soon dry up and loose sand is easily blown by any wind of over 15 knots.

90. Oases occur in low-lying areas where there are exposed water-bearing rock strata. Also in mountainous country rainfall and thunderstorms are locally fairly frequent and sometimes seasonal. Here the land is sometimes cultivated. Elsewhere, where the prevailing wind steadily blows out to sea, the desert may extend right to the coast. Temperature ranges from day to night are great—the nights can be cold, even frosty, in winter in the Sahara, and in the Gobi desert of central Asia severe frosts occur. Vegetation, if any, is sparse and largely confined to hard-leafed varieties, *e.g.* cacti, palms, prickly pear, and certain grasses. (Examples of this climate: Sahara, Arizona, central Australia, the Kalahari desert, the tropical section of Chile.)

Subtropical Oceans and Islands

91. The ocean areas between latitudes 20° and 40° are the principal region of subtropical anticyclones. These areas are characterized by mainly light winds, equable temperatures, considerable moisture, and varying amounts of cloud but a good deal of sunshine. The winds and weather are, however, more variable than in the trade-wind zone, and there is a seasonal rise and fall of average temperature of the order of 10°F. (5°C.). Periods of cyclonic weather sometimes occur, especially with invading fronts of cold air from higher latitudes in the winter time. At such times there are days of rather cold, cloudy weather with a fair amount of rain or drizzle. Parts of the zone become involved in extensions of the trade-wind system in summer, *e.g.* the cool northerly breezes at Madeira and on the Portuguese coast. Tropical cyclones occasionally pass through the zone on tracks curving back towards high latitudes, especially in the western parts of the great oceans (*e.g.* near Japan, Phillipines, Madagascar, Mauritius, the east coast of Australia, and the Bahamas-Bermuda region of the North Atlantic).

Subtropical Desert Fringe

92. The Mediterranean is the classic example of this type of climate with its sunny, warm, usually rainless summers, and cool, disturbed, rainy winters in which stormy cyclonic sequences alternate with calmer sunny interludes. Similar climates are found in California, the coastal regions of Cape Province, South Africa, and South and South-West Australia. The native vegetation is mainly of the hard-leafed varieties (*e.g.* olive, carrob, and eucalyptus trees); but many other crops, notably citrus fruits, are grown with the aid of artificial irrigation. Away from the coasts very high temperatures occur in summer and frosts in winter. The autumn and winter rains are commonly accompanied by thunder. Sea fogs sometimes affect the coasts and coastal lowlands in spring and summer (especially night and morning); valley fogs may form inland at night especially in late summer and autumn. Dew deposits are sometimes very heavy. A particularly humid heat may be developed in late summer and autumn, when the sea is at about its warmest (*e.g.* during Sirocco winds).

Steppes and Prairies

93. Climate of this type occurs in latitudes 35° to 50° in continental interior regions, remote or screened by mountain ranges from oceanic moisture. The summers are hot and the winters cold or very cold. Precipitation comes in the form of summer thunderstorms and winter snow, but is insufficient to support most forms of vegetation other than grasses and grain crops, which fail in the drier years. The lakes are also liable to dry up, leaving salty marshes and dry salt deposits. Malarial mosquitoes breed in summer in marshy districts, in spite of the low winter temperatures. (Examples of steppe climate: Eastern Ukraine and regions east of Don, parts of central Asia and Mongolia, the Great Plains and Prairies in N. America, the Argentine Pampas, the South African veldt, and parts of the Australian bush. In the southern hemisphere examples the winters are less cold than in the northern.)

Temperate and Subpolar Oceans and Islands

94. The oceanic regions between 40° and 70°N. and between 35° and 65°S. are broad regions of almost continual storminess. Average wind-speeds are in general higher than in any other zone, and the stress of the wind is an ever-present accompaniment of human activity. There are, however, a few months in summer (late May to August in the northern hemisphere, and to some extent late November to February in the southern hemisphere) when winds seldom reach gale force and are often light to moderate. The temperatures differ widely between the higher and lower latitudes, though everywhere cooler in summer and milder in winter than in corresponding latitudes over the continents. Cloudy or overcast skies and frequent, though seldom very heavy, precipitation are common characteristics. Settled weather is rare at all seasons, and changes of wind direction and temperature are frequent. Trees do not thrive on the smaller and windier islands, which are usually bleak with grassy slopes, heaths and moors (or peat bogs) and in the higher latitudes partly ice-covered. (Examples: (a) Warm temperate: N.W. Spain, Ireland, Tasmania, Tristan de Cunha. (b) Cold temperate: Newfoundland, Northern Japan, Aleutians, Outer Hebrides, Shetland, Falklands. (c) Subpolar: Iceland, Bear Island, South Georgia.)

Temperate (Northern) Continents and Off-Lying Islands

95. The vast land areas north of 45° to 50°N. have a wide range of climates with a fairly steady transition towards extreme seasonal range of temperature in the eastern and northern part of the interior. Towards the north and north-east winters become longer and the summers shorter, though there is relatively little change in the maximum summer temperature. Windiness decreases sharply away from the coastal regions.

96. Changeability of the weather from day to day is a common characteristic of the temperate zone and higher latitudes; some of the changes of temperature are specially severe in the continental interiors in spring and autumn. Nevertheless, another curious characteristic of this zone, apart from the ocean regions, is the liability to long spells of one type of weather or another. These often give a pronounced character to the season in which they occur. There is even a suggestion of regularity about the dates of their occurrence—for instance, the wettest summer weather in Britain and Europe commonly sets in about the longest day of the year or soon after. But the character of these seasonal periods may differ radically from one year to another.

97. The transition from maritime climates near the ocean fringe is abrupt on crossing certain mountain ranges, *e.g.* the Norwegian mountains and the northern Rockies. It is, however, relatively gradual in other regions, especially where an open plain—*e.g.* the north German plain and Baltic lands—allows the prevailing westerly winds to carry the maritime influence (mild in winter, cool in summer) far in towards the heart of the continent.

98. There is a period of great difficulty each spring in regions where a large winter accumulation of snow melts, the frozen ground thaws to mud, and the rivers flood. The summer evaporation is not everywhere sufficient to dry out the soil and there are great marshes in Eastern Europe and parts of Siberia.

Northern Lands

99. The climate of the northern lands is in many ways similar to that of the central and eastern part of the temperate continents, though the summer is at once shorter and more tranquil. High temperatures are reached when the sun shines all through the day and night, especially where the ground is rocky or heath-covered and dry. In the moister regions with permanently frozen sub-soil and near the coast of the Arctic Ocean, summer is a period of overcast skies and a good deal of fog. Autumn and spring are disturbed periods, and in autumn and early winter considerable falls of rain and snow and frequent gales mark the most unpleasant time of the year. At the height of summer and in the long, frozen winter many periods of quiet weather prevail. The native trees are pine and birch, and beyond the northernmost birches a heath with dwarf birch and willow is found. Insect life includes abundant flies and midges in the summer. (Examples: Lapland, the Alaskan interior, parts of the Canadian North-West, and Western Greenland.)

The Arctic Ocean

100. Strong winds are much less frequent over the pack ice than over the open oceans, and in the central Arctic gales are rare. There is frequent, but never heavy precipitation, which falls as rain in the

summer months. The peak of summer (May to mid-July) is a period of rather quiet weather with temperature always close to the freezing point, and for a while there is a good deal of water lying in pools on the ice. Quiet weather returns in winter, after the long autumn period (August to November or December) which brings the strongest winds and most of the precipitation. Clear skies are common between mid-winter and early summer (December to May). Very great changes of temperature occur in winter with changes of airstream (*e.g.* from —30°C. to near the freezing point in a few hours.) The lowest temperatures are not so low as in the interior of Siberia, Greenland, or Canada. Overcast skies are heavily predominant in summer, when leads of open water appear among the ice, and fogs are common. Sometimes in summer the sky remains overcast for weeks on end.

Greenland and Antarctic Ice-Caps

101. These have a climate rather similar to that of the Arctic Ocean ice-pack, except that clear skies prevail in the interior at all seasons and there is prolonged sunshine in the daylight season. Temperatures are lower than on the floating ice. The valleys and hollows in and around Antarctica probably produce the lowest temperatures in the world. Gales are much rarer on the heights of the inland ice than near the coast, where they are both frequent and severe except at the height of summer. However, they occur on 8 to 10 days a year in central Greenland and probably considerably oftener on the south polar plateau. There is evidence of periods of strong winds and gales in winter in central Antarctica and the winter gales at exposed places near the coast of Antarctica are exceptionally severe. Enormous changes of temperature take place with changes of airstream around the coasts of Greenland and Antarctica in winter. Changes from —30°C. or lower to +5°C. may occur in a few hours with Föhn winds or near open water. Some coastal places have had occasional temperatures in midwinter as high as any which occur in summer (+9° to +11°C. in Graham Land and +11° to +14°C. in West Greenland).

TECHNICAL TERMS

102. The following short glossary of terms is designed to help the reader to use the climatic tables which follow. It may also be of assistance in understanding a few common terms occurring in accounts of climate and weather statistics. (For further information the reader should refer to "The Meteorological Glossary", M.O.225(A.P. 897).)

103. **Absolute Humidity.** An absolute measure of the quantity of water vapour in the air without reference to the question of whether it is saturated or not. It is usually measured either in grams per cubic metre (the *vapour density*) or in terms of the partial pressure in millibars exerted by the water vapour (the *vapour pressure*).

104. **Absolute Maximum.** The highest value (usually of air temperature) known to occur at a given place.

105. **Absolute Minimum.** The lowest value (usually of air temperature) known to occur at a given place.

106. **Adiabatic.** This adjective is used to describe changes of air temperature which occur as the result of changes of pressure on the air as it rises and falls in the atmosphere, and in which no gain or loss of heat is involved.

107. **Annual Mean.** An average value (usually of temperature or atmospheric pressure) for the whole year. Annual mean temperatures quoted are usually the arithmetic mean of each day's highest and lowest values taken over the whole year.

108. **Annual Range.** This term is variously applied to describe the difference between the highest and lowest values of the year and the range between the highest and lowest monthly mean values. The latter is properly described as the annual range of the monthly means.

109. **Average Daily Maximum.** The arithmetic mean of the highest values (usually of temperature) observed each day of some specified period, usually a month.

110. **Average Daily Minimum.** The arithmetic mean of the lowest values (usually of temperature) observed each day of some specified period, usually a month.

111. **Average Monthly Maximum/Minimum.** The arithmetic mean of the highest/lowest values (usually of temperature) observed in a given month over a period of years.

112. **Average Rainfall/Precipitation.** The arithmetic mean of the total amounts of moisture falling from the atmosphere in a day, month or year (as specified), over some stated period of years, measured after melting any snow or ice.

113. **Average Yearly (Annual) Maximum/Minimum.** The arithmetic mean of the highest/lowest values (usually temperature) observed in the course of the whole year over some specified period of years.

114. **Clear Days.** The short title for "day of clear sky", *i.e.* days on which less than a quarter of the sky is covered by clouds when averaged over the principal morning, afternoon, and evening observations.

115. **Cloudy Days.** The usual description in English of the days described in various languages as "dull", "overcast", or "murky". Defined as days on which over three-quarters of the sky is clouded over when averaged over the principal morning, afternoon, and evening observations.

116. **Daily Mean Temperature.** The average temperature of the day is usually taken to be the arithmetic mean of the highest and lowest values.

117. **Diurnal Range, Diurnal Variation.** Air temperature, humidity, wind speed and other elements show some approach to a regular rise and fall from night to day or *vice versa*, superimposed on any trend due to other causes. This variation from night to day is called the diurnal variation, and average values of the range between the extremes occurring within the 24 hours are described as the diurnal range.

118. **Gale Days, Days with Gale.** Days on which the wind was of gale force ($\geqslant$ 34 knots, *i.e.* Beaufort force 8 or above) for at least 10 minutes at any time during the day or night.

119. **Isobar.** Line (on a map) joining places with equal values of atmospheric pressure corrected to sea level.

120. **Isohyet.** Line (on a map) joining places with the same rainfall.

TABLE 6

SELECTED CLIMATIC DATA

Place		Alt. (ft.)	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
ADELAIDE	A	140	34°56′S.	138°35′E.	108	105	100	89	78	68	67	73	81	92	99	104	110
	B				51	51	49	46	42	38	37	38	39	41	45	48	36
	C				118	114	111	99	89	76	74	85	91	103	113	115	118
	D				45	45	44	40	37	33	32	32	33	36	41	43	32
	E				38	41	46	55	67	76	76	69	60	51	43	39	53
	F				31	32	36	45	56	65	63	57	52	42	36	32	43
	G				0·8	0·7	1·0	1·8	2·7	3·0	2·6	2·6	2·1	1·7	1·1	1·0	21·1
	H				5	5	5	10	13	15	16	16	13	10	8	6	122
ADEN	A	22	12°50′N.	45°01′E.	85	85	90	93	101	102	102	100	100	97	90	86	103
	B				64	68	70	70	75	80	78	76	79	68	67	66	63
	C				86	87	95	99	103	106	104	101	101	100	91	87	106
	D				61	63	67	68	75	79	73	74	77	66	65	62	61
	E				78	79	82	83	83	76	76	78	78	77	77	76	79
	F				63	65	66	66	66	51	49	50	56	58	61	62	59
	G				0·2	0·1	0·2	0·1	0·1	0·1	0·2	0·1	0·1	0·1	0·1	0·2	0·9
	H				1	0·5	0·3	0·1	0·1	0·1	1	0·7	0·2	0·2	0·2	2	6
ALEXANDRIA	A	150	31°12′N.	29°53′E.	73	78	86	95	98	97	91	91	94	92	86	78	103
	B				44	46	49	53	59	65	70	71	68	62	54	47	43
	C				82	91	103	108	111	111	103	105	106	103	96	88	111
	D				38	37	42	49	54	57	64	64	60	54	46	37	37
	E				71	70	67	67	70	72	76	72	68	68	69	72	70
	F				61	59	57	60	64	68	70	68	63	61	60	60	63
	G				1·9	0·9	0·4	0·1	0·1	0·1	0·0	0·1	0·1	0·2	1·3	2·2	7·2
	H				7	5	3	1	1	0·1	0·0	0·1	0·1	1	4	8	30
ALGIERS	A	194	36°46′N.	03°03′E.	67	72	76	83	88	91	97	99	94	85	78	69	102
	B				41	42	43	47	53	59	65	67	61	54	48	41	38
	C				76	86	84	99	101	101	106	107	103	100	88	76	107
	D				34	34	37	43	44	45	62	64	53	45	40	32	32
	E				75	72	71	67	72	72	73	70	74	72	73	72	72
	F				66	60	59	57	60	60	60	60	62	60	63	64	61
	G				4·5	3·3	2·9	1·6	1·8	0·6	0·1	0·2	1·6	3·1	5·1	5·3	30
	H				11	9	9	5	5	2	0·4	0·5	4	7	11	12	76

ALICE SPRINGS	A	1,901	23°38′S.	133°35′E.	107	104	100	93	87	80	80	87	95	101	104	106	108
	B				56	56	50	39	34	29	27	31	36	43	50	54	26
	C				111	109	110	99	96	86	86	96	100	106	108	111	111
	D				51	48	45	36	29	22	19	25	31	39	42	50	19
	E				31	34	36	40	47	54	49	39	31	27	27	29	37
	F				23	24	25	28	32	35	31	25	22	21	21	22	26
	G				1·7	1·3	1·1	0·4	0·6	0·5	0·3	0·3	0·3	0·7	1·2	1·5	9·9
	H				4	3	3	2	2	2	1	2	1	3	4	4	31
AMMAN	A	2,548	31°57′N.	35°57′E.	65	71	80	90	97	99	98	100	98	92	83	70	87
	B				32	33	34	37	46	52	58	58	55	49	41	34	49
	C				76	85	90	103	105	109	104	109	103	99	91	77	109
	D				21	23	26	34	41	46	56	55	52	44	35	25	21
	E				79	75	65	53	37	37	38	43	51	51	65	75	56
	F				57	53	42	35	25	25	27	28	29	29	41	51	37
	G				2·7	2·9	1·2	0·6	0·2	0·0	0·0	0·0	0·0	0·2	1·3	1·8	10·9
	H				8	8	4	3	0·8	0·0	0·0	0·0	0·0	1	4	5	34
AUCKLAND	A	85	36°47′S.	174°39′E.	79	79	77	73	67	63	62	63	65	68	73	76	81
	B				53	53	51	47	42	39	38	39	41	44	47	50	37
	C				90	90	86	81	73	70	67	67	71	75	81	90	90
	D				45	47	42	39	36	35	33	34	34	36	41	43	33
	E				71	72	74	78	80	83	84	80	76	74	71	70	76
	F				62	61	65	69	70	73	74	70	68	66	64	64	67
	G				3·1	3·7	3·2	3·8	5·0	5·4	5·7	4·6	4·0	4·0	3·5	3·1	49·1
	H				10	10	11	14	19	19	21	19	17	16	15	12	183
BAGHDAD	A	120	33°21′N.	46°26′E.	68	74	84	93	104	112	116	117	112	102	86	71	95
	B				29	34	40	50	58	69	73	72	63	54	40	33	51
	C				80	85	99	108	113	119	123	121	117	108	95	81	123
	D				21	28	33	44	47	63	70	69	56	47	29	19	19
	E				89	79	75	64	47	35	32	33	38	50	75	84	58
	F				53	43	37	38	18	13	12	13	15	24	44	52	30
	G				1·1	1·1	1·2	0·8	0·2	0·0	0·0	0.0	0·0	0·1	0·8	1·2	6·5
	H				5	4	5	3	1	0·1	0·0	0·1	0·1	0·7	3	5	27

KEY A = Average highest temperature each month °F.

B = Average lowest temperature each month °F.

C = Absolute maximum temperature °F.

D = Absolute minimum temperature °F.

E = Average relative humidity a.m. %.

F = Average relative humidity p.m. %.

G = Average monthly rain in inches.

H = Average number of days with rainfall.

SELECTED CLIMATIC DATA—*continued*

Place		Alt. (ft.)	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
BAHREIN	A	18	26°12′N.	50°30′E.	79	84	89	98	103	104	107	108	104	97	91	82	110
	B				48	51	54	61	70	75	79	79	74	69	62	53	47
	C				85	94	95	105	108	111	112	113	112	103	97	88	113
	D				41	45	51	56	66	70	75	75	71	66	58	48	41
	E				85	83	79	75	71	69	68	74	75	80	80	85	77
	F				71	70	70	66	63	64	74	72	71	73	77	77	71
	G				0·3	0·7	0·5	0·3	0·1	0·0	0·0	0·0	0·0	0·0	0·7	0·7	3·2
	H				1	2	1	1	0·1	0·0	0·0	0·0	0·0	0·0	1	2	8
BANGKOK	A	7	13°45′N.	100°28′E.	96	98	100	101	100	97	96	96	95	95	94	94	103
	B				59	65	68	72	73	73	72	74	72	71	66	60	57
	C				100	106	104	106	106	100	101	99	98	100	99	100	106
	D				55	56	62	67	71	70	71	72	69	64	56	52	52
	E				91	92	92	90	91	90	91	92	94	93	92	91	92
	F				53	55	56	58	64	67	66	66	70	70	65	56	62
	G				0·3	0·8	1·4	2·3	7·8	6·3	6·3	6·9	12·0	8·1	2·6	0·2	55·0
	H				1	1	3	3	9	10	13	13	15	14	5	1	88
BASRA	A	60	30°25′N.	47°39′E.	73	79	90	103	111	115	118	118	114	106	93	77	119
	B				31	34	40	50	63	71	75	74	66	55	43	33	29
	C				81	87	102	111	115	121	122	125	118	112	100	88	125
	D				21	23	29	44	51	64	70	67	58	47	32	19	19
	E				87	85	76	65	56	44	35	38	44	53	75	87	62
	F				53	45	36	28	21	17	15	14	16	21	39	54	30
	G				1·1	1·0	0·6	0·5	0·3	0·1	0·1	0·1	0·1	0·1	1·1	1·1	5·5
	H				4	4	3	2	1	0·1	0·1	0·1	0·1	0·1	3	4	21
BENGHAZI	A	82	32°06′N.	20°04′E.	69	74	86	94	100	101	93	92	96	92	85	75	104
	B				42	42	44	48	53	60	65	67	62	57	51	45	41
	C				76	82	101	105	108	109	105	105	106	100	95	78	109
	D				38	38	37	41	48	55	57	60	52	51	45	40	37
	E				69	63	51	49	49	53	59	61	55	49	57	65	57
	F				60	58	49	50	51	56	61	61	56	51	54	59	55
	G				2·6	1·6	0·8	0·2	0·1	0·1	0·1	0·0	0·1	0·7	1·8	2·6	10·5
	H				11	11	3	1	0·4	0·4	0·1	0·0	0·3	3	5	10	45

BERLIN	A	187	52°27′N.	13°18′E.	48	51	63	72	82	85	89	85	80	68	56	50	91
	B				13	12	30	28	33	41	47	46	37	28	21	14	6
	C				55	62	73	83	92	93	96	94	94	77	64	58	96
	D				1	−15	7	20	28	35	43	43	31	15	8	−3	−15
	E				89	87	87	83	79	78	79	86	90	92	91	90	86
	F				80	72	61	57	53	57	57	59	63	69	77	83	66
	G				1·9	1·3	1·5	1·7	1·9	2·3	3·1	2·2	1·9	1·7	1·7	1·9	23·1
	H				10	8	9	9	8	9	10	10	8	8	8	11	108
BOMBAY	A	37	18°54′N.	72°49′E.	88	89	92	93	93	93	88	87	88	93	92	89	95
	B				62	63	68	74	78	75	75	75	74	73	69	65	62
	C				94	97	101	100	96	99	96	90	95	97	96	94	101
	D				53	53	62	68	73	70	72	72	71	70	64	55	53
	E				70	71	73	75	74	79	83	83	85	81	73	70	76
	F				61	62	65	67	68	77	83	81	78	71	64	62	70
	G				0·1	0·1	0·1	0·1	0·7	19·1	24·3	13·4	10·4	2·5	0·5	0·1	71·2
	H				0·2	0·2	0·1	0·1	1	14	21	19	13	3	1	0·1	73
CAIRO	A	381	29°52′N.	31°20′E.	74	81	91	100	104	106	103	101	97	96	89	79	108
	B				40	41	44	49	56	62	68	68	64	59	50	43	39
	C				88	92	101	113	116	117	109	109	108	109	100	87	117
	D				35	35	38	42	49	55	61	63	58	51	42	34	34
	E				69	64	63	55	50	55	65	69	68	67	68	70	64
	F				40	33	27	21	18	20	24	28	31	31	38	41	29
	G				0·2	0·2	0·2	0·1	0·1	0·1	0·0	0·0	0·0	0·1	0·1	0·2	1·1
	H				1	1	0·8	0·4	0·2	0·1	0·0	0·0	0·0	0·3	0·8	1	5
CALCUTTA	A	21	22°30′N.	88°20′E.	84	90	99	103	103	99	93	92	93	92	87	82	104
	B				49	52	61	68	70	74	75	76	75	68	58	50	49
	C				89	98	104	107	108	111	98	96	97	96	92	87	111
	D				44	46	50	61	65	70	73	74	72	63	51	45	44
	E				85	82	79	76	77	82	86	88	86	85	79	80	82
	F				52	45	46	56	62	75	80	82	81	72	63	55	64
	G				0·4	1·2	1·4	1·7	5·5	11·7	12·8	12·9	9·9	4·5	0·8	0·2	63·0
	H				1·7	3·2	2·7	4·2	6·1	11·9	7·2	10·0	14·5	6·8	3·3	2·1	14·5

KEY A = Average highest temperature each month °F.

B = Average lowest temperature each month °F.

C = Absolute maximum temperature °F.

D = Absolute minimum temperature °F.

E = Average relative humidity a.m. %.

F = Average relative humidity p.m. %.

G = Average monthly rain in inches.

H = Average number of days with rainfall.

SELECTED CLIMATIC DATA—*continued*

Place		Alt. (ft.)	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
CAPETOWN	A	40	33°56′S.	18°29′E.	95	95	95	91	83	76	76	78	82	86	89	92	99
	B				52	52	50	44	40	38	37	38	40	44	47	50	36
	C				104	105	104	104	99	86	85	91	93	99	102	103	105
	D				48	45	43	38	35	33	32	32	35	37	42	44	32
	E				66	66	69	74	76	79	80	79	76	71	67	64	72
	F				49	51	52	56	63	67	68	68	65	57	52	51	58
	G				0·7	0·6	0·9	1·9	3·7	4·4	3·6	3·3	2·3	1·6	1·1	0·8	24·9
	H				4	4	5	7	11	12	12	12	10	9	6	5	97
CHURCHILL	A	43	58°47′N.	94°11′W.	19	16	30	43	61	74	82	79	69	52	32	22	84
	B				−40	−37	−32	−19	4	26	36	38	26	6	−20	−34	−42
	C				39	31	41	62	87	88	96	90	84	65	45	34	96
	D				−57	−52	−52	−26	−14	13	22	25	15	−17	−53	−47	−57
	E				—	—	—	93	92	88	88	93	94	95	94	97	—
	F				—	—	—	88	86	73	71	74	84	89	91	93	—
	G				0·5	0·6	0·9	0·9	0·9	1·9	2·2	2·7	2·3	1·4	1·0	0·7	16·0
	H				5	6	6	6	7	9	10	12	11	12	9	8	101
COLOMBO	A	24	06°54′N.	79°52′E.	90	92	91	90	89	86	86	86	87	87	88	89	92
	B				67	67	70	72	72	73	73	73	73	71	70	68	65
	C				94	96	96	92	91	89	88	88	89	89	90	91	96
	D				59	61	64	70	69	72	71	71	71	69	66	63	59
	E				73	71	71	74	78	80	79	78	76	77	77	74	76
	F				67	66	66	70	76	78	77	76	75	76	75	69	73
	G				3·5	3·5	5·8	9·1	14·6	8·8	5·3	4·3	6·3	13·7	12·4	5·8	93·1
	H				7	5	8	14	19	18	12	11	13	19	16	10	152
COPENHAGEN	A	43	55°41′N.	12°33′E.	45	44	53	64	75	79	82	78	72	62	52	46	83
	B				17	16	22	28	35	42	47	46	38	30	24	19	11
	C				49	50	62	82	82	88	91	89	84	74	56	53	91
	D				6	−3	14	21	30	37	42	40	29	24	13	3	−3
	E				89	92	87	80	73	73	77	82	87	90	89	89	84
	F				86	86	77	66	60	61	63	67	70	77	83	87	74
	G				1·6	1·3	1·2	1·7	1·7	2·1	2·2	3·2	1·9	2·1	2·2	2·1	23·3
	H				9	7	8	9	8	8	9	12	8	9	10	11	108

DAWSON	A	1,062	64°04′N.	139°29′W.	15	24	40	57	74	83	84	80	68	52	33	21	56
	B				−15	−43	−34	−9	21	32	36	30	18	−1	−30	−43	−55
	C				35	48	52	69	85	91	95	88	79	68	52	55	95
	D				−68	−73	−50	−33	9	25	29	17	8	−23	−49	−63	−73
	E				—	—	—	—	89	89	91	94	94	—	—	—	—
	F				—	—	—	—	49	52	59	65	70	—	—	—	—
	G				0·9	0·7	0·5	0·5	1·0	1·2	1·5	1·5	1·4	1·2	1·1	1·0	12·6
	H				8	6	8	5	9	11	13	14	11	11	11	10	117
DUNEDIN	A	240	45°52′S.	170°32′E.	82	80	75	72	64	60	57	62	67	73	75	78	84
	B				41	41	39	37	34	31	30	32	33	35	37	39	29
	C				94	90	85	85	72	68	66	70	77	83	85	88	94
	D				36	37	34	31	29	24	23	25	29	30	32	35	23
	E				69	71	74	77	76	77	77	73	71	67	68	73	73
	F				68	68	70	71	76	76	74	73	70	69	69	71	71
	G				3·4	2·8	3·0	2·8	3·2	3·1	3·0	3·0	2·7	3·0	3·2	3·5	36·9
	H				14	11	13	13	14	13	13	13	14	14	14	15	161
ENTEBBE	A	3,878	00°04′N.	32°29′E.	85	83	84	81	80	80	80	81	82	82	85	83	86
	B				59	59	60	61	61	60	58	57	59	59	60	59	57
	C				89	90	91	83	82	84	82	84	87	85	89	85	91
	D				57	57	57	59	59	58	57	57	58	57	59	58	57
	E				85	85	86	86	87	86	86	87	85	82	84	85	85
	F				63	65	69	72	74	72	70	70	68	66	67	66	69
	G				2·6	3·6	6·3	10·1	9·6	4·8	3·0	2·9	2·9	3·7	5·2	4·6	59·3
	H				9	11	16	22	23	14	10	12	11	13	17	12	170
FREETOWN	A	37	08°30′N.	13°14′W.	87	90	92	92	91	89	88	87	87	88	88	88	93
	B				71	73	73	72	71	69	70	70	71	70	70	71	69
	C				91	93	95	95	94	92	90	88	90	91	94	89	95
	D				68	70	70	70	69	68	69	68	69	67	68	67	67
	E				82	80	81	81	83	86	89	91	90	87	85	82	85
	F				67	67	69	71	74	76	81	82	81	77	75	71	74
	G				0·5	0·1	0·5	2·2	6·3	11·9	35·2	35·5	24·0	12·2	5·2	1·6	135·2
	H				0·8	0·7	2	6	15	23	27	28	25	23	12	4	167

KEY A = Average highest temperature each month °F.
B = Average lowest temperature each month °F.
C = Absolute maximum tamperature °F.
D = Absolute minimum temperature °F.
E = Average relative humidity a.m. %.
F = Average relative humidity p.m. %.
G = Average monthly rain in inches.
H = Average number of days with rainfall.

SELECTED CLIMATIC DATA—*continued*

Place		Alt.(ft.)	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
GIBRALTAR	A	90	36°06′N.	05°21′W.	67	69	71	76	81	87	90	91	87	81	73	69	93
	B				42	43	45	48	52	57	62	63	59	52	47	42	38
	C				75	81	78	87	90	97	100	100	95	95	79	77	100
	D				33	33	37	43	45	49	55	57	50	44	35	30	30
	E				82	82	82	82	80	80	80	80	82	83	83	83	82
	F				68	67	68	62	59	60	61	61	64	67	68	69	65
	G				4·6	4·5	4·7	2·7	1·6	0·5	0·0	0·1	1·3	3·3	6·4	5·4	35·1
	H				8	9	10	7	4	2	0	0·4	3	6	10	9	68
HONG KONG	A	109	22°18′N.	114°10′E.	74	74	79	84	89	90	91	91	91	87	82	76	93
	B				45	46	51	59	68	73	74	74	72	65	56	49	43
	C				79	79	83	89	91	94	94	97	94	94	86	82	97
	D				32	38	45	52	60	67	72	72	65	57	44	41	32
	E				77	82	84	87	87	86	87	87	83	75	73	74	82
	F				66	73	74	77	78	77	77	77	72	63	60	63	71
	G				1·3	1·8	2·9	5·4	11·5	15·5	15·0	14·2	10·1	4·5	1·7	1·2	85·1
	H				4	5	7	8	13	18	17	15	12	6	2	3	110
KARACHI	A	13	24°48′N.	66°59′E.	83	86	97	98	102	101	96	91	93	99	94	86	107
	B				47	49	57	66	74	79	77	76	73	64	57	50	45
	C				89	93	106	111	118	114	110	99	106	108	100	91	118
	D				40	43	47	57	65	68	73	73	69	57	48	39	39
	E				63	72	79	87	88	86	88	90	89	83	68	64	80
	F				49	45	57	62	68	69	73	74	71	57	49	45	60
	G				0·5	0·4	0·3	0·1	0·1	0·7	3·2	1·6	0·5	0·1	0·1	0·2	7·7
	H				1	1	1	0·2	0·1	1	2	2	1	0·1	0·3	1	11
KHARTOUM	A	1,280	15°37′N.	32°33′E.	97	102	108	112	112	112	109	106	108	107	102	97	114
	B				49	51	55	61	68	71	70	69	70	69	62	52	48
	C				102	108	114	114	116	116	117	109	110	109	106	104	117
	D				40	45	49	53	61	67	66	64	61	62	55	45	40
	E				34	30	21	21	26	35	54	61	51	36	30	34	36
	F				20	12	9	8	11	15	29	36	25	16	17	20	18
	G				0·0	0·0	0·1	0·1	0·1	0·4	2·0	2·9	0·7	0·2	0·1	0·0	6·3
	H				0·0	0·0	0·1	0·1	1	2	5	7	3	0·9	0·1	0·0	19

KIMBERLEY	A	3,991	28°48′S.	24°46′E.	99	96	92	87	80	74	75	82	89	94	96	99	88
	B				54	53	48	38	30	26	24	27	32	38	45	49	38
	C				103	101	96	93	86	82	79	86	93	99	99	103	103
	D				44	43	40	30	23	22	20	20	25	31	36	43	20
	E				55	62	69	69	70	71	66	55	48	48	48	50	59
	F				28	32	37	35	34	33	30	26	23	24	25	26	29
	G				2·4	2·5	3·1	1·5	0·8	0·2	0·2	0·3	0·6	1·0	1·6	2·0	16·2
	H				8	9	10	6	4	2	1	2	2	5	6	7	62
LAGOS	A	10	06°27′N.	03°24′E.	19	92	93	92	91	88	86	86	87	88	91	91	95
	B				68	72	71	71	71	71	71	70	71	70	71	70	67
	C				95	96	99	99	104	93	93	96	94	96	99	99	104
	D				63	66	60	63	62	69	66	67	68	69	69	66	60
	E				84	83	82	81	83	87	87	85	86	86	85	86	85
	F				65	69	72	72	76	80	80	76	77	76	72	68	74
	G				1·1	2·1	3·7	5·7	10·5	18·7	10·7	2·8	5·3	7·8	2·6	0·8	71·1
	H				2	3	6	9	14	17	13	6	11	14	6	2	103
LIMASSOL	A	55	34°41′N.	33°03′E.	69	69	78	84	92	98	99	100	97	92	84	72	103
	B				35	34	37	42	48	55	59	60	58	53	44	39	32
	C				86	75	83	97	101	111	106	107	105	98	89	78	111
	D				30	24	31	38	43	50	55	54	52	48	35	30	24
	E				80	77	72	65	61	60	60	62	60	64	70	77	67
	F				69	67	62	58	52	51	55	56	50	53	59	65	58
	G				4·3	3·1	1·7	0·9	0·5	0·2	0·0	0·1	0·1	1·0	2·4	4·4	18·5
	H				11	9	5	3	2	0·5	0·0	0·1	0·4	2	5	10	48
LONDON	A	18	51°28′N.	0°19′W.	53	54	60	67	75	80	82	81	75	65	58	54	85
	B				22	24	26	31	35	42	47	45	38	32	28	25	19
	C				57	62	68	80	87	88	90	94	92	83	63	59	94
	D				9	11	17	26	30	37	43	41	31	25	20	11	9
	E				89	87	87	85	81	78	80	85	90	91	90	88	86
	F				81	73	76	62	58	57	57	61	64	70	78	81	67
	G				1·8	1·5	1·7	1·5	1·7	2·1	2·2	2·2	1·9	2·7	2·2	2·3	23·8
	H				6	5	5	5	5	5	6	6	5	7	7	7	69

KEY A = Average highest temperature each month °F.
B = Average lowest temperature each month °F.
C = Absolute maximum temperature °F.
D = Absolute minimum temperature °F.
E = Average relative humidity a.m. %.
F = Average relative humidity p.m. %.
G = Average monthly rain in inches.
H = Average number of days with rainfall.

SELECTED CLIMATIC DATA—*continued*

Place		Alt. (ft.)	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
MANILLA	A	47	14°35′N.	120°59′E.	91	92	95	97	97	96	93	92	92	92	92	91	98
	B				63	63	64	67	70	72	72	72	72	70	67	65	61
	C				95	96	98	100	101	100	97	95	95	95	93	94	101
	D				58	60	61	63	68	71	69	69	69	67	62	60	58
	E				89	88	85	85	88	91	91	92	93	92	91	90	90
	F				63	59	55	55	61	68	74	73	73	71	69	67	66
	G				0·9	0·5	0·7	1·3	5·1	10·0	17·0	16·6	14·0	7·6	5·7	2·6	82·0
	H				6	3	4	4	12	17	24	23	22	19	14	11	159
MARSEILLES	A	246	43°18′N.	05°23′E.	61	64	68	75	82	87	91	91	85	77	69	62	76
	B				25	27	29	35	42	49	53	53	47	38	31	25	38
	C				69	71	79	83	93	99	100	101	92	86	76	70	101
	D				14	9	20	28	32	41	47	47	34	27	21	11	9
	E				77	75	74	70	69	70	68	72	78	83	82	79	75
	F				55	51	50	51	51	54	49	50	55	61	61	62	54
	G				1·9	1·5	1·9	2·0	2·0	1·0	0·6	0·9	2·7	3·7	3·1	2·2	23·5
	H				6	5	5	6	5	3	1	2	5	7	7	5	57
MELBOURNE	A	115	37°49′S.	144°58′E.	102	100	95	84	73	64	63	69	76	85	93	99	105
	B				48	48	44	41	37	34	32	34	36	38	42	46	31
	C				114	110	107	95	84	72	69	77	89	98	106	111	114
	D				42	40	37	35	30	28	27	28	31	32	37	40	27
	E				58	62	64	72	79	83	82	76	68	61	60	59	69
	F				48	50	51	56	62	67	65	60	55	52	52	51	56
	G				1·9	1·8	2·2	2·3	2·1	2·1	1·9	1·9	2·3	2·6	2·3	2·3	25·7
	H				9	8	9	13	14	16	17	17	15	14	13	11	156
MOMBASA	A	52	04°03′S.	39°39′E.	91	93	94	93	88	87	84	85	86	88	91	92	94
	B				73	74	75	74	71	70	69	68	70	71	73	73	68
	C				95	94	95	96	89	88	86	86	89	90	93	93	96
	D				70	71	72	72	71	67	67	66	67	68	70	71	66
	E				76	75	77	81	85	82	82	76	81	79	78	78	79
	F				66	63	63	71	76	72	72	72	70	69	69	69	70
	G				1·0	0·7	2·5	7·7	12·6	4·7	3·5	2·5	2·5	3·4	3·8	2·4	47·3
	H				6	3	7	15	20	15	14	16	14	10	10	9	139

MOSCOW	A	505	55°46′N.	37°40′E.	37	37	45	68	79	87	88	84	75	62	43	37	89
	B				−16	−8	−3	16	31	38	45	41	30	23	6	−12	−19
	C				39	40	53	80	86	94	95	96	86	74	47	42	96
	D				−27	−17	−20	8	25	31	43	36	26	17	−5	−27	−27
	E				89	88	88	83	72	74	79	83	89	89	89	88	84
	F				85	80	70	60	50	54	56	56	62	70	81	86	67
	G				1·5	1·4	1·1	1·9	2·2	2·9	3·0	2·9	1·9	2·7	1·7	1·6	24·8
	H				11	9	8	9	9	10	12	12	9	11	10	9	119
NAIROBI	A	5,971	01°16′S.	36°48′E.	81	83	81	79	76	75	75	77	80	81	79	78	83
	B				49	50	51	55	52	49	46	46	46	48	50	50	45
	C				84	87	86	82	82	80	79	80	82	86	82	82	87
	D				47	48	49	52	48	45	43	44	41	45	43	47	41
	E				74	74	81	88	88	89	86	86	82	82	86	81	83
	F				44	40	45	56	62	60	58	56	45	43	53	53	51
	G				1·5	2·5	4·9	8·3	6·2	1·8	0·6	0·9	1·2	2·1	4·3	3·4	37·7
	H				5	6	11	16	17	9	6	7	6	8	15	11	117
NEW YORK	A	314	40°43′N.	74°00′W.	57	56	69	80	87	92	96	94	90	80	70	60	98
	B				7	7	17	30	42	52	59	57	47	36	24	12	2
	C				68	73	84	91	95	97	102	102	100	90	75	68	102
	D				−6	−14	3	12	34	44	54	51	39	27	7	−13	−14
	E				72	70	70	68	70	74	77	79	79	76	75	73	72
	F				60	58	55	53	54	58	58	60	61	57	60	61	58
	G				3·7	3·8	3·6	3·2	3·2	3·3	4·2	4·3	3·4	3·5	3·0	3·6	43·0
	H				12	10	12	11	11	10	12	10	9	9	9	10	125
OSLO	A	82	59°55′N.	10°43′E.	44	45	51	63	77	83	86	80	71	61	49	43	87
	B				3	5	11	23	32	41	46	43	35	25	14	6	−2
	C				55	59	60	79	86	93	95	91	81	74	58	55	95
	D				−12	−12	−6	3	24	33	42	36	25	12	4	−11	−12
	E				86	83	81	74	69	66	73	79	84	86	87	87	80
	F				83	74	66	56	52	53	57	63	66	72	83	85	67
	G				1·6	1·3	1·5	1·5	1·8	2·0	3·0	3·6	2·4	2·6	2·0	2·0	25·3
	H				7	6	7	6	7	7	10	11	7	9	8	9	94

KEY A = Average highest temperature each month °F.
B = Average lowest temperature each month °F.
C = Absolute maximum temperature °F.
D = Absolute minimum temperature °F.
E = Average relative humidity a.m. %.
F = Average relative humidity p.m. %.
G = Average monthly rain in inches.
H = Average number of days with rainfall.

SELECTED CLIMATIC DATA—*continued*

Place		Alt.(ft.)	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
PARIS	A	164	48°49′N.	02°29′E.	54	57	66	74	83	85	89	88	83	73	61	56	92
	B				23	22	26	31	37	44	47	47	40	32	26	22	16
	C				59	63	73	84	92	93	101	96	93	83	69	62	101
	D				8	4	20	28	33	40	43	43	35	25	15	11	4
	E				90	90	88	80	79	79	81	84	91	94	93	92	87
	F				77	69	59	50	52	55	55	54	59	68	76	80	63
	G				1·5	1·3	1·5	1·7	2·0	2·2	2·0	2·0	2·1	2·2	1·9	1·7	22·1
	H				17	12	13	15	15	12	14	13	12	17	18	16	174
PENANG	A	17	05°25′N.	100°19′E.	93	93	94	93	93	93	92	92	91	91	91	91	95
	B				70	71	71	72	72	71	71	71	71	71	71	71	69
	C				98	97	98	98	96	97	95	96	98	94	95	95	98
	D				66	66	67	67	67	68	69	69	68	67	65	67	65
	E				75	74	75	79	78	77	77	78	80	81	79	76	77
	F				68	64	64	66	66	67	67	67	69	70	71	68	67
	G				3·7	3·1	5·6	7·4	10·7	7·7	7·5	11·6	15·8	16·9	11·9	5·8	107·7
	H				8	7	11	14	16	12	12	15	18	21	19	11	164
PERTH—(AUST.)	A	197	31°57′S.	115°51′E.	102	102	98	91	81	72	68	73	79	85	95	100	105
	B				54	53	51	47	43	41	39	40	42	44	48	52	38
	C				110	112	106	100	90	82	76	82	91	95	105	108	112
	D				49	48	46	39	34	35	34	35	39	40	42	48	34
	E				51	53	58	61	72	76	76	73	67	60	54	50	63
	F				44	43	45	49	58	63	63	61	58	55	49	47	53
	G				0·3	0·4	0·8	1·7	5·1	7·1	6·7	5·7	3·4	2·2	0·8	0·5	34·7
	H				3	3	5	8	15	17	19	19	15	12	7	5	128
PORT DARWIN	A	97	12°28′S.	130°51′E.	96	95	96	96	95	93	92	94	96	98	98	97	99
	B				72	72	72	71	66	63	61	64	69	72	72	72	60
	C				100	101	102	104	102	99	98	98	102	105	103	102	105
	D				68	69	68	66	60	56	56	58	63	69	69	69	56
	E				78	79	78	69	63	61	59	63	65	65	68	73	68
	F				71	72	67	54	47	47	44	45	49	52	58	65	56
	G				15·2	12·3	10·0	3·8	0·6	0·1	0·1	0·1	0·5	2·0	4·7	9·4	58·7
	H				20	18	17	6	1	1	0·1	0·1	2	5	10	15	95

PORT MORESBY	A	126	09°29′S.	147°09′E.	94	93	92	91	89	88	86	86	88	91	92	94	95
	B				72	73	73	72	72	71	70	70	71	72	73	73	69
	C				98	96	96	96	94	91	90	90	94	94	96	97	98
	D				69	69	70	65	70	64	66	66	66	68	69	70	64
	E				72	73	74	75	77	78	78	77	78	75	73	72	75
	F				69	72	73	74	77	77	78	77	77	76	73	69	74
	G				7·0	7·6	6·7	4·2	2·5	1·3	1·1	0·7	1·0	1·4	1·9	4·4	39·8
	H				8	7	9	5	2	3	2	2	2	2	3	6	51
SALISBURY (RHODESIA)	A	4,831	17°50′S.	31°01′E.	84	83	83	83	80	76	78	81	88	91	90	85	91
	B				54	54	51	47	41	37	36	37	42	49	53	53	35
	C				87	87	89	89	83	79	81	87	92	93	95	89	95
	D				47	49	46	43	36	32	32	34	37	45	46	49	32
	E				74	77	73	67	59	60	57	49	42	42	57	68	60
	F				57	53	52	44	37	36	33	28	26	26	43	57	41
	G				7·9	6·8	3·8	1·2	0·4	0·2	0·1	0·2	0·1	1·3	4·5	6·7	33·1
	H				16	13	9	4	1	1	0·1	0·6	0·9	3	10	13	71
SHARJA	A	18	25°20′N.	55°24′E.	81	85	97	100	103	107	111	112	108	100	93	85	113
	B				46	50	51	56	65	70	75	76	72	66	58	52	45
	C				85	91	104	103	109	112	117	118	113	104	97	88	118
	D				37	46	46	53	61	67	73	73	69	64	54	47	37
	E				81	81	74	66	61	64	64	66	73	77	78	82	72
	F				61	63	61	63	63	65	64	64	64	62	59	62	63
	G				0·9	0·9	0·4	0·2	0·0	0·0	0·0	0·0	0·0	0·0	0·4	1·4	4·2
	H				2	2	1	0·3	0·0	0·0	0·0	0·0	0·0	0·0	0·2	2	7
SINGAPORE	A	33	1°18′N.	103°50′E.	89	91	92	91	92	91	91	91	91	91	91	90	93
	B				70	70	71	72	73	72	72	72	72	72	72	71	69
	C				93	94	94	95	97	95	93	93	93	93	92	93	97
	D				68	66	67	70	70	70	70	69	69	69	69	68	66
	E				82	77	76	77	79	79	79	78	79	78	79	82	79
	F				78	71	70	74	73	73	72	72	72	72	75	78	73
	G				9·9	6·8	7·6	7·4	6·8	6·8	6·7	7·7	7·0	8·2	10·0	10·1	95·0
	H				17	11	14	15	15	13	13	14	14	16	18	19	179

KEY A = Average highest temperature each month °F.

B = Average lowest temperature each month °F.

C = Absolute maximum temperature °F.

D = Absolute minimum temperature °F.

E = Average relative humidity a.m. %.

F = Average relative humidity p.m. %.

G = Average monthly rain in inches.

H = Average number of days with rainfall.

SELECTED CLIMATIC DATA—*continued*

Place		Alt. (ft.)	Lat.	Long.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
SYDNEY	A	138	33°52′S.	151°12′E.	95	91	89	82	74	69	69	74	83	89	91	95	100
	B				58	58	56	50	45	41	40	41	44	48	52	55	39
	C				114	108	103	91	86	80	78	82	92	99	103	107	114
	D				51	49	49	45	40	36	36	37	41	42	46	48	36
	E				68	71	73	76	77	77	76	72	67	65	65	66	71
	F				64	65	65	64	63	62	60	56	55	57	69	62	61
	G				3·5	4·0	5·0	5·3	5·0	4·6	4·6	3·0	2·9	2·8	2·9	2·9	46·5
	H				14	13	14	14	13	12	12	11	12	12	12	13	152
TOKYO	A	19	35°41′N.	139°46′E.	60	60	68	75	80	87	91	92	89	79	72	64	93
	B				22	23	27	35	43	54	62	65	56	43	33	25	21
	C				72	77	77	85	88	93	99	101	96	90	81	74	101
	D				17	18	22	30	36	47	55	60	51	36	26	20	17
	E				74	72	75	81	85	89	91	91	91	88	84	80	83
	F				47	50	51	58	62	67	68	65	68	64	58	55	59
	G				1·9	2·9	4·2	5·3	5·8	6·5	5·6	6·0	9·2	8·2	3·8	2·2	61·6
	H				5	6	10	10	10	12	10	9	12	11	7	5	107
TORONTO	A	379	43°40′N.	79°24′W.	45	45	54	70	80	87	91	88	84	72	59	48	93
	B				−6	−6	2	21	32	42	49	46	36	26	10	−1	−11
	C				58	55	80	90	93	97	105	102	96	85	70	61	105
	D				−26	−25	−16	5	25	28	39	40	28	16	−5	−22	−26
	E				78	78	76	74	73	78	79	83	87	87	82	80	80
	F				70	67	62	56	55	58	56	58	60	62	68	71	62
	G				2·7	2·4	2·6	2·5	2·9	2·7	2·9	2·7	2·9	2·4	2·8	2·6	32·1
	H				16	12	13	12	13	11	10	9	12	11	13	13	145
TRIPOLI (N. AFRICA)	A	72	32°54′N.	13°11′E.	70	73	85	95	97	103	99	97	98	94	85	73	106
	B				40	42	44	48	53	59	65	67	64	58	49	42	39
	C				80	90	101	104	109	110	111	112	109	102	95	83	112
	D				35	37	39	44	48	57	61	63	59	50	42	37	35
	E				68	63	57	54	61	59	63	62	55	55	59	62	60
	F				58	57	61	61	69	70	71	69	68	59	56	54	63
	G				3·2	1·8	1·1	0·4	0·2	0·1	0·1	0·1	0·4	1·6	2·6	3·7	15·1
	H				10	7	4	1	1	0·3	0·1	0·2	1	3	5	9	41

VALETTA	A	233	35°54′N.	14°31′E.	65	66	78	75	81	89	95	93	89	84	76	68	97
	B				44	42	45	49	54	69	69	68	64	58	52	46	42
	C				76	76	83	93	92	99	104	105	100	94	82	75	105
	D				39	34	37	44	49	57	62	62	57	45	42	39	34
	E				77	76	78	77	75	72	71	76	76	76	78	77	76
	F				67	67	66	64	64	61	59	62	64	65	68	68	65
	G				3·3	2·3	1·5	0·8	0·4	0·1	0·0	0·2	1·3	2·7	3·6	3·9	20·3
	H				13	8	6	3	2	0·3	0·1	0·5	3	6	9	13	64
WELLINGTON (N.Z.)	A	415	41°16′S.	174°46′E.	78	78	75	70	65	61	60	61	65	68	71	75	80
	B				46	47	44	41	37	35	33	33	36	38	41	45	32
	C				85	88	81	74	71	69	66	66	69	75	81	83	88
	D				39	41	39	36	32	30	30	29	31	34	36	38	29
	E				73	75	76	79	80	81	81	80	76	75	76	74	77
	F				67	71	69	76	77	78	76	74	75	74	69	69	73
	G				3·2	3·2	3·2	3·8	4·6	4·6	5·4	4·6	3·8	4·0	3·5	3·5	47·4
	H				10	9	11	13	16	17	18	17	15	14	13	12	165

KEY A = Average highest temperature each month °F.

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E = Average relative humidity a.m. %.

F = Average relative humidity p.m. %.

G = Average monthly rain in inches.

H = Average number of days with rainfall.

121. **Isotherm.** Line (on a map) joining places with the same temperature (usually mean temperature of the day, month or year).

122. **Katabatic Wind.** This is the name given to a wind produced by relatively dense cold air flowing down off the heights (under gravity) into and through the valleys, generally following the natural drainage channels.

123. **Precipitation.** The amount of moisture which falls from the sky in the form of water drops or ice crystals (rainfall plus snowfall), measured after conversion to the liquid form (see also "Average Rainfall / Precipitation").

124. **Rain Days.** Days on which the precipitation measured exceeds some defined minimum amount. (The defined amounts are not yet standardized in different countries. The statistics must therefore be treated with caution in making comparisons.)

125. **Relative Humidity.** The amount of water vapour present in the air *relative to* the amount required for saturation (in a state of equilibrium over a surface of, or in the presence of, unfrozen water) at the given temperature. The proportion is always expressed as the *percentage* of the saturation amount. Average values of relative humidity are usually quoted for specific times of the day, taken as near as possible to the usual times of maximum and minimum temperature: these indicate some approach to the lowest and highest relative humidities respectively, since the diurnal variation of relative humidity follows a trend roughly inverse to that of the temperature.

126. **Snow-Cover, Days with.** Days on which more than half the ground is covered with snow and ice (*not* including hail) at the principal morning hour of observation.

127. **Thunderstorm Days.** Days on which thunder is heard at any time.

128. **Vapour Pressure.** The partial pressure in millibars exerted by the water vapour in the air.

CHAPTER 7

EFFECTS OF CLIMATIC HEAT AND COLD

HEAT—PHYSIOLOGICAL PRINCIPLES

General

1. The maintenance of body temperature depends upon an equilibrium between heat gain and heat loss.

2. In man there are certain inevitable heat gains from metabolic processes within the body; and there are daily losses from the excretion of urine and faeces, the exhalation of warmed and moistened gases from the lungs, and the evaporation of insensible perspiration from the surface of the skin.

3. Further heat gains accrue from increased metabolism, exercise, and the absorption of heat from external sources. These can usually be balanced by losses from radiation, conduction, convection and, most important of all, by the production of sweat and its evaporation from the surface of the skin. In addition to these physiological factors man may modify the rate of heat gain or loss, for his own comfort, by change of clothing and alteration of the physical state of his environment.

Normal Body Temperature

4. The range of normal body temperature is from 96·7°F. to 99·0°F. (oral) and from 97·2°F. to 99·5°F. (rectal). Axillary and groin temperatures approximate to the oral temperature except in thin subjects.

5. The daily variation in body temperature is about 1·0°F. and may reach 1·5°F., being usually lowest in the early hours of the morning and highest between 5 and 8 p.m. In the tropics the normal body temperature is often a degree higher than in temperate climates. The temperature regulation of infants is imperfect and greater variations are common; the temperature of old people tends to be lower than that of young adults.

FACTORS INFLUENCING THE MAINTENANCE OF HEAT EQUILIBRIUM

Skin Temperature

6. The temperature of the skin is normally about 5°F. less than that of the internal body. The skin can be warmed by vaso-dilatation until the temperature approximates to that of the internal body; this increases the outflow of heat by radiation and convection, provided the external temperature is lower than that of the body surface. If the external temperature is the same or higher than the body temperature, heat accumulates and can only be lost by the production of sweat and its evaporation from the skin.

Sweat Glands

7. There are two types of sweat glands: eccrine and apocrine. Eccrine sweat glands are distributed throughout the skin and are most numerous on the head, palms of the hands, and soles of the feet. Sweat produced by eccrine glands is a true secretion consisting essentially of a dilute solution of salt and a little urea. Apocrine sweat glands are confined to the axillae,

nipples, genital areas, and the perineum. Sweat produced by apocrine glands is formed by the disintegration of the surface of the columnar cells lining the glands; it plays comparatively little part in the mechanism of cooling the body.

Sweat Production

8. Sweat may be secreted as a response to heat (thermal sweating) or from emotion (mental or nervous sweating). Thermal sweating is mainly under central autonomic control with a heat regulating centre in the hypothalamus; it starts simultaneously over the whole body very shortly after the skin temperature rises above 94°F. The amount of sweat produced varies according to the degree of heat stress and may even attain a flow of 3 litres an hour for short periods in the fully acclimatized. The amount is usually more than theoretical requirements; much is wasted and the cooling effect is influenced greatly by humidity, air movement, and clothing.

Humidity

9. The amount of moisture air is capable of absorbing depends, within certain limits, on its temperature: the higher the temperature the greater the power of absorption. Evaporation of sweat cannot take place if the air is completely saturated (100 per cent. relative humidity), or if it is less than completely saturated but still. Still air in immediate contact with the body rapidly becomes saturated.

10. Extreme muscular exertion in any climatic environment may produce 600 Kg. calories per hour. Each litre of sweat completely evaporated could theoretically remove 580 Kg. calories. During strenuous exercise at 100°F., the average man produces about 1 litre (1·8 pints) of sweat per hour and at higher temperatures as much as 2 to 3 litres per hour for short periods if fully acclimatized. Unfortunately, this does not mean that he can lose 580 Kg. calories for each litre of sweat produced; for under the conditions encountered in most tropical climates total evaporation of all sweat is seldom possible.

Air Movement

11. As a general rule air movement aids the evaporation of sweat from the body; it is essential to body comfort in hot humid climates, as it prevents the air in contact with the skin from becoming saturated. But in very hot dry climates, where the air temperature is much above body temperature, the rate of evaporation increases with increased air velocity until all the sweat produced is evaporated completely. Any further increase in air velocity above this point results in an increase in the total heat load, with consequent rise in body temperature. It is in these conditions that it is cooler to wear clothes.

Acclimatization

12. The efficiency of the various heat-regulating mechanisms of the body increases with continued exposure to heat stress. In the majority of persons a rapid improvement takes place within a few days, though it may take two or three weeks to become fully acclimatized. In the acclimatized, sweating begins more quickly as a reaction to heat stress; the sweat contains less salt, and the total quantity that can be produced is increased. Other changes also take place such as the lowering of muscle tone, a better control of heat equilibrium on muscular exercise, and an

overall improvement in the ability to continue work without fatigue. A few people have excellent heat regulating mechanisms and need little acclimatization. Similarly, there are some who seem incapable of acclimatization or become poorly acclimatized and remain specially prone to heat stress.

13. The ability to withstand continued heat stress depends not only on physical factors but also on the mental adjustment of the individual to his environment. Regular home leave is advisable for Europeans who live and work continuously in tropical climates. In the R.A.F. the lengths of tours abroad are adjusted to suit the climate encountered. Most men seem able to maintain a satisfactory heat equilibrium, even without such aids as air conditioning; but this is at the expense of their reserves of compensation to heat stress. Air-conditioned quarters are of great assistance in maintaining efficiency; and it has been shown experimentally that man is able to tolerate continued heat stress during the day over a longer period if he rests in lower temperatures and humidity at night. It has been noted that, provided the general health is good, the loss of efficiency which occurs towards the end of a tour abroad may often be an expression of mental attitude rather than of physical deterioration.

Water and Salt Balance

14. The basic requirement of water for an average adult is about 2 litres per day (30 to 40 ml./Kg. body weight (Tovey)) to offset the following losses:—

Urine	1,000 to 1,500 ml.
Insensible skin loss	500 ml.
Lungs	350 ml.
Faeces	150 ml.
	2,000 to 2,500 ml.

It will be seen that there is an "inevitable loss" of about a litre of water each day (from the skin, lungs and in the faeces) over which the body has no control. In a temperate climate the water obtained from solid food (approx. 700 ml. + 300 ml. water of oxidation) more or less balances the "inevitable loss", and the volume of urine passed is approximately equivalent to the amount of fluid taken as drink.

15. The amount of salt needed per day in a temperate climate to maintain internal balance and permit the excretion of a small surplus in the urine is about 4 gms. The average diet normally contains sufficient salt to provide a urinary output of about 10 gms. per day. In hot climates where sweating is heavy it is advisable to increase the salt intake as an insurance against depleting the salt reserves by unexpected additional heat stress.

16. If the food intake is kept low, survival is possible for a long time on very small quantities of water in spite of a daily debit balance. Dehydration amounting to a loss of 5 pints (2.8 litres) affects performance: a loss of 10 pints may cause death but a loss of 15 or even 25 pints can be withstood by some individuals.

17. Additional water and salt are required if there is sweating. The concentration of salt in sweat varies considerably and is related to intake and requirement. For practical purposes sweat can be considered as equivalent in salt concentration to ⅓rd Normal (Isotonic) Saline and it is only in the acclimatized person that the salt concentration of sweat will

be reduced as a response to salt deficit. Sweat loss in acclimatized individuals doing work varies from 0·3 pints to 3 pints per hour, depending upon temperature, humidity and the severity of the effort.

18. For a given climate the approximate loss of water as sweat, excluding "inevitable loss", can be calculated for the type of work done and the clothing worn (Table 7). The figures in the table are average figures at a specified air velocity; variation either way will occur at different air velocities and with different degrees of individual acclimatization. The table may also be used to predict losses when wearing "light clothing", such as bush jackets and shorts, by taking values midway between those given for "stripped to the waist", and "in overalls".

Example: Relative humidity 60 per cent. Dry bulb 95°F. A man sleeps stripped to the waist for 8 hours ($8 \times 0{\cdot}28 = 2{\cdot}24$ pints): does 6 hours moderate work wearing shorts ($6 \times 1{\cdot}01 = 6{\cdot}06$ pints) and 2 hours in overalls ($2 \times 1{\cdot}44 = 2{\cdot}88$ pints): takes 1 hour's strenuous exercise in shorts (1·40 pints) and rests lightly clothed for the rest of the day ($7 \times 0{\cdot}33 = 2{\cdot}31$ pints. 0·33 is the mid-value between 0·28 and 0·39). Over the 24 hours the water loss comes to about 15 pints as sweat, plus 4 pints for "inevitable losses", a total of about 19 pints. He will excrete about 20 gms. of salt in his sweat and another 10 gms. in his urine and faeces—a total of 30 gms.

19. Losses of water and salt should be replaced from hour to hour, rather than in large quantities at long intervals. As a rule more water should be taken than is necessary and the salt requirements should be met by increased intake at meal times if heat equilibrium is to be maintained under heat stress. Until salt loss or dehydration is severe, sweating is little affected; it will continue with mounting body deficits until exhaustion is reached.

20. It is useful to consider the effects of pure water and pure salt depletion separately although it is rare for either to be seen alone in clinical practice.

	Pure Water Depletion	*Pure Salt Depletion*
Dehydration	Simple or primary	Secondary or extracellular
Thirst	Marked	Absent
Lassitude	Minimal until late	Marked
Syncope	Rare	Common
Vomiting	Absent	Frequent
Cramps	Absent	Frequent
Blood Pressure	Normal	Fall: collapse common
Urine	Scanty	Normal output till late
NaCl Urine	Normal	Absent or much reduced
Blood Urea	High normal	Raised

It is important to remember that the symptoms of water and salt deficiencies may be superimposed upon the clinical picture of any disease or syndrome.

CLINICAL EFFECTS OF EXPOSURE TO HEAT

21. The clinical effects of exposure to heat can be divided broadly into:—

(*a*) Those related to upsets in water and salt balance:—
- (i) Heat cramps.
- (ii) Heat exhaustion, salt deficiency type.

TABLE 7

PREDICTED SWEAT RATES (1)
(pints per hour)

ESTIMATED AT STANDARD AIR VELOCITY OF 75 FEET PER MINUTE

A=STRIPPED TO WAIST WEARING SHORTS
B=WITH STANDARD(2) OVERALL WORN OVER SHORTS

	RELATIVE HUMIDITY 20%						RELATIVE HUMIDITY 60%						RELATIVE HUMIDITY 80%					
	At Rest		Moderate Work		Heavy Work		At Rest		Moderate Work		Heavy Work		At Rest		Moderate Work		Heavy Work	
DRY BULB T° F.	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
80	*	*	0·48	0·87	0·87	1·47	*	*	0·48	0·87	0·87	1·48	*	*	0·49	0·92	0·92	1·48
90	0·11	0·23	0·78	1·17	1·17	1·74	0·13	0·24	0·81	1·22	1·19	1·78	0·15	0·27	0·91	1·39	1·31	2.05
95	0·25	0·37	0·92	1·31	1·31	1·87	0·28	0·39	1·01	1·44	1·40	2·09	0·36	0·52	1·75	2·85	2·15	4·25
100	0·37	0·48	1·04	1·42	1·43	2·0	0·42	0·58	1.42	2·15	1·78	3·13	0·87	1·38	*	*	*	*
105	0·52	0·63	1·18	1·58	1·58	2·16	0·78	1·02	2·28	*	2·67	*	2·76	*	*	*	*	*
110	0·68	0·79	1·36	1·75	1·75	2·34	1·53	2·19	*	*	*	*	*	*	*	*	*	*
120	1·02	1·18	1·8	2·23	2·19	3·17	*	*	*	*	*	*	*	*	*	*	*	*

(1) From McArdle *et al* (1947) R.N.P. 47/391. See Smith, F. E. (1955) "Indices of Heat Stress". M.R.C. Memorandum No. 29. H.M.S.O. For calculation purposes it has been assumed that the globe and dry bulb temperatures are the same.

(2) Standard overall weighing 1,140 g.

* Not calculated

Note: These rates are based on average figures: variations will occur depending on factors such as acclimatization. For persons lightly clothed, rates intermediate between those given for stripped to the waist and dressed in overalls should be taken.

(*b*) Those associated with the reaction of the skin to its hot environment:—

(i) Sunburn.
(ii) Prickly heat.
(iii) Heat anhidrosis.
(iv) Heat exhaustion, anhidrotic type.

(*c*) Those which appear to be due to some central disorganization of heat regulation:—

(i) Heat stroke.
(ii) Heat hyperpyrexia.

(*d*) Other heat effects:—

(i) Heat oedema.
(ii) Heat neurotic reaction.

These divisions are useful for descriptive purposes, but the syndromes encountered in various different climates are not so clear-cut and may consist of signs and symptoms having more than one aetiological basis.

Heat Cramps (Syn. Miners' cramp: Stokers' cramp)

22. Heat cramps are characterized by the sudden onset of painful spasms of voluntary muscles. They usually occur following heavy physical work under hot conditions in which sweating is pronounced. The syndrome is due to salt deficiency and can be relieved by the administration of salt. It is often precipitated by drinking unsalted water which has the effect of increasing the water content of the body and thereby reducing the relative salt concentration. Heat cramps may be associated with other signs or symptoms of salt and water deficiency.

Heat Exhaustion (Salt deficiency type)

23. This condition is prevalent in hot dry climates. It is seen mainly in the first half of the hot season at peaks of temperature and occurs most often in the recently arrived and others less acclimatized to heat stress. Exercise, parades in the sun, or sitting and working too long in a hot aircraft, may be precipitating factors; but the syndrome can occur at any time of the day or night or be superimposed upon an acute pyrexia. It may be chronic with general asthenic symptoms or acute with collapse.

24. **Symptomatology.** In the classical case the onset is usually sudden though the patient may have had a headache, lost his appetite, and felt off colour for several days. He is often brought to sick quarters with a history of collapse at work and of vomiting. On examination he presents the signs of acute salt lack associated with a varying degree of dehydration. He is pale, collapsed, and cold and clammy to touch. The face is anxious and pinched and he may or may not be sweating profusely. The blood pressure is low and there is tachycardia and rapid shallow respiration. The oral temperature is usually subnormal or normal and the rectal temperature only slightly raised to between 100°F. and 102°F., unless there is concomitant infection, in which case it may be higher. If the salt lack is severe the patient may complain of abdominal cramps, or be unaware of the nature of his abdominal discomfort. The urine is scanty and concentrated if there is dehydration. Haemoglobin and plasma protein concentrations are raised. Blood chlorides are reduced and the blood urea concentration is nearly always raised to figures of the order of 100 mgms. per cent. even without renal dysfunction. The condition is potentially fatal.

25. **Diagnosis.** The history is usually diagnostic but it must be remembered, particularly if sweating has been heavy, that the syndrome can be superimposed upon any acute febrile illness such as pneumonia or malaria. If the patient is in an area endemic for P. falciparum malaria *blood slides must be taken to exclude algid malaria.* The syndrome may also occur as a secondary feature in patients with severe vomiting or diarrhoea. The clinical picture in children is often very suggestive of cerebro-spinal meningitis. Salt depletion can be confirmed by testing the urine for chlorides. Two simple tests are recommended:—

(*a*) *Urichlor Paper Test.* Open the plastic envelope; tear off a strip of paper from one of the books. Drop the strip into a sample of urine. The time taken for the paper to turn bright yellow is a rough measurement of the urinary chloride concentration in grammes per litre (as NaCl).

Time for Change	*Concentration NaC*l
At once	above 3 gms./litre
10 seconds	above 1·5 gms./litre
Over 40 seconds	less than 1 gms./litre

(*b*) *Fantus Test.* Place 10 drops of urine in a test tube washed in distilled water and add 1 drop of 20 per cent. potassium chromate as an indicator. Mix and add drop by drop a 2·9 per cent. solution of silver nitrate, shaking after each drop. The end point is the change from yellow to brick red. In salt depletion the end point is reached after the addition of between 1 to 3 drops. In a normal person *with a normal urine output* the number of drops of silver nitrate added is roughly equivalent to the number of grams of sodium chloride excreted each day, if it is assumed that the sample tested is representative of the day's output. Fantus test is an excellent qualitative test but only a rough quantitative test.

26. **Treatment.** The principles of treatment are to replace the water and salt losses, control the temperature, and treat infection if present. Well-kept intake and output charts are essential. Replacement by mouth is satisfactory for patients who are not severely collapsed or vomiting. Water and fruit drinks, salted to taste by the patient, soon overcome the acute needs, but additional salt and water are needed for several days until balance has been attained and the urine output is normal. It is advisable to allow the patient to salt his drinks to his personal taste, since patients with severe salt lack are capable of imbibing remarkably strong solutions of salt without vomiting. In the more severe cases, or if there is uncontrollable vomiting, intravenous therapy is necessary to restore the circulating blood volume and to overcome collapse. Isotonic saline should be given until the acute phase is over and the vomiting controlled, but an initial bottle of plasma or dextran may be necessary in the severely shocked patient. The amount to be given must be decided by clinical judgment taking into account the blood pressure, the jugular venous pressure, and the general condition of the patient. Usually two bottles are sufficient for immediate needs but more may be required as a life-saving measure; as a general rule not more than 6 bottles should be given in the first 24 hours. Frequent checks of the urinary chloride concentration must be made during intravenous therapy and half saline and glucose given when concentration rises. Once the patient can take salt and fluids by mouth the drip should be discontinued.

27. The control of temperature requires constant vigilance because the patient may develop a rising pyrexia, due either to secondary infection or as a reaction to exhaustion. The pulse and rectal temperature should be taken quarter- or half-hourly until the acute phase is over and, should the rectal temperature rise above 103° to 104°F., tepid sponging under a fan must be carried out at intervals until the temperature is controlled.

28. Specific therapy should be given if there is infection. If malarial parasites of P. falciparum are found on examination of blood smears the patient should be treated as a case of algid malaria.

29. Heat regulation is upset by an attack of heat exhaustion; patients may continue to have a mild pyrexia in early convalescence and require gradual re-acclimatization to heat stress. A common incident during convalescence is an attack of non-specific enteritis ("local tummy").

Sunburn

30. "There is a tendency to regard sunburn lightly but it must be realized that the general reaction may be severe and sometimes even fatal. The progress of local lesions depends on the degree of exposure and the development or otherwise of secondary infection. Usually recovery is complete." (Adams and Maegraith, Clinical Tropical Diseases, 1953.)

31. Sunburn is an acute solar dermatitis. The severity of the symptoms depends on the time of exposure and the intensity of the sun's rays. In hot dry climates the radiation is intense; but in hot humid climates there is slight reduction in intensity due to water vapour held in the atmosphere.

32. The reaction to exposure is erythema which is transient in mild cases but progresses to the formation of bullae associated with oedema in the more severe cases. The pain is intense and the sensitivity of the skin greatly increased. The general symptoms include headache and nausea with a varying degree of malaise. Vomiting is common and collapse may ensue. Variations in the degree of pigmentation of the skin occur and differ with the type of lesion.

33. **Treatment.** The local lesions must be treated as first or second degree burns. Healing is rapid provided secondary infection can be avoided. Heavy sedation, even morphia, may be necessary and penicillin or other antibiotics required for the control or prevention of secondary infection. If shock is present treatment follows general lines. Antihistamines may be of value in reducing the severity of the symptoms.

Prickly Heat

34. Prickly heat is the name given to a characteristic pricking sensation of the skin which is associated with an itching erythematous rash. The condition is very common in hot humid climates and is most prevalent when the wet bulb temperature remains continually over 75°F.

35. **Pathology.** Prickly heat is only the first part of a syndrome arising from the response of the skin to heat stress, and though the clinical picture alters with the progressive changes in the skin the pathology is the same throughout. The primary lesion appears to be an obstruction of a

sweat duct with the formation of a minute vesicle surrounded by a ring of erythema. It is this lesion in multiple which gives rise to the characteristic rash and may be responsible for the pricking sensation. The reaction around any one affected duct probably subsides within a few days and the duct is left chronically obstructed for a varying time until desquamation clears it. Other ducts become affected in turn thereby maintaining the rash and other symptoms. The condition is aggravated by secondary infection which may result from scratching.

36. The cause of the obstruction is uncertain and it is probable that there are several factors which influence its onset. Sunlight causes an increase in thickness of the squamous layer of the epidermis. It has been observed that a light tan, presumably by toning up the skin, is often protective, whereas increased exposure to the sun may exacerbate the condition. Increased sweating and the sodden nature of the skin play a part in hot humid climates, where the rate of evaporation of sweat is reduced. There is probably some quantitative or qualitative deficiency either of sebum or fatty acids of the skin, because substances such as anhydrous lanoline will relieve temporarily the subsequent chronic obstruction of the affected sweat ducts. Some authorities postulate a relationship between prickly heat and infection, particularly by fungi; and it is of interest that some of the skin fatty acids in normal persons are fungicidal or batericidal. There is much personal variation in the susceptibility to prickly heat. Women are affected less than men but it is more likely that this is due to a difference in the coolness of the clothing worn than to any sex difference. Babies are often more affected than adults and coloured persons are not immune. It is probable that fair-haired persons are more severely affected than dark-haired; but it is common to find a higher proportion of fair-skinned persons among those completely free from the condition. Fat persons, with their reduced heat tolerance, are often more severely affected once they have developed the condition. Acne, with its increased oiliness of the skin, is no protection, and the experimental use of various prophylactic fatty preparations and cortisone creams have been a failure; so has the reduction in the amount of washing on the pretext of preserving the "oiliness" of the skin.

37. **Symptomatology.** The rash occurs mainly at skin folds and points of contact of clothing but may involve the whole trunk and adjacent parts of the limbs. The sites most affected are the forehead, shoulders, waist, and back.

38. Symptoms depend on the extent and degree of obstruction of the sweat ducts. The severity varies with local changes of temperature and the degree of secondary infection. The condition itself is of minor clinical importance in adults but the effects of chronic skin irritation and loss of sleep may be severe enough to reduce an efficient man to an irritable state of incompetence. In babies and young children secondary infection may necessitate temporary admission to sick quarters or hospital.

39. The symptoms associated with the onset of obstruction of a particular duct subside with the development of chronic obstruction. More and more ducts become chronically obstructed as the hot season advances and, depending on the severity of the original prickly heat, a relative degree of anhidrosis ultimately develops in the areas most affected.

40. If an area of anhidrotic skin is examined with a hand lens after exercising, numerous small "sago grains" or mamillariae are seen in the epidermis, each corresponding to a blocked duct. The term miliaria pallida has been given to collections of mamillariae. Prickly heat and miliaria pallida coexist to start with in the same area of skin but as the degree of duct obstruction increases sweating ultimately ceases in the affected area and the symptoms associated with prickly heat disappear.

41. There are fortunately an enormous number of eccrine sweat glands and the relative degree of anhidrosis produced is usually insufficient to upset heat equilibrium, though the tolerance to heat stress may be reduced. When large areas of the body such as the whole back and chest become anhidrotic, the condition is termed heat anhidrosis as distinct from congenital anhidrosis.

42. There is some variation encountered in the clinical picture of prickly heat in babies and young children. The rash may be characteristic but in a few the minute vesicles may enlarge and isolated small bullae form in the affected areas. These bullae soon become secondarily infected and thereafter are indistinguishable from bullous impetigo. A similar condition may be encountered in adults who have been over-conscientious in taking additional salt.

43. **Treatment.** The ordinary rash is notoriously difficult to treat. Local applications of calamine or an astringent solution such as mercuric chloride are often helpful (but what is beneficial for one patient will not necessarily relieve another). Treatment with penicillin lotions and creams is contra-indicated owing to the danger of sensitization. Treatment, when necessary, should be assisted by mild sedation to aid sleep and by advice on the reduction of the general heat load by modification of exercise habits, such as the substitution of swimming for tennis or cricket. It may be necessary to admit babies and children to hospital to treat their secondary infection.

Heat Anhidrosis

44. Nearly everyone who has had prickly heat has some degree of anhidrosis. As explained, the term anhidrosis is not applied until sweat production is reduced or absent over comparatively large body areas. In addition to the obstructive aetiology of the condition there appears to be some central upset as well; for once anhidrosis is established there may be inhibition of sweating over areas of the body which have been free from prickly heat. Not all eccrine glands are affected because sweating is often increased on the face, palms of the hands, soles of the feet, loins and axillae, providing a marked contrast to the remaining dry body.

45. In general there are no symptoms related to the skin. On examination of the skin at rest there is nothing to distinguish it from normal, but on exercise extensive miliaria pallida is easily observed. If a fatty substance such as anhydrous lanoline is applied to one half of an affected area, sweat pours through on exercise; in contrast the untreated area remains dry (O'Brien's test) and the mamillariae in the treated area disappear. The effect of the lanoline, however, is transient. This test proves the presence of an obstructive element in the aetiology. If however the dry skin is closely examined it will be seen that, although the area is dry, mamillariae are not as numerous as the number of sweat glands present thus demonstrating that there is some additional factor causing the inhibition of sweating in the unaffected glands.

46. The ability to maintain heat equilibrium under normal work-day conditions is influenced by the degree of anhidrosis. Most men with anhidrosis still have sufficient heat control to be symptom free. Others have a reduced tolerance to heat stress and may report sick complaining of lassitude, loss of energy, breathlessness on exertion, insomnia or headache: they are usually unaware of any absence or reduction of sweating. On examination there are few signs apart from tachycardia, a rectal temperature of between 100° to 101°F., anhidrosis and the presence of miliaria pallida on exercise. Performance on a 40-mm. mercury test is often poor or reduced. Unless the possibility of anhidrosis is considered, the patient may be diagnosed as neurotic or classified as "effort syndrome".

47. All personnel, and especially aircrew, who have had severe prickly heat should be watched. If their symptoms of prickly heat subside without a change in the weather, their degree of anhidrosis should be assessed and their duties modified. Unless this precaution is taken a man with anhidrosis may become decompensated and develop heat exhaustion when exposed to heat loads which normally he could withstand. As a general rule the condition is cured by a combination of natural desquamation and the onset of the cool season. In due course the majority of the obstructed ducts clear and sweating returns to normal; but a residual degree of anhidrosis may persist until the next hot season or return to the United Kingdom.

Heat Exhaustion (Anhidrotic type)

48. The degree of heat stress necessary to decompensate a man with anhidrosis varies. The commonest stresses are exposure to a wet bulb temperature of more than 80°F. for several consecutive days, excessive exercise, a lengthy parade in the sun, sitting fully clothed in a hot cockpit, the acquisition of some acute infection, or a combination of these factors. When decompensation is slight recovery is rapid and many cases of incipient heat exhaustion never reach sick quarters because the men affected have been able to remove themselves from the environment responsible for the extra heat stress. In the established case the syndrome is typical.

49. Questioning usually elicits a history of previous extensive prickly heat, recent reduction of sweating on the body and of polyuria. The onset may be gradual and associated with anorexia, insomnia, and attacks of giddiness; or sudden if there is some precipitating factor. Headache and photophobia are common features and have resulted in many an unnecessary lumbar puncture. The patient is hot and dry to touch; the skin is flushed. Sweating is usually pronounced on the face and in the axillae; it is variable around the loins but absent from the limbs and trunk. The pulse is bounding and blood pressure normal. In contrast to the salt deficiency type of heat exhaustion, serious water and salt unbalance is uncommon. The temperature may be 103° to 114°F., but this is variable and is related to the degree of decompensation and to how soon the patient is admitted.

50. **Treatment.** This consists of reducing the temperature by tepid sponging under a fan, treating any infection, and giving adequate fluid and salt. Blood smears must also be taken to exclude malaria. Recovery is usually rapid once the factor causing the decompensation has been removed. In severe cases there is a danger of hyperpyrexia; half-hourly pulse and rectal temperature charts should be kept until the temperature falls and remains stable. To prevent hyperpyrexia tepid sponging may

be necessary at regular intervals for several hours, but can usually be discontinued once the patient starts to sweat from his unobstructed sweat glands. Convalescence must be gradual and duties adjusted to fit in with the degree of anhidrosis. Observation for at least 14 days after discharge is recommended.

Heat Stroke and Heat Hyperpyrexia

51. **General.** Hyperpyrexia is defined as a pyrexia of 106°F. or above. At such body temperatures lesions are liable to develop in the central nervous system producing a syndrome which, in the past, has been known by several names (*e.g.* heat stroke, sun stroke, heat hyperpyrexia). Hyperpyrexia associated with heat stress is now classified as heat hyperpyrexia; the term heat stroke is reserved for heat hyperpyrexia associated with collapse, unconsciousness, or delirium. Heat hyperpyrexia may be superimposed on an existing pyrexial illness under conditions of heat stress.

52. Heat hyperpyrexia and heat stroke are caused by the accumulation of body heat consequent upon a central inhibition of sweating. Continuous exposure to a heavy heat load for at least several hours is an essential factor in the production of these syndromes; they are seldom initiated by short exposures such as are encountered in stokers. Heavy heat loads can be produced by an abnormally hot environment or by severe muscular exercise when unsuitably clothed or unacclimatized; they may also be experienced by those who normally work under severe heat stress but have lost their acclimatization to heat owing to absence from work. Heat loads, which normally would not give rise to hyperpyrexia, can initiate the syndrome in persons already suffering from a pyrexial disease, or from heat anhidrosis. Finally, hyperpyrexia may be induced accidentally in a febrile patient by an injection of atropine in very hot weather.

53. Heat stroke is most often encountered in hot dry climates and is independent of direct sunlight which may, however, be a precipitating factor. It is more common in the unacclimatized, the fat, the hypertensive, and in babies, who have a less stable heat equilibrium than adults.

54. **Pathology.** In all cases of abnormally high body temperature there is damage to the central nervous system, the degree depending on the height of the fever and its duration. Irreversible changes occur more quickly the higher the temperature; a temperature of 108°F. persisting for two hours usually results in some irreversible damage but there is great variation in degree of severity. Temperatures of 110°F. or more are often fatal, but survival has followed as high a temperature as 115°F. and ante-mortem temperatures as high as 117·8°F. have been recorded. If treatment is delayed, and sometimes even after starting treatment, secondary symptoms of vascular failure, electrolyte imbalance and severe shock may supervene. The mortality depends on the height of the pyrexia and how soon treatment is started; death may occur within 24 hours or be delayed as long as a week or more. Early deaths are due to the abnormally high fever and its associated neuronal degeneration; later deaths are due mainly to shock and the pathological changes associated with severe vascular failure, superimposed upon the initial thermal lesions.

55. **Symptomatology.** The onset may be gradual and spread over several days, or sudden. When the onset is gradual there are prodromal

symptoms of headache, dizziness, anorexia or nausea, drowsiness or lassitude, and often of intense thirst. Vomiting may supervene as the symptoms increase in severity. Ultimately the patient passes into a state of mental confusion, delirium or coma, with or without convulsions. When the onset is sudden it is related either to a history of continuous exposure for several hours to an unusual heat load, or to some precipitating factor superimposed upon someone in a precarious state of heat balance. If the patient has taken alcohol before collapsing he may be diverted in error to the guardroom as drunk and incapable, instead of being taken to hospital.

56. On examination, the patient is flushed and the face slightly bloated and cyanosed. The skin is very hot and quite dry to touch. The rectal temperature is 106° to 107°F. and may be much higher. The pulse is rapid, often bounding, and the blood pressure normal or only slightly lowered. Respiration is shallow and the rate increased to about 30 or more per minute. The signs of thermal damage to the central nervous system, apart from those already mentioned, are extremely variable and may change from hour to hour. States of mental confusion, muscular twitchings or convulsions usually disappear with treatment; but delirium and coma, especially if occurring early, may persist. Varying degrees of incontinence are common. The urinary chloride concentration is usually normal, but will depend on the state of water and salt balance.

57. **Treatment.** All cases of heat stroke and hyperpyrexia should be treated as emergencies.

58. *Cerebral malaria is capable of presenting an identical clinical picture, and unless it can be excluded specific treatment with intravenous quinine or chloroquine must be given, in addition to other measures, without necessarily waiting for the results of examination of blood slides for malarial parasites.*

59. The patient should be removed to a cool or air-conditioned room, stripped naked, and placed under a fan. Ice bags should be applied to the head, tepid sponging started at once, and a 5 to 10 minute chart of the rectal temperature and pulse kept. If malaria cannot be excluded, 10 grains of quinine bihydrochloride (adult dose) dissolved in at least 10 ml. of distilled water should be given intravenously through a fine needle at a rate not greater than 1 ml. per minute. The alternative drug is chloroquine intravenously at a dosage of 300 mgms. of base in 10 ml. distilled water. Thick and thin blood slides should then be taken for malarial parasites.

60. Sponging should be continued until the temperature is lowered to 103°F. from 109°F. or to 102°F. from 106°F. Further lowering of the temperature may produce sudden collapse, as may the use of ice baths and iced sheets. The quickest and safest way to cool the body is by tepid sponging, which provides artificial sweat for evaporation from the skin. Tepid sponging may have to continue at intervals for many hours until the patient shows signs of a return of control of the heat equilibrium. Initial convulsions are better controlled by venesection than pentothal. Throughout treatment accurate intake and output charts are essential, and fluids and salt should be given by mouth as soon as the patient can take them. If coma persists intravenous threapy will have to be instituted to maintain the water and salt balance and to provide calories, using the urinary chloride concentration as a guide to salt replacement.

61. **Complications.** The most serious complication is shock. It may arise during treatment or occur as a secondary feature in patients whose treatment has been delayed. The patient passes from a state of hyperpyrexia to one of profound shock and resembles clinically the patient with a severe salt deficiency heat exhaustion. The prognosis is invariably bad. The temperature and blood pressure fall rapidly and shivering may begin. The patient becomes pale, cold, collapsed, and lifeless. The mental condition deteriorates and he becomes restless, anxious, or stuporose, if not in coma. Vomiting is an additional complication and is often associated with a watery diarrhoea; both vomit and stools may become blood-stained. Treatment is based on general principles for treating shock.

62. The re-establishment of the circulating blood volume is of critical importance. If anuria develops subsequently the patient should be placed on a restricted fluid intake and, if possible, removed to a special centre for treatment.

63. **Sequelae.** A common complaint during convalescence is persistent headache with photophobia. Dark glasses may be required even indoors. The degree of residual damage to the central nervous system depends on the severity of the attack. Various cranial nerve palsies have been encountered; Nerves II, III, VI, and VIII are the commonest affected.

Heat Oedema

64. A diffuse oedema of the hands and feet may occur in the unacclimatized in hot climates or in the acclimatized at peaks of temperature. The fingers feel and appear swollen and in severe cases there may be actual swelling of the ankles. The condition subsides within a few days. It may be associated with a transient cheiropompholyx, which does not appear to be related to epidermophyhton or other fungus infections and which disappears when the oedema subsides.

Heat Neurotic Reaction

65. Heat stress is only one of the forms of stress which may produce a neurotic reaction. When it occurs it is of a temporary nature and is usually attributable to short-term exposure to a hot environment, especially if ventilation is reduced and skilled or semi-skilled work is being done. The symptoms are ill-defined and consist mainly of fatigue, extreme tiredness, disinclination to work, irritability, and inattention to detail. Water and salt balance is not disturbed and sweat production is satisfactory. Symptomatic relief is rapid on removal from the stress-causing environment. The syndrome may be partly attributable to poor acclimatization to heat, but evidence is usually lacking and the aetiology can seldom be proved.

66. Heat neurotic reaction must be distinguished from the syndrome which may arise in someone with heat anhidrosis. History of previous severe prickly heat and the examination of the skin for absence of sweating will help in differentiation. It must be emphasized again that provided the general health is good, the loss of efficiency which occurs towards the end of a tour abroad ("tour ex") is nearly always an expression of mental attitude rather than of physical deterioration.

PROPHYLAXIS AGAINST HEAT EFFECTS

General

67. All troops inexperienced in tropical conditions should receive lectures, either in transit or as soon after arrival abroad as possible, on the simple measures to be taken to avoid heat stress and to maintain their efficiency. Lectures are also advisable at the beginning of each hot season to recapitulate the main points; and short reminders on hot weather precautions can be included with advantage in unit routine orders.

Acclimatization

68. The majority of men newly arrived in the tropics are both unacclimatized and inexperienced in looking after themselves in hot climates. Opportunities for at least partial acclimatization are afforded by the increasing temperatures met on troopships during eastbound voyages, especially if the gradual acquisition of a sun tan has been allowed and there are opportunities for exercise on board. Even after a voyage of this nature it is advisable to allow at least a week to elapse, after arrival in the hot season, before permitting duties which involve strenuous work in the heat of the day. Longer periods must be allowed for those who have travelled by air and who are therefore exposed to extreme contrasts in climates. Marching, especially when loaded with kit-bags, is particularly liable in these circumstances to lead to syncope or even cases of heat exhaustion or hyperpyrexia among newcomers when they first disembark. It should be the invariable practice to provide transport, or delay movement until the cooler time of the day. Such personnel should not, if it is avoidable, be employed on handling baggage. But if circumstances compel, frequent relief for baggage parties should be provided.

Water and Salt Balance

69. An adequate intake of water and salt is essential. Supplies of water, preferably cooled, should be easily and conveniently available, particularly at places of work. Notices such as "DRINK MORE WATER" and "EAT MORE SALT" are of great value in bringing the point home. Water intake should be greater than that physiologically necessary and a good general rule is that the minimum intake in hot climates should be that which will give the individual a urine output similar to his urine output in the United Kingdom. In practice this entails an intake of at least 10 pints of water in 24 hours and more than 10 pints will be necessary if sweating is heavy. During the hot season, and at any time when work is heavy, additional salt must be taken with meals or added to drinks to individual taste. The additional salt can be taken as salt tablets after food, but most people find it more palatable as table-salt added to food or drinks. Losses of water and salt should be replaced from hour to hour rather than in large quantities at long intervals. The amount of fluid necessary may be unattractive as plain water, but is more acceptable in the form of fruit drinks, squashes, lemonade, etc. particularly to children.

Exercise

70. In hot weather the axiom of "moderation in all things" applies to exercise. Exercise and outdoor games should be encouraged for general reasons but should be taken or played during the cooler part of the day and not during the early afternoon. Strenuous games should be limited or forbidden at the height of an unusually hot spell, and other forms of exercise, such as swimming, encouraged instead.

Hours of Work

71. Hours of work are adjusted locally to suit the climate; during hot weather it is customary to start work early to take advantage of the cooler part of the day. The working day can well begin soon after first light and, when operational and other commitments allow, should end before or shortly after noon. The hot afternoon should be devoted to rest and the evening to recreational activities.

Rest and Leave

72. The length of operational tours abroad are adjusted to suit the climate. Efficiency is much enhanced if facilities exist for short periods in cooler surroundings and leave camps should be established in accessible hill districts where these exist. Such camps are particularly valuable for troops convalescing after discharge from hospital, and for those who have been exposed to continued very hot weather for two or three months.

Air Cooling and Air Conditioning

73. It has been shown experimentally that the average man can withstand, within limits, continued severe heat stress during working hours for a long time without loss of efficiency provided adequate sleep in cool surroundings can be guaranteed at night. The temperature control of sleeping quarters is of greater importance than the conditioning of normal places of work. Systems of air conditioning or air cooling are provided on some stations abroad in sick quarters, in the operating blocks of various hospitals, and in a varying number of wards. An air-conditioning system controls humidity as well as temperature. An air-cooling system controls primarily the temperature and the humidity varies, according to the initial humidity of the entering air and the degree of condensation of moisture taking place upon the coolant tubes. In hot dry climates air cooling is often satisfactory and the resultant drop in temperature is usually accompanied by a slight increase in relative humidity which, however, still remains low. Air cooling in hot and humid climates, with certain combinations of temperature and humidity, may actually decrease the environmental comfort, because although the dry bulb temperature may be reduced there can be an increase in relative humidity to well over 95 per cent. Unless true air conditioning is available in hot and humid climates it is easier to reduce the high fevers of hyperpyrexias under a fan in an ordinary ward than in an air-cooled block in which the relative humidity may be higher than that of the outside atmosphere. Air conditioning and air cooling units for individual rooms have been developed over the last ten years and are coming into increasing use. The adaptation of existing buildings to centrally air-conditioned blocks is often both structurally and financially impracticable. Refrigerant units blowing a supply of cold air through a large flexible tube are available to cool the insides of aircraft when work has to be carried out in them during hot weather.

Medical Observation

74. A close watch on temperature conditions and the reactions of personnel to them should be kept by medical officers. Those working inside aircraft and in other thin-skinned structures are especially exposed to risk. In strong direct sun, refrigerant units should be used to cool the air and to provide circulation inside these comparatively airless structures. The use of a refrigerant unit is a valuable adjunct to comfort in hot

weather when dealing with the disemplanement of patients from aircraft employed on casualty air evacuation.

75. A medical officer should never hesitate to urge strict limitation of work or even its complete cessation in special places when the wet bulb temperature remains continually above 85°F.

76. Testing for urinary chlorides should be a matter of daily routine for all febrile patients during the hot season.

Medical Organization for the Treatment of Heat Stroke and Hyperpyrexia

77. All medical officers must ensure that adequate facilities are available for the treatment of heat stroke and hyperpyrexia and that their staff are fully trained in the routine of medical treatment.

THE EFFECTS OF EXTREME COLD

Physiology

78. The physiology of living in very cold climates is not so clear-cut as that of response to climatic heat. The problem facing the body is to conserve heat, and prevent damage to the central and peripheral tissues, when exposed to excessively low temperatures. In cold climates the greatest heat loss is from the extremities; the controlling physiological response is vasoconstriction, which must not reduce the peripheral circulation to the extent of loss of limb function, yet must be sufficient to maintain the internal temperature of the body. The balance between these two essentials is helped by the body's limited natural ability to produce more heat by increased metabolic activity, shivering and increase of muscle tone, supplemented by exercise, and reinforced artificially by appropriate clothing. If necessary heat may also be given up from that stored in the less vital tissues, intermediate between the extremities and the core of the body. Other physiological responses are diuresis, reduction in plasma volume, and lowered total red cell volume.

Acclimatization

79. There has been disagreement whether, in fact, acclimatization to cold occurs. It has been shown, however, that the vascular response of those accustomed to living in cold climates, compared with the unacclimatized, differs on exposure to cold and between exposures; their extremities have greater tolerance of cold, without affecting the temperature of the core of the body. The acclimatized also have a higher basal metabolic rate, and are able to contribute more heat from storage; the extra heat is distributed by the adapted vascular system, so that the extremities are maintained at a higher functional level than in the unacclimatized. It has been suggested that the mechanism of acclimatization is based on increased thyroid activity. Further evidence of acclimatization is that endurance gradually increases with residence in cold climates and that acclimatized people can shiver during sleep without being disturbed.

Cold Effects

80. General cold effects result if the body temperature is excessively lowered by exposure, for example when mountaineers are stranded in a blizzard or a drunken man falls asleep out of doors in mid-winter. The condition is termed hypothermia. Local effects occur if the tissues are exposed for a prolonged period to low temperatures and wet, or to extreme low temperatures for a shorter time. Immersion and trench foot are the conditions associated with the former, frostbite with the latter.

Hypothermia

81. The body may be thought of as consisting of a surface shell, an inch deep, surrounding a core containing the vital organs. The temperature of the shell is lower than that of the core, which is equivalent to the

rectal temperature. The shell constitutes almost 50 per cent. of the body mass; great heat loss from it can occur without alteration of the temperature of the core. This is because in response to cold there is cutaneous vasoconstriction, which delays outward heat transference. Any heat loss at first sustained by the core is made good by shivering, and only when this mechanism fails to keep pace will the core temperature start to drop. In consequence there is a marked time lag between cold exposure and fall in the rectal temperature. This time lag also operates when a person is removed from cold exposure, such as immersion. There is peripheral vaso-dilation and a very high rate of blood flow follows. The venous blood returning to the body core is cooled and the rectal temperature continues to fall until the shell is warmed.

82. Damage does not usually occur if exposure to cold is brief; for example, a short immersion in very cold water. But if more prolonged, bradycardia, due to direct cooling of the pace-maker of the heart, arrythmias and auricular fibrillation may follow, at rectal temperatures of 86° to 88°F. When death occurs at rectal temperatures of 76° to 86°F., it is probably from ventricular fibrillation. In prolonged hypothermia the blood pressure falls, there is decreased blood plasma, and haemoconcentration rises.

83. On initial exposure to intense cold vasoconstriction and high peripheral resistance are marked. Shivering occurs until the rectal temperature falls below 93°F., when it diminishes until at 88° to 90°F. it becomes sporadic or ceases; intense muscular rigidity sets in, with the subject semi-conscious and indifferent. With continued cooling the rigidity passes off, reflexes diminish and finally vanish. As shivering diminishes, oxygen consumption decreases and the respiratory rate falls. A stage is reached when the oxygen demand is so low that there is little oxyhaemoglobin dissociation and acidosis develops through the accumulation of carbon dioxide in the blood.

84. **Treatment.** It was a common experience in the Second World War that survivors from prolonged immersion collapsed and died almost as soon as treatment was started. This was probably due to the continued fall in rectal temperature, on warming the shell, leading to ventricular fibrillation or to medullary thrombosis (already present but made apparent only on rewarming). If hypothermia has developed quickly, rapid rewarming in baths of 113° to 122°F. are effective and counteract the continued drop of the rectal temperature. If hypothermia has developed slowly, from prolonged exposure, the patient should be allowed to thaw himself out gradually in an environment of about 70°F. This results in a rise of the rectal temperature at from 1° to 2°F. per hour. The danger of rapid warming is collapse of the blood pressure, because of low peripheral resistance due to too great a reduction in the blood volume to meet the sudden demands of the intense vaso-dilation.

Immersion Foot and Trench Foot

85. Following on long exposure of the legs and feet to water or wet conditions at 14° to 64°F., the limbs first feel intensely cold then become numb. Survivors with immersion foot cannot walk, or do so with utmost difficulty, and complain of the sensation of walking on cotton wool. The feet are white, cold, and show patches of cyanosis. There is considerable oedema and loss of sensation. As recovery begins they become hot, red, and swollen with blisters and areas of gangrene, depending on the severity of the case. The patient complains of an agonizing sensation of burning. Recovery is very slow. There may be tissue loss and persistent anaesthesia and paraesthesia. Hyperhidrosis is a troublesome complication.

86. These effects are due to neurovascular damage by local chilling, but are always associated with general body chilling as well. Tissues can withstand without damage much more severe and prolonged exposure to cold, if the body is warm. The small vessels, muscle and nerve fibres are the tissues mainly affected by prolonged cold. On rewarming there is intense vasodilation and increased blood flow, resulting in oedema by the escape of plasma through the damaged capillaries. Blood stasis follows, as the red cells become concentrated in the vessels, resulting in conglutination and the formation of plugs. Areas of ischaemia and tissue loss may ensue.

87. **Treatment.** Immediate treatment must aim at avoiding injury to the affected limbs and at preventing sepsis. Slow rewarming at normal room temperature is safest.

88. **Prevention.** The prevention of immersion foot is limited to the development of survival techniques, equipment, and clothing. Trench foot may be prevented by ensuring that in cold, wet conditions men are adequately clothed to avoid body chilling, that footwear and socks are not too tight, and that there are adequate drying facilities. Men should be educated in the care of their feet and there should be frequent foot inspections to ensure early diagnosis and to enforce foot discipline.

Frostbite

89. The extremities of the limbs, the ears, nose, and the cheeks are the parts normally susceptible to frostbite. It occurs most commonly in conditions of frost and wind; the combined effects of wind and cold are known as "wind chill", the components and results of which are shown in Fig. 52. Severe cold in dry, calm weather is not so dangerous. Predisposing conditions are poor physique, exhaustion, hunger, anoxia, shock, loss of blood, restricted mobility, and low morale.

90. The skin freezes at 28°F. (skin temperature) and ice crystal formation occurs in the tissues at about 14°F. The exact mechanism by which cold causes tissue damage is not certain. Whereas prolonged cooling at temperatures above freezing can be harmful, experimentally cells can survive freezing and crystal formation. It is probable that the time factor is important, as the thawing of frozen tissues within about 20 minutes prevents irreversible injury. Beyond this time mechanical trauma occurs, either due to crystal formation or to the effects of thawing which cause red cell haemolysis and thrombus formation or conglutination.

91. The appearance and sequence of events closely resemble those in immersion foot. The damage to muscles and nerves is greater than to the skin and occurs before the blood vessels are affected; thus the vascular changes are more probably secondary to direct tissue damage, rather than cold initially causing the vascular lesion. Clinically there are three degrees of frostbite:—

(*a*) Erythema and cyanosis of the skin with slight swelling.

(*b*) The same but with marked swelling and blisters.

(*c*) Superficial or deep gangrene, of which the latter is rare.

Sequelae include disturbances of motor, sensory and vasomotor function. Hyperhidrosis is often troublesome, as are flat foot and increased cold sensitivity. The oedema fluid is rich in fibrinogen and residual fibrosis may cause contractures. Tissue loss may impair function, according to its severity.

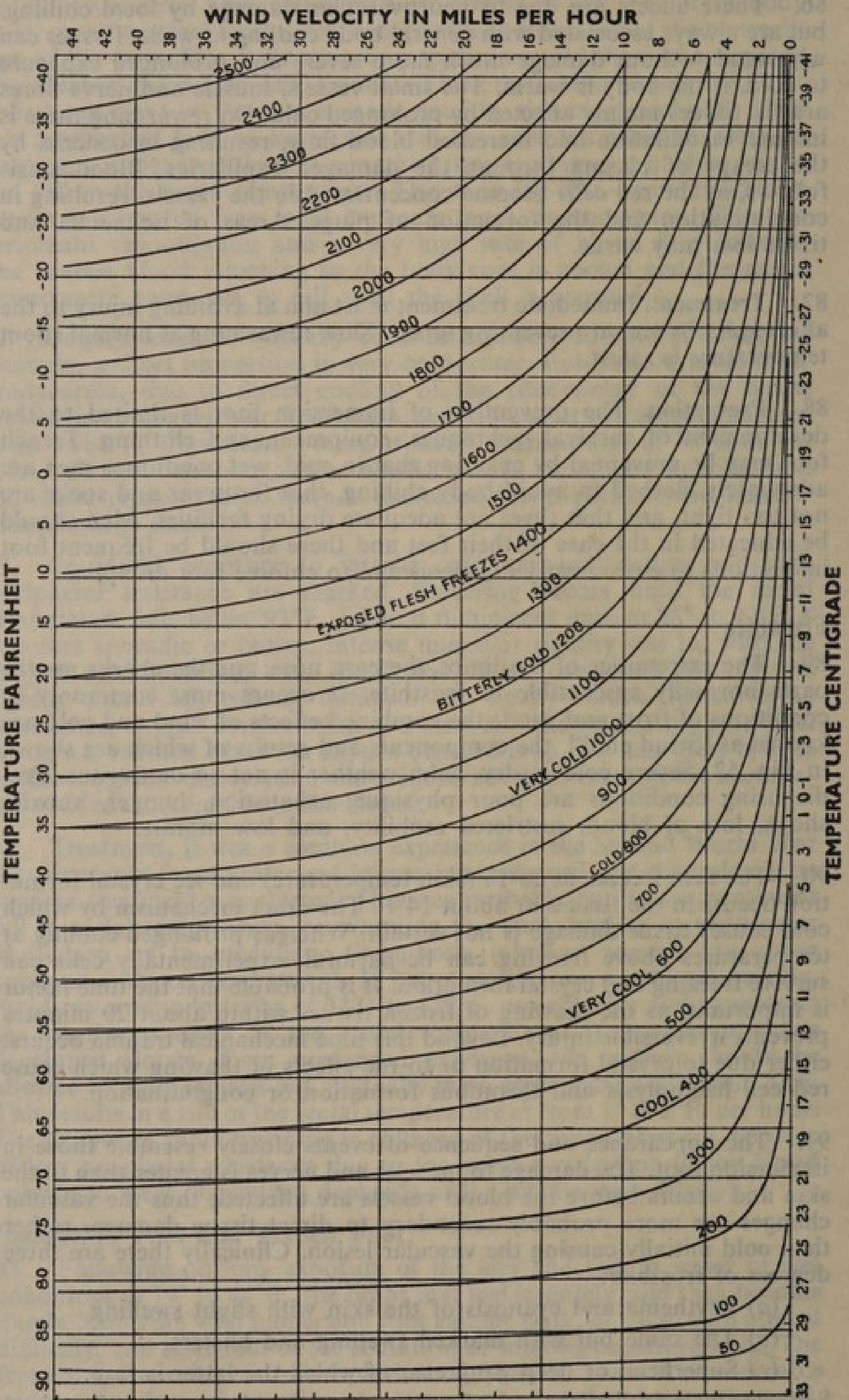


FIG. 52. NOMOGRAM OF WIND CHILL FACTOR

92. **Treatment.** Initial treatment is best confined to light bandaging to prevent further injury to the part and the use of antibiotics to prevent sepsis. Rapid or moderately rapid rewarming is not advisable. It is valueless if the cold damage is limited to the tissues; in damaged vessels it will promote a violent vascular reaction resulting in dilatation and stasis due to red-cell plugs. Heparin, cortisone and ACTH have been tried with varying claims to success but no special treatment of this kind has proved its value. After slow thawing, treatment should be expectant and surgery delayed until the extent of tissue loss can be finally assessed. Prolonged rehabilitation may be necessary.

93. **Prevention.** Apart from doing all possible to anticipate predisposing conditions, by ensuring that men are physically fit and properly fed, it is important that the peripheral circulation should not be impeded. Prolonged immobility must be avoided and the limbs exercised periodically. Positions should not be taken up which may reduce the blood flow to the extremities, for example by compression of the thighs when sitting. Similarly, clothing should not cause constriction, and it must be as dry as possible before wear. For aircrew the proper use of oxygen is essential. Care must be taken not to touch very cold metal with the bare skin, for this can result in frostbite in a few seconds. Most important is that protective clothing should be scientifically designed and windproof. Irrespective of all such precautions, however, cold effects will occur if men are not indoctrinated in cold weather routine and are not instructed in the elements of their physiology in response to extreme cold.

CHAPTER 8

ENVIRONMENTAL CONTROL

INTRODUCTION

The Environment

1. The environment includes every factor and circumstance that reacts on the individual during his waking, sleeping, working, and leisure hours. In this chapter the term environment is used in a more limited sense. Food, drink, sanitation, the control of pests and of infection, and occupational hygiene, all concern the general environment; they are however discussed in other chapters. The environmental control to which this chapter refers concerns protection from the elements and the provision of satisfactory conditions within buildings.

ASSESSMENT OF THE THERMAL ENVIRONMENT

Thermal Environment

2. The elements which together affect comfort, efficiency, and health, through body heat loss and temperature regulation, constitute the thermal environment. Individual idiosyncrasies make the accurate definition of thermal comfort difficult, as it is impossible to satisfy a minority who feel either too hot or too cold when others are comfortable.

3. The elements constituting the thermal environment are the air temperature, radiation, humidity, and air movement. The measurement of a single one of these gives incomplete and inaccurate information on thermal comfort as a whole. A dry bulb temperature of 85°F. in a dry climate, for example, is not comparable in terms of comfort with the same temperature in a humid place. Further, radiant heat can exert an effect on comfort equivalent to an increase of from 2° to 20°F. in the wet bulb temperature and 5° to 30° in the dry bulb. It is necessary, therefore, to use some form of temperature scale which allows for all or most of the factors concerned.

Equivalent Temperature Scale

4. In England heating and ventilation engineers sometimes use the equivalent temperature scale. It allows for air temperature, radiation, and air velocity, but not for humidity. Its use is therefore limited to conditions where the air temperature is 75°F. or less; up to this level humidity is unimportant.

Effective Temperature Scale

5. American workers developed the effective temperature scale, which is defined as "that temperature of saturated motionless air which would produce the same sensation of warmth or coolness as that produced by the combination of temperature, humidity and air motion under observation". It is thus a sensory scale and allows for air temperature, humidity, and air movement, but not for radiation. Since the amount of clothing worn influences thermal comfort, the scale is assessed differently for people stripped to the waist and for those wearing light indoor clothing. For the latter the effective temperature is obtained from the normal scale nomogram (Fig. 54), for the former from the basic scale nomogram (Fig. 53).

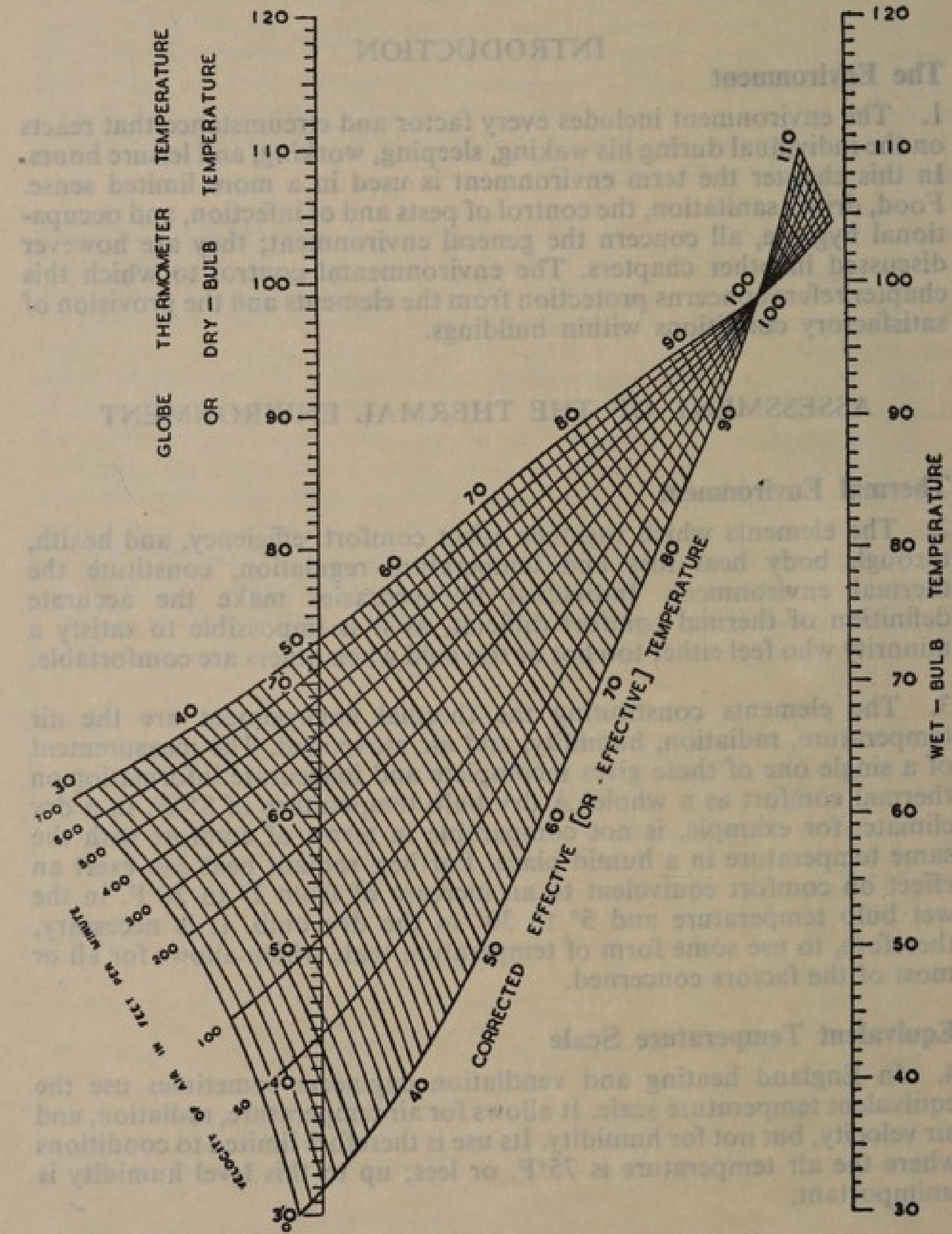


FIG. 53. CHART SHOWING BASIC SCALE OF CORRECTED EFFECTIVE (OR EFFECTIVE) TEMPERATURE

Reproduced by courtesy of the Medical Research Council (*Environmental warmth and its measurement*, a book of reference prepared for the Royal Naval Personnel Research Committee by T. Bedford. Medical Research Council Memorandum, No. 17).

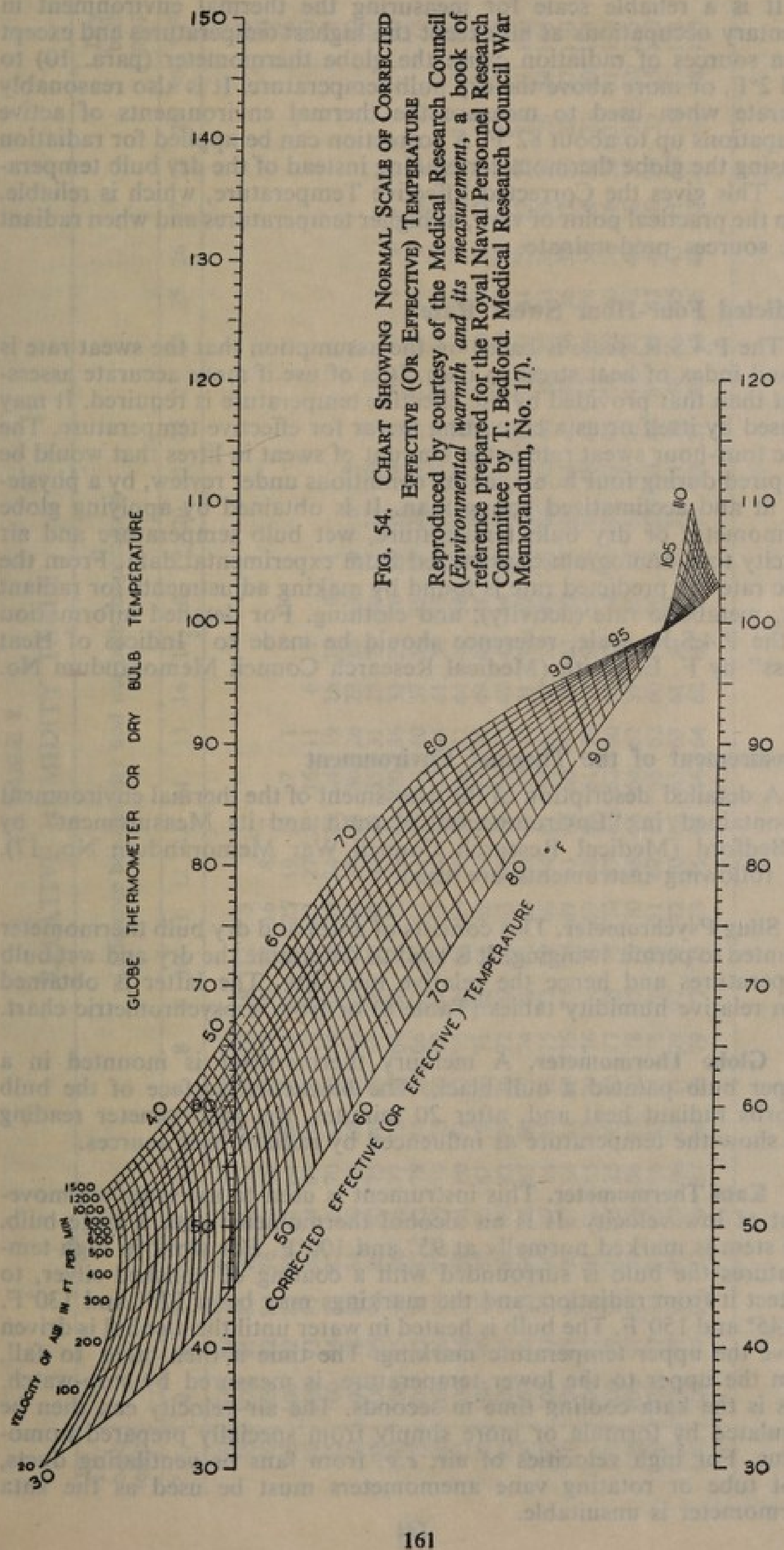


FIG. 54. CHART SHOWING NORMAL SCALE OF CORRECTED EFFECTIVE (OR EFFECTIVE) TEMPERATURE

Reproduced by courtesy of the Medical Research Council (*Environmental warmth and its measurement*, a book of reference prepared for the Royal Naval Personnel Research Committee by T. Bedford. Medical Research Council War Memorandum, No. 17).

6. It is a reliable scale for measuring the thermal environment in sedentary occupations at all except the highest temperatures and except when sources of radiation cause the globe thermometer (para. 10) to read 2°F. or more above the dry bulb temperature. It is also reasonably accurate when used to measure the thermal environments of active occupations up to about 82°F. A correction can be applied for radiation by using the globe thermometer reading instead of the dry bulb temperature. This gives the Corrected Effective Temperature, which is reliable, from the practical point of view, at higher temperatures and when radiant heat sources predominate.

Predicted Four-Hour Sweat Rate

7. The P.4.S.R. scale is based on the assumption that the sweat rate is a good index of heat stress in man. It is of use if more accurate assessment than that provided by the effective temperature is required. It may be used by itself or as a correcting factor for effective temperature. The basic four-hour sweat rate is the amount of sweat in litres that would be perspired during four hours, in the conditions under review, by a physically fit and acclimatized young man. It is obtained by applying globe thermometer or dry bulb temperature, wet bulb temperature and air velocity to a nomogram constructed from experimental data. From the basic rate the predicted rate is found by making adjustments for radiant heat, metabolic rate (activity), and clothing. For detailed information on the P.4.S.R. scale, reference should be made to "Indices of Heat Stress" by F. E. Smith (Medical Research Council Memorandum No. 29).

Measurement of the Thermal Environment

8. A detailed description of the assessment of the thermal environment is contained in "Environmental Warmth and its Measurement" by T. Bedford (Medical Research Council War Memorandum No. 17). The following instruments are used.

9. **Sling Psychrometer.** This consists of a wet and dry bulb thermometer mounted to permit swinging. It is used to determine the dry and wet bulb temperatures and hence the relative humidity. The latter is obtained from relative humidity tables (Table 8) or from a psychrometric chart.

10. **Globe Thermometer.** A mercury thermometer is mounted in a copper bulb painted a dull black. The blackened surface of the bulb absorbs radiant heat and, after 20 minutes, the thermometer reading will show the temperature as influenced by radiant heat sources.

11. **Kata Thermometer.** This instrument is used to ascertain air movement of low velocity. It is an alcohol thermometer with a large bulb. The stem is marked normally at 95° and 100°F. For work in high temperatures the bulb is surrounded with a coating of polished silver, to protect it from radiation, and the markings may be at 125° and 130°F. or 145° and 150°F. The bulb is heated in water until the alcohol is driven above the upper temperature marking. The time it then takes to fall, from the upper to the lower temperature, is measured by stop-watch. This is the kata cooling time in seconds. The air velocity can then be calculated by formula or more simply from specially prepared nomograms. For high velocities of air, *e.g.* from fans or ventilating ducts, pitot tube or rotating vane anemometers must be used as the kata thermometer is unsuitable.

TABLE 8

RELATIVE HUMIDITY TABLE

Dry bulb temp.	Difference between dry and wet bulb temperatures																															Dry bulb temp.
° F.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	° F
30	100	89	78	67	57	47	36	26	17																							30
35	100	91	82	73	65	54	45	37	28	19	12	3																				35
40	100	92	84	76	68	60	53	45	38	30	22	16	8	1																		40
45	100	92	85	78	71	64	58	51	44	38	32	25	19	13	7	1																45
50	100	93	87	80	74	67	61	55	50	44	38	33	27	22	16	11	6	1														50
55	100	94	88	82	76	70	65	59	54	49	43	39	34	29	24	19	16	10	6	1												55
60	100	94	89	84	78	73	68	63	58	53	48	44	39	34	30	26	22	18	14	10	6	2										60
65	100	95	90	85	80	75	70	65	61	56	52	48	44	39	35	31	28	24	20	17	13	10	6	3								65
70	100	95	90	86	81	77	72	68	64	60	55	52	48	44	40	36	33	29	26	23	19	16	13	10	7	4	1					70
75	100	95	91	87	82	78	74	70	66	62	58	55	51	47	44	40	37	34	31	27	24	21	19	16	13	10	7	5	2			75
80	100	96	92	87	83	79	75	72	68	64	61	57	54	51	47	44	41	38	35	32	29	26	23	20	18	15	13	10	8	6	3	80
85	100	96	92	88	84	80	77	73	70	66	63	60	56	53	50	47	44	41	38	36	33	30	28	25	22	20	17	15	13	11	9	85
90	100	96	92	88	85	81	78	75	71	68	65	62	59	56	53	50	47	44	41	39	36	34	32	29	26	24	22	20	17	15	13	90
95	100	96	93	89	86	82	79	76	72	69	66	63	60	58	55	52	49	47	44	42	39	37	35	32	30	28	25	23	21	19	17	95
100	100	97	93	90	86	83	80	77	74	71	68	65	62	59	57	54	51	49	47	44	42	39	37	35	33	31	29	27	25	23	21	100
105	100	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56	53	51	49	46	44	42	40	38	35	33	31	30	28	26	24	105
110	100	97	94	90	87	84	81	78	76	73	70	67	65	62	60	57	55	53	50	48	46	44	42	40	38	36	34	32	30	28	27	110
115	100	97	94	91	88	85	82	79	76	74	71	69	66	64	61	59	57	54	52	50	48	46	44	42	40	38	36	34	33	31	29	115
120	100	97	94	91	88	85	83	80	77	75	72	70	67	65	62	60	58	56	54	51	49	47	45	44	42	40	38	36	35	33	31	120
125	100	97	94	91	88	86	83	80	78	75	73	70	68	66	64	62	59	57	55	53	51	49	47	45	43	42	40	38	37	35	33	125
130	100	97	94	91	89	86	83	81	78	76	74	71	69	67	65	62	60	58	56	54	52	50	49	47	45	43	42	40	38	37	35	130
135	100	97	94	92	89	86	84	81	79	77	74	72	70	68	65	63	61	59	57	55	53	51	50	48	46	45	43	41	40	38	37	135
140	100	97	95	92	89	87	84	82	79	77	75	73	71	68	66	64	62	60	58	56	55	53	51	49	48	46	44	43	41	40	38	140

12. **Calculation of Results.** Results can be calculated by formulae for which books of reference must be consulted. It is far simpler, however, to use charts and nomograms. Examples of these are in Figs. 53 and 54. A full set can be obtained with the Medical Research Council War Memorandum No. 17.

Comfort Zones

13. At temperatures below 75°F. the equivalent temperature is the scale that correlates the most closely with comfort. The globe temperature is the best single measurement of warmth, provided air movement is negligible. The kata cooling power of the air is not accurate as a single measurement, owing to the sensitivity to air movement of the kata thermometer. For practical purposes and all-round accuracy the effective temperature scale, corrected when necessary, is the index of choice for thermal comfort.

14. Subjective comfort varies according to personal idiosyncrasy, health, clothing, and acclimatization. Comfort zones must consequently be relatively wide, and differ according to season and situation. In England in winter the following temperatures are generally accepted as comfortable:—

Equivalent temperature	58° to 66°F.
Globe thermometer temperature	62° to 68°F.
Effective temperature (normal)	57° to 63°F.
Dry bulb temperature (indoors)	60° to 65°F.

For warmer seasons and hot climates, only effective temperatures are reliable (corrected if necessary). The comfort zone in summer in England is considered to be 60° to 66°F. but 67° to 71°F. is regarded as the comfort zone in America. For hot climates as a whole 66° to 76°F. is the range accepted.

15. Factors other than heat influence comfort; for example draughts, cold feet, and lack of freshness of the atmosphere. Draughts are felt when the air movement at 60°F. is greater than 3 to 4 feet per second. As the temperature rises, the higher is the air velocity necessary to produce discomfort. Cold feet result from a floor temperature materially lower than that at head level. The difference between the temperature at head and floor level is known as the temperature gradient. A steep temperature gradient, especially if the walls are cooler than room air temperature, leads to a sensation of stuffiness, to which radiant heat sources above head level may also contribute. A stale atmosphere of this kind is the result of faults in the system of heating and ventilation employed. The atmosphere feels fresh when there is variability, within small limits, of air movement, temperature, and humidity and when the temperature of the walls approximate to room temperature.

Effects of Thermal Environment on Work

16. Output and accuracy of work are adversely affected by extremes of temperature. If the environment is too cold manual dexterity is impaired and the accident rate rises. Above certain levels of environmental warmth, discomfort may cause loss of efficiency; at critical higher levels, after increasing inefficiency, the point is reached where work is impossible and heat effects occur.

17. These levels depend on such factors as acclimatization, clothing, and degree of activity. Research on acclimatized men, performing skilled but not strenuous tasks for comparatively short periods and stripped to the waist, has shown that performance declines significantly at effective temperatures of 83° to 87°F. The best level was at 81°F. effective temperature, which corresponded to the men's everyday climatic environment. However, clothed persons working regularly for longer spells require a materially lower environmental temperature, especially when the work is strenuous.

18. In general, an effective temperature up to 76° or 78°F. is acceptable for most ranges of work, if the more strenuous types are performed stripped to the waist. In the Royal Navy the upper limit recommended for clothed men is 80°F. The United States Army at Fort Lee, Virginia, found that by suspending training activities when the effective temperature reached 83°F., heat casualties, previously prevalent, were eliminated. It is possible to do sedentary work at 90°F. effective temperature, but owing to discomfort it may not be particularly productive; the utmost limit for strenuous work however is best placed at 80°F. At high temperatures the wet bulb temperature can also be used to assess the limiting conditions for work. The generally accepted level is 90°F. (wet bulb), but specially trained men can, for short periods, work at considerably higher wet bulb temperatures; for example, fire fighters in South African gold mines at 110°F. for 20 minutes. It is also recorded that men employed in welding leaks, inside a tank in a floating dock at Massawa, were able to endure, for one-hour shifts, a wet bulb temperature of 100°F. and an effective temperature of 102°F.

CLOTHING

General

19. The chief function of clothing is protective, but owing to other related factors clothing problems are far from simple. Military forces must be provided with scales of clothing suitable for operations in all climates. Adaptations are necessary for camouflage, yet uniforms must be comfortable and the value to morale of smartness must not be forgotten. Special fabrics that will resist penetration by thorns and biting insects may be necessary, especially in jungle campaigns. The impregnation of materials with insecticides, insect repellents and other protective chemicals is a growing practice. Special protective clothing is required for various industrial occupations.

20. Working clothing must be designed so that men can carry out their normal duties without hindrance. In order that physical efficiency may be maintained in any environment, clothing must help to control the rate of body heat loss within the comfort range. Consequently in designing clothing assemblies, the activity of the wearer, temperature, humidity, wind velocity, and the degree of protection required from other topographical hazards have a most important bearing.

Theoretical Assessment of Clothing Requirements

21. The theoretical assessment of insulation provided by clothing is based on the fact that a layer of still air next to the skin discourages heat transmission by convection. The insulation by this layer is proportional to its thickness up to ¼ inch; beyond this it grows less effective but still increases up to 1 inch, even if the space is partially filled with textile

fabric of any description. The purpose of clothing is to imprison a layer of air of the optimum thickness and to keep it stagnant. It is this still air that is the essential insulator, although the fabric helps in addition by reducing loss of heat by radiation.

22. Until the atmospheric temperature approaches skin temperature, heat loss is 75 per cent. by radiation and convection, 25 per cent. by insensible perspiration. Above air temperatures of 31°C. (88°F.), heat is almost entirely dissipated by evaporation. At low atmospheric temperatures the aim is to control the dissipation of heat and to maintain comfort, represented by a skin temperature of 33°C. (91°F.). Body heat is generated by metabolic activity, which at rest represents 50 kilocalories per square metre body surface per hour. As 25 per cent. of this, at lower atmospheric temperatures, is dissipated by insensible perspiration, only the remainder can be controlled by the clothing. The insulation required to exert this control is related to activity, which governs the generation of heat, and to the atmospheric temperature which governs its rate of dissipation. From this relationship the theoretical insulation of clothing can be calculated. The result is expressed in Clo units.

23. **The Clo.** By definition, the Clo is the amount of insulation to be provided by the clothing to keep a resting man comfortable in still air at 21°C. (70°F.), comfort being represented by a skin temperature of 33°C. One Clo represents the insulation provided by everyday clothing. The value is doubled by an overcoat and can be quadrupled by special clothing. These values can, however, be greatly reduced if movement is imparted to the imprisoned air by penetration of wind through the clothing. So besides providing the necessary insulation, clothing should as far as possible be wind-proof.

24. It is emphasized that even when a theoretical basis for insulation requirements has been determined, little progress has been achieved in devising the clothing assembly. Problems of weight, ventility, water repellancy, functional effectiveness and sizing remain, and call for careful research and trials. The R.A.F. range of cold-weather clothing has been evolved, bearing these problems in mind.

Cold-Weather Clothing

25. In this country in winter it is the practice to add layers of underclothing, sweaters or pullovers to the type of clothing normally worn in summer. This is quite contrary to the principles of cold-weather clothing which are based on the insulating qualities of garments and not their quantity. Insulation depends mainly on the air trapped in the clothing material and between the layers of the assembly. Since moisture is a relatively good conductor of heat, this air must be kept dry. It must as far as possible be left undisturbed as well; so over the inner insulating layers of the assembly a wind-proof layer must be worn, with closures specially designed to prevent the ingress of wind, rain, and blown snow. The outer garment must fit well over the inner layers and there must be head protection in the form of a hood. Normally over the inner assembly battle-dress or cold-weather flying dress is worn. Over these, wind-proof cold-weather overalls are put on and finally the main outer garment. the parka. The items, which comprise the inner and outer assemblies developed for wear by R.A.F. aircrew and ground personnel, are as follows.

26. **String vest.** The conventional type of knitted string vest is used. Cotton cord, which is not harsh and does not stretch unduly, has been specially selected for its manufacture. Nylon is inferior to cotton. Nylon vests lose shape easily and the material is less comfortable, because it is not absorbent. The vest is hip length and has shoulder pieces of woven cotton fabric. The armholes are cut fairly low to facilitate arm movement and to enable the elbows to be easily pressed to the sides of the body.

27. **Underpants.** Lightweight cotton underpants have been developed with a minimum of seams in the crutch to enhance comfort. The waist adjustment is by small buttons and a flap, as elastic waistbands deteriorate. They may be worn instead of or in addition to pyjama underpants.

28. **Pyjama-Type Underpants.** These underpants are ankle length and made of woven cotton. They are loosely shaped to the body, so ensuring the maximum use of the entrapped insulating air. The waistband fits over the string vest and has a front adjustment. One or two pairs may be worn, with or without lightweight underpants, depending on the degree of insulation required.

29. **Shirt.** The shirt is 70 per cent. wool and 30 per cent. cotton, with collar attached and cuffs that button. The open collar ensures complete freedom of movement and allows free ventilation which can be controlled when necessary.

30. **Sweater.** A ribbed sweater, with long sleeves and a slit neck, is available as an optional item of cold-weather clothing. The wrists are narrowed to reduce bulk and the ribbing allows a snug, but not tight, fit over the clothes beneath. The slit neck permits ventilation, controllable according to conditions by a draw-cord.

31. **Neck Square.** This is a large scarf made of knitted string, like a dish cloth. By controlling the neck closure it can be used to vary ventilation, and is also useful for protecting the face when sleeping under conditions of extreme cold in a sleeping bag.

32. **Handwear.** Wristlets, woollen mitts and outer mitts are essential and must not be too tight. Wristlets cover the back of the hand and leave the fingers exposed. Mitts promote the warmth of the fingers by keeping them together.

33. **Headwear.** The cold-weather cap is of the ski-type with a wide peak. It is made of ventile material and lined with serge, having a continuous flap, folding down from inside the crown, to provide protection for the temples and ears in mild wind-chill conditions.

34. **Footwear.** The mukluk assembly consists first of three pairs of woollen socks, sized to fit over each other without wrinkling or restriction. Over these is worn a single-layer duffle sock and an insole, which fits the mukluk accurately. Mukluks are roomy mid-calf boots which are insulated and have a heavy rubber sole, the uppers being of canvas. On each side of the closure of the mukluk are five D-rings, through which the lace runs. A wide gusset prevents the snow penetrating the closure; for the same purpose a draw-cord is fitted around the top of the mukluk, which is designed primarily for extreme dry-cold conditions. For wet-cold conditions there is a stout, roomy, leather boot of conventional shape, with which a modified mukluk assembly can be worn.

35. **Parka.** This is an outer garment, of nearly knee length, of wind-proof ventile material. It has inside a quarter-inch wool pile, which to prevent soiling, is covered by a lining of lightweight ventile material or gaberdine. It has a mohair pile collar into which is rolled the hood, which can be closed around the face by a drawstring. The parka is closed by an open-ended slide fastener protected by a single button flap, with a second flap in case the slide fastener fails. Projecting forwards is a cowl, with a malleable copper wire ring inserted in front so that it can be adjusted to protect the face from the wind. The inner edge of the cowl is lined with wolverine fur.

36. **Flying Dress.** The cold-weather flying dress has been designed so that it can be worn as a uniform. The design aims at an assembly functionally effective for aircrew use, with freedom of movement ensured by the use of pivot sleeves. The trousers are of conventional type and supported by braces, to avoid restriction around the waist and impairment of ventilation. The material used is gaberdine.

37. **Cold-Weather Overalls.** The flying overall is a two-piece garment consisting of blouse and trousers. The latter are wind-proof, being made of ventile material, and supported on hook-type braces for ease of release. The blouse is of gaberdine lined with sewn-in kersey shirting. It has a tailpiece which can be buttoned up between the legs to control ventilation and prevent the skirt of the blouse rucking up. It also has a kersey-lined hood for head protection, which by means of an elastic insert at the side can be pulled over the flying helmet whilst in flight. The cold-weather overalls provided for gound personnel consist of a jacket and trousers of wind-proof material.

Hot-Weather Clothing

38. In temperate climates, in conditions where a smart uniform dress is demanded, the only permissible method of relieving the heat load is to remove the tunic or battle-dress blouse. The value of this measure is limited, as a belt and tie must be worn, which restrict ventilation. In the tropics and sub-tropics, and varying to some degree with local regulations, khaki drill shirts, or bush jackets, and shorts or slacks are worn as working dress. On formal occasions a khaki tunic, collar and tie are worn. There is now no special everyday tropical headgear, but in some circumstances jungle hats or ski-type caps may be worn. Flying clothing consists of underpants, string vest, and an overall of light-weight material.

39. It has been shown in tropical conditions that, for those who have developed an adequate sun tan, the nearest decent approach to nudity provides the greatest comfort. An exception is in hot dry climates with a strong wind blowing; under these conditions evaporative cooling becomes insufficient to prevent direct heating of the unclothed body by the hot wind and by radiation. Clothing which provides adequate ventilation helps to promote evaporation, even under conditions of high humidity and low air movement. A string vest worn under a bush shirt, with shorts, allows trunk ventilation and aids evaporative cooling.

Impregnated Clothing

40. When troops are in contact with louse-infested populations, or if facilities for personal hygine are restricted, impregnation of clothing with DDT is an effective precaution against lice. Shirts and underclothes should be treated by dipping in an oily solution of DDT after laundering. Protection against the mite vectors of scrub typhus is similarly obtained

by smearing clothing with DBP, DMP or M.1960 (see Chapter 10). Wide-meshed head nets treated with DDT or a repellent give some measure of head protection against mosquitoes. Impregnation of clothing is not satisfactory against mosquitoes, but fabrics may be used through which the mosquitoes cannot bite.

Protective Clothing for Special Occupations

41. Protective clothing is required in occupations which are wet, dirty or offensive, and in many where there is exposure to toxic substances, skin irritants, or risk of injury. It includes headgear, outer garments, aprons, gloves, and footwear. Goggles and respirators are more specialized forms of protective clothing. Its use is, to some extent, a confession of failure to find other effective and practicable means of eliminating occupational risks.

42. The use of protective clothing is not a reliable preventive measure, as misuse or negligence may destroy its value. Design, fit, and maintenance must be of a high standard; otherwise agility and dexterity will be impaired, chafing particularly at neck and wrists may occur, and there may be excessive sweating. If the clothing is allowed to become dirty, this, together with chafing and sweating, may cause the dermatitis it is meant to prevent. Design must aim at ensuring that there are no loose ends, buttons or projections which by catching in machinery might cause accidents. For the same reason the clothing must be kept in good repair. These factors demand careful thought before recommendations for protective clothing are made; subsequently close supervision of its use is essential.

43. **Headgear.** Reinforced helmets to prevent head injury from falling objects are worn by miners, but in other industries in England are relatively uncommon. The most everyday example is the wearing by motor cyclists of crash helmets. Various forms of cap and turban are worn to protect against dirt or toxic substance, for example by cooks and those exposed to trinitrotoluene respectively. The design of this type of headgear is particularly important for women working near machinery. They should wear a pattern that completely encloses the hair to prevent the tragic scalping accidents that occur when long hair is caught in revolving machinery.

44. **Overalls.** Overalls and dustcoats are the protective outer garments normally worn. Fit and design have already been mentioned. When the normal stout textile material is insufficient, for example in handling kerosene or strong oxidant fuels, special proofed fabric is necessary. The problem then arises of adequate ventility, to prevent excess sweating and inadequate heat loss, particularly in hot climates. If it is impracticable to provide sufficient ventilating apertures in the clothing, it is necessary to supply air cooling within the suit. The ventilated aircrew suit is an example, but other designs are also used in industry.

45. **Aprons.** Aprons should be worn over overalls when additional protection is required. Depending on the process the aprons may be of leather, rubber, or asbestos. Radiographers wear leaded aprons.

46. **Gloves.** Gloves are used to prevent absorption of toxic substances, for protection against thermal and chemical burns, for prevention of electric shock, laceration or crush injuries, and to protect the skin from grease and other irritants likely to cause dermatitis. Depending on the

purpose, gloves may be of rubber, neoprene, leather, or cotton. They may be specially reinforced. One disadvantage of gloves is that they impede dexterity; another is that they may become impregnated with sweat, grease, and other substances which cause skin irritation. Rubber gloves in particular encourage sweating of the hands; consequent maceration of the skin renders it more susceptible to infection. Misuse of gloves may in fact cause rather than prevent dermatitis.

47. **Footwear.** In industry it is most important that everyday boots and shoes fit well and are kept in good repair. Efficiency is impaired by wet, cold, and painful feet. Accidents can occur through worn heels and flapping soles. Flimsy slippers or plimsolls offer no protection from injury. Special footwear in the form of clogs or rubbers are necessary in wet processes. Boots with heavy external tongues are used in industry to prevent burns when manipulating molten metal. Reinforced toecaps are fitted to boots, or incorporated in their manufacture, in industries where the risk of crush injuries is high, for example in mining.

48. **Goggles.** Goggles may be required to protect against dazzle, dust, flying particles, splashes, fumes, vapours, and radiation. In some processes protection against more than one of these hazards may be necessary. Goggles, by British Standards definition, enclose a space in front of the eyes to protect them from injury. This differentiates them from spectacles which, again by definition, are frames, with or without side shields, holding lenses in front of the eye. Spectacles are only effective against glare or dazzle; they must have lenses of the correct tint for their purpose. Goggles, of varying closeness of fit, are essential to protect the eyes in all directions from the other types of hazard. They must, however, be ventilated to prevent fogging and must allow as wide a field of vision as possible. For protection against flying particles, lenses must be of toughened or laminated glass. The essential requirements for various types of industrial eye protectors, other than for glare and radiation, are contained in British Standard 2095/54. Welders' goggles must protect against the radiation emitted by the oxyacetylene flame or electric arc, as well as against flying particles. Special opaque lenses are required, varying according to the intensity of the radiation. These are dealt with by British Standard 679/47, which specifies various tints according to the degree of protection necessary.

Respirators

49. There are three main classes of respirator and it is important to differentiate these, as the use of the wrong type, particularly in an emergency, may be disastrous. In this connection reference should be made to British Standard 2091/54.

(*a*) *Breathing Apparatus Type.* Breathing apparatus may be self-contained, the air or oxygen being fed to the close-fitting face-piece either from gas bottles or compressors. Alternatively it may be of the remote type, in which air is drawn from an uncontaminated source through a long tube by the action of the wearer's lungs. Such appliances protect against oxygen deficiency, carbon monoxide, and excessive concentrations of all toxic substances in the atmosphere, whether in the form of vapour, fume, or dust.

(*b*) *Gas Mask Type.* This group have face-pieces shaped to cover the eyes, nose, and mouth in an air-tight manner. Air is breathed in through a canister containing a filter unit, capable of affording

TABLE 9

THE SELECTION OF RESPIRATORY APPARATUS

APPARATUS	INDICATIONS
BREATHING APPARATUS *Types available in R.A.F.* 21F/611. Apparatus, remote breathing. 21F/86F. Apparatus, breathing, compressed air.	(*a*) Should be used in all cases of doubt concerning the effectiveness of a respirator. (*b*) Should be used in any confined space and in any vessel, room, building, or other enclosed space, where there is likely to be a deficiency of oxygen. (*c*) Should always be used in rescues from confined spaces.
CANISTER RESPIRATORS *Types available in R.A.F.* 22G/1527. Masks, dope and paint spraying. (Half-mask pattern. Does not protect against anything but dope and paint fumes or dusts.)	(*a*) Should only be used in the presence of gases against which they are designed to protect. (See British Standard 2091: 1954). (*b*) Should only be used in the presence of dust and fume, if fitted with a particulate filter. (*c*) Should NEVER be used in atmospheres deficient in oxygen. (*d*) Should NOT be used when gases are present in a high concentration. (*e*) Should NEVER be used for rescue from confined spaces.
DUST RESPIRATORS *Types available in R.A.F.* 22G/444. Respirators, dust.	(*a*) These are only suitable for the removal of non-voltatile dust from the air. (*b*) Should NOT be used in presence of gases or toxic vapours. (*c*) Should NEVER be used in atmospheres deficient of oxygen. (*d*) Should NEVER be used in rescue work.

Note: The service respirator (gas mask) is specifically designed for protection against certain concentrations of chemical warfare agents. It should not be used for protection in the way in which specific industrial-type respirators are used. It gives no protection against nitreous fumes, carbon monoxide or dioxide; it protects for less than 5 minutes against low concentrations of petrol fumes, dry cleaning agents, methyl bromide, hydrogen cyanide, and ammonia.

protection for a limited time against toxic substances in vapour or dust form; the filter must, of course, be appropriate to the poisonous substance concerned. These respirators can be used only in atmospheres that are respirable apart from the presence of the toxic substance. The filter units are usually designed to protect against both vapours and dusts, but this may not be so if intended to protect only against a specific vapour or gas.

(*c*) *Half-Mask Type*. In this type the face-piece covers the mouth and nose only, giving no protection to the eyes. Air may be breathed through the same kind of canister used with the gas mask type, or through filters designed to protect only against dust. In some designs the amount of charcoal gas-absorbent in the filter unit is so small that it will give protection only against low concentration of toxic vapour. Half-mask respirators resemble gas masks, as they cannot be used in atmospheres that are irrespirable owing to oxygen deficiency.

50. Respirators, although provided, may not be worn because of unwillingness or negligence. Failure to maintain respirators properly will result in their inefficiency and loss of repute. Weekly inspections are advisable by a competent person, who should keep a record of these and of any defects found. This will help to ensure careful handling and the renovation of parts that have deteriorated, before a significant defect develops. It is also advisable for all respirators, except breathing apparatus types, to be personal issues. Table 9 is a guide to the selection of the right type of respirator.

BUILDINGS

General

51. Buildings help to control the environment by giving shelter; they should, too, provide the optimum standards of heating, lighting, and ventilation for their purpose. According to circumstances they may be temporary, semi-permanent or permanent structures. Ill-design and poor construction may affect health adversely. Medical advice may therefore be appropriate at any phase of building, from initial planning to the time the premises are taken over for occupation (Q.Rs. 1452, 1461, 1751, and 1758 refer).

Siting

52. The function of a building will largely determine its site on an existing station; and availability of land may further restrict the choice. Even if alternative sites are limited, consideration is necessary of the sub-soil, accessibility, the availability of water and drainage, the orientation of the building to the sun, the prevailing wind, and the proximity of potential nuisances or threats to health.

53. **Sub-Soil.** The sub-soil should be porous to ensure good surface drainage, but firm enough to provide sound foundations. Porous rock, chalk, and deep gravel are the best types. It is, however, rare to find an ideal sub-soil; it is commonly necessary to provide sub-soil drainage to improve the porosity of the ground and remove surface water.

54. **Accessibility.** The accessibility of premises by roads and public transport may have a bearing on choice of site, in particular when the transport of personnel and equipment is likely to be of importance. It is naturally more economical to use existing facilities than to construct special means of access.

55. **Water.** A sufficient supply of potable water is always essential for premises where men are to live or work; usually the most suitable and the most convenient source is a public supply.

56. **Drainage.** It is always preferable to connect a new building to existing drainage where possible. The drainage may be to a local authority sewer or an R.A.F. sewage plant. The fall to either must be sufficient to ensure an adequate flow; and it is important to ascertain whether they can take the extra load from new buildings.

57. **Orientation of the Building.** To get as much sun as possible, dwellings in the northern hemisphere should face South-South-East. Larders and kitchens should be so placed that the sun reaches them only in the evening during summer. When several buildings are being planned close to each other, their mutual screening effects should be studied.

58. **Prevailing Wind.** Shelter from the prevailing wind will reduce penetrating dampness and the chances of storm damage. Protection may be afforded by building under the lee of rising ground or of woods. It may be advisable to plant trees to give eventual shelter, but these should not be so close to buildings that light is obstructed.

59. **Proximity to Nuisances or Threats to Health.** Premises should not be sited near places where any offensive trade or process is carried out, or near any potential reservoir of disease. Buildings in general should not be sited within 100 yards of a sewage works; in the R.A.F. the minimum distance for dwellings, except under exceptional circumstances, is 200 yards. Potential reservoirs of infection are particularly important abroad; examples are mosquito breeding areas and native villages.

Density

60. To prevent overcrowding, impairment of natural lighting and general loss of amenity, the number of houses and residents in a given area must be limited. The highest permissible net residential density in the United Kingdom is 200 persons per acre. The density of barrack blocks should seldom be more than 100 persons per acre and of married quarters 8 and 12 residences per acre in rural and urban districts respectively.

61. Close grouping of buildings may sometimes be unavoidable. Whenever possible, however, open spaces should be provided in the interests of recreation and amenity in general. But unnecessary dispersal should be discouraged; the distance between working and living sites should not be more than one mile, unless there are very good reasons to the contrary; in tropical climates it should be even less.

Plans

62. The term "plans" should refer only to architects' drawings, but it is also applied loosely to working drawings and specifications. Architects' plans show the shape of the building, its layout and its site in relation to the points of the compass and adjacent features, such as other buildings or roadways. Working drawings tell the builder of the constructional details, including drainage. Both are drawn in plan and elevation, but in addition working drawings show sections. Specifications are written directions stating the nature of the material that is to be used, its exact composition, the required dimensions, and the method to be employed in its working.

63. The Air Ministry Works Directorate are responsible for the design, construction, and maintenance of all R.A.F. buildings (Q.R. 1743). When plans are made for new work which may affect sanitation or accommodation, or have other health implications, commanding officers are required by Q.R. 1751 to ask the advice of the medical officer. Before final approval of such plans they should be scrutinized by the principal medical officer at command headquarters (Q.R. 1452).

64. The following points require study when plans are submitted for medical scrutiny:—

(*a*) Site.
(*b*) Layout.
(*c*) Floor area (to exclude overcrowding) and window space.
(*d*) Heating, lighting, and ventilation.
(*e*) Damp prevention.
(*f*) Sanitary accommodation.
(*g*) Plumbing and drainage.

Types of Construction

65. A considerable variety of building construction is found on stations, ranging from temporary wartime huts to permanent buildings erected either before or since the Second World War. Temporary buildings may be constructed of wood or single (4½ inch) brick or may be of the Nissen type. They are now erected only for short-term projects or when the future of a station is uncertain. They possess many inherent disadvantages, being difficult to maintain, troublesome to heat (even when lined), and often subject to damp from condensation. Their normal expectation of life is 5 to 10 years.

66. An improvement on these is semi-permanent construction in the shape of Seco huts or Nissens of improved design. The latter have either sky-lights or dormer windows to improve lighting, and brick ends; they may be lined and can be centrally heated. Seco huts are of sturdy construction, have good window space, reasonable insulation, and can be kept warm. In fact, the latter verge on permanent construction.

67. Normally the term permanent construction is reserved for orthodox brick buildings with wall thickness exceeding 9 inches. These are obviously the most satisfactory type of building, have a long life and are adopted whenever possible.

68. In the tropics the type of construction has in the past depended very much on the local resources of building material. Temporary huts have been made in the basha style of Malaya, of mud and wattle in Africa, or of sun-baked mud and straw bricks elsewhere. It is best to use properly fired bricks when these are available, but excellent substitutes in the form of prefabricated aluminium buildings have been tried recently. The problem in the tropics consists of ensuring insulation, shade, ventilation, and air movement. There are secondary problems to do with fly and mosquito proofing, harbourage of pests, and the attacks of white ants on timber. Cavity walls and double roofs help to insulate; lofty ceilings reduce radiation effects. By painting roofs white, a proportion of the radiation is reflected and internal radiation is thereby cut down. Shutters and verandahs (about 10 feet wide) help to provide shade. If the building is raised some four feet off the ground on pillars,

and the space underneath left open, cooling is improved by the ventilation this provides. Ventilation is also improved if through air currents are ensured by having windows on opposite sides of each room. This means careful thought in the layout of buildings; central corridors with rooms opening from each side should be reduced to a minimum.

Barrack Blocks

69. Permanent barrack blocks consist of centrally heated brick buildings, with two or more floors on each of which are separate bathrooms and lavatories. Each barrack room accommodates approximately 20 men, the space allowance for each being not less than 67 square feet. Some have smaller rooms as well to house 3 or 4 men, while N.C.Os. usually have a room or cubicle to themselves. Other accommodation on each floor allows for the drying of clothes and the storage of cleaning materials. It is emphasized, however, that barracks of this standard are by no means universal and that many airmen are still accommodated in temporary buildings of varying degrees of inferiority. In hutted camps it is not uncommon to find lavatory and washing facilities in blocks common to several huts and separated from them by varying distances. This arrangement, enforced by wartime economy, is conducive neither to comfort nor health. Attention to heating, ventilation, lighting, and decoration can however make even the poorest accommodation tolerable.

Messes

70. Airmen's messes are used only for feeding, other amenities being provided by their institute. In officers' and sergeants' messes, however, domestic, social and recreational facilities are all provided under the one roof. Airmen's messes should be spacious, well lighted, warm in winter and well ventilated in summer. Decoration is important and everything must be done to make the room as attractive as possible. At the entrance there should be lavatories and arrangements to hang hats and coats. There should be enough seating for at least half the unit strength at one time. The dining hall should be separated from the kitchen by a servery long enough to provide room for sufficient servers to reduce queueing to a minimum. Adjacent to the servery should be a hatch to receive dirty plates. At the exit arrangements are needed for the washing of personal eating utensils, such as fork, spoon, knife, and mug. The layout of the dining hall is important; it should ensure that the streams of men, from the entrance to the servery, from here to the tables and back, past the dirty-plate hatch and thence to the exit, interfere as little as possible with each other.

Kitchens

71. Kitchens should be constructed so that food can pass on a continuous line system from delivery, to storage, through preparation, cooking, and serving to the consumer. Besides the kitchen itself ancillary rooms are required for dry goods, bread and vegetable storage, refrigeration, vegetable, meat and pastry preparation, and staff accommodation. Sanitary facilities are essential, including a wash basin in the kitchen itself. The kitchen yard must include a properly constructed swill compound.

72. Kitchen floors must be smooth and impermeable but not slippery. Tiles are the best material. They should slope to sunken drainage gutters covered with removable iron grids. Walls are best tiled to a height of at

least six feet. Above the tiles (or when tiling is not possible) walls and ceilings should be painted with a durable and washable gloss paint. The angles between walls and floors should be coved to facilitate cleaning and for the same reason dead space beneath fittings must be avoided. Kitchens must be big enough to accommodate all the necessary equipment and to allow cooks to work in safety and comfort. Adequate natural and artificial lighting is essential; natural ventilation alone is rarely enough and exhaust ventilation hoods over cooking ranges and steam-operated equipment are usually most desirable. Fly-proofing is necessary and all drainage from kitchens should pass through grease traps.

Offices

73. The design should allow for adequate space, lighting, warmth, and ventilation, besides freedom from noise. The Gowers Committee have recommended a minimum space per occupant of 47 square feet and a warmth standard of at least 60°F. after the first hour's work. Natural lighting should whenever possible be to the left of desks and should be not less than 2 per cent. Daylight Factor at desk level. Artificial light should give at least 10 foot-candles at desk level and be arranged so that shadows are not cast on the work. The opening space to allow for natural ventilation should be about 5 per cent. of the floor area. All possible measures to reduce noise should be taken (see Chapter 14), but what is practicable may be very much limited by circumstances.

Workshops

74. The function of a workshop will mainly govern its design and layout. Minimum standards are described in the Factories Act, 1937 and this subject is discussed in Chapter 14.

Foundations

75. The foundations of a building are laid in trenches, the width and depth of which depend on the weight of the building and the firmness of the sub-soil. These trenches are filled with a mixture of cement, sand, and aggregate. If the sub-soil is insecure the foundations may be constructed as a reinforced concrete raft extending completely over the area of the building, or as a concrete table built on the top of piles. On the foundations are built wide footings, which take the weight of the walls and distribute the pressure evenly over a greater area of the foundations (see Figs. 55 and 56).

Walls

76. External walls are load-bearing and may be of solid or cavity construction. Cavity walls are usually preferable; they consist of two independent walls usually each of 4½ inches, separated by a 2-inch space. This space provides insulation and prevents the access of damp. The resistance to damp of external walls is also increased by rendering, rough-cast finish, tile or slate hanging, and by weather boarding.

77. Internal or partition walls may take some weight, for example of the floor above. In this event they are normally solid and of brick construction. If they are not load-bearing they may be comparatively flimsy and made, for instance, from beaver boarding on wooden frames, lath and plaster, or breeze blocks.

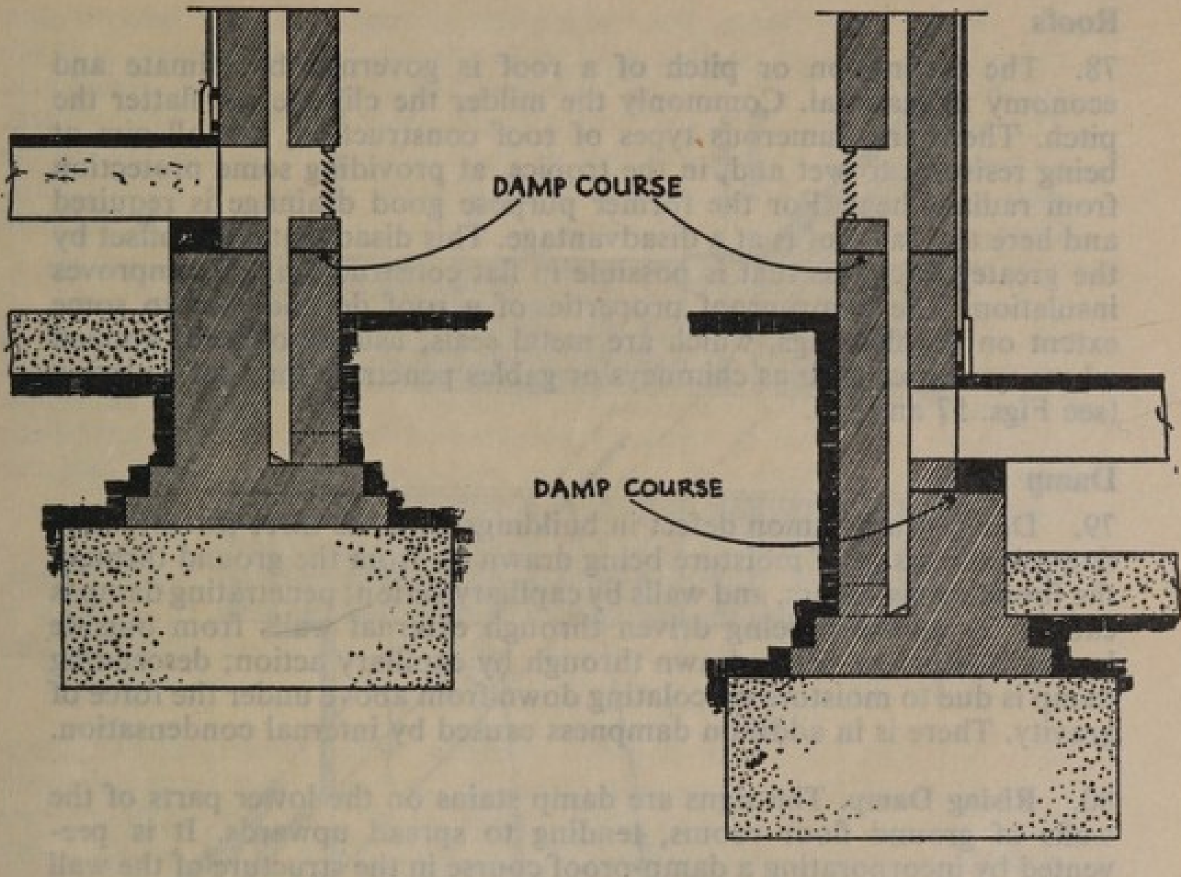


FIG. 55. DAMP COURSES IN HOLLOW WALLS

Floor above ground level   Floor below ground level

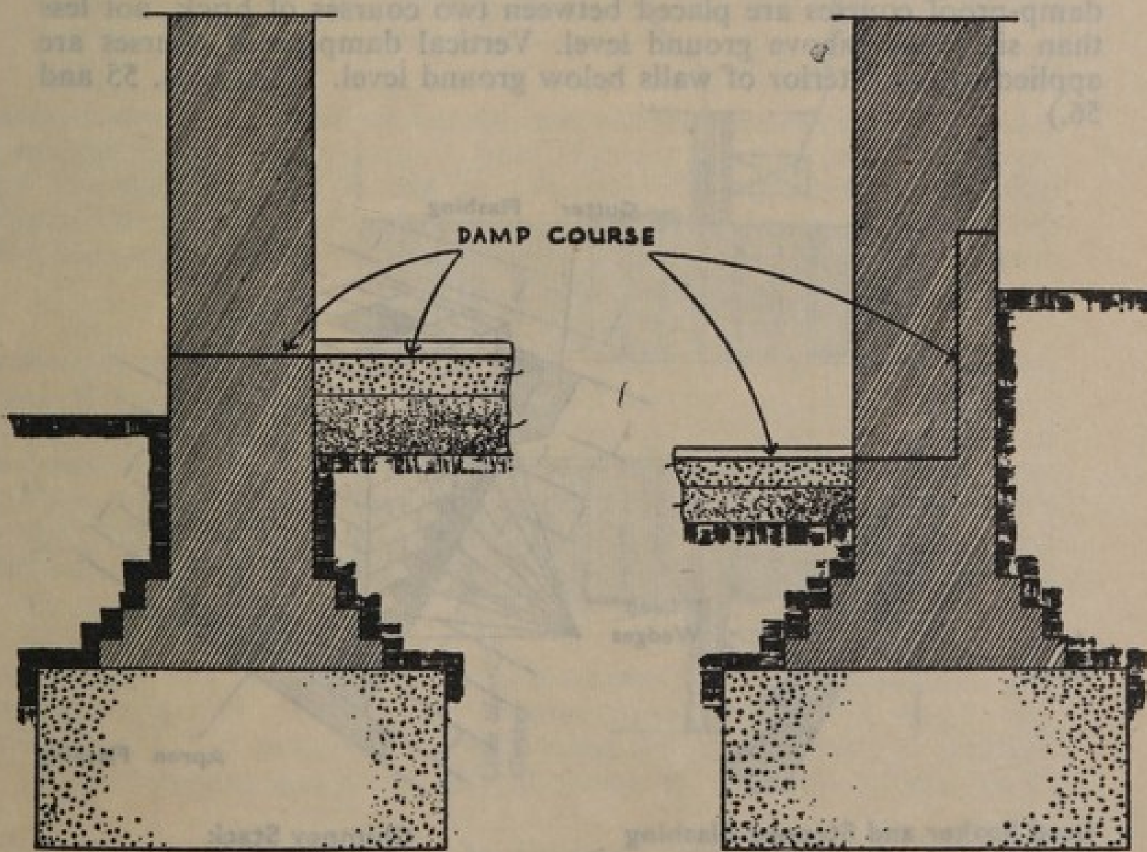


FIG. 56. DAMP COURSES IN SOLID WALLS

Floor above ground level   Floor below ground level

Roofs

78. The inclination or pitch of a roof is governed by climate and economy in material. Commonly the milder the climate the flatter the pitch. There are numerous types of roof construction, but all aim at being resistant to wet and, in the tropics, at providing some protection from radiant heat. For the former purpose good drainage is required and here the flat roof is at a disadvantage. This disadvantage is offset by the greater thickness that is possible in flat construction; this improves insulation. The damp-proof properties of a roof depend also to some extent on the flashings, which are metal seals, usually of lead, applied where structures such as chimneys or gables penetrate the roof covering (see Figs. 57 and 58).

Damp

79. Damp is a common defect in buildings. It takes three forms: rising damp is the result of moisture being drawn up from the ground through the foundations, floors, and walls by capillary action; penetrating damp is caused by moisture being driven through external walls from outside by the weather or being drawn through by capillary action; descending damp is due to moisture percolating down from above under the force of gravity. There is in addition dampness caused by internal condensation.

80. **Rising Damp.** The signs are damp stains on the lower parts of the walls of ground floor rooms, tending to spread upwards. It is prevented by incorporating a damp-proof course in the structure of the wall to inhibit the passage of moisture by capillary action. Damp-proof courses may be vertical or horizontal and consist of such materials as lead, slate, asphalt, bitumen, or vitrified stoneware. Horizontal damp-proof courses are placed between two courses of brick, not less than six inches above ground level. Vertical damp-proof courses are applied to the exterior of walls below ground level. (See Figs. 55 and 56.)

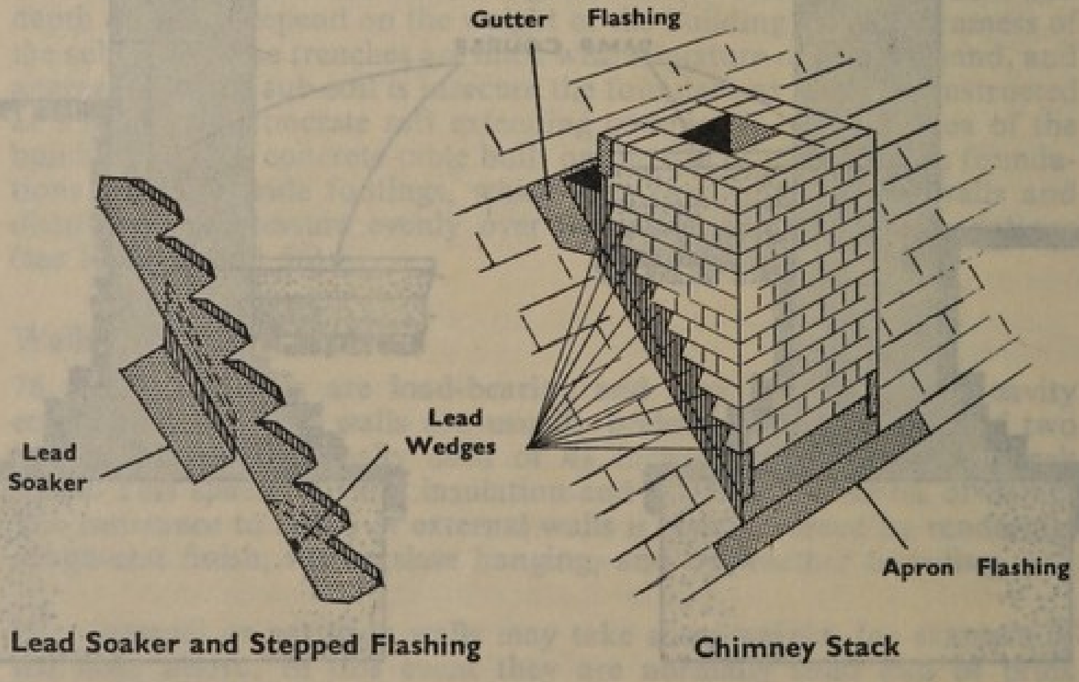


FIG. 57. CHIMNEY FLASHINGS

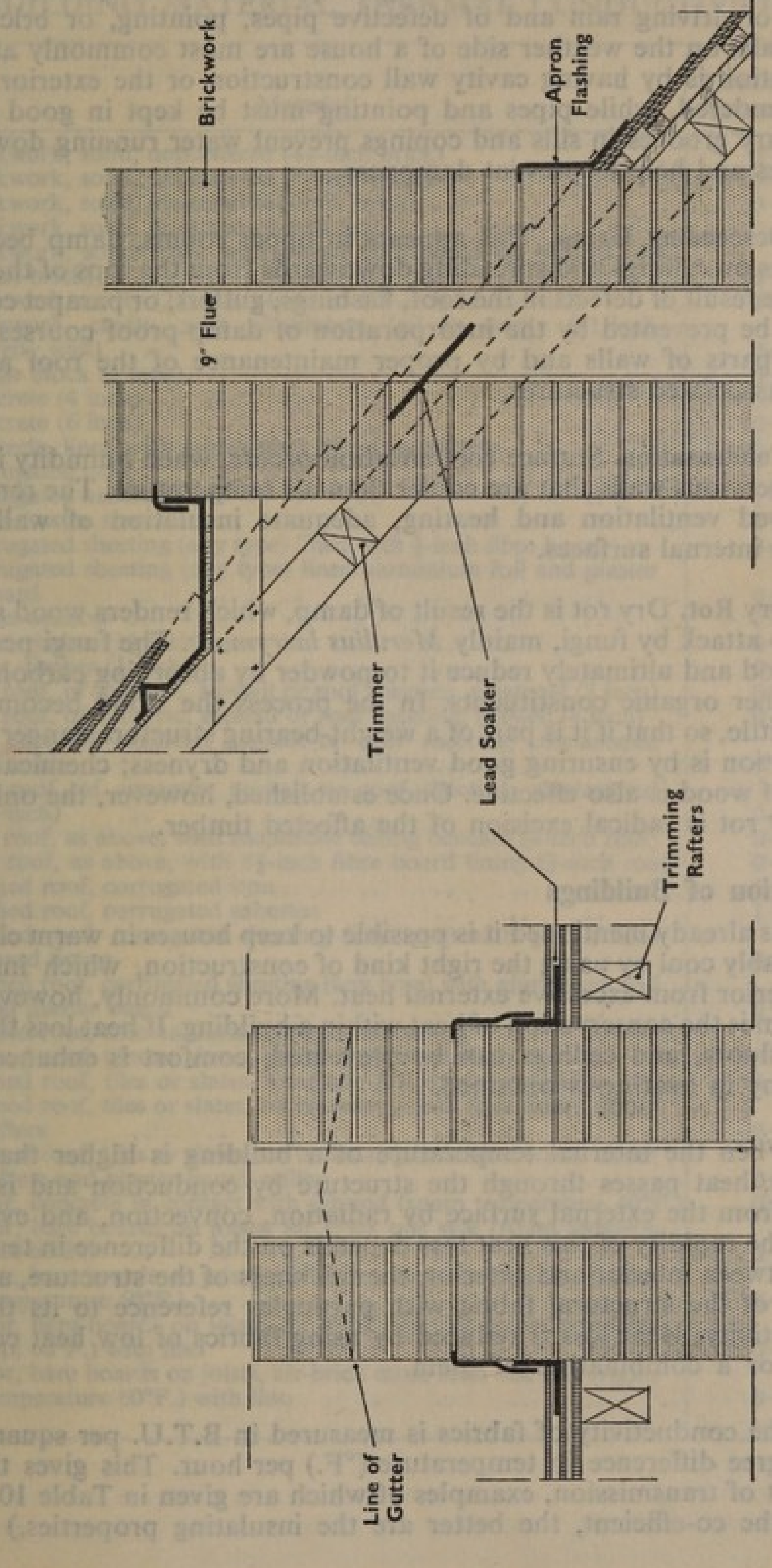


FIG. 58. CHIMNEY FLASHINGS

Section across slope of roof — Section along slope of roof

81. **Penetrating Damp.** Penetrating damp appears on the interior face of walls, in isolated patches tending to spread in all directions. It is the result of driving rain and of defective pipes, pointing, or brickwork. The walls on the weather side of a house are most commonly affected. Prevention is by having cavity wall construction or the exterior of the wall rendered, while pipes and pointing must be kept in good repair. Capillary grooves in sills and copings prevent water running down wall surfaces and help to prevent dampness.

82. **Descending Damp.** This appears in upper rooms, damp becoming obvious on ceilings and spreading downwards from the tops of the walls. It is the result of defects in the roof, flashings, gutters, or parapet copings. It can be prevented by the incorporation of damp-proof courses in the upper parts of walls and by proper maintenance of the roof and the other associated structures.

83. **Condensation.** Surface condensation occurs, when humidity is high, on impervious walls that are cooler than air temperature. The remedy is improved ventilation and heating, adequate insulation of walls, and porous internal surfaces.

84. **Dry Rot.** Dry rot is the result of damp, which renders wood susceptible to attack by fungi, mainly *Merulius lacrymans*. The fungi penetrate the wood and ultimately reduce it to powder by absorbing carbohydrate and other organic constituents. In the process the wood becomes dry and brittle, so that if it is part of a weight-bearing structure danger arises. Prevention is by ensuring good ventilation and dryness; chemical treatment of wood is also effective. Once established, however, the only cure for dry rot is radical excision of the affected timber.

Insulation of Buildings

85. As already mentioned it is possible to keep houses in warm climates reasonably cool by using the right kind of construction, which insulates the interior from excessive external heat. More commonly, however, the problem is the conservation of heat within a building. If heat loss through walls, floors, and ceilings can be prevented, comfort is enhanced and economy in heating is obtained.

86. When the internal temperature of a building is higher than that outside, heat passes through the structure by conduction and is dissipated from the external surface by radiation, convection, and evaporation. The rapidity of this heat loss depends on the difference in temperature between interior and exterior, the thickness of the structure, and the nature of the structural fabric with particular reference to its thermal conductivity. Heat loss is reduced by using fabrics of low heat conductivity, or a combination of them.

87. The conductivity of fabrics is measured in B.T.U. per square foot per degree difference in temperature (°F.) per hour. This gives the co-efficient of transmission, examples of which are given in Table 10. (The lower the co-efficient, the better are the insulating properties.)

88. The heat loss through the fabric of a building is calculated from the area of each of the fabrics concerned, their respective co-efficients of transmission, and the difference between the internal and external temperature. (The formula is given in para. 93.) The improvement

TABLE 10

BUILDING MATERIAL THERMAL CONDUCTIVITIES

Material	Coefficient of Transmission
Brickwork, solid, unplastered (4½-inch brick)	0·59
Brickwork, solid, unplastered (9-inch brick)	0·39
Brickwork, solid, plastered (4½-inch brick)	0·53
Brickwork, solid, plastered (9-inch brick)	0·36
Brickwork, solid, lined with ⅜-inch fibre board on battens (4½-inch brick)	0·25
Brickwork, cavity (2 inch), plastered (11-inch cavity wall)	0·27
Brickwork, cavity, with aluminium foil in cavity (11-inch cavity wall)	0·15
Breeze block (4 inch)	0·20
Concrete (4 inch)	0·75
Concrete (6 inch)	0·61
Concrete, lined with ⅜-inch fibre board on battens	0·26
Corrugated iron	1·5
Corrugated asbestos	1·4
Flat asbestos sheets	1·0
Corrugated sheeting (any type) lined with ⅜-inch fibre board	0·31
Corrugated sheeting (any type) lined aluminium foil and plaster board	0·13
Single window	1·0
Door, timber (1½ inch)	0·4
Door, timber (1 inch)	0·5
Flat roof, of concrete, asphalt or roof sheeting, plastered (3 inch)	0·63
Flat roof, of concrete, asphalt or roof sheeting, plasted (4 inch)	0·58
Flat roof, of concrete, asphalt or roof sheeting, unplastered (3 inch)	0·72
Flat roof, of concrete, asphalt or roof sheeting, unplastered (4 inch)	0·66
Flat roof, as above, with suspended ceiling beneath (4-inch roof)	0·35
Flat roof, as above, with 8⅜-inch fibre board lining (3-inch roof)	0·33
Pitched roof, corrugated iron	1·5
Pitched roof, corrugated asbestos	1·4
Pitched roof, corrugated sheeting (any type) with ⅜-inch fibre board lining	0·31
Pitched roof, corrugated sheeting (any type) with aluminium foil and plaster board	0·13
Pitched roof, tiles or slates, unlined; no ceiling	1·5
Pitched roof, tiles or slates, unlined; plaster ceiling	0·56
Pitched roof, tiles or slates, lined and felted; plaster ceiling	0·32
Pitched roof, tiles or slates, on battens; ⅜-inch fibre board under rafters	0·41
Pitched roof, tiles or slates, on battens; ⅜-inch fibre board under rafters and plaster board ceiling	0·2
Floor, concrete in contact with ground (room temperature 60°F.)	0·13
Floor, bare boards on joists, air brick one side (room temperature 60°F.)	0·24
Floor, bare boards on joists, air brick more than one side (room temperature 60°F.)	0·32
Floor, bare boards on joists, air brick one side (room temperature 60°F.) with lino	0·20
Floor, bare boards on joists, air brick more than one side (room temperature 60°F.) with lino	0·28

that can result from insulation is shown in the following comparison between two huts of different construction, each 30×20×10 feet in size.

	Hut A	Co-efficient	Area (square feet)
Roof (flat)	3-inch concrete, unplastered	0.72	600
Walls	4½ inch, plastered (solid)	0·53	900*
Floors	Bare boards on joist	0·24	600
Windows (6)	Plain	1·0	60
Doors (2)	1-inch timber	0·5	40
			(*less windows and doors)

	Hut B		
Roof (flat)	3-inch concrete; lined fibre board	0·33	600
Walls	4½-inch solid brick; lined fibre board	0·25	900*
Floor	Boards on joist with lino	0·2	600
Windows (6)	Plain	1·0	60
Doors (2)	1-inch timber	0·5	40

If the temperature difference is 30°F., the heat loss per hour from each hut is:—

	Hut A	Hut B
From roof	0·72×600×30=12,960 B.T.U	0·33×600×30=6,040 B.T.U.
From walls	0·53×900×30=14,310 ,,	0·25×900×30=6,750 ,,
From floor	0·24×600×30= 4,320 ,,	0·2 ×600×30=3,600 ,,
From windows	1·0 ×60 ×30= 1,800 ,,	1·0 × 60×30=1,800 ,,
From doors	0·5 ×40 ×30= 600 ,,	0·5 × 40×30= 600 ,,
	Total 33,990 B.T.U.	*Total* 18,790 B.T.U.

Thus simply by lining the hut and laying linoleum, its ability to retain heat is about doubled at low outdoor temperatures. By ensuring that the walls were relatively warm this would increase environmental comfort, and to maintain a given internal air temperature in the region of 60°F. only about half the fuel would be required in comparison with an unlined hut.

Sanitary Fittings

89. Baths, showers, wash basins, lavatories and urinals are provided according to scales, which vary according to circumstances. Tables 11 to 16 are guides to the scales normally allowed.

HEATING

Introduction

90. People can acclimatize to a wide range of conditions, but those living in temperate climates have never been able to adapt themselves to doing without artificial domestic heating. As a result the hearth has become the centre of the home, and heating is essential if health, comfort and efficiency are to be maintained.

91. Questions of cost, the natural resources of a country, atmospheric pollution, and other similar subjects are closely related to the problem of heating, but in this chapter discussion is limited to:—

(*a*) The premises to be heated.

(*b*) The warmth to be provided.

(*c*) The methods of providing warmth.

TABLE 11

SANITARY ACCOMMODATION SCALES (per cent. establishment) R.A.F. OFFICERS

	PEACE				INTERIM		WAR	
	Mess	Sleeping Quarters			Establishments above 100 Mess	Establishments above 100 Sleeping Quarters	Communal Site	Sleeping Site
		G.C. and above	Other Senior Officers	Junior Officers	All Officers		All Officers	
Baths	—	1 number	50	25	Nil	12·5	Nil	Nil
Showers	—	1 number	50	10	Nil	12·5	20	Nil
Basins	10	100	100	100+1 in each lavatory	5	30	3 In Mess	13
Urinals	6	Nil	Nil	Nil	4	Nil	2 In Mess	Nil
W.Cs.	5	100	50	20	4	15	3 In Mess	10

TABLE 12

SANITARY ACCOMMODATION SCALES (per cent. establishment) R.A.F. SENIOR N.C.Os.

	PEACE		INTERIM		WAR	
	Mess	Sleeping Quarters	Establishments above 100 Mess	Establishments above 100 Sleeping Quarters	Communal Site	Sleeping Site
Baths	Nil	15	Nil	8	Nil	Nil
Showers	Nil	5	Nil	8	7	Nil
Basins	5	100+1 in each lavatory	4	25	3 In Mess	13
Urinals	5	6	3	4	3 In Mess	2
W.Cs.	2	15	3	10	3 In Mess	4·5

TABLE 13

SANITARY ACCOMMODATION SCALES (per cent. establishment)
R.A.F. CORPORALS AND AIRMEN

	PEACE		INTERIM		WAR	
			Establishment above 800			
	Mess	Sleeping Quarters	Mess	Sleeping Quarters	Communal Site	Sleeping Site
Baths	Nil	5	Nil	2	Nil	Nil
Showers	Nil	10	Nil	10	4	Nil
Basins	1	25	0·75	16·7	1·5	12·5
Urinals	0·75	6	0·75	4	2	2
W.Cs.	1 number	12	1 number	8	3	3

TABLE 14

SANITARY ACCOMMODATION SCALES (per cent. establishment)
W.R.A.F. OFFICERS

			Basins	W.Cs.	Baths	Showers
PEACE	MESS	*Establishment* 10–25 26–100 101–150	1 number 2 " 3 "	1 number 2 " 3 "	Nil	Nil
	QUARTERS	Gp. Off. & above	100	100	1 number	100
		Other Sen. Offs.	100	50	1 number	100
		Jun. Offs.	100+1 in lavs.	25	30	Nil
		2 Jun. Offs. only	100	1 number	1 number	1 number
INTERIM	MESS		1 number or 5% whichever is the greater	1 number or 4% whichever is the greater	Nil	Nil
	QUARTERS		100 or 25 where grouped	20	20	5
WAR	COMMUNAL SITE		3 (minimum 1 in Mess)	5 (minimum 1 in Mess)	Nil	Nil
	SLEEPING SITE		13	12	2	10

TABLE 15

SANITARY ACCOMMODATION SCALES (per cent. establishment)

W.R.A.F. SENIOR N.C.Os.

	PEACE		INTERIM		WAR	
	Mess	Sleeping Quarters	Mess	Sleeping Quarters	Communal Site	Sleeping Site
Baths	Nil	16	Nil	10	Nil	2 (A)
Showers	Nil	4	Nil	4	Nil	4 (A)
Basins	*Estab.* 20-50 2 number 51-100 3 ,, 101-200 4 ,, 201-400 4 ,,	100+1 in each lav.	1 number or 3% whichever is the greater	100 or 25 where grouped	3 Minimum 1 number	13
W.Cs.	*Estab.* 20-50 2 number 51-100 2 ,, 101-200 3 ,, 201-400 4 ,,	20	1 number (C) or 3% whichever is the greater	18	5 Minimum 1 number	9 (B)

Notes: A. One bath minimum. Baths and showers not to exceed 6 per cent. Where the number of baths meet this requirement, no showers are required.

B. 4 per cent provided in separate latrine blocks; 5 per cent night latrines, minimum of one being attached to each sleeping hut.

C. For female visitors; if for female visitors and W.R.A.F. N.C.Os. where latter are established, 2 to 3 basins and 1 to 2 W.Cs.

TABLE 16

SANITARY ACCOMMODATION SCALES (per cent. establishment)

W.R.A.F. CORPORALS AND AIRWOMEN

	PEACE		INTERIM		WAR	
	Mess	Sleeping Quarters	Mess	Sleeping Quarters	Communal Site	Domestic Site
Baths	Nil	12	Nil	10	Nil	1 (A)
Showers	Nil	3	Nil	2	4	4 (A)
Basins	1 (C)	25	2 number	20	1·5	12·5
W.Cs.	1 number	18	2 number	15	5	7 (B)

Notes: A. One bath minimum. Bath and showers not to exceed 5 per cent. Where number of baths meet this requirement, no showers are required.

B. 4 per cent. provided in separate latrine blocks; 3 per cent. night latrines, with a minimum of one attached to each sleeping hut.

C. Below 250 total establishment, the 1 per cent. basins may be slightly exceeded if W.R.A.F. established; otherwise the 1 per cent. basins for W.R.A.F. counts against the entitlement for the total establishment.

Thermal Properties of Buildings

92. The heat needed to keep a building warm depends on the level of warmth required, on the atmospheric temperature, and on the thermal properties of the building. Once the temperature of the building has been raised above that of the air outside, there will be a constant loss of heat to be made good. This loss occurs by the transmission of heat through the structure of the building, by the escape of warm air, and by the infiltration of cold air. The rate of loss is influenced by the type of building material and the size, design, and exposure to the elements of the building.

93. Heat loss through building material is governed by its thermal conductivity. This is represented by the transmission co-efficient, expressed in British thermal units (B.T.U.) per square foot per degree difference (Farenheit) per unit inch thickness per hour. Examples are given in Table 10. In England, the difference between 30°F. outdoors and 65°F. indoors is often used as a standard temperature difference. Heat loss is calculated from the formula:

$$H = AU\,(T - t)$$

Where:

H = heat loss transmitted through wall, roof, ceiling, floor, or glass in B.T.U. per hour.
U = co-efficient of transmission.
T = inside temperature °F.
t = outside temperature °F.
A = area of wall, glass, roof, ceiling, or floor in square feet.

94. This formula is applied in turn to each area of ceiling, walls, and floor where the building material is different, so that the total heat loss in B.T.U. per hour will be the sum of H values for each such area; doors, windows, skylight and so on being assessed separately.

95. Heat loss by infiltration is more difficult to assess. It depends on the porosity of the building material, the fit of windows and doors, the presence of flues, the ventilation required, and the exposure of the building to the wind. As a working rule it is easiest to estimate air change according to the theoretical requirement of the occupants. For example, in living rooms the amount of air available for each person should be 600 cubic feet per hour, in large offices and workshops 1,000 cubic feet per hour. The heat needed to make good the loss is obtained by multiplying the air volume required per hour by its specific heat (0·02 B.T.U. per cubic foot at 45°F.) and by the temperature difference. To the sum of heat loss by infiltaration and transmission is added an allowance for the height of the premises, varying from 2 per cent. at 14 feet to 40 per cent. at 70 feet.

96. The final result gives the number of B.T.U. per hour required to provide and maintain the pre-determined level of warmth. The provision of heat sources can then be planned, or the adequacy of existing ones checked, if their rate of heat emission is known. Examples of such ratings are given in Table 17.

Degree of Warmth Required

97. The degree of warmth required depends on the nature of the work of the occupants of the premises, and on whether comfort or a minimum tolerable temperature is the object. It is preferable to express comfort in

TABLE 17

HEATING APPLIANCES—HEAT EMISSION RATES

HOT WATER PIPES	Emission B.T.U. per foot per hour			
Size	Temperature difference (°F.) between air and mean water temperature			
	60°	80°	100°	120°
1 inch	41	60	80	101
2 inch	70	101	135	171
3 inch	95	138	184	234

RADIATORS	Emission B.T.U. per square foot per hour			
Type	Temperature difference (°F.) between air and mean water temperature			
	70°	80°	100°	120°
Hospital, 3 inch	116	139	185	234
Plain, single column	100	120	160	202
Plain, two column	98	117	156	197

GAS FIRE

Heat emission calculated from fuel consumption and calorific value of gas.

Let V = consumption of gas in cubic feet per hour.

C = calorific value of gas in B.T.U. per cubic feet (usually between 350 and 560 B.T.U.). Then emission = CV B.T.U. per hour. To allow for wastage and inefficiency divide by 4. To convert to therms divide by 100,000.

ELECTRIC FIRE

Heat emission calculated from consumption of electricity.

Let K = Kilowatts consumed per hour.

Then emission = 3415K B.T.U. per hour.

SOLID FUEL FIRE

Heat emission calculated from fuel consumption and its calorific value.

Let F = fuel in lbs. consumed per hour. Average calorific values of solid fuel may be taken as 12,000 B.T.U. per lb.

Then emission = 12,000 F. B.T.U. per hour. To allow for wastage and inefficiency divide by 5 or 6.

Note: These examples are approximations to enable the making of rough estimates. They should not be used if a precise answer is required.

terms of the effective or equivalent temperature scale, rather than to use the air temperature alone. In the Department of Scientific and Industrial Research Post-War Building Study Number 19, the following recommendations are made for dwellings:—

Living rooms	— Equivalent temperature		62 to 66°F.
	Air	,,	58 to 62°F.
Bedrooms	— Equivalent	,,	50 to 55°F.
Halls and passages	— ,,	,,	50 to 55°F.

98. In workplaces where the work is mostly sedentary, the Factories Act, 1937, requires that after the first hour the temperature shall be not less than 60°F. This is a minimum requirement and it is generally accepted that 65°F. is the optimum, although lower temperatures are acceptable when the work is strenuous. However, below 60°F. efficiency tends to deteriorate and the accident rate to increase. It is a reasonable working rule to centre the warmth of workplaces at the lower end of the effective temperature comfort zonewhere work is strenouus and towards its upper limit where it is sedentary. In England the zone is 57° to 63°F. (effective temperature) in winter, in summer 60° to 66°F.

Methods of Heating

99. Heat can be supplied entirely from one source, or background heating to provide warmth up to a minimum level can be supplemented by another source, which will ensure general or local comfort continuously or intermittently as required.

100. Heating appliances emit heat either by convection or radiation or a combination of the two. Convection heaters warm the air directly and the heat is distributed by air currents caused by the difference in density of the air at different temperatures. From radiant sources heat is transmitted through the air without warming it and is liberated only when the heat rays impinge on a surface. The air is warmed by contact with the surface and the heat again distributed by convection.

Open Fires

101. Most of the heat from open fires is lost up the chimney. In well-designed grates a certain amount of radiation is reflected from the firebrick back and heat is derived by radiation and convection from the warmed chimney breast. Open fires are only 15 to 20 per cent. efficient; they are dirty, labour consuming, and generally uneconomical. However, they form a centre of interest in a room and give it a cheerful appearance. They also help ventilation, but in doing so may cause objectionable draughts. Modern grate design has overcome many of these disadvantages. Continuous burning reduces labour, external air supplies eliminate draughts, and convection heating is increased by special devices.

Stoves

102. Closed stoves burning solid fuel may be 50 per cent. efficient. They warm by radiation and convection. The slow continuous-burning type of stove is useful for providing background heating. Some modern designs have doors which can be opened to give the cheerful appearance of an open fire. The somewhat primitive design of stove used in barrack huts is often their sole source of warmth. These give off a fierce local heat without much effect on the general level of warmth. Their performance is improved if the main part of the flue is within the room, although this may cause rather steep temperature gradients. If the main

part of the flue is outside the building, the heat from it goes to waste and rapid cooling may reduce its drawing power; this interferes with combustion and causes the possibility of down-draughts blowing back smoke and fumes. Stoves in barrack blocks often have to withstand rough handling; they require regular inspection, especially at the beginning of the heating season. It is necessary to ensure that they are free from cracks and other defects, that the dampers work properly, and that the flue is in good repair and fits securely into the stove. These precautions are essential to prevent carbon monoxide mishaps.

103. Paraffin stoves may be of use as a local source of heat if the background heating is insufficient. To be effective they require careful maintenance. In addition, if low-grade paraffin with a high sulphur content is used, excess sulphur dioxide fumes are produced. These cause respiratory irritation and on account of their acid reaction are harmful to furnishings. The maximum allowable concentration of sulphur dioxide in the general atmosphere is 10 parts per million. (See Chapter 16.)

Electrical and Gas Fires

104. Electric fires are 100 per cent. efficient, gas 60 per cent. The open element types heat predominantly by radiation. Their main use is to supply intermittent heat when background heating is either absent or does not provide the necessary level of comfort; they are particularly useful in bedrooms, dining-rooms, and offices. Both gas and electricity have the advantage that heat is readily on tap and that they are labour saving. Some designs improve their performance as space heaters by incorporating air heating devices so that convection is increased. In these the elements are usually enclosed.

105. Electric panel and tubular heaters warm mainly by invisible radiation. High-temperature panels emit at about 500°F. and are mounted high up on walls, facing obliquely downwards. Low-temperature panels and tubular heaters are usually placed low down in a room, often little above floor level. Owing to the risk of fire or burns their emitting temperature is only around 160°F. As all these heaters are mainly radiant, they must be adjusted to play on room occupants if they are to provide a direct sensation of warmth.

Central Heating

106. Central heating may be used to provide background heating or full warmth. In the most common type of installation hot water is circulated from a central boiler by gravity or pump. The heat is distributed from exposed pipes or radiators, about 60 to 70 per cent. by convection and the remainder by radiation. Steam may be used instead of water, the great advantage being that heat can be transmitted distances of up to one-third of a mile; this is far further than can be achieved with water. Steam heating, however, involves serious technical difficulties, although steam vacuum heating, in which steam is circulated at a pressure of less than one atmosphere, overcomes most of these.

107. Instead of using hot-water radiators, pipes may be embedded in ceilings, walls or floors. This is known as the panel system and gives a very uniform warmth. Most commonly the panels are placed in the ceiling, which is warmed to about 100°F. This so reduces convection currents that the temperature gradient between floor and head level is virtually eliminated. If the panels are in the floor the temperature should be about 70°F.

108. Heating may be combined with ventilation; for example, in the plenum system the incoming ventilating air is heated to the level required. Another system is to distribute warmth by circulating the air of the room through heating coils with fans. This is known as the unit heater system and is commonly used in large workshops and hangars.

Unit Heaters

109. Unit system heaters consist of a heating coil through which air is driven by an electric fan. This coil is warmed by hot water, steam, gas, or electricity. The degree of warmth produced depends on the amount of air blown through the coil. Unit heaters are an economical means of warming large, high premises such as workshops or hangars.

110. One type of unit heater is a floor fitting and discharges air horizontally, usually at a height of about 8 feet with a velocity of some 1,500 feet per minute. The other type is a roof fitting; the air is discharged either horizontally or vertically, louvres being fitted so that the direction of the air current can be adjusted. Horizontal roof fittings discharge air at 400 to 1,000 feet per minute, vertical at 1,200 to 2,000 feet per minute.

111. In high buildings unit heaters should discharge air with a high velocity at a temperature of 100°F. to 110°F. If a height for the fitting of at least 12 feet above floor level is impracticable, the air velocity and output temperature must be reduced, and compensated by providing more heaters. The difficulty is to achieve sufficient warmth without subjecting people to objectionable blasts of hot air and without causing draughts or unacceptable temperature gradients. To this end siting of heaters and the direction of the air current are as important as output velocities and temperatures. It has been found that if the air flow is directed towards the walls and to the colder parts of the building, effective air circulation is achieved. Air at 135°F. can spread horizontally from an airstream 15 to 20 feet for every 100 feet per minute velocity. Thus floor unit heaters (1,500 feet per minute) sited not more than 200 feet apart are complementary. The spacing of roof fittings should be similarly arranged.

Insulation of Buildings

112. Insulation of buildings, by preventing heat loss, reduces the amount of heat required to ensure warmth. It is of similar importance in keeping buildings cool in hot climates. Insulation is discussed in paras. 85 to 88.

VENTILATION

General

113. The virtues of fresh air are proverbial; the problem is to supply enough air in such a way that the resultant atmosphere is wholesome, fresh, and comfortable. Ventilation and heating are closely related, for air movement is an important factor in thermal comfort, air exchange affects the amount of heat required to warm a building, and the amount of natural ventilation that can be tolerated depends on the seasonal air temperature.

Standards of Ventilation

114. At one time the standard of ventilation was judged by the amount of carbon dioxide in the atmosphere. However, no harm is caused physiologically by breathing an atmosphere containing 2 to 3 per cent. of

carbon dioxide and even higher concentrations can be tolerated. In fact the carbon dioxide in a room rarely exceeds 1 per cent. under the poorest conditions of ventilation. Thus the amount of carbon dioxide present gives little information, although the rate of change in its concentration can be used to assess air exchange.

Body Odour

115. American workers have used disappearance of body odour as a standard by which ventilation may be judged. It is, however, subject to a number of variables, for example the number and personal cleanliness of room occupants. The following data show the relationship between the nature of occupants, density of occupation, and the ventilation rate required to prevent body odour becoming disagreeable.

Occupants	*Air space per person (cu. ft.)*	*Air supply required per person per min. (cu. ft.)*
Sedentary adults of average social status	100	25
	200	16
	300	12
	500	7
Labourers	200	23
School children of poor class	200	38

116. Body odour decreases as the space per head increases, as the pungency of the source diminishes and, up to a certain point, as the ventilation improves. Beyond this point, further increase in the supply of fresh air is not followed by equivalent removal of odour. The main reason is that at greater rates of ventilation, odour diffuses less completely; thus a proportion of the ventilating air fails to remove its full share. The ventilation rate for a living room recommended by the Building Research Board (Post-War Building Report No. 15) is 10 cubic feet per person per minute. By body odour standards this rate would apply to an air space of between 300 and 500 cubic feet per person; this corresponds quite well with the size of an average sitting room. However the L.C.C. requirement for theatres and cinemas is a ventilation rate of 1,000 cubic feet per head per hour, which is on the low side according to the above data. But a higher rate would probably not be proportionately effective. Ventilation rates, sufficient to remove body odour, may not always be sufficient to provide enough air movement to ensure comfort, especially in summer. Such rates may also be misleading in factories, where there may be other odours and atmospheric impurities to consider, or where workshops may be so sparsely occupied that air space per person is misleading.

Methods of Ventilation

117. Methods of ventilation may be natural, artificial, or a combination of both. In any system there is a circuit starting and finishing in the outside air. The circuit consists of inlets and outlets, between which air is driven by an aeromotive force or head. The head is supplied by natural or mechanical means, but in either case its relationship to the air flow is expressed by the equation:

$$H = R\,V^2$$

Where:

H = feet of air (aeromotive force)

R = resistance in pounds per square foot

V = rate of air flow in cubic feet per second.

Natural Ventilation of Dwellings

118. The head or aeromotive force, in natural ventilation, is supplied by the wind and by gravity. Air is driven into a building by perflation, either through ventilating space designed for the purpose or through cracks around windows and doors or through porous building material. Air is removed by aspiration, caused by air flow over or past ventilating spaces, especially chimneys or flues. The extent of the ventilating space, the strength of the wind and its direction are the main factors governing the rate of ventilation. Warm air is less dense than cold, so that gravity causes the former to rise and the latter to fall; thus convection currents are set up. A difference of temperature between the air inside and outside a room will consequently cause air circulation through ventilating spaces. Heating appliances, open fires, and warmed flues contribute in this way to room ventilation.

119. In a completely closed room the ventilation rate by the infiltration of air through crevices and building fabric is unlikely to be greater than 1 air change per hour. This is further reduced by the fitting of weather strips to windows and treating wall surfaces with impermeable materials. In flueless rooms it is necessary to provide ventilators to ensure air change when windows are closed. Small air gratings, with an opening space of approximately 50 square inches, are effective and do not cause draughts. However, the velocity and direction of the wind has considerable influence, as the following example shows:—

	Ventilation rates in air changes per hour	
Wind direction	*Closed room*	*Room with 50 sq. inch ventilator*
0°	0·4	1·2
45°	0·4	1·6
90°	0·4	3·0
Wind velocity at 45°		
1 m.p.h.	0·4	0·9
3 m.p.h.	0·5	1·9
5 m.p.h.	0·6	2·9

Ventilation rates of this order may be obtained from ventilating bricks or gratings. Increased rates are obtained from flues, heated and unheated, or windows.

Flues

120. The wind is the main ventilating factor in an unwarmed room with an unheated flue. For example, in a room with a flue measuring 81 square inches and a chimney throat of 53 square inches, it has been shown that opening the flue increased the ventilation from 0·7 to 2·1 changes per hour. An increase in wind velocity from 9 m.p.h. to 22 m.p.h. raised the air changes per hour from 1·8 to 3·5. The effect of heating the flue resulted in a rise of the ventilation rate from 1·6 to 4·5 changes per hour. The aspirating effect of an unheated flue is inversely proportional to its height owing to the increased air resistance. This is the opposite to heated flues where the ventilating power is directly proportional to the height of the column of hot air they contain.

Windows

121. The effectiveness of window ventilation depends, primarily, on the area of opening space. In consequence casement windows, the whole of which can be opened, are better than sash windows. The strength and direction of the wind naturally influence the ventilation rate for any

given area of window space, and the extent of room ventilation depends on the placing of the windows. With wide-open windows, placed on opposite sides of a room, 30 changes of air per hour have been observed. The presence of a flue increases the amount of ventilation to be obtained from a window. With a window open 2 inches, and the flue closed, ventilation of around 1·8 changes have been increased to over 5 on opening the flue. In good weather with the wind in the right direction almost any amount of window ventilation can be provided. The problem is rather to ensure comfortable ventilation when, for climatic or other reasons, windows cannot be opened or can be opened only a very little.

Natural Ventilation in Factories

122. The natural ventilation of workshops and other work places is less simple in comparison with that of dwellings. Besides the removal of body odour and respiratory products, there may be odours, vapours, fumes, steam and other impurities in the atmosphere as the result of the processes concerned. And if extensive general ventilation is necessary, it may be difficult to ensure comfort. On this account artificial ventilation is on many occasions desirable, but very often natural ventilation alone is available.

123. The main factors in the natural ventilation of factories are the design and placing of windows, supplemented by special types of ventilator, and the disposition of heating appliances. A general guide to the amount of opening space required is that it should be 5 per cent. of the floor area. Angus' Opening Factor is a more precise measurement. The factor is obtained by dividing the total opening space, including doors, windows, and ventilators, in square feet, by the cubic content of the room or building, in cubic feet, and multiplying the result by 1,000. Suitable factors for various premises and work are:—

	Factor
Offices	3
Laboratories	4-5
Light manual work (cool processes)	5-6
Light manual work (moderate heat)	6-7
Heavy work in great heat	9-11

124. In narrow buildings adequate cross ventilation can be provided by windows alone. It helps to prevent draughts if the windows are of the hopper type, which deflect the air upwards. The ventilation can be improved two to five times if heating appliances are sited below windows. The warm air rising from radiators mingles with the upward flow of air from the hopper windows, so that distribution is improved and draughts are prevented. In broader rooms, or in those having windows on one side only, roof ventilators are necessary to aid extraction, unless mechanical exhaust ventilation is to be used. Double-sided ridged louvres are commonly used, but cause down draughts when the wind blows at right angles to them. Roof cowls, such as the Robertson ventilator, are better and, according to their size, have a known performance under given conditions. Roof ventilators cannot work efficiently unless there is sufficient air inlet space; the lack of this also causes objectionable draughts, since air is drawn into the room through spaces not intended for the purpose. Inlet space should be at least twice the outlet area, placed four or five feet above the floor and provided with louvres, so that the incoming air can be directed upward or downward as required. Such inlet space is especially important in winter, when climatic conditions often prevent the adequate opening of windows.

Artificial Ventilation

125. For rooms or premises where much heat, dust or fumes are generated, or where there is insufficient space allowance for the occupants, natural ventilation will not be enough and artificial ventilation must be used. This may be applied as an exhaust system, a positive pressure or plenum system, or a combination of the two. The provision of filtered, washed air that is dried or humidified and heated or cooled, as necessary, constitutes full air conditioning.

Exhaust Ventilation

126. Mechanical exhaust ventilation is used as a supplement to natural ventilation, usually in order to eliminate areas of stagnation and to ensure adequate air exchange. It can also however be used in the absence of natural ventilation. The system consists of an extractor fan to provide the aeromotive force, with adequate air inlets, to provide the continuity of the air circuit. The extractor fans used are usually of the propeller or axial flow type, revolving at comparatively high speeds. Their efficiency is lessened by marked increase or decrease in the speeds for which they are designed and by any resistance to the airflow. Their output can be computed from the formula:

$$C = KND^3$$

Where:

C = airflow in cubic feet per minute.
K = a constant, usually taken as 0·6.
N = number of revolutions per minute.
D = diameter of fan in feet measured from blade tip to blade tip.

Examples of the performance of propeller fans are:—

D (feet)	*N (r.p.m.)*	*C (cubic feet per min).*
1	1,300—2,100	780—1,260
1·5	850—1,400	1,720—2,835
2	630—1,050	3,020—5,040

The fan should be screened on its output side to prevent resistance from the wind. Air inlets must be adequate. They should be provided low down on the opposite side of the room, with a total surface area of not less than three times the total disc area of the fans. Provision should be made if necessary for warming the air at the inlet. Short-circuiting of air from the inlets occurs if there are open windows or other apertures near the extractor fan; this must be avoided, otherwise the benefits of exhaust ventilation are wasted.

Pressure Ventilation Systems

127. Positive pressure, or plenum systems, are adopted when very large volumes of air must be supplied. Exhaust systems are unsuitable for this purpose as they are liable to create draughts. Air is driven into the building by centrifugal fans and distributed by ducting. There is no need for special air outlets. A slight positive pressure is set up, which prevents air leaking into the building to cause draughts near doors or windows. Added advantages are that the air can be delivered exactly where it is most required and, if necessary, it can on entry be warmed, filtered, and its humidity adjusted.

128. The centrifugal type of fan is used. The advantage of this type of fan is that it can drive air against pressure. The air is distributed through ducts, or trunking, planned to ensure an even flow to all parts of a

building. The maximum air velocities in ducts are limited by the noise caused by the passage of the air. The following velocities are 10 per cent. below the maximum compatible with quietness and are recommended in America; main ducts 1,200 to 1,800 feet per minute; branch ducts 800 to 1,000 f.p.m.; branch risers 800 f.p.m. If higher velocities are necessary, the resistance of ducts must be minimized or the trunking must be insulated to reduce noise. The following formula can be applied to ascertain the volume of air delivered from ducts:

$$Q = AV \times 60$$

Where:

Q = volume of air in cubic feet delivered per hour.
A = area of the cross section of the duct in square feet.
V = velocity of the air as it leaves the duct in feet per minute.

129. The air from a plenum system must be delivered at a velocity that sets up a certain degree of turbulence. The direction of delivery must ensure satisfactory mixing with the atmosphere without causing discomfort. Unheated air is best discharged horizontally, warm air downwards. Inlet air velocities vary from 300 to 2,000 feet per minute. At the higher velocities good distribution, without draughts or areas of stagnation, is obtained by fitting diffusers at the mouth of ducts. Alternatively, when air is delivered from narrow slots good turbulence is obtained by the entrainment of the room air. The slots should be a quarter or half inch wide and, if multiple, must be at least six inches apart; otherwise the air stream behaves as though it came from a single outlet of area equivalent to the sum of the slots.

Combined Exhaust and Pressure Systems

130. Added control is obtained by supplementing a pressure system with exhaust ventilation; this eliminates any stagnant pockets of air in places not reached by the pressure flow. This system may be applied to general ventilation, or in the form of local exhaust ventilation where it is necessary to prevent the contamination of the atmosphere with some toxic or objectionable product. Because of the flexibility of this system in general ventilation, large volumes of air can be supplied in densely occupied areas and can be restricted where occupants are few.

Local Exhaust Ventilation

131. Certain industrial and other processes give off dusts, fumes, and vapours, which may be harmful or objectionable. If it is not practicable to provide a harmless substitute or to enclose the process, local exhaust ventilation will be necessary in addition to ample general ventilation. Local ventilation is always an exhaust system; it may be applied through extraction ducts, the fan being central; or there may be multiple units, each consisting of hood, duct, and fan, at each point where the harmful substance originates.

132. A sufficient volume of air must be extracted to entrain the harmful material before it can diffuse into the atmosphere; the air velocity must be sufficient to overcome any opposing force (such as gravity) acting on the material, and to prevent the latter from settling out in the ducting. Air volume and velocity thus depend partly on the nature of the substance to be removed; for example, both must be greater to exhaust dust than to exhaust vapour. The manner in which the substance is produced is also important; particles of dust, thrown out at high speed from a grinding wheel, require a different design of exhaust system from that required for fumes rising slowly from a large tank containing a solvent.

133. The exhaust ventilation system should be arranged so that the air is drawn over the process away from the operator. The hood should be placed as near as possible to the point of origin of the harmful substance; this is because the air velocity decreases approximately according to the square of the distance from the mouth of the duct. The mounting of the duct must not of course, interfere with the process. The hood should be large enough to prevent escape of dust or fumes by diffusion around its edges; it may be mounted above, below, or in the horizontal plane, according to the nature of the substance. The following are typical air velocities:—

Air Velocity	*At Point of Origin of Substance*	*In Exhaust Ducts*
Fumes, vapours, gases	50—100 f.p.m.	2,000 f.p.m.
Paint spraying, fine dust	100—200 ,,	3,000 ,,
Moderate dust	200—500 ,,	3,500 ,,
Coarse dust, metal filings	500—2,000 ,,	4,500 ,, and over.

Canopy Hoods

134. Another form of exhaust ventilation is provided by canopy hoods, mounted directly over vats or tanks, forges, or kitchen ranges. They are used when the material can be drawn off by an air current of low velocity (*e.g.* 25 to 75 f.p.m.). Such hoods should extend laterally from the apparatus six inches per foot elevation; they should have a surrounding apron, to prevent entrainment of air from elsewhere than over the apparatus. Hoods should be placed as low as is practical to increase effectiveness.

Lip Exhaust Systems

135. High-velocity ventilation at surface level is required for tanks containing potentially toxic solvents or electroplating solutions, especially chrome. This is provided by lateral or lip exhaust systems, by which air and fumes are drawn across the top of the tanks into slotted ducts along the whole length of one or both sides. Tanks wider than 18 inches require exhaust ducts on both sides. The level of the tank fluid should be six to eight inches below the slots, which are about 1-inch wide. The air velocity at the entrance to the slots is usually around 2,000 f.p.m.

Measurement of Ventilation

136. The measurement of natural ventilation is usually made by indirect means using a tracer substance such as carbon dioxide. Volumetric gas analysis is necessary to ascertain progressive changes in the concentration of tracer, from which the rate of ventilation is calculated.

137. Artificial ventilation can be measured directly by ascertaining the air velocity at inlets or outlets using an anemometer, and relating it to the area of cross section of the ducts concerned. The volume of air entering or leaving a room is then obtained from the formula $Q = AV \times 60$ (see para. 128). The number of air changes is the resultant divided by the cubic capacity of the room.

138. If the occupancy of a room is variable, the ventilation rate is usually expressed as the amount of air passing through it in unit time; that is, so many cubic feet per hour or minute. It may also be expressed as the amount supplied per occupant, in unit time, if occupancy is constant and the standard used is the control of body odour. The number of air changes per hour may also be related to the number of occupants.

Air-Conditioning

139. In general the purpose of air-conditioning is to provide full indoor comfort, irrespective of external atmospheric conditions. In full air-conditioning the air provided must be cleaned, warmed, or cooled, and have its humidity adjusted. In partial air-conditioning, the air is cleaned, and warmed or cooled, but the humidity control is incomplete. In the tropics an air-cooling plant of this nature is of use only when the climate is hot and dry; cooling raises the relative humidity of the air and, if the atmosphere is already damp, environmental discomfort will be increased by supplying cool moist air. As a general principle in air conditioning, if warmed air is to be supplied it should be humidified, if cool it should be dehumidified.

140. In full air-conditioning the air is driven by fans through a plant which filters, washes, cools or warms it, and adjusts the humidity. The volume of air to be supplied depends on the difference in temperature and humidity planned between the incoming air and that at the outlet, and on the potential heat gain or loss due to conditions within and without the room. Economy in the size and power of the plant and its running may be achieved by re-circulating the room air, in whole or in part. The air is delivered by ducts, which should be designed and placed to ensure that there is no air stagnation and that there is enough air movement to promote comfort and freshness.

LIGHTING

Introduction

141. Dark, gloomy rooms are cheerless and often dirty. Ill-lit workshops are inefficient and dangerous. Good lighting is therefore not a luxury, but is essential to health and economy. Effective natural and artificial lighting enhance the amenity of the home, and by revealing dirt, play a necessary part in domestic hygiene. In the factory, bad lighting causes lowered output, spoiled work, accidents, fatigue, and eyestrain; absentee-ism and general unrest are also encouraged. These undesirable consequences stem from the reduced visual efficiency caused by insufficient illumination, locally or in general.

Definitions

142. **Light.** Light is a continuous flow of radiant energy from a source and is spoken of quantitatively as the luminous flux.

143. **Illumination.** This is the luminous flux incident upon an object. The term is often, however, used less accurately as synonymous with lighting, the correct interpretation being clear only from the context.

144. **Lighting.** The term includes the quality, diffusion, direction and application in general of light.

145. **Brightness.** The brightness of a surface results from the light it emits, either as a source or by reflection. When the surface is a source, its brightness is also termed its intrinsic brilliance. The brightness of a reflecting surface equals the brilliance of the source multiplied by the reflection factor of the surface. Every surface absorbs some of the light it receives and reflects the remainder; the percentage or fraction that is reflected is known as the reflection factor.

146. **Candle-Power.** The unit of intensity of the light source is the international or standard candle, made of spermaceti, weighing one-sixth of a pound and burning at the rate of 120 grains an hour.

147. **Foot-Candle.** The amount of light reaching an object is measured in foot-candles. One foot-candle (f.c.) is the illumination produced at a distance of one foot by a standard candle.

148. **Lumen.** The quantity of light emitted by a source is measured in lumens, which are thus the units of measurement of the luminous flux. One lumen illuminates a surface of one square foot, every point on which is at a distance of one foot from the source, to an average level of one foot-candle. Thus one lumen per square foot equals one foot-candle.

149. **Foot-Lambert.** The brightness or luminance of an object determines how easily it can be seen. If its reflection factor is low, the brightness will not be great even when the illumination applied to the object is high. One foot-lambert is the luminance of a matt surface reflecting or emitting one lumen per square foot.

General Illumination

150. General illumination must always be sufficient for the performance of everyday normal visual tasks. When visual tasks are more demanding, it must form a suitable background against which effective local illumination can be provided. It should be uniform and should not contrast too strongly with local lighting, otherwise pools of light surrounded by dark areas will result. It should penetrate to the upper parts of the room, to prevent the production of an oppressive, overhanging canopy of darkness. Good lighting should not cause shadow or glare.

151. The effectiveness of general illumination can be considerably helped by the interior decoration of premises. Ceilings and walls should be of a light colour with reflectivity (reflection factor) of 75 and 60 per cent. respectively. Dark dados should be avoided, except in large rooms or workshops, as they tend to reduce the sense of space and to increase contrast. If a dado is necessary it should be moderately light with reflectivity of about 30 per cent. Pastel shades applied with a matt finish are preferable to prime colours, which are distracting. Gloss surfaces may cause reflected glare. It has become the practice in some industries to paint plant and machinery in colours to harmonize or contrast with the background. Prime colours may be useful for this purpose by emphasizing parts of particular significance or danger.

Local Illumination

152. Local illumination is necessary when a visual task is highly exacting. The visibility of objects, however, differs according to their size, shape, colour, reflectivity, and background. Unless the visual task can be eased by increasing the visibility of the object, difficulty may occur in providing local illumination that is both effective and economical.

153. The apparent size of an object may be increased by decreasing the viewing distance or by the use of an optical aid, such as the watchmaker's loup. The reflectivity may require reduction to modify reflected glare;

conversely, the outlines of the object may be sharpened if its brightness is increased by improved reflectivity. Contrast may also be improved by adjusting colour or background. The direction from which the light falls on the object, or selective lighting of object and background, may also improve its visibility. Speed and irregularity of movement are other factors which may make the visual task more difficult. Stroboscopic effects and flicker may therefore require elimination.

Amount of Illumination Required

154. The threshold of vision is 0·000001 foot-candles. From this level visibility increases, as the illumination is raised, to a point where further illumination is of no advantage and may even be a disadvantage. The object of local illumination is to provide this optimum; the poorer the viewing conditions the more illumination there must be to reach the optimum. Examples of the illumination required for certain classes of task are given in Table 18.

TABLE 18

STANDARDS OF ILLUMINATION

(Illuminating Engineering Society Code)

Recommended Foot-Candles	Class of Task
2– 4	Casual observation where no specific work is performed.
4– 6	Work of simple character not involving close attention to detail.
6–10	Less exacting visual tasks, such as casual reading and large assembly work.
10–15	Visual tasks such as medium machine and benchwork and sustained reading.
15–25	Prolonged critical visual tasks, such as proof reading, fine assembling, and fine machine work.
25–50	Severe and prolonged visual tasks; discrimination or inspection of fine details of low contrast.
Above 50	Precision work to a high degree of accuracy; tasks requiring rapid discrimination; displays.

155. The installation of lighting to provide the necessary illumination raises further problems. Sources must be capable of emitting the required amount of light without causing glare. Their brightness should not in consequence exceed 10 candle-power per square inch. The distance between the source and the object must be as short as practicable, to ensure economy in the intensity of the source (since the illumination varies inversely as the square of this distance); it must not, however, be so short that glare is experienced by the operator or people nearby. Sometimes screening may be necessary to prevent glare, particularly if the light has to fall on the work from a certain angle. Finally, the contrast of local with general illumination must not be too great, otherwise objectionable shadows will occur and spoil the advantages of the local illumination.

Natural Lighting

156. The quality of artificial light cannot match that of daylight. Daylight of reasonable strength is excellent for seeing fine detail and does not distort colours. The quality and quantity of daylight, however, vary considerably according to the seasons, the weather, and the time of day. Building design and siting also influence its availability and utilization. In consequence, artificial light must at times be used as a supplement; such mixed lighting may give rise to unpleasant effects

unless the artificial light sources are properly sited and the resultant illumination blends with the daylight. The main faults to be avoided are double shadows, undesirable contrasts, and bright areas interspersed by dark shadows.

157. The design and placing of windows are important factors in obtaining the utmost value from daylight; in addition, buildings should be orientated to secure the maximum amount of summer and winter sunlight. In England the sun rises in the south-east and sets in the south-west, its greatest elevation above the horizon being 61° in summer and 15° in winter. Maximum summer and winter sunlight in living rooms will be obtained in houses facing S.S.E. But regard must be paid to such obstructions as nearby trees and buildings, which might cut off sunlight or any part of the sky that should be visible from a window. The angle subtended by the arc of the sky visible at the point of observation through a window is known as the "sky angle". At table level and two-thirds of the depth of the room from the window it should never be less than 5°. This can be appreciated more readily from Fig. 59.

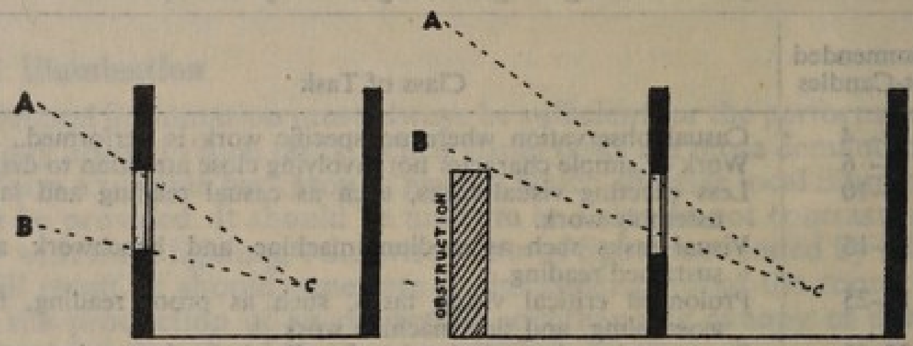


FIG. 59. SKY ANGLE
In each diagram the point C is at table level and two-thirds of the depth of the room from the window. ACB is the sky angle.

Daylight Factor

158. A scientific method of assessing lighting is to use the Daylight Factor (d.f.); it makes allowance for the variable factors of time, place, weather, and seasons. This factor is the fraction of light reaching any point in a room, compared with the total light emitted by the hemisphere of the sky, if it were entirely and simultaneously visible. The resultant is expressed as a percentage. Information has been collected, over many years at various places, on the amount of illumination provided by the hemisphere of the sky at different seasons and times of day. For a few hours on a number of days in all months, except November, December, and January, it may reach as much as 1,000 lumens per square foot or over. At the opposite end of the scale, on a few days each year at 9 a.m., noon, and 3 p.m. it is below 100 lumens per square foot. It is usual to use an average of 500 lumens per square foot. For precise calculations, however, the light from the sky is measured directly with a photometer or obtained from appropriate tables and graphs. The indoor daylight is measured by a photometer. If for example the indoor reading is 25 lumens per square foot (foot-candles) and the sky gives 500 foot-candles, the d.f. is 25 multiplied by 100 divided by 500, equalling 5 per cent. Such readings can be taken at various points in a room, which may then be zoned according to the d.f. values. It is emphasized that each

point within a room has its own d.f. value. The room as a whole may have an average d.f., but this does not mean much; the point concerned must be defined, for example a d.f. of 1 per cent. at table level 8 feet from the centre of the window.

159. Another method of calculating d.f. is to use special daylight factor protractors, prepared by the Building Research Station. These can be used to forecast d.f. from building plans.

160. **Window Design.** The tall, relatively narrow Georgian type of window, set in a thick wall, with deep reveals sloping away from the window surface both inside and out, gives the best light penetration and area of illumination. The deep reveals also prevent excessive contrast with the wall, so that apparent glare from the sky is minimized. Light penetration and the area of illumination are inevitably reduced by modern low windows, as these cut out some of the light from the sky. In addition, the contrast from a small window in an expanse of wall is excessive and causes glare. Improvement can, however, be made, even if the walls are thin, by running the glazing to meet the side brickwork; this gives the impression of reveals by reducing contrast at the edges of the window. The placing of windows is also important. If there is a window in one wall only, the d.f. on the opposite side of the room will be poor. For example, it is unusual to obtain readings higher than 1 per cent. at a distance of 15 feet across a room, even with 20 to 30 per cent. d.f. at the window. Increasing the number of windows in the same wall does not improve penetration, although the area of illumination will be extended laterally, and the distribution will be more uniform. Penetration will be increased if the windows are in different walls, particularly if opposite one another. The provision of a roof-light will improve the d.f. very considerably; it is a common feature of the lighting in single-storied factories.

161. However effective the placing and design of windows, interior or exterior obstructions can ruin natural lighting. Badly placed furniture, machinery or other apparatus may unnecessarily obscure large areas of a room or workshop. Adjacent trees or buildings obscure daylight in proportion to their height and proximity. Some compensation from reflected light is obtained if obstructing buildings are light-coloured. This is the main reason for the enclosed wells of large buildings, such as hotels and blocks of offices, being white tiled.

Standards of Natural Illumination

162. The Building Research Board of the Department of Scientific and Industrial Research (Post-War Building Study No. 12) suggest the following standards:—

Daylight factor 0·5 per cent.	Bedrooms (minimum value at table level 7 to 8 feet from window)
1 per cent.	Living rooms (minimum value at table level 7 to 8 feet from window)
2 per cent.	Kitchens (working areas)
5 per cent.	School class-room (working area)
10 per cent.	Rooms in schools used for fine visual tasks (working area)

The Illuminating Engineering Society scale of natural illumination requirements are as follows:—

Apparent size of object to be seen	Daylight Factor per cent.		
	A Contrast Good	B Contrast Average	C Contrast Poor
1. Minute	10 to 20	—	—
2. Very small	4 to 10	14 to 20	—
3. Small	2 to 4	6 to 14	—
4. Fairly small	1 to 2	3 to 6	10 to 20
5. Ordinary	0·4 to 1	1·4 to 3	5 to 10
6. Large	0·2 to 0·4	0·6 to 1·4	2 to 5

163. This Society has also prepared a schedule of recommended illumination values for a large number of specific tasks; examples are given in Table 19. If the sky illumination is taken as 500 lumens per square foot, the approximate daylight factor for such tasks can be assessed by dividing the required illumination value by 5. It will be seen that daylight alone cannot supply enough illumination for certain tasks; for others very high d.f. values are required, which can only be attained if the work is carried out close up to an unobstructed window.

Artificial Lighting

164. The general illumination in dwellings should enable all routine daily tasks to be performed without inconvenience. The daylight requirements have already been discussed. When artificial lighting is required, either as a substitute or supplement, equivalent standards should be the aim. An illumination of 5 to 10 lumens per square foot is sufficient for routine tasks, including casual reading. Local lighting may be required to illuminate finer tasks such as writing, prolonged reading, and needlework. For these 10 to 15 lumens per square foot are needed and for fine sewing about 20 lumens per square foot. The precise arrangement of general and local artificial illumination in homes is a matter of individual taste; its suitability, apart from quantity, depends on constancy, uniformity, colour, and freedom from glare and shadow. These factors are governed by the lighting system, which consists of the type and distribution of light sources and the method of diffusion.

165. **Light Sources.** Electric light may be emitted by incandescent bulbs, high-pressure discharge lamps, or fluorescent tubes. Incandescent or filament electric light bulbs are usually filled with an inert gas and have an opalescent finish to aid diffusion. They are available in a wide range of intensities so it is easy to provide the exact amount of light required. They are cheap, easy to fit and to keep clean. High-pressure discharge lamps contain either mercury or sodium vapour. Through this an electrical discharge passes between an anode and cathode, producing respectively greenish or orange coloured light, which is of good intensity but otherwise unpleasant. These lamps use little current and their serviceability is about the same as filament bulbs. They are most commonly used for road and flood lighting, but are occasionally found in large buildings such as hangars.

TABLE 19

EXAMPLES OF I.E.S. RECOMMENDED VALUES OF ILLUMINATION

	L/Sq. ft.	Size Classification	Contrast Grading
Garages. Repairs.	20	4	B
General maintenance work.	7	5	B
Laboratories. Extra fine instruments, scales.	50	3	B
General.	20	4	B
Machine Shops. Very small machine and bench work: gauge inspection and precision grinding.	100	2	B
Small bench and machine work; medium grinding.	50	3	B
Fairly small bench and machine work: rough grinding.	20	4	B
Ordinary bench and machine work.	10	5	B
Paint Shops. Fine painting and finishing.	30	5	C
Rubbing down, medium painting and finishing: mixing.	15	5	B
Dipping: rough spraying.	7	6	B
Plating and Tinning. Buffing, polishing and burnishing.	10	5	B
Shops. Vats and baths.	7	6	B
Smith's Shop. Forging.	7	6	B
Stores, etc. Packing and dispatch.	7	5	B
Welding and Soldering. Fairly small soldering and contact welding.	20	4	B
Ordinary soldering and contact welding.	15	5	B
Flame welding and brazing.	7	5	B
Woodworking. Fairly small bench and machine work: fine sanding and finishing.	20	4	B
Glueing, medium machine and bench work, rough sanding and pattern making.	15	5	B
Saw mills.	7	6	B
Fabric Work. Mending, examining and hand finishing (dark).	50	4	C
Reading Rooms. General.	7	4	A
Tables.	15	3	A
Operating Table.	300	1	B/C
Offices. General.	10	5	B

166. **Fluorescent Tubes.** These contain mercury vapour and argon at a low pressure. Electrical discharge through this column of vapour between two electrodes at each end of the tube produces radiation, most of which is ultra-violet and the rest of low luminosity value. The ultra-violet rays activate the fluorescent material with which the tube is lined to produce light; the colour and quality of this light vary according to the fluorescent material used. The ultra-violet rays are absorbed by this material and in addition the glass of the tube is opaque to the wave-lengths concerned, so that there is no ultra-violet emission from fluorescent tubes. At one time the fluorescent material contained beryllium salts so that there was toxic risk in the manufacture and from accidental breakage of these appliances; now most manufacturers have replaced the beryllium salts with harmless materials. These lamps are highly efficient, giving approximately three times as much light for the current

consumed as filament bulbs and having a working life of nearly double. Their large area gives them a relatively low surface brightness, which is well below the permissible level of 10 candle-power per square inch. They are, however, expensive to install initially and the light emitted flickers at a very high frequency imperceptible to the naked eye. This can cause stroboscopic effects with moving objects. If the tubes are wired in slightly different phases so that the frequencies of the flicker do not correspond, stroboscopic effects are prevented.

Diffusion of Light

167. The diffusion of light from a source depends on whether the fitting sheds light generally, directly or indirectly, or in a combination of these ways. Lighting from sources enclosed in an opalescent globe diffuse light in all directions and are classed as general. Sources with an opaque shade above which sheds not less than 90 per cent. of the light downwards, are direct. If the shade is translucent or does not wholly cover the source from above so as to allow 10 to 40 per cent. of the light to diffuse upwards, the lighting is semi-direct. Indirect sources are shaded by opaque, often reflecting, material so that not less than 90 per cent. of the light is directed against the ceiling or a wall, from which it is reflected into the room area. If some light is allowed to diffuse directly into the room and the rest is reflected, the lighting is semi-indirect. (See Fig. 60.)

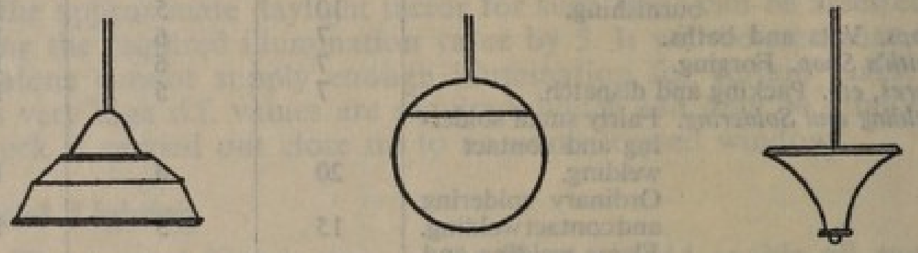


FIG. 60. LIGHTING FIXTURES DESIGN

Direct General Indirect

168. Direct lighting is economical as most of the light is utilized, but it tends to be harsh and may cause glare and shadow. It also leaves an area of darkness above the fitting, leading to the so-called tunnel effect. This can be overcome in high buildings by having direct lighting in two tiers, the upper near roof-level illuminating the dark area above the lower tier. Semi-direct lighting by allowing some light to escape upwards has the same effect. Indirect lighting is wasteful, and so to a lesser extent is semi-indirect, as much light is lost by double reflection. The illumination from both these methods is, however, of pleasant quality, even and free from glare, being particularly suitable for homes and hotels, rather than in workshops. General lighting fittings are the type most commonly used, particularly in industry, as they are economical. Also the light is well diffused in all directions and the quality is pleasant, while glare and shadow are minimal. Fluorescent tubes are often installed without any shade fittings, but in some circumstances direct, semi-direct or general diffusion may be desirable. Indirect or semi-indirect fittings for fluorescent tubes may be decorative but are usually ineffective.

Distribution of Light Sources

169. The success of providing sufficient illumination without causing glare or shadow depends on the correct distribution of sources. The factors concerned are height, spacing, numbers, and placing. These will be discussed when glare, shadow and the calculation of lighting requirements are considered.

Standards of Artificial Illumination

170. The standards of illumination generally accepted are those stated in the Illuminating Engineering Society Code, examples of which are given in Tables 18 and 19. The Air Ministry Works Directorate synopsis of lighting does not differ materially from this code. There are also certain minimal statutory requirements for factories. The Factories Act, 1937, requires that there must be sufficient and suitable lighting in every part of the factory in which persons are working or passing. This requirement is expanded by the Factories (Standards of Lighting) Regulations, 1941, which state that:—

(*a*) General illumination in work places shall not be less than six foot-candles measured in the horizontal plane at a level of 3 feet above the floor.

(*b*) The illumination over all other interior parts of the factory over which persons employed pass shall be not less than 0·5 foot-candles measured at floor level.

(*c*) Where any source of artificial light in the factory is less than 16 feet above floor level, no part of it having a brightness of more than 10 candles per square inch shall be visible to persons normally employed within 100 feet of it, except where the angle of elevation from the eye to the source exceeds 20°.

(*d*) Any local light must be shaded in such a way that neighbouring workers are protected from glare.

(*e*) By suitable screening or siting of surfaces, glare reflected from smooth or polished surfaces must be prevented.

(*f*) Measures must be taken, so far as practicable, to prevent the formation of shadows which cause eyestrain or risk of accident.

171. It is emphasized that these statutory requirements constitute no more than a legal minimum aimed at preventing discomfort, ill health, and risk of accident. In fact the regulations contain a clause to the effect that the standards shall be without prejudice to the provision of any additional illumination required to render the lighting sufficient and suitable for the nature of the work.

Glare

172. Glare may be direct or indirect. Indirect glare is reflected from a smooth and shiny surface. Besides causing discomfort it renders the eye less sensitive and may even cause momentary blindness. It hinders adaptation and leads to eye-muscle fatigue. At the periphery of vision it distracts from the visual task and the after-images that may result also hinder vision. Glare leads to reduced output, risk of accidents, fatigue, and eyestrain; it is moreover uneconomical, as increased illumination is required to compensate for it.

173. Although glare is experienced on passing from a dimly lighted area into a brighter one, the commonest cause is an area in the field of vision that is relatively or absolutely too bright. A small window in a large expanse of wall, owing to the excessive contrast, gives the impression of glare; so does the over-concentration of artificial sources in one part of a room, in which the general brightness is satisfactory. In workshops, however, it is more often reflected glare from material or plant that is the problem.

174. Light sources should not exceed a brightness of 10 foot-candles per square inch and should be placed so that they do not obtrude into the normal visual field. If this cannot be arranged they must be screened. The height and distance of a source must be arranged so that light is not indirectly reflected into a worker's eyes from known bright surfaces. The contrast of sources and surroundings should not be greater than 100 to 1. The use of indirect lighting or fluorescent tubes may be necessary. Any surface should be made non-reflecting, where practicable, by substituting a matt finish instead of a polished one. Even in offices small adjustments can improve the comfort of workers; for example, the use of matt instead of shiny writing paper, or covering the bright area of a highly polished desk prevents glare that might otherwise be tiresome.

Shadow

175. Heavy shadows are unpleasant and dangerous. A sense of isolation is felt by some people working in a pool of light surrounded by a heavily shadowed area. A feeling of oppression arises from working beneath a low canopy of darkness overhead. Passing repeatedly from well to dimly lit areas throws a constant strain on visual adaptation and accommodation. Besides causing eyestrain and fatigue this reduces visual sensitivity and so accidents are liable to occur. In some processes, however, some shadowing is necessary to produce adequate contrast in the visual task. This is achieved by adjusting the siting and brightness of local illumination and is never of the degree that will be objectionable or angerous.

TABLE 20

LAMP SPACING
(in feet)

Mounting height above working plane	Maximum distance between points	Maximum distance between points and walls		Distance from ceiling to top of reflector (indirect units)
		Aisles or storage next to wall	Desks or benches next to wall	
4	6	3	2	1
5	7½	3½	2½	1¼
6	9	4	3	1½
7	10½	5	3½	1¾
8	12	6	4	2
9	13½	6½	4½	2¼
10	15	7½	5	2½
11	16½	8	5½	2¾
12	18	9	6	3
13	19½	9½	6½	3¼
14	21	10½	7	3½
15	22½	11	7½	3¾
16	24	12	8	4
18	27	13½	9	4½
20	30	15	10	5
22	33	16½	11	5½
24	36	18	12	6
27	40½	20	13½	6¾
30	45	22½	15	7½
35	52½	26	17½	8¾
40	60	30	20	10

176. Shadows are prevented by proper balance between local and general lighting. Local illumination alone is unsatisfactory; it must have a background of general illumination of a suitable ratio. A good working

TABLE 21
ROOM LIGHTING INDEX

Use upper column headings for direct or general lighting units and lower column headings for indirect lighting units. If the room index falls between two letters, interpolate or use the letter first in alphabetical sequence.

Room width in feet	Room length in feet	Height of fitting above plane of work in feet						
		5	10	14	18	22	26	30
8	10	A*	—	—	—	—	—	—
	12	A*	—	—	—	—	—	—
	16	B	—	—	—	—	—	—
	24	B	—	—	—	—	—	—
	35	B	—	—	—	—	—	—
	50	C	A	—	—	—	—	—
10	10	B*	—	—	—	—	—	—
	14	B*	—	—	—	—	—	—
	20	B	—	—	—	—	—	—
	30	C	—	—	—	—	—	—
	40	C	A	—	—	—	—	—
	70	C	B	A	—	—	—	—
12	12	B*	—	—	—	—	—	—
	18	B*	—	—	—	—	—	—
	24	C	A	—	—	—	—	—
	35	C	A	—	—	—	—	—
	50	D	B	—	—	—	—	—
	90	D	B	A	—	—	—	—
16	16	C*	A*	—	—	—	—	—
	30	D	B	—	—	—	—	—
	50	D	B	A	—	—	—	—
	80	D	C	B	—	—	—	—
	120	D	C	B	A	—	—	—
20	20	D	B	A	—	—	—	—
	40	D	B	A	—	—	—	—
	60	D	C	B	A	—	—	—
	100	D	C	B	B	—	—	—
	140	D	C	B	B	A	—	—
30	30	E	C	B	A	—	—	—
	60	E	D	B	B	A	—	—
	100	E	D	C	B	A	—	—
	140	E	D	D	B	B	A	A
40	40	F	D	C	B	A	—	—
	80	E	D	D	B	B	—	—
	140	E	D	D	C	B	B	B
60	60	F	E	D	C	B	B	B
	100	F	E	D	C	C	B	B
	200	F	E	E	D	D	C	C
80	80	F	E	E	D	C	D	B
	140	F	E	E	D	D	C	C
100	100	F	F	E	D	D	C	C
	120	F	F	E	E	D	D	D
120	120	F	F	E	E	D	D	D
	200	F	F	F	E	E	D	D
		7½	15	21	27	33	39	45
		Ceiling height in feet above plane of work						

***Room indices marked thus should be advanced two letters when only a single light fitting is employed; A* becomes C.**

rule is that background illumination should be not less than the square root of local illumination, both being expressed in lumens per square foot, provided the former does not fall below 6 foot-candles. The general illumination should also be diffuse, and so sited that dark patches do not occur between the effective areas of neighbouring sources. A guide to the distance between fittings is given in Table 20.

Measurement of Illumination

177. Illumination should be measured with a portable photometer consisting of a photoelectric cell connected to a galvanometer. The instruments are usually calibrated in foot-candles, except continental makes which may be marked in lux values (10·764 lux are the equivalent of one foot-candle). There may be more than one set of calibrations to give a wide range of measurement. The photometer will require setting to the range appropriate. When measuring illumination at the site of work the worker should be in position, to allow for any light that his presence may cut off. The amount of light found needs referring to the brightness of the visual task before any opinion can be given on whether it is in fact sufficient. Light just sufficient for writing in ink on white, highly reflective paper would not be sufficient for darning a black sock with black wool, the reflectivities of which are very low.

Calculation of Artificial Lighting Requirements

178. The illumination necessary for a particular visual task may be obtained from I.E.S. tables or the A.M.W.D. building synopsis, or can be determined according to the following data.

Apparent size of object detail to be seen	Lumens per sq. ft. (foot-candles)		
	A Contrast Good	B Contrast Average	C Contrast Bad
1. Minute	50–100	150–300	500–1,000
2. Very small	20– 50	70–150	200– 500
3. Small	10– 20	30– 70	100– 200
4. Fairly small	5– 10	15– 30	50– 100
5. Ordinary	2– 5	7– 15	20– 50
6. Large	1– 2	3– 7	10– 20

179. The height of the mounting of the light fittings is governed largely by the physical characteristics of the building, but in general should not be less than 4 feet above the working plane of 2 feet 9 inches above floor level. The spacing of lamps can be ascertained according to the mounting height from Table 20; from this the number of lamp units that will be required for the room concerned can be calculated.

180. The light from any fitting which reaches the working plane is affected by the size and shape of the room and the mounting height. For purposes of calculation, rooms are classified according to these dimensions and are given an alphabetical symbol known as the Room Index. The necessary data are contained in Table 21.

TABLE 22

COEFFICIENT OF UTILIZATION

Type of Lighting Unit	Room Lighting Index	Ceilings: Fairly Light (40%)		Ceilings: Very Light (20%)	
		Walls: Fairly Dark (25%)	Walls: Fairly Light (50%)	Walls: Fairly Dark (25%)	Walls: Fairly Light (50%)
		Coefficients of Utilization			
Direct (with Open Reflectors)	A	0·33	0·37	0·33	0·38
	B	0·37	0·40	0·37	0·41
	C	0·43	0·46	0·43	0·47
	D	0·47	0·50	0·48	0·51
	E	0·52	0·55	0·53	0·56
	F	0·56	0·58	0·57	0·60
Direct (with Globe Enclosed)	A	0·24	0·27	0·25	0·29
	B	0·27	0·30	0·28	0·32
	C	0·31	0·33	0·32	0·36
	D	0·35	0·36	0·36	0·40
	E	0·39	0·40	0·40	0·44
	F	0·42	0·44	0·45	0·48
General	A	0·20	0·24	0·23	0·28
	B	0·23	0·27	0·26	0·32
	C	0·29	0·32	0·33	0·38
	D	0·32	0·36	0·37	0·43
	E	0·38	0·42	0·44	0·49
	F	0·43	0·46	0·50	0·55
Indirect	A	0·08	0·10	0·15	0·18
	B	0·10	0·12	0·18	0·22
	C	0·13	0·15	0·23	0·27
	D	0·16	0·18	0·26	0·30
	E	0·19	0·21	0·32	0·36
	F	0·22	0·24	0·38	0·42

181. The Coefficient of Utilization is the ratio of the light flux actually received by the working plane to the total lumens emitted by the lamp. It is influenced by the type of fittings used and by the reflectivity of the walls and ceiling. Coefficients of utilization according to these factors and the room index are given in Table 22. The reflection factors of various standard colours are given in Table 23.

182. The following information is now available:—

FC = Illumination required for type of work in lumens per square foot (foot-candles).

N = Number of lamp units required.

A = Floor area of room in square feet.

U = Coefficient of utilization.

DF = A constant depreciation factor to allow for ageing of lamp, dirt, etc., of 1·43.

TABLE 23

LIGHT REFLECTION FACTORS

References are to British standard colours for ready mixed paints (B.S.S. 381)

Colour	Standard Colour No.	Reflection Factor (expressed as a percentage)
White paper	—	84
Golden yellow	56	80
Pale cream	52	76
Primrose	54	76
Deep cream	53	70
Lemon	55	69
Portland stone	64	62
Light buff	58	61
Light stone	61	58
Middle buff	59	54
Eau de nil green	16	47
Salmon pink	43	44
Orange	57	42
Sea green	17	38
Silver grey	28	37
Middle stone	62	37
French grey	30	36
Dark stone	63	33
Light battleship grey	31	31
Deep buff	60	31
Quaker grey	29	30
Sky blue	1	30
Light brown	10	27
Golden brown	14	25
Sage green	19	19
Grass green	18	18
Post Office red	38	17
Turquoise blue	2	15
Middle brown	11	12
Dark battleship grey	32	11
Peacock blue	3	11
Crimson	40	6

Then the lumens per lamp unit (L) can be obtained from the following formula:

$$L = \frac{FC \times A \times DF}{N \times U}$$

Finally from Tables 24 or 25, where the lumen ratings of different types of lamp are given, the wattage requirements may be determined.

Example. Adequate lighting is required in a carpenter's shop 20 feet wide and 35 feet long. The ceiling is white in colour and the walls light stone. Benches against the wall are to be used as well as those in the centre of the room. Direct lighting with open reflectors has been decided upon. The mounting height for lamp units will be five feet above the working plane. The current available is 230 volts.

(*a*) FC = Foot-candles required=12 (Illuminating Engineering Society Code) or six (legal minimum).

(*b*) From Table 20 it is seen that the maximum permissible distance between lamp points is 7½ feet and that they should not be more than 2½ feet from the side walls. Symmetrical distribution can be obtained with three rows of five lamps in each row, making a total of 15 lamp units.

(*c*) From Table 21 the room index is found to be D.

(*d*) Table 23 shows the reflection factors of ceiling and walls to be 84 per cent. and 58 per cent. respectively.

(*e*) The coefficient of utilization (U) can now be obtained from Table 22 and is shown as 0.51.

(*f*) Substituting in the formula $L = \dfrac{FC \times A \times DF}{N \times U}$

we obtain $L = \dfrac{12 \times 700 \times 1{\cdot}43}{15 \times 0{\cdot}51}$

$= 1{,}570$ lumens per lamp unit.

From Table 24 it is seen that 150-watt lamps will provide the number of lumens, or 75-watt lamps if the minimum legal standard of 6 foot-candles is accepted as adequate lighting.

TABLE 24

LUMEN RATING OF GAS FILLED LAMPS
(of 200/250 volts)

Watts	Nominal Lumens
15	124
25	225
40	324
60	582
75	795
100	1,160
150	1,920
200	2,660
300	4,260
500	7,700
1,000	17,400
1,500	27,900

TABLE 25

LUMEN RATING OF ELECTRIC DISCHARGE LAMPS

Watts	Type	Shape	Nominal Lumens
80	Mercury	Pear	3,040
125	Mercury	Pear	5,000
250	Mercury	Pear	9,000
400	Mercury	Pear	18,000
400	Fluorescent mercury	Isothermal	15,200
80	Fluorescent mercury	5 ft. tube	2,400

CHAPTER 9

DISINFECTION AND DISINFESTATION

DISINFECTION

General

1. The object of disinfection is to destroy pathogenic organisms. It is necessary, therefore, to distinguish between disinfectants, which kill pathogens, and antiseptics which only inhibit their growth. All true disinfectants are in fact germicides. Many so called are only deodorants, having little influence on the life or growth of pathogenic organisms.

2. Disinfection is applied particularly to infective excreta and discharges or to articles and premises contaminated by these. If concurrent disinfection of all infectious material is carried out during the illness of a patient, terminal disinfection at its conclusion may be limited to thorough cleaning of the room and surroundings with soap and water, as described later. Concurrent disinfection is necessary for infective sputum, urine, faeces, skin debris, wound dressings, handkerchiefs, towels, bed linen, clothing, and any other contaminated articles such as feeding utensils, bed-pans, or urine bottles.

Methods of Disinfection

3. Disinfection may be effected by physical or chemical agents. Physical disinfection is carried out by employing sunlight, fire, dry heat, or moist heat. Chemical disinfection is achieved by gas, liquid, or solid disinfecting agents.

4. **Burning.** Infective articles of little or no value are best burned. Sputum and faeces may also be incinerated if the necessary facilities are available, but the addition of combustible material such as oil, sawdust, or shavings may be required to ensure that combustion is complete.

5. **Dry Heat.** Baking at a temperature of 150°C. to 160°C. applied for one hour will kill all organisms and their spores. This is the method used essentially in laboratories for the disinfection of glassware and similar articles. It is of no use in treating fabrics, for textiles cannot withstand a temperature above 110°C. without damage, and leather or fur should not be exposed to more than 70°C. other than momentarily.

6. **Boiling.** Many articles, including feeding utensils, crockery, glass, towels, and linen, can be disinfected by boiling, which destroys all except a few spore-bearing organisms in five minutes. The addition to the water of an alkali, for example one per cent. sodium carbonate, will effect the destruction of spores by boiling in one to two minutes. Stains, particularly those due to protein substances, must be removed by soaking before fabrics are boiled, otherwise they will become fixed.

7. **Steam.** Steam is the most effective way of applying heat. It may be used as current steam, as in the portable disinfectors used in the Royal Air Force, or as saturated steam under pressure as in the autoclave or large static disinfector. As steam condenses it gives off latent heat which is taken up by the articles being disinfected. It also undergoes a reduction in volume so enabling uncondensed steam to take its place progressively until all the articles have been completely penetrated. If fed into a space

from above it drives out all the air present by downward displacement. This ensures an even distribution of steam and temperature throughout the articles in the disinfecting chamber and prevents residual pockets of cooler air which would prejudice complete disinfection.

8. **Current Steam.** Current steam is at atmospheric pressure and disinfects by passing freely at 100°C. through the articles concerned. It must always be applied by downward displacement if it is to be effective. Its application is typified in the portable disinfectors illustrated in Figs. 61 and 62.

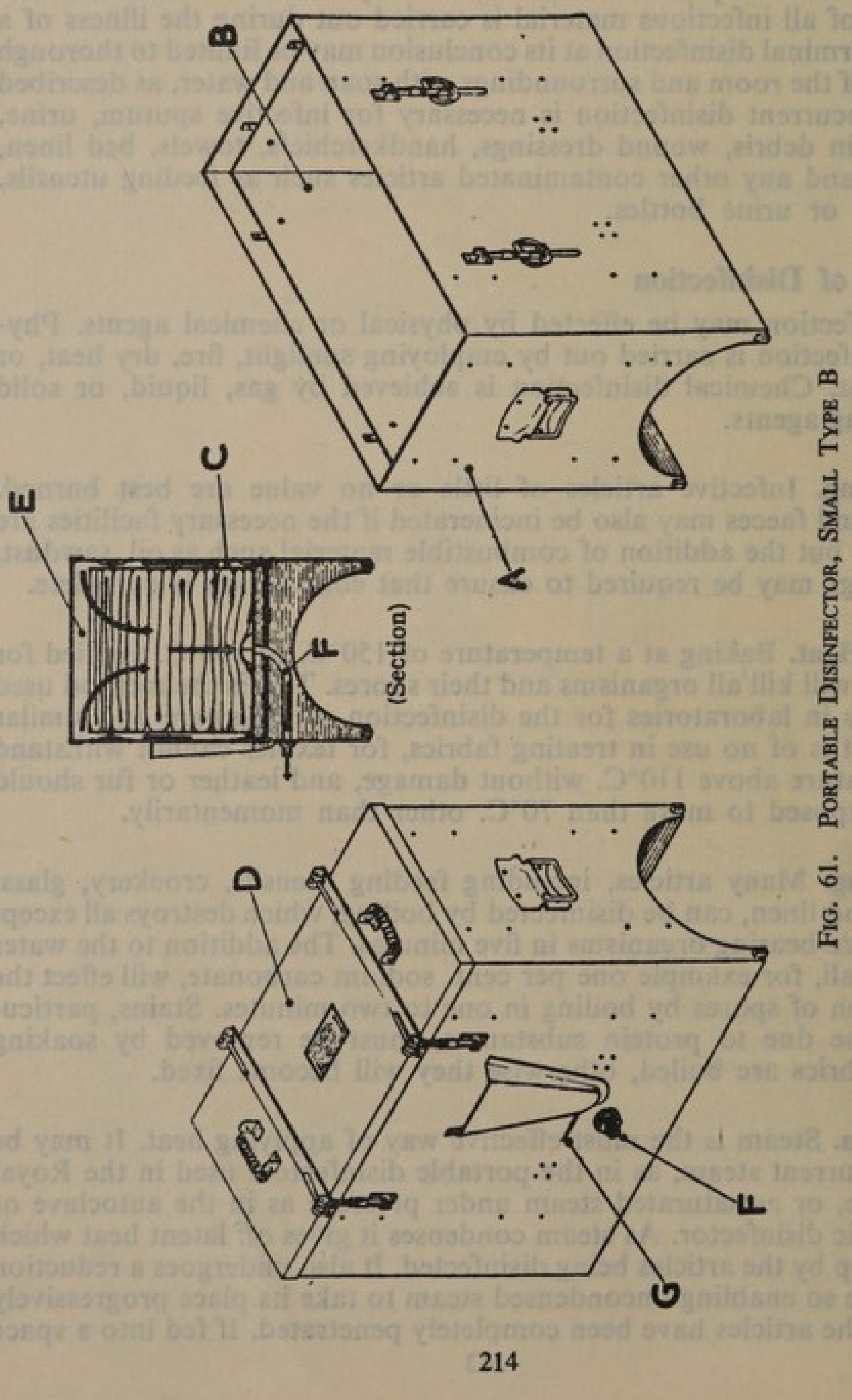


FIG. 61. PORTABLE DISINFECTOR, SMALL TYPE B

A—Outer casing C—Steam space (sides) E—Steam space (top)
B—Inner container D—Lid F—Steam exit pipe
G—Water level

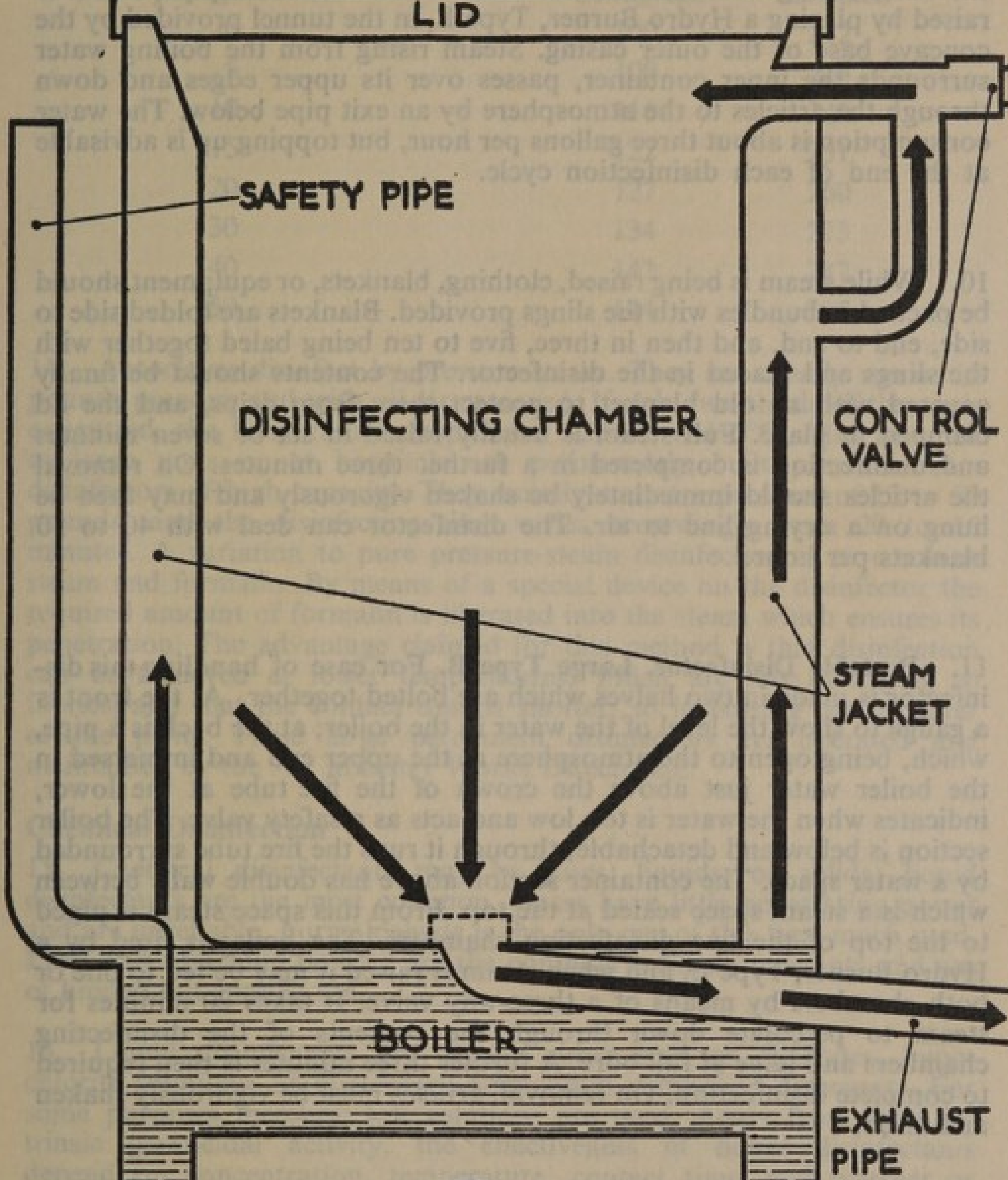


FIG. 62. PORTABLE DISINFECTOR, LARGE TYPE B

9. **Portable Disinfector, Small Type B.** This disinfector consists of an outer casing, separated from an inner container by a narrow space in which steam is raised. A steam-tight lid clamps over the outer casing, leaving a space above the top edges of the inner container. After filling the outer casing with water to the level of the steam exit pipe, steam is raised by placing a Hydro Burner, Type E, in the tunnel provided by the concave base of the outer casing. Steam rising from the boiling water surrounds the inner container, passes over its upper edges and down through the articles to the atmosphere by an exit pipe below. The water consumption is about three gallons per hour, but topping up is advisable at the end of each disinfection cycle.

10. While steam is being raised, clothing, blankets, or equipment should be packed in bundles with the slings provided. Blankets are folded side to side, end to end, and then in three, five to ten being baled together with the slings and placed in the disinfector. The contents should be finally covered with an old blanket to protect them from drips, and the lid clamped in place. Full steam is usually raised in six or seven minutes and disinfection is completed in a further three minutes. On removal the articles should immediately be shaken vigorously and may then be hung on a drying line to air. The disinfector can deal with 40 to 50 blankets per hour.

11. **Portable Disinfector, Large Type B.** For ease of handling this disinfector is made in two halves which are bolted together. At the front is a gauge to show the level of the water in the boiler; at the back is a pipe, which, being open to the atmosphere at the upper end and immersed in the boiler water just above the crown of the fire tube at the lower, indicates when the water is too low and acts as a safety valve. The boiler section is below and detachable; through it runs the fire tube surrounded by a water space. The container section above has double walls between which is a steam space sealed at the top. From this space steam is piped to the top of the two disinfecting chambers. The boiler is fired by a Hydro Burner, Type E, and when steam is raised it may be fed to one or both chambers by means of a three-way valve. It takes 20 minutes for steam to percolate down through the contents of the disinfecting chambers and issue at full bore. A further three minutes is then required to complete disinfection. On removal, articles must be vigorously shaken and aired.

12. The best method of preparing clothing and equipment is to put them in blankets to form bundles of suitable shape and size, or to load them directly into the containers in layers using blankets or clothing to fill in the spaces, especially around the sides. Blankets should be folded end to end, side to side, and then again end to end, and baled in eights with the slings provided. For the disinfection of "biscuits", three blankets are first folded and placed in the bottom of the container. On these are placed the "biscuits", on edge, tightly wrapped in a blanket in bundles of six. A further three or four folded blankets are finally added to fill up the container. Mattresses do not fit easily into the disinfector, but will go in one at a time if rolled tightly and placed diagonally in the container, the surrounding spaces being packed with blankets or other loose articles.

13. **Pressure Steam.** The temperature of steam varies directly as the pressure under which it is contained, as follows:—

Pressure lbs. per square inch	*Temperature of Steam Centigrade*	*Farenheit*
0	100	212
5	109	228
10	116	240
15	122	251
20	127	260
30	134	273
40	142	287
50	144	291

14. Autoclaves disinfect by pressure steam. They are usually run at 15 pounds pressure and with all air removed. If only two-thirds of the air is exhausted, the temperature drops from 122°C. to 115°C. Also installed at large units or at hospitals are permanently built pressure-steam disinfectors of high capacity. They usually run at a pressure of 10 to 30 pounds, and the disinfecting time varies accordingly from 20 to 15 minutes. A variation to pure pressure-steam disinfection is to combine steam and formalin. By means of a special device on the disinfector the required amount of formalin is liberated into the steam which ensures its penetration. The advantage claimed for this method is that disinfection can be achieved at lower temperatures, which are less damaging to fabrics, and that the contact time is shorter, so increasing the turnover of the plant. These large permanent disinfectors are operated and maintained by the Air Ministry Works Directorate.

Chemical Disinfection

15. Chemical disinfectants may be gases, liquids, or solids; liquid disinfectants are the most common. Gases have little penetrating power and are unreliable. Formaldehyde is the only one of this type much used. Lime and bleaching powder are the common solid disinfectants and are of limited but specific use.

16. Liquid disinfectants are usually either coal-tar distillates, hypochlorite solutions, or quaternary ammonium compound detergents. For some purposes mercuric salt solutions are used. Apart from their intrinsic germicidal activity, the effectiveness of liquid disinfectants depend on concentration, temperature, contact time, and whether or not their action is affected by the presence of organic matter. The efficacy of disinfectants is assessed by such tests as the Rideal-Walker and the Chick-Martin. These are not, however, reliable indices because of the many variables concerned.

17. Coal-tar distillates are the commonest general-purpose disinfectants. Crude carbolic acid is the basic coal-tar disinfectant; it consists of a mixture of phenol, cresols, and inert tar oils. Phenol is the crystalline portion and cresol the liquid part of the acid. Cresol has three times the bactericidal power of phenol. It is provided, as a disinfectant, either in the form of liquor cresolis saponatus (B.P.), which is lysol, or in the form of "black" or "white" fluids. These fluids are the subject of British Standard Specification No. 2462/54. The disinfectant chloroxylenol is also a coal-tar derivative, being a chlorinated phenol.

Formaldehyde

18. Formaldehyde is an effective germicide and also has the advantage of being harmless to leather, fur, rubber, and fabrics, which may all be damaged by heat. Although it can be used in liquid form, formaldehyde is the gaseous disinfectant of choice when such is required. It is safe to use as a gas because its strong smell makes it easily detectable. Its commonest use is for the terminal disinfection of a room by fumigation.

19. Formaldehyde gas is produced by the action on formalin of bleach or potassium permanganate. Formalin contains about 40 per cent. formaldehyde. Two pints of formalin and two pounds of bleach, or ½ pint of formalin and 5 ounces of potassium permanganate, are required for every 1,000 cubic feet of room space. As the evolution of the gas is accompanied by much frothing, these quantities and no more should be placed in each of the requisite number of buckets evenly dispersed about the floor, standing the buckets in trays is a worthwhile precaution. All doors, windows and other apertures must be sealed with gummed paper strips to prevent the escape of gas, and left thus for eight hours. Before use thereafter the room must be thoroughly aired.

20. An alternative to fumigation for the disinfection of rooms and their contents is formalin spraying. A five per cent. solution is used and applied at the rate of one gallon for every 400 square feet of wall, floor, and ceiling surface.

21. The materials for formaldehyde disinfection are barrack stores:—

33F/353, 354 and 374	Formaldehyde
33F/361	Bleach
33F/321	Potassium permanganate.

Phenol

22. Pure phenol is not as germicidal as crude carbolic, because of the absence of cresols. Owing to its action on tissue cells it is dangerous to use. However, it does not stain fabrics. As a disinfectant it is not of great practical use. Most organisms, except spores, will be killed by a one per cent. solution applied for 20 minutes. Phenol, liquefied B.P., is a medical store, supplied under reference number 6505-99-210-1502.

Cresol

23. Cresol disinfectants are the most useful for general purposes. The form in which cresol is supplied as a medical store is liquor cresolis saponatus (B.P.), stores reference 6505-99-210-0522. This is the equivalent of lysol, contains about 50 per cent. cresol and has a Rideal-Walker coefficient of 5 to 10. The general-purpose cresol disinfectant supplied as a barrack store is 33F/68, Fluid Disinfectant White. This conforms to B.S.S.2462/54, Group WB fluid, with a Rideal-Walker value of 10 to 12. For the disinfection of respirators there is another white fluid, 33F/355, Fluid Disinfectant (respirators); this conforms to Group WC of the same specification, having a Rideal-Walker value of 18 to 20.

24. There is considerable variation in the dilutions of disinfectants recommended for various purposes. The British Standards Institution, however, recommends a dilution for general purposes of 20 times the Rideal-Walker coefficient. Stronger solutions must of course be used in proportion to the infectivity of the material to be disinfected and to the length of the contact times practicable.

25. In general, cresol disinfectant solutions in strength of 0·5 to 2·5 per cent. will be adequate for all purposes except the disinfection of excreta, sputum, and discharges. For these a strength of 10 per cent. is required.

Chloroxylenol

26. Chlorinated phenol is the active principle in such disinfectants as Dettol, Streph, and Zant. Liquor chloroxylenolis (B.P.) contains 5 per cent. of the active principle; Dettol contains 3 per cent., and instrument Dettol 6 per cent. These disinfectants are more suitable for ward and sickquarters use than for general purposes. They are particularly effective against streptococci, but their germicidal power dwindles rapidly if the concentration of chloroxylenol is less than 1 per cent. They should not in general be diluted more than 1 to 3 or 4, in consequence. Their activity is also reduced in the presence of organic matter.

27. Dettol is a medical stores item under reference 6505-99-210-0563. Antiseptic fluid concentrate 6505-99-210-0154, -0155 and -0156 is also a chloroxylenol and corresponds to instrument Dettol. It should be used diluted 1 to 2.

Hypochlorite Solutions

28. Hypochlorite solutions tend to be unstable and the available chlorine is rapidly inactivated by organic matter. It is best in consequence to make up fresh solution as required from bleach (33F/361), although ready-made solution is available as a barrack store (33F/377 and 382). A solution of 1 in 1,000 is obtained by adding 70 grains of bleach to 1 gallon or 1 ounce to 6 gallons of water, approximately.

29. Hypochlorites are used in water sterilization, for disinfecting the skin of the hands, for the disinfection of vegetables, eating utensils, and kitchen equipment, and in scrubbing the duckboards and floors in ablutions. A solution of 1 in 1,000 is adequate for these purposes.

Quaternary Ammonium Compounds

30. These compounds are cationic detergents. Examples of them, with their trade names, are cetrimide (Cetavlon; C.T.A.B.), benzalkonium chloride (Roccal; Zephiran), and domiphen bromide (Bradosol). Their germicidal property is due to interference with the mechanism of synthesis and cell division of organisms, which are killed by disruption of the cell membrane, inactivation of enzymes and precipitation of essential proteins. Their cleansing properties also augment their disinfecting powers, which are, however, inhibited by soaps, phospholipids and proteins. They are particularly useful for cleaning and disinfecting glasses and crockery in bars and canteens. They are also of use in sickquarters for disinfecting instruments, small items of ward equipment, and baths. For these purposes cetrimide and benzalkonium chloride should be used at 1 per cent. strength. Both are medical stores items with reference numbers respectively 6505-99-210-0360 and -0218.

Lime

31. Lime may be used as a solid for some purposes, for example in the disposal of infected animal carcases or infective faeces. A 1 per cent. solution will kill all organisms other than spores in a few hours. It is a useful disinfectant applied as a lime wash to the walls of stables or byres,

stands for refuse bins, and other places liable to fouling. The wash is prepared from 1 part slaked lime to 4 parts water. Slaked lime is issued under stores reference 33C/672.

Bleach

32. Bleaching powder is chlorinated lime; it is unstable and deteriorates on storage, although specially stabilized preparations can be obtained. Its chief use is in water sterilization and the disinfection of vegetables. Its application as a solid around refuse bins and other foul sites is quite ineffective except perhaps as a temporary deodorant. Bleach is issued under the stores reference 33F/361.

Practical Disinfection

33. When infectious disease occurs in any premises, bedding, clothing, and other articles exposed to infection, should not be sent to the laundry or returned to store until disinfected as directed by the medical officer. If infection is only suspected, these items should be put aside until confirmation or otherwise is received.

34. **Rooms.** Terminal disinfection is achieved by thorough cleaning with soap and water, or a 2·5 per cent. cresol solution, of all surfaces and articles within a six-foot radius of the bed. However, formaldehyde fumigation or spraying is sometimes desirable on psychological grounds.

35. **Bed Linen; Cotton and Linen Articles.** These are disinfected by steam, boiling, or soaking for at least 30 minutes but preferably overnight, in 2 per cent. cresol.

36. **Mattresses and Pillows.** Unless soiled with excreta, discharges, or infective skin debris, exposure to the fresh air for 24 hours is sufficient disinfection. Otherwise high pressure steam is advisable. Drying after current steam disinfection is difficult.

37. **Blankets and Woollen Articles.** Pressure steam disinfection tends to fix stains and alter the texture of white blankets, but is less harmful to brown or grey service blankets. Current steam is the method of choice. A temperature of 127°C. for 30 minutes will make flannel brittle, but this is remedied by subsequently hanging the articles on lines in the open.

38. **Boots, Shoes, Belts, and Leather, Rubber, or Felt Articles.** These should be well swabbed with formalin solution (one ounce to a pint of water). A contact period of five minutes is sufficient to destroy microorganisms and fungi. Footwear should be dried and well aired after treatment. Exposure to formalin vapour in a disinfector chamber or other sealed space for 45 minutes is an alternative method of disinfecting articles liable to damage by heat.

39. **Crockery and Feeding Utensils.** These should be boiled for at least 5 but preferably 10 minutes. Otherwise they should be soaked in a sodium hypochlorite solution (1 in 1,000) for 30 minutes.

40. **Bed-Pans and Urine Bottles.** Soaking as long as possible in 2·5 per cent. cresol solution, boiling, or steam disinfecting is necessary when these have been used for patients with infective excreta.

(*A.L.2, July* 62)

41. **Sputum.** The use of paper sputum cups (Stores ref. 4A-02275) which can be incinerated with their contents is best. Otherwise sputum may be disinfected by contact for as long as possible up to 4 hours with 10 per cent. cresol.

42. **Faeces, Vomit, and Urine.** Infective faeces, vomit, and urine should be mixed with an equal volume of 10 per cent. cresol and allowed to stand for at least 2 but preferably 4 hours.

43. **Dressings.** Wound dressings and other similar materials soiled by infective discharges should be burned.

44. **Books.** Books do not play much part in the spread of infection. Staphylococci may survive months in old books but die out rapidly in new ones. Streptococci can survive one month, but the number of organisms diminishes rapidly. If precautions are essential, cheap or tattered books should be burned, but most infections can be guarded against by "quarantining" the book for 1 to 2 months. New or valuable books will be safe, whatever the infection, after quarantine of 6 months.

45. **Telephones.** It is an established practice periodically to disinfect the mouth and ear pieces of telephones and similar instruments, although investigations by the Public Health Laboratory Service suggest that this is a needless precaution. Section 33F/418 Antiseptic Fluid Concentrate for Instrument Sterilization is provisioned for this purpose.

DISINFESTATION

General

46. Insect, arthropod, and animal pests can exert a profound effect on the health, economy, and comfort of man. Disinfestation is aimed against these pests, particularly those that are vectors of disease. Nearly all methods of disinfection are lethal to insects and arthropods, but their use in disinfestation is limited. Conversely, methods of disinfestation rarely disinfect; for example, lice and their eggs are killed by hot air disinfestation which does not destroy the infective rickettsiae of typhus contained in the lice and their faeces.

47. Animal pests commonly the target of disinfestation include rats and mice. Flies, mosquitos, fleas, lice, bed-bugs, cockroaches, ticks, and mites are the insects and arthropods normally concerned. It is important that the method of disinfestation employed kills eggs, larvae and pupae as well as adults whenever possible; consequently the bionomics of the pest influences the choice of method. The range of methods available include the use of heat, gases, medicaments, poisons, and insecticides; but these must be supplemented by general sanitation, methods of building construction, civil engineering, and personal protection.

48. **Heat.** Baking in dry heat 70°C. for one hour will kill any pests harboured in clothing or personal belongings. The use of a hot iron is a traditional method of destroying lice. Any form of steam disinfection will disinfest clothing and bedding.

49. **Gases.** Formaldehyde is completely ineffective against insects. Hydrocyanic gas is used in the eradication of rats and sometimes for ridding houses and furniture of bugs. Insecticides have largely replaced hydrocyanic gas and sulphur dioxide in insect control.

50. **Medicaments.** Examples of medicaments used for personal disinfestation are sulphur ointment and benzyl benzoate against sarcoptis scabeii, blue ointment and lethane hair oil against the crab and head louse respectively.

51. **Poisons.** The use of poisons is now limited to rodent control. Insecticides have replaced poison baiting against cockroaches.

52. **Insecticides.** The majority of pest control methods now involve the use of the modern synthetic insecticides. An account of these is given in the next chapter.

53. **Disinfestation of Textiles and Other Equipment.** A.P. 830, Vol. 2, Chap. 2, Appx. "B", describes the control of such pests as moths, carpet beetles, silver fish, firebrat, termites, and wool beetles.

CHAPTER 10

INSECTICIDES AND REPELLENTS

INTRODUCTION

1. The common insecticides, until 1942, included arsenical preparations, rotenone (derris), oils, sodium fluoride, and pyrethrum. In 1942 the Kenya pyrethrum crop failed. This stimulated interest in D.D.T., which the Swiss had been developing since 1939. The needs of war spurred research in England and the United States. The results showed that D.D.T. was an effective insecticide, safe to use, and with a persistent effect. The modern range of synthetic insecticides originated from these researches. Those, besides D.D.T., most commonly used in insect control include B.H.C. (gammexane), dieldrin, aldrin, and chlordane. But pyrethrum still also has its uses.

CHARACTERISTICS OF SYNTHETIC INSECTICIDES

Attributes

2. Insecticides should be highly toxic to insects but should not be poisonous to vertebrates; they should have a persistent action and they should not cause the development of resistance in insects. Persistence means the retention by the insecticide of its toxicity for an appreciable period after application. Resistance is the acquisition by an insect of immunity to the toxicity of an insecticide.

3. These attributes vary from insecticide to insecticide. For example, the comparative toxicity to insects of dieldrin, chlordane, B.H.C. and D.D.T. are:

Dieldrin > B.H.C. = aldrin > chlordane > D.D.T.

But the order changes when the persistence of these insecticides is compared:

D.D.T. = dieldrin > B.H.C. > chlordane = aldrin.

Dieldrin is the best insecticide by these standards, but is more toxic to vertebrates than the others. Chlordane and D.D.T. are the ones most likely to cause resistance in certain insects. Hence, according to circumstances, one advantage may be outweighed by some disadvantage.

Action

4. The synthetic insecticides are contact poisons. That is, they kill without being swallowed or inhaled. They penetrate the insect's cuticle and poison nerve centres; this causes differential intoxication of reflexes. The rate of penetration varies, but there is always a latent period between contact and the death of the insect. Penetration is accelerated when the insecticide is in an oily solution.

5. Insects rarely rest long enough on a treated surface to die on the spot. It is important in consequence that enough insecticide should adhere to them, so that they will carry away a lethal dose. The particle size of an insecticide, and the fumigant action of the more volatile types are important in ensuring this.

Particle Size

6. The insecticide on a treated surface is in particulate form. The particles most adherent to an alighting insect have diameters of less than

20 microns or are very thin crystals up to 60 microns in length. The power to adhere is increased if the particles are slightly oily. The higher the toxicity of the insecticides, the less important is particle size, for the lethal dose is much smaller.

7. Certain characteristics of insects influence the amount of insecticide they pick up. These are the structure of their tarsae, the stance they adopt, and the amount they move about on the treated surface.

Fumigant Action

8. B.H.C. and aldrin are less persistent than D.D.T. and dieldrin; this is because they are more volatile. This volatility accounts for the fumigant action of B.H.C. and aldrin. However, in spite of their greater persistence and stability, D.D.T. and dieldrin have also been noticed to have something akin to a fumigant effect. This is probably attributable to airborne particles of insecticide or to dust impregnated with it.

INSECTICIDAL PREPARATIONS

Oily Solutions and Emulsions

9. The initial toxicity of insecticides applied in these forms to an impermeable surface is very high. It drops sharply when crystallization occurs. This is because:—

(*a*) The oil that helps the penetration of the insect's cuticle is lost.

(*b*) The crystals tend to be too large to adhere satisfactorily.

(*c*) The residue of the oil gums the crystals to the surface.

10. Oily solutions and emulsions immediately penetrate absorbent surfaces, carrying the insecticide with them. Initial toxicity is not so high; but when crystallization occurs on fibrous material a surface bloom of crystals appears. This does not occur on surfaces of mud, adobe, or plaster, for which in consequence oily solutions and emulsions are unsuitable. The persistence of toxicity on treated fibrous surfaces is good, because regeneration of the bloom is mechanically stimulated; the minute disturbance caused by the passage of an insect across the surface is sufficient stimulus.

11. Oily solutions of insecticide are more effective and economical in the control of mosquito larvae than oils used alone. Insecticide oil ensures the death of larvae even though a very much thinner layer is applied, compared with the older forms of larvicidal oil. As insecticides can be mixed with oils of very high spreading power, it is possible to ensure the coverage of water surfaces with the use of very much less material.

Wettable Powders and Dusts

12. Powders containing insecticide may have wetting agents added so that they form even suspensions in water and can be applied by a sprayer. Suspensions of wettable powder are good preparations for treating absorbent and semi-absorbent surfaces. If applied to brick, mud, or plaster the water is quickly absorbed and leaves a crystalline insecticidal residue on the surface. On impermeable surfaces the residue left after the water has dried may be a little caked, so that the toxicity is less than on porous surfaces.

13. Insecticidal dusts consist of insecticide in some form of inert medium. They have limited applications but are useful to disinfest verminous persons and in the control of cockroaches. Their limitation is that they can only be applied to more or less horizontal surfaces, or to clothing and similar fabrics that will retain the dust.

Space Sprays and Aerosols

14. These are used for the rapid destruction of adult insects in confined spaces. As a quick kill is required, pyrethrum, synergised by piperonyl butoxide, is the insecticide that is most effective. One of the synthetic insecticides combined with pyrethrum may, however, be used. Besides being rapidly lethal, pyrethrum stimulates insects to fly about, which increases their exposure to the airborne insecticidal droplets.

15. The size of these droplets is important. If they are too large they cascade ineffectively to the floor. If they are too small they do not impinge adequately on the insect; they are swept aside by its "slipstream". Droplets of 10 to 20 microns diameter are the most effective.

Fogs and Smokes

16. Insecticidal fogs and smokes are promising methods of insect control. Their use in the killing of both adults and larvae seems particularly suited in areas where heavy vegetation makes ordinary methods ineffective. The manner of their application allows large areas to be treated by comparatively few men. They are not effective if the weather conditions cause rapid upward dispersion.

17. Indoors, fogs and smokes penetrate to insect harbourages out of reach of sprayed insecticides; their residual effect, however, is very slight.

D.D.T.
(Dichlorodiphenyltrichloroethane)

18. D.D.T. is a stable substance which when pure is a fine, white crystalline powder. It is a contact poison to most insects, but is not toxic to man in the preparations and circumstances in which it is normally used. Its lethal action on insects is slow but its persistent properties make it a particularly useful residual insecticide. A disadvantage is that certain insects develop resistance to it.

19. An insect poisoned by D.D.T. shows characteristic signs of intoxication. These are continuous unco-ordinated movements due to disorganization of the reflexes. Recovery from mild intoxication may take place. Resistance to lethal doses has been developed by flies, lice, culicines and increasingly anopheline mosquitoes. The mechanism of this is not yet known. In flies, resistance may be hereditary for some generations; it passes off if subsequent generations are not exposed to D.D.T. The insecticide has an irritant effect on insects, especially flies and mosquitoes. This tends to prevent them resting on treated surfaces long enough to acquire a lethal dose. The characteristic is known as "contact repellency", or behaviouristic resistance.

20. Commercial D.D.T. contains 60 to 70 per cent. of the active principle. It is easily dissolved in organic solvents and to a lesser extent in mineral oils: it is insoluble in water. It is usually dissolved in kerosene

and used as a spray, but it can also be applied in powder form. It is issued in the Royal Air Force as:—

(*a*) *33F/393, D.D.T.* (*Crude*). For making up residual spray.

(*b*) *33F/408 D.D.T. 50 per cent. Water Dispersible Powder*. To prepare as residual spray mix 14 ozs. powder with 1 gallon of water.

(*c*) *33F/409 D.D.T. 25 per cent. Emulsion Concentrate*. To prepare as a residual spray, 2 pints of the concentrate are added to 1 gallon of water.

(*d*) *33F/395 Powder, Anti-Louse, Mark IV*. This is D.D.T. 10 per cent. in talc or china clay.

(*e*) *33F/387 Powder, Cockroach*. D.D.T. 10 per cent. with pyrethrins 0.4 per cent. and piperonyl butoxide 1 per cent. in an inert base.

21. D.D.T. may be used in the control of mosquitoes, flies, bed-bugs, lice, fleas, and cockroaches. Recommendations on the application of the various preparations follow.

D.D.T. Residual Spray (5 per cent.)

22. **Use.** This general purpose spray may be used as a residual insecticide to control adult mosquitoes, bed-bugs, fleas, and sandflies. It may be applied as an area larvicide in the control of mosquitoes. It is also suitable for use in thermal fog machines.

23. **Preparation.** A 5 per cent. solution is prepared by dissolving 1 lb. crude D.D.T. (33F/393) in 2 gallons kerosene (see para. 26).

24. **Application**

(*a*) The residual surface deposit of D.D.T. should be 200 mgm. per square foot. The application of 1 gallon of 5 per cent. solution to 1,000 square feet of surface gives a deposit of approximately 200 mgm. Subsequent applications should be at intervals of one to three months, depending on local circumstances.

(*b*) As a mosquito larvicide the dosage per acre of water surface is 1 quart of 5 per cent. solution. (It may be easier to use a larger quantity of a more dilute solution in practice).

D.D.T. Residual Spray (10 per cent.)

25. **Use.** A stronger solution of D.D.T. is required in the control of cockroaches. B.H.C. is the insecticide of choice for this purpose, but if it is not available 10 per cent. D.D.T. in kerosene may be used.

26. **Preparation.** D.D.T. 10 per cent. spray is not issued; it must be prepared by dissolving 2 lbs. crude D.D.T. in 2 gallons of kerosene. All lumps in the crude D.D.T. must be broken down into a fine powder. Sufficient kerosene is then added to the required amount of D.D.T. powder to form a cream or thin paste. This paste should be stirred into the remainder of the kerosene, which should be agitated at intervals until solution is complete. A good method of agitation is to roll the drum containing the mixture. If the work is carried out in the open under a hot sun, stirring or rolling for half an hour in the morning and afternoon for three days will be sufficient. Solution will take longer under cooler conditions, and it may be necessary to add a proportion of an organic solvent, such as xylol, to achieve full solution.

27. **Application.** The spray should be applied as a residual, at the rate of 1 gallon per 1,000 square feet (see Chapter 11, paras. 7 to 15).

D.D.T. Powder Anti-Louse, Mark 4

28. **Use.** Anti-louse powder is used mainly for the treatment of persons infected with lice. It is applied with a dust gun without the person undressing, as described in paras. 54 and 55. It may also be applied to infested clothing or bedding, if other methods of disinfestation are not available. It may be used as a substitute if cockroach powder is not obtainable.

29. **Preparation.** The powder is issued, ready for use, under the stores reference number 33F/395.

D.D.T. Cockroach Powder

30. **Use.** This powder may be used to control minor cockroach infestations, or to follow-up residual spraying with D.D.T. or B.H.C. Since it contains pyrethrins it has a rapid knock-down effect.

31. **Preparation.** D.D.T. cockroach powder is supplied ready for use under the stores reference number 33F/387.

32. **Application.** D.D.T. cockroach powder should be lightly scattered on floors or shelves, with a dust gun, in places likely to be frequented by cockroaches (see Chapter 11, paras. 7 to 15).

B.H.C.
(Benzene hexachloride)

33. In pure form B.H.C. is a white crystalline substance. Its active insecticidal principle is the gamma isomer; hence the trade name "Gammexane". Crude preparations have a musty odour and inhalation of B.H.C. powder is highly irritating.

34. B.H.C. is moderately soluble in organic solvents, slightly soluble in mineral oils, and insoluble in water. It is not so stable a substance as D.D.T. and its crystals volatilize slowly. Consequently it is less persistent than D.D.T., but has a toxic effect on insects eight times as great. This high toxicity enables a very small dose of the insecticide to be used effectively.

35. B.H.C. is a contact, poison, acting much faster than D.D.T. Its volatility gives it a fumigant effect, which enhances its lethal powers. Insects poisoned by B.H.C. do not show the persistent ataxic movements of D.D.T. intoxication. Nor does B.H.C. have the same contact repellency as D.D.T.

36. B.H.C. is used in the Royal Air Force as a spray made up from a wettable powder or an emulsion concentrate, in the control of mosquitoes, flies, bed bugs, fleas, cockroaches and sandflies. It may be used in powder form against lice resistant to D.D.T. The emulsion concentrate can be added to kerosene or diesel oil and used in a thermal fog machine to produce an insecticidal fog.

Insecticide B.H.C.

37. B.H.C. is supplied under this title in two preparations:—

(*a*) 33F/410 B.H.C. water dispersible powder, containing 50 per cent. gamma B.H.C. (Lindane quality).

(*b*) 33F/411 B.H.C. 20 per cent. gamma emulsion concentrate (Lindane quality).

The water dispersible powder is the preparation of choice for absorbent or semi-absorbent surfaces. The emulsion concentrate is more efficient than the powder on relatively non-absorbent surfaces. The emulsion concentrate is less liable to stain decorated surfaces than the powder. It can also be added to high grade kerosene for use as a solution where there is a risk of water-staining of fabrics and furnishings. In general, the emulsion concentrate should be reserved for better class living quarters, whilst the dispersible powder is more suited for the spraying of mud-huts, native labour lines, outhouses, etc. B.H.C. emulsion concentrate can be added to diesel oil or kerosene for use in thermal fog machines.

38. **Preparation.** After making sure that there are no lumps in the powder, water should be stirred into the required amount to form a thin paste. The paste should then be mixed thoroughly with the rest of the water to form a uniform dispersion. While spraying, the insecticide should be periodically stirred, or the sprayer agitated, to prevent the powder settling out and blocking the nozzle. The quantities recommended are 3 ounces of B.H.C. water dispersible powder per gallon of water; this makes a solution of 0.5 per cent. gamma isomer. Using the B.H.C. emulsion concentrate, 4 fluid ounces to a gallon of water also produces a solution of the same strength.

39. **Application.**

(*a*) As a residual, the appropriate surfaces should be sprayed at the rate of 1 gallon of 0·5 per cent. gamma isomer solution per 1,000 square feet. This gives a dosage of gamma isomer of 20 to 40 milligrammes per square foot.

(*b*) As a larvicide in the control of flies, the application rate of the same solution to breeding grounds should also be 1 gallon per 1,000 square feet. In the control of mosquito larvae 2 gallons of this solution should be applied per acre of water surface.

DIELDRIN

40. Dieldrin is a complex chlorinated naphthalene. It belongs to the same chemical group as aldrin, chlordane, and heptachlor. These insecticides have no advantage over B.H.C. and D.D.T.; but dieldrin is at least as toxic to insects as B.H.C. and as persistent as D.D.T. It is, however, more toxic to vertebrates and requires caution in handling.

41. **Use.** Dieldrin is supplied as a wettable powder or as a concentrated emulsion. It is effective against mosquitoes (adults and larvae), flies, bugs, fleas, cockroaches, ticks and mites. For example, it was used with success to eradicate trombiculid mites from an area in a camp abroad, where cases of scrub typhus had occurred.

42. **Application.** For indoor residual spraying a solution of 0·625 per cent. dieldrin should be used. (Note. Because of its toxicity, caution must be used in the application of dieldrin indoors.) This is obtained by mixing 3½ ounces of wettable powder (50 per cent. dieldrin) or 10 fluid ounces of

emulsion concentrate (18·6 per cent. dieldrin) with 1 gallon of water. In each case the powder or the concentrate are added to the water. The spray is applied at the rate of 1 gallon per 1,000 square feet which gives a dosage of 50 mgm. per square foot. For the control of mosquito larvae and of trombiculid mites, 16 gallons of the mixture should be applied per acre. Dieldrin emulsion may be added to diesel oil or kerosene for use in thermal fog machines. Because of its toxicity, care must be exercised in breaking down concentrates and protective rubber gloves and aprons should be worn. A respirator should be worn when handling powder concentrates and good washing facilities should be available.

PYRETHRUM

43. Pyrethrum is a botanical insecticide extracted from the heads of certain chrysanthemums. The active insecticidal components of the extract are pyrethrins. Allethrin is the chemically synthesized form of pyrethrin; it has similar insecticidal action.

44. Pyrethrum has no residual insecticidal properties, but it kills insects very rapidly. Its toxicity to insects is much enhanced by the addition of synergists, of which piperonyl butoxide is the best. Its main use is for the rapid destruction of insects by space spraying. It is also added to residual insecticides to accelerate their lethal effects.

45. It is supplied in the Royal Air Force as 33F/407 Insecticide, Space Spraying, Concentrate. One part of the concentrate is added to 99 parts by volume of high-grade kerosene (roughly 1 pint to 12 gallons). The spray then contains 0·06 per cent. pyrethrins and 0·6 per cent. piperonyl butoxide. The insecticide in the aerosol dispenser (33F/415) also contains pyrethrins (see paras. 48 to 51).

APPLICATION OF INSECTICIDES

Space Spraying

46. Space spraying is aimed at killing adult flying insects in confined spaces, such as rooms or aircraft. It consists of releasing a liquid insecticide into the air in the form of fine droplets. "Flit" guns or aerosol dispensers are used for the purpose.

47. Flit guns are less efficient than aerosol dispensers because the droplets formed are too coarse and fall rapidly to the ground. The correct method of use is to spray the insecticide into the air, for the length and breadth of the room, using about 40 strokes of the gun per 1,000 cubic feet. Doors and windows should be closed and remain so for 20 minutes after spraying is over. It may be necessary to repeat spraying at frequent intervals. Only rapidly acting insecticides, containing pyrethrum, should be used.

48. **Aerosol Dispensers** (33F/415). Although very effective for any type of space spraying, aerosol dispensers have a particular use in the disinsecting of aircraft. The droplet size of the spray emitted ensures that the insecticide will persist in the air for several minutes; and the droplets are not so small that they do not impact effectively on flying insects.

49. The aerosol dispenser consists of a small canister charged with approximately 430 grammes of insecticide and with freon gas. On release the insecticide is driven out, through a pinhole orifice, in the

form of a fine particulate spray. The time required for all the insecticide to be discharged is about 7 minutes. The composition of the insecticide is:—

D.D.T.	3 per cent.
Cyclohexanone	5 per cent.
Pyrethrum; total pyrethrins equivalent to	0·4 per cent.
Hydrocarbon oil	5 per cent.
Freon	85 per cent.

The addition of the hydrocarbon oil ensures droplets of the right size and persistence.

50. When disinsecting aircraft, insecticide should be released from the dispenser for 15 seconds per 1,000 cubic feet. It is important to spray under seats, in lavatories, crew, and baggage compartments. The aircraft should remain closed for at least five minutes after spraying.

51. When spraying a room insecticide should be released over the length and breadth of the room, for five seconds per 1,000 cubic feet. Doors and windows should be closed while spraying is being carried out and for at least 20 minutes thereafter.

Residual Spraying

52. Residual spraying is aimed at killing adult insects either in or out of doors. It consists of applying a persistent insecticide to surfaces upon which insects will alight and rest, or which they are likely to cross. Hand or powered pressure sprayers are generally used, but the insecticide may be applied by brush in the case of insecticidal lacquers.

53. Hand sprayers may be of the knapsack type carried on the back; stirrup pumps are also useful. Sprayers currently available are listed in R.A.F. Equipment Scale B. 109 (Revised 1961). Enough insecticide should be applied to make surfaces wet, without the liquid running off. The surface to be sprayed should be divided into vertical sections about 10 feet wide, *i.e.* the span of arm and lance. Each section should be sprayed in four horizontal bands overlapping about 4 inches at the edges. The first and third bands should be sprayed from the top downwards, the second and fourth from the bottom upwards. This method economises in time, labour and insecticide and is less tiring to the operator. The rates of application of D.D.T., B.H.C. and dieldrin are given earlier in this chapter.

Dusting

54. Powdered insecticides are best applied by dust guns of the currently approved pattern. The scattering of powder by hand is clumsy and wasteful. These dust guns have long detachable nozzles to facilitate the application of powder to inaccessible places.

55. When humans are disinfected, A.L.63 powder is blown up each sleeve, down the back and front of the shirt at the neck, and down the back and front of the trousers at the waist. About 1½ ounces is used for each person.

Smokes

56. Insecticidal smokes are generated by heating solid insecticides. A convenient type of generator is a small canister containing insecticide and a combustible. The particle size of the smoke is optimal for persistence and impingement on flying insects, which can be killed by this method in or out of doors. The eradication of cockroaches and other crawling

insects from infested premises, where they are difficult to get at, may be successfully achieved with a smoke insecticide. An insecticidal residue is left on all surfaces in treated buildings but its residual toxicity is short-lived.

Fogs

57. The generation of insecticidal fogs requires special apparatus. These have been found effective for the area control of insects and for the disinfesting of ships and buildings. The particles of the fog are of suitable insecticidal size; in addition residual deposits are left on surfaces in treated buildings. Insecticidal fog appliances are used by the Royal Air Force for certain special control problems at home and abroad.

Insecticidal Lacquers

57A. Residual lacquers are urea-formaldehyde resins, containing about 20 per cent. D.D.T. or dieldrin. The resin base is saturated with a high concentration of the insecticide, causing the insecticide crystals to "bloom" on the surface in a form highly toxic to alighting insects. "Blooming" continues over long periods: a year is typical; and such surfaces withstand the usual methods of cleaning, in fact rubbing the surface encourages blooming. Insecticidal lacquers are most effective on smooth non-absorbent surfaces which are kept clean. The expense of these formulations, and the necessity for their application to be supervised by personnel trained in insect control, prohibits their widespread use. They are of value in specific cases, *e.g.* the control of ants in hospital wards. Application is by a flat 4-inch paint brush and 4-inch bands of lacquer are applied in selected places, depending on the site and type of infestation. For small jobs the lacquer may be applied by means of an aerosol dispenser.

Application of Insecticides from Aircraft

58. Insect control by aerial spraying is of value in difficult or impassable terrain, when large tracts of country must be treated. Aerial spraying causes an immediate reduction in adult insects and is also successful in the control of the larvae of certain species. Anophelines, culicines, simulium, house-flies, and tse-tse flies, have all been controlled in various parts of the world by this method.

59. The spray may be emitted below the aircraft through a straight gravity pipe, dispersion into droplets occurring on impact of the insecticide with the slipstream. A finer spray is obtained if the spray is dispersed either through a specially designed and fitted wire brush rotating at 2,500 r.p.m. or through a perforated boom.

(*Continued on page 231*)

60. An effective dosage of D.D.T. is 0·25 pounds per acre. Using a solution of 10 per cent. D.D.T. in fuel oil, this means applying 0·25 gallons per acre, which per square mile works out at 160 pounds D.D.T. and 160 gallons of solution. The rate of emission of the insecticide from the aircraft is given by the following formula:

$$E = \frac{S \times T \times D}{4,840} \text{ gallons per second, where:}$$

E = rate of emission in gallons per second.
S = ground speed of aircraft in yards per second.
T = width of track or swath to be covered each run, in yards.
D = dosage of D.D.T. required, in gallons or pounds per acre, using a 10 per cent. solution.

61. When the insecticide delivery apparatus is an improvised gravity tank and pipe, the aircraft must fly, so far as possible, cross-wind while spraying. This ensures that the insecticide discharged is converted into a broad swath. The swath is distributed down-wind from the line of flight, no insecticide falling on the ground immediately below the aircraft. The width and displacement of the swath depends on the height of the aircraft, the strength of the wind, and the direction of its cross-track component. If the angle of the wind to the line of flight is $\theta°$ then the cross-track component is cos θ.

62. The aim should be to lay overlapping swaths of about 300 yards width from an altitude of about 200 feet at a ground speed of about 150 miles per hour. It is important to spray at the times of day when convection up-currents are least strong. Soon after sunrise and before sunset are the best times.

63. Careful organization and control of a spraying operation are essential to its success. The area concerned must be carefully mapped and a system of ground marking worked out. Allowances must be made for the meteorological conditions expected. Ground control of the aircraft by radio is important.

REPELLENTS

Uses and Characteristics

64. Repellents are used as a means of personal protection against insects and arthropods. They are applied to the skin, the clothing, or both. A good repellent should have a persistent effect and repel a wide variety of insects: it should not be toxic or irritant to the skin; it should not damage or discolour textiles; it should not be unpleasant or difficult to apply.

65. One difficulty in selecting a suitable repellent is that the efficacy of most vary according to the insect concerned. Some in fact kill the insect rather than repel it, and the miticides are of this class. The present tendency is to combine the attributes of a number of repellents by using a mixture.

Examples of Repellents

66. **D.B.P. (dibutyl phthalate).** D.B.P. is a colourless, oily fluid, largely used for the impregnation of clothing as protection against the mite vectors of scrub typhus. It kills mites less quickly than D.M.P. but is more persistent, its activity surviving eight as compared with two

washes. Individuals can impregnate their own socks, trousers, and shirts with this substance, which is less a repellent than a miticide. One ounce is smeared with the fingers on socks, trousers, sleeves, and shirt.

67. **D.M.P. (dimethyl phthalate).** D.M.P. is a fluid substantially similar to D.B.P., but is primarily a repellent against mosquitoes and sand-flies. Although quite useful, its repellency ranks low in comparison with the mixed repellents; with some insects its persistence may last no more than one hour, although on the average it lasts three.

68. **Rutgers 612 and Indalone.** These repellents alone are moderately effective, approximating to D.M.P. Combined with other repellents their usefulness is increased. Examples of mixed repellents are:—

(*a*) D.M.P., indalone and R612 equal parts.

(*b*) D.M.P., 4 parts with R612 and D.M.C. (dimethyl carbamate), each three parts.

(*c*) D.M.P., 6 parts, indalone and R612 each two parts. This is Repellent 6-2-2.

(Rutgers 612 is 2-ethyl-1, 3-hexanediol; indalone is n-butyl mesityl oxide oxalate.)

69. **M.1960.** This is an American mixed repellent for the impregnation of clothing. It repels mites, mosquitoes, fleas, and leeches. It consists of butyl-ethyl propanediol, benzyl benzoate and n-butyl-acetanilide with 10 per cent. Tween-80 as an emulsifier. The R.A.F. combined sun-screen insect repellent cream is a development of this.

70. **D.M.C. (dimethyl carbamate).** This repellent has been found particularly effective against aëdes and is a useful component of mixtures.

CHAPTER 11

PEST CONTROL

BED BUGS
(*Cimex lectularius*)

Importance and Habits

1. Bed bugs feed only on blood. They are not highly specialized parasites and certain species take blood from animals or birds as well as man. They are not known to be vectors of disease, but their presence is a sign of poor hygiene. They are a nuisance because the irritation caused by bites leads to serious loss of sleep.

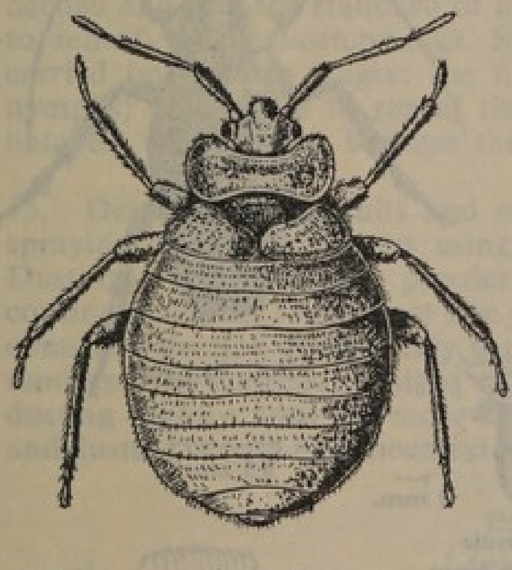
2. The bugs live in crevices in furniture or walls of bedrooms and visit their hosts only to feed. They are normally transmitted from one building to another by furniture or bedding or by the movement of these in infested vans. Wood salvaged from infested buildings may also act as a method of spread. Migration may occur from room to room.

Morphology

3. The adult bed bug is a flat, oval insect, one-fifth of an inch in length and about one-eight of an inch in breadth (see Fig. 63). Its colour varies considerably. Sometimes it is a bright chestnut, at others a dark mahogany, and often after a feed, deep purple or red.

Life History

4. The egg of the bug is deposited in its lair and cemented in place. Temperature is most important for incubation and subsequent development. At 82°F. the incubation period is five to six days and the complete life cycle 34 days. At 59°F. the incubation period is 34 days and the complete life cycle over 200 days. There are five nymphal stages, all of which resemble the adult in shape, and all of which require a full meal of blood before the next moult.



Adult Female Dorsal view

FIG. 63. BED BUG
(*Cimex lectularius*)

Control

5. Serious infestations of bed bugs are uncommon in the United Kingdom, provided the standard of hygiene is adequate. Abroad, especially in hot climates, they are a constant source of trouble. Disinfestation may be effected by using D.D.T. or B.H.C. which kill the bugs when they pass over treated surfaces on their way to feed. Although the eggs are unaffected, the residual properties of these insecticides lead to the extermination by degrees of subsequent generations. In colder climates, however, because the life cycle is long, follow-up treatment may be necessary. The repair of cracks and crevices providing harbourage for bed bugs is in addition always essential.

6. Five per cent. D.D.T. in kerosene is applied liberally to the walls, floors, ceilings, and furniture, special attention being paid to crevices. Alternatively B.H.C. may be used. (See Chapter 10.)

COCKROACHES
(*Blattidae*)

Importance and Habits

7. Cockroaches require a habitat which is warm, dark, and near to food. They are therefore usually found in kitchens, particularly around cooking ranges, in pantries, and storerooms, hiding behind steam radiators, hot plates, or hot water pipes, and between skirting boards and floors. The insect feeds in the dark and is omnivorous.

8. Experiments have shown that cockroaches are potential vectors of disease, yet they have never been implicated as the cause of an outbreak. Nevertheless, their indiscriminate feeding habits, associated with their presence in such places as hospitals, imply some risk. Cockroaches are normally spread by infested furniture, groceries, crates, and packing cases; but local migration can take place.

Morphology

9. The general appearance of the cockroach is well known and requires no detailed description (see Fig. 64.) Three kinds are commonly found.

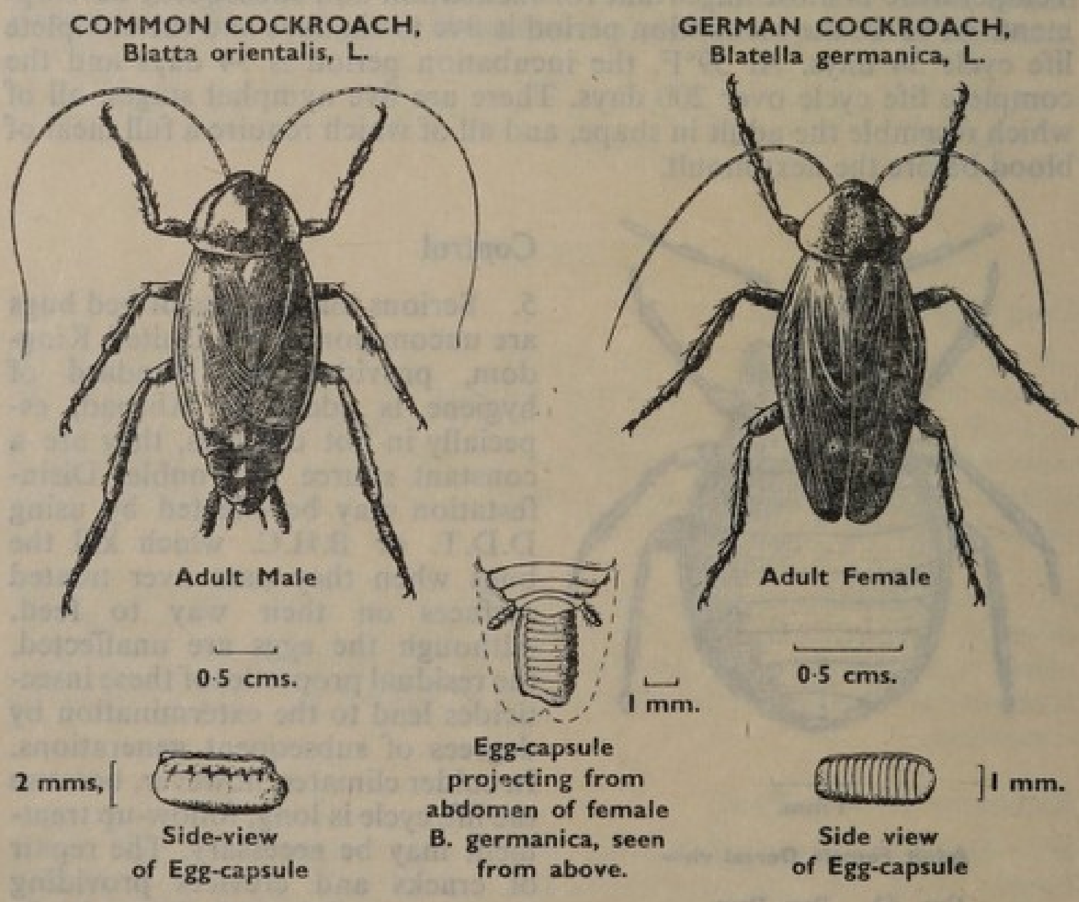


FIG. 64. COCKROACHES

10. **Blattella Germanica.** This is the commonest of the three types. It is about half-an-inch in length, yellowish-brown in colour, and both sexes have large wings. It is referred to as the German cockroach, steam-fly, or croton bug.

11. **Blatta Orientalis.** This is a shiny, chocolate coloured insect about one inch in length. The male has wings covering two-thirds of the abdomen. In the female the wings are reduced to short lobes. It is sometimes called the oriental cockroach or blackbeetle. Formerly it was the most common type of cockroach in Great Britain and is still seen in small old-fashioned houses; now blattella is more frequent. In a dual infestation blatta eventually succumbs.

12. **Periplaneta Americana.** The adult insect is about one-and-a-half inches in length and is reddish-brown in colour. Both sexes have large wings. It is commonly referred to as the American cockroach or Bombay canary. This cockroach is rarely found on land in this country, except in the tropical houses of zoological gardens. It is, however, a common pest in ships.

Life History

13. Cockroaches (except *blattella germanica*) lay their eggs in pod-like cases, which are deposited when filled; blattella carries the egg-cases for several weeks until the nymphs are ready to emerge. The incubation period of the egg varies considerably with the temperature but is usually two or three months. The morphology and habits of the nymph do not differ greatly from the adult. Development is slow even at high temperatures and there are numerous moults. The whole cycle from egg to adult usually takes several months.

Control

14. Old buildings and those in poor repair are particularly liable to invasion, because the insects are attracted by good harbourage, dirt, and food debris. The presence of cockroaches often indicates that repairs are needed and that the standard of hygiene needs probing. The first step is to remedy such shortcomings. Subsequently disinfestation should be carried out in two stages; the first is to destroy existing adults and nymphs; the next is to repeat the treatment, to deal with subsequent hatches, which occur because the eggs are unaffected by insecticides.

15. Destruction of adults and nymphs is carried out by the residual spraying of infested rooms using B.H.C. or D.D.T. (see Chapter 10). Dusting with cockroach powder should follow immediately and be continued nightly for at least one week. The follow-up treatment should consist of dusting once weekly with cockroach powder for at least three months. Any subsequent signs of reinfestation should be dealt with by dusting nightly until no more dead cockroaches are found. Spraying and dusting should be concentrated around known or likely harbourages.

FLEAS
(*Aphaniptera*)

Importance and Habits

16. Adult fleas feed intermittently on blood from mammals and birds. Most species visit their hosts to feed and are carried around by them for only a short time. They are only partially host-specific and if compelled by necessity will feed on most warm-blooded animals.

17. Although all fleas are potential vectors of disease, the human flea, *Pulex irritans*, seldom acts as such. Rat fleas can however transmit plague and murine typhus to man. The species primarily responsible for transmission of disease from rat to man is *Xenopsylla cheopis* in the tropics, and *Nosopsyllus fasciatus* in temperate climates.

18. Flea infestations may originate from the neglected sleeping places of cats and dogs. They may be spread either by the movement of the host or by the transfer of eggs from one place to another, for example in infested rugs or carpets. They may also attach themselves to a temporary host passing through flea-infested premises and thus be carried elsewhere.

Life History

19. Fleas lay their eggs at random. These may stick temporarily to the fur, feathers, or clothing of their hosts, but eventually fall off to lie on the floor or ground. The eggs are pearly white, oval in shape, and approximately 0·5 millimetre in size. In from two to ten days the eggs hatch into larvae which are whitish and hairy, resembling minute caterpillars. They are mobile, especially when disturbed, and feed on any organic debris to be found in their vicinity, especially the faeces of adult fleas. They live on the floor, usually in dust-filled crevices, and form cocoons before pupation. This takes from three weeks to twenty months depending on the temperature and food supply. Fleas can resist starvation for long periods; this accounts for their survival in uninhabited places.

Morphology

20. The shape of the adult flea is characteristic and unlike that of any other insect, being flat from side to side (see Fig. 65). The head is helmet-shaped; the three thoracic segments resemble each other, are freely mobile, and heavily covered with bristles. The legs are highly modified for leaping and the feet bear claws for clinging to the host.

Control

21. Infested rooms should first undergo thorough domestic cleaning. The floors and walls should be sprayed to a height of two feet with a solution of D.D.T. or B.H.C. (see Chapter 10). Infested rugs, carpets, and upholstery should be treated with either D.D.T. or B.H.C. powder. Infested animal bedding should be burned. The animals themselves should be thoroughly dusted with powder containing D.D.T. or B.H.C.

FEMALE:—Lateral View

FIG. 65. HUMAN FLEA
(*Pulex irritans*)

Chigger Fleas (*Tunga penetrans*)

22. The chigger or sand flea is common in America, Africa, and on the west coast of India; its favourite haunts are dry sandy soil, dust, stables, or poultry pens. It is smaller than the common flea and has similar habits, except for reproduction. The impregnated female settles on the first warm-blooded animal encountered, burrows into the skin and ovulates; later the mature eggs are ejected and fall to the ground. The adult develops in

approximately one month. The chigger is not a good jumper and therefore is seldom found above the ankle, but other sites than the foot are attacked when people squat or sleep on the ground. The main importance of the chigger is that the lesions it causes become a site for severe secondary infection. Residual spraying of haunts with D.D.T. or B.H.C. controls the insect.

LICE
(*Anoplura*)

Importance and Habits

23. Human beings may be infested by the body louse (*Pediculus humanus corporis*), the head louse (*Pediculus humanus capitis*) or the crab louse (*Phthirus pubis*). The first two are varieties of the same species. Human lice transmit the rickettsial diseases, exanthematic typhus and trench fever as well as carrying the spirochaete of relapsing fever. Both species of pediculus can transmit these diseases but major epidemics are usually associated with *corporis* infestations, which are common in endemic areas. Under laboratory conditions *Phthirus pubis* has been shown to be a potential vector of disease.

24. Lice spend their entire lives in close relationship with the host; any separation other than for a brief period is fatal. Spread is normally direct from person to person, but transmission by fomites also occurs. The body louse is commonly found in people who, by habit or force of circumstances, neglect personal hygiene and infrequently change their underclothing. Its life is spent mainly on the clothes and it visits the body only to feed. The other two species infest clothing only by chance. The head louse may on occasions be found infesting the body but the body louse never infests the head. *Phthirus pubis* is normally found on the hairs of the pubic and perianal regions and occasionally on the thighs, abdomen, eyebrows, and eyelashes.

Morphology

25. Adult body lice vary in colour from dirty white to greyish black; head lice tend to be browner. There are morphological differences between the head louse and the body louse but these are of little practical importance. The pubic louse is more easily differentiated by its square appearance, the body being broader in proportion to the length.

Life History

26. **Head and Body Louse** (see Fig. 66). The eggs of these lice are opaque, yellowish white in colour and oval in shape; those of *Pediculus capitis* are attached to the eyebrows and hairs of the head, those of *Pediculus corporis* to the clothing. The nymph hatches after an incubation period of six to fourteen days depending on the temperature. In general appearance nymphs resemble the adult in miniature and their mode of life is similar. After three moults the nymph reaches the adult stage. Adults live for about 30 days when they are on the host. On discarded clothing under winter conditions nits and adults survive respectively only nine and six days.

27. **Pubic Louse.** The life cycle of *Phthirus pubis* does not differ greatly from that of the *pediculi*. Its eggs are cemented to the hairs in the pubic and perianal regions but may also be found in the axillae, or on the eyebrows and eyelashes. The eggs hatch in seven to eight days and, after three nymphal stages, maturity is reached in thirteen to seventeen days.

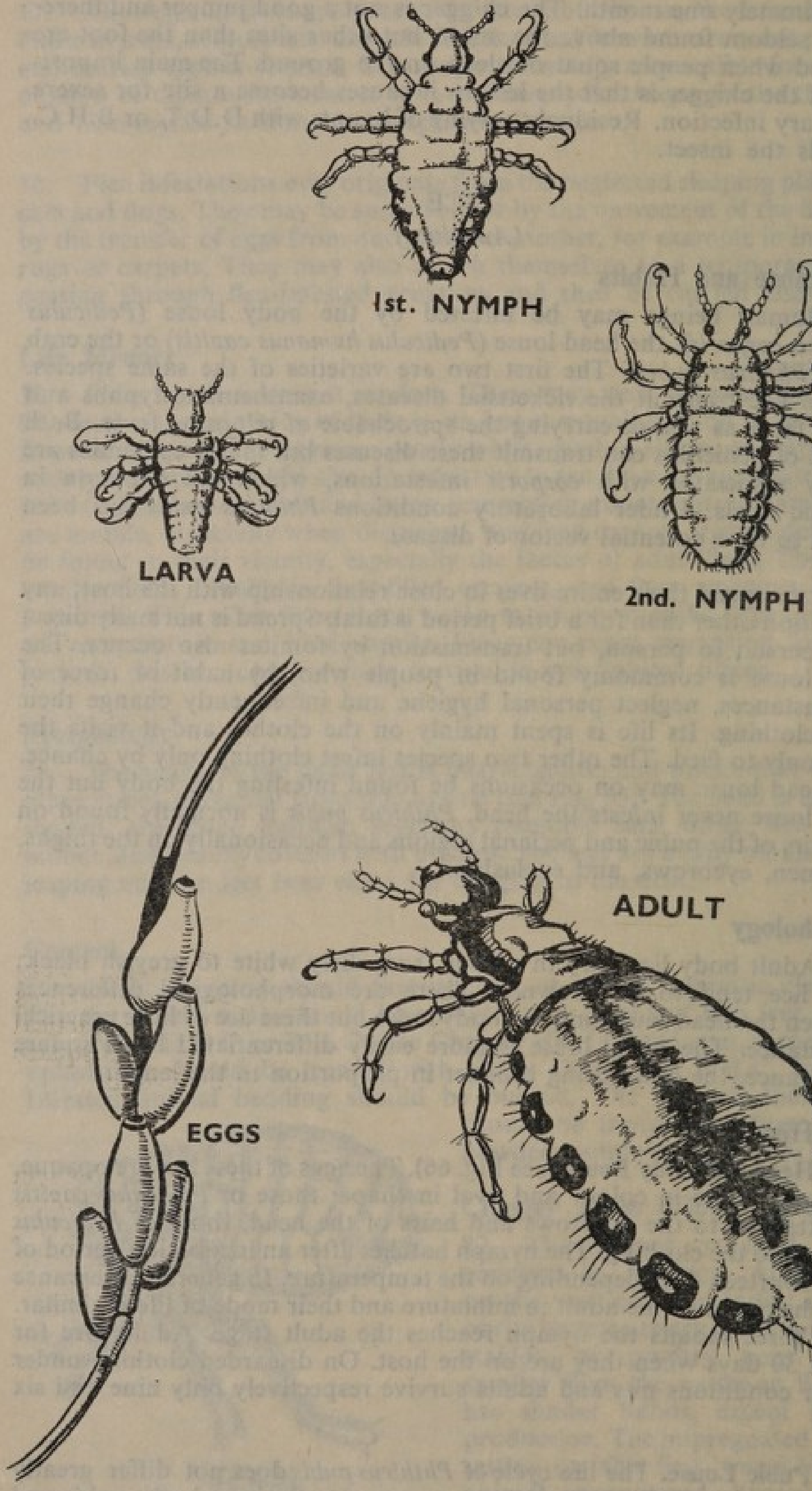


FIG. 66. LIFE CYCLE OF THE BODY LOUSE
(*Pediculus corporis*)

Control

28. **Head Louse.** Head lice should be treated by rubbing a persistent insecticide well into the roots of the hair. A suitable preparation is Dicophane Application, B.P.C. (2 per cent. D.D.T. hair oil). The Inter-service vocabulary reference is 6505-99-210-0603. An emulsion containing 2 per cent. of D.D.T. or 0·2 per cent. of B.H.C. may be used as alternatives. Adult lice are all quickly killed by these preparations but the hair must not be washed for at least a week after application, as the nits survive this treatment.

29. **Body Louse.** Insecticidal dusts are most effective against the body louse. A.L.63 Mark 4 powder (10 per cent. D.D.T.) provides the simplest treatment. Experience, however, has shown that lice may become D.D.T. resistant. A change to B.H.C. powder is immediately effective. About one ounce of anti-louse powder is scattered among the underwear and rubbed into the seams, or may be applied to persons fully clothed (see Chapter 10). Although all lice are killed, the nits survive. The lethal effects of the powder persists, however, for about three weeks, so protects from re-infestation by destroying the nymphs as they hatch. When practicable, clothing should be disinfected by heat. The usual laundering methods destroy lice and their eggs, but woollen material may be washed in water which is insufficiently hot to be lethal.

30. **Pubic Louse.** The simplest treatment is the application of a dust containing D.D.T. (10 per cent.) or B.H.C. (0·6 per cent.). An alternative is to use a 2 per cent. D.D.T. or 0·2 per cent. B.H.C. emulsion. A second treatment one week later will kill any newly hatched lice that survive. This method avoids the necessity of shaving the affected parts.

THE HOUSEFLY
(*Musca domestica*)

Importance and Habits

31. Flies are a pestilential nuisance besides being important carriers of disease. They are attracted to and feed on human faeces, from which, on their legs, in their excreta, and in their vomit, they transfer infection to food and eating utensils. Among the diseases that houseflies transmit are cholera, enteric fever, dysentery, and worm infestations. Their distribution is world-wide. Prevalence is related to climate, since temperature governs the rate of breeding. The availability of breeding places is the main factor in local distribution.

Morphology

32. The adult housefly is about one-quarter of an inch in length and grey in colour; the thorax is marked on the back with four narrow black stripes (see Fig. 67). The sides of the abdomen are buff. It has a retractable proboscis with an expanded end through which it sucks and regurgitates food. This regurgitation is an essential part of its feeding; it is by this means that food is contaminated by pathogenic organisms from the gut of the fly.

Life History

33. Flies breed in a variety of organic substances which they prefer to be moist, fermenting, or putrefying. Examples are manure, rotting vegetables, decaying carcases, and garbage. They usually lay their eggs on breeding material exposed to light, but sometimes they may deposit them deep in small crevices. A fly may lay up to 100 or 150 eggs in one day, four or five times during its lifetime.

34. The eggs are white spindle-shaped bodies about one millimetre long. The incubation period varies from eight hours to three days, depending on the temperature of the breeding material. They hatch into white maggots which burrow into the feeding material to feed, growing rapidly to attain a full size of slightly under half-an-inch in length. This development takes from 42 hours to four or five days depending on the environmental conditions; it is longer at lower temperatures. Late in the larval stage the maggots become creamy coloured and cease to feed; they leave the warmth of the breeding ground, emigrate to the periphery and burrow into loose soil. Pupation then occurs and the larval skin contracts, becoming dry, firm, and eventually dark brown. The adult fly, still in the soil, emerges fully grown from this pupal case, the presence in any numbers of which indicates the site of active breeding. The insect eventually burrows its way out by means of a head organ developed for this purpose and for rupturing the pupal case.

Control

35. The control of the housefly consists of the prevention of breeding, the destruction of the larvae, and the killing of adults.

36. **Prevention of Breeding and Destruction of Larvae.** The main breeding grounds for the housefly are household refuse, refuse tips, latrines, and dung heaps. Household refuse should be dealt with as described in Chapter 4. In properly supervised refuse tips there is little breeding but, should this occur, spraying with BHC/water mixture, 3 ozs. 50 per cent. gamma B.H.C.to 1 gallon of water, applied at a rate of 40 gallons to the acre should control the infestation. The spraying should be repeated in 14 days, and subsequently not less than every 28 days. The insecticide can be applied by means of the knapsack sprayer, or a power sprayer. For small areas, application by domestic watering can is effective. Abroad, and in the field, steps must be taken to ensure that there is no breeding in latrines. The precautions

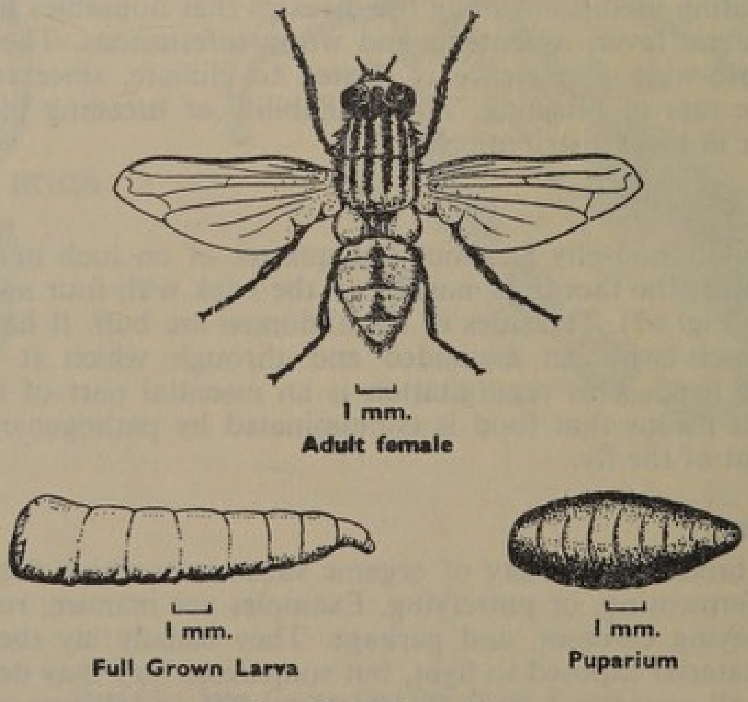


FIG. 67. HOUSE FLY
(*Musca domestica*)

outlined in Chapters 4 and 5 should be followed. Breeding may occur in stables and pig sties, unless they are cleaned out frequently; it will inevitably take place in uncontrolled manure heaps. These can be controlled by D.D.T. or B.H.C. in the concentrations required for refuse tips. Manure stacked in heaps generates heat by fermentation, so that it becomes too hot for fly larvae to develop. This is known as "curing". Tight compacting ensures the effectiveness of curing. Fresh dung should be buried in the centre of the pile, where the temperature is already high. Alternatively it should be covered with strong sacking or tarpaulins which prevent contamination by flies and promote the generation of heat. A covering of earth at least nine inches in depth will further conserve heat and assist in preventing the emergence of adult flies. Nuisance from flies is often caused by transferring manure from stables or pig sties to unit market gardens, mess gardens, and married quarter plots. This should not be permitted unless the manure has been adequately cured.

37. **Control of Adult Flies.** The destruction of adult flies has little effect on the fly population as a whole. Its main purpose is to prevent nuisance indoors and to promote kitchen hygiene. Rapid knockdown of flies is ensured by using a space spray containing pyrethrum, discharged from a Flit-gun or aerosol dispenser. For residual effects the walls, ceilings, and pendant fittings should be sprayed periodically with a solution of one of the persistent insecticides. These can be applied with either a knapsack sprayer, stirrup pump, or power sprayer. A distemper brush may be used to apply the insecticide to wire gauze frames, window frames, and electric light shades. The appropriate insecticides and details of their application are contained in Chapter 10. Spraying should start at the beginning of the fly season and be repeated periodically throughout. Flies prefer to settle on sharp edges, wires, or strings, rather than on flat surfaces such as walls, tables, or floors. For this reason special lethal frames have been designed, which can be moved to any part of a room particularly favoured by flies. These frames consist of four pieces of wood, ½ inch by 18 inches, fixed together as a square and criss-crossed with 25 feet of string, $\frac{1}{16}$ inch thick. The frame is painted and the string is soaked with 15 per cent. D.D.T. or B.H.C. In large rooms such as kitchens, dining rooms, or N.A.A.F.Is., dieldrin strips are effective. These are made from galvanized screening, containing 18 × 14 mesh per inch (length and width respectively). The screening is cut into strips ¾ inch in width which are dipped in an emulsion of dieldrin and allowed to dry. The strips are then tacked into position, one foot apart, across the roof of the room, being allowed to sag a few inches. This method economises in the quantity of insecticide used and reduces the need for spraying.

Other Flies

38. **Musca Autumnalis.** This is the principal swarming fly. The life history and morphology are similar to *Musca domestica*, but it is found indoors only during the cold winter months. During the summer it feeds on the dung, sweat, and excretions of cattle, but swarms into dwelling houses with the onset of cold weather. After swarming it can be controlled by insecticidal spraying. Beforehand its haunts and breeding places are so dispersed that effective treatment is not practicable.

39. **Stomoxys Calcitrans (Stable Fly).** Both male and female flies bite and suck blood. They prefer cattle, sheep, and horses, but will at times bite man. The maggots are very like those of the housefly and are found

together with these in piles of grass cuttings, decomposing hay or straw, and in manure. Control consists of preventing the accumulation of breeding material and of residual spraying.

40. **Blowflies** (*Calliphora, Lucilia, Sarcophaga, Phormia*). All species of blowflies have the same life cycle. They breed mainly in manure and in carcases, never in purely vegetable matter. Like houseflies they remain as close as possible to their breeding places, which are always in moist places. The larval forms exist on dead or living flesh but pupate in the soil. The total life cycle varies from 13 to 35 days. The control of blowflies rests mainly on prevention of breeding by good sanitation.

MOSQUITOES

Importance and Habits

41. There are well over 1,000 different varieties of mosquito, of which 33 may be found in the British Isles. Although mainly of tropical importance, the mosquito is common in temperate countries; it is even found within the Arctic Circle.

42. There are two main tribes, the Culicine and the Anopheline. The culicine tribe contains the greater number of species, certain of which are responsible for the spread of yellow fever, virus encephalitis, filariasis, and dengue. All species that are vectors of malaria are anopheline but all anophelines are not vectors.

43. Mosquitoes, irrespective of species, may be classified broadly according to their breeding places.

(*a*) *The Domestic Mosquito*. Domestic mosquitoes breed close to towns and villages. Eggs are laid in rainwater barrels, roof gullies, cesspools, small puddles, and old tins or any other accessible collection of water.

(*b*) *Stream and Pool Mosquitoes*. Most of the malarial anopheline species are members of this group. Individual species have different breeding habits; some prefer sunlight, others shade; some swift flowing streams, yet others sluggish pools. Like the domestic mosquito their breeding sites are often adjacent to human habitation.

(*c*) *Sylvan Mosquitoes*. These types breed in shade provided by forests, woods, and bush. None is a vector of malaria but sylvan aedes spread yellow fever in Brazil and Central Africa and filariasis in the South East Pacific.

(*d*) *Swamp Mosquitoes*. The mosquitoes in this class breed mainly in permanent swamps, shallow inland lakes, and on salt marshes along the coast. Most are culicines and often they are more of a nuisance than a danger to health.

Domestic, stream, and pool mosquitoes are of especial importance as vectors, on account of the proximity of their breeding grounds to human habitation, and the large number of malarial anopheline species among them.

Bionomics

44. The habits of mosquitoes differ from species to species; those of the same species may vary in different parts of the world or in different environments. Study of the bionomics of mosquitoes in general, and of the local species in particular, is in consequence essential for effective control. Males and females hatch in approximately equal numbers. The males swarm in still weather, when the light intensity is low, in batches

of 50 to 500. The females, which hatch later, enter the swarm to be fertilized, after which they seek their first blood meal. This normally takes place the night after hatching, but in cooler weather may be delayed. Males feed only on fruit and plant juices.

45. Most species rest during the day and are active at night. Some however are active both by day and night, others during the early evening or the early morning. Most anophelines feed inside houses and near to ground level. Some culicines, which are yellow fever vectors, attack only at tree-top level. If feeding takes place indoors some anopheline species rest before or after or both, then go out; others feed directly on entering and go out afterwards without resting; yet others, being house-dwellers, rest indoors irrespective of feeding. The importance of these feeding habits have much to do with the effectiveness of residual insecticides on the adult mosquito population and on the spread of malaria from infected persons.

46. The stimuli which attract the female to the host include colour, movement, temperature, and humidity, and there may be some host specificity. Mosquitoes of the European *maculipennis* group prefer cattle; *A. minimus flavirostris* in the Phillipines attack mainly man and the water buffalo. In India *A. culifacies* attack man, with cattle as the second choice; but *A. fluviatilis* do the reverse. The amount of blood taken at each meal may vary from about 0·5 mg. to about 3·0 mg.; this is digested in two to fourteen days, depending on the temperature.

47. During the day most mosquitoes prefer quiet, shady, and slightly humid resting places. The undercut of stream banks, under culverts and beneath bridges are favourite haunts. Some shelter in stables, cowsheds, and outhouses; others prefer human habitations. In India *A. culifacies* rest high up on walls and ceilings where there is rather more light; in the jungle certain species rest high up in the foliage; others, for example *A. gambiae* in Africa, prefer ground level.

48. The effective range of flight is the distance the females can travel from breeding places to maintain endemic malaria or cause epidemics. In the tropics this may be up to two miles but is usually less than one mile; in temperate zones the range may be two to three miles. The prevailing wind affects both the range and the direction of flight. With a strong tail wind individual mosquitoes may be found 10 to 20 miles from their breeding site. Considerable distances may also be covered in prehibernation flights.

49. The survival of mosquitoes depends mainly on the temperature and humidity of their surroundings. They cannot breed when the temperature falls below 61°F. or when the humidity is less than 63 per cent. Males are shorter lived than females; they survive only a few days in warmer climates, but up to one to two months in more temperate zones. Females live from six months or longer in favourable temperatures, but in a dry unfavourable environment they may only survive two or three days. The females of certain species survive the winter months by hibernation. Larvae may also survive the winter by hibernation. In Siberia *A. messeae* can hibernate in cellars at a temperature as low as 0·4°F. and on thawing may lay post-hibernation eggs. Aestivation is the migration during hot, dry seasons to places where moisture and cooler conditions may be found. The prevalence of different species may be seasonal, but some, like *A. punctipennis* in the United States of America, breed throughout the year.

Morphology

50. Mosquitoes have a head to which are attached antennae, palps, and a proboscis; they have a thorax with two wings, two halteres (vestigial wings), and six legs; the thorax is separated from the abodmen by the scutellum, (see Fig. 68). The larva has a head, thorax, and nine distinct abdominal segments. At various points there are tufts of bristles, which are feathered in the anopheline, but plain in the culicine. Both types of larvae breathe by means of a spiracle on the eighth abdominal segment. In the culicine this is found on the end of the siphon and the larvae hang at an angle of 45° to the water surface. Anopheline larvae lie parallel to the surface. The pupa is comma shaped, the dot being made up of the head and thorax, with the tail formed by the flexible abdomen. There is a pair of respiratory trumpets on the back of the pupa's thorax, and in the thorax there is a large air cavity which gives it buoyancy.

51. The detailed differentiation between species requires specialized knowledge and techniques; general differentiation between an anopheline and a culicine and a male or female of each tribe may be made from the characteristics given in Tables 26 and 27 and illustrated in Fig. 68.

TABLE 26

DIFFERENTIATION BETWEEN ANOPHELINE AND CULICINE MOSQUITOES

	Anopheline	Culicine
Eggs	Provided with floats and laid separately.	No air floats and often found in rafts.
Larvae	Held up horizontally beneath the water by flat hairs. The hind spiracle is on the body surface of the 8th abdominal segment.	Hangs down at an angle from the water surface, the hind spiracle being situated on a tube-like siphon which projects from the 8th abdominal segment.
Pupa	No marked difference.	No marked difference.
Adult	(*a*) Female with palps as long as proboscis. (*b*) Rests with proboscis and abdomen in a line at an angle to the surface.	(*a*) Female with short palps. (*b*) Rests with proboscis and abdomen forming obtuse angle, the abdomen more or less parallel with the surface.

TABLE 27

DIFFERENTIATION BETWEEN MALE AND FEMALE ANOPHELINE AND CULICINE MOSQUITOES

	Anopheline		Culicine	
	Male	Female	Male	Female
Palps	Club-shaped segmented	Long and not clubbed	Shaped like a hockey stick	Very short and straight
Antennae	Feathered	Less heavily feathered	Feathered	Slightly feathered

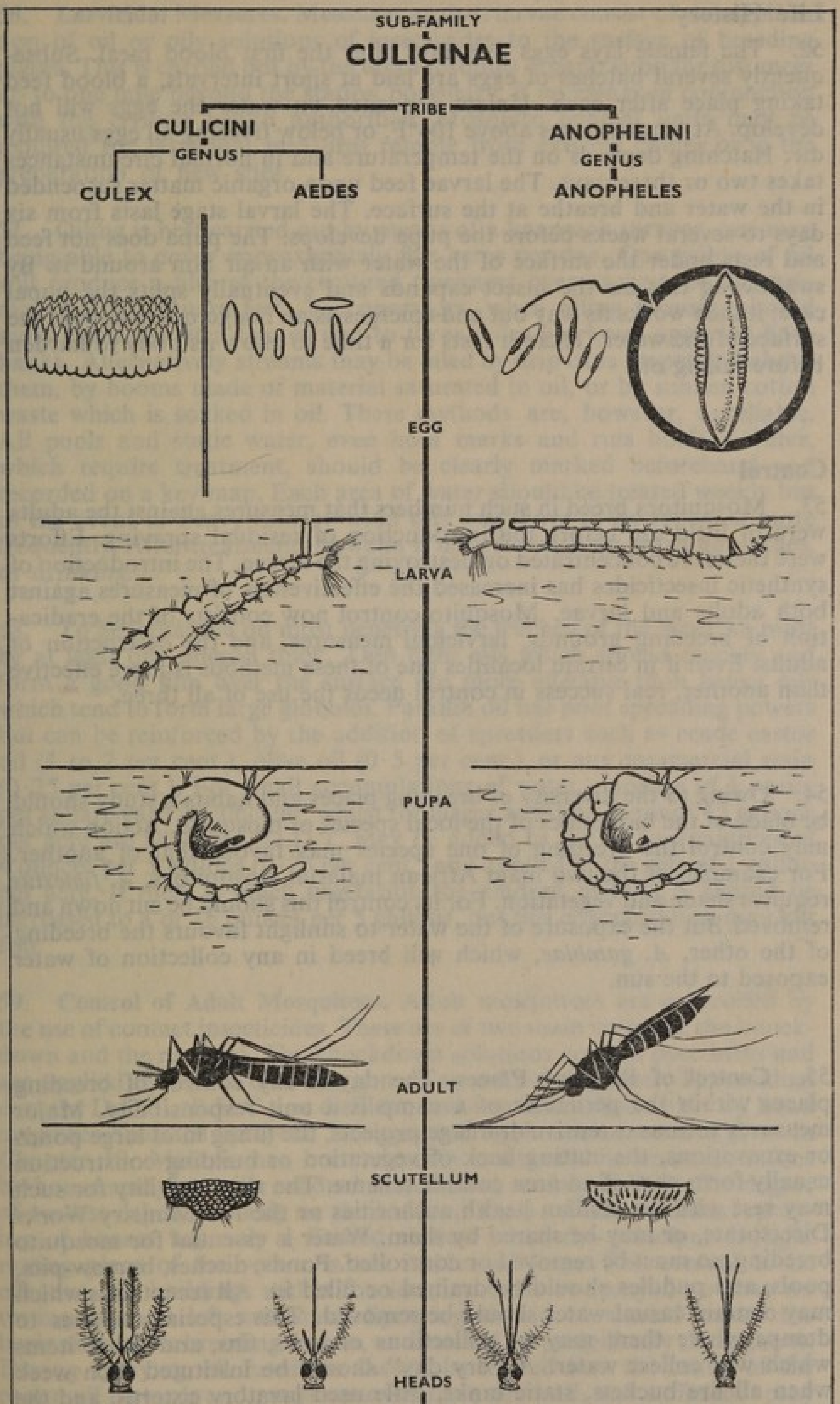


FIG. 68. MOSQUITOES

Life History

52. The female lays eggs five days after the first blood meal. Subsequently several batches of eggs are laid at short intervals, a blood feed taking place after each. Unless deposited on water the eggs will not develop. At temperatures above 104°F. or below freezing all eggs usually die. Hatching depends on the temperature and in normal circumstances takes two or three days. The larvae feed upon organic matter suspended in the water and breathe at the surface. The larval stage lasts from six days to several weeks before the pupa develops. The pupa does not feed and rests under the surface of the water with an air film around it. By swallowing this air the insect expands and eventually splits the pupal case; it then works its way out and emerges as an imago or adult onto the surface of the water. There it rests for a time to allow its body to harden before taking off.

Control

53. Mosquitoes breed in such numbers that measures against the adults were of little use before the introduction of residual spraying. Efforts were therefore concentrated on destroying the larvae. The introduction of synthetic insecticides has increased the effectiveness of measures against both adults and larvae. Mosquito control now consists of the eradication of breeding grounds, larvicidal measures, and the destruction of adults. Even if in certain localities one of these methods is more effective than another, real success in control needs the use of all three.

54. Owing to the diversity of breeding places and habits a study should be made of the bionomics of the local species of mosquito. Action which may control the breeding of one species may favour that of another. For example, of the two main African malarial mosquitoes, *A. funestus* requires shade and vegetation. For its control this should be cut down and removed. But the exposure of the water to sunlight favours the breeding of the other, *A. gambiae*, which will breed in any collection of water exposed to the sun.

55. **Control of Breeding Places.** The day-to-day control of breeding places within the perimeter of a camp is a unit responsibility. Major measures such as extensive drainage projects, the filling in of large ponds or excavations, the cutting back of vegetation or building construction usually form part of an area control scheme. The responsibility for such may rest with the civilian health authorities or the Air Ministry Works Directorate, or may be shared by them. Water is essential for mosquito breeding, so must be removed or controlled. Ponds, ditches, borrow-pits, pools, and puddles should be drained or filled in. All receptacles which may contain casual water should be removed. This especially applies to dumps where there may be collections of tyres, tins, and other items which will collect water. A "dry day" should be instituted each week when all fire buckets, static tanks, little used lavatory cisterns, and the like should be emptied, cleaned, and refilled. Water courses should be periodically flushed and weeds cut back from the edges of streams or rivers to allow a free flow of water. This will prevent the formation of stagnant pools and wash away eggs or larvae.

56. **Larvicidal Measures.** Measures against larvae consist of the application of oil or oily solutions of insecticides to the surface of breeding places. This is carried out by the unit mosquito organization for distances up to one mile beyond the station boundary, if necessary in conjunction with the civilian health authorities. Mosquito control units may be required for larvicidal measures remote from existing camps or in the preparation of new sites.

57. Oiling is best carried out by means of a knapsack sprayer, one man being able to cover approximately five acres per day. One gallon of oil will produce a film of the required thickness over an area of approximately 2,500 square feet. The operators, when oiling streams, should move upstream at a rate of two to three miles per hour, spraying both banks. Alternatively streams may be oiled by drip cans suspended above them, by booms made of material saturated in oil, or by sunken cotton waste which is soaked in oil. These methods are, however, unreliable. All pools and static water, even hoof marks and ruts holding water, which require treatment, should be clearly marked beforehand and recorded on a key map. Each area of water should be treated weekly but in the event of heavy rain or wind this may have to be repeated more frequently. After treatment the water is unfit for bathing, washing clothes, or drinking.

58. To be lethal the oil must penetrate the trachea of the larva, so must be at least one micron thick. Thin light oils which spread quickly and form a good film over the surface are more effective than heavy oils which tend to form large globules. Paraffin oil has poor spreading powers but can be reinforced by the addition of spreaders such as crude castor oil (1 to 2 per cent.), olive oil (0·5 per cent.), or any commercial resin (0·25 per cent.). For small accumulations of water a dosage of ½ ounce per square yard is sufficient, whilst for larger breeding grounds 15 gallons per acre are adequate. D.D.T. may be added to the oil in quantities of 4 ounces per 5 gallons (0·25 per cent.) and applied at the rate of 1 gallon per acre. If there is much vegetation the amount of D.D.T. should be increased to 8 or 16 ounces per 5 gallons, but this concentration may kill fish.

59. **Control of Adult Mosquitoes.** Adult mosquitoes are controlled by the use of contact insecticides. These are of two main varieties, the knockdown and the residual. The knockdown solutions contain pyrethrins and are applied by means of a Flit gun or an aerosol dispenser. The residual contain D.D.T., B.H.C., or dieldrin, and can be applied either by hand or power-operated sprayers. Dosages and application rates are given in Chapter 10. Malaria has been virtually eradicated in some countries by house spraying with residual insecticides, mainly D.D.T. The degree of success depends chiefly on the habits of local vectors. Residual spraying of houses has only a limited success when the principal daylight resting place of the vector is not inside buildings. For control to be effective, all buildings within the locality must be sprayed so that no resting place is left untreated. Spraying should be started before the beginning of the breeding season, and carried on periodically throughout. During spraying, all furniture should be moved into the centre of the room, all pictures and maps removed from the wall, and sufficient spray applied to wet the wall without running off. Walls, ceilings, pendant fittings, and floors should be treated. Insecticidal smokes or fogs have been experimentally successful in large buildings filled with many immovable objects.

SANDFLIES
(*Phlebotomus*)

Importance and Habits

60. Sandflies are responsible for the spread of sandfly fever and leishmaniasis. Both sexes suck blood and the bites may cause a local reaction. Many species, however, do not attack man but feed on the blood of animals or lizards.

61. Sandflies are abundant in the drier portions of the tropics and sub-tropics. They fly by night and shelter in dark corners during the day. Their flight is feeble, with a range of not more than 50 yards from their breeding places, and little above ground level. They dislike sunlight but are attracted by artificial light.

Morphology

62. Sandflies are minute insects measuring 1·5 to 2·5 millimetres. The body is covered with long hairs and the wings, which are also hairy, are pointed and folded roof-wise over the back. The proboscis is short and stout (see Fig. 69).

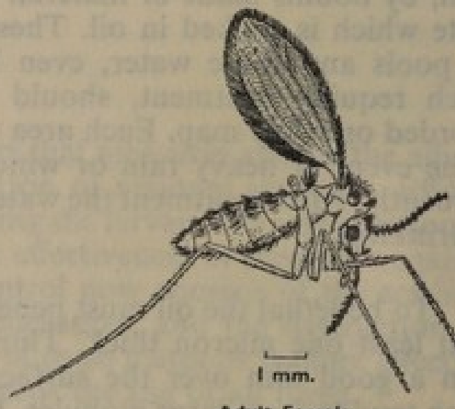


FIG. 69. SANDFLY
(*Phlebotomus papatasii*)

Life History

63. The eggs of the sandfly are black and reticulated. They are laid singly in the cracks of masonry, amongst rubble, or in the crevices of broken paving. They measure approximately 0·1 millimetres and hatch in six to nine days into caterpillar-like larvae which feed mainly on the faeces and corpses of adult sandflies. The duration of the larval stage may extend to four weeks during which time there are four distinct moults. The pupal stage lasts about nine days, the imago hatching out in the early hours of the morning when the atmospheric humidity is high.

Control

64. Control of sandflies consists of the repair of broken masonry, the removal of rubble, and residual spraying with D.D.T. or B.H.C. All nooks, crevices, and dark places outdoors should be carefully sprayed. The residual spraying of houses will keep rooms free from sandflies; but alone this has little effect on the sandfly population as they soon seek alternative resting places. Spraying methods and application rates are the same as for mosquitoes.

MITES

Importance and Habits

65. Mites are of importance as the vectors of scrub typhus and possibly epidemic haemorrhagic fever. They were especially notorious during the years 1941 to 1944, when 5,500 cases of fevers of the typhus group occurred in South East Asia Command. Of these over 90 per cent. were mite borne.

66. Only the larvae of the trombiculid mites transmit disease. The adults are of no medical interest. Several species attack man and the majority of these cause an intense specific local reaction, known as trombidiasis. The sole British species is known only in the larval form; it is the harvest bug, *Leptus autumnalis*. The vectors of scrub typhus are the larvae of *Trombicula akamushi* and *Trombicula deliensis*.

67. The natural hosts of many trombiculids are birds and reptiles; others are harboured by small rodents such as rats and field voles, man being attacked accidentally. They remain with their hosts for only a few days and are usually attached to the inside of the ears of field voles and rats. Larval mites live on lymph and tissue fluids, rather than blood. *Rickettsia orientalis* has been found in the salivary glands of the larval stage of *T. akamushi* and *T. deliensis* and may persist from one generation to the next.

Morphology

68. The adult mite is bright red or orange in colour, measuring up to 2·5 millimetres. It has rudimentary eyes, four pairs of legs, and two pairs of ventral suckers (see Fig. 70). The larvae measure about 200 microns, have six legs, and vary in colour from orange, red, through pale pink to creamy white. After feeding, the larvae moult and become eight-legged nymphs which are similar in shape to the adult.

Life History

69. Mites lay comparatively few but relatively large eggs in the soil. The larvae hatch in approximately 14 days, climb upwards, and attach themselves to the surrounding vegetation to await a host. Having fed they fall to the ground and after moulting develop into nymphs in 10 to 12 days. The nymphs have further moults, becoming adults in another 14 to 21 days.

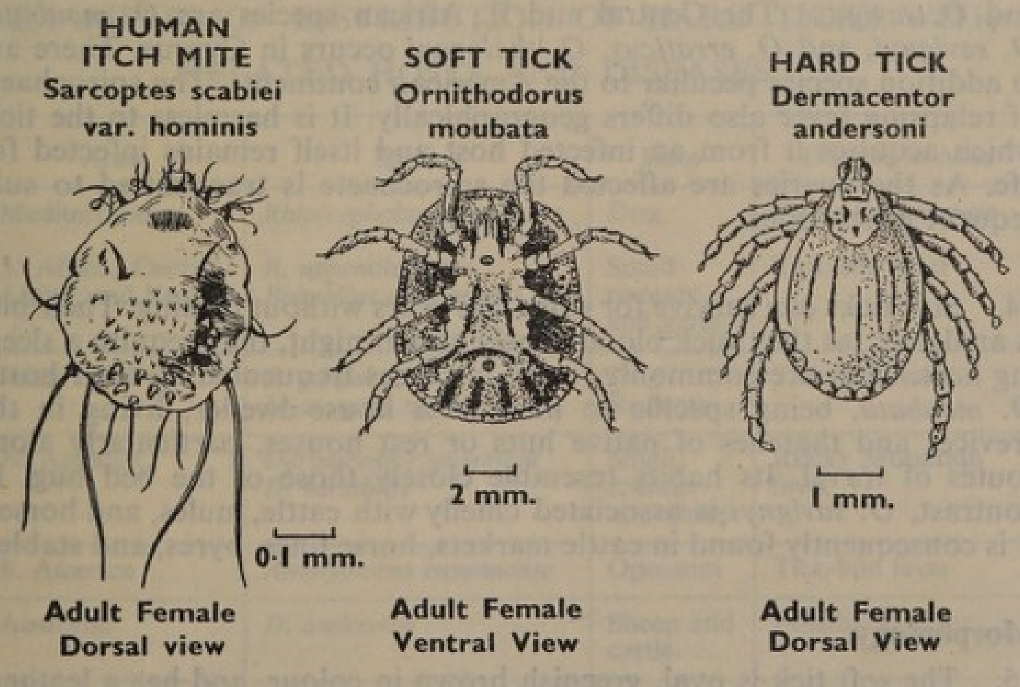


FIG. 70. HUMAN ITCH MITE, SOFT TICK, AND HARD TICK

Control

70. Areas suspected of infestation with mites should be investigated by a survey of the rodent population. Rats should be trapped and their ears examined for mite colonies, which resemble reddish grains of sand. Rats caught should be plotted on a map, the infested and free being differentiated. Once the area has been defined, a full scale campaign to destroy the rats should be mounted and the area sprayed to kill off the mites.

71. In their normal habitation mites are exceedingly difficult to control. Where feasible, especially near houses, all grass and foliage should be reduced to a minimum. Small areas may be sprayed repeatedly with B.H.C. (see Chapter 10). A single application of dieldrin in a 6 to 12 per cent. solution giving an application rate of 2·2 pounds per acre has been found effective. Assessment of results is achieved by periodical surveys of the rat population, re-infestation of which means that the area must be treated again. Personal protection against mite larvae is provided by repellents applied to the skin or clothing (see Chapter 10).

SOFT TICKS
(*Argasidae*)

Importance and Habits

72. Soft ticks are vectors of relapsing fever. According to the species of tick, the hosts are small mammals such as rats, voles, rabbits, or hedgehogs, although dogs, jackals, and in certain places, monkeys may be infested. Man and the large mammals are attacked accidentally by all species except *Ornithodorus moubata*, which feeds on man only.

73. Although the ticks have a world-wide distribution, different species have fairly close geographical associations. *O. lahorensis* is found in Iran and N.W. India, as well as *O. papillipes*, which also occurs in Israel. In S. Spain and Morocco there are *O. erraticus*, *O. morocanus*, and *O. savignyi*. The Central and E. African species are *O. moubata*, *O. savignyi*, and *O. erraticus*. *O. thalozani* occurs in Cyprus. There are in addition species peculiar to the American continents. The spirochaete of relapsing fever also differs geographically. It is harmless to the tick, which acquires it from an infected host and itself remains infected for life. As the ovaries are affected the spirochaete is transmitted to subsequent generations.

74. Soft ticks can survive for some five years without feeding. Their bite is analgesic; as they suck blood slowly and at night, they require a sleeping host. They are commonly found in places frequented by their hosts. *O. moubata*, being specific to man, is a house-dweller, living in the crevices and thatches of native huts or rest houses, particularly along routes of travel. Its habits resemble closely those of the bed bug. In contrast, *O. savignyi* is associated chiefly with cattle, mules, and horses; it is consequently found in cattle markets, horse lines, byres, and stables.

Morphology

75. The soft tick is oval, greenish brown in colour, and has a leathery cuticle. It has no eyes and from above its mouth parts are invisible. It is 10 to 14 millimetres in length and has eight legs (see Fig. 70).

Life History

76. *O. moubata* lays its eggs in batches in the cracks, crevices, and the thatch of huts. Other species lay their eggs on the ground. In about 20 days these hatch into hexapod larvae, which almost at once become octopod nymphs. The nymphs behave in the same way as adults into which they develop after several moults. Soft ticks require only one blood feed for their complete development, so need but a single host. As they are strongly resistant to starvation they can survive long periods without a host. The latter is attacked when resting in one of their particular haunts.

Control

77. Dwellings can be freed from ticks if all cracks and crevices are first repaired, then B.H.C. applied as a residual spray. Personal precautions should be taken by avoiding the use of native huts, rest houses, and other potential haunts; repellents such as D.M.P. or D.B.P. should be applied to the skin or clothing. If it is essential to occupy possibly infested buildings before they have been sprayed, men should sleep off the ground, away from walls, and use repellents.

HARD TICKS
(*Ixodidae*)

Importance and Habits

78. Hard ticks are vectors of rickettsial infections which include tick typhus, tick-bite fever, *fiévre boutonneuse*, Rocky Mountain fever, and, on occasion, Q-fever. Their distribution is world-wide but different species tend to be geographically localized as shown in Table 28. They are parasitic to mammals such as cattle, dogs, squirrels, and other small rodents, man being attacked accidentally. A host is required at each stage of development from larva to adult, but only the adult tick is of real significance in the transmission of infection from animals to man.

TABLE 28

EXAMPLES OF DISTRIBUTION OF HARD TICKS WITH RELATED HOSTS AND DISEASES

Area	Species	Host	Disease in Man
Mediterranean	*Rhipicephalus sanguineus*	Dog	*Fiévre boutonneuse*
S. Africa, Central Africa, and Kenya	*R. appendiculatus* *Boophilus decoloratus*	Small rodents and game	Tick-bite fever
India	*R. sanguineus* *Hyalomma aegyptium*	Dog Rodents	Tick-bite fever
N. America	*Dermacentor andersoni* *D. variabilis*	Small rodents and sheep	Rocky Mountain fever
S. America	*Amblyomma cayennense*	Opossum	Tick-bite fever
Australia	*D. andersoni*	Sheep and cattle	Possibly Q-fever
England	*Haemaphysalis cinnabarina*	Sheep	Possibly Q-fever

Morphology

79. The ticks are 6 to 12 millimetres long and have eight legs. They are broader at the rear, so are pear-shaped (see Fig. 70). The body is covered with a sharp-edged chitinous plate, brownish in colour. The shell of some species is highly ornamented.

Life History

80. The eggs are laid in grass, soil, or decaying vegetation, and may number several thousand in a batch. They hatch into hexapod larvae which climb up grass stalks to await the passing of a host. After feeding on blood the larvae become octopod pupae, which finally become adults having fed on blood again. Pupae and adults wait on long grass for passing hosts in the same way as larvae. Rickettsial infection is not passed on from one generation of ticks to the next.

Control

81. The cutting of long grass and area spraying as for the control of mites may be effective in freeing comparatively localized areas from hard ticks. Personal precautions to be taken include the avoidance of scrub and long grass in infected areas, the wearing of shirts with long sleeves, and slacks with anklets over the ends. Repellents should be used.

ANTS

82. Two varieties of ants may become serious pests in buildings in the United Kingdom. They are:—

(*a*) The garden, or common black, ant (*Lasius niger*).

(*b*) The house, or Pharoahs, ant (*Monomorium pharoanis*).

Their habitat and behaviour vary one from the other and control depends in each case on knowledge of these facts.

The Common Black Ant

83. Common black ants breed outdoors in nests in the soil. They frequently enter buildings in search of food. Control depends on tracing the ant stream by means of careful test baiting with moist carbohydrate, following the stream to the nests, and eradicating these by means of boiling water or digging them up and liberally dusting with B.H.C. powder.

Pharoahs Ant

84. Pharoahs ants prefer a higher temperature than the outdoor temperatures in this country. They therefore live and breed in colonies inside heated buildings, preferably in inaccessible places between hot-water pipes, behind stoves, etc. They are especially to be found in buildings warmed to a constant temperature and are thus often a pest of hospitals and institutions. They are difficult to eradicate because their nests can seldom be located with ease.

Eradication

85. Control of an infestation of Pharoahs ants must be planned as a campaign, working from the top of the building downwards, and from without inwards. There are two control methods, best used in conjunction:—

(*a*) *Poison Baiting*. The poisons used are 1 per cent. thallium sulphate or 1 per cent. sodium fluoride mixed with a carbohydrate base, such as moist cake or sugar, or a protein base, such as minced meat or fish. Alternation of protein and carbohydrate baits is desirable monthly to avoid bait repulsion. Bait must be renewed twice weekly and the campaign continued for about nine months. Great patience is required and continuity is essential. Small closed containers, e.g. tins or waxed boxes, each having several perforations to allow free access to the ants, should be used as bait containers. Each box must be numbered and charted and labelled "poison" prominently in order to prevent accidents. The boxes should be placed along the regular run of the ants.

(*b*) *Application of Insecticides*. D.D.T. and B.H.C. are not very effective against Pharoahs ant. The newer insecticides dieldrin and chlordane are more effective. Chlordane (as a 2½ per cent. emulsion or refined kerosene solution), or Dieldrin in ½ per cent. solution or emulsion, should be applied once monthly in 6-inch bands along runs, at points of emergence, around sinks, ovens, windows, and door frames, and along the bottom of walls (interior and exterior). Infested ducts may be treated by fogging or spraying with the solution or emulsion. Emulsions of these two substances in synthetic resins painted on walls in strips are effective for periods up to two years. Chlordane and Dieldrin are very toxic substances (toxicity to humans 5 to 100 times that of D.D.T.) and should not be used by unskilled personnel.

Ants in the Tropics

86. In warm climates ants normally live outside buildings and only enter them for food, but certain species, such as *Monomorium indicam*, and a small black ant, *Prenolepis longicornis*, are found as household pests in larders. Termites which are commonly but erroneously referred to as "white ants" also invade the timber of buildings and cause great destruction. Most of these ants are sensitive to dieldrin and chlordane.

CONTROL OF RODENTS

Introduction

87. It has been estimated that in the United Kingdom alone rats cause over thirty million pounds worth of damage every year by depredations into stored food and by damage to buildings. Further, they are the vectors of several important diseases. Mice, although not commonly vectors of disease, are associated with dirt, food spoilage, and a low standard of hygiene.

Rats

88. **Common Rat** (*Rattus Norvegicus*). This rat is ubiquitous throughout the United Kingdom. It is a burrowing animal, nesting underground in hedgerows, ricks, banks, and refuse tips. Its close association with man makes it common in sewers, cafés, shops, restaurants, and factories.

89. **Ship Rat** (*Rattus Rattus*). The ship rat is essentially a climber and is found mainly in ships and the upper storeys of buildings. Although normally an inhabitant of seaports it is also sometimes found inland. (For the differentiation between the ship and the common rat see Table 29.)

TABLE 29

DIFFERENTIATION BETWEEN THE COMMON RAT AND THE SHIP RAT

	Common Rat	Ship Rat
Muzzle	Blunt	Pointed
Ears	Small and furry	Large and translucent
Tail	Shorter than the head and body. Thick	Longer than the head and body. Thin
Colour	Grey-brown, may be black; yellow to white belly	Black-grey-brown or tawny; may have white belly
Droppings	In groups and spindle-shaped	Scattered and sausage-shaped
Behaviour	Burrows, climbs, and gnaws	Burrows and climbs

Signs of Infestation

90. Rats establish colonies close to food, water, nesting material, and undisturbed nesting sites. The nesting sites and feeding places, with their associated pathways or runs, can usually be identified in any infested area. Evidence of an infestation is provided by traces of rats, consisting of smears, runs, gnawings, holes and scrapes, droppings, foot and tail marks, and damage. When normal evidence of infestation is inconclusive, a small number of test baits of about one ounce each should be laid and inspected two days later. If any are taken the presence of rats can be presumed, and the number taken will give an indication of the size of the infestation.

91. **Smears.** Rats running frequently along a path rub their fur on projections or over surfaces causing a dark greasy mark or smear.

92. **Scrapes.** These are heaps of earth or debris scratched out when the rat is making a hole or burrow.

93. **Runs.** These are beaten-down tracks in earth or on mounds of refuse, caused by the frequent passage of the rodent population to and from their nesting place.

94. **Gnawings.** Marks of gnawing are normally of two types; those found on foodstuffs or cardboard cartons containing food and those found on lead-piping, timber, and electric cables. The latter are caused by the rat attempting to force an entry or to control the excessive growth of its teeth.

95 **Droppings.** The droppings of the common rat are found round its feeding ground and to a lesser extent near its home. It very rarely leaves them on its run. The size and activity of an infestation may be assessed by the droppings, which remain moist and shiny for about twelve hours. The ship rat's droppings are usually scattered indiscriminately and, as they dry rapidly, do not provide such reliable evidence of recent activity.

96. **Feet Marks and Tail Marks.** These may be left in dust or mud or in spilt goods such as flour. Tracking dusts may be put down (whiting or flour) to show where rats are running.

97. **Damage.** The first indication of an infestation may be damage in the form of spillage from sacks containing flour or sugar or other foodstuff. Rats may gnaw furniture or bedding in a search for nesting material.

Baits and Baiting

98. **Prebaiting.** Prebaiting consists of laying unpoisoned bait for several days before the addition of poison. This overcomes the rat's innate suspicion and ensures that it eventually eats a lethal quantity of the poisoned bait. If insufficient poison is taken the results will not be lethal, feeding will cease, and the rat will become bait-shy. The same bait must always be used for poisoning and prebaiting.

99. **Bait Bases.** Bait bases may be wet or dry. The bases described below are known to be effective in the United Kingdom. Elsewhere, however, it has been found that soaked crushed maize, soaked crushed barley, coconut or boiled rice may be used in the same fashion as soaked wheat.

(*a*) *Damp Sausage Rusk*. Sausage rusk is a biscuit meal used as a filler for sausages. A medium grade, mixed with its own weight in water, is suitable. It can be used with any poison.

(*b*) *Sugar Meal*. This consists of nine parts by weight of national flour and one part of castor or fine granulated sugar. It can be used with zinc phosphide.

(*c*) *Bread Mash*. Dry stale bread is soaked in water so that it has the consistency of porridge. It can be used with zinc phosphide or red squills.

(*d*) *Soaked Wheat*. Whole millable wheat* is soaked overnight in water. The excess of water is then poured off. The base can be used with zinc phosphide.

Poisons and Poisoning

100. **Poisons.** The methods of preparing the poisons provided for service use are described below:—

(*a*) *Zinc Phosphide* (33F/399). With any of the wet bait bases the proportion of poison is $2\frac{1}{2}$ per cent. (1 part in 40 parts by weight). With sugar meal it should be used in the proportion of 1 part in 20 by weight and will keep for three weeks. In contact with water, zinc phosphide gives off phosphine and must therefore be mixed out of doors.

(*b*) *Red Squills Powder* (33F/342). The amount used with damp sausage rusk or bread mash is in the proportion of 1 part in 10 by weight. It should not be used with other bait bases.

(*c*) *Warfarin* (33F/402). This poison is described in para. 107.

* Millable wheat means threshed grain as purchased for hen food.

101. The mixing of poisons and bait must be done with great thoroughness to ensure even distribution. Wet poisons should be mixed on the day of use.

102. **Placing of Baits.** Baits may be placed in holes; this is the most efficient method, and when it can be used exclusively it is only necessary to prebait for two days. After the whole operation, the holes should be blocked; their reopening will betray the continued presence of rats. Surface baiting is the method most commonly used in buildings, but it may also be used out of doors. It is most important to lay the baits on the runs as near to the nesting and feeding sites as possible. The baits may be placed in containers, if necessary.

103. Baiting in containers is primarily a safety measure to prevent domestic animals having direct access to the poison. Suitable containers perform this function, protect the bait from disturbance and, in the open, from the effects of weather. All containers must be placed on the runs. The following types may be used:—

(*a*) P3 (protected poison point) is most commonly used in buildings (see Fig. 71).

(*b*) Agricultural drain pipes or any similar objects approximately fifteen inches long, three inches in diameter, and blocked at one end are useful improvisations. Added protection for the bait is gained by placing each pipe with the open end three inches from a wall, stone, or brick.

So that the rats may become accustomed to strange objects, an interval of ten days must be left between the time of the installation of the containers and the beginning of prebaiting. Prebaiting may have to be carried out for one or two days extra when containers are used.

Prebaiting and Poisoning Time-Table

104. Having surveyed the infested area and estimated the size of the infestation from the traces or by test-baiting, a time-table, similar to that outlined in the example given in paras. 105 and 106 should be put into operation.

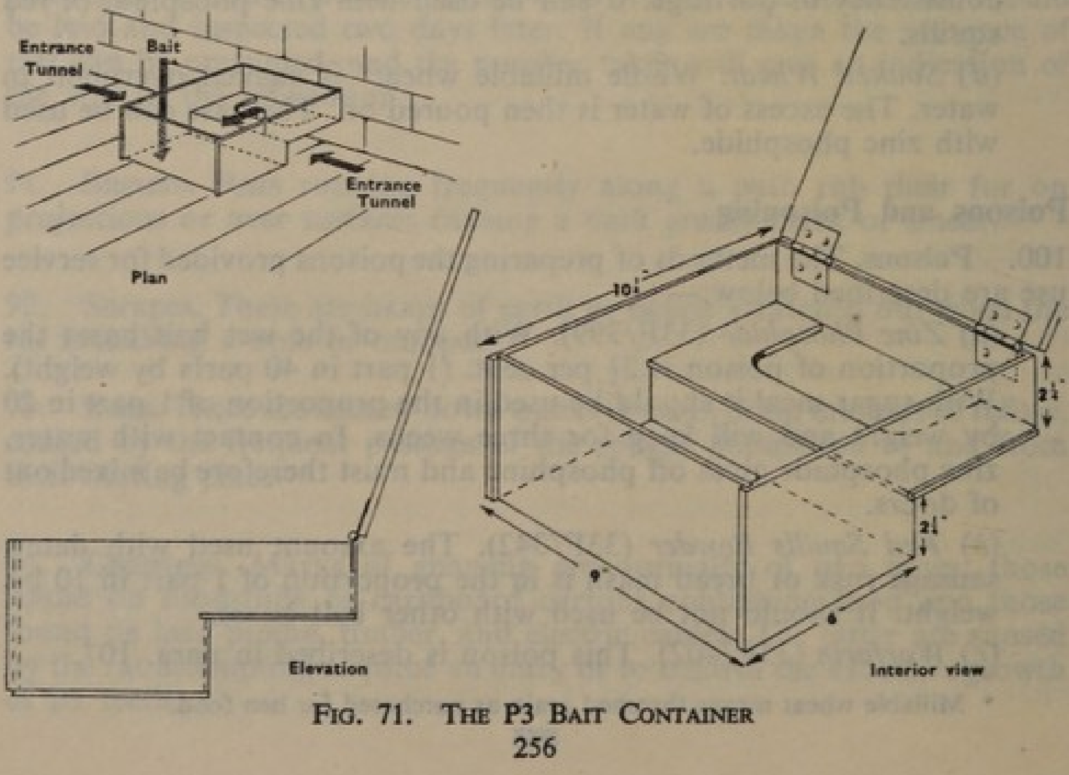


FIG. 71. THE P3 BAIT CONTAINER

105. During the first week unpoisoned damp sausage rusk is laid for four days; 2·5 per cent. zinc phosphide is added on the fifth day. The bait and any dead bodies are removed on the sixth day. No further action is taken until the fourth week, when test baiting is carried out with a different base. Should the test baits be taken, more are laid, a different poison being added on the fifth day. All baits and corpses are removed on the following day. If a third treatment is necessary it should be carried out a fortnight later, using yet another base and poison.

106. This sequence is designed for surface and container baiting. It should be modified if hole baiting is used by reducing prebaiting to two days. Further if poisoning has been attempted during the preceding three months neither a bait nor a poison already used during that period should be employed again.

Warfarin

107. Warfarin is a cumulative poison which acts as an anti-coagulant, preventing the formation of prothrombin in the liver. Death is brought about mainly by internal haemorrhage, and occurs in two to nine days. The rat is particularly susceptible, the mouse relatively resistant to this poison. A single accidental dose is harmless to man and domestic animals, but cases have been recorded of human fatalities due to repeated ingestion of poisoned bait base. Warfarin has the advantage over the older poisons in that its slow action creates no suspicion in the rodent population, thus removing the necessity for pre- and post-baiting. Besides eradication, fresh infestation can be prevented by suitable siting of baiting points; but it must be emphasized that prevention entails good hygiene and rat-proofing as well as the use of the perimeter baiting technique. Warfarin has the added advantage that tolerance is not established and therefore resistant strains of rats are not encountered.

108. **Use of Warfarin.** Warfarin is a fine white powder insoluble in water. It is supplied in master mixes containing 0·1 per cent. or 0·5 per cent. by weight of the pure substance in oatmeal. This should be further mixed with medium grade oatmeal to give the final concentration of 0·005 per cent. and 0·025 per cent. for the common and ship rat respectively. These concentrations are obtained by adding 1 part by weight of the master mix to 19 parts of bait for the common rat, and 1 part by weight of master mix to 3 parts of bait for the ship rat. Too high a concentration of warfarin will make the bait distasteful to the rat; low concentrations are not detected by the animal, yet remain lethal.

109. The best sites for warfarin baits are those which, according to the signs of infestation, are most commonly frequented. At first many small baits of four to six ounces should be laid. When these baits are being taken they should be built up to one pound, so that they will not be completely consumed; they must be replenished as long as feeding continues. This is normally seven to fourteen days. Untouched baits should be removed and laid elsewhere.

110. **Perimeter Baiting.** When the infestation is under control, perimeter baiting points should be established to destroy any rats coming into the cleared area. These should be placed at likely points of entry, which are usually near food stores, kitchens, bakeries, and other similar buildings. Such points should be visited every three to four weeks and the bait, of one to two pounds, replenished or replaced if it has become mouldy or sour.

Trapping

111. Infestations which are limited to small numbers may be controlled by trapping. For effective trapping a large number of traps relative to the size of the infestation should be used. These should be of the break-back treadle variety and should be placed at intervals along the runway, with the treadle on the track and the trap at right angles to it. Unset traps suitably baited are placed in position for five nights, being eventually set on the sixth night. Suitable baits are the bases used in poisoning (para. 99). On the following day all dead bodies are removed and the traps are reset. A further visit is made on the eighth day, all corpses and traps being removed. If necessary this programme may be repeated fourteen days later using a different bait.

Rat Prevention

112. **Hygiene.** The presence of rats in an area depends on the availability of food supplies. The less food accessible the fewer rats will be attracted. Where possible food should be stored in rat-proof containers; waste should be removed daily and placed in covered bins until collected. Cover as well as food should be denied to rats. Accumulations of rubbish offering harbourage must be removed. Objects leaning against walls or fences may provide good cover and should be taken away.

113. **Proofing.** After disinfestation, buildings should always be surveyed to detect the means of entry by the rats, which may come in by holes made through the walls for pipes, drains, or electric cables. In outside walls all such openings should be filled with fine concrete, to which broken glass has been added. Broken fittings such as air bricks, gully grids and manhole covers may also provide entry and should be repaired. Wooden doors and frames should be protected against gnawing; a plate of sheet steel should be nailed to the face over the lowest twelve inches and turned round both edges. Where doors open over worn steps the latter should be repaired or replaced. Trap doors should have their edges and frames covered with sheet metal. In heavily infested places, accessible windows that have to be left open at night should be covered with wire netting. Rats may burrow down towards the foundation of the building. If the holes are few they can be filled in with concrete or by laying a concrete paving around the building for a distance of two to three feet. Rats frequently enter buildings through defective drains. Drain connections to sewers, rodding-eye caps for the intercepting traps, drain pipes, air inlets, gullies, or down-pipes may require repair or replacement.

Mice

114. **Trapping.** Mice, unlike rats, do not travel far from their holes and are not in the habit of using fixed runways. Except in emergency they run close to walls and solid objects. Breakback treadle traps should be laid in large numbers about two feet apart, with the treadle at right angles to the walls, and near to the holes. It is unnecessary to lay unset traps in advance. Suitable baits are flour, oatmeal, breadcrumbs, chocolate, cheese, and bacon.

115. **Poisoning.** Mice may be poisoned in a similar way to rats using baits of about ¼ ounce in size. Bait bases of sausage rusk or damp rolled oats are laid out in trays in the feeding areas for two or three nights, before the addition of poison. Two-and-a-half per cent. zinc phosphide by weight is a suitable poison. As the poison is often laid in domestic premises care must be taken to prevent access by young children or pets. A period of fourteen days should elapse before repetition of the treatment, using a different bait base and poison. Mice are relatively resistant to warfarin and require concentrations of 0·025 per cent. of the pure substance, but the technique for poisoning is similar to that of rats.

CHAPTER 12

COMMUNICABLE DISEASES

ADMINISTRATIVE ASPECTS

General

1. When communicable disease occurs at a unit, preventive measures must be taken in the interests of service and public health. Besides general medical measures and those specific to the particular disease, certain administrative steps are always necessary. These are described in Q.Rs. 1411 and 1485.

2. The general responsibility for the health of the unit rests with the commanding officer and he will take the executive action required to enforce control measures; it is therefore essential that the occurrence of communicable disease be notified to him immediately. The medical officer should at the same time advise on the control measures to be taken. In the face of an extensive outbreak when hospital beds are scarce, it may be necessary to extend sickquarters by taking over a barrack block. The medical officer should have consulted the commanding officer previously on the selection of emergency accommodation, so that the scheme can be put smoothly into operation when required.

3. In addition, cases of certain communicable diseases must be notified to the medical authorities at headquarters of group and command, as well as to the Air Ministry and the local health authority. Medical officers should also maintain personal touch with the public health officials of their districts to arrange mutual exchange of information and to ensure collaboration in control measures.

4. Special reports are required by the Air Ministry on any outbreak of communicable disease of unusual extent at a unit and on the occurrence of a case of any particularly dangerous communicable disease. Such reports are to be forwarded through group and command headquarters.

Notifiable Diseases

5. Besides the diseases notifiable by law, there are others, notification of which is a Royal Air Force requirement only.

(*a*) *Diseases Notifiable by Law.*

Anthrax
Cholera
Diphtheria or Membranous croup
Dysentery; amoebic and bacillary
Encephalitis
  (i) Infective
  (ii) Post-infective
  (iii) Post-vaccinal or post-inoculation
Erysipelas
Food poisoning
Leprosy
Malaria (type and whether primary case or relapse)
Measles
Meningococcal infection
Ophthalmia neonatorum
Plague
Pneumonia (i) Acute influenzal
  (ii) Acute primary
  (iii) Others
Poliomyelitis
  (i) Paralytic
  (ii) Non-paralytic
Puerperal pyrexia
Relapsing fever
Scarlet fever
Smallpox
Tuberculosis (all forms)
Tyhpoid fever (including para-typhoid)
Typhus (all forms)
Whooping cough.

(*b*) *Additional Diseases Notifiable in the Royal Air Force.*

Chicken pox	Leptospirosis
Infective enteritis	Mumps
Infective hepatitis	Rabies
Leishmaniasis	Schistosomiasis
(i) Visceral (Kala Azar)	Tetanus
(ii) Cutaneous (Oriental sore)	Undulant fever
	Yellow fever.

6. The following notes amplify the above requirements:—

(*a*) *Anthrax*. This is also a notifiable industrial disease (see Chapter 14).

(*b*) *Leprosy*. Cases are notifiable direct to the Chief Medical Officer, Ministry of Health, under confidential cover.

(*c*) *Encephalitis*. The infective type is primary and of microbic or viral origin. Post-infective encephalitis occurs as a complication of virus infections.

(*d*) *Pneumonia*. Only primary pneumonias are notifiable, whether of bacterial, viral, or rickettsial origin.

7. Anthrax, farcy, and glanders in animals are notifiable to the Medical Officer of Health, normally by veterinary surgeons.

Notification

8. Notification is made on Form Med. 85. Copies are distributed as follows:—

(*a*) One copy to S.M.O. Group.

(*b*) One copy to P.M.O. Command.

(*c*) One copy to the Air Ministry (D. of H. & R.). This does not apply to commands abroad.

(*d*) One copy to the local medical officer of health if the disease concerned is notifiable by law (see para. 5(*a*)).

(*e*) One copy for retention in unit sickquarters.

9. Cases of tuberculosis are to be notified on Form Med. 30 as well as on Form Med. 85. The distribution is set out on the reverse of Form Med. 30.

10. Cases of meningococcal infection, smallpox, typhoid, and paratyphoid fever, poliomyelitis, and infectious diseases of rare occurrence, as well as outbreaks of food poisoning and bacillary dysentery, are in addition to be notified by signal to S.M.O. Group, P.M.O. Command, and Air Ministry (D. of H. & R.).

GENERAL CONTROL MEASURES

Spread of Infection

11. When faced with an outbreak of disease and with the necessity of devising control measures, the chain of infection by which the disease concerned may spread should be considered. The links are:—

(*a*) The source, which is always an infected person or animal. The infected person may either have the disease or be a symptomless carrier.

(*b*) The vehicle, which may be air, water, food, or milk, contact (either personal or with fomites), and animal or insect vectors.

(*c*) The susceptible individual, who requires protection from infection.

12. The aim is to break the chain of infection; the control measures required depend on which link is most important or which is most susceptible to attack.

Measures Applicable to the Source

13. Measures intended to contain the infection at the source are applicable to frank cases of infectious disease, to sub-clinical infections, and to temporary or chronic convalescent or contact carriers.

14. **Early Diagnosis and Isolation.** The sooner an infective person can be isolated the less likely he is to pass on his infection. It follows that early diagnosis is of first importance. Isolation entails the confinement under medical supervision in a specified building of infected individuals and suspects,

15. **Quarantine.** The aim of quarantine is to reduce the chance of persons, who are or may become infective, handing on their infection to others. For contacts it implies restrictions, short of isolation, for a time equal to the incubation period of the disease to which they have been exposed.

16. **Surveillance.** This is a less stringent measure than quarantine; its aims are to ensure early diagnosis and the tracing of contacts. It does not necessitate limitation of movement, but periodical medical examination of contacts is necessary during the incubation period of the disease concerned. This is different to the surveillance of travellers, which aims rather at keeping track of the movements of those who might possibly become the source of an outbreak of a major epidemic disease.

17. **Observation.** Contacts and suspects are kept under observation by daily medical examination during the incubation period, irrespective of whether they are in isolation, segregation, or unrestricted in their activities.

18. **Current Disinfection.** Steps must be taken to ensure that infection is not spread from a case under treatment. Current disinfection is necessary of infective discharges and excreta, of the patient's bed linen, towel, clothing, eating utensils, and of all other articles he uses.

19. **Terminal Disinfection.** It is normally sufficient at the end of an illness, provided current disinfection has been adequate, to cleanse the room or the ward area adjacent to the bed with soap and water. Steam disinfection of bedding and clothing may in addition be advisable. Fumigation is not necessary.

Measures Applicable to Susceptibles

20. The general resistance of individuals to disease should be maintained by ensuring a favourable environment, a satisfactory level of

nutrition, and a healthy way of life. In addition, extra protection may be afforded to susceptibles at risk.

21. **Segregation.** This is particularly applicable to the separation of susceptible from immune persons when the latter are liable to acquire a carrier state, as in diphtheria.

22. **Restriction of Contact.** It may be advisable to restrict unnecessary gatherings of people indoors, for example in cinemas and at concerts. It is sometimes necessary to restrict the activities of children by the exclusion from attendance at school of those particularly susceptible, by barring them from swimming baths and camp cinemas, and very rarely by school closure. Contacts of certain diseases and those recovered should be excluded from school for varying periods (see Table 30).

TABLE 30

SCHOOL EXCLUSION PERIODS FOR THE COMMONER INFECTIOUS DISEASES

Disease	Patients	Contacts
Scarlet fever	7 days after discharge from hospital or from home isolation unless child has cold, discharge from nose or ear, sore throat or septic spots.	7 days after last contact with case in the home.
Diphtheria	Until pronounced free from infection by a doctor.	7 days after last contact with case in the home. If there are any suspicious signs exclusion must continue until the child is pronounced free from infection by a doctor.
Measles	14 days after appearance of rash if child appears well.	Infants who have not had measles; 14 days from appearance of rash in last case in the home. Other contacts; no exclusion unless suspicious signs are present.
German measles	7 days from appearance of rash.	None.
Whooping cough	28 days from appearance of characteristic cough.	Infants who have not had whooping cough; 28 days from onset of last case in the home.
Mumps	14 days from onset or 7 days from subsidence of swelling.	None.
Chickenpox	14 days from the appearance of the rash.	None.
Smallpox	Until pronounced free from infection by a doctor.	21 days unless recently vaccinated when exclusion is unnecessary.

23. **Immunization.** The resistance to certain diseases of the community or herd can be so raised by active immunization, that epidemics will not occur, even though a proportion of susceptibles remain. In the face of an epidemic susceptibles may be immediately protected for a short time by passive immunization. The combined use of active and passive immunization in such circumstances provides both immediate and prolonged resistance. The ideal however is to maintain a constant high level of resistance by regular active immunization.

24. **Chemoprophylaxis.** Some success in epidemic control by reducing the carrier rate has been claimed for sulphonamide and penicillin prophylaxis. This procedure, however, carries the risk of producing resistant strains of the organism and of sensitizing individuals to the sulpha drugs or antibiotics. It should not be used except in the most exceptional circumstances.

Measures Applicable to the Vehicle

25. Besides general measures to ensure a high standard of personal and environmental hygiene, steps are necessary to check the spread of infection by air, food, milk, water, and by vectors. The control of insect and animal vectors is described in Chapter 11. Measures to ensure pure food and water supplies are discussed in Chapters 2 and 3. The control of droplet and intestinal infections is outlined below.

CONTROL OF AIRBORNE INFECTIONS

General

26. Infective organisms may be conveyed to a new host by the air, which is contaminated by oral and nasopharyngeal discharges and by dust. Droplets are projected, mainly from the mouth, by sneezing, coughing, and talking; they vary in size and numbers according to the violence of projection and the size of the orifice through which they are projected. A moderate sneeze results in 120,000 droplets of which 20 per cent. fall immediately to the floor, 76 per cent. remain suspended in the air for one or two minutes, while the remainder stay in the air for 30 minutes or longer. Those that fall immediately to the floor are classified as droplets, those that remain suspended as droplet nuclei.

Droplets

27. Droplets are of variable coarseness and on the average are not projected horizontally more than 2 to 3 feet. They consist of mucus and may each contain a number of organisms, which may infect the dust on the floor or any other inanimate object upon which they land. Less commonly they may be inhaled by another host in direct proximity. The size and moisture of droplets is favourable to the survival and continued virulence of any organisms they may contain.

Droplet Nuclei

28. The finer droplets dry out very rapidly by evaporation to become minute droplet nuclei. These consist of dried secretion and a little moisture which may contain one or more organisms. According to size they remain suspended in the air from a few minutes to over half an hour, and are disseminated by air currents. Their range may be considerable but the further from the source the greater their dilution; and the organisms in them find survival and maintenance of virulence difficult. Eventually the majority will settle and add to the infection of dust and inanimate objects; but some may be inhaled by new hosts at a distance from the source of infection.

Dust

29. Dust may be rendered infective by other discharges and excreta besides droplets. Daylight and desiccation help to kill organisms in dust or to reduce their virulence; but their susceptibility varies, the respiratory pathogens being the most resistant. Dust is raised by sweeping, dry dusting, bed-making, dressing and general human activity; it is disseminated in the air by currents and results in infection by inhalation or through transmission by inanimate objects. The infectivity of dust on inhalation depends on its particle size to some extent, deep respiratory penetration occurring only with particles of less than five microns diameter.

Mediate Infection

30. Droplets and dust may convey infection to the hands, to wounds, instruments, books, toys, eating utensils, food, and drink. Airborne infection is therefore not associated with the respiratory portal of entry alone. Secondary transmission by mediate infection also occurs.

Containing the Infection

31. **Personal Habits.** A certain amount can be achieved in preventing air contamination by containing the infection at the source. This entails education in proper habits of personal hygiene. Spitting should be prohibited and unguarded coughing or sneezing discouraged. A large handkerchief over the nose and mouth will effectively contain the droplets from a sneeze or cough; the hand alone will not. It should also be impressed on people that after trapping droplets with a hand before the mouth, or using a handkerchief to do so or to blow the nose, the skin of the hand is contaminated; it requires washing before engaging in any task involving the possibility of transmitting the infection to someone else.

32. **Handkerchiefs.** Once used these are infective; the habit of vigorously shaking out a handkerchief before use is a bad one; the use of paper handkerchiefs and their destruction thereafter should be encouraged. Handkerchiefs impregnated with a disinfectant have been advocated, but appear to be of limited value.

33. **The Wearing of Masks.** This is necessary under certain circumstances to prevent the infection of patients by those attending them. Masks may also afford attendants protection, but they have little practical value in the general control of airborne infection.

34. **Open-Air Exercise.** For the healthy this is of value during epidemics of airborne infection, by helping to free the upper respiratory tract of pathogenic organisms. But violent exercise by a person incubating or in the early stages of an upper respiratory infection may provoke the development of segmental pneumonitis.

35. **Gargling and Nasal Douching.** These measures are useless either for reducing the carrier rate or for protecting the individual against infection. They may even increase susceptibility if used in strengths that irritate the mucous membranes.

36. **Cleansing of Eating and Drinking Utensils.** It may be advisable during an epidemic to arrange for eating and drinking utensils to be sterilized after use. Suitable methods are described in Chapter 9.

Aerial Disinfection

37. The relationship of severity and frequency of illness to the duration and degree of exposure to infection makes aerial disinfection an attractive proposition in the control of airborne infection. So far no method has been evolved of easy and general application. Many methods have been found that reduce the bacterial content of the air; but in practice it seems that while the incidence of major illness may be somewhat reduced, minor morbidity remains unaffected.

38. **Daylight and Sunlight.** These are effective bactericides even after passing through glass. Plenty of window space is of advantage in reducing airborne and dustborne bacteria, but this alone does not make other methods of disinfection unnecessary.

39. **Ventilation.** If there is little or no change of air in an occupied room the bacterial concentration in the air gradually increases, so adding to the duration and severity of exposure. Constant dilution by frequent air changes prevents this. Optimum ventilation rates are discussed in Chapter 8. Natural ventilation is unfortunately unreliable, as respiratory infections are most common in cold weather, so that there is conflict between health and comfort. This is overcome if heating and ventilation is combined in a plenum system or in air-conditioning, when air can be further decontaminated by filtration or by recirculation through a cleaning plant.

40. **Ultra-Violet Radiation.** The cost of installation and the technical difficulties of application of ultra violet light for aerial disinfection are considerable. Nevertheless it is highly bactericidal to moist organisms, although ineffective against those borne by dust.

41. **Chemical Disinfection.** Chemicals used for aerial disinfection are dispersed as vapours or aerosols. Those so far found most successful include hypochlorous acid, triethylene glycol, lactic acid, resorcinol, and alkyl resorcinols. One difficulty in their use is to maintain an effective concentration, due to the variability of ventilation rates in rooms and to the rapid disappearance of the chemical because of instability or extraneous influences. Further, in the concentrations used chemicals must not be irritating, toxic, or obnoxious or be harmful to metals and fabrics. The application of a formaldehyde spray from a hand sprayer as an aerial disinfectant is quite useless. Should it ever be necessary in an emergency to improvise aerial disinfection the best method is to apply a 1 per cent. solution of sodium hypochlorite every half-hour from a hand sprayer that atomizes very finely, using 20 to 30 strokes per 1,000 cubic feet of space.

Dust Control

42. Certain organisms such as the streptococcus, the clostridium of diphtheria, the tubercle bacillus, and the virus of smallpox, resist drying and persist in dust. Dust may contain very large numbers of pathogenic organisms; and sources of dust such as blankets and bedding can become highly infective. Dust control is of particular importance in preventing cross infection in hospitals; it is necessary in all premises if airborne infection is to be controlled. Besides ventilation and aerial disinfection the following measures are effective.

43. **Dust-Raising Activities.** Constant traffic through a room, cleaning, sweeping, dusting, dressing, and bed-making, all raise dust. Dust-raising

activities should be carried out when rooms are, so far as possible, unoccupied and sufficiently long before they are again occupied for the dust to settle. The timing of cleaning and bed-making in hospital and sickquarters wards is of especial importance in preventing the cross-infection of wounds. Ample time must be allowed for dust to settle before wounds are exposed for dressing. Methods are also required to reduce dust-raising.

44. **Sweeping and Dusting.** Vacuum cleaning is preferable to sweeping. If sweeping is essential a damp method should be employed. A wet brush or one moistened with spindle oil should be used, or the floor should be sprinkled with water or with moist or oiled sawdust; for asphalt or stone floors sawdust treated with calcium chloride solution may be used. Dusting should always be carried out with a damp duster.

45. **Oiling of Floors.** The treatment of linoleum and wood floors with spindle oil prevents the dispersal of dust, but floors cannot be polished afterwards. Oil is not suitable for polished linoleum, terrazo, asphalt or cement floors. Oiling is of value, but remains unpopular on account of the appearance it gives to floors and because, if improperly applied, it makes floors slippery.

46. **Oiling of Blankets.** Blankets may be treated in a washing machine with a watery emulsion of an oil such as Olinol I or Fixanol C. The excess is then removed in a hydro-extractor leaving the blankets non-oily to the touch. Sheets may be similarly treated. More recently the washing of blankets in a non-ionic detergent followed by dipping in cetyl trimethylamine bromide (0·036 per cent. solution) has been shown to reduce their infectivity for some weeks.

PREVENTION AND CONTROL OF ALIMENTARY INFECTIONS

General

47. In this context alimentary infections include diseases due to the ingestion by mouth of pathogenic organisms which do not always necessarily affect the alimentary tract. Bacillary dysentery is clearly an alimentary infection; but scarlet fever, diphtheria, poliomyelitis and infective hepatitis, although more commonly associated with droplet spread, may also for example be acquired by the ingestion of infected material.

48. The sources of alimentary infections are the discharges and excreta of infected cases, missed cases and carriers, as well as the excreta, products and carcases of infected animals. Infection is ingested mainly in food and drink, but also by the sucking of fingers and inanimate objects. The development of disease and its severity depend on the general and specific resistance of the new host, on the dosage of organisms ingested and on their virulence.

Prevention

49. Prevention consists of the general measures already described in this chapter, together with:—

(*a*) Steps to ensure wholesome sources of food, to maintain a high standard of kitchen hygiene, and to supervise the health of food handlers as described in Chapter 3.

(*b*) Steps to ensure pure water supplies as described in Chapter 2.

(*c*) Steps to ensure an efficient conservancy system as described in Chapters 4 and 5.

(*d*) Control of insect and animal vectors as described in Chapter 11.

Control of Outbreaks

50. The nature and pattern of infection will give some indication of the probable source and means of spread of infection when an outbreak occurs. (This is considered further in paras. 55 to 66.) The aim is to block potential routes by immediate emergency measures until investigations can be carried out and more radical preventive action taken.

51. **Water Supply.** If a water-borne infection is suspected, the first step is to recommend that all water for drinking and the brushing of the teeth must be boiled. Next, samples for bacteriological examination must be taken as described in Chapter 2. Thereafter arrangements for extra chlorination of the water may be made and investigation of the reason for contamination, such as a fractured main, may be pursued.

52. **Milk Supply.** If an outbreak is thought to be due to contaminated milk, the boiling of all milk until further notice should be recommended. The unit milk supply should then be investigated, normally in conjunction with the civilian public health authorities.

53. **Food.** When food is the suspected vehicle of infection, the immediate step is to recommend that cold, made-up and raw foods should not be served meanwhile. The use of cream fillings, custards, mayonnaise and allied products should also be stopped. Samples of suspected foods or their constituents should be collected, as well as samples of vomit or faeces, for laboratory investigation. It may be necessary to enlist the help of the public health authorities. Food handlers must be examined and their methods of food handling scrutinized. The hygiene standards of kitchen premises also require careful check. Once any immediately obvious faults or possible causes have been eliminated, further investigation should be continued if necessary.

54. **Immunization.** When immunization is appropriate, it should be offered to all susceptibles at risk.

INVESTIGATION OF OUTBREAKS OF DISEASE

Pattern of Infection

55. The starting points in investigating an outbreak are the nature of the causal organism and the pattern of infection, which is made up of:—

(*a*) *Distribution in Time.* This is obtained by plotting cases according to the date on which first symptoms appeared.

(*b*) *Distribution in Space.* This can be shown by preparing a spot map of the cases, according to accommodation occupied on the unit or according to the place of work or both, at the time they may have been infected (*i.e.* date of first symptoms minus average incubation period).

(*c*) *Distribution of Persons.* Cases may be grouped according to age, sex, occupation, or any other category, which might indicate that some section of the population was at particular common risk.

56. The resulting pattern may expose or throw suspicion on the source of infection and its route of transmission. Contact tracing may provide further evidence, but usually confirmatory investigations are also necessary.

Causal Organism

57. The vehicles of transmission of certain organisms commonly associated with epidemics are:—

(*a*) *S. typhi.* Most commonly water, less commonly food or milk.

(*b*) *S. paratyphi.* Most commonly foods, especially those containing custard, cream, and similar fillings. Rarely water.

(*c*) *Sh. dysenteriae.* Food and milk, rarely water.

(*d*) *E. histolytica.* Uncooked vegetables and water.

(*e*) *V. cholera.* Water or water-contaminated uncooked food.

(*f*) *Streptococci.* Usually airborne, but sometimes food or milk.

(*g*) *C. diphtheriae.* Usually airborne, sometimes milk.

(*h*) *Other Salmonellae.* Most commonly made-up food.

(*j*) *Staphylococci.* Toxins usually in over-manipulated or made-up food.

Investigation of Water-borne Outbreaks

58. Water-borne outbreaks may be explosive, but are not necessarily so. It depends on the degree of pollution and whether this is constant or intermittent. It is usual to find no geographical or focal connection between cases, other than a common water supply. It is always necessary to bear in mind the possibility of water infecting a secondary vehicle of spread, such as milk. Unless this happens infection is rarely massive as the organisms do not multiply in water.

59. Investigation, after the emergency steps described in para. 51 have been taken, consists of:—

(*a*) Determining the pattern of the infection.

(*b*) Physical and bacteriological examination of the water supply as described in Chapter 2.

Investigation of Milk-borne Outbreaks

60. The outbreak is usually explosive but this is not invariable. The incidence falls mainly on regular consumers of milk such as women and children. Cases will normally have a common milk supply but vagaries of distribution may obscure the common factor. For example, a farm may sell to several milk retailers. All the consumers of the contaminated supply are not usually attacked, but it is common for all milk consumers in a household to become ill.

61. After the emergency steps described in para. 52 have been taken, investigation consists of:—

(*a*) Determining the pattern of infection.

(*b*) Following up the resultant clues to ascertain the contaminated supply.

(*c*) Liaison with the civilian public health authorities to determine the source of contamination.

(*d*) Should the supply be R.A.F. controlled, careful scrutiny must be made of the techniques of production, treatment, bottling, and delivery. Medical examination of milk handlers who might be sources of infection will be necessary. It may be necessary also to arrange for veterinary examination of the herd.

Investigation of Food-borne Outbreaks

62. The characteristics of food-borne outbreaks vary widely according to causal organism, the kind of food infected, and the circumstances of its ingestion. After immediate control measures have been taken the following steps may be indicated:—

(*a*) Ensure that no suspected food is thrown away.

(*b*) Inspect kitchens to check on cleanliness, storage, and refrigeration methods, technique of food preparation, the health and cleanliness of food handlers, and the possibility of food contamination by insects or rodents.

(*c*) Determine the pattern of infection and if possible establish the particular meal and article of food concerned.

(*d*) Ascertain the exact ingredients and origins of the suspect food. Inquire into precisely how it was prepared, by whom, how long it was ready before being eaten, and whether during this time it was refrigerated. In particular find out whether before being put in the refrigerator it was allowed to cool slowly.

(*e*) Send samples of the food, as well as of vomit and faeces from the patients, to the laboratory.

(*f*) If it seems likely that the source of contamination is a carrier, an intensive search for the food handler concerned must be made.

Investigation of Airborne Outbreaks

63. General control measures are usually effective in airborne outbreaks, which are in addition to some extent self-limiting; investigation is profitable only in exceptional circumstances. The type of investigation required varies so much according to the infection concerned that, instead of a general description, it is better to give examples.

64. **Diphtheria.** Investigations are indicated only if the outbreak is explosive or smouldering and long drawn-out. If it is explosive, milk should be suspected and investigated accordingly. Routine search for carriers in most outbreaks is unjustified as they will be found in large numbers. In smouldering outbreaks post-nasal swabbing and the examination of skin infections is worthwhile. Any carriers of gravis or intermedius strains should be considered virulent; test of virulence should be performed for mitis carriers.

65. **Streptococcal Infections.** The indications for investigation are similar to those for diphtheria, but in addition investigation will be necessary when a small explosive outbreak occurs following inoculations or other surgical procedures. Carriers are, however, most commonly associated with smouldering outbreaks. Normally, routine swabbing is pointless. When indicated, swabs should be taken from nose, throat, and skin lesions. Grouping and typing should be carried out if streptococci are found.

66. **Cerebrospinal Fever.** Outbreaks are usually amenable to general control measures. The number of carriers is normally so high that swabbing is of no use. The investigation of the source of infection is thus of little value, but it is advisable to inquire into the general health and environment of any community stricken by an outbreak.

IMMUNIZATION

General

67. Outbreaks of disease can have disastrous effects on the efficiency of an armed force. A potent weapon in the prevention of such disasters is active artificial immunization. The object is to immunize sufficient people to prevent or limit epidemics, rather than to prevent individual cases of illness. From this point of view it is very much more important to raise herd immunity than it is to protect every individual. But the unprotected individual in a reasonably protected community also benefits, for he will be at less risk to infection from others. It is this concept of herd immunity that makes voluntary immunization medically acceptable; there will always be enough individuals, who accept the immunization offered, to ensure an adequate level of protection in the community. However, the immunity obtained is never complete; massive dosage of organisms, prolonged exposure to infection, and factors liable to lower individual resistance, may result in the infection of an immunized person. But no corresponding failure of herd immunity is likely.

Active Artificial Immunization

68. Active immunity follows the introduction of antigens which stimulate the production of antibodies. The production of antibodies is not immediate, but the protection they afford is relatively persistent. This is in contrast to passive immunity in which the antibodies are supplied ready-made, and protection is immediate but short-lived. Passive immunization is of therapeutic use or for the temporary protection of susceptibles in the presence of disease; but for long-term prophylactic purposes active immunization is required.

69. The initial stimulus from a bacterial antigen may result in little or no rise in antibody titre. It causes cell sensitization, however, so that subsequent similar antigenic stimuli lead to an accelerated production of antibody and greatly increased protection. This is the rationale underlying the administration of spaced doses of bacterial antigens. Cell sensitivity persists, so that even after a high antibody titre has in the course of time diminished or disappeared, a single recall dose will again cause a massive antibody response.

70. Diseases against which active immunization is available include smallpox, the enteric fevers, tetanus, cholera, typhus, yellow fever, diphtheria, whooping cough, plague, scarlet fever, poliomyelitis, influenza, and tuberculosis. The preparations used may be suspensions of dead or attenuated live organisms (vaccines) or toxins rendered harmless by formalin (toxoids). The exception is that for scarlet fever toxin is used. In contrast, passive immunizing agents are sera obtained from actively immunized animals or humans. Combined prophylactics are sometimes used and have the advantage of reducing the number of inoculations that need be given; and in some, antigenic potency is mutually reinforced. Examples are combined enteric vaccine and tetanus toxoid (T.A.B.T.) and combined diphtheria toxoid and pertussis vaccine.

R.A.F. Requirements

71. The basic regulations on inoculations and vaccinations are contained in Q.R. 1409. These are expanded as required by Air Ministry Orders and policy letters. It is to be especially noted that the acceptance of immunization is entirely voluntary and that no penalty of any kind attaches to refusal. Nevertheless, it is the duty of C.Os. and medical officers to stress to officers, airmen, and airwomen, especially those going abroad, the importance of being protected.

72. Vaccinations against smallpox and inoculation against poliomyelitis, the enteric fevers, tetanus, diphtheria, whooping cough, yellow fever and cholera are offered at home and abroad as appropriate to members of the Royal Air Force and their families, to members of the Women's Royal Air Force and to certain entitled civilians. B.C.G. and influenza vaccine are made available to limited categories in certain circumstances. The Air Ministry issue from time to time, instructions and tables giving the appropriate immunizations, to accord with international requirements and existing health risks. Apart from special requirements, or any that are considered necessary by commanders-in-chief on medical advice, the following regulations apply in general, details being contained in Air Ministry letters.

73. **Smallpox.**

(*a*) Service personnel should be vaccinated on enlistment and thereafter every three years, at home and abroad.

(*b*) Infants should be vaccinated within the first two years of life, preferably during the second year.

(*c*) Primary vaccination of children and adolescents who have not been vaccinated in infancy should be done when exposed to risk and on going abroad. Apprentices and boy entrants should be offered vaccination on entry.

(*d*) Adult dependants should be vaccinated before going abroad unless they have so been within the previous three years and hold a valid international certificate.

74. **Enteric Fevers and Tetanus.** Combined immunization against the enteric fevers and tetanus is normally given except to younger children. To these and in other special cases tetanus toxoid may be given separately.

(*a*) Service personnel should be inoculated against the enteric fevers and tetanus on entry and thereafter as instructed by Air Ministry.

(*b*) Infants of 2 years old and under should not be immunized against the enteric fevers. They may receive tetanus immunization at the wish of their parents.

(*c*) Immunization against the enteric fevers and tetanus is recommended for all other dependants, before going abroad or during residence there. For children between 2 and 12 years a dilute T.A.B. vaccine should be used with tetanus toxoid given separately.

75. **Diphtheria.** Inoculation is offered to recruits if they are shown to have low immunity and may also be offered to susceptibles who are a special risk. Parents should be encouraged to have their children immunized before the age of one year and every effort should be made to ensure that no child goes abroad without immunization.

76. **Whooping Cough.** Pertussis vaccine may be given alone or combined with diphtheria toxoid. Owing to the risks from whooping cough in the first year of life, immunization should be started between the ages of 3 and 6 months. Booster doses at 1 and 5 years old are advisable. If combined prophylaxis has been used, subsequent immunity against

diphtheria should be maintained beyond the age of 5 years by booster doses of diphtheria toxoid (as in para. 75).

77. **Yellow Fever.** Inoculation is an international requirement for travel through or to certain countries and applies to all service personnel, civilians, and dependants, including children of all ages. It may also be an R.A.F. requirement in theatres, not themselves in a yellow fever zone but where travel at short notice to or through a yellow fever endemic area is not uncommon. There is a slight risk of encephalitis after yellow fever vaccination in infants of less than nine months. Everything practicable should be done to get round the need for inoculating such children. When it is essential for an infant to travel through or to, or to reside in, a yellow fever endemic area, the slight risk of inoculation should be explained to the parents and their consent to it must be obtained in writing. There is no such risk to older children. Primary smallpox vaccination should not, however, be given simultaneously with yellow fever vaccination. If both are necessary yellow fever should be given first, when smallpox vaccination may be given four days later. If primary smallpox vaccination is given first, yellow fever inoculation must be delayed for three weeks. If both primary smallpox and yellow fever vaccination are essential for an infant under nine months, the three-week interval must be allowed, irrespective of which is given first. Immunization against yellow fever can only be carried out at special vaccination centres by medical officers trained in the technique. This is because of the laboratory facilities required for the storage and handling of the vaccine. Lists of service and civilian yellow fever vaccination centres are circulated from time to time. Yellow fever vaccination confers immunity for six years.

78. **Cholera.** Immunization against cholera may be a requirement for travel or under conditions of special risk. Under such circumstances it should be offered to all service personnel, civilians, and dependants, except infants under one year. Immunity requires maintenance by inoculation every six months.

79. **Plague.** As for cholera.

80. **Typhus.** Immunization against typhus may be recommended for all service personnel, civilians, and dependants, except infants under one year, when circumstances involving special risk occur. Immunity is maintained by yearly inoculation.

International Requirements

81. Under the International Sanitary Regulations, 1951, as amended 1955–1959, of the World Health Organization, the health administration of any subscribing country may make travel immunization requirements only for smallpox, yellow fever, and cholera. Such international requirements are notified annually to W.H.O. and published by them. Any changes in regulations are notified to them immediately by the country concerned. The only acceptable evidence that a traveller has complied with international immunization requirements is the possession of a valid international certificate R.A.F. immunization regulations are designed to conform to international requirements and all R.A.F. hospitals and sick-quarters are recognized inoculation centres. (Only certain of them, however, are authorized to perform yellow fever vaccination. See para. 77.) Tables giving the necessary information are issued and amended from time to time as required.

Recording of Immunization

82. **Certificates.** All persons immunized at R.A.F. inoculation centres must be given the appropriate certificates at the time of immunization. All such certificates are to be franked with the official "Royal Air Force Inoculation Centre" stamp, which is recognized by W.H.O. No other stamp is ever to be used. The certificates concerned are:—

(*a*) *International Certificates.*

(i) Smallpox (F.Med.101).

(ii) Cholera (F. Med. 102).

(iii) Yellow fever (F. Med. 103).

(*b*) *R.A.F. Inoculation Certificate* (R.A.F. Form 3884). This form is to be used for the recording of all other types of immunization except smallpox, cholera, and yellow fever.

83. **Re-Immunization.** The validity of immunization certificates on re-immunization is extended by inoculations with the stated dose on or before expiry. Re-inoculations are to be recorded in the spaces provided on the original certificate and stamped again as before. When in due course a new certificate is needed, the original must be preserved as evidence of satisfactory initial immunization.

84. **Entry on F. Med. 4.** Dates and dosage, where appropriate, of inoculations and vaccinations are to be entered in the appropriate table of the medical history envelope of all serving personnel, at the time they are immunized.

85. **Refusal to be Immunized.** Those who refuse immunization will not be prevented from going abroad. They will, however, be subject to such quarantine measures as may be considered appropriate by the health authorities of the countries concerned. The nature and value of the protection offered should be explained by the medical officer to anyone refusing. Refusals by service personnel are to be recorded on F. Med. 4 in red ink. These entries are to be dated and signed by the person refusing. Details of refusals are also to be recorded on the individual's R.A.F. Form 280. There is nothing sinister about such entries and their signing; they act as a record indemnifying the Service against any subsequent allegation of negligence in failing to offer protection.

Validity of International Certificates

86. If a certificate is to be acceptable as evidence of compliance with international immunization requirements, it must be valid. Every care must be taken to ensure this, for an invalid certificate can cause extensive individual and collective inconvenience and trouble. Since immunity does not follow immediately upon immunization, and eventually wanes, there are internationally agreed periods related to the time of immunization, when certificates are invalid. Thus there is a period that must elapse after immunization before the certificate is valid; and thereafter there is another period limiting the valid life of the certificate (see Table 31).

TABLE 31

TIME FACTOR IN VALIDITY OF INTERNATIONAL CERTIFICATES

Certificate	Time which must elapse after immunization before certificate is valid		Time after the lapse of which certificate becomes invalid
	Initial immunization	Re-immunization	
Smallpox (F. Med. 101)	8 days	Forthwith	3 years
Cholera (F. Med. 102)	6 days	Forthwith if done within 6 months	6 months
Yellow Fever (F. Med. 103)	10 days (Pakistan and India 12 days)	Forthwith if done within 6 years	6 years

N.B. F. Med. 101 becomes valid after 3 unsuccessful attempts at primary vaccination at 8-day intervals.

87. The following points must also be observed to ensure validity:—

(*a*) The immunized person's name and personal particulars must be clearly recorded and he must sign the certificate in the appropriate space.

(*b*) The origin and batch number of the vaccine must be inserted correctly on F. Med. 103.

(*c*) Dates must be recorded in full.

(*d*) The medical officer must himself sign the certificate; facsimile stamped signatures are not permitted.

(*e*) The certificate must be franked with the official "R.A.F. Inoculation Centre" stamp and no other.

(*f*) Alterations to entries are not permitted. If an error is made a new certificate must be made out.

(*g*) Only officially printed certificates are acceptable. Typed or stencilled pro formae are not to be used.

CONTROL OF INDIVIDUAL DISEASES

Control of Communicable Diseases in the Services (A.P. 3272)

88. Control of the following diseases is described in the inter-service publication with the above title:—

Botulism (under Food Poisoning)
Canicola fever (under Leptospirosis)
Cerebrospinal fever (under Meningococcal Infections)
Chicken pox
Cholera
Diphtheria
Dysentery (amoebic)
Dysentery (bacillary)

Enteric group of fevers
Epidemic catarrhal jaundice (under Infective Hepatitis)
Epidemic parotitis (under Mumps)
Erysipelas (under Streptococcal Infections)
Food poisoning
German measles
Homologous serum jaundice
Infective hepatitis
Influenza
Leptospirosis
Measles
Meningococcal infections
Morbilli (under Measles)
Mumps
Non-specific bacterial food poisoning (under Food Poisoning)
Paratyphoid fevers A, B, and C (under Enteric Group of Fevers)
Pertussis (under Whooping Cough)
Poliomyelitis
Psittacosis
Puerperal infection (under Streptococcal Infections)
Q-fever
Rubella (under German Measles)
Salmonellosis (under Food Poisoning)
Scarlet fever (under Streptococcal Infections)
Smallpox
Staphylococcal food poisoning (under Food Poisoning)
Streptococcal infections
Streptococcal Sore Throat (under Streptococcal Infections)
Tuberculosis
Typhoid fever (under Enteric Group of Fevers)
Vaccinia (under Smallpox)
Variola (under Smallpox)
Weil's disease (under Leptospirosis)
Whooping cough.

Chancroid

89. (*a*) Chancroid or soft sore is a venereal disease caused by *Haemophilus ducreyi*. There is no evidence of natural or acquired immunity and an attack does not protect against subsequent infection.

(*b*) *Source of Infection*. Discharges from lesions.

(*c*) *Method of Spread*. Venereal; but accidental inoculation of children and rarely of the hands of doctors and nurses, through professional contact with infected persons, may occur. Indirect transmission through articles soiled with moist discharges from lesions is rare.

(*d*) *Incubation Period*. Usually 3 to 5 days; limits 1 to 10 days.

(*e*) *Period of Infectivity*. During persistence of organism in original lesion or regional glands. There is evidence that there are carriers of the organism in former but healed chancroidal lesions.

(*f*) *Isolation*. Exclusion from intimate contact with others until lesions have healed.

(*g*) *Quarantine*. Nil.

(*h*) *Immunization*. Nil.

(*j*) *Chemoprophylaxis.* Local application of prophylactic ointment before and after exposure.

(*k*) *Current Disinfection.* Discharge from lesions and articles soiled therewith.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* See Gonorrhoea.

Dengue

90. (*a*) Dengue is a mosquito-borne virus disease. Susceptibility is universal but immunity is usually conferred by an attack.

(*b*) *Source of Infection.* Blood of infected person during first 3 to 5 days of the disease.

(*c*) *Method of Spread.* By the bite of infected *Aèdes aegypti* or *albopictus* mosquitoes, which become infected for their lifetime from the 11th day after an infective blood feed.

(*d*) *Incubation Period.* Usually 5 to 6 days; limits 3 to 15 days.

(*e*) *Period of Infectivity.* From the day before onset to the 5th day of the disease.

(*f*) *Isolation.* Nurse cases under a mosquito net.

(*g*) *Quarantine.* Nil.

(*h*) *Immunization.* Nil.

(*j*) *Chemoprophylaxis.* Nil.

(*k*) *Current Disinfection.* Nil.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* Mosquito control (see Chapter 11). Personal protection from the vector, which bites voraciously at any hour, but particularly in the afternoon and early morning.

Gonorrhoea

91. (*a*) The causal organism is *Neisseria gonorrhoea*; susceptibility is general and an attack confers no immunity.

(*b*) *Source of Infection.* Discharges from mucous membranes and glands of infected individuals.

(*c*) *Method of Spread.* Venereal; but rarely by contact with articles freshly soiled by discharges.

(*d*) *Incubation Period.* Usually 3 to 5 days; limits 1 to 8 days; rarely longer.

(*e*) *Period of Infectivity.* While the organism persists in the discharges.

(*f*) *Isolation.* During period of infectivity.

(*g*) *Quarantine of Contacts.* Nil.

(*h*) *Immunization.* Nil.

(*j*) *Chemoprophylaxis.* Oral prophylaxis is contraindicated. Local application of prophylactic cream before and after exposure.

(*k*) *Current Disinfection.* Discharges and articles soiled therewith.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* Education of personnel on dangers of the disease and the use of prophylactic measures. Co-operation with civil authorities in contact tracing.

Malaria

92. (*a*) There are four species of malarial parasite that affect humans:—

(*i*) *Plasmodium vivax* causing benign tertian or B.T. malaria.

(*ii*) *P. falciparum* causing malignant subtertian or M.T. malaria.

(*iii*) *P. malariae* causing quartan malaria.

(*iv*) *P. ovale*.

Infections may be by one species or multiple. Susceptibility is universal. Relative immunity to clinical attacks can be acquired only against specific strains of parasites, after repeated infections. Immunity to other plasmodium species is not developed in this way and only slight immunity is developed to other strains of the same species.

(*b*) *Source of Infection.* Blood of an infected person.

(*c*) *Method of Spread.* The bites of infected female anopheline mosquitoes. Uncommonly by blood transfusion or the use of an unsterilized syringe. After an infected blood feed the mosquito does not become infective until the completion within its body of the sporogenic cycle. Under favourable conditions of temperature and humidity this takes 10 to 14 days, or for *P. malariae* 21 days.

(*d*) *Incubation Period.* This varies with the species of parasite and the amount of infection. After a sufficient exposure to the bites of infected mosquitoes, tertian malaria usually develops in about 14 days. The infection may, however, remain latent for many weeks or even months, until a clinical attack is precipitated by some illness.

(*e*) *Period of Infectivity.* As long as the gametocytes of the malaria parasite are present in the circulating blood in sufficient numbers to infect mosquitoes. This may last for months in both treated and untreated cases; *P. falciparum* can, however, be completely eliminated by treatment.

(*f*) *Isolation.* Cases should be nursed under mosquito nets.

(*g*) *Quarantine.* Nil.

(*h*) *Immunization.* Nil.

(*j*) *Chemoprophylaxis.* Drugs used to prevent malaria may be true causal prophylactics, which destroy pre-erythrocytic stages of the plasmodium, or suppressants which are schizonticides. Paludrine (*proguanil*) is the drug of choice as it is a causal prophylactic for M.T. (*falciparum*) strains and a good suppressant for the others. The dosage is 1 tablet (100 mgm.) daily from one day before entering an endemic area to 48 hours after departure from it. Chloroquine and mepacrine are other good suppressants. Suppressive treatment is used to supplement other control measures under exceptional circumstances, for example, when the risk of infection is high and other methods of reducing the incidence of malaria are insufficient, or when it is necessary to keep a special group of personnel entirely free of symptoms for a definite period, or when the local hospital facilities are inadequate or too far distant.

(*k*) *Current Disinfection.* Nil.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* Control of adult mosquitoes and larvae are described in Chapter 11. In malarious areas, no living quarters should be sited within flight range of anopheline mosquito breeding grounds unless these are strictly controlled. In such areas no native habitations should be permitted within half a mile, preferably one mile, of living quarters. Measures for personal protection should be enforced; these consist of wearing long sleeves and long trousers between dusk and dawn, also two pairs of socks, gaiters, or mosquito boots. Under certain circumstances fishnet veils and sleeves impregnated with repellent are used. Repellents may be applied to the skin. Mosquito nets must be used. The enforcement of anti-malaria measures is the responsibility of commanding officers and their duties in this respect require strong emphasis and support from the highest executive authorities, especially under field or mobile conditions.

Plague

93. (*a*) The causal organism is *Pasteurella pestis*. Susceptibility is general, particularly to the pneumonic form which is intensely communicable during the acute stage. Recovery from an attack is almost always followed by lasting immunity.

(*b*) *Source of Infection*. Blood of infected rodents, including rats, gerbilles, and ground squirrels. Sputum of pneumonic cases.

(*c*) *Method of Spread*. Droplet and dust-borne infection in the pneumonic form. Bubonic and septicaemic forms are generally transmitted by the bites of fleas which leave dead or dying rodents in search of new hosts.

(*d*) *Incubation Period*. Usually 3 to 6 days ; occasionally longer.

(*e*) *Period of Infectivity*. Pneumonic form during stage of acute symptoms. Bubonic form only communicable by insect vector.

(*f*) *Isolation*. In hospital for one month.

(*g*) *Quarantine of Contacts*. Six days. They should be protected by serum and vaccine, or by chemoprophylaxis and D.D.T. dusting.

(*h*) *Immunization*. A measure of personal protection for those especially at risk, rather than of general control. Passive immunity of 3 to 4 weeks' duration and active immunity of 6 months can be conferred.

(*j*) *Chemoprophylaxis*. Sulfadiazine or sulphamerazine 3 grams daily for at least 5 days after exposure.

(*k*) *Current Disinfection*. Sputum and articles soiled therewith in pneumonic form. Evacuation, thorough cleaning, and disinfestation (fleas and rats) of premises in which cases of bubonic plague have occurred. Personnel undertaking these duties should be protected with gum boots, gauntlets, overalls, and immunization.

(*l*) *Terminal Disinfection*. Thorough cleaning, fumigation, and further disinfestation. Bodies of persons dead from plague should be handled with strict antiseptic precautions. Dead rats should be lifted only with tongs.

(*m*) *General Control Measures*. Unremitting anti-rat measures in endemic districts, particularly in dock areas. Immediate active immunization of all those at special risk on first signs of rat epizootic. Special protective clothing for nursing attendants. Flea control. Personal dusting with D.D.T. or the use of D.D.T. impregnated clothing.

Rabies

94. (*a*) Rabies is an acute encephalitis caused by a filterable virus. Once symptoms have developed it is invariably fatal. Natural immunity is not known to exist.

(*b*) *Source of Infection*. Infected animals, mainly canines (dogs, jackals, and foxes), but also wild carnivores and blood-sucking bats.

(*c*) *Method of Spread.* Usually through bites of a rabid animal, but also through contact of the broken skin with the saliva of a rabid animal.

(*d*) *Incubation Period.* Very variable in man depending on the extent of laceration, the site of the wound in relation to the richness of the nerve supply, and the length of nerve supply to the brain. Average is 6 to 8 weeks, but variation is 2 weeks to 6 months. A safe estimate in dogs is 6 months.

(*e*) *Period of Infectivity.* The dog is infective before the onset of symptoms and thereafter until death. Presymptomatic infectivity varies from 3 to 10 days.

(*f*) *Isolation.* Nil.

(*g*) *Quarantine.* Human; nil. Dogs as follows:—

(i) A biting or suspect animal should be captured, not shot, and kept under observation for 10 days. If by then it shows no signs of illness it is not rabid.

(ii) During an outbreak all dogs should be restrained by leashing or kennelling for 90 days from last case of rabies, or for 30 days after vaccination.

(iii) Dogs and cats bitten by a rabid animal should be destroyed; but if this is undesirable isolation in a kennel for 6 months, vaccination and isolation for 3 months or, if previously vaccinated within 12 months, revaccination and restraint for 30 days should be imposed.

(*h*) *Immunization.*

(i) *Human.* Prophylaxis after exposure to infection may be carried out in humans by active, passive, or combined immunization, using vaccine or hyperimmune serum, according to the W.H.O. recommendations contained in Table 32.

(ii) *Dogs.* All dogs kept by service personnel and families or others on R.A.F. property in regions where there is risk of rabies should be actively immunized between the ages of 3 and 6 months. Re-immunization is necessary at one year old and thereafter three-yearly.

(*j*) *Immediate Treatment of Bites.* In an epizootic area any bite inflicted by an animal, whether or not rabid, should be thoroughly cleaned at once with soap or detergent solution, then cauterized with pure concentrated phenol.

(*k*) *Chemoprophylaxis.* Nil.

(*l*) *Current Disinfection.* Saliva of patients and articles soiled therewith.

(*m*) *Terminal Disinfection.* Nil.

(*n*) *General Control Measures.* Detention and examination of suspect rabid dogs, which should not be killed until observed for at least 10 days or confirmed as rabid on clinical grounds. If a dog dies or must be killed, the brain must be sent for laboratory examination. The following measures should be taken at units in epizootic areas:—

(i) All dogs kept on or brought onto R.A.F. stations should be registered, immunized, and wear an identification tag giving the registered number.

(ii) Stray dogs should be eliminated.

TABLE 32
INDICATIONS FOR SPECIFIC POST-EXPOSURE TREATMENT OF RABIES

Nature of Exposure	Condition of Biting Animal: At time of exposure	Condition of Biting Animal: During observation period of ten days	Treatment
1. *No lesions*; only indirect contact.	Rabid	—	None (but see Note 1).
2. *Licks*; unabraded skin.	Rabid	—	None (but see Note 1).
3. *Licks*; abraded skin and abraded or unabraded mucosa.	(*a*) Healthy	Healthy	None
	(*b*) Healthy	Signs of rabies or proven rabid.	Start vaccine at first signs of rabies in animal.
	(*c*) Signs suggestive of rabies.	Healthy	Start vaccine immediately; stop treatment if animal normal on 5th day after exposure. (See Note 2.)
	(*d*) Rabid, escaped, killed, or unknown.	—	Start vaccine immediately.
4. *Bites*; simple exposure.	(*a*) Healthy	Healthy	None
	(*b*) Healthy	Signs of rabies or proven rabid.	Start vaccine at first signs of rabies in animal.
	(*c*) Signs suggestive of rabies.	Healthy	Start vaccine immediately; stop treatment if animal normal on 5th day after exposure. (See Note 2.)
	(*d*) Rabid, escaped, killed, or unknown; or any bite by wolf, jackal, fox, or other wild animal.	—	Start vaccine immediately.
5. *Bites*; severe exposure (multiple or face, head, or neck bites).	(*a*) Healthy	Healthy	Hyperimmune serum immediately; no vaccines as long as animal normal.
	(*b*) Healthy	Signs of rabies or proven rabid.	Hyperimmune serum; start vaccine at first sign of rabies.
	(*c*) Signs suggestive of rabies.	Healthy	Hyperimmune serum immediately, followed by vaccine; vaccine may be stopped if animal is normal on 5th day after exposure.
	(*d*) Rabid, escaped, killed or unknown; any bite by wild animal.	—	Hyperimmune serum immediately, followed by vaccine.

Note 1. Start vaccine immediately in young children and in patients where a reliable history cannot be obtained.

Note 2. An alternative treatment would be to give hyperimmune serum and not start vaccine as long as the animal remained normal.

(iii) If rabies is prevalent dogs should be muzzled.

(iv) Dogs should be kept under reasonable control, including leashing in congested areas, and when necessary more vigorously restrained as detailed in sub-para. (*g*).

(*o*) Cases requiring specific anti-rabic treatment should in commands at home be notified by signal to D.G.M.S., abroad to the competent medical authority. The medical officer attending the case is also to notify the competent medical authority in duplicate of the following particulars:—

(i) Name, rank, age, and unit of person bitten.

(ii) Time and date when bitten.

(iii) Locality where injury occurred.

(iv) Part of body bitten and whether through clothing.

(v) Number of bites received and their severity.

(vi) Kind of animal inflicting bite.

(vii) Whether animal was captured and what action has been taken regarding it.

(viii) Whether rabies has been diagnosed in the animal; whether post-mortem has been held and by whom.

(ix) Name and address of owner of animal or other information which will enable the animal to be identified.

Relapsing Fever (Louse-borne)

95. (*a*) The causal organism is *Spirochaeta recurrentis*. Acquired immunity after a clinical attack, in which there may be up to four relapses, probably does not last more than one or two years.

(*b*) *Source of Infection*. Infected lice, whose natural reservoir of infection is not known.

(*c*) *Method of Spread*. The louse becomes infective about 16 days after biting an infected person and remains so for life, passing on the infective state hereditarily. Transmission of the infection from louse to man is effected not by the bite, but by crushing an infective louse into a bite, wound or scratch or by rubbing louse excreta into an abrasion.

(*d*) *Incubation Period*. About 3 to 7 days; limit 2 to 12 days.

(*e*) *Period of Infectivity*. While infected with lice.

(*f*) *Isolation*. Nil.

(*g*) *Quarantine*. Nil.

(*h*) *Immunization*. Nil.

(*j*) *Chemoprophylaxis*. Nil.

(*k*) *Current Disinfection*. Nil.

(*l*) *Terminal Disinfection*. Nil.

(*m*) *General Control Measures*. Prevention of louse infestation of personnel.

Relapsing Fever (Tick-borne)

96. (*a*) This form differs from the louse-borne type in the vector, the species of *spirochaete*, and the number of relapses which may number up to 11. Acquired immunity is similar. The species of *spirochaete* concerned differs according to the part of the world, but the classical type is *Sp. duttoni* of Central Africa.

(*b*) *Source of Infection.* Infected ticks of the genus *Ornithodorous*, the species varying according to geography (see Chapter 11). The condition is primarily an infection of wild rodents, which form the natural reservoir. In ticks the infective state is hereditary.

(*c*) *Method of Spread.* By bites of infected tick or by its excreta or coxal fluid secreted during feeding. The *spirochaetes* can penetrate unbroken skin.

(*d*) *Incubation Period.* Usually 7 to 10 days.

(*e*) *Period of Infectivity.* Not communicable from man to man without intervention of tick vector.

(*f*) *Isolation.* Nil.

(*g*) *Quarantine.* Nil.

(*h*) *Immunization.* Nil.

(*j*) *Chemoprophylaxis.* Nil.

(*k*) *Current Disinfection.* Nil.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* Avoidance of tick-infested areas; the use of repellents; refraining from lying or sitting on the ground (see Chapter 11).

Sandfly Fever

97. (*a*) Sandfly or phlebotomus fever is caused by a filterable virus to which susceptibility is universal. Acquired immunity is variable. The disease is seasonal and is particularly liable to affect personnel who have recently arrived from a non-endemic area. As it can suddenly put large numbers of men temporarily out of action, it is a disease of military importance.

(*b*) *Source of Infection.* The blood of an infected person, one day before onset and for first two days of the fever.

(*c*) *Method of Spread.* The bite of *Phlebotomus papatasii*, a night-biting blood-sucking midge (see Chapter 11). The vector becomes infective eight days after an infected blood feed and remains so for the remainder of its life.

(*d*) *Incubation Period.* 4 to 7 days; limits 4 to 13 days.

(*e*) *Period of Infectivity.* One day before onset of disease and two days thereafter.

(*f*) *Isolation.* Nurse under mosquito net impregnated with D.D.T.

(*g*) *Quarantine.* Nil.

(*h*) *Immunization.* Nil.

(*j*) *Chemoprophylaxis.* Nil.

(*k*) *Current Disinfection.* Nil.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* All personnel must sleep under mosquito nets impregnated with D.D.T. (the meshes of the net will not exclude sandflies if untreated). Use of insect repellents. Control of sandflies (see Chapter 11).

Schistosomiasis

98. (*a*) Schistosomiasis is an infestation by *trematode helminths*, which enter the body while in the larval stage from water inhabited by certain species of snail that are their intermediate hosts. The adult worms inhabit the rectal and vesical venous plexuses and the pathological effects of the disease result from the irritation set up by the very large number of eggs deposited in the mucous membranes of the rectum and bladder. Three species of these flukes mature in man: *Schistosoma mansoni*, *S. haematobium*, and *S. japonicum*. Their snail hosts respectively are *Planorbis*, *Bullinus* or *Physopsis*, and *Oncomelania*.

(*b*) *Source of Infection*. An infected person by contamination of fresh water inhabited by intermediate snail hosts with excreta containing ova of the parasite.

(*c*) *Method of Spread*. When ova from infected excreta are liberated in fresh water, they hatch into larvae (*miracidia*) that are infectious only to the snail. The *miracidium* dies unless within 24 hours it finds a snail host, which it enters and where in about six weeks develops in the liver into a cercaria. Cercariae are bifid-tailed and free-swimming; they are discharged from the snail and are infective to man if they find a human host within 24 hours. They enter the body through unbroken skin by means of an acid secretion, often causing an irritative dermatitis at the site of entry; they then gain access to the blood-stream.

(*d*) *Incubation Period*. Toxic symptoms: 2 to 4 weeks. Specific symptoms and ova found in urine or faeces: 2 months to 2½ years or even more.

(*e*) *Period of Infectivity*. As long as ova are excreted in faeces or urine, but transmission from man to man can occur only through the intervention of the intermediate snail host.

(*f*) *Isolation*. Nil.

(*g*) *Quarantine*. Nil.

(*h*) *Immunization*. Nil.

(*j*) *Chemoprophylaxis*. Nil.

(*k*) *Current Disinfection*. Sanitary disposal of faeces and urine.

(*l*) *Terminal Disinfection*. Nil.

(*m*) *General Control Measures*. Sound conservancy. Treatment of infected persons. Prohibition of washing, wading, or bathing in contaminated waters. Elimination of snails; copper sulphate added to water at the rate of 1lb. per 100,000 gallons kills them. All suspect water for drinking or washing must be treated by either superchlorination, chloramination, boiling, or (if snail free) storage for 48 hours until cercariae die.

Syphilis

99. (*a*) Casual organism is *Treponema pallidum*. Recovery from the disease following specific treatment does not protect from subsequent infection.

(*b*) *Source of Infection*. The lesions of an infected person, discharges from such lesions; rarely articles freshly soiled by these discharges or blood containing the *spirochaete*.

(*c*) *Method of Spread.* Direct contact, usually venereal. Congenital. Blood transfusion. Indirect contact with infected article (rarely).

(*d*) *Incubation Period.* About 3 weeks; limits 10 days to 6 weeks.

(*e*) *Period of Infectivity.* During primary and secondary stages and muco-cutaneous recurrences until the disease process has been controlled by treatment. Inadequately treated patients may transmit infection for up to about five years, but the most important period of communicability is during the first two years, especially the earliest months of infection. Congenital transmission by the inadequately or untreated mother may take place throughout the childbearing period.

(*f*) *Isolation.* Until rendered non-infective by treatment.

(*g*) *Quarantine.* Nil.

(*h*) *Immunization.* Nil.

(*j*) *Chemoprophylaxis.* Local application of prohylactic ointment before and after exposure.

(*k*) *Current Disinfection.* Discharges of open lesions and all articles soiled therewith.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* As for gonorrhoea.

Trichinosis

100. (*a*) Caused by the nematode worm, *Trichinella spiralis*. The worms are set free as larvae from the cystic stage in which they occur in the pig, when infested pork or pork saugases are eaten without having been cooked at a high enough temperature. The adult worms inhabit the small intestine into which viviparous embryos are liberated. These travel by lymphatics and veins, finally to encyst once more in striated muscle.

(*b*) *Source of Infection.* Insufficiently cooked pork or pork products.

(*c*) *Method of Spread.* Only through consumption of meat containing viable larvae.

(*d*) *Incubation Period.* Usually 6 to 7 days but may be much less.

(*e*) *Period of Infectivity.* The disease is not transmitted from man to man.

(*f*) *Isolation.* Nil.

(*g*) *Quarantine.* Nil.

(*h*) *Immunization.* Nil.

(*j*) *Chemoprophylaxis.* Nil.

(*k*) *Current Disinfection.* Nil.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* Pork and pork products should be cooked so that in all parts of the meat a temperature of 150° F. is attained. The hygiene of pig farms should be closely supervised and particular attention paid to the control of rats, which are the normal intermediate host of the worm. Pigs must not be fed with uncooked swill and garbage.

Typhus (Epidemic Louse-borne)

101. (*a*) Caused by *Rickettsia prowazeki* (Weil Felix reaction: OX19 positive).

(*b*) *Source of Infection.* Infected person.

(*c*) *Method of Spread.* By louse, usually *Pediculus corporis*. Inoculation of the organism occurs by crushing infected lice or their faeces into a bite wound or skin abrasion. In heavily louse-infested persons, the clothes become impregnated with louse faeces, which may be inhaled as dust and cause infection.

(*d*) *Incubation Period.* 8 to 14 days.

(*e*) *Period of Infectivity.* Patient is infective to louse for first 10 days of disease and occasionally later.

(*f*) *Isolation.* In vermin-free room, after delousing.

(*g*) *Quarantine.* Susceptible contacts : 15 days from last exposure or after delousing, whichever is the longer.

(*h*) *Immunization.* Inoculation with vaccine reduces chance of infection, modifies the course of the disease, and lowers case fatality rate.

(*j*) *Chemoprophylaxis.* Nil.

(*k*) *Current Disinfection.* Disinfestation of cases and contacts by D.D.T. or B.H.C. dusting (see Chapter 11). Steam disinfestation of clothing and bedding to kill rickettsiae. Special protective clothing, immunization and D.D.T. dusting required for those handling typhus cases and their belongings, until disinfestation is completed.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* Organized and systematic disinfestation especially centred around dwellings of typhus cases, by D.D.T. or B.H.C. dusting. Immunization of those requiring special protection. Infected areas to be placed out of bounds. Travel in public vehicles during epidemic should be prohibited unless these are regularly and effectively disinfected.

Typhus (Endemic murine)

102. (*a*) Caused by *R. mooseri* (Weil Felix; OX19-titres lower than for *R. prowazeki*).

(*b*) *Source of Infection.* Infected rodents, especially the common brown or sewer rat.

(*c*) *Method of Spread.* From rodent to man by fleas, usually *Xenopsylla cheopis*, the rat flea.

(*d*) *Incubation Period.* Usually 12 days; limits 6 to 14 days.

(*e*) *Period of Infectivity.* Not communicable from man to man.

(*f*) *Isolation.* Nil.

(*g*) *Quarantine.* Nil.

(*h*) *Immunization.* Nil.

(*j*) *Chemoprophylaxis.* Nil.

(*k*) *Current Disinfection.* Nil.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* Control of rats and fleas (see Chapter 11).

Typhus (Tick-borne)

103. (*a*) Caused by *Rickettsiae*, the strain differing according to the geographical situation. Synonyms for this disease are Rocky Mountain spotted fever, *fièvre bouttoneuse*, and Mediterranean fever (Weil Felix; OX19 and OX2 positive).

(*b*) *Source of Infection*. Small mammals form a natural reservoir of infection, differing according to geographical situation.

(*c*) *Method of Spread*. By bite or skin contact with blood or faeces of *Ixodidae* family of ticks.

(*d*) *Incubation Period*. 3 to 10 days.

(*e*) *Period of Infectivity*. Not communicable from man to man.

(*f*) *Isolation*. Nil.

(*g*) *Quarantine*. Nil.

(*h*) *Chemoprophylaxis*. Nil.

(*j*) *Current Disinfection*. Remove ticks.

(*k*) *Terminal Disinfection*. Nil.

(*l*) *General Control Measures*. See Chapter 11.

Typhus (Mite-borne)

104. (*a*) Caused by *R. orientalis* and also known as scrub typhus (Weil. Felix; OX19 usually negative; OX2 usually negative; OXK positive).

(*b*) *Source of Infection*. Animal reservoir; voles, rats, tree shrews, bandicoots, civets, and similar small animals. The mite vector also forms a natural reservoir.

(*c*) *Method of Spread*. Bites of infected trombiculid mites, such as *Trombicula akamushi*. The infection is passed hereditarily in mites and reinforced from the animal reservoir.

(*d*) *Incubation Period*. 7 to 10 days; limits 4 to 18 days.

(*e*) *Perod of Infectivity*. Not communicable from man to man.

(*f*) *Isolation*. Nil.

(*g*) *Quarantine*. Nil.

(*h*) *Immunization*.

(*j*) *Chemoprophylaxis*. Nil.

(*k*) *Current Disinfection*. Nil.

(*l*) *Terminal Disinfection*. Nil.

(*m*) *General Control Measures*. See Chapter 11.

Undulant Fever

105. (*a*) Caused by *Brucella melitensis*, *Br. abortus*, and *Br. suis*, which are found in goats, cattle, and swine respectively, with a world-wide distribution. Hence the disease is also known as *Brucellosis*. Most persons have some degree of resistance to infection, especially to *Br. abortus*, or have acquired partial immunity by ingestion of sub-infective doses of these organisms.

(*b*) *Source of Infection*. Tissues, blood, milk, and urine of infected animals. Laboratory infection is readily acquired.

(*c*) *Method of Spread*. Ingestion of milk from infected animals or, especially in farm or veterinary workers, by direct contact with infected animals or animal products.

(*d*) *Incubation Period.* 6 to 30 days or more.

(*e*) *Period of Infectivity.* Practically non-communicable from person to person, but organism may be present in urine and other discharges.

(*f*) *Isolation.* Nil.

(*g*) *Quarantine.* Nil.

(*h*) *Immunization.* Nil.

(*j*) *Chemoprophylaxis.* Nil.

(*k*) *Current Disinfection.* Ordinary sanitary precautions. Extreme care is necessary by laboratory workers.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* Pasteurization of cows' and goats' milk. Boiling if pasteurization is impossible. Care in handling carcases of infected animals. Elimination of infected animals from herds.

Yellow Fever

106. (*a*) A virus disease, to which there is no natural immunity. Recovery from an attack is followed by apparently lasting immunity. The disease has a definite geographical distribution in belts across Africa and South America. Epidemiologically there are two types of yellow fever, urban and jungle.

(*b*) *Source of Infection.* The reservoir of infection of urban yellow fever is man, of jungle yellow fever animals such as monkeys, marmosets, and others.

(*c*) *Method of Spread.* Urban: by bite of infected *Aëdes aegypti*. Jungle: by bite of *Aëdes aegypti* and other forest mosquitoes of genus *Aëdes*.

(*d*) *Incubation Period.* 3 to 6 days; rarely longer.

(*e*) *Period of Infectivity.* For two days prior to onset of fever and for three, possibly four days thereafter. *Aëdes aegypti* can infect from 9 to 28 days after an infective blood feed till the end of its life.

(*f*) *Isolation.* Nurse cases under a mosquito net, in a room kept free from mosquitoes for the first four days of the illness.

(*g*) *Quarantine.* Persons on arrival from endemic yellow fever areas, who are not in possession of a valid international certificate of immunization, are liable to quarantine by the health authorities of certain countries, under international sanitary regulations.

(*h*) *Immunization.* Active immunity is conferred by a single dose of vaccine made from attenuated live virus. Protection lasts at least six years. Full protection is not developed until the tenth day after inoculation.

(*j*) *Chemoprophylaxis.* Nil.

(*k*) *Current Disinfection.* Nil.

(*l*) *Terminal Disinfection.* Nil.

(*m*) *General Control Measures.* Control of *Aëdes aegypti* and other potential mosquito vectors of yellow fever, particularly in the vicinity of aerodromes, townships, ports, stopping places along transport routes, and on board ships engaged in coastal and intercontinental traffic. The degree of control of *aëdes* breeding aimed at in urban areas should maintain the *aëdes* index at not more than 1 per cent. (*i.e. aëdes* larvae should not be found in more than 1 per cent. of dwellings at any time of examination, premises occupied by a single family to count as a dwelling). In endemic areas, mosquito control should be effective within and for half a mile around the perimeters of all aerodromes, especially those on trunk routes, not only for *aëdes* but for all other species concerned in the transmission of disease. *Aëdes* species breed in barrels, puddles, cisterns, rain gutters, water containers in houses, flower vases, holes in trees, dead leaves, banana palms, old tins, coconut shells, palm fronds, and similar small collections of water, particularly in and around dwellings. There should be a building-free zone 440 yards in depth around the perimeter of all aerodromes within endemic areas. Pending the freeing of this zone from buildings, all habitations should be sprayed with an insecticide once a week and all persons living in the zone should be immunized against yellow fever. The perimeter of an airfield is defined as the line enclosing the area containing airfield buildings and any land used or intended to be used for the parking of aircraft. Measures for disinfecting aircraft are essential.

CHAPTER 13

THE PROMOTION OF MENTAL HEALTH

INTRODUCTION

Definition of Mental Health

1. Mental health implies more than the absence of mental illness. Mental illness becomes apparent only when the individual can no longer adjust to those stresses and conflicts to which he is subjected. Before this stage is reached there may be many manifestations of increasing tension, either because adjustment is failing or because stress is increasing, or both. Mental health is a positive condition of mind which keeps the personality adequate in the face of stresses normal in a man's social environment or group, and provides him with some reserves with which to face the abnormal. The promotion of mental health entails the reinforcement of the power of adjustment and the diminution of stresses.

Extent of the Problem

2. In a recent sample of National Service candidates on examination at medical boards before call-up, 167 out of a thousand were rejected and in 44 the reason was mental defect or emotional instability. The poorest material is thus weeded out; but in 1952 the incidence of mental illness in the R.A.F. was about 6 per thousand of strength. Comparison of the incidence of fractures (5·89) and of common colds (18·96) puts this figure into perspective. Of invalidings from abroad to the United Kingdom, in the same year, 21 per cent. were due to mental illness; of final invalidings from the Service, 25 per cent. were because of this, which rates second highest of all causes.

3. These statistics refer to cases of mental defect, psychosis, or psychoneurosis, that were diagnosed and admitted to sickquarters or hospital for over 48 hours. For each one of these there must have been many more with psychososmatic symptoms and other minor manifestations of maladjustment; and there must have been those who endured without complaint tension to the limits of their tolerance. It is clear that mental illness and indifferent mental health are the cause of much wastage in manpower and efficiency; their prevention or arrest in the early stages are worth thought and effort.

MENTAL ILLNESS

4. In spite of all preventive measures, mental or psychiatric illness sooner or later will be met. Such disorders fall roughly into two classes: the psychoses, which are usually acute emergencies, and the psychoneuroses, which may be acute emergencies but which more often are the causes of chronic inefficiency. The former indicate a complete failure to make adjustment and are, therefore, a flight from reality. The latter are essentially an attempt to adjust to the tension of the environment. The one condition may shade into the other and separation is based largely on an estimate of the insight present and the social disability caused by the illness.

5. Difficulty may arise over cases of psychiatric illness in the Service. For a variety of reasons medical officers see a large number of patients presenting trivial symptoms. It is in consequence not difficult to overlook the case in which these trivialities eventually turn out to be the early symptoms of a vital illness. In addition, the patient's description of his

symptoms may not infrequently be exaggerated to his advantage, whilst it is rare to have the assistance of relatives or friends who can fill in gaps in the story or furnish objective accounts of incidents of illness. However, from the preventive point of view, formal psychiatric disorder is not so important as the overall loss of efficiency caused by the less formal disturbances. This applies in particular to the psychosomatic disorders, associated as they are with the psychoneuroses.

Psychoneuroses

6. The commonest neuroses met in the R.A.F. are of the affective type, in the form of anxiety, depression, or mixed states. Hysteria and other types of psychological disorder are less common. The central feature of affective disorders is a disturbance of feeling, affect, or mood. Abnormalities of thought and behaviour may be associated with disturbance of mood and there may be associated bodily symptoms consistent with emotional disturbance.

7. The basic cause is emotional tension due to conflict. Conflict arises out of the promptings of a fundamental instinct in the face of circumstances from which there is no practicable or honourable escape. The conflict may be conscious or repressed. The degree of tension tolerable differs considerably from individual to individual; the threshold may be lowered by ill health, injury, or fatigue. The degree and nature of stress required to produce abnormal tension also show individual variation. Cumulative effects may result, if stress is persistent or repeated, or if there is subjection to numerous unrelated stresses of minor degree.

8. The onset of symptoms may be sudden, but more often is gradual. There may be complaint of fear, or anxiety, with a feeling of tension, inability to relax, restlessness, irritability, and depression. The individual may be abnormally easily startled and be in a perpetual state of anticipating the worst; he may be unduly preoccupied with his troubles and so unable to concentrate on his work; he may present a wide variety of minor physical symptoms, such as headache, loss of appetite, indigestion, and bowel disfunction. Throbbing in the head or chest, shortness of breath, frequency of micturition and sexual impotence are other complaints. Objective signs are tremor, perspiration, tics, and tachycardia. Behaviour changes at work or in the individual's social life may also be noticed. Insomnia and bad dreams are further manifestations.

9. The fully fledged case of psychoneurosis is, however, comparatively uncommon. The medical officer will far more frequently see individuals who are misfits, who have inadequate personalities, who may be dull to the point of mental defectiveness, or who are otherwise incapable of adjustment to service life. Some may be regular absentees or petty offenders; most will be regular attenders on sick parades with a wide variety of complaints, which on account of their basic aetiology are remarkably resistant to treatment. However, these cases are not hopeless and the medical officer can do much to ensure that they maintain some degree of efficiency and make a contribution to the life of the unit.

10. Experience suggests that the prognosis in psychiatric illness becomes less favourable if the patient is admitted to hospital. This course should, therefore, be reserved for the occasions when it is essential for the safety of the patient, or for diagnosis or special methods of treatment. Similarly reference to a neuropsychiatrist should not be made too readily, but only when doubts arise about diagnosis, treatment, and disposal. Medical officers should whenever practicable look after their own

psychoneurotic patients. The aim should be to ensure that symptoms cause the minimum interference with efficiency and personal happiness; but it must be remembered that most neurotic reactions are the crutch that enables vulnerable personalities to continue through life without serious breakdown. The complete removal of symptoms carries a danger of personality disintegration.

Depression

11. Where the most noticeable feature of a neurosis is depression, caution is advisable because it is in this state that suicidal attempts are most of all to be expected. In such cases specialist advice should be sought, as special forms of physical treatment such as convulsive therapy and narcosis are often of particular value.

12. When the condition is due to an obvious cause, it is termed exogenous or reactive depression. In endogenous depression there is no detectable reason. Physical factors such as infection, intoxication, or fatigue may precipitate either type. The disorder may be mild and short-lived or continue for weeks or months, working up to a peak and then declining. The chief complaint is loss of pleasure in all things; work, social contacts, and family life. The trend of thought is despondent and events normally causing minor depression result in the depths of despair. Failure is ever present in the individual's mind; he blames himself extravagantly for minor faults or mistakes; he is anxious, slow in thought, and lacking in decision. Behaviour tends to be solitary, apathetic, and undecided. Physically there may be complaints of headache and fatigue; disorders of sleep are not so common as in the anxiety state. Mixed states of anxiety and depression are so common that a distinction between the two is often unimportant.

Hysteria

13. Hysteria is a condition in which mental and physical symptoms, not of organic origin, are produced and maintained by motives never fully conscious, directed at some real or fancied gain to be derived from such symptoms. The constitutional element in hysteria is of importance, but is affected by such factors as psychological immaturity, emotional dependence upon others, lack of persistence, and extreme self-regard. The fortuitous and timely development of physical symptoms may provide the basis for a hysterical disability. These symptoms may be of physical origin, such as pain in an old scar or haemorrhoids, or psychogenic such as headache or the dyspepsia of an anxiety state. The combination of anxiety and hysteria are frequently met as the result of the last sequence. Symptoms take a great variety of forms, being determined partly by the chance occurrence of a physical basis, partly by the knowledge of those likely to be accepted as disabling. The criteria for a diagnosis of hysteria are that there is no appropriate physical disability to account for the symptoms and that there is adequate evidence of motivation which is not fully conscious.

MENTAL HEALTH

14. The mental health of an individual depends primarily on his innate mental constitution and power of adaptation. These together with his personality largely determine his threshold to stress. The innate mental constitution is determined by heredity and shaped further by the influence of environment in childhood. In consequence there is considerable

individual variation. By the time a man enlists the innate mental constitution is fairly firmly fixed and difficult to influence, although some plasticity may persist.

Innate Mental Constitution

15. Parts of the adult mental constitution difficult to influence include intelligence, conscience, and mental functions such as cognition and memory. It may be possible to build up an individual's self-confidence, determination, and self-respect, through identification with the purpose of his social group. He may also be assisted to rid himself of mental tension normally. Inability to do this results in anxiety and the abnormal discharge of tension leads to disturbances of behaviour of varying types and degree.

Environment

16. The environmental factors that promote mental health encourage a sense of security, ability, worth, and identity in the social group of which the individual is a member. Detrimental factors have the opposite effect and increase emotional or mental tension.

17. **Security.** Any change of environment, by presenting a new situation, tends to cause some degree of mental tension. Many people are ill at ease in new surroundings until they have settled down. This circumstance affects primarily the recruit, but also any man who is repeatedly posted. On top of this tension there is frequently separation from the family, with its attendant anxieties. In the young man, who is dependant and emotionally immature, acute, almost intolerable home-sickness may result. Older men, particularly if they tend to be solitary and are poor mixers, lose the protection afforded by the personal impact of home, wife, and children; this may destroy all sense of purpose and duty. In service life separation corresponds to the loss of earning capacity in industry as the greatest threat to sense of security.

18. **Ability and Worth.** It is impossible for the individual to have a sense of ability unless he and his work match; and the results produced must satisfy his sense of skill and be of obvious purpose in the life of his social group. To be fully satisfying the work must be valued by others; endless frustration may be caused if effort is too often taken for granted. Recognition of effort, on the other hand, identifies the individual with his group and gives him status, another prop to self-esteem. There is, however, great individual variation in the influence these stimuli, or their lack, have on different people.

The Social Group

19. A well-organized group has a common purpose; its members help each other to achieve the common purpose and to protect each other from any ensuing stresses. Obedience to and acceptance of such a purpose by its members enhance the discipline of the group and relieve individual stress. Solidarity of the group is promoted by traditions, customs, and competition with others. Its success and morale depend on leadership. The individual cannot be fully obedient to or accept the group purpose unless he is made aware of it and is convinced that the group is sufficiently efficient to achieve it. He cannot identify himself with the group unless his skills and abilities are engaged in work that oth suits him and is of obvious use to the group. He cannot properly

use his skills and abilities if his personal relationship to the group engenders emotional stress. In the prevention of mental illness it follows that there are two main factors: the first is to promote the efficiency and morale of the group; the second is to ensure the maximum adaptation by the individual to the group environment.

20. **Group Morale.** The group must have an aim, and confidence in its ability to achieve the aim. Leadership must point the aim and ensure that the means and skill necessary for achievement are there. Loss of faith in the leadership will undermine the morale of the group; there will be failure to achieve the aim. This must reflect on individual members of the group by increasing stress, the reaction to which will vary according to the individual's innate mental constitution. Hence measures to promote mental health are as much applicable to the group as to the individual.

21. **Leadership.** Morale is intrinsically bound up with leadership. Inspired leadership is rare and often vulnerable to adversity. Good leadership is based on sound administration. If by foresight and correct executive action proper provision is made for feeding, shelter, clothing, relaxation, and rest, the optimum environment will be ensured and the stresses due to minor or accumulative irritation will be minimized. Needless privation and discomfort undermine morale; if they are known to be unavoidable, and that everything that can be done to alleviate them is being done, they will be accepted and may even increase morale. The second factor in good leadership is personal interest in collective and individual welfare. This includes in the wide sense pay, promotion, distribution of duties, and disciplinary matters, besides the more limited aspects of personal grievances, hardships, and family problems. In such matters, whatever the result, morale will be maintained if men realize that efforts are being made on their behalf. Additionally, in the handling of men the wise leader will make a point of praising good work, while his criticism of poor efforts will be tempered by circumstances. If a group believes in the ability of its leader and knows that he will subordinate their interests and welfare only to the achievement of its accepted aims, morale cannot fail to be high.

INDIVIDUAL FACTORS

22. It has already been mentioned that it may be possible, on the one hand, to build up the individual's threshold to stress by encouraging his self-confidence, determination, self-respect, and identification with his social group. Wise management of the individual, together with the effects of group morale, can be of considerable assistance here, and the medical officer is in the most favourable position to further these influences. On the other hand, everything possible should be done to reduce environmental stress, in order to prevent it rising above the individual's threshold.

Personnel Selection and Work

23. A job may be beyond the mental or physical capacity of an individual; or it may be too simple for him and fail to allow him scope for psychological satisfaction; it may be within his capacity but at variance with his skill and inclinations; it may be of a kind totally unsuitable for one of his personality. An individual in any of these situations will be subject to stress that will cause mental tension.

24. By ascertaining intelligence, aptitude, and personality, much can be done to help normal individuals into the right work and to place unstable personalities in jobs where they may be to some extent productive. Dissatisfaction with a job may be caused by failure to understand its value in the scheme of things, and here the remedy is obvious. However, when signs of mental tension occur in a man who is clearly a misfit, steps are required to alter or modify his work, if practicable.

25. Particular care is required over the work of those whose personalities are inherently unstable. In the right jobs and correctly handled such men can be most efficient and lead normal lives. They include those with obsessional, hysterical, or over-anxious temperaments, besides those with marked personality trends, such as the paranoids, cycloids, and schizoids. Paranoids are usually solitary, selfish, middle-aged individuals, of intelligence and ability, but with a perpetual grievance and abnormally ready to take offence. They are unsuitable for work requiring close supervision or subordination to team interests. The cycloids are good mixers, able administrators, and useful members of a team. Their judgment may be impaired by over-reaction to success or failure, which may cause lack of persistence in the face of adversity. They also react by depression to situations that deprive them of company, so are unsuitable for work that involves a degree of isolation. The schizoids are solitary, unaggressive individuals, who are not good mixers and find adjustment to change difficult. Although giving rise to little trouble, they are apathetic and of little use except in a sheltered undisturbed environment where they can be left to their own devices. In addition, there are the psychopathic personalities who are invariably useless to the Service and are better out of it.

Domestic Stress

26. Separation undermines the sense of security and so causes stress. In the United Kingdom regular leave and week-end passes help the unmarried airman to go home to his family, but abroad separation can only be offset by adequate welfare and recreative facilities. For the married man in the Service everything must be done to keep families together and this is recognized by the present policy on building and hiring quarters. Frequent moves militate against this, however, as the individual with children must choose between educational continuity, with separation, and keeping the family together at the expense of continuity. Anxiety may also be caused if the individual has no confidence in the welfare arrangements for separated families or in the adequacy of the arrangements for their well-being and safety when travelling abroad to join him.

27. A more difficult problem is domestic strife. It is obviously impossible to intervene unless approached by one or both of the parties concerned, and even then any effective action may be impracticable. If, however, the disharmony is due to ill health, ignorance, or domestic inefficiency, some alleviation may be possible in co-operation with the unit welfare organization.

Health

28. Mental ill health is known to affect physical health, for example in the etiology of certain cases of dyspepsia and skin disease. The reverse is also true; physical ill health can cause stress and can lower the individual's threshold to stress. The promotion of health by attention to nutrition and environment, as well as regulation of work to avoid

fatigue and boredom, plays an important part in preventing mental illness. In addition, active measures to promote physical fitness, endurance, and agility can play a large part; these help to occupy leisure interestingly and so mitigate boredom. They also increase the sense of physical wellbeing and alertness, without which full mental health is rare.

Role of the Medical Officer

29. The medical officer is in a unique position to influence both the environment and the individual. He can advise on all health aspects of accommodation, feeding, clothing, working environment, hours of work and recreation, including those likely to cause mental stress. Being a trained observer he should be able to identify early those who are misfits in their social group, either because of employment in the wrong kind of work, because of inadequate personality or unstable personality characteristics, or because some personal circumstance is preventing adjustment. In his relationship with his patients he will become aware of factors causing individual or collective dissatisfaction. He will be able to advise the individual on these and to make representations to the appropriate unit authority which may be unaware of the problem, so that adjustment may be made through the normal service channels, of which the individual may be unaware. The more thorough knowledge he has of service procedure, trade structure, pay and conditions of service, welfare services, and kindred subjects, the better qualified he wil l be to deal successfully with mental health problems.

30. Apart from such positive measures in preventing mental illness. the medical officer can be of great direct help to an individual subject to excessive mental tension by affording him an outlet and by giving him assurance and support. In this respect the doctor can achieve much by being no more than a good listener.

AIRCREW PROBLEMS

Background

31. The importance of the mental health problems of aircrew lies not so much in any difference compared with those of other occupations, but in the potential danger they constitute to operational efficiency. The basic etiology is the same, *i.e.* the balance between the individual threshold and the stress sustained. The type of stress, however, is different and the degree magnified. This is true of flying stress in both war and peace, the only fundamental difference being in degree.

32. It is not possible, however, to consider the problems of mental health in aircrew without some reference to the flying stress of war. The medical care of combatant aircrew calls for an understanding of the sustained courage required by wartime flying; some idea of this may be obtained by reading Gibson's "Enemy Coast Ahead", Klosterman's "Fighter Pilot", Brickhill's "Dam Busters", and Hillary's "Last Enemy", as well as the official reports "Coastal Command", "Bomber Command", and "Atlantic Bridge" published by H.M. Stationary Office. It is also essential to refer to "The Psychological Disorders of Flying Personnel" (A.P. 3139) by Sir Charles Symonds and Dr. Denis Williams.

Psychological Aspects

33. Flying, whether in peace or war, presents psychological conditions of a novel kind. It is an occupation to which danger is attached and, so long as the machine is in the air, the pilot and crew depend for their

safety upon their own efficiency. Thus in a bomber every member of the crew has the lives of the rest more or less in his hands, a responsibility which some feel more than others. They at least have the support and incentive of being members of a team, compared with the solitary figure of the fighter pilot, who must have the high qualities of resolution needed to fight alone.

34. Most aircrew are very young with little experience in leadership. To be efficient they must have individual courage, resource, and self-control. The regimented discipline of large numbers is not available to them as a reinforcement. Moreover, in combat the enemy is impersonal; machines and missiles may be seen, but seldom a human adversary. There is thus relatively little stimulus from anger and the fighting spirit it engenders. This makes a heavy demand on morale and the spirit of aggression, since the perception of danger is still clear enough and results in the automatic reaction of fear that must be controlled.

35. Aircrew tend to spend much time waiting for sorties and operations. A fighter pilot may be at readiness for many hours and make repeated sorties without meeting the enemy. A bomber crew may have long periods of expectancy awaiting an operation which is dependent on the weather or other variables; they further are subjected to hours of tension on the way to and from the target. The anxious tension of waiting for action over long periods day after day is very trying and has an accumulative effect, usually producing fatigue in the long run.

36. Air combat is rarely continuous, so between sorties and operations aircrew are often able to live in relative comfort and safety or even in their own homes. This is very different from the front line soldier or the crew of a warship. The result is a violent psychological contrast when the transition occurs from security to danger; this tends to reinforce the impressions produced by the circumstances. Self preservative tendencies are apt to be reinforced also, especially if the airman is repeatedly involved in family farewells. These factors accentuate conflict.

Fear

37. Fear is a natural and instinctive reaction to danger; it affects not only the mind but the body. The mental effects vary from difficulty in concentration to acute panic with confusion of thought, the degree depending on the strength of the stimulus and the temperament of the individual. The bodily effects include pallor, indigestion, vomiting, sweating, headache, and tremor. Once the effects of fear have been experienced in a certain situation, a repetition, or any reminder of it, tends to produce the same effects by mere suggestion.

38. The psychological problems of flying are largely concerned with fear, its effects and the means of its control. In the last war fear was the most potent cause of inefficiency and breakdown in aircrew so that strenuous effects were required to modify its effects. To experience fear does not imply lack of courage, but men require courage to control natural fear and its promptings to run away, as well as to ignore the bodily discomforts it produces. It is a duty to exert this control and the great object of morale and discipline is to enable men to do so. Conversely, if the fear stimulus is particularly strong, especially if repeated (for example, the terrifying experience of a crash or being afloat on a raft for hours in the North Sea), it may overcome the resistance set up by self-discipline, at least for a time.

Conflict

39. It is normal to experience fear on exposure to danger and to feel anticipatory anxiety before danger is met. However, symptoms analagous to those of fear may persist all the time irrespective of exposure or possible exposure to danger. Unusually this may be the prolongation of a previous emotional experience; more commonly it is due to conflict, which is a source of mental tension. The conflict arises from the promptings of instinctive fear in the face of the dictates of duty, discipline, comradeship, morale, and patriotism. The primitive urge for self-preservation may be reinforced by upbringing, family ties, and similar factors. The resultant inward battle may become manifest by physical symptoms.

Repression

40. Another psychological mechanism in the face of fear and tension is repression. It is a form of self-deception by which a disciplined man may persuade himself that he is not afraid or that he does not wish to evade the duty or situation, from which in fact he has a strong urge to escape. The individual experiences the mental or bodily effects of fear but will not acknowledge that he is afraid. The repression may be very superficial and consist merely of a denial of fear, of which inwardly the individual is well aware. This may be rationalized by claiming loss of confidence or by laying blame on other things or people. Most commonly, however, the physical symptoms of mental tension are used as an excuse to escape the situation. In a predisposed person hysteria may follow.

Fatigue

41. Fatigue is conducive to inefficiency and breakdown in aircrew. It is an important factor whenever there is an intense operational effort and in consequence is comparatively uncommon in peace. Objectively it results in a lowered capacity for performance, when unexpected mistakes are made and the individual tends to relax at the wrong, often critical, moment. Subjectively there is a feeling of tiredness and irritability. The individual unreasonably finds fault with others and blames his machine rather than himself for his shortcomings, which he is commonly unaware are his own. Exhaustion, that is total incapacity for further effort, is rare, although cumulative effects may approach this level. A fatigue syndrome was seen in aircrew during the Battle of Britain; it consisted of temporary exhaustion through the prolonged effort of self-control in pilots of good morale without neurotic predisposition. Recovery followed adequate rest.

42. In aircrew, fatigue is nervous rather than physical, and appears to be due to the prolonged exercise of sensory-motor pathways. By causing mental tension it lowers the individual's threshold to stress which promotes further tension, so that a vicious circle is set up. It is the result of long employment on skilled work with inadequate intervals for rest and sleep. It is accelerated by illness, continued anxiety, and disturbance of sleep. Exacerbation results from the emotional strain of combat and the prolonged exercise of courage, where the anticipation of danger is as fatiguing as actual exposure to it. Both the intensity and the duration of these experiences are of importance; their effects are aggravated by noise, vibration, cramped positions in the aircraft, the effort of movement in full flying kit, especially at altitude, and the lack of hot meals. Special types of duty may make particular demands, for example general reconnaissance over the sea, when prolonged scanning induces not only visual fatigue but a weariness of the whole mind.

43. Aircrew fatigue, being cumulative, tends to appear suddenly. The effect is also liable to persist, so that after inadequate rest, fatigue will reappear sooner than it did before. It is clear that on account of its pernicious effects on efficiency and morale, strenuous efforts are essential to reduce fatigue.

Other Stresses

44. There may be other stresses, unrelated to flying, which by increasing tension reduce the resistance of the individual. These include financial worry, separation, poor personal relationships with comrades, worry over responsibility, boredom and ill health. Ill health includes physical injury.

45. Other factors are repeated strenuous efforts without the satisfaction of visible results. This is especially so if there are heavy casualties, which in any case are depressing, and dull the resistance of the stoutest, particularly if survivors are without hope of relief from duty. Even the best troops in the world must have some hope of ultimate success and survival.

Production of Neurosis

46. Exaggerated fear and abnormal tension due to emotional conflict may act together or separately in producing neurosis in aircrew. In individuals with poor personality or with their resistance lowered by such factors as fatigue or infection, an experience to which controlled fear is a normal reaction will produce fear that is exaggerated or persistent. If the fear stimulus is intense or repeated, reactions may be caused even in the well-adjusted, without the operation of other factors; an example of such reactions is the panic state. When there is also conflict, the extra tension engendered will exaggerate the fear mechanism. In over-anxious persons neurosis occurs, often of the depressive kind engendered by fear allied with the tension caused by the constant attempts to subdue fear. In all cases there will be an awareness of symptoms and mental feelings, but their cause may or may not be appreciated by the individual.

47. The symptoms in aircrew are much the same as in neuroses unrelated to flying as already described. It is always, however, most important to exclude physical causes for psychological symptoms, such as tuberculosis, thyrotoxicosis, chronic malaria, and dysentery.

Prevention

48. The measures already described to reduce stress and mental tension in general apply equally to aircrew. It is particularly important to promote the group spirit of crews through leadership and training. Their mode of life should be reasonably regular and attention must be paid to their physical fitness. Reinforcing measures are the development of a communal squadron life, entertainment, recreation, and regular short leave at frequent intervals. The confidence of aircrew must be fostered in their leaders, their machines, and in the ground staff.

49. These measures all aim at fortifying aircrew against stress. Further steps are required to reduce stress so far as possible. Anticipatory fear may be lessened by briefing on targets and flight details after a hot meal shortly before the sortie. Time of waiting on the ground and in aircraft before take-off should be cut down to the minimum practicable, and cancellations of operations should be avoided when possible. Navigational and technical aids have been developed to a high standard to

reduce the risk of all-weather flying, especially at night; otherwise once airborne the only shield against danger is the inherent quality and skill of the crew. Thus control of the fear situation cannot be influenced once the operation has started.

50. The effects of the fear situation can, however, be modified by controlling its duration and frequency of repetition. In the Second World War it was found necessary to limit operational tours to a certain number of sorties, depending on the type of duty concerned. Normally aircrew were expected to carry out two tours, with a spell of non-operational flying in between. A tour might be terminated if it was considered that, on account of special reasons of stress, an individual had made a reasonable and efficient contribution before completing the prescribed number of sorties. This helped to safeguard the less robust and preserve efficiency for the second tour. Third tours were exceptional and discouraged so as to limit any undesirable competitive element. During a tour sorties for any one crew were spaced, and after a series, especially if particularly arduous, the crew was rested. The benefits of this system were that men knew what was expected of them, they were given a reasonable hope of survival, and there was a reasonable equity of sacrifice.

TREATMENT AND DISPOSAL

The Acute Reaction

51. The acutely disturbed case is an immediate cause for anxiety since the mental complications of physical illness most commonly occur in this form. Having excluded physical causes, including infective and toxic factors, treatment should be directed at sedation to prevent the fatigue of over-activity and at remedying defects of nutrition. A good sleep, food, and a hot bath will render most acute anxiety reactions approachable within twelve hours. If thereafter there is no response to simple reassurance and discussion, or if there is prolongation of the state, psychiatric advice should be taken. The drugs used in sedation of the acute reaction should act quickly and have no cumulative toxic effects. Paraldehyde (2 to 3 grains) or short-acting barbiturates such as sodium amytal (6 to 9 grains) are recommended.

The Sub-acute Reaction

52. Early recognition is important, as the longer psychogenic symptoms persist unrecognized the more fixed they become and the harder they are to relieve. As a rough rule, symptoms without adequate physical explanation and resistant to recognized treatment should be suspected of having a psychogenic origin. Such a diagnosis cannot be confirmed, however, unless positive psychogenic factors are disclosed. Confirmation should not be awaited before instituting treatment on the strength of the provisional diagnosis. First, good sleep and nutrition must be ensured; if there is marked tension, mild regular sedation is essential. The patient's symptoms, in particular the timing and circumstances of their onset, should then be discussed with him; this may elucidate the factors to which the symptoms are a reaction. Relief is often obtained from the mere ventilation of difficulties followed by reassurance. Unless the patient is over-active, the longer-acting barbiturate drugs such as phenobarbitone are contraindicated as they are depressant. Sodium amytal (1½ to 3 grains) or nembutal (1½ to 3 grains) are recommended.

Disposal

53. When the disposal of a neurotic comes to be considered, the following questions arise:—

(*a*) Whether treatment can render him reasonably efficient.

(*b*) Whether he will be able to maintain efficiency in his existing service environment or a service environment suitably modified.

(*c*) Bearing in mind his skill and experience and the difficulty of maintaining a constant service environment, whether it is in the interests of the Service to retain an unstable individual who may be a poor risk.

54. If after response to treatment an individual predisposed to neurosis can lead a reasonably happy life and be reasonably efficient, while protected from undue stress, his retention is worth considering. This is particularly so if he possesses skills or experience of special value. But it is not often that there can be any guarantee in service life of indefinite protection from stress; the individual's potential value to the Service is thus prejudiced by the strong possibility of relapse. When the individual is unskilled and of little experience, or when service environment is intrinsically inimical to him, his retention is usually pointless.

55. If a member of aircrew is found to have lost confidence for flying, or, through inefficiency, forfeits the confidence of his commanding officer, procedure is taken in accordance with the relevant Air Ministry Confidential Letter. Loss of confidence for flying may be frankly expressed, even to the extent of requesting relief from flying duties for personal reasons. It may alternatively come to light from medical complaints. The squadron commander may observe deterioration in performance, including loss of zest and determination. The procedure to be taken aims at eliminating medical causes and at providing the executive with information for the assessment of how far failure to perform flying duties satisfactorily is within the control of the individual.

CHAPTER 14

OCCUPATIONAL HEALTH OF GROUND PERSONNEL

INTRODUCTION

1. There is a close relationship between occupation and health; and there is wide scope for the practice of occupational hygiene in a community with an extensive range of occupations, such as the Royal Air Force. Not only industrial work but all occupations, in which service and civilian personnel are engaged, come within its orbit. The principles stated in this chapter are general and in the main based on civilian industrial practice, but they are freely adaptable to circumstances in the R.A.F. The more specialized occupational problems of aircrew are considered in Chapter 15.

Occupational Hygiene

2. Occupational hygiene aims at promoting full physical and psychological efficiency, safety and well-being in relation to work. It is not only concerned with the prevention of industrial disease or injury, important as these are. Much occupational sickness is related to general environmental factors; dangerous work or trades are responsible for relatively few serious disabilities in comparison. Besides the precautions required to avoid injury and toxic hazards, occupational hygiene is, therefore, very much concerned in the working environment and the physiological, anatomical, and psychological implications of work.

The Role of the Medical Officer

3. The medical officer plays a leading part in the application of occupational hygiene as one of a team, which includes also scientific, engineering, and executive members. He is responsible for advising on all occupational health matters, for the medical supervision of personnel at work and of their working environment, for the organization of first aid, and for the study of specific occupational hazards. The advisory aspect of his work is most important; consequently he must be familiar with the organization, working methods, and processes peculiar to his unit. It is essential for him to spend time in those places where the work is done, for practical advice can only be based on practical knowledge of men, machines, and material. The following paragraphs are designed to outline the kind of problems involved.

THE WORKING ENVIRONMENT

Factory Hygiene

4. Factory hygiene is concerned with standards of cleanliness, ventilation, heating and lighting, the provision of sanitary conveniences, washing facilities, drying rooms, and canteens. The minimal requirements are contained in the Factories Acts of 1937 and 1948, together with their Statutory Regulations and Orders. It is stressed that these standards are the minimum statutory requirements rather than the scientific best. To civilian-manned R.A.F. units they apply in law; but to those where mainly service personnel are employed they apply in spirit only. Some of these requirements are outlined in the following paragraphs.

Cleanliness

5. Every factory must be kept clean. Accumulations of dirt and refuse must be removed daily from floors and benches. Floors must be cleaned at least weekly and interior walls washed, painted, or limewashed periodically. Windows must be kept clean, and floors adequately drained if wet processes are carried on. Cleanliness prevents pollution of the air by dust, improves the general amenity of the environment and, by ensuring orderliness, militates against the accidents that occur where there is untidiness, lack of method, and general confusion.

Ventilation

6. Adequate ventilation must be maintained by the circulation of fresh air. If dust or fume is likely to cause discomfort or injury, localized exhaust ventilation will be required, in addition to good general ventilation. Workrooms must not be overcrowded and there should be 400 cubic feet of space for each person, not counting space occupied by plant or more than 14 feet above the floor.

Heating

7. A reasonable temperature must be maintained in each workroom. Where a substantial portion of the work is sedentary, the temperature must not be less than 60°F. after the first hour. At least one thermometer should be provided in each workroom so that the temperature may be recorded and regulated. No method of heating may be used that is likely to give rise to injurious or offensive fumes.

Lighting

8. There must be sufficient and suitable lighting in every part of the factory where persons work or pass. The Factories Act standards are contained in S.R. & O. 1941 No. 94, the Statutory (Standard of Lighting) Regulations.

9. The general illumination in workshops must be not less than 6 foot-candles as measured at a level of 3 feet from the ground. Any source of artificial light less than 16 feet from the floor may not have a brightness greater than 10 foot-candles per square inch, nor be directly visible to persons normally employed within 100 feet of it. Any local source of light must be effectively shaded to prevent glare. In corridors and passageways the lighting at floor level may not be less than 0·5 foot-candles. (See Chapter 8, para. 141 *et seq.*)

Sanitary Conveniences

10. Sanitary conveniences must be provided to the required scale for each sex. The details are contained in the Sanitary Accommodation Regulations, 1938, No. 611. The regulation scale is:—

(*a*) *Females*. 4 per cent.

(*b*) *Males* (if there are 100 employees or less). 4 per cent.

(*c*) *Males* (if there are over 100 employees and there is sufficient urinal accommodation). 2·5 per cent.

Meals

11. Persons employed where any poisonous substance is used and gives rise to fume or dust must not eat or remain during mealtimes in the workroom. Suitable alternative accommodation must be provided.

Washing Facilities

12. Adequate and convenient washing facilities must be provided, together with soap and towels. The scale is 20 per cent. wash basins with hot and cold water available. A trough, with hot and cold taps in pairs every two feet, each pair equivalent to one basin, is a permissible alternative.

Drinking Water

13. An adequate supply of wholesome water must be provided, and clearly marked "Drinking Water". The upward jet-type of drinking water fountain can be used. If cups are provided, facilities are also required for rinsing them in drinking water.

Accommodation for Clothing

14. Adequate and suitable accommodation and drying facilities must be provided for clothing not worn during working hours.

Seats

15. Seats with backrests must be provided for all women whose work is done standing, so that they can take advantage of opportunities to rest. In addition, seats must also be provided for persons, irrespective of sex, who without detriment to their work can take advantage of opportunities for sitting (Factories Act 1948, Sections 6 to 16).

First Aid

16. First-aid equipment and facilities must be provided and are prescribed by regulation.

17. One box of first-aid equipment must be provided in every workshop for each 150 persons or part thereof. It must be under the care of a first-aid attendant, who must be trained if more than 50 people are employed. The box must be clearly marked "FIRST AID" and the name of the attendant plainly displayed in the vicinity.

18. The minimal statutory contents required depend on the number of people in the workshop. First-aid outfits for workshops complying with these requirements are an R.A.F. medical supply (stores reference 9A/02530). It is advisable, where there are special risks, to have additional equipment readily available, *e.g.* resuscitation apparatus.

THE WORK

Hours of Work

19. Experience and research, especially during the First and Second World Wars, show that the weekly number of hours worked can reach a limit beyond which any increase results in a lowering of output. This fall in output is accompanied by a decrease in individual efficiency and by an increase in absenteeism. The fall in output, caused by too long hours, was demonstrated after the evacuation from Dunkirk in May, 1940. An immense effort was then made by industrial workers throughout the United Kingdom and the average weekly working hours in some factories rose to as much as 73½. An immediate increase in output was obtained but, by the end of August, production had fallen below the pre-Dunkirk level and remained there, despite the longer hours, till the spring of 1941. It was subsequently found that the Ministry of Supply output during the

three months of May, June and July, 1941, when more reasonable hours were worked, was one-third greater than that of the three months' almost superhuman effort that immediately followed Dunkirk.

20. It is now established that working hours for men should not exceed 60 and for women 55 per week, while it is probable that even shorter hours would be equally or more productive. A spurt in production will follow an increase in working hours, provided there is sufficient incentive; but prolongation of excessive overtime, for more than three or four weeks, will cause a decline in output to a level often much below that existing previously. And, if the shorter hours are then restored, weeks or even months may pass before output reaches its original level. In the same way an immediate increase in production does not follow a reduction in normal working hours. A preliminary fall, which may last for several weeks, is to be expected before any beneficial effects are observed. At a fuse factory employing women workers during the First World War, a 74½-hour week was changed first to a 63½-hour week, and finally to a 55½-hour week with no Sunday work. During the first month of no work on Sunday there was no rise in output, but in the succeeding four weeks, output steadily increased to an average level of 13 per cent. more than was obtained with the 74½-hour week; and it remained at that level for an observed period of five months.

Organization of Hours of Work

21. It has been suggested that the maximum hours of work should be 10 per day; 60 per week for men and 55 for women. Owing to the different circumstances of the Service, these figures can be no more than a rough guide. Whatever the length of weekly working period, it must be as productive as possible; in achieving this the organization of working hours can play an important part.

22. **Shifts.** When work is organized in shifts, there is some dislocation of the daily routine of normal life. It may suit individuals always to be on early shift or late shift, but in general periodical interchange is desirable. This occurs automatically on a three-shift system (three 8-hour shifts each 24 hours). The arrangements for shift workers in the R.A.F. are published in Air Ministry Orders from time to time.

23. **Night Work.** Exceptional individuals thrive on whole-time night work. To others it is intolerable. Normally, however, spells of one to two weeks should be the limit. One difficulty is that, although 8 hours of unbroken sleep in 24 is essential, it is often impossible for the night worker to obtain them, owing to daytime disturbances in and about the home. In the R.A.F. it is a principle that shift workers should be quartered together. Night work also entails a complete reversal of feeding and other physiological habits, to which some people find it impossible to adapt. Six night shifts per week are the maximum that should be worked.

24. **Repetitive Work.** The repetition of the same task over and over again, for example at a conveyor belt, becomes excessively boring to most people. Individual susceptibility varies but the more intelligent the worker the more he is affected. Proper selection of workers for such jobs, alternation of work, rest pauses, music and incentives may mitigate the monotony.

25. **Rest Pauses.** Shifts may be broken by rest pauses of 10 to 15 minutes, when light refreshments can be provided. Few people can maintain their peak rate of work for more than about two hours at a stretch, so rest pauses morning and afternoon may be required. For very heavy work shorter rest pauses at closer intervals may be necessary. It has been found that production is increased in the periods both immediately before and after rest pauses.

26. **Holidays.** During the week there should be at least one whole day off work. Preferably Saturday afternoon and the whole of Sunday should be free. A complete holiday of at least two weeks once each year is an essential.

Fatigue

27. Fatigue is difficult to measure, but has been defined as the sum of the results of activity which leads to a diminished capacity for work. Evidence of group fatigue is provided by diminished output, increased mistakes and accidents, lateness, absenteeism, and an increased rate of sickness and labour turnover. Individually psychosomatic symptoms, decreased intellectual function, greater emotional instability, loss of judgment, and irritability may be found.

28. Fatigue should be distinguished from boredom. People can be unconsciously fatigued, but never unconsciously bored; boredom may, however, exacerbate fatigue. Factors causing fatigue include long hours, a poor working environment, faulty machine design, faulty posture, and personal circumstances such as ill health, lack of motive, and domestic anxieties.

29. **Boredom.** Boredom is the result of too little mental stimulation, due to lack of variety or to work making insufficient demands on ability. Its manifestations are very similar to those of fatigue. Measures to mitigate boredom have been mentioned under repetitive work.

Posture

30. Work which entails the adoption of an unnatural posture is unnecessarily fatiguing and may, especially in young workers, lead to physical deformities. Stooping, over-reaching, a cramped position and the need to make awkward movements should be avoided. For this reason design of machinery and workshop fittings is important. The bench or working height should enable the worker to stand or sit upright. The best height for most men is 41 inches from floor level, for women 38 inches. Whenever possible work should be done sitting down ; seats must be comfortable, of the right height, with back and foot rests, and a comfortable angle of tilt.

The Hazards of Work

31. Occupational ill health may be caused by subjection to an indifferent working environment or by exposure to a toxic substance or process. There is also the risk of accidental injury, the chance of which varies considerably from trade to trade.

32. Toxic substances may be solids, liquids, vapours, fumes, smokes, or dusts. They may be absorbed by inhalation, ingestion, or through the skin and mucous membranes. Contact with the substance may cause damage to the skin or eyes. In addition there are radiation hazards and

acoustic trauma due to high intensity noise. In industry inhalation is the most important means of entry into the body by harmful materials. Toxic and radiation hazards are discussed in subsequent chapters.

Accidents

33. Industrial accidents are responsible for much disability and loss of output each year. In 1951, for example, there were 828 fatal and 182,616 non-fatal accidents in civilian industry. There are many factors which influence the occurrence of accidents such as plant safety, hours of work, heating, lighting and ventilation, age, experience, ill health, and attitude of mind. The speed of work called for is another important factor, especially when it is a little beyond the capacity of the worker.

34. There is an extensive set of safety requirements laid down in the Factories Acts. There are also many ingenious safety devices designed to make machinery accident-proof. It has been claimed, however, that even if all machinery, plant and apparatus could be made accident-proof, it would result in only a 10 per cent. reduction in accidents. This is due to the overriding influence of human error.

35. Among industrial workers there are some who are liable to accident owing to the degree of risk to which they are exposed. There are others, however, who without being unduly at risk, sustain more than their share of all accidents; these are the accident prone. Accident proneness is now regarded as an inherent characteristic which makes certain individuals abnormally susceptible to accidents. Real accident proneness is fairly stable although it can sometimes with difficulty be modified or eradicated by training. There is also a temporary form due to such factors as ill health or emotional disturbance. It is important to detect the accident prone by keeping records of accidents sustained, especially minor ones. Those detected should be drafted to work in which the likelihood of accidents is small and the consequences potentially mild.

Accident Prevention

36. For certain trades or processes specific precautions are necessary. These are laid down for the R.A.F. in appropriate technical Air Publications and from time to time in Air Ministry Orders. Specific precautions are, however, of little value unless there is a general background of safety, which can be ensured only by attention to basic detail.

37. **Personal Qualities.** Besides accident proneness, ill health, and emotional disturbance, age and experience may predispose to accidents. Until a job has been thoroughly learned it is easy to make mistakes which may have unfortunate consequences. It is therefore important that learners be carefully supervised until they are competent. The rashness of youth may also aggravate the susceptibility of the learner. As age and experience increase, liability to accidents decreases, but a stage is eventually reached where age neutralizes experience. For example, the older worker is more susceptible to fatigue and, perhaps, has to overreach himself to keep up the pace.

38. **Environment.** Temperature has an important influence on the accident rate. The discomfort of cold can dull concentration and chilling reduces manual dexterity. At high temperatures fatigue is accelerated, concentration affected, and the hands may be made slippery by sweat. With heat is associated ventilation, the lack or inefficiency of which exacerbates conditions by producing discomfort.

39. Lighting is also an important factor. Inadequate illumination makes work more difficult and therefore more dangerous. Glare, either direct or reflected from a bright surface, causes discomfort or temporary impairment of vision. Shadows, especially if deep, are also dangerous, as vision is impaired on passing from light to darker surroundings or the reverse.

40. **Good Housekeeping.** In a factory this term denotes tidiness, cleanliness, and efficient organization in the premises as a whole. In its absence accidents occur; for example, by colliding with something left in a dark passage, by sustaining lacerations from protruding nails, tripping over debris, or slipping on a patch of oil on a dirty floor. Prevention entails methodical organization, so that no passageways are obstructed, everything has its own place and is kept there, debris is not tolerated, and cleanliness is enforced. Cramped and crowded conditions make good housekeeping impossible.

41. **Clothing.** Besides the use of various special types of protective clothing under certain circumstances, attention is required to everyday working clothes. This is discussed in Chapter 8, para. 19 *et seq.*

42. **Education and Propaganda.** Workers should be informed of risks inherent in their process or trade. They should be instructed how to do their work safely; for example, in the correct method of weight lifting, by adopting a narrow stance and using the powerful muscles of the thighs instead of straddling and lifting with arms and back alone. Propaganda of every form should be employed to promote accident consciousness.

43. **Safety of Machinery and Plant.** In spite of the limitations of safety devices in reducing the accident rate appreciably, their neglect would certainly cause an undesirable increase in numbers and severity. It is essential that the statutory safety provisions of the Factories Acts be applied and wherever possible bettered. It is worth remembering two of Sir Thomas Legge's axioms in this connection. They are equally applicable to accident prevention and protection from toxic hazard.

(*a*) "Unless and until the employer has done everything—and everything means a good deal—the workman can do next to nothing to protect himself, although he is naturally willing enough to do his share."

(*b*) " If you can bring an influence to bear external to the workman (*i.e.* one over which he can exercise no control) you will be successful; and if you cannot or do not, you will never be wholly successful."

THE WORKER

Medical Supervision

44. The object of the medical supervision of workers is first to ensure that men are placed in work within their physical and psychological capacity, and to protect them thereafter from occupational hazards of all kinds. The placement of workers includes the pre-employment medical examination, as part of the general system of selection.

45. **Selection of Workers.** The aim of selection is to give people jobs which suit their physique, intelligence, and temperament. It is, therefore, only partially a medical responsibility. The greater part consists of testing, in a variety of ways, intelligence, aptitude, temperament and skills in order to advise a person for what range of vocations he is suitable, or to choose from a group of candidates only those who are likely to be successful in a specific job. In either case the results have to be correlated with physique, which is assessed at the pre-employment medical examination.

46. **Pre-employment Medical Examination.** Although the pre-employment examination is clinical, its applications are functional. The presence of physical or psychological abnormalities is important mainly in deciding whether the candidate can carry out the employment proposed, without harm to himself or danger to others. It is therefore essential to know what demands the work will make, with special reference to toxic hazards and risk of accidents. It is emphasized that the object is not the rejection of all but the fittest men, but the protection of the individual and his fellows. In this the role of the medical officer is to advise; acceptance or rejection is an executive responsibility.

47. **Periodic Medical Examinations.** Periodic examinations may aim at ensuring that there is no deterioriation in general health, for example the annual examination of all officers and aircrew. More often, however, the object is to detect the earliest signs of ill health due to some hazardous type of employment. In a number of dangerous processes workers must, by law, be examined periodically. Examples of trades and processes in the R.A.F. where such examinations are necessary are given in Table 33. Workers returning after absence due to injury or sickness must be examined, as well as those employed under the Disabled Persons Acts 1944, and certain young persons.

TABLE 33

PROCESSES IN WHICH PERIODIC MEDICAL EXAMINATIONS ARE REQUIRED

Processes Involving Exposure	Examination Required
Lead	Every 1 to 3 months depending on nature of process.
Nitro and amido phenol derivatives	Within 14 days of employment, thereafter once per month.
Benzene and its homologues	Within 14 days of employment, thereafter once per month.
Chrome (electroplating) Chromates and bichromates	At intervals not exceeding 14 days, also twice-weekly inspection of fingers by first-aid attendant.
Radioactive substances	Within 7 days of starting work and thereafter monthly.
Radioactive sources and emanations	On starting work and thereafter every six months.

48. Examples of processes related to toxic hazards are given in Table 34. Further information on toxic hazards and any special type of medical examination required is given in Chapter 16.

TABLE 34

EXAMPLES OF PROCESSES RELATED TO TOXIC HAZARDS

Hazards arising from	Process
Lead	Welding Tinning Accumulator repair and salvage Use of lead paint Handling of leaded petrol
Chromates Chrome	Anticorrosive processes Electroplating
Nitro derivatives	Handling explosives
Benzene	Doping Cocooning
Radioactive substances Radioactive emanations	Luminizing Radiography (medical and industrial) Storage of radioactive sources

Psychological Aspects

49. Reference has already been made to the psychological aspects of fatigue, boredom, and accidents. The psychology of work and of the worker has however a much wider significance. Studies of the incidence of neurosis in industry have shown that 30 per cent. of the factory workers in a sample interviewed suffered from disabling nervous symptoms; another study found that neuroses were responsible for 21 per cent. of absenteeism among women. Psychological problems are clearly of considerable importance in industry.

50. Occupational stress, short of that required to cause neurosis in stable individuals, also occurs. It arises from discontent, frustration or boredom due to the organization of work, to its nature, or to working conditions. In a group of workers this is shown by lowered output, increased absenteeism, a high labour turnover, industrial disputes, and strikes. In the individual there is irritation, inefficiency, and disinterest. Thus where psychological stress is allowed to continue, productivity suffers and wastage of manpower is serious.

51. Mental health is discussed in Chapter 13. Here the importance of its promotion is stressed, in particular relation to occupational health and efficiency. Much can be achieved by attention to proper selection, environment, organization of the work, and welfare. The rest is achieved by enlightened personnel management.

NOTIFICATION OF INDUSTRIAL ACCIDENTS AND DISEASES

52. **Accidents.** Notifiable accidents are those causing death or disabling workers for more than three days. When a civilian sustains an industrial accident, it is the responsibility of the employer (commanding officer) to notify the local factory inspector and the appointed factory doctor.

53. **Diseases.** Notifiable industrial diseases are:—

(*a*) Poisoning by lead, mercury, arsenic, aniline, phosphorus, carbon bisulphide, or manganese.

(*b*) Chronic benzene poisoning.

(*c*) Compressed air illness.

(*d*) Toxic jaundice.

(*e*) Toxic anaemia.

(*f*) Anthrax.

(*g*) Epitheliomatous ulceration.

(*h*) Chrome ulceration.

54. The notification of these diseases is to be forwarded by the medical officer making the diagnosis, whether the patient is service or civilian, to H.M. Chief Inspector of Factories through service medical channels.

INDUSTRIAL DERMATITIS

55. Industrial dermatitis is largely preventable, and unless prevented can cause considerable individual and collective economic loss. Although the incidence may not be high, the condition is often intractable, which means long periods off work. It may entail a change in occupation if re-exposure to the causative substance is contraindicated. Loss of earnings, loss of man-hours, and wastage of technical skill, not to mention acute discomfort for the victim, mean that prevention of industrial dermatitis is well worthwhile.

Factors Governing Development

56. The basic factor is exposure at work to a substance capable of causing skin lesions. The development and extent of dermatitis that may ensue depend on general factors such as liability to trauma, temperature and humidity, dirty working conditions, absence of adequate washing facilities, and neglect of such preventive measures as protective clothing, skin inspections, first aid, and selection. These general factors are aggravating rather than causative.

57. Many individuals subjected to such basic and general factors still do not develop dermatitis. There are secondary factors governing this, such as susceptibility, habits, health, and nutrition. Individual sensitivity to skin reagents varies considerably and depends partly on the characteristics of the skin. A resistant skin is thick, not too dry, and is free from obvious defects. A history of skin disease, such as previous dermatitis, eczema, icthyosis, seborrhoea, excessive sweating or itching, indicate susceptibility to occupational dermatitis.

Types of Industrial Dermatitis

58. Industrial dermatitis may be destructive, reactive, or neoplastic. Examples of substances liable to cause industrial dermatitis are listed in Table 35. Destructive lesions are caused by acids, alkalis, and certain other chemicals that cause necrosis if they enter the deeper layers of the skin. Characteristic lesions are blisters or superficial destruction of the skin, ulceration and "trade holes", on all of which secondary infection may become superimposed. Trade holes are deep, punched out, flask-shaped ulcers.

TABLE 35

EXAMPLES OF SUBSTANCES CAUSING OCCUPATIONAL DERMATITIS

	DESTRUCTIVE		
ACIDS	Hydrobromic Hydrochloric Hydrofluoric Lactic	Nitric Sulphuric Oxalic	Carbolic Cresolic Phenolic Salicylic
ALKALIS	Ammonia (concentrated) Caustic potash (concentrated) Caustic soda (concentrated)		
OTHER CHEMICALS	Arsenic Chrome Nickel	Fulminate of mercury Nitrate of mercury Zinc chloride	Potassium cyanide Sodium cyanide Slaked lime
	REACTIVE		
ALKALIS	When dilute; especially when in soaps, or washing and scouring powders		
COAL TAR and ITS DERIVATIVES	Tar and pitch (short exposure) Nitro- and amido-compounds		Chlorinated naphthalenes
OILS	Lubricating oils	Cutting oils and emulsions	
INORGANIC CHEMICALS	Ammonium nitrate Bleach Chlorine	Iodine Iodoform salts Hydrogen peroxide	Sulphates Sulphides Hyposulphites
ORGANIC CHEMICALS	Formaldehyde Synthetic resins All organic solvents		
	CARCINOGENIC		
INORGANIC	Arsenic	Nickel	
ORGANIC	Tar Pitch	Soot Shale oil	
PHYSICAL	Radiation		

59. Reactive dermatitis may be local, when it is papular, follicular, or keratotic in form. If it is generalized, it is either an allergic reaction or an extension of the local lesion due to prolonged exposure to the irritant concerned. Papular reactions typically follow exposure to mists, fume,

and vapours; follicular reactions are caused by liquids, dusts, oils, and sepsis; keratitis is the result of chronic, mild exposure to slow acting agents of low toxicity.

60. Skin carcinoma may follow chronic irritation for many years by certain inorganic chemicals, organic compounds, or physical agents. Examples are arsenic, tar, pitch, soot, shale oil, X-rays, and other radioactive emanations. After chronic irritation, which may be of the order of 20 to 40 years, the skin becomes pigmented and keratotic; horny warts or papillomata develop followed by epitheliomata. The carcinoma is relatively benign and rarely metastasises but may be multiple. The site is usually characteristic to the occupation.

Diagnosis of Industrial Dermatitis

61. Since the signs and symptoms are similar whether the origin of the dermatitis is occupational or otherwise, diagnosis from the eruption alone is usually impossible. Early diagnosis is, however, important as it will reduce the time required to effect cure and will prevent the development of multiple sensitivity due to prolonged exposure.

62. **History.** A full dermatological history is required, with special reference to any previous occupational skin trouble. An occupational history is also essential and should include an exact description of the process involved, materials handled, and the working environment. The degree and length of exposure to any suspected substance must be recorded and inquiry made whether others thus exposed have been similarly affected. Information should also be obtained on materials used for washing the face and hands, as well as whether there is possible exposure to an irritative substance at home or in pursuing a hobby.

63. **Eruption.** The characteristics of the eruption will depend on the stage of development and may not provide much information. However its mode of development, the relationship of time of contact with onset and its distribution related to areas exposed to irritation are important diagnostic factors. Although sensitization may cause the eruption to spread to areas remote from that originally affected, the initial site in industrial dermatitis is always that most exposed to irritation.

64. **Site of Initial Eruption.** The site is governed by the physical and chemical properties of the irritant as well as by the nature of the process concerned. If there is direct contact, the backs of the hands, fingers and flexor aspects of the forearms are likely to be first affected. Fume, vapours and sprays will involve the face early. The irritation from dust is first usually observed around the neck, axillae, perineum, genitals, feet, ankles, or waist.

65. **Confirmation.** Rapid improvement following removal from work is strongly suggestive that the eruption is of occupational origin. Corroboration may also sometimes be possible by the use of patch tests.

Prevention

66. **Selection.** Susceptibility to industrial dermatitis is likely in persons giving a history of skin complaints or found to be suffering from a skin disease. Such findings should not entail automatic rejection for work where there is exposure to skin irritants, but the risks of exposure will require careful assessment before a decision is taken.

67. **Minimizing Exposure.** Exposure to fume, vapours, splashes and dust should be minimized by enclosing processes or by the provision of local exhaust ventilation. Contact may be reduced by mechanization or the use of tools in the place of manipulation by hand. In addition, efficient general ventilation to control temperature and humidity in the working environment is essential to minimize the effects of exposure.

68. **Personal Protection.** Where general measures to minimize exposure are insufficient, protective clothing is necessary. Such clothing must be impermeable to the irritant concerned and designed so that it does not chafe at the neck, wrists, waist, and ankles. It must be washed frequently and kept in good repair. Gloves should be reserved for processes where the skin hazard is acute; they may in fact increase the risk of dermatitis by causing maceration of the skin through sweating, or by becoming impregnated with the irritant.

69. **Barrier Creams.** The use of barrier creams of the correct composition protect the skin and aid cleansing. They should be applied at the beginning of a shift and subsequently each time after washing the hands, if work is to be resumed.

70. **Washing Facilities.** Adequate washing facilities with hot water, soap and towels are essential. Sufficient time must also be allowed at meal breaks and before ceasing work for the thorough washing of exposed skin. The use as skin cleansers of abrasives and solvents such as petrol, paraffin, turpentine and spirits must be strongly discouraged.

71. **Medical Supervision.** Periodic inspection of the skins of those known to be exposed to irritants is advisable. The inspection may be carried out by a medical officer or a first-aid attendant. This will ensure early diagnosis and treatment as well as being a check on the effectiveness of preventive measures. Those who suspect that their skins are being affected should be encouraged to report sick. First-aid arrangements must be especially organized to minimize skin sepsis.

INDUSTRIAL EYE INJURIES

General

72. The majority of industrial eye injuries are preventable, yet in spite of the potentially tragic consequences to the individual the risks are often ignored and preventive measures neglected. Medical officers should be on the alert for eye hazards, the commoner of which are reviewed below, together with methods of prevention and immediate treatment.

Classification of Eye Hazards

73. Eye hazards may be classified as:—

(*a*) Those arising from direct or indirect violence to the eye.

(*b*) Those caused by injurious chemicals.

(*c*) Those due to radiation.

74. **Direct Violence.** The eye may be struck by a large blunt object which may cause injuries varying from a corneal abrasion to rupture of the globe. A contusion may affect any part of the eye, for example the lens or the retina, which might not be easily visible after such injuries; changes may be progressive, so that a guarded prognosis is necessary. Such injuries may also be complicated by fracture of the orbit which may

be followed by diplopia or optic atrophy. More commonly, however, the eye is struck by a flying particle, resulting in a corneal abrasion or a foreign body in the eye. A foreign body may lodge on the surface of or be embedded in the cornea, or may penetrate the globe and injure the lens or other structures in its path. Conjunctival and corneal burns may be sustained from splashing by molten metal. Indirect violence may cause damage to the eye by "contre coup".

75. **Chemical Injuries.** These occur if a chemically active particle lodges in the eye, from chemical splashes and through exposure to fume and vapours. Acids and some neutral chemicals cause severe burns of the cornea and conjunctiva, but their effect is mainly confined to the surface. Alkalis on the other hand are more dangerous as the burns rapidly increase in depth and extent, resulting in a chronic deep-seated keratitis.

76. **Radiation.** Prolonged exposure over many years to infra-red rays may cause cataract. This is also caused by X- and gamma rays. Infra-red rays of less than 13,000 A.U. can cause damage to the retina. A combination of infra-red rays and ultra-violet rays between 3,600 and 2,950 A.U. may cause "arc eye", an acute kerato-conjunctivitis sustained by arc welders, in whom chronic exposure leads to chronic blepharo-conjunctivitis and keratitis.

Prevention

77. Approximately 80 per cent. of industrial eye injuries are due to flying particles. They occur chiefly in engineering processes such as grinding, lathe work, hammering, chipping, boring, milling, and turning. Risks of eye injury are also inherent in soldering and welding. The potential seriousness of injury to the eye varies from process to process. For example, particles thrown out by grinding are relatively small and slow moving; they tend most often to cause corneal abrasions or become surface foreign bodies. Hammering results in larger particles of higher velocity liable to become intraocular foreign bodies.

78. The basic principle of prevention is that everything possible must be done to machines and processes to reduce the chance of eye injury. Only thereafter should resort be made to personal protection. Transparent screens should be attached to machines so that particles thrown off are intercepted. Fumes and vapours should be controlled by enclosure of the process or by exhaust ventilation. The risk of splashes should be minimized by mechanization to reduce manipulation and by enclosure. Sources of radiation should be blanked off or screened by appropriate filters. Everything should be done by way of education and propaganda to enlist the co-operation of workers to make full use of precautionary arrangement, especially personal protection.

79. **Personal Protection.** Where general precautions fail or are insufficient workers must wear goggles. The type of goggles required depends on the nature of the hazard. The question of suitability is pursued in British Standard 679-47 "Protective filters for welding and other industrial operations" and British Standard 2092-54 "Industrial eye protectors for operations other than welding". Goggles are also discussed in Chapter 8, para. 48.

First-Aid Treatment

80. Correct and immediate first-aid treatment may influence the prognosis of an eye injury very considerably. First-aid attendants must be instructed to refer all cases of eye injury to the doctor after any immediate treatment that is within their powers, such as irrigation, has been given.

81. **Foreign Bodies and other Direct Violence Injuries.** The first-aid attendant should apply a pad and bandage and send the patient to a doctor. He should not try to remove a foreign body except by irrigation. He should not instil cocaine eye drops (the pad and bandage will minimize pain by preventing blinking). The risk is that anaesthetizing the eye may mask an intraocular foreign body, while cocaine retards healing. Even for a doctor it is not always easy to locate a foreign body on or in the eye. He should invariably take a full history and test the vision; this will afford valuable evidence in such cases if legal proceedings follow subsequently. After eversion of the upper lid, the eye should be examined with a loup under oblique illumination. The history of the injury and the use of fluorescin are valuable aids to diagnosis. If the foreign body is visible it should be removed by the doctor after the eye has been anaesthetized with 1 per cent. xylocaine. Anti-biotic ointment, for example albucid, should then be applied; 24 hours later the eye and the vision should be examined again. The possibility of the foreign body being intraocular should be kept in mind. If the history, signs and symptoms suggest this, the patient must be referred to an ophthalmologist without delay. In the United Kingdom R.A.F. patients with this injury should be sent to P.M.R.A.F. Hospital, Halton, when possible by air if this means of transport will save time.

82. **Chemical Injuries.** Immediate and prolonged irrigation is necessary. Freshly prepared normal saline or water should be used for both acid and alkali burns. After at least 30 minutes irrigation, a pad and bandage should be applied and the patient sent to a doctor.

83. **Arc Eye.** The eyes may be irrigated with a solution containing zinc sulphate ¼ per cent., boric acid 1 per cent., and adrenaline 1 in 2,000. A cold compress should be applied and if pain is still severe the patient should be sent to a doctor.

NOISE

Introduction

84. Noise has been defined as unwanted sound; but since such a definition is a subjective one, it is very flexible. What is music to one person may be cacophony to another. In any event noise is a modern problem of growing importance both at work and in the home. Noise destroys amenity, acts as an irritant, and impairs working efficiency, while if excessive it may cause acoustic trauma. It is best described and assessed in terms of its sound spectrum.

Sound

85. Sound is produced by alternations of pressure in an elastic medium, causing waves of varying amplitudes and frequencies. The waves are propagated at various speeds according to the medium; in air at 68°F. and normal pressure the speed of sound is 1,125 feet per second.

86. Since sound is a wave motion it possesses energy and exerts pressure or force. And the sound wave energy is proportional to the square of the pressure variation. A direct quantitative evaluation of sound can be made either in terms of energy per unit area (*i.e.* microwatts per square centimetre) or of pressure per unit area (*i.e.* dynes per square centimetre). Another attribute of waves is the number of repetitions of the fundamental period that occur per second. Applied to sound, this is the frequency in units of cycles per second (c/s).

87. The loudness of a sound is governed, in general, by its intensity, which in turn depends on its energy or pressure. The pitch of a sound is governed by the frequency; high-pitched sounds have high frequencies and vice versa. The faintest sound that can be detected by the ear has energy of 0·001 dynes per square centimetre and is in the frequency range 400 to 600 c/s. Sound of about 1,000 dynes per square centimetre causes ear pain. The frequencies that can normally be appreciated are 20 to 16,000 c/s.

88. From 0·001 to 1,000 dynes per square centimetre is an increment of a millionfold. So that even relative to the ear alone there is a very wide range of sound energies or pressure variations to be assessed, and the direct use of energy or force units is inconvenient. Instead a logarithmic scale is used, the unit being the decibel. This does not describe a direct measurement, but the proportional increase in relation to an arbitrary base level. The decibel is the decilog of this relative increase. The sound level to which the logarithmic scale is most commonly referred is 0·0002 dynes per square centimetre, at 1,000 c/s. This is termed the Sound Pressure Level (S.P.L.). Referred to the S.P.L., the minimum intensity difference perceptible to the ear is about 0·5 decibels.

89. The relative intensity of a sound can be calculated in decibels, from either the sound wave energy or pressure, by the following formulae:—

(*a*) Let Vx = intensity of sound in question, in microwatts per square centimetre.

Vy = intensity of reference sound = 1×10^{16} watts/cm² at S.P.L.

Then, Sound level = $10 \log \frac{Vx}{Vy}$ decibels.

(*b*) Let Px = intensity of sound in question, in dynes per square centimetre.

Py = intensity of reference sound = 0·0002 dynes/cm² at S.P.L.

Then (bearing in mind that the sound wave energy is proportional to the square of the pressure)

Sound level = $20 \log \frac{Px}{Py}$ decibels.

Both formulae can be used to determine the difference in decibels between any two sounds. The energy or pressure values of the second sound are substituted instead of the S.P.L. values at Vy and Py.

90. It is emphasized that the decibel is not a linear measurement, but a measure of relative increase or decrease. For example, if to one sound another of equal energy (intensity) is added, the intensity is doubled but the sound in decibels is not. It is 10 log 2, or 3 decibels. Equally, a change of tenfold in intensity is represented by 10 decibels, of a millionfold by 60 decibels.

Loudness

91. Loudness is the subjective perception of the intensity of sound. Here frequency plays a part. Two sounds of equal intensity but different frequencies may not appear equally loud; or if they do appear equally loud, equal intensity increases to each may result in sounds of different loudness. Loudness is measured subjectively by equating two sounds of different qualities and frequencies. The unit of measurement is the phon; a loudness of X phons means that the sound is subjectively equal to a pure tone reference sound at 1,000 c/s which is X decibels above standard pressure (0·0002 dynes per square centimetre).

92. Because of its effect on loudness and its influence on acoustic trauma, the frequency spectrum of sound is important. It is ascertained with a wave-band analyser commonly in octave bands. The recordings show the sound pressure level above standard in decibels plotted against each frequency band in the form of a tracing.

Acoustic Trauma

93. Classic examples of occupational deafness are those found in blacksmiths, boiler makers, and rivetters. The occupations affected today are becoming more extensive; machinists, pilots and engine test-bed workers are typical of them. Most persons exposed without protection to noise of 100 decibels or more for two to three years will suffer some measurable damage to hearing. The upper safe limits of noise depend on intensity and frequency; with noise of the most damaging frequency 90 decibels is the upper limit. Interrupted sound is more traumatic than continuous.

94. The part of the ear injured by intense noise is the organ of Corti, although very intense noise of 160 db. (S.P.L.) may rupture the tympanic membrane. A sudden loud detonation may cause immediate destruction of the outer hair cells, or continuous intense noise gradual deterioration of them. Once destroyed there is no regeneration in the organ of Corti and the impairment of hearing is of the perceptive type. In the early stages there is no complaint of disability as the range of hearing impaired is in the higher frequencies, which do not affect the understanding of speech. The first sign may be found by audiometry in the form of a notch or dip in the audiogram in the range 3,000 to 6,000 c/s. Auditory acuity for speech is not impaired until the frequencies of 500 to 300 c/s are involved.

95. It is not always safe to attribute hearing loss to noise, as other causes such as age, infection, drugs, head injuries, otosclerosis and progressive nerve deafness may well be operative even in a person with a history of exposure to noise. In evaluating the part played by noise the past aural history requires careful investigation as well as other personal factors such as age and susceptibility. The intensity, frequency spectrum and nature of the noise stimulus then must be assessed, as well as the total length of exposure, the periodic exposure, and the degree of personal protection.

Effects on Communication

96. Noise may mask sounds, particularly those of similar character, by raising the threshold of audibility. As the intensity rises, the more it masks those upper frequencies by which speech is conveyed intelligibly. Raising the voice and shouting can overcome masking noise to some

extent but beyond 100 decibels this becomes impossible. Difficulty in hearing properly or making oneself heard is a source of acute irritation; failure to hear correctly leads to mistakes and friction; the effort of concentrating on hearing means the relaxation of concentration on the work in hand. Disruption of communication of this kind causes fatigue, tension, and general loss of efficiency. There is in addition the inconvenience of temporary deafness which takes time to wear off after a period of exposure to noise, for example a lengthy flight in a noisy aircraft.

Effects on Work

97. Although it has been found that protection from noise can increase the efficiency of weavers by 12 per cent., industrial experiments have not all been so convincing and it must be accepted that certain tasks can be performed as well in a noisy environment as in a quiet one. However, noise affects efficiency in the type of work that in any case is susceptible to impairment through fatigue; noise accelerates the effects of fatigue. Another type of work particularly influenced by noise is one that requires continuous alertness to stimuli, especially visual, when not one moment's relaxation of concentration is permissible for fear of making an error. Noise encourages mistakes and also lowers output if time so lost cannot be compensated subsequently by raising the rate of work. Noise of 90 decibels and above has this effect, and higher frequencies are worse than lower ones in this respect. It is found also that noise does less harm to efficiency in easier than in difficult tasks, and that the effects of noise may disappear when a task is made simpler. This is of importance as noise may be expected to play a greater part in producing inefficiency in times of stress, for example when operational intensity is high.

98. It is not possible to react simultaneously to all sensory stimuli or to concentrate indefinitely on one. Shifts of attention are in consequence inevitable and during such a shift it takes at least 1½ seconds before the attention is once more fully focussed on the task in hand. High intensity noise increases the frequency of such shifts, thus slowing reactions, providing the opportunity for mistakes or accidents, and reducing the effective time applied to the task. In many kinds of work output will not be influenced by such factors, but the effects may be shown by spoiled work and other mishaps. This is likely only in the kind of work where effective "blindness" of the operator for 1½ seconds or so is important.

Reduction of Noise

99. When a problem of noise reduction arises, the source of sound must be located and the method of its propagation determined. A sound survey should be carried out to ascertain the intensity and frequency of the noise to which people are being subjected. Such surveys are carried out in the Royal Air Force by the Central Medical Establishment Acoustics Laboratory. When all the information required has been assembled, the appropriate mitigating measures can be considered in the following order:—

(*a*) Reduction of the noise at source.

(*b*) Reduction of the propagation of the noise by insulation or absorption.

(*c*) Deflection of the noise away from people.

(*d*) Personal protection.

(*e*) Administrative measures.

Reduction at Source

100. All moving machinery emits noise of some degree. This will be increased if the balance or loading is incorrect, when there is wear and tear, if lubrication is neglected, or the machinery is otherwise misused. Much may be done by careful design and maintenance to reduce noise at source, but many cases occur which are not amenable to this treatment.

Sound Insulation

101. Insulation consists of interrupting the path of propagation of the sound from the source. The transmission of vibrations from machinery may be reduced by isolating it with supports of rubber or other spongy material, or by having spring mountings deadened by rubber and shock absorbers. Floors on which mountings are fixed should be as massive as practicable to reduce resonance.

102. Sound transmitted along pipes or ventilation ducts can be interrupted by the introduction of sections having different densities and elastic properties. Absorbent linings and baffles may also be fitted. Similar principles are involved when floors and ceilings are constructed in layers of different materials on insulated supports and have resilient coverings.

103. The obstruction of airborne sound is only possible by screening. To be effective screens, walls must be thick and made of heavy material. When it is not possible to have partitions of sufficient mass, they should consist of multiple layers with intervening air spaces.

Sound Absorption

104. Reverberation is the reflection of sound from surface to surface within a building. This raises the general noise level by delaying the dissipation of sound energy. It can be overcome by covering surfaces with acoustic absorbents, which permit the entry of sound into their substance and the conversion of its energy into heat. These absorbents are porous materials such as hair felt, porous asbestos, porous fibre board, slag wool, glass wool, and perforated board. They cannot be used as insulators.

Deflection

105. Obstacles such as high walls will screen a limited area from excessive noise by deflecting it. This principle has been used for aircraft running-up pens. Absorbent ducts fitted to aircraft exhausts have been tried as a means of directing the noise into the upper air. Advantage may be taken of the prevailing wind when siting buildings near a source of noise. The greater velocity of wind at a height compared with ground level tends to force sound upwards on the windward side of the source, so forming a relatively noiseless area.

Personal Protection

106. When no more can be done by the reduction of noise at source, insulation, absorption, or deflection, the only remaining method of dealing with undesirable noise levels is to use personal protection. Such protection may be afforded by inserts to block the external ear or pads covering the whole ear and part of the surrounding bony structure of the skull. In addition, the personal protection thus afforded should be reinforced by medical supervision. Ideally all those exposed to noise of 90

decibels or above should undergo audiometric examination before employment and periodically thereafter. Unfortunately this is not often practicable.

107. Owing to the conduction of sound by the bony structure of the skull, there is a limit to the amount of attenuation that ear defenders can achieve. Attenuation is, however, most important in the high cochleo-toxic frequencies and it is by their properties of attenuation of frequencies between 2,000 and 4,000 c/s that ear defenders should be judged. The maximum reduction possible by the best ear defenders is 47 decibels at 400 c/s, so that there are obvious limits to the intensity of noise to which exposure is safe even when protected.

Insert Ear Defenders

108. Insert types of ear defender should be made of resilient material to ensure both comfort and a good acoustic seal. They should also be supplied in a number of sizes and arrangements are essential to ensure that care is taken over fitting men with the right size. Comparative tests have shown that the best pattern of insert is the Harvard NDRC Type V-51R, of which a British version is now available in the R.A.F. At frequencies of 3,000 and 4,000 c/s, it achieved an average attenuation of 30 decibels. The mean attenuation over the range 250 to 8,000 c/s was 24 decibels and the attenuation of speech hearing 12 decibels. In each case the corresponding attenuation value for cotton wool is about 8 decibels. As a method of protection against noise, plugging the ear with cotton wool is useless.

Noise Occluding-Pad Ear Defenders

109. Noise occluding pads may be worn fitted to helmets or to head bands. The pads or wardens should cover as much of the bony structure around the ear as is practicable in order to reduce sound conduction. The helmet or head band with the wardens must be as comfortable as possible to wear; this includes the avoidance of excessive weight. The R.A.F. Acoustic Laboratory Mark VI Headband was found in trials to have a mean attenuating power of 47 decibels at 400 c/s and 43 decibels at 3,000 c/s. The average attenuation over the range 250 to 8,000 c/s was 33 decibels and speech attenuation 31 decibels. Allowing for the standard deviations of these means, the protective limitations of the ear defender for 98 per cent. of individuals has been computed as follows:—

Representative Frequencies	*Minimum Attenuation Afforded*	*Tolerable Sound Level*
600/1,200 c/s	15 decibels	110 decibels
1,200/2,400 c/s	24 „	120 „
2,400/4,800 c/s	30 „	126 „

At sound levels greater than those assessed as tolerable, adequate protection from acoustic trauma cannot be guaranteed by these ear defenders or any others, although improved designs are being developed. The combined use of inserts and pads does not improve attenuation over the cochleo-toxic range or higher frequencies to an appreciable extent, although protection is increased against the lower ranges.

Administrative Measures

110. In the siting of buildings relative to a source of noise, or the reverse, advantage should be taken of the fact that the loudness will decrease in proportion to the square of the distance. This can also be applied to working positions in workshops.

111. The organization of work may help to mitigate the effects of noise. If rotation of work is possible it will reduce effective exposure over a period of time; this is of particular importance if the noise concerned threatens acoustic trauma. Work needing unremitting attention is the most susceptible to noise, and if the surroundings cannot be quietened it may improve efficiency if the work is done in short bursts rather than in long sessions.

112. Some individuals are more susceptible than others to acoustic trauma and to disturbance of concentration by noise. It is not easy to identify such individuals but when such disabilities come to light, change of work or of working environment may have to be considered.

CHAPTER 15

OCCUPATIONAL HEALTH OF AIRCREW

INTRODUCTION

1. Aircrew are in general young and healthy. The nature of their occupation, however, subjects them to stress, physical, mental, and psychological. Service flying is a strenuous life and may make heavy demands on the health of those who pursue it. The medical officer can make a valuable contribution to the flying effort by ensuring that the stresses met do not undermine the health of aircrew. To assess their health requirements it is necessary to examine their task. The following are some of the more important factors concerned.

High Rates of Ascent and Descent

2. Rapid changes of altitude entail abrupt changes in environmental pressure. This affects the volume of free gases in the body. During ascent expanded gases in the gut can usually be released without difficulty. At high altitudes, however, severe abdominal discomfort may occur if a meal of gas-forming food has been eaten before take-off.

3. Expanded gases in the middle ears and sinuses on ascent escape easily because of the lower pressure externally; they present no problem. The return of air to equalize the pressure on descent may be more difficult due to the valvular action of the walls of the foramina. This is particularly so if the upper respiratory passages are congested by infection. Pain and other effects sufficiently severe to be totally disabling may result. In fact, the chief limitation to the rate of descent of a supersonic aircraft may well be the state of the crew's eustachian and sinus mucosae. Hence upper respiratory infections in aircrew are a major problem. Even a simple cold must be treated with respect.

High Speeds

4. The high speeds of modern aircraft demand of the pilot quick reactions and accurate timing, besides instant judgement of relative positions and distances. These demand an alert mind and a fit body. Anything detrimental to either causes impaired performance and even danger. Some everyday examples of detrimental factors are unwise social activities, lack of sleep, reactions to inoculations, and treatment with drugs having undesirable side effects.

Centrifugal Accelerations

5. During turns at high speed the *g* experienced produces the well known circulatory disturbance leading to "grey-out" and "black-out". Good abdominal muscle tone helps to combat these effects. For this reason the fit may have an increased tolerance of one *g* or more in comparison with the flabby.

Psychological Stresses

6. Service flying entails inherent stresses that may cause fatigue out of all proportion to the muscular effort involved. There are periodical long hours of waiting at readiness, and general dislocation of the normal routines of life. The intervening sorties are frequently exacting. For example, in a single day a pilot may have to carry out two 45-minute

sorties, involving the tension and concentration of formating at high speed in bad weather, followed by the anxiety of instrument approaches, possibly short of fuel. The fatigue that results may be transient, but over the years it may be cumulative and more permanent. There is much individual variation in susceptibility to fatigue. Those developing cumulative fatigue can often be restored by rest from the more arduous types of flying duties.

7. The psychological health of aircrew is discussed in Chapter 13.

THE MEDICAL OFFICER ON A FLYING STATION

8. Successful supervision of the health of aircrew demands close personal knowledge of the men and their jobs. It is also essential for the medical officer to gain the full confidence of the aircrew. This knowledge and confidence can only be won by spending time in the flight dispersals, at briefings, and in mixing freely with aircrew in the normal social round. The medical officer should besides take some part, however small, in the organization, supervision or conduct of sport on the station.

9. The medical officer, as their confidential adviser, is obliged to liaise closely with the wing commander (flying) and with the squadron commanders. He should, however, take care to avoid giving the impression to aircrew that he is interested only in senior officers. This situation will not arise if aircrew realize that the medical officer is approachable, helpful, and sympathetic. Their appreciation will be reinforced if they find him conscientious and competent. Unless, however, his turn-out and deportment are at least as smart as their own, the medical officer may come to be looked on by aircrew with some measure of benevolent contempt. He will be regarded as a civilian unwillingly or unfittingly in uniform, and consequently one not subscribing to the general *esprit de corps*.

10. Lastly, but most important, the medical officer is well advised to take every possible opportunity to gain air experience (Q.R. 1480), in the types of aircraft with which his station is equipped. He should make a point, as well, of flying with as many different pilots as possible.

THE PHYSICAL HEALTH OF AIRCREW

Medical Treatment

11. In the treatment of the ailments or injuries of aircrew one important principle is to interfere as little as possible with the flying task. There are four points to consider:—

(*a*) Is the ailment or injury itself of such a nature that it precludes flying?

(*b*) Is the treatment such that it might affect efficiency in flight?

(*c*) If not, are the arrangements for administering the treatment so organized that they will not interfere with flying times?

(*d*) If so, are the treatment and the arrangements for administering it the best possible, from the point of view of resuming flying with the minimum delay?

12. If the ailment or injury is likely to be exacerbated by flight, or to limit efficiency in the air, there should be no hesitation in grounding the patient. This, however, is not to be done lightly and without careful consideration of all attendant circumstances. The decision, when made, should be communicated in writing at once to the patient's squadron commander in person.

13. The effect on aircrew of drugs, especially side effects, should be remembered. Flying should not be permitted when patients are under treatment with or feeling the after-effects of anthistamines, atropine, barbiturates or other persistent sedatives, dexedrin, benzedrine, and prophylactic inoculations.

14. Aircrew should not act as blood donors unless there are strong compassionate grounds for doing so, or in an emergency. If they do so, they must be removed from flying duties for at least 17 days.

Annual Medical Examinations

15. The annual medical examination should not be a perfunctory formality. It is in the interests of the safety of individual aircrew, of their flying colleagues, and of all those who go into the air with them. The examination must be performed and recorded meticulously. At the same time the results of previous medical boards and annual examinations should be studied. Otherwise it will not be possible to assess the gravity of defects newly discovered or the progress of those previously recorded.

16. If a defect is found it is worthwhile to try to discover whether it is due to some cause that can be readily adjusted. It is wrong to recourse immediately to medical boarding without having done so.

17. When a defect is found that is likely to affect a man's flying category, it should be broken to him with considerable tact and kindness. Such an occurrence is a severe blow to nearly every flying man and every effort should be made to soften it. But his intelligence should never be insulted by prevarication or mumbo-jumbo.

Advice to Individuals

18. Aircrew, without in any way being hypochondriacs, are in general, health conscious. This is because they know that on health depends to a large extent their efficiency and safety in the air. The advice of the medical officer will in consequence often be sought on individual health problems.

19. Minor problems are rarely brought to sickquarters and the medical officer must not resent being button-holed on such matters out of hours. Usually all that is required is frank information and reassurance. But the medical officer should never dismiss the possibility that the voicing of such a problem is a symptom requiring closer investigation.

20. The medical officer should not always wait for his advice to be asked or reserve it for such occasions as the annual medical examination. Being in constant touch with aircrew, on and off duty, he should be able to observe early signs and symptoms of deterioration in health, and of habits prejudicial to health. Then the sooner he investigates and puts things right the better.

Physical Fitness

21. Service flying is a strenuous occupation; but not in the normally accepted sense, for the effort involved is not all muscular. In some respects it is a sedentary occupation. The physiological and psychological stresses involved naturally demand a certain level of physical fitness. But in the main the job is done sitting down. Some roles, also, involve long periods of sitting and waiting about in flight dispersals. This militates against the desired standards of physical and mental alertness.

22. Since the exercise necessary to keep aircrew fit is not provided by their occupation it is essential to provide some form of recreational exercise. The main object of this is not general muscular development. It is to produce a good level of fitness which can be maintained over a long period, rather than a peak that cannot. This raises the question of what is fitness in relation to the occupation of aircrew. Clearly it must be such that the individual can sustain:—

(*a*) Centrifugal accelerations.

(*b*) Low barometric pressure.

(*c*) Low oxygen tension in an emergency.

(*d*) Long periods of concentration when harnessed in one position.

(*e*) Quick and accurate reaction to dangerous emergency.

(*f*) Heavy foot loads in holding asymmetric power on multi-engined aircraft.

23. The degree of success in dealing with these conditions will depend to some extent on a man's inherent constitution. Physical exercise contributes by raising the threshold to fatigue, by promoting alertness, by increasing keenness and drive in approach to daily tasks, by ensuring the attainment of the maximum individual *g* threshold, and by reinforcing the chances of survival on forced landing in remote areas.

24. The basis of any programme designed to promote aircrew fitness should be exercise involving rapid and accurately co-ordinated movements. Physical training exercises should have special reference in addition to respiratory efficiency and the muscle tone of abdomen, thighs, and legs. Sports should be encouraged that call for agility of thought and action. Activities that possess particular virtues for aircrew are running, squash, tennis, badminton, golf, fencing, basket ball, swimming, rowing, and riding. Besides sports such as these, long walks and hill climbing are useful pursuits.

25. In the past, claims have been made that the more physically violent games, such as football, rugby, and boxing are of particular importance because they develop the attributes of toughness and aggression. There is no evidence that this is true. It is more likely that men who possess these attributes are especially attracted to these forms of sport. With the exception of boxing, aircrew who like these games should be encouraged to play them.

26. So far as boxing is concerned there is ample evidence that, because of the potential damage to the higher cerebral centres, to the special senses, and to the nasal airways, it is best discouraged among aircrew.

27. The role of the medical officer is to co-operate closely with the physical fitness officer to ensure that recreational exercise of the right kind is available for aircrew. He must also be prepared to advise unit and squadron commanders on the subjects. The chief points that require consideration are:—

(*a*) The provision of adequate facilities, *e.g.* pitches, equipment, gymnasia, including changing and bathing arrangements.

(*b*) The organization of adequate time that is not only convenient but does not clash with the flying effort.

(*c*) The provision of an adequate variety of recreational exercise. The usual run of Wednesday afternoon team games is insufficient. It is necessary to cater for a wider range of tastes and athletic prowess.

(*d*) The supply of proper supervision. This is particularly necessary for exercise organized in gymnasia. In the interests of safety and to ensure that the best advantage is taken of this type of activity, supervision by a physical fitness instructor is essential.

Escape and Evasion Exercises

28. Escape and evasion exercises are a test of initiative and endurance rather than a routine means of building up physical fitness. Medical officers should interest themselves in the results of such exercises. Not only may they indicate those whose physical fitness requires some special attention, they may show also whether in general the physical fitness programme is up to standard. Besides this, such exercises can be effectively used to stimulate aircrew interest in physical training. Apart from the physical aspects, the reactions of aircrew to obstacles met during the exercises may provide the medical officer with information on the psychological characteristics of individuals.

Night Vision Training

29. Men require to be trained to make the best use of their eyesight at night. The first step is to instruct aircrew in the basic physiological principles of night vision, as part of their aero-medical indoctrination. They should besides be taught the technique of how best to use the eyes at night. Practical training follows in the form of games played under low-intensity lighting or under normal lighting while wearing dark goggles. The organization of this type of training is the responsibility of the physical fitness officer, as is dinghy drill.

General Environmental Factors

30. The environmental factors on the ground that influence the health of aircrew are basically the same as those associated with any body of healthy young men. There are, however, times when the flying task makes demands that can only be met if routine arrangements are modified. The medical officer may be called on to advise, in this respect, on aircrew accommodation, messing arrangements, requirements at places of duty, and on the hours or conditions of work.

31. **Accommodation.** Aircrew should not be expected to share rooms unless it is quite unavoidable. One reason is that each man should have his own personal niche, the comfort and atmosphere of which he will be able to embellish according to his own tastes. This provides for privacy and relaxation rather than just a place to sleep. Another reason is that it is impossible to ensure that the hours of duty of the occupants of a shared room will coincide. This may lead to disturbed sleep and allied irritating inconvenience. For the same reason it is wise where possible to separate the accommodation of aircrew of different squadrons, particularly if they have different roles.

32. **Messing.** It is not uncommon for the flying task to last round the clock. There are crews going on and coming off duty continuously. This throws a severe burden on the mess organization, which unless supervised closely may fail to provide adequate, appetising food for aircrew. The difficulties are increased when the mess is distant from dispersals.

The provision of certain meals for aircrew in the airmen's mess and of aircrew buffets at dispersals are expedients that have been tried to overcome these difficulties. Whatever the arrangements adopted, it is incumbent on the medical officer to observe them closely and to advise on any improvements required.

33. **Flight Dispersals.** At flight dispersals are found the squadron offices, aircrew locker-room, and a general sitting-room for aircrew—the crew-room. In the crew-room briefing is carried out and the crews wait at standby. A large part of their day may be spent there. Usually flight dispersals are permanent buildings adjacent to or part of the hangars. In wartime, during exercises, or because of squadron redeployment, they may be temporary hutted buildings on remote parts of the airfield. In these it may be necessary to press for improvements in heating, lighting, sanitation, and general amenity. It is most important to have comfortable seats and chairs during long periods at readiness. The cleanliness and comfort of dispersals usually reflect the efficiency of the squadron concerned. When these are obviously neglected, the medical officer should quietly investigate the reason.

34. **Aircrew Cloakroom.** Because of the complexity of modern flying clothing, the locker-rooms at flight dispersals are being replaced by aircrew cloakrooms. There is either a central cloakroom for the whole station or one for each squadron or flight. Besides a clothing store and facilities for testing equipment, there are in the same building changing rooms, with lockers for personal clothing, and showers. All flying clothing is held in a special hanging room under the care of a flying clothing worker, who is responsible for maintaining and testing it. The clothing is handed out and returned over a counter before and after sorties or the day's flying. Each time it is thoroughly scrutinized and made good by the specially trained storeman. In this way aircrew can thoroughly rely on the efficiency of their personal flying equipment. A diagramatic illustration of an aircrew clothing store is in Fig. 72.

35. **Hours of Work.** It is impossible, and undesirable, to lay down hard and fast limits to the hours of flying or total work undertaken by aircrew. At times the flying effort may make intensive unremitting demands; but little harm is likely to be the result provided these are not too prolonged or frequent. There are, however, two important points about the arrangement of work. The first is that when flying times occur at all hours of the day or night, they should be allotted so that nobody is constantly deprived of opportunities to join in the daily general and social activities of the station. The second is that leave and shorter breaks should be systematically organized, so that aircrew may take advantage of their whole entitlement during the year and at predictable intervals.

FLIGHT FEEDING

36. The meals for aircrew and for passengers in the air are complementary to those supplied on the ground. Ground and in-flight meals should together comprise a balanced diet and have an adequate calorific content. But the critical consideration on which in-flight nutrition requirements should be based is the length of time between meals on the ground. Secondarily, the long hours of lack of occupation in the air, to which passengers may be subjected, should be taken into account. In-flight feeding has been planned with these points in mind; the following notes are designed to enable the medical officer to ascertain whether such plans are being effectively practised and to advise if they are not.

Timing of Meals

37. During the waking hours a periodicity of about 4 to 5 hours between meals is a suitable pattern to aim at. Tea, coffee or squash should in addition be taken between meals; this ensures an adequate blood sugar level and is of value in reducing fatigue and maintaining efficiency. This periodicity should be regarded as important for aircrew and advantageous so far as it applies to passengers.

38. The facilities for serving meals in flight can never be as good as those on the ground; so pre- and post-flight meals should be taken as near as possible to the estimated time of departure or arrival. It will be possible in this manner to limit the nourishment required in flight.

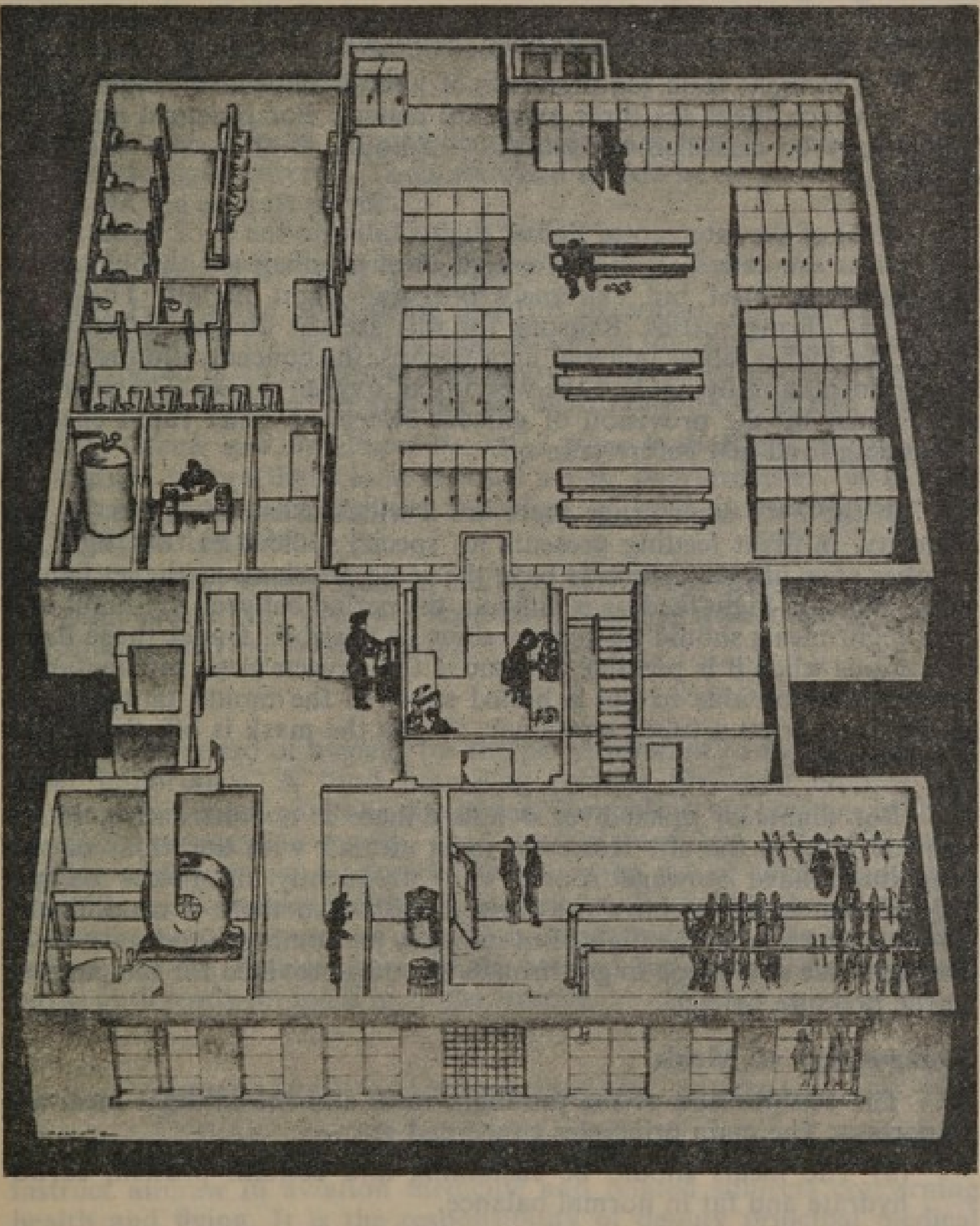


FIG. 72. AIRCREW CLOAKROOM

39. The following table suggests a scale of in-flight meals related to flying times and times between ground meals. It is assumed that a total of three hours is lost for taxying, emplaning, disemplaning, and flight preparation. Meal "A" is a main meal equivalent to breakfast, lunch, or dinner. Meal "B" is a snack similar to a tea meal. Meal "C" is light refreshment consisting of a beverage and cake or biscuit.

Flying Time (in hours)	*Time Between Ground Meals* (in hours)	*In-Flight Meal Requirement* *Aircrew*	*Passengers*
0 – 2	3 – 5	C	C
2 – 4	5 – 7	B + C	B
4 – 6	7 – 9	A	A
6 – 8	9 – 11	A + B	A + C
8 – 10	11 – 13	A + B + C	A + C + C

Aircrew Feeding in Flight—Special Problems

40. The in-flight food requirements of aircrew depend on flight duration, of which there are three empirical classes. For practical purposes flights may be classified as lasting 0 – 2 hours, 2 – 4 hours, and over 4 hours.

41. Most of the interceptor fighter flights fall into the 0 – 2 hours class. The pilots are called upon for a high level of efficiency throughout a comparatively brief but extremely fatiguing flight period. They can rarely eat during sorties. Reasons for this are the absence of stowage space, the high *g* factor in aerial manoeuvres, the concentration required during formation flying, and the wearing of oxygen masks. The problem is best met by the provision of glucose sweets or other rapid energy-producing food just before take-off.

42. In the 2 – 4 hour range there are a wide variety of flights. In the majority, in-flight feeding presents no special difficulties. But light jet bomber crew in many respects have the same problems as the jet fighter pilot. When in-flight feeding is difficult, the period between pre-flight and post-flight meals should be kept as short as possible. Under those flight conditions when it is possible to remove the oxygen mask momentarily, aircrew may be able to put a boiled sweet in the mouth or to take a quick drink from a tubed container. (While the mask is off, the breath must be held.)

43. For flights of much over 4 hours there is no alternative but to provide food in the air. However, most aircraft with durations of this magnitude have stowage room. They frequently fly below oxygen requirement levels or have pressurized cabins, so there is no difficulty about eating during the flight. But in heavy jet bombers food must be of the right size and shape to go through the trap provided for the purpose in the pressure helmet.

Composition of Meals

44. The composition of the pre-flight meal and the in-flight meal are important. The main principles concerned are:—

(*a*) The meals should be sustaining and contain protein, carbohydrate and fat in normal balance.

(*b*) Foods productive of intestinal gases should be avoided, *e.g.* peas, beans, and high-roughage carbohydrates.

(*c*) Foods normally requiring a lengthy digestive process should be avoided, *e.g.* fats and high residue foods.

(*d*) Adequate quantities should be available but the ingestion of much bulk food or overeating should be discouraged.

(*e*) Attractive presentation and variety are of paramount importance.

45. Aircrew should be advised on pre-flight and in-flight feeding. In addition to warning against overeating at these meals and on the discomforts of gas-producing foods in the bowel at high altitudes, the importance of not missing meals and of maintaining a regular bowel habit should also be stressed.

46. The post-flight meal should be satisfying and appetizing, but not elaborate. If the meal is to be eaten immediately before going to bed, attention should be paid to its digestibility. To avoid monotony the post-flight menu should take account of the dishes served that day, at other meals (pre-flight or in-flight).

47. The table in para. 39 may be applied to the types of meal required aboard transport aircraft. Their standard should be as good as facilities on board the aircraft permit.

48. The various forms of in-flight meal are as follows:—

(*a*) *Pre-Packed Meal Boxes and Hot Beverages.* The beverages may be prepared on the ground and carried in thermos flasks or may be prepared in an electric urn on board. In either case one of the crew must be delegated to arrange the distribution of food and fluids.

(*b*) *Meals and Beverages Prepared from Bulk Issues.* Rations are issued before flight to a steward or air quartermaster, who must have preparation facilities including at least an electric urn and preparation table.

(*c*) *Meals Partially Cooked and Served on Trays.* Reheating facilities in a special tray oven are necessary, together with a steward or air quartermaster, to serve meals of this kind.

Hygiene

49. The standard of hygiene for the preparation of in-flight foods is of great importance. A food poisoning episode involving aircrew and passengers in flight could be disastrous. Scrupulous supervision of food-handlers, preparation rooms, food storage facilities, and food transporting arrangements, is essential to reduce the risk of contamination to a minimum. To reduce the risk of bacterial multiplication in the event of contamination, preparation should be undertaken as late as possible before take-off. Refrigerators should be used for storing the completed boxes until ready for loading on the aircraft.

AEROMEDICAL TRAINING OF AIRCREW

50. An important duty of the medical officer at a flying station is to instruct aircrew in aviation medicine and related subjects concerning health and flying. It is the responsibility of deputy principal medical officers (flying) to advise on appropriate instructional programmes. The information upon which to base such instruction is contained in notes

supplied by deputy principal medical officers (flying) of certain commands, in Air Ministry publications and pamphlets, in Air Ministry Orders and Air Ministry Flying Orders, in "Air Clues", in text books such as "The Principles and Practice of Aviation Medicine" by H. G. Armstrong, and in Agardographs such as "Collected Papers on Aviation Medicine". Medical officers also receive appropriate basic and refresher training in aviation medicine at the R.A.F. Institute of Aviation Medicine.

51. At flying training units formal instruction in aviation medicine is organized as part of the syllabus. In operational units it should be possible to organize a certain amount of systematic instruction with squadron commanders. Often, however, it will be necessary for medical officers to take the opportunity when the weather is bad or the flying task light to get squadron commanders to assemble aircrew for lectures. Of the greatest value is informal discussion at odd times in dispersals or elsewhere with aircrew in groups or individually.

52. The following subjects are among those normally included in such instruction:—

(*a*) Aviation medicine:—

(i) Physiology.
(ii) Personal flying equipment.
(iii) Practical decompression demonstrations.
(iv) New developments in theory, practice, and equipment.
(v) Recent regulations, publications, and articles.

(*b*) Survival.

(*c*) First aid.

(*d*) Hygiene (personal and environmental).

(*e*) Physical fitness.

(*f*) International sanitary regulations, including immunization requirements.

53. Useful information on certain of these subjects will be found in:—
R.A.F. Flying Manual (A.P.129)
Jungle Survival (A.M. Pamphlet 214)
Sea Survival (A.M. Pamphlet 224)
Desert Survival (A.M. Pamphlet 225)
Arctic Survival (A.M. Pamphlet 226)

The following notes provide information not readily available elsewhere.

First Aid

54. Aircrew should be given elementary first-aid training. This should cover the first-aid treatment of shock, haemorrhage, fractures, and burns. The important thing is that they should be thoroughly familiar with the different types of first-aid equipment supplied for aircrew or aircraft, and where it is stowed. They should be taught the way to use the items contained in these kits especially such items as morphine ampoules and

tourniquets. (For list of contents see A.P.3130, Part 8, and for regulations concerning their carriage in aircraft see Q.R.697.) The range of first-aid kits available is:—

9A–02409 Kit, First Aid, Aircrew, Personal
9A–02430 Kit, First Aid, Aircraft
9A–02440 Kit, First Aid, Aircraft Dinghy, Large
9A–02450 Kit, First Aid, Aircraft Dinghy, Small
9A–02455 Kit, First Aid, Survival Pack
9A–02480 Kit, First Aid, Passenger Aircraft, Daily Use
9A–02490 Kit, First Aid, Passenger Aircraft, Emergency Landing, Large
9A–02491 Kit, First Aid, Passenger Aircraft, Emergency Landing, Small.

Hygiene

55. Aircrew travel fast and far. They may find themselves in situations where ignorance of practical hygiene could militate against the successful completion of a mission. They should in consequence be taught the elementary principles of the spread of infection and of its control, both in barracks and in the field. As officers they should know the elements of the application of these principles to the care of the health of their men. They should also be told of the risks to health of physical factors, such as extremes of heat or cold. Useful references for this subject are "Handbook of Army Health" (W.O. Code No. 5691) and "Your Health in Warm Climates" (A.M. Pamphlet 160).

International Sanitary Regulations

56. Large numbers of special flights to many parts of the world are now commonplace. Aircrew, especially those in Transport Command, should be told of the reasons underlying the international sanitary regulations on immunization and disinfecting of aircraft. They should also know their responsibilities related to quarantine control in general. The regulations may be found in H.M.S.O. Publication, Miscellaneous No. 6 (1951) "International Sanitary Regulations adopted by the World Health Assembly", which is summarized in Appendix "D".

SUPERVISION OF PERSONAL FLYING EQUIPMENT

57. The provision of aircrew cloakrooms simplifies the supervision of personal flying equipment; but the more haphazard organization of dispersal locker rooms will persist for some time at a number of stations. In either case it is the responsibility of the medical officer to ensure that flying clothing is not neglected. Some guidance on this matter is contained in A.P.129. The following points require attention:—

(*a*) Check is required that aircrew are equipped with the most up-to-date equipment in accordance with the latest scales.

(*b*) Inquiry is necessary into any anomalies of performance of equipment. It is essential to make reports in writing on any that occur.

(*c*) The efficiency of the storage of equipment requires checking.

(*d*) Close observation on the serviceability of equipment in use is essential.

(*e*) Suggestions for new requirements that may become apparent should be made without hesitation.

(*f*) Care of first-aid kits should be systematically planned.

58. Personal flying equipment is the concern of others besides aircrew and the medical officer. The equipment branch, including flying clothing workers, and the technical branch must each play their part if the most effective and safe use is to be made of personal flying equipment. The medical officer, however, has an overall interest, and because of his close association with aircrew is in the best position to exercise overall supervision in an advisory capacity. The correct procedure when a medical officer considers that the health, safety or efficiency of aircrew are prejudiced by the faulty design, construction or maintenance of an item of equipment, is first to discuss the matter with the station senior technical officer. If he agrees with the criticism, the latter will report the matter on Form 1022A. In addition the medical officer should prepare his own report, which should include reference to the discussion with the senior technical officer and to whether or not Form 1022A has been raised. Any flying incident, even though aircrew and aircraft suffer no consequences, should always be reported on Form 2752 (see para. 70) when defective equipment is involved.

AIRCRAFT ACCIDENTS

General

59. There are two main categories of aircraft accident: those that occur in the airfield circuit and those that happen further off. The majority of circuit crashes occur on take-off or landing. It is these at which the medical officer is most often able to be of some assistance. The medical officer is rarely first at the scene of those crashes that occur more remotely. And in these more often than not the crew are either not in need of immediate medical attention, or are beyond it. It follows that the organization for crash emergencies should be primarily aimed at dealing with those on or adjacent to the airfield.

Emergency Organization

60. **Sickquarters.** The operating theatre should be kept constantly prepared, at the correct temperature (68° to 72°F.), with table, instruments, drums of sterile instruments and intravenous drips ready for use. Arrangements should be made in advance for setting up resuscitation beds if necessary. The staff should have emergency duties allotted to them in advance and should be well drilled in them.

61. **Ambulance.** A crash ambulance must stand by while flying is in progress, either at sickquarters or near the control tower, in accordance with local circumstances (Q.R.698 refers). A driver and nursing attendant must be especially detailed as the crash ambulance crew. Meticulous attention must be paid to the serviceability of the crash ambulance and, to ensure immediate starting, the engine should be run at regular intervals during standby. The ambulance equipment must be checked frequently and kept up to scale. In addition to medical equipment it is worthwhile to keep extra items in the ambulance such as an axe and asbestos gloves.

62. **Alarm.** There must be an efficient alarm system directly between the control tower and sickquarters. On the alarm sounding, the sickquarters' staff must know precisely what they are required to do, in accordance with the pre-arranged plan. The medical officer's whereabouts must be known to them (in particular to the duty N.C.O.) at all times when flying is in progress. To facilitate identification of the site of the crash, a large-scale map of the local area, overlaid with a reference grid, should be kept in sickquarters.

63. **Scene of Crash.** Having reached the crash the primary duty of the medical officer is the care of casualties; fire fighting and forced entries are the task of the crash and fire crews specially trained for the purpose. Once access to the aircraft has been gained, it is rarely that treatment can be given to the injured before removal, because of the presence of toxic fumes or of the danger of fire. Usually, therefore, priority must be given to the rapid removal from the aircraft of the crew, without aggravation of injury. This is the responsibility of the medical officer and his staff, with such extra assistance as they may need from the crash and fire crews. Consequently it is essential for medical staff to be thoroughly familiar with the cockpits, crew spaces and break-in points in the aircraft with which their station is equipped. They must know about the operation of all parachute and seat harness, including especially their release boxes. They must have a sound knowledge of ejection seats, their operation and the safety precautions essential before attempting to remove an injured man from them.

64. **Care of Injured.** After immediate first aid has been given at the scene of a crash near the airfield, the injured should usually be removed to sickquarters. Here further treatment and resuscitation may be necessary before evacuation to hospital. Transfer to hospital should be delayed until the patient seems reasonably likely to be able to withstand the journey. If it seems that surgical intervention may be essential before the patient can be safely evacuated, the nearest R.A.F. hospital should be contacted and consulted on the need to send surgical aid. On some occasions it may be preferable or more practicable to take the injured direct to the nearest hospital from the scene of the crash.

65. **Fatalities.** After fatal accidents the medical officer may be required to give evidence at the inquest. Often the establishment of identity is an important point. A careful note should be made of where remains, items of clothing, pieces of flying equipment, and personal belongings are found. They should be labelled and kept until required as evidence. Scars, birthmarks, old injuries, and dental work may assist when identification is difficult. Post-mortem findings and pathological investigations may help in discovering the cause of the crash. In order that investigation may, if indicated, be carried out by a specialist in aviation pathology, a copy of the signal reporting a fatal accident (in U.K. and 2nd T.A.F.) is to be sent to the R.A.F. Institute of Pathology and Tropical Medicine.

Administrative Aspects

66. In order to ensure that his emergency organization is familiar to the executive and that it fits in with the remainder of the fire and crash arrangements, the medical officer should attend at flight-safety conferences.

67. After an accident the medical officer must, if called on, give all possible assistance to the Court of Inquiry (A.P.3207).

68. All uninjured occupants of an aircraft involved in an accident must be medically examined (Q.R.1436).

69. After every aircraft accident R.A.F. Form 2752 is to be completed in accordance with the instructions contained thereon. The completed forms are then forwarded to D.P.M.O.(F) at command headquarters. This form is a report on injuries received and other medical evidence in a flying accident or forced landing.

REPORTS

70. It is necessary for the medical officer, from time to time, to render reports on the aeromedical aspects of his work. These include:—

(*a*) An annual report on the state of aviation medicine on the station. This report is called for by the deputy principal medical officer (flying) in accordance with Q.R.1471 and is in a form prescribed by Air Ministry Orders.

(*b*) Special reports, when called for; an example is reporting on some new item of personal flying equipment from the medical aspect after user trials.

(*c*) Reports on unusual occurrences of aeromedical interest.

71. In the preparation and writing of reports, attention should be paid to the principles set out in the Manual of Service Writing and Office Management (A.P.3184).

CHAPTER 16

TOXIC SUBSTANCES

INTRODUCTION

Industrial Poisoning

1. Industrial progress has led to the production and use of an ever-increasing range of materials. Many of these may be toxic, and unless adequate precautions are taken the risk of industrial poisoning will increase. Precautions cannot, however, be devised unless something is known of the nature of the materials concerned and how they are to be used or produced. Particular difficulties occur when the substance is a new one, the toxic characteristics of which are unknown, or when it goes by a proprietary name giving no indication of its constitution. Moreover, in assessing the risks attached to processes and materials, the characteristic pattern of industrial poisoning must be taken into account.

2. Industrial poisoning differs from other forms in that it is more often chronic than acute, although sudden catastrophes do occur. The routes of absorption are also characteristic, in that the respiratory tract is by far the most important means of access to the body by industrial poisons. Next most important is absorption through the skin and, far away last, ingestion by mouth. It follows that gases, fume, smokes and dusts are the most dangerous forms that industrial poisons can take, followed by substances that can be absorbed through the skin.

3. The nature of a process influences the form an industrial poison may take. Hot processes encourage volatility and the production of fume. Heat may convert a relatively inert solid into a dangerous liquid. Processes involving crushing or attrition encourage dust. Wet processes, or those liable to cause splashing, increase the risk of eye and skin injury, besides facilitating skin absorption. The nature of the process also governs the type of precaution that can be taken. Technical reasons may make enclosure, local exhaust ventilation, or the wearing of protective clothing impracticable. Unless a harmless substitute can be found for the poisonous substance, it may be necessary under such circumstances to advise that a process be abandoned.

4. The toxicity of any substance is rarely easy to define. Individual susceptibility varies widely from hypersensitivity to almost miraculous resistance. The man who works indefinitely, exposed to unsafe concentrations of a harmful substance yet apparently in good health, often makes it very difficult to convince others that precautions should be taken. Similarly it is sometimes difficult to persuade people to respect chronic or cumulative poisons, in contrast to those that are more dramatic in their effects. Toxicity is expressed in terms of time of exposure related to concentration. It is clear that considerably higher concentrations can be tolerated for a short or relatively short time, than can be allowed in the day-long working atmosphere. The latter is known as the maximum allowable concentration (M.A.C.). The prediction of toxicity is even more difficult, but sometimes the physical and chemical properties of a substance may give some indication.

Physical Properties of Potential Poisons

5. Gases, fume, smokes and dusts are more likely to be dangerous than stable liquids, while solids in their existing state usually give least trouble. Volatility and stability are thus important physical properties. Melting point and boiling point also indicate the ease with which a change of state, and thus possibly a change in toxicity, may occur. The density of a gas shows whether high concentrations may build up at working level. Particle size of fume, smokes and dusts influences dispersibility and the depth of respiratory penetration. Solubility and solvent properties dictate skin absorption and to some extent the subsequent fate of the substance in the body. In general, physical properties govern the ease with which substances can enter the body and to some extent the resulting physiological responses.

Chemical Properties

6. Although there is no general correlation between chemical structure and toxicity, it is sometimes possible to deduce potential toxicity by comparison with the chemistry of another substance, the effects of which are known. Properties such as high acidity or alkalinity suggest the probability of skin, eye and respiratory damage under certain circumstances. Strong oxidizing or reducing agents, if absorbed, are liable to impair the function of the blood pigments. In general, isomeric forms are likely to be less toxic than the original, but different isomers may vary considerably from each other in type and degree of effect. There are, however, some established chemico-toxicological relationships. For example, until they reach the stage at which they become sparingly soluble in body fluids, the alcohols tend to increase in toxicity as they go up the scale from lower to higher forms. The introduction into aliphatic compounds of chlorine radicles makes them progressively more poisonous. This does not, however, occur in aromatic compounds. The effect and degree of poisoning by the organic compounds of mercury, phosphorus and sulphur are very different from those of the inorganic. Chemical properties are not, therefore, a wholly reliable guide to toxicity.

Physiological Response

7. Factors that influence the physiological response include the rate of absorption, the metabolic breakdown, retention in the tissues, and the method and rate of excretion of the poison. Few attack one system or one organ alone, and every system, or parts of it, can be affected by one or another poison. Sometimes, also, in industrial poisoning more than one toxic substance is absorbed. In consequence the symptomatology resulting from the physiological responses may be extremely complex, and industrial poisons cannot be classified according to pathological effects, signs, or symptoms.

The Problem of Toxic Substances

8. The problem of toxic substances lies in the balance that must be struck between their technical value and their potential harmfulness to health. Danger to health depends on the essential toxicity of the substance and the extent of exposure to it. If exposure, in terms of time and concentration, can be reduced sufficiently to prevent absorption of the substance in amounts that can cause acute or chronic effects, its use is permissible in spite of high toxicity. The practicability of reducing exposure thus depends on the nature of the process concerned, which may or may not permit the application of control measures. Finally the cost of control may outweigh the technical value of the substance. An

outline of control and other measures, which may be used in the prevention of occupational poisoning, is given below. Notes follow on the properties, uses, effects and symptomatology of some of the harmful substances used in the R.A.F. Preventive measures are noted only if they differ from normal, and treatment only if it is other than symptomatic.

PREVENTION

General

9. General measures for protecting workers from harmful substances are broadly similar, whether the substance is in the form of a vapour, fume, gas, dust, liquid, or solid. The aim is to minimize exposure to and keep the environment free from poisons. If this is not successful the workers must be provided with some form of personal protection. In case of accidents, first aid and rescue organization is essential. The entire system must be backed up by education and propaganda, discipline, and medical supervision. Success, however, depends on the extent to which measures are applied that are outside the control of the workers.

Substitution

10. The ideal solution is to substitute a harmless substance for a toxic one. Unfortunately this is rarely practicable, but being the perfect preventive measure it should always be considered. Examples are the use of carborundum abrasives instead of silica sand in sand-blasting, and the classic elimination of phossyjaw by the substitution of red phosphorus for yellow in the manufacture of matches.

Isolation

11. It may be possible to site plant so that sources of contamination are isolated. This will limit the number of persons necessarily exposed to risk and will simplify control of the hazard.

Enclosure

12. All processes which produce harmful fumes, vapours or dusts, or from which there is risk of splashing with harmful liquids, should if practicable be fully enclosed so that contaminants cannot escape. An example is the laboratory fume cupboard.

Local Exhaust Ventilation

13. If it is impossible to contain atmospheric contaminants at the source, efficient exhaust ventilation must be fitted (see Chapter 8, para. 113 *et seq.*). For example, fumes and vapours can be effectively sucked away from tanks by the fitting of lip exhaust ventilation.

General Ventilation

14. Local ventilation is not a substitute for good general ventilation or vice versa. An adequate number of air changes must be ensured to dilute any contaminant reaching the atmosphere and to keep it below its maximum allowable concentration (M.A.C.).

Mechanization

15. Mechanization can reduce exposure by eliminating the need to handle harmful substances and by enabling hazardous work to be done at a distance by remote control. Mechanical devices can also be used to increase protection if they automatically ensure that a dangerous process cannot be carried out unless the protective arrangements are in operation.

Wet Methods

16. In certain dust-producing operations it may be possible to prevent the contamination of the atmosphere with dust by using wet methods. For example, wettable sandpaper is available or grindstones can be kept moist by a drip feed or by a trough of water that soaks the lower periphery. Care is required that wet dust is not allowed to dry and to be disseminated subsequently into the air.

Work

17. It may be necessary to reduce exposure by restricting the amount of time spent working at a hazardous process. This may be achieved by alternating hazardous with safe work in short spells daily or weekly; another method is to limit the number of hours that may be spent at a dangerous occupation each day, week, month or year, irrespective of alternate work.

Personal Protection

18. Personal protection should never be used as a substitute for the general measures already described. When it is essential it means that such measures have failed or are impracticable. Protective clothing, goggles, respirators and gloves are referred to in Chapter 8, para. 19 *et seq.*

Discipline and Education

19. It may be necessary to forbid eating, smoking and the application of cosmetics in certain workshops, for example where there is a lead or radiation hazard. For various reasons workers may be unwilling to wear protective clothing or to observe other safety regulations. For the sake of the individual and his fellows it is essential to enforce protective measures. Safety discipline is easier to enforce if workers are educated in the risks of their work and in the possible results of neglecting precautions. They should be aware of the early symptoms of poisoning and be encouraged to report sick as soon as they suspect occupational illness.

Supervision

20. Medical supervision of the health of workers at risk will ensure the early detection of intoxication. This improves prognosis and, by indicating exposure, points to the need for reviewing protective measures. In addition, the medical officer should observe the working environment closely and advise if he considers tests of ventilation systems, sampling of the atmosphere and other safety checks should be carried out.

Rescue and Immediate Treatment

21. An adequate organization is required to deal with emergencies such as gassing or other acute intoxication when rescue operations will be required. From the medical aspect it is necessary to ensure that first-aid equipment is adequate to deal with resuscitation and immediate treatment. It is also necessary to make certain that the rescue apparatus available includes the correct type of respirators or breathing apparatus for the anticipated risk, and that there are life lines and belts.

ALCOHOLS

Methyl Alcohol

22. **Properties.** Synonyms for methyl alcohol (CH3OH) are methanol, carbinol, wood alcohol, wood spirit, and wood naptha. It is a clear, colourless, highly inflammable liquid completely miscible with water and most organic solvents. It has a burning taste and an alcoholic odour. Its boiling point is 64·6°C., freezing point —94°C., density 0·79, and flash point 6° to 9·5°C.

23. **Uses and Occurrence.** Methyl alcohol occurs in the production of formaldehyde and is used as a solvent, in anti-freeze, dyes, rubber accelerators, paints, varnishes, and paint removers. It is in common use for degreasing metal when the complete effectiveness of this process is of particular importance.

24. **Absorption and Effects.** Inhalation of the vapour depresses the central nervous system and irritates the digestive tract, but individual sensitivity varies greatly. The rate of oxidation and excretion is slow, so cumulative effects are possible. When methyl alcohol is ingested it is oxidized to formic acid or formaldehyde, which among other ill effects poison nerve tissues and cause acute acidosis.

25. **Signs and Symptoms.** Inhalation of low concentrations causes headache, nausea, vomiting, and irritation of mucous membranes. Stupor, dizziness, cramp, digestive disturbances, irritation of the bladder, acidosis and depression of the nervous system follow inhalation of high concentrations. Ingestion leads to acute intoxication, headache, violent vomiting, and acidosis. Optic neuritis and blindness may result from inhalation or ingestion.

26. **Prevention.** The normal precautions against the inhalation of fumes and vapours are necessary. Everything possible must also be done to prevent theft of methyl alcohol for illicit drinking.

27. **Toxic Concentrations.** Severe toxic effects occur after exposure to 2,000 ppm for 1 hour, and symptoms of illness may arise after exposure to 500 ppm for more than a short time. The maximum allowable concentration (M.A.C.) is 200 ppm.

28. **Treatment.** Immediate treatment of a person who has ingested methyl alcohol consists of emetics and gastric lavage with 4 per cent. sodium bicarbonate solution. This should be followed by warmth, rest, and measures to correct acidosis.

Ethyl Alcohol

29. **Properties.** Synonyms for ethyl alcohol (C2H5OH) are ethanol and grain alcohol. Commercial alcohol consists of 95·6 per cent. ethyl alcohol and 4·4 per cent. water. Ethyl alcohol is a colourless, inflammable liquid with a characteristic odour. It is miscible with water and most organic solvents. It boils at 78·3°C., freezes at —117·3°C., and has a flash point of 12°C.; the vapour pressure at 20°C. is 44 mm. of mercury.

30. **Uses and Occurrence.** Ethyl alcohol is the basis of all reputable alcoholic drinks. It is a solvent for nitrocellulose, lacquers, shellac, resins, adhesives, inks, cosmetics, and drugs. It is used in the manufacture of synthetic rubber and plastics, as anti-freeze, and for explosives, as well as in the chemical industry.

31. **Absorption and Effects.** Inhalation of fumes causes some irritation of the respiratory tract and narcosis. Contact with the fumes irritates the eyes. Ingestion of ethyl alcohol, depending on the quantity, results in varying degrees of gastro-intestinal irritation and central nervous depression. As it is completely oxidized to carbon dioxide and water fairly quickly, cumulative effects are not the rule.

32. **Signs and Symptoms.** According to the amount inhaled or ingested varying degrees of intoxication occur. Chronic alcoholic poisoning may cause permanent central nervous damage. Prolonged exposure to fumes may lead to dermatitis and conjunctivitis.

33. **Toxic Concentrations.** Severe toxic effects occur in persons exposed to 8,000 ppm for 1 hour. Exposure for more than a short time to 2,000 ppm may lead to symptoms of illness. The maximum allowable concentration is 1,000 ppm.

Propyl Alcohol

34. **Properties.** The formula for iso-propyl alcohol is (CH3)2.CHOH, and synonyms for it are propanol—two, or secondary propyl alcohol. It is a clear, colourless fluid with a slight odour of acetone. It is miscible in water, ether, and other alcohols. The boiling point of iso-propyl alcohol is 82·4°C., and freezing point —89·5°C. Its volatility is too low to contaminate air, unless it is heated. Industrially it constitutes little risk in consequence, and no case of industrial poisoning has been reported.

Butyl Alcohol

35. **Properties.** The formula for butyl alcohol is (C2H5-CH2-CH2OH) and a synonym for it is butanol. It has four isomers and is a colourless fluid freely soluble in organic solvents. It is slightly soluble in water (one part to eleven at room temperature). The boiling point of n-butyl alcohol is 118°C., freezing point —90·2°C., and flash point 34°C. The vapour pressure at 20°C. is 4·3 mm. of mercury and at 40°C. 18·6 mm.

36. **Uses and Occurrence.** Butyl alcohol is used as a solvent of lacquers, resins, plastics, in the chemical industry, in photography, as a constituent of hydraulic brake fluids, for the blending of chemicals, and as an oil additive.

37. **Absorption and Effect.** The inhalation of butyl alcohol fumes causes the same effects as ethyl alcohol but the vapour is more irritating. Contact of eyes and skin with the vapour causes conjunctivitis and keratitic dermatitis.

38. **Toxicity.** Experimentally butanol is three times as toxic as ethyl alcohol, but this is offset by its lower volatility and solubility in body fluids. The maximum allowable concentration (M.A.C.) is 50 ppm.

AMMONIA

39. **Properties.** Ammonia is a colourless gas with a pungent odour. It is easily liquefied under pressure and very soluble in water with which it forms ammonium hydroxide. A strong solution contains 28 per cent. ammonia at 25°C. Ammonia (NH3) has a boiling point of —33·3°C. and melting point of —77·7°C.

40. **Uses and Occurrence.** Ammonia occurs naturally as part of the nitrogen cycle, and is a by-product of coal tar distillation. It is used as a refrigerant, in petroleum refining, vulcanization of rubber, the manufacture of storage batteries, in the steel industry, chemical industry, fertilizer industry, and for water purification. It is supplied either as a liquid under pressure in steel cylinders or in carboys as a solution of hydroxide.

41. **Absorption and Effects.** Inhalation of ammonia vapour above certain concentrations is highly irritant to the respiratory tract. Contact with concentrated vapour also causes irritation of the eyes and skin. Contact with liquid ammonia causes burns of the eye and skin, while ammonia released from under pressure will freeze the tissues. Ammonia is not usually met in toxic quantities except in massive accidental exposures. The severity of results depends on the time elapsing before escape is possible. Ample warning is given of a gradual increasing concentration as odour and irritation are detectable before a dangerous level is reached, even to people who have developed a tolerance for ammonia.

42. **Signs and Symptoms.** High concentrations cause a sensation of choking, with cough and arrest of respiration. Pulmonary oedema may follow and sequelae include chronic catarrh, salivation, and retention of urine. There is also immediate damage to conjunctiva and cornea. Abdominal pain and nervousness appear 24 hours after gassing, when there is also a rise in blood haemoglobin level.

43. **Prevention.** The best prevention consists of awareness of potential accidents. Workers should be instructed of the significance of effects produced by varying concentrations. When these indicate danger they should remove themselves from exposure. For rescue operations special cannister respirators can afford protection for a short time, but self-contained or remote-breathing apparatus are best.

44. **Toxic Concentrations.** Severe toxic effects occur after exposure to 500 ppm for 1 minute. Exposure for more than a short time to 200 ppm may lead to symptoms of illness. The maximum allowable concentration is 100 ppm. Odour is detectable at 53 ppm and slight irritation may occur at 70 ppm.

45. **Treatment.** Contaminated clothing must be removed at once and any contaminated skin well sluiced with water. Immediate inhalation of oxygen will reduce the chance of pulmonary oedema. If the eyes are affected, copious irrigation with water should be started at once and the patient should be referred to an ophthalmologist without delay.

ARSENIC

46. **Properties.** The metal, arsenic (As), is not often met industrially as such. It has an atomic weight of 74·9, melts at 814°C. and sublimates at 611°C. The forms in which it usually occurs in industry are the oxides, As2O3, As2O4, and As2O5. Arsenical salts such as the arsenates of lead and calcium, cupric acetoarsenite (Paris green), and cupric arsenite (Schweinfurth green), are also common. The dusts of arsenic salts are very light and so are highly dispersible. Toxicologically the most important arsenic compound is arsine, As2H3.

47. **Uses and Occurrences.** Arsenic or its compounds are used in the manufacture of metal alloys, in wood preservatives, dyes and paints, as an insecticide, rat poison, cattle dip, and therapeutically. Arsine is evolved by nascent hydrogen in the presence of arsenic. The action of acids on metals containing arsenical impurities, or of water on certain industrial residues containing arsenic, will result in the evolution of this gas.

48. **Absorption and Effects.** Arsenic poisoning by ingestion is rare in industry, where it occurs in acute or chronic form, by inhalation of or contact with dust, fume, or arsine. The chronic form is due to dust or fume and affects the skin, respiratory system, nervous system, and gastro-intestinal tract. If exposure is sufficiently prolonged arsenic may be carcinogenic. Acute poisoning occurs from exposure to arsine, which is a haemolytic poison.

49. **Signs and Symptoms.** Dermatitis and eczema may occur, the skin becoming oedematous and ulcerated. Bronze pigmentation may develop and scleroderma with continued exposure; if exposure is sufficiently prolonged epitheliomatous ulceration may result. There may be blepharitis and loss of hair. Irritation occurs of the nose and throat, with perforation of the septum, hoarseness, and cough. Pulmonary carcinoma may follow long exposure. Neuralgic pains, multiple neuritis and slight motor palsy have been recorded. Depending on the acuteness of the poisoning varying degrees occur of vomiting, diarrhoea, thirst, cyanosis, and circulatory collapse.

Arsine

50. Arsine is one of the few industrial poisons that can kill outright. Its action may be delayed up to two days, although haemoglobinuria can occur in six hours, jaundice in 24 hours. Nausea, vomiting, epigastric pain, headache and dizziness with exhaustion and shivering may in mild cases simulate food poisoning. The urine becomes dark, containing albumen and casts. Blocking of the renal tubules by the products of haemolysis may lead to anuria. Jaundice occurs and the liver is tender and subject to haemorrhagic inflammation. Within three days of onset the blood count may have fallen to below a million red cells. Haemoglobin is greatly diminished and the colour index low, with symptoms of anoxaemia. Delirium and coma result while death, which is often due to anuria, may follow.

51. **Prevention.** Besides the routine measures to control hazards from dust and fume, workers require education on potential risks inherent in their work from arsine poisoning. In particular they should be made familiar with the early signs of poisoning. In rescue operations remote or self-contained breathing apparatus is essential.

52. **Toxic Concentrations.** The maximum allowable concentration of arsine is 0·5 ppm. Severe toxic effects follow exposure to 10 ppm after 1 minute and symptoms of illness result from exposure to 1 ppm for a short time. The maximum allowable concentration (M.A.C.) of arsenic is 0·15 mgm. per cubic metre of air.

BENZENE

53. **Properties.** Benzene (C_6H_6) is also known as benzol and is a coal-tar derivative. It is not to be confused with the petroleum product benzine. There are three grades of benzene; the pure crystallizable form,

100 per cent., which distils below 100°C.; 90 per cent. benzene which contains also appreciable amounts of toluene and xylene; and the 50 per cent. form with a great variety of impurities. Pure benzene is a colourless volatile fluid with a characteristic pleasant odour. It is inflammable and burns with a smoky flame, is sparingly soluble in water, and easily miscible with organic solvents. The boiling point is 80·1°C., freezing point 5·5°C., and the flash point −12° to −10°C. It is a solvent for oils, fats, waxes, gums, cellulose, natural and synthetic resins; it is a constituent of a large variety of varnishes and dopes as well as of paint and varnish removers. With the exception of tetrachlorethane, benzene is the solvent most dangerous to health. It also forms an explosive mixture with air at a concentration of 5 to 8 per cent.

54. **Uses and Occurence.** Benzene is used in the manufacture of a large number of chemical dyestuffs and their intermediates, motor fuel, explosives, rubber, paints, and varnishes. It occurs also in engineering as a degreasant or solvent and as a constituent of some aircraft dopes.

55. **Absorption and Effects.** Absorption is by inhalation and possibly through the skin. Effects may be acute or chronic, depending on length and concentration of exposure, but there is great individual variation in susceptibility. The acute effects of benzene are on the central nervous system and cause narcosis, with convulsions and death in severe cases. In milder forms alcoholic intoxication is simulated. Chronic exposure causes damage to the blood-forming tissues, especially the marrow of the long bones, and to lymphatic tissues. Before marrow destruction there is stimulation of red cell formation; after destruction the marrow remains capable of regeneration to some extent. Benzene also has a direct toxic effect in the blood stream on leucocytes and platelets and may have some neurotoxic action. In the body it is oxidized to phenol and dioxybenzol; these combine in the kidney with sulphuric and glycuronic acids to form conjugate acids and corresponding dioxy compounds, which are excreted in the urine.

56. **Signs and Symptoms.** Acute benzene poisoning is industrially less important than is chronic.

(*a*) *Acute.* Exposure to heavy concentrations results in rapid unconsciousness preceded by helpless confusion, or euphoria, restlessness, fatigue, and drowsiness. Unconsciousness lapses into coma with convulsions and may be followed by death. Headache, vertigo, vomiting, weakness, ataxia, twitchings and loss of consciousness may follow exposure to lower concentrations. In some cases there may be a stage of wild excitement or delirium.

(*b*) *Chronic.* Although benzene poisoning may become manifest while the patient is still exposed to this substance at work, it is not uncommon for it to occur years after exposure has ceased. Similarly, if poisoning has occurred, signs and symptoms persist for varying periods after the patient has been removed from exposure. Early symptoms are general ill health and malaise, but cases are most frequently first seen at the start of the haemorrhagic stage. This consists of purpura, epistaxis, bleeding from the gums and into the retina, stomach, intestines, and uterus. There is anaemia, leucopenia (especially of granulocytes) and thrombocytopenia. Secondarily infected ulceration occurs, especially of the mouth and throat; bleeding time may be prolonged and clotting delayed. Death may be the result of haemorrhage or of toxaemia from secondary infections. Although the blood picture in benzene poisoning is classically anaemia, leucopenia, and thrombocytopenia, it varies widely. One reason for this is that as one part of the marrow is being destroyed another is being stimulated. The earliest sign and the most frequent is a decrease in red cells with some macrocytosis. Degenerate or primitive forms of red cell may be present. In some cases anaemia is severe but usually it is moderate and is followed by a fall in the platelet count and reduction of haemoglobin, so that the colour index is less than one. The white cells may be reduced to a very low level and occasionally this is the initial sign of poisoning. Owing to the destruction of granular polymorphs there is a relative lymphocytosis.

57. **Prevention.** All the general precautions to control fumes from a volatile liquid are essential, if no substitute for benzene can be used. When there is a known risk from this solvent, periodic checks of the concentration of benzene in the atmosphere should be arranged. Only workers in the best of health should be allowed to work with benzene, and exposure should be limited by rotation of work. Workers should be educated in the risks of their work and told of the early symptoms of poisoning. They should be instructed to report sick if these appear. Periodic medical examinations should be made, including differential blood counts, and removal from exposure should follow the least suspicion of benzene poisoning.

58. **Toxic Concentrations.** Severe toxic effects follow exposure to 1,500 ppm for 1 hour. Symptoms of illness may follow exposure for more than a short time to 500 ppm. The maximum allowable concentration is 50 ppm in the atmosphere.

59. **Treatment.** Acute poisoning should be treated by artificial respiration and the administration of oxygen. The anaemia of chronic poisoning may be treated by repeated transfusions, liver, and iron. A diet rich in calcium and fat with intravenous glucose saline and vitamin C has been advised. Stimulation of the marrow with pentnucleotide (10 to 40cc. intramuscularly daily) or by irradiation may be tried. If poisoning is severe there is little chance of therapeutic success.

CADMIUM

60. **Properties.** Cadmium (Cd) is a metal of atomic weight 112·41 which melts at 321°C. and boils at 767°C. On heating in air to high temperatures it volatilizes and burns with a bright flame, producing dense, brown fume of cadmium oxide. It is soluble in hydrochloric acid and to a small extent in sulphuric acid. Associated compounds met in industry are cadmium hydroxide, Cd(OH)2, the ammonium and cyanide salts, Cd(NH3)4 and Cd(CN)4.

61. **Uses and Occurrence.** Cadmium is used in electroplating, manufacture of alloys, pigments and chemicals, in metallization and the making of dry electric batteries.

62. **Absorption and Effects.** The main risk is the accidental ignition of finely divided cadmium and inhalation of the resultant cadmium oxide fume. It may also be absorbed by ingestion of salts formed by the action on cadmium-plated containers of acid foods or fruit juices. Inhalation

causes acute inflammation of the respiratory tract, with pneumonitis, bronchopneumonia, or pulmonary oedema. Ingestion causes acute gastro-intestinal irritation, sometimes with renal damage.

63. **Signs and Symptoms.** The result of inhalation of fume is delayed, (compare nitrous fume). Some time after exposure a dry throat, with cough, headaches, vomiting, constriction of the chest and profuse sweating develop. Later there is more severe cough, pain in the chest, severe dyspnoea and prostration. After ingestion acute diarrhoea and vomiting follow in 15 to 30 minutes. There may be oliguria with a dark-coloured urine. Treatment of pulmonary and intestinal disturbances is symptomatic.

64. **Toxic Concentration.** The maximum allowable concentration of cadmium oxide is 1 mgm. per 10 cubic metres.

CARBON DIOXIDE

65. **Properties.** Carbon dioxide (CO2) is a colourless gas without odour. At atmospheric pressure water dissolves its own volume of carbon dioxide to form carbonic acid. The gas is less soluble in alcohol and other organic solvents. Under pressure it liquefies readily; rapid evaporation of the liquid causes freezing and the formation of dry ice. At N.T.P. the relative density of carbon dioxide is 1·53 and 1 litre weighs 1·97 grams.

66. **Uses and Occurrence.** Carbon dioxide is used for the manufacture of dry ice and mineral drinks, in the chemical industry, and as a fire extinguishant. It occurs in silos, brewery vats, wells, the holds of ships, vaults and cellars, sewers, boilers, coke ovens, and lime kilns.

67. **Absorption and Effects.** Inhalation of carbon dioxide is slightly irritating to the respiratory tract at high concentrations. Low concentrations stimulate the respiratory centre causing hyperventilation. The breathing of air containing 8 per cent. carbon dioxide or more causes asphyxia in a very short time. The signs and symptoms are those of anoxia and asphyxia, except that convulsions do not occur before death.

68. **Prevention.** Workers should be made aware of conditions where irrespirable carbon dioxide atmospheres are likely to be met. If these conditions are suspected a test can be made by lowering a lighted candle or other naked flame which will be extinguished if excess carbon dioxide is present. In rescue operations cannister respirators are useless since the atmosphere is irrespirable. Self-contained or remote-breathing apparatus is essential.

69. **Toxic Concentrations.** Exposure for 1 hour to 300,000 ppm causes severe toxic effects. Symptoms of illness may follow exposure for more than a short time to 10,000 ppm. The maximum allowable concentration is 500 ppm.

CARBON MONOXIDE

70. **Properties.** Carbon monoxide is a colourless gas without taste or smell. It boils at 190°C. and melts at —206°C., and has at N.T.P. a density relative to air of 0·967, one litre weighing 1·25 grams. It is slightly soluble in water and combines with metals, for example iron and nickel, to form carbonyls. It burns in air with a blue flame and forms an explosive mixture in air at a dilution of 12·5 per cent. by volume. In mines carbon monoxide is known as "black damp".

71. **Uses and Occurrence.** Carbon monoxide (CO) is a constituent of producer gas and coal gas, in which the content varies from 6 to 30 per cent. It is a normal by-product of combustion in the presence of inadequate oxygen. It is in consequence produced by blast furnaces, the gas of which may contain 24 to 30 per cent., from charcoal and coke braziers, coal fires and slow combustion stoves, and occurs in motor car, diesel and other internal-combustion engine exhaust fumes.

72. **Absorption and Effects.** Inhalation is followed by absorption from the lungs into the blood stream. Carbon monoxide has an affinity for haemoglobin 300 times that of oxygen. By the formation of carboxy-haemoglobin, the oxygen-carrying and dissociation properties of the blood are diminished and anoxaemia follows. Blood saturation of 60 to 80 per cent. is fatal. The tissues most sensitive to oxygen lack, for example nervous tissue, are those most rapidly damaged. Congestion of the cerebral vessels, with cerebral oedema and neuronal damage, also occurs. In those with vascular disease there may be damage to the basal ganglia and corpus striatum. Although there is no accumulation of carbon monoxide in the body, damage may occur on account of repeated doses. Some tolerance may be developed but permanent impairment of the central nervous system and polycythaemia have been reported.

73. **Signs and Symptoms.** The poison is an insidious one, the primary symptoms being headache and mental dullness. There is early loss of judgement and insight into the situation. Dizziness, nausea, abdominal pain and loss of power of the limbs may occur before loss of consciousness. The blood pressure drops, the heart dilates and auricular fibrillation develops. There is progressive depression of the respiratory centre. In those that recover pulmonary oedema or pneumonia may occur. Sequelae are mental confusion, loss of initiative and will power, lack of judgement and parkinsonism. There may be visual defects with reduction of the visual fields. The existence of chronic poisoning is disputed but the following symptoms have been attributed to it: headache, nausea, vomiting, muscular weakness, fatigue, depression, insomnia, irritability, dyspnoea, tachycardia, tremors, and increase in red cells and haemoglobin.

74. **Toxic Concentrations.** Severe toxic effects follow exposure to 400 ppm for 1 hour. Exposure to 150 ppm for more than a short time will cause symptoms of illness. The maximum allowable concentration (M.A.C.) is 50 ppm.

75. **Treatment.** Immediate treatment consists of removal of the victim to the fresh air, artificial respiration, and the administration of oxygen. Later blood transfusion may help. Anoxaemia does not immediately cease as fresh air is inhaled, as for other asphyxiants, but gradually diminishes as carbon monoxide is eliminated from the blood. The rationale of artificial respiration and administration of oxygen is to displace the carbon monoxide from the haemoglobin by the mass action of excess oxygen. Once displaced the carbon monoxide is eliminated unchanged from the lungs and is not oxidized to carbon dioxide.

CARBON TETRACHLORIDE

76. **Properties.** Carbon tetrachloride (C. C14) is also known as tetrachlormethane and C.T.C. It is a colourless volatile liquid, insoluble in water but soluble in alcohol and ether. It is not inflammable, has an

odour resembling chloroform, and is a lipsolvent. On heating it vapourizes and on thermal decomposition releases chlorine, hydrochloric acid, and a little phosgene. Its molecular weight is 153·8 and specific gravity 1·6; it boils at 77°C., has a freezing point of −23°C., and a vapour pressure at 25°C. of 114 mm. of mercury.

77. **Uses and Occurrence.** Carbon tetracholoride is used as a solvent in the rubber, lacquer, chemical, drug, and paint industries. In engineering it is used as a degreasant for metals and for the cleaning of textiles, particularly in dry-cleaning establishments. It is a fire extinguishant, an insecticide, and therapeutically an anthelmintic.

78. **Absorption and Effects.** Absorption is by inhalation, although poisoning from accidental or therapeutic ingestion has occurred. Effects may be acute or chronic and are on the central nervous system, liver, and kidneys. There may also be pulmonary irritation. Acute narcosis may occur and be rapidly fatal. Death may, however, be delayed 3 to 12 days and result from necrosis of the liver or acute nephritis with anuria. Recovery from narcosis may occur with no subsequent liver or kidney damage or a degree of damage that is not fatal. There is considerable variation in individual response to carbon tetrachloride poisoning, alcoholics being particularly susceptible.

79. **Signs and Symptoms.** Typically there is rapid loss of consciousness followed, unless death occurs, by nausea, vomiting, epigastric pain, diarrhoea, weakness, vertigo, headache, cough, and excitement. Three to twelve days later the urine may become dark, scanty, and loaded with albumen and casts. Complete anuria may follow and last several days; it may then cease, suddenly and spontaneously, or may persist leading to uraemia and death. During the same period the liver may become enlarged and jaundice may develop. Chronic exposure does not commonly cause poisoning but in such cases there is gastro-intestinal disturbance sometimes accompanied by jaundice, central nervous depression with headache, fatigue, irritability, insomnia, and loss of energy, while amblyopia with concentric restriction of the visual fields may occur. The solvent action of carbon tetrachloride may cause dermatitis.

80. **Prevention.** The routine measures for the control of fume are essential. As carbon tetrachloride is heavier than air, exhaust ventilation should extract from a low level. Pre-employment medical examination should exclude susceptibles such as alcoholics, diabetics, the obese and undernourished, those with hyperthyroidism or with lung, liver, and kidney complaints. Rotation of work may be advisable. Routine medical examinations should be carried out and, if poisoning is suspected, estimations of the icteric index, Van den Bergh reaction and blood calcium may be performed. Self-contained or remote-breathing apparatus is essential for rescue.

81. **Toxic Concentrations.** Severe toxic effects follow exposure for 1 hour to 2,000 ppm. Exposure to 500 ppm for more than a short time may cause symptoms of illness. The maximum allowable concentration (M.A.C.) is 50 ppm. The odour of carbon tetrachloride becomes apparent at 80 ppm and very strong at 475 to 790 ppm.

82. **Treatment.** If poisoning is by ingestion immediate treatment consists of emetics and gastric lavage, followed by resuscitation. If inhalation is the cause it is particularly important to remove the patient into fresh air as he may be lying in a pocket of carbon tetrachloride, which is

heavier than air and so tends to be more concentrated at floor level. Contaminated clothing should be removed and the skin cleansed, after which resuscitation by artificial respiration and administration of oxygen should commence, if the patient is unconscious. If the patient is shocked, fluids and calcium should be given by mouth or by transfusion. Subsequent renal or hepatic damage should be treated according to accepted methods.

CHLORINE

83. **Properties.** Chlorine (Cl) is a greenish yellow gas with a pungent irritating smell. Its atomic weight is 35·46 and at N.T.P. its density relative to air is 2·5. It boils at —34·7°C. and melts at —102°C. It is not combustible in air and is easily liquefied under pressure. There is risk of fire and explosion from its physical or chemical reactions with most substances. It is easily detected on account of its smell and power of irritation.

84. **Uses and Occurrence.** Chlorine is used in the purification of water, in the manufacture of disinfectants, bleaching, petrol refining, and the recovery of tin from scrap. It is also a war gas.

85. **Absorption and Effects.** Effects follow inhalation and contact. There is acute respiratory irritation, with massive exudation and damage to the pulmonary mucosa. Exposure of the eyes to the gas causes conjunctivitis and splashes by solutions result in acid eye burns of varying degree. Exposure of the skin causes lesions varying in severity from erythema to acid burns. In industry, poisoning is not common as the early warning from odour and irritation lead to rapid withdrawal from danger.

86. **Signs and Symptoms.** There is inflammation and pain in the nose and throat, followed by a deep burning pain in the chest. Cyanosis and dyspnoea follow as the massive exudation develops, causing respiratory embarrassment, pulmonary oedema, and pneumonia. Chronic pulmonary damage is a relatively frequent sequel.

87. **Toxic Concentrations.** Severe toxic effects occur after exposure of 1 minute to 10 ppm. Exposure to 4 ppm for more than a short time may cause symptoms of illness. The maximum allowable concentration (M.A.C.) is 1 ppm. The odour of chlorine is detectable at 3·5 ppm; it causes throat irritation at 15 ppm and cough at 30 ppm.

88. **Treatment.** Immediate treatment consists of removal of the victim to the fresh air and the administration of oxygen. Contaminated clothing should be removed and the eyes or affected areas of skin copiously irrigated with water. Subsequent treatment must be aimed chiefly at the prevention or relief of pulmonary oedema and pneumonia.

CHLORONAPHTHALENE

89. **Properties.** Synonyms for chloronaphthalene are chlorinated diphenyl, Halowax, Arochlor, Seekay, and Perna. There is a whole series of chloronaphthalenes, based on diphenyl (C6H5.C6H5), in which varying numbers of hydrogen atoms are replaced by chlorine. They range from thin fluids to crystalline or amorphous waxes, the more chlorine atoms being present the more waxy the compound. The waxes have excellent water resisting and insulating properties. They are free from moisture and do not absorb it, are neutral and non-corrosive. They are

not inflammable and are very resistant to the conduction of electricity. The chlorine content is from 20 to 65 per cent., boiling point 288° to 371°C., melting point 87° to 130°C., and specific gravity 1·4 to 1·7. The penta- and hexa- compounds are the most toxic.

90. **Uses and Occurrence.** The waxes are used for the insulation of condensers, wires, and cables, especially in warships. The lesser chlorinated members of the series are sometimes used as solvents of rubber, aniline, varnish, glue, and resins.

91. **Absorption and Effects.** The unheated wax is inert but skin contact leads to the development of a dermatitis known as "cable rash" or chloracne. If heated the wax gives off a highly toxic fume, absorption of which by inhalation causes acute yellow atrophy of the liver. The use of carbon tetrachloride as a solvent for the wax adds to the danger.

92. **Signs and Symptoms.** Skin eruptions occur in the form of chloracne, which is also caused by cutting oils containing chlorinated hydrocarbons. The acneiform eruption is caused by the irritation of the sebaceous glands, which become plugged by cell proliferation and excess secretion. Secondary infection may follow and a highly resistant exfoliative dermatitis develops. Inhalation of chloronaphthalene fume may result in anorexia, nausea, severe abdominal pain, and jaundice, with hypoproteinaemic oedema due to liver damage. Death may result from acute yellow atrophy of the liver.

93. **Prevention.** Workers must be informed of the danger when chloronaphthalenes are heated and be instructed to report sick at once if symptoms of intoxication occur. If heating of the waxes is likely, every means of fume control must be employed and, as the vapour is heavier than air, local exhaust ventilation should extract from low down. Men with impaired liver function should not be employed on this work. The maximum allowable concentration in the atmosphere of chloronaphthalene is 1 mgm. per cubic metre. Frequent changes of clothing, showers and washing facilities reduce the incidence of chloracne.

CHROMIUM

94. **Properties.** Chromium (Cr) is an inert metal of atomic weight 52·01, which boils at 2,200°C. and melts at 1,615°C. Associated compounds met in industry include chromic acid, chromates, and dichromates. The most toxic forms are the hexavalent compounds which are protein precipitants.

95. **Uses.** Chromium is used in electroplating and the hardening of steel; chromic acid in electroplating and lithography; chromates as mordants in dyeing, in explosives, paints, varnishes and rubber, in photography and in tanning. Dichromates are used in tanning and dyeing.

96. **Absorption and Effects.** Inhalation of chrome or its compounds results in lesions to the nose and upper respiratory tract. It has a caustic action in contact with the skin and mucous membranes. Chromates and especially dichromates are carcinogenic. When chromium is absorbed it is excreted by the kidneys.

97. **Signs and Symptoms.** In the nose there may be chronic inflammation, with a purulent discharge and crusting, followed by perforation of the septum. The perforation is painless, causes no deformity, and rarely heals. Conjunctivitis, pharyngitis and laryngitis may also occur. Skin contact results in dermatitis, which is exudative if caused by dichromates. Skin ulcers may form and become "chrome holes"; these are deep and punched out, relatively painless and never suppurate. Exposure to chromates or dichromates may eventually result in pulmonary carcinoma.

98. **Prevention.** The general measures for prevention are covered by the Chrome Plating Regulations, 1934. Local exhaust ventilation of electroplating tanks should be at the rate of 120 to 150 cubic feet per minute per square foot. The skin of the face and hands may be protected by a barrier cream containing 5 per cent. sodium hyposulphite, the nose by applying vaseline or lanoline ointment inside the nostrils. A 5 per cent. solution of sodium hyposulphite should be available for rinsing the face and hands after washing and for the treatment of skin contamination, abrasions, and cuts. The maximum allowable concentration of chrome as chromates is 0·1 mgm. per cubic metre.

99. **Treatment.** Skin contaminated with chrome compounds should be thoroughly cleansed in running water, then scrubbed with 5 per cent. sodium hyposulphite. Ulcers and abrasions should be thoroughly cleaned and dressed with sodium hyposulphite for three days, then for a few days more with sodium citrate, lactate or tartarate (5 to 10 per cent.), to dislodge chrome from the tissues. Dermatitis, which may be erythematous, weeping or fissured, should otherwise be treated on orthodox lines. The nose may be irrigated with a solution of sodium bicarbonate and sodium chloride. Perforations should be cleaned with eusol and an ointment applied containing zinc oxide, icthyol, and compound tincture of benzoin.

CYANIDE

100. **Properties.** Hydrogen cyanide (HCN) is a clear colourless fluid of low boiling point (26°C.). It is volatile and smells of almonds. It is very soluble in water and alcohol, but solutions decompose rapidly. Synonyms for hydrogen cyanide are prussic acid, cyanhydric acid, and formonitrile. Associated compounds include sodium and potassium cyanides.

101. **Uses and Occurrence.** Cyanides are used in the control of insects and rats, in the case-hardening of metals, in the extraction of gold, and the manufacture of dyes or chemicals. Gas may be liberated in the heat treatment of metals and when cyanides are treated with acids in certain processes, for example in electroplating. It may also be formed by the wetting of dross contaminated with cyanides.

102. **Absorption and Effects.** In industry ingestion is rare. The vapour may be inhaled and can also be absorbed through the skin. Percutaneous absorption also occurs if clothes or skin are contaminated by a cyanide solution. The cyanogen compounds are protoplasmic poisons and arrest activity by inhibiting oxidation. Internal respiration is prevented and asphyxia results.

103. **Signs and Symptoms.** Poisoning may be very rapid with death in a few moments. In less acute forms there is irritation of the throat, difficulty in breathing and palpitations, watering of the eyes, headache,

giddiness, and weakness of the limbs. Collapse, convulsions, slow shallow respiration, a cold sweat and paralysis may follow. If the victim survives for a few hours there is a chance of successful resuscitation.

104. **Prevention.** In industry cyanide poisoning is usually the result of accident or ignorance. In consequence, rescue arrangements are most important. When there is a risk of such occurrences, remote-breathing or self-contained air respirators should be available and life lines also. In emergencies respirators with charcoal absorbent canisters are of little protection, but this can be increased by additional pads impregnated with caustic soda which will neutralize the gas chemically up to concentrations of 200 ppm. The pads must be renewed after each exposure. Over 200 ppm remote or self-contained respirators are essential. It must be emphasized that respirators do not protect against skin absorption. Suitable protective clothing is also needed and rescuers should take a shower after exposure.

105. **Toxic Concentrations.** Severe toxic effects follow exposure for 1 minute to 40 ppm. Symptoms of illness may occur after exposure to 20 ppm for more than a short time. The maximum allowable concentration (M.A.C.) is 10 ppm.

106. **Treatment.** The victim must be removed from a contaminated atmosphere; contaminated clothing must be removed. As already stated, rescue workers should protect themselves from toxic exposure. Inhalations of amyl nitrite must be given immediately and, for this purpose, stocks of amyl nitrite capsules should be kept in the workplace. The capsule is broken into a handkerchief which is then held over the patient's nose and mouth for 30 seconds whilst manual artificial respiration is applied; this procedure is repeated at short intervals for a period of 5 minutes. The doctor administers sodium nitrite (0·5 G. in 15 ml. water) by slow intravenous injection, viz. over a ten minute period. Thereafter, and through the same needle, sodium thiosulphate (25·0 G. in 50 ml. water) is likewise given intravenously over a ten minute period. These two drugs are given thus because (*a*) the nitrite causes the formation of methaemoglobin which combines with the cyanide ion to form harmless cyanmethaemoglobin; (*b*) as cyanmethaemoglobin subsequently dissociates, the thiosulphate combines with the released cyanide ion to form harmless thiocyanate. A doctor's set containing these substances must therefore be kept available at such workplaces. If cyanide has been swallowed, the victim, if conscious, should be made to swallow a quarter pint of antidote mixture which consists of equal parts of:—

Solution A. 158·0 G. $FeSO_4$ crystals in 1 litre of water.

Solution B. 60·0 G. anhydrous Na_2CO_3 in 1 litre of water.

The antidote mixture should also be applied locally to areas of contaminated skin. Bottles of antidote solution are thus part of the essential first aid and medical equipment located at such workplaces.

GLYCOLS

Ethylene Glycol

107. **Properties.** Ethylene glycol (CH2OH.CH2OH) is a colourless, viscous, sweet-tasting fluid miscible in water and alcohol. It is very hygroscopic and will absorb from saturated air at room temperature twice its own weight in water. It is not inflammable, boils at 197°C. and freezes at —30°C. Its molecular weight is 62 and vapour pressure at 20°C. is 0·12 mm. of mercury. As a result of this low volatility, concentrations, even in unventilated places, do not become high.

108. **Uses and Occurrence.** Ethylene glycol is most commonly used in anti-freeze coolants and de-icing fluids. It also occurs as an industrial solvent, in explosives, cosmetics, and flavouring essences.

109. **Absorption and Effects.** Ethylene glycol poisoning only occurs from the ingestion of a quantity, accidentally or under the mistaken impression that it is a good substitute for alcohol. About 100 ml. appears to be the fatal dose and the effects are mainly on the central nervous system and kidneys, death being due to respiratory failure following on central nervous depression, or to haemorrhagic nephritis from the formation of oxalic acid crystals in the renal tubules. Central nervous lesions range from congestion and oedema to a generalized encephalitis.

110. **Signs and Symptoms.** Ingestion of ethylene glycol is followed by intoxication, vomiting, twitching and tremor, stupor, convulsions, and coma with the skin cold and cyanotic. If death does not occur rapidly, haematuria and oxaluria follow, then anuria and uraemia.

111. **Prevention.** It should be made generally known that ethylene glycol is not a good substitute for alcoholic drinks and that its consumption may be fatal. Unauthorized access to it should in addition be made as difficult as possible.

112. **Treatment.** In acute poisoning by ingestion immediate treatment consists of gastric lavage and if necessary resuscitation as in acute alcoholic intoxication. Subsequently treatment for oxalate poisoning is indicated.

Other Glycols

113. **Ethylene glycol monomethyl ether** (methyl cellosolve). This is used as a solvent for lacquers and the trubenizing of collars or shirts. Acute poisoning is extremely rare. Chronic effects have been reported on the central nervous system, resulting in a toxic encephalopathy, and on the bone marrow, causing a macrocytic anaemia with relative lymphocytosis.

114. **Ethylene glycol menoethyl ether** (cellosolve). Cellosolve is used as a lacquer solvent, especially for kitchen furniture. There have been no reported acute or chronic cases of poisoning in man.

KEROSINE AND PETROLEUM

General

115. The distillation of crude oil results in the production of petroleum fuels, the properties of which vary according to the fraction of separation. For example petrol, which has a boiling point between 60° and 120°C., is a higher distillate than kerosine with a boiling point between 140° and 300°C. The higher the distillate the more volatile and combustible is the fuel, the industrial toxicity of which rises the more carbon atoms there are in the hydrocarbon chain.

Kerosine

116. **Properties.** Synonyms for kerosine include paraffin, vapourizing oil, and kerosene. It is made up of complex hydrocarbons such as paraffins, naphthenes, and aromatics, the exact composition varying according to the grade of distillation. Volatility also depends on this and is

measured by the flash point. Kerosine distillates have a flash point (Abel) of not less than 73°F. The sulphur content is rarely more than 0·4 per cent., but on combustion this results in the evolution of sulphur dioxide fumes which are irritant and corrosive.

117. **Uses.** Kerosine is used in lighting, heating, cooking, as fuel for heavy internal combustion and jet engines, for degreasing machine parts, and as a solvent for insecticides. The composition is varied according to use, a high proportion of paraffin hydrocarbons being required in a good burning oil, whereas naphthene and aromatic compounds that burn with an oily smoke and prevent knocking are needed in greater amounts in vapourizing oils for engines.

(*para 118 on page 155.*)

118. **Absorption and Effects.** Industrial poisoning from kerosine does not occur, but there are occasional cases of accidental ingestion especially in children. Skin contact however leads to dermatitis, and massive exposure of the skin to jet engine fuel may cause chemical burns.

119. **Signs and Symptoms.** Ingestion is followed by gastro-intestinal upset, variable central nervous depression, and possibly lipoid pneumonia or pulmonary oedema. It is uncertain whether the pulmonary damage is due to ingestion alone or whether it results from aspiration of kerosine during swallowing or vomiting. Dermatitis takes the form of an oil acne, with folliculitis, comedones, follicular papules, and pustules.

Petrol

120. **Properties.** Petrol is derived from the fractional distillation range above kerosine, that is from the first fraction. It consists of highly volatile complex hydrocarbon compounds, mainly octane, heptane, and hexane. The composition varies according to use, for example piston aircraft engines require a high octane fuel. To improve performance it may also contain additives, of which tetraethyl lead is the most important toxicologically.

121. **Uses.** Petrol is used in heating, lighting and cooking burners, for degreasing metal, and as a fuel for internal combustion engines. Hazards may arise from it in carburettor testing, refuelling, maintenance of aircraft and motor vehicles, handling of leaky containers in storage depots, and the cleaning of storage or transport tanks.

122. **Absorption and Effects.** Absorption is mainly by inhalation, but it may possibly occur through the skin also. There have been cases of accidental ingestion. The effect of acute poisoning is on the central nervous system, being narcotic and additionally irritative. In chronic poisoning there are central nervous depression, psychological disturbances, and rarely effects on the blood.

123. **Signs and Symptoms.** Severe poisoning by the inhalation of petrol fumes results in narcosis, unconsciousness and death, or if there is recovery, by delirium, vomiting, cyanosis, and shallow or stertorous breathing, with a thready pulse. Less severe exposure causes a condition simulating the excited stage of alcoholic intoxication, without incoordination or staggering. Inhalation of lesser concentrations of fume over a period leads to lassitude, drowsiness, heaviness in the head, and possibly sleep or unconsciousness with amnesia. Acute petrol poisoning may be followed, on recovery, by sequelae of nervous and mental disturbances. Chronic poisoning may result in headache, giddiness, anorexia, respiratory complaints, fatigue, drowsiness, and neuritic symptoms. Anaemia has also been reported. Petrol containing tetraethyl lead may cause lead encephalopathy (see LEAD.)

124. **Prevention.** Indoors the usual precautions against fumes should be taken. The general precautions to adopt when handling petroleum and allied substances, and in particular when storage and transport tanks are being cleaned, are described in A.P. 3160.

LEAD

125. **Properties.** Lead (Pb) is a heavy malleable metal resistant to sulphuric acid but readily oxidized in the presence of weak organic acids. It is usually coated with a thin layer of grey oxide which protects it from corrosion. It has an atomic weight of 207·22, a boiling point of 1,470°C., and melts at 327°C. When lead is heated a surface scum of suboxide is formed, disturbance of which causes lead particles to disperse into the air. Danger of air contamination by lead fume thus starts at a temperature lower than that of vapourization. Lead carbonate, sulphate and monoxide are more toxic than metallic lead; lead arsenate is very poisonous owing to its arsenic content. The toxicity of lead acetate is very high when ingested, but it is a sticky substance and not industrially dangerous, since it does not form dust. The organic compound tetraethyl lead is a clear, heavy, oily liquid, with a sweetish odour. It is volatile at room temperatures, highly soluble in lipoids, and very poisonous.

126. **Uses and Occurrence.** Lead and its compounds are used in pigments, or cable coverings, in accumulators and printing. Tetraethyl lead is added to petroleum fuels to reduce knocking and is a special risk when sludge is removed from petrol storage tanks. Lead dust or fumes are met in such processes as the oxyacetylene cutting of steel covered with lead paint, the repair of accumulators, soldering, the remelting and handling of printing type, and the burnishing of soldered joints.

127. **Absorption and Effects.** Industrially only the inhalation of lead dust and fume are of importance, although tetraethyl lead may also be absorbed through the skin. The effects of inorganic lead compounds depend more on their solubility in tissue fluids than on particle size of dust or fume; after absorption lead is transported in the blood in a finely divided colloidal state as phosphate. It is excreted in the urine and faeces but, once the excretory threshold is exceeded, it is deposited in the trabeculae of bone as tertiary lead phosphate. Intoxication occurs, however, before the stage of bone storage, while lead is still in the blood and tissues. Lead has a direct effect on the red cells by surface absorption, which causes them to become brittle and to break down. It also affects the central and peripheral nervous systems, the muscles, the great organs, and the blood vessels. Tetraethyl lead on account of its lipoid solvency has an especial affinity for the central nervous systems.

128. **Signs and Symptoms.** No single sign or symptom is reliable in the diagnosis of plumbism. The prodromal symptoms of acute lead poisoning are malaise, anorexia, nausea, vomiting, constipation alternating with diarrhoea, severe headaches, weakness, lassitude, and disturbed sleep. These are followed by severe and intractable attacks of colic. Lead encephalopathy is not common in acute poisoning by inorganic lead, but is the usual result of tetraethyl lead intoxication. It consists of insomnia, delusions, excitement, muscular twitching, hallucinations, and acute mania. There may be visual disturbances. Lead absorption may, however, occur without intoxication. Early signs are general ill health and pallor, Burton's blue line on the gums, and anaemia with punctate basophilia. There may also be tremor and muscular weakness. Punctate basophils are primitive red cells (reticulocytes) modified by the action of lead so that stippling takes the place of the reticulum. Excess lead is present in the urine, in which the normal level is 0·21 mgm. per litre. Chronic lead poisoning may take the form of palsies of the muscles most commonly used at work, for example wrist drop in painters. Arteriosclerosis, nephritis and hypertension are other chronic manifestations, while multiple sclerosis and peptic ulcer have also been attributed to it.

129. **Prevention.** The routine precautions against the inhalation of dust and fume are essential. In particular lead should not be used if there is a practicable substitute for it, and there must be close medical supervision of those working with lead and its compounds. They should be medically examined quarterly (or more frequently if there is a statutory requirement), when a blood count, including a punctate count, should be carried out. Adequate arrangements are necessary for washing and changing facilities as well as for protective clothing. There are numerous statutory regulations governing work in which lead is a risk; these are contained in Factory Orders, published by H.M.S.O.

130. **Toxic Concentration.** The maximum allowable concentration (M.A.C.) of lead in the atmosphere is 0·15 mgm. per cubic metre.

MERCURY

131. **Properties.** Mercury (Hg) is a silvery mobile liquid. It forms mercuric and mercurous inorganic salts and various mercurial organic compounds. Most metals dissolve readily in or amalgamate with mercury, which vapourizes at room temperature. In air saturated with mercury there is 1·84 ppm at 20°C. and 8·5 ppm at 40°C. The rate at which saturation is reached depends on temperature, pressure, the area of the surface of mercury exposed, and the rate of air exchange. The atomic weight is 200·61; boiling point is 357°C. and freezing point −39°C. Soluble mercury salts are violent corrosives.

132. **Uses and Occurrence.** Mercury is used in electrical apparatus, the manufacture of scientific instruments, in pharmacy and chemistry. It is a constituent of explosives, antifouling paint and, in organic forms, of agricultural fungicides. Mercury became notorious, as an industrial poison, in the silvering of mirrors by the old amalgam process and in the carrotting of fur in the hat trade (hence "mad as a hatter").

133. **Absorption and Effects.** Absorption in industry is by inhalation of dust or fume, but mercury can be absorbed through the skin and therapeutic poisoning by this means or by ingestion have occurred. Industrial poisoning is typically chronic and affects the nervous system mainly. Mercury fulminate causes dermatitis. Organic mercurials cause specific irreversible degeneration of the posterior column of the spinal cord, of its occipital continuation, and of the cerebellum.

134. **Signs and Symptoms.** Inorganic mercury intoxication takes the form of salivation, stomatitis, loss of teeth and cachexia, with mercurial erethism. The latter consists of intention tremor, nervous shyness and shrinking, loss of confidence, vague fears, and inability to perform a task under observation. There is irritability, drowsiness, insomnia, apathy, and amnesia, with at times outbursts of anger on trifling provocation. The gait may be unsteady. There is some resemblance to chronic encephalitic parkinsonism. Intoxication by organic mercurial compounds causes ataxia, dysarthria, muscular inco-ordination, and optic atrophy with gross constriction of the visual fields; there are no mental changes. Fulminate dermatitis is severe and accompanied by conjunctivitis, blepharitis, and inflammation of nose and throat. Punched-out ulcers or "holes" occur if particles of fulminate become lodged in abrasions or cracks on the skin.

135. **Prevention.** Prevention consists of all measures to protect workers against fume and dust. There should be periodic medical examinations

and estimates of mercury in the urine if absorption is suspected. If excretion exceeds 0·25 mgm. per litre, there is hazardous exposure to mercury.

136. **Toxic Concentration.** The maximum allowable concentration (M.A.C.) is 0·1 mgm. per cubic metre of atmospheric air.

METHYL BROMIDE

137. **Properties.** Methyl bromide (CH3Br) is also called monobromomethane. It is a stable substance very slightly soluble in water but easily dissolved in acolhol, ether, chloroform, and carbon disulphide. It has no flash-point and its vapour is not inflammable. At high temperature it decomposes into hydrobromic acid, carbon dioxide and water, but if little oxygen is present carbonyl bromide and carbon monoxide are formed. It is almost odourless except at very high concentrations and is not immediately irritating to eyes or nose; there is thus little warning of its presence. The molecular weight is 94·95 and specific gravity 1·7: it boils at 4·5°C. and freezes at —94°C.

138. **Uses and Occurrence.** Methyl bromide is used as a methylating agent in chemical and colour manufacture. It is a fire extinguishant, insecticide, and refrigerant. It is most commonly met as a fire extinguishant.

139. **Absorption and Effects.** Absorption is by inhalation. Methylbromide also causes lesions to skin and mucous membranes by contact. Owing to lack of warning of its presence, high concentrations can be inhaled unaware. The effects, often delayed, are on the central nervous system. There may be narcosis, but death may occur without this. Methyl bromide is broken down in the body to methyl alcohol and sodium bromide; excretion is slow so cumulative poisoning can occur. Contact causes severe blistering of the skin, the lesions healing with difficulty; there is also marked irritation of the conjunctivae and respiratory mucous membranes.

140. **Signs and Symptoms.** Massive exposure results in collapse, unconsciousness, coma, convulsions and death with no latent period. In more moderate exposures, after a latent period of varying duration, there is abdominal pain, nausea, vomiting, weakness and irritability, headache, cyanosis, giddiness and somnolence. This is followed by clonic spasms of the muscles, excitement, convulsions, coma, and death or recovery. There may be pulmonary oedema and eye damage, such as retinal haemorrhage. If recovery occurs it is slow with delirium, depression, bewilderment, and other nervous disorders. There may be permanent central nervous system damage. Post-mortem, brain and nerve tissues are oedematous, while the lungs are oedematous and engorged. Skin exposed to liquid or gaseous methyl bromide after a few hours develops massive, painful blisters.

141. **Prevention.** Methyl bromide should only be manipulated, for example in the filling of containers or extinguishers, by an enclosed process or at 10°C. Extinguishers should not be used in enclosed spaces or emptied indoors. The periodic inspection of containers is essential. If spillage occurs indoors workers should leave the building at once. Contaminated clothes must be removed immediately and the skin washed with a weak solution of sodium carbonate. Methyl bromide soaks

into and is retained by rubber and leather; these substances are of no use for protective clothing. Remote-breathing or self-contained breathing apparatus must be used for entering contaminated areas.

142. **Toxic Concentrations.** Exposure to 250 ppm for 1 minute will give rise to severe toxic effects. Symptoms of illness may follow exposure for more than a short time to 50 ppm. The maximum allowable concentration (M.A.C.) is 20 ppm.

NITROGLYCERIN

143. **Properties.** Nitroglycerin is a nitric acid ester of glycerol and is also known as glyceryl nitrite. The formula is CH2 (NO3). CH(NO3). CH2(NO3). It is a colourless, oily fluid with a sweet burning taste, of density 1.6. It is very slightly soluble in water, but freely in alcohol and ether. It is very sensitive to slight shock which causes violent detonation. Kieselguhr absorbs up to two or three times its own weight of nitroglycerin and still remains dry. This is the basis of dynamite.

144. **Uses and Occurrence.** Nitroglycerin is the basic constituent of explosives such as dynamite, blasting gelatine, gelatine dynamite, gelignite, and gelatinized gun-cotton.

145. **Absorption and Effects.** Absorption is by inhalation and through the skin. It causes vaso-dilation with lowering of the blood pressure. There are also effects on the central nervous system, gastro-intestinal tract, and the skin.

146. **Signs and Symptoms.** Alcohol predisposes to and increases the severity of poisoning. Severe poisoning results in confusion, hallucinations, aggressiveness, and mania. In milder forms there is headache, excitement, vertigo, fainting, cyanosis, and pulmonary irritation. Digestive upsets, tremors and neuralgia occur in chronic poisoning. Headache is most common in those new to work with nitroglycerin. Transient acclimatization occurs but may wear off even in so short a time as a meal break. For this reason it has become a habit for some workers to moisten their hatbands with nitroglycerin to maintain acclimatization. Dermatitis occurs especially of the hands, dryness and rhagades being found particularly on the palms and in the interdigital clefts.

147. **Prevention.** The precautions to be taken are those to protect workers from fume and dust, as well as from skin contact. Suitable protective clothing should be supplied including headgear and there must be adequate washing facilities.

148. **Toxic Concentrations.** Exposure to 20 ppm for 1 hour will cause severe toxic effects. Symptoms of illness may follow exposure for more than a short time to 1 ppm. The maximum allowable concentration (M.A.C.) is 0·5 ppm.

149. **Treatment.** Nitroglycerin headache is relieved by caffeine sodium benzoate followed by amphetamine. Amphetamine with prostigmine bromide prevents reoccurrence.

NITROUS FUMES

150. **Properties.** Nitrous fumes consist of a mixture of the oxides of nitrogen. Nitric oxide (NO), nitrous oxide (N2O), nitrogen dioxide (NO2) and nitrogen peroxide (N2O4) are all present in varying proportions. The

fumes also contain nitric and nitrous acids if moisture is present. The chief toxic risks are nitrogen dioxide and peroxide. Normally the fumes are dense and of a reddish brown colour, but sometimes even at dangerous concentrations the colour may not be perceptible. The oxides of nitrogen are only sparingly soluble in water and this accounts for the fact that their main effects take place deep in the respiratory tract.

151. **Uses and Occurrence.** Nitrous fumes are evolved by the action of nitric acid on any organic matter or when the acid is heated. They occur in the manufacture of nitric acid, and when gun-cotton, cordite and dynamite are burned, whether or not they explode. Nitrous fumes are thus a hazard of blast and shot-firing. They may also be produced by the combination of the nitrogen and oxygen of the atmosphere under the influence of the intense heat from oxyacetylene or arc welding.

152. **Absorption and Effects.** Absorption is by inhalation and the fumes act as strong irritants of the respiratory tract, especially of the lungs. High concentrations cause immediate severe caustic effects on the whole respiratory tract resulting in asphyxia, convulsions, and respiratory arrest. Exposure to lower concentrations are followed after a latent period by pulmonary effects and methaemoglobinaemia.

153. **Signs and Symptoms.** Severe exposure causes spasm of the larynx, oedema of the glottis, asphyxiation, convulsions, coma, and death. After lesser exposure there may be irritation of the throat and lungs, choking and cough, followed later by exudative bronchitis and pulmonary oedema. Often delayed effects may come on several hours after leaving work, without the patient being aware of exposure. Toleration of the fumes follows chronic exposure to small concentrations. Those who have developed toleration often suffer from chronic cough, headache, anorexia, constipation, erosion of the teeth, and inflammation of the mouth, nostrils, and eyes.

154. **Prevention.** All the usual measures for the protection of workers from fumes are essential. Workers must be educated about the danger of brown or irritating fumes and be informed about their delayed action. If they notice these while at work they should leave the premises at once. They should be familiar with rescue drill and be supplied for this purpose with remote-breathing or self-contained breathing apparatus and safety belts. When there is a risk of nitrous fume poisoning, oxygen resuscitating apparatus should be available.

155. **Toxic Concentrations.** Exposure to 100 ppm for 1 minute causes severe toxic effects. Symptoms of illness may follow exposure for more than a short time to 30 ppm. The maximum allowable concentration (M.A.C.) is 10 ppm. Mild irritation is noticed at 30 ppm and is just perceptible at 10 ppm.

PHOSGENE

156. **Properties.** Synonyms for phosgene ($COCl2$) are carbonyl chloride, carbon oxychloride, chlorcarbonic acid, and OG (British war gas). The gas has an odour resembling mown grass, sweet corn, or musty hay. It is not inflammable or explosive. It has a molecular weight of 98·9 and relative to air at N.T.P. the density is 3·5. It boils at 8°C. and melts between —75° and —128°C.

157. **Uses and Occurrence.** Besides its use as a war gas, phosgene is used in the manufacture of dyes and is a by-product of the combustion of halogenated hydrocarbons, for example of trichloroethylene and carbon tetrachloride.

158. **Absorption and Effects.** Absorption is by inhalation and the effect is highly irritant owing to the breakdown of the gas in the respiratory tract to hydrochloric acid and carbon dioxide. Lesions to the mucous membranes of the respiratory passages and of the lungs result.

159. **Signs and Symptoms.** The onset of serious symptoms may be delayed from a few hours to two days. Initially there may be irritation of the respiratory passages, with cough and a sense of constriction or pain in the chest. Later there is bronchitis and respirations become rapid and shallow; if pulmonary oedema develops dyspnoea and cyanosis increase and are followed by asphyxia and circulatory collapse.

160. **Prevention.** In the storage of war gases frequent inspection of containers must be made and indicators must be placed in storage places to ensure that leakage is detected early. Where halogenated hydrocarbons are used, stoves must be kept in good repair so that any phosgene formed by breakdown of these substances in contact with the burning fuel is carried off by the flue. Gas or electric fires with open elements should not be permitted. Smoking in such places should be forbidden. For rescue work canister respirators may be used, but self-contained or remote-breathing apparatus is safest.

161. **Toxic Concentrations.** Severe toxic effects follow exposure for 1 minute to 5 ppm. Exposure to 1 ppm for more than a short time may cause symptoms of illness. The maximum allowable concentration (M.A.C.) is 0·5 ppm.

PHOSPHORUS

162. **Properties.** Phosphorus (P) occurs in two allotropic forms, white and red. White phosphorus is unstable and ignites in air at 50°C.; it is slightly soluble in water, more readily in ether, olive oil, benzene, and carbon disulphide. At room temperature it oxidizes spontaneously and is phosphorescent. Red phosphorus is stable, oxidizes little at room temperature, and ignites at 240°C. The atomic weight of phosphorus is 30·98 and the boiling point is 280°C.; the melting points of white and red are respectively 44° and 72°C. Phosphorus compounds are formed in di-, tri- and pentavalent series.

163. **Uses and Occurrence.** Phosphorus and its compounds are used in the manufacture of fertilizers. Industrially, however, it is now most commonly met in the manufacture and handling of explosives and pyrotechnics. Phosphine (PH3) may be evolved in the quenching of metal alloys, such as wet ferro-silicon or wet aluminium phosphide. Organic phosphorus compounds are used as agricultural pesticides.

164. **Absorption and Effects.** Toxic effects are caused by inhalation of fumes of phosphorus and its compounds; burns and other skin lesions result from contact with them. Phosphorus after absorption attacks the bones, particularly the periosteum of the maxilla (often after the extraction of a tooth). Inhalation of phosphine causes hyperaemia and oedema of most organs, but especially the lungs. The vapours of phosphorus trichloride, pentachloride and oxychloride are strong mucous membrane irritants. The trichloride causes burns of the skin and tetraphosphorus trisulfide causes eczematous dermatitis. Organic

phosphorus compounds are potent cholinesterase inhibitors. Capillary dilation, hyperaemia, oedema of the lung and oedema of the brain are found post-mortem.

165. **Signs and Symptoms.** Classical industrial phosphorus poisoning (phossyjaw) consists of periostitis and necrosis of bone, especially of the jaw; there is secondary infection with a fetid discharge, fistula formation, tissue absorption, and deformity. Chronic septicaemia and cachexia follow. Chronic phosphine poisoning takes the form of embrittlement of teeth and bones, anaemia, and nervous disorders. If poisoning is acute, dyspnoea, fainting, bradycardia, lowered blood pressure, nausea, vomiting, convulsions, paralysis and coma occur. Inhalation of chlorides causes irritation of nose, throat and lungs with pulmonary damage. In sensitive persons tetraphosphorus trisulfide causes eczematous dermatitis, while phosphorus sesquisulfide causes erythema and vesiculation, painful pustulation, and conjunctivitis. Direct contact with white phosphorus causes severe burns. Early manifestations of organic phosphorus poisoning are nausea, vomiting, giddiness, weakness, drowsiness, and fasciculation of the eyelids. Further developments include abdominal cramps, sweating, salivation, anorexia, apprehension, restlessness, and giddiness, often exacerbated by taking food or smoking. Contraction of the pupils is fairly constant. Neuromuscular involvement is shown by twitching of eyelids, tongue, face and neck, with slurring of the speech. Generalized muscular spasms, great weakness, and death from neuromuscular paralysis may ensue. Diarrhoea, tenesmus, incontinence, pulmonary oedema and bronchial constriction may also occur. Treatment is to give atropine (gr: 1/30—1/60) hourly until symptoms respond. Artificial respiration is required if paralysis sets in.

166. **Prevention.** White phosphorus should only be manipulated if special arrangements have been made for enclosure, exhaust ventilation, protective clothing, and ample washing facilities. Close medical supervision of workers is essential and should include arrangements for dental inspections and care. It is more likely, however, that phosphorus will be met as a complication of an injury received from pyrotechnics or incendiary ammunition. When there is risk of this, first-aid outfits should contain copper sulphate, 4 per cent. in soft soap. This should be applied at once and liberally, before the patient is sent to the medical officer. Those using organic phosphorus pesticides should wear full protective clothing and respirators. Adequate arrangements must be made for washing and first-aid kits should contain atropine.

167. **Toxic Concentrations.** Red phosphorus is relatively non-toxic, but 1 mgm. per kilo body weight of white phosphorus is a lethal dose and the maximum allowable concentration is 0·1 mgm. per cubic metre. A few hours exposure to phosphine at 100 ppm can be fatal and exposure to 2,000 ppm results in rapid death. The maximum allowable concentration for phosphorus trichloride is 0·5 ppm.

SULPHUR DIOXIDE

168. **Properties.** Sulphur dioxide (SO2) is a colourless gas; it is very irritant, has a suffocating odour, and tastes acid. It is highly soluble in water, forming sulphurous acid. It is not inflammable but is corrosive to metals and textiles in the presence of moisture. The molecular weight is 64·06 and the density relative to air at N.T.P. is 2·3. It is stored under pressure as a liquid, which freezes if the pressure is suddenly released. The liquid boils at −10°C. and solidifies at −73°C.

169. **Uses and Occurrence.** Suphur dioxide is used in the manufacture of cellulose and glue, as a bleaching agent, in disinfection, and for the destruction of rats. It is also used as a food preservative, as an anti-oxidant in the melting and pouring of magnesium, in refrigerating machines, and in the manufacture of artificial silk. It occurs in the casting of metals, the heating of any compounds containing sulphur, in the combustion of coal and paraffin, and when sulphuric acid reacts with reducing agents. It is one of the main constituents of atmospheric pollution around large cities.

170. **Absorption and Effects.** Sulphur dioxide is absorbed by inhalation and has a local action on the mucous membranes of the respiratory tract through the formation of sulphurous and sulphuric acid.

171. **Signs and Symptoms.** Exposure to sulphur dioxide is rarely fatal except to aged bronchitics. Prolonged exposure leads to some tolerance. Moderate exposure causes irritation of the nose, throat, and conjunctiva with sneezing and spasmodic cough. Prolonged or massive exposure results in catarrhal inflammation, which to some extent protects the pulmonary mucous membrane from further injury. The sputum in these cases is viscid and sometimes blood-stained; bronchopneumonia may follow. Pulmonary oedema and gastro-intestinal upsets occur at times.

172. **Prevention.** Owing to the ample warning, dangerous exposure is likely only through accident. Workers should be instructed to leave premises as soon as irritation is noticed. If rescue operations are necessary remote or self-contained breathing apparatus is best, but respirators with special canisters will give 30 minutes protection if there is no oxygen deficiency.

173. **Toxic Concentrations.** Concentrations of about 400 to 500 ppm are lethal. Ample warning is given of rising concentrations, the odour becoming noticeable at 3 ppm, while irritation of the nose and throat occur respectively at 10 and 20 ppm. Exposure to 200 ppm for 1 minute causes severe toxic effects. Symptoms of illness may follow exposure for more than a short time to 20 ppm and the maximum allowable concentration (M.A.C.) is 10 ppm.

SYNTHETIC GLUES

174. **Properties.** Synthetic glues are either of the casein or the urea-formaldehyde type. They consist, alone or in combination, of protein, natural resins, and synthetic resins. The glues are very strong and dry rapidly.

175. **Uses.** These glues are used in the paper industry, in book binding, as sizing, and in woodwork generally, but particularly in aircraft manufacture and maintenance.

176. **Absorption and Effects.** There is inhalation of formaldehyde fumes from the urea-formaldehyde types, and also of resin dust when treated wood is rubbed down. The chief effect is, however, from contact with the liquid glues, their fumes and dust. The glues are skin irritants and sensitization to resins may occur after three to several weeks' exposure. Irritation of the eyes and conjunctivae also occurs, as well as respiratory irritation.

177. **Signs and Symptoms.** Dermatitis of the palms, dorsum of hands, forearms and legs develops. The lesions tend to be keratotic with casein glue, eczematoid with resins. If sensitization occurs, there is oedematous erythema followed by a papular eruption and eczema with intense itching. Conjunctivitis and bronchitis may also occur.

178. **Prevention.** Work should be done under exhaust ventilation and the general ventilation of work places must be good. Clean overalls must be supplied daily and impervious gloves, sleeves, and aprons should be worn. Damp swabs should be at hand to remove glue from the skin before it hardens, and there must be adequate washing facilities, including showers if practicable. Workers should be warned not to touch the face or eyes with their hands if contaminated with glue. A soap containing 5 parts of sodium sulphate neutralizes formaldehyde and an acid soap is required to remove casein.

179. **Treatment.** Cases of dermatitis must be removed from contact with glues and few can return to this work. Crusts should be removed by mopping with olive oil or liquid paraffin. Fomentations of 12 per cent. sodium sulphate may help. Weeping surfaces should be treated with a drying paste or an astringent lotion.

TOLUENE

180. **Properties.** Toluene (C6H5.CH3) is a homologue of benzene also derived from the distillation of coal tar and having similar properties. Synonyms are toluol, methyl benzene, and phenylmethane. It is a colourless liquid with a characteristic odour resembling benzene. It burns with a smoky, luminous flame, and is sparingly soluble in water, but readily in organic solvents. It is less volatile than benzene, saturated air at 20°C. containing 10 mgm. per litre. Commercial toluene may contain up to 15 per cent. of benzene. Toluene boils at 110°C. and freezes at —95°C. It has a flash point around 7°C. and at 30°C. the vapour pressure is 37 millimetres of mercury.

181. **Uses and Occurrence.** Toluene is a solvent for cellulose, rubber, ester gums, fats, and oils. It is used in the manufacture of synthetic rubber, paint, lacquer, trinitrotoluene, and linoleum. It is also met in the dyeing and cleaning industry.

182. **Absorption and Effects.** Absorption is by inhalation of fumes, but there is less danger of poisoning than from benzene owing to the lower volatility of toluene. Because of the presence of benzene in commercial toluene it is difficult to differentiate its precise effects, but toluene is a mucous membrane irritant, a central nervous system depressant, and affects the liver. Its action on the blood and haemopoietic system is doubtful; blood changes reported in cases of toluene poisoning may be due to the benzene content of the commercial product. In the body toluene is broken down by oxidation to benzoic acid; this combines in the kidney with glycine to form hippuric acid which is excreted in the urine.

183. **Signs and Symptoms.** As the volatility is comparatively low, acute poisoning is uncommon. Massive exposure to toluene, however, causes headache, dizziness, weakness, anorexia, palpitations, and lack of muscle co-ordination. A pronounced drop in red cells has been recorded. Chronic exposure leads to anorexia, with a bad taste in the mouth, nausea, vomiting, lassitude, nervous irritability and incapacity for work, headache, dizziness, insomnia, impairment of co-ordination and reaction

time, together with enlargement of the liver. Cases have been reported where there has been moderate decrease in red cells with macrocytosis and relative or absolute lymphocytosis, but no leukopenia.

184. **Prevention.** The usual measures to protect workers from fumes should be taken. If commercial toluene is being used, periodic medical examinations including blood counts should be carried out.

185. **Toxic Concentrations.** Exposure for 1 hour to 600 ppm causes severe toxic effects. Symptoms of illness may follow exposure for more than a short time to 300 ppm. The maximum allowable concentration (M.A.C.) is 100 ppm.

TRICHLOROETHYLENE

186. **Properties.** Trichloroethylene is a halogenated aliphatic hydrocarbon also known as ethylene trichloride, "tricho", chlorylene, and trilene. Its formula is CHCl = CCl2. It is a clear, colourless liquid with a not unpleasant sweetish odour which is characteristic. It is not inflammable. It is very slightly soluble in water but mixes readily with ether, alcohol, and oils. It is strongly liposolvent. At high temperatures in the presence of moisture, as from an open flame, it decomposes to give hydrochloric acid, carbon monoxide, and phosgene. The molecular weight is 131·39, boiling point 87°C. and freezing point —73°C.; at 20°C. the vapour pressure is 58 millimetres of mercury.

187. **Uses and Occurrence.** Trichloroethylene is used as a thinner in paints and varnishes, as a solvent for rubber, in degreasing, dry cleaning, and as an insecticide. It is also used as an anaesthetic.

188. **Absorption and Effects.** Absorption is by inhalation and through the skin. Trichloroethylene is an acute narcotic and if exposure is sufficiently severe and prolonged will cause death from respiratory failure. There is, however, a relatively wide interval between the narcotic and the lethal dose. After recovery from acute poisoning, effects may be observed on the sensory nerve fibres and optic nerve, the liver, the gastro-intestinal tract, and the lungs. Trichloroethylene is also a skin and mucous membrane irritant. Prolonged contact or immersion may cause reddening and blistering of skin; lesser exposure causes dermatitis. The irritation of the respiratory mucous membranes by trichloroethylene leads to bronchitis, congestion of the lungs, pneumonia, and occasionally to pulmonary oedema. These effects may be due to the breakdown products, hydrochloric acid, or phosgene. In the body trichloroethylene is converted to trichloroacetic acid which is excreted in the urine. Chronic poisoning is rare in industry but long exposure to low concentrations may result in central and peripheral nervous system damage, gastro-intestinal disturbance, damage to the liver, and functional neurosis. Addiction to trichloroethylene occurs occasionally.

189. **Signs and Symptoms.** Rapid loss of consciousness followed by recovery is normal after exposure to heavy concentrations. Residual symptoms include trigeminal paralysis, optic nerve lesions, anorexia, nausea and vomiting, jaundice, and varying degrees of irritation of the respiratory tract. Mild exposure may cause, instead of unconsciousness, headache, giddiness, excitement and confusion, possibly with abdominal pain and vomiting.

190. **Prevention.** All the usual precautions to protect workers from fumes and contact are necessary. Where practicable, degreasing with trichloroethylene should be carried out only in specially designed baths which prevent the escape of fumes. Open fires or heaters with exposed elements should not be used in places where the atmosphere is likely to be contaminated with trichloroethylene.

191. **Toxic Concentrations.** Exposure for 1 hour to 2,000 ppm causes severe toxic effects. Symptoms of illness may follow exposure for more than a short time to 800 ppm. The maximum allowable concentration (M.A.C.) is 400 ppm.

TRINITROTOLUENE

192. **Properties and Uses.** Trinitrotoluene is a nitro-derivative of benzene. It is a basic explosive for military purposes. Despite its explosive properties it is safe to manipulate but gives rise to toxic effects in manufacture and in the filling of explosive charges. It is prepared in the form of flakes, crystalline powder, or as a slab or biscuit. When a charge is filled with molten trinitrotoluene, fumes are evolved; dust is caused by the breaking-up of biscuits and in the preparation of baratol or amatol charges. Since trinitrotoluene vapour deposits in a fine crystalline form on surfaces cooler than 70°C., dust and fume may both be present together.

193. **Absorption and Effects.** Absorption is by inhalation of dust and fume or through the skin. Trinitrotoluene affects the skin (especially in the sensitive), the blood pigments, the gastro-intestinal tract, liver, and bone marrow. Results of exposure to it include dermatitis, methaemoglobinaemia, liver necrosis, and aplastic anaemia.

194. **Signs and Symptoms.** Signs of anilism or methaemoglobinaemia are cyanosis, with a striking pallor, and a lilac tinge of the lips and lobes of the ears. There is dyspnoea, tightness in the chest, headache, lassitude, anorexia, nausea, and abdominal pain. The liver may be enlarged and jaundice may follow, according to the degree of liver damage. Purpura may develop and a fall occur in the level of red cells and haemoglobin, with some reticulosis. Aplastic anaemia is not common but profound normocytic anaemia, agranulocytosis and a fall in blood platelets may develop. The skin is stained a dark orange by trinitrotoluene and in sensitive persons an acute erythema occurs of the exposed skin of the hands, wrists, face and neck. Susceptibility to dermatitis is very variable but is commonest among those new to the work.

195. **Prevention.** All the usual precautions to protect workers from dust, fume, and contact are essential. These include good general and local ventilation, the use of mechanical enclosed processes, the provision of protective clothing, washing facilities, and barrier cream. The selection of workers is important; those with histories of skin disease, or illness related to the gastro-intestinal tract, gall bladder, liver or haemopoietic system should not be employed. There should be a weekly medical examination of all those exposed to trinitrotoluene.

Tetryl

196. **Properties and Uses.** Tetryl or compound explosive (C.E.) is a derivative of trinitrotoluene; its properties and uses are similar.

197. **Absorption and Effects.** Absorption is by inhalation but harmful effects also follow direct contact. It is an irritant to the skin and mucous membranes. Dermatitis, gastro-intestinal upsets and irritation of the respiratory tract are the main results of exposure.

198. **Signs and Symptoms.** There may be anorexia, mild nausea, flatulence, and abdominal cramps. Small ulcerations of nasal mucosa with epistaxis may occur and there may be a dry cough with pain in the chest. Irritability, sleeplessness and lassitude occur. Skin sensitivity to tetryl varies, but it is more liable to cause dermatitis than trinitrotoluene. The face and neck are particularly affected. Other symptoms similar to those caused by trinitrotoluene may occur but, as tetryl is less readily absorbed, these are rare.

199. **Prevention.** The same precautions should be taken as for trinitrotoluene.

TURPENTINE

200. **Properties.** Turpentine oil is also known as spirits of turpentine, oleum terebinth, or "turps". The formula is $C_{10}H_{16}$. It is a colourless, oily, volatile liquid consisting of a mixture of terpenes. Pure gum spirit consists mainly of alpha pinene, while commercial turpentine often contains naphtha, pine oil, benzene and its homologues, or resin. Turpentine has a characteristic pungent odour and a burning bitter taste. It is almost insoluble in water but miscible with absolute alcohol and ether. It dissolves sulphur, phosphorus, rubber, fats, resins, asphalt, and bitumen. It boils between 155° and 180°C., the flashpoint being 33° to 36°C.

201. **Uses and Occurrence.** Turpentine is used as a solvent in the paint and varnish industry, in shoe polish and leather dressing, for cleaning fabrics, in the cleaning of printing machinery, and in the chemical and pharmaceutical industries.

202. **Absorption and Effects.** Absorption may be by accidental ingestion, but industrially it is by inhalation and through the skin. Whichever the route, the effect of turpentine is first to stimulate, then to paralyse the central nervous system, and to injure the liver and kidneys. It can cause violent gastric or respiratory irritation and, if contact is long enough, vesication of the skin.

203. **Signs and Symptoms.** Ingestion is followed by nausea, vomiting, diarrhoea, colic, dysuria, haematuria, glycosuria, and coma. Inhalation of high concentrations causes dyspnoea followed by bronchitis, headache, giddiness, mental confusion or excitement, visual disturbances and convulsions. Acute nephritis may develop subsequently. Direct application of turpentine to the skin or exposure to its vapour leads to dermatitis. Long contact causes reddening with swelling, exudation, and possibly vesication. The blisters are painful and slow to heal. Chronic turpentine poisoning does not occur.

204. **Prevention.** The normal precautions to protect workers against inhalation of fumes and contact with liquid or vapours are required.

205. **Toxic Concentrations.** Mild irritation of the nose and throat begins at 75 ppm and becomes intolerable at 175 ppm. The maximum allowable concentration is 100 ppm.

XYLENE

206. **Properties.** Xylene is also known as xylol and dimethylbenzene. It is a homologue of benzene with the formula CH3.C6H4.CH3, and has ortho-, meta- and para- isomers. Commercial xylene consists of all three, the meta- isomer constituting about 75 per cent. The ortho and meta- isomers are colourless liquids, the para- a crystalline solid. All are insoluble in water but readily soluble in alcohol and ether. Xylene is inflammable and the commercial product boils between 135° and 145°C.; the specific gravity is 0·86 and the flash point 24°C. It is volatile but less so than toluene, and is a solvent for gum, copal, rubber, oil and some celluloses.

207. **Uses and Occurrence.** Xylol is used as a degreasant, as a spreader for certain cellulose solutions, in the manufacture of brake linings, in the rubber industry, and as a constituent of quick-drying paints, lacquers, and cellulose sprays. It also occurs as an additive to aviation petrol, in protective coatings, inks, dyes, adhesives, cements, and cleaning fluids.

208. **Absorption and Effects.** As it is less volatile there is less danger of poisoning from xylene than from toluene. Although the toxicity is somewhat less, absorption and effects otherwise closely resemble those of toluene, and occur in acute or chronic form.

209. **Signs and Symptoms.** As for toluene.

210. **Prevention.** As for toluene.

211. **Toxic Concentrations.** Exposure for 1 hour to 1,000 ppm causes serious toxic effects. Symptoms of illness may follow exposure for more than a short time to 300 ppm. The maximum allowable concentration (M.A.C.) is 100 ppm.

ZINC

212. **Properties.** Zinc (Zn) is at ordinary temperatures a blue-grey, hard, brittle metal. It dissolves in concentrated alkalies with the evolution of hydrogen, but in the absence of another metal as a catalyst is insoluble in dilute acids. Zinc dust combusts spontaneously in moist air. Compounds of industrial importance include zinc oxide, zinc chloride, zinc sulphate, and zinc hydroxide. Zinc oxide is soluble in acids and alkalis; zinc hydroxide dissolves sparingly in water. Solutions of zinc salts have a harsh bitter taste. Zinc chloride is a corrosive. The atomic weight of zinc is 65·38, the boiling point 918° and melting point 419°C. The metal becomes malleable between 100° and 150° and burns at above 500°C. Zinc often contains traces of cadmium and arsenic.

213. **Uses and Occurrence.** Zinc dust is used as a reducing agent and as a pigment. Zinc occurs in galvanizing, and in the manufacture of brass products and alloys. In smelting, galvanizing, brazing, brass founding and welding, zinc oxide fumes are evolved when the temperature approaches the boiling point of the metal. Zinc chloride is used in smoke generators, as a wood preservative, and as a flux in soldering.

214. **Absorption and Effects.** Ingestion of zinc salts causes acute gastro-intestinal irritation; this may occur if acid foods are stored in galvanized containers. The inhalation of zinc oxide fumes causes metal fume fever.

Inhalation of zinc chloride smoke is intensely irritant to the respiratory tract. Contact with zinc oxide, chromate, sulphate or chloride causes dermatitis.

215. **Signs and Symptoms.** The gastro-intestinal symptoms following ingestion of soluble zinc salts resemble food poisoning. Metal fume fever starts a few hours after leaving work and recovery is complete in from 24 to 48 hours. Attacks are most common on Mondays, after the freedom during the week-end from exposure to zinc oxide fume. There is pyrexia with rigors, fatigue, headache, muscular pain, nausea and vomiting, dyspnoea, and pain in the chest. Immunity is developed but is short-lived, as susceptibility after the week-end shows. Inhalation of zinc chloride fume damages the mucosa of the nasopharynx and respiratory tract; a pale grey cyanosis is characteristic.

216. **Prevention.** The usual precautions to protect workers from fume are required as well as to protect from contact those working with zinc chloride and other zinc salts.

217. **Toxic Concentrations.** The maximum allowable concentration, in terms of zinc oxide fume, is 10 mgm. per cubic metre.

ROCKET FUELS

Introduction

218. Rocket propellent fuels are capable of causing injury to health unless adequate handling precautions and other preventive measures are taken. The injury may be caused by the fuels themselves or by their reaction products.

219. These notes are a review of the health hazards to be expected and of control measures. Such measures may be general or specific. General measures have engineering, personnel, medical and disciplinary aspects.

Engineering Measures

220. These measures should aim, during all stages from storage to ultimate use, at:—

(*a*) Enclosing processes, so that dangerous material is contained.

(*b*) Isolating processes, so that personnel are so far as possible kept away from the hazard.

(*c*) Mechanization, to reduce manipulation of dangerous substances by personnel and to prevent the escape during crude manual operations of noxious substances.

(*d*) Special ventilation, to remove any noxious substances that have escaped to the atmosphere.

Personal Protection

221. Personnel exposed to these fuels should be provided with:—

(*a*) Impervious protective clothing that can be worn under all climatic conditions. It should be washable so that fuel contamination may be removed by sluicing after each operation. It should afford maximum coverage for skin.

(*b*) Washing facilities, including showers if practicable.

(*c*) Eye protection.

(*d*) Respiratory protection.

Medical Supervision

222. **Pre-employment Medical Examination.** Those found at such examinations to have a history, or to be suffering from disabilities of the respiratory system, blood or skin should be rejected.

223. **Periodic Medical Examinations.** Exposure to certain fuels demands periodic medical examinations to ensure early diagnosis of poisoning. Such examinations also provide a check on the efficiency of preventive measures.

Discipline

224. Men engaged on work connected with fuels and oxidizers should be thoroughly trained in handling techniques, in the risks attached, and in first aid. Close supervision will be required thereafter to enforce the observance of safety measures.

Aniline

225. **Properties.** This is an oily liquid, colourless or straw-coloured when freshly distilled, which darkens on exposure to air. It has a burning taste and a characteristic aromatic odour. It does not ignite easily (F.P.71°C.) and is not particularly volatile (V.P. 15 mm. Hg. at 77°C.). However, it volatilizes freely in steam. It is miscible in most organic solvents but is only slightly soluble in water. It boils at 184°C.

226. **Toxicity.** Aniline may be absorbed through the respiratory tract, but owing to its low volatility this is uncommon except in the presence of steam or under very hot conditions. It may cause poisoning after accidental or suicidal ingestion. Most commonly, however, it gains entry to the body through the skin. The maximum allowable concentration is 5 ppm (8 hour exposure). It may cause:—

(*a*) *Methaemoglobinaemia.* Headache, weakness, dyspnoea, cyanosis, convulsions, and psychic disturbances result from its action on the blood and nervous system.

(*b*) *Skin Effects.* Prolonged exposure causes skin eruptions of various forms.

227. **Personal Protection.** Protective clothing to prevent skin and eye contamination is required. Respirators should be worn if hot or steamy conditions are likely to cause high aniline concentrations in the atmosphere.

228. **First Aid.**

(*a*) Heavily contaminated or permeable clothing should be removed at once.

(*b*) Contaminated skin should be immediately flushed with copious quantities of water. Similar copious flushing with plain water should be carried out if aniline gets into the eye or ear.

(*c*) Personnel should be instructed in these decontamination measures, particular emphasis being placed on the removal of contaminated clothing.

(*d*) If symptoms of poisoning develop, in spite of decontamination, the patient should be removed to the fresh air. If breathing stops artificial respiration and the administration of oxygen are indicated. The patient should be removed to sick quarters as soon as he is fit to move.

(*e*) Any man contaminated with aniline should, after decontamination, report to the medical officer, irrespective of symptoms of poisoning.

229. **Medical Treatment.** Rest, mild stimulants (other than alcohol) and fresh air should be adequate treatment in mild cases. Artificial respiration and oxygen administration may be indicated if apnoea or marked cyanosis are present. Methaemoglobinaemia may be reduced by giving methylene blue (1 to 2 mgm. per kilo body weight).

230. **Medical Supervision.**

(*a*) Special attention should be paid to the functional efficiency the cardiovascular system and to the blood picture on pre-employment medical examination.

(*b*) Men should be instructed to report sick if they feel breathless.

(*c*) Officers and N.C.Os. should be instructed to watch for cyanosis in the men under their charge, so that they may be referred to the medical officer as soon as early symptoms of poisoning appear.

(*d*) Men exposed to aniline should have periodical medical examinations when blood and urine tests should be performed.

Nitric Acid

231. **Properties.** Nitric acid is a highly corrosive, strongly fuming liquid of brownish yellow colour. The fumes evolved are the oxides of nitrogen; these are suffocating and poisonous. They have a yellowish red colour. The acid is a powerful oxidizing agent and will promote combustion with most organic materials. It reacts explosively with many organic liquids, *e.g.* aniline and furfuryl alcohol.

232. **Toxicity.**

(*a*) *Skin Contact.* Momentary contact causes yellow staining only, but severe burns follow if contact is more than momentary.

(*b*) *Inhalation.* Inhaled fumes of the oxides of nitrogen cause severe irritation and damage to the respiratory tract. Death may follow immediately on overwhelming exposure to high concentration, but acute fatal poisoning may occur with little or no warning or discomfort at the time of exposure. Concentration of 25 ppm causes mild irritation of eyes, nose and throat. Concentrations of 50-150 ppm can be inhaled without much discomfort. The maximum allowable concentration is 10 ppm (8 hour exposure). It should be noted, however, that such dangerous concentrations as those quoted may be met without any warning from the colour intensity of the fumes.

(*c*) Chronic exposure may result in erosion of the teeth, emphysema, chronic irritation of the respiratory tract, and ulceration of the nose or mouth.

233. Nitrous fumes may, after a latent period of variable duration following exposure, cause respiratory distress, accompanied by a general constitutional upset. Acute bronchitis, pulmonary oedema and broncho-pneumonia may result. Alternatively pneumonia may occur later, well after the initial irritative symptoms have subsided.

234. **Personal Protection.** Everything possible must be done to exclude nitrous fumes from the atmosphere by engineering measures. When it is known that men will be exposed to nitrous fumes, or when there is risk of accidental exposure, the following should be provided:—

(*a*) Impermeable protective clothing that will give complete skin coverage.

(*b*) Goggles or face shields.

(*c*) Respirators. These must be of the self-contained breathing apparatus design or of the gas-mask type with special canisters. (The latter protect for a short time only.)

(*d*) Washing facilities and if practicable showers near the place of work. A large open container holding a saturated solution of sodium bicarbonate should be placed adjacent to handling areas for decontamination of contaminated skin.

235. **First Aid.**

(*a*) Skin contamination should be at once copiously flushed with water or sodium bicarbonate solution, whichever can be reached first. Contaminated clothing should be removed as soon as possible and placed in a vessel containing sodium bicarbonate solution. After first-aid treatment the patient should be sent to sick quarters.

(*b*) *Eyes*. Copious irrigation of the eyes with water should be started immediately and the medical officer should be sent for. Irrigation should continue for at least 30 minutes or until the medical officer arrives and directs otherwise.

(*c*) Personnel should be instructed in the dangers of nitrous fumes and in the first aid of acid contamination. They should be warned of the latent period between exposure and the onset of respiratory symptoms and of the possible onset of the latter without knowledge of exposure. If they suspect that they are suffering from nitrous fume poisoning, they must report sick at once.

236. **Medical Treatment.**

(*a*) *Respiratory Damage*. Patients should be observed for at least 24 hours and expectant treatment for pulmonary oedema started. Antibiotics in anticipation of pneumonia may be indicated. If after 24 hours there are no signs of pulmonary involvement, the patient may be discharged to duty, but should be kept under observation for two further weeks in case of the late development of pneumonia.

(*b*) *Skin Burns*. The treatment is the same as for thermal burns.

(*c*) *Eye Injuries*. The emphasis is on immediate and adequate first aid. Thereafter the patient should be referred as soon as possible to an ophthalmologist.

237. **Medical Supervision.** Those with respiratory or heart disease, or a history of either, should be excluded from nitrous fume exposure. Periodical medical examinations are not indicated, but close supervision of safety precautions and their observance by personnel is essential.

High Test Peroxide (H.T.P.)

238. **Properties.** This is hydrogen peroxide of minimum 80 per cent. concentration, a colourless, caustic liquid which slowly decomposes with the evolution of oxygen. It is miscible with water in all proportions.

239. **Toxicity.** Hydrogen peroxide causes damage in contact with the tissues by its strong oxidizing properties. It is not constitutionally toxic, but exposure to it may result in the following ill effects:—

(*a*) *Skin.* Brief exposure causes blanching with pain and burning. Severe burns may follow prolonged exposure.

(*b*) *Eyes.* Vapours cause irritation, lacrimation, and burning of the eyes. Splashes or mists may cause tissue damage.

(*c*) *Respiratory Tract.* Inhalation of vapour causes irritation of the nose and throat, with burning, coughing, and excessive nasal and throat secretions. The inhalation of a mist or aerosol may cause respiratory tissue damage.

240. **Personal Protection.** Non-inflammable goggles or face masks, acid and fire-resisting clothing, helmets, boots and gloves should be worn. Neoprene, P.V.C., or polythene are suitable materials. Mist-protecting respirators are required only if exposure to aerosols is likely.

241. **First Aid.** In case of gross contamination showers or a plunge bath should be available. The great danger is that if inflammable clothing is contaminated it will in a very short time burst into flames. Contaminated skin should at once be thoroughly sluiced with water, a supply of which should be at hand. Copious irrigation with water should be carried out if eyes are contaminated.

242. **Medical Treatment.** Hydrogen peroxide burns should be treated in the same way as thermal burns. Any man who has had a hydrogen peroxide eye splash should be referred to an ophthalmologist.

Iso-Propyl Nitrate (Avpin)

243. **Properties.** Iso-propyl nitrate is used as a rocket propellent and is also used in the Royal Air Force in aircraft turbine-engine starter systems. It is a colourless liquid with an ethereal, inoffensive odour. The flash-point is 52°F. and the liquid is therefore highly inflammable.

244. **Toxicity.** Iso-propyl nitrate is mildly toxic and may be inhaled as vapour or absorbed through the skin. The maximum allowable concentration is 100 ppm. It acts as a vasodilator; excessive exposure causing headache due to lowering of the blood pressure.

245. **Precautions.** The safety regulations in force for highly inflammable materials are to be rigidly observed. Contact with the skin and inhalation of the fumes are to be avoided. Special clothing or masks are not required but gloves should be worn. In the event of contact, the skin is to be washed thoroughly as soon as possible. If clothing becomes contaminated it must be removed immediately and allowed to dry in the open air. Great care is to be taken to avoid spilling the fuel. Decanting from containers is to be carried out under conditions of the greatest possible ventilation; if a headache develops it is a sign that ventilation is inadequate.

Liquid Oxygen

246. **Properties.** Liquid oxygen is an odourless, colourless liquid which boils at normal atmospheric pressure. In contact with easily oxidizable materials it forms extremely inflammable and often explosive mixtures.

247. **Toxicity.** The vapour given off is virtually non-toxic. The dangers to be considered in handling liquid oxygen arise from its vigourous support of combustion and from its extreme coldness. Contact with the skin surface or eyes will produce effects similar to scalding or burning.

248. **Precautions.** To avoid spontaneous combustion adequate ventilation of storage spaces must be ensured. The working place must be kept clean and free from dust and all combustibles, such as cotton, wool, or other porous materials. All contact with oil and grease must be avoided, so that tools and handling equipment should be degreased with carbon tetrachloride. Personnel handling liquid oxygen must wear suitable protective clothing including face shields and goggles.

249. **First Aid.** Contaminated clothing should immediately be removed and areas of skin splashed with the liquid should be immersed in water; splashing of the eyes calls for immediate and prolonged irrigation with water.

OTHER SUBSTANCES

250. Ammonia and solids containing nitroglycerine may also be encountered in connection with guided missiles. These have been described in paras. 39 to 45 and 143 to 149.

CHAPTER 17

STATISTICS

INTRODUCTION

The Function of Medical Statistics

1. The planning and control of any large organization depend on the provision of accurate information. The medical services of the Royal Air Force are responsible for the prevention of ill health and the treatment of disease or injury among men in numerous units of all kinds scattered over the world. Success in this task depends on a high degree of organization, realistic planning, and central direction. These demand a close knowledge of the incidence of diseases, the methods and results of their treatment, the geographical, age and trade distribution of disabilities, and the time taken to restore patients to health. Such information is supplied by medical statistics.

2. In the general field of public health it has long been an axiom that the first statistical step must be the organized notification of births and deaths. Thereafter the aim is to obtain full records of morbidity. Lack of such records is at present keenly felt in nearly every branch of medicine and is hindering progress. Since its inception, however, the Royal Air Force has had a system of medical records capable of analysis and of providing the statistical and other information so much missed in other medical fields.

THE STATISTICAL METHOD

3. The statistical method has been defined by Yule and Kendall in their "Introduction to the Theory of Statistics" as:—

"The elucidation of quantitative data affected by a multiplicity of causes.".

Application

4. The statistical method is too rarely applied in medicine. It is natural for the doctor dealing with individual patients to rely on clinical impressions gained possibly from small and unrepresentative samples. The aim of the statistician is to prevent the inconsistencies likely to arise from such a practice. It is his job to ensure that the right figures are collected, that they are presented in a form that does not mislead, and that wrong deductions are not made.

5. An example of misleading statistics and of misinterpretation is given by the following:—

Sickness per 1,000 per annum	W.A.A.F.	1945	692 cases
" " " " "	W.R.A.F.	1949	1,008 cases.

This seems to show marked deterioration in health from 1945 to 1949, but the rates used are uncorrected or "crude". If the rates are corrected for age (see para. 14) they become:—

1945	607 cases
1949	546 cases.

These figures give the true picture, for the disparity with the crude rates is due to a change in the age structure; the W.R.A.F. in 1949 contained a greater proportion of the younger age groups, which in all spheres of life have higher rates of sickness than the older.

6. To avoid erroneous deductions of this kind, statistical thinking must be encouraged. To this end an outline is necessary of some of the simple procedures of statistics with examples of the expressions used and their application. Although some illustrations and definitions may appear obvious and elementary, they will help to refresh memories of the pitfalls entailed when embarking on experimental work or when handling quantitative data.

Averages

7. The use of the term "average" can be misleading; it is usually taken to indicate the arithmetic mean (*i.e.* the sum of all observations, divided by the number of observations); but the mean may be a very inadequate summary of a number of observations. The "median" or the "mode" may be more informative; the former is the central observation in a series arranged in strict numerical order, the latter the most frequently occurring observation in a series. Thus in a hypothetical office staff incomes may be as follows:—

1 at	£10,000 p.a.	=	10,000
2 at	£1,000 ,,	=	2,000
3 at	£600 ,,	=	1,800
3 at	£400 ,,	=	1,200
6 at	£300 ,,	=	1,800
15		=	16,800

In this establishment—

The *mean* income is £16,800 ÷ 15 = £1,120
The *median* income is the eighth in order = £400
The *mode* income is the commonest = £300.

8. The information given by a mean will also be qualified by the range of variation around the mean; for example, 100 observations may be scattered over a range of 100 units (from 1 to 100) and yet give a mean of 50; or the same number of observations may produce the same mean of 50 but may not vary more than 1 or 2 units each way (*e.g.* 48-52). This scatter may be demonstrated by giving the "standard deviation", or by stating the range of the observations. The former expression is defined as *the square root of the mean of the sums of the squared differences of any number of observations from their mean.* If a series of observations is subject to "normal" variability, it will be found that 96 per cent. of them fall within a range of twice the standard deviation on each side of the mean, while 99 per cent. lie within three standard deviations either side of the mean. Other forms of distribution about the mean exist, but most human or medical observations will be found to follow a "normal" frequency distribution of this nature, sometimes known as a Gaussian curve. It should be mentioned that "normal" in statistics strictly implies "usual" or "most common" or "average", and does *not* necessarily connote "right", "correct", or even "healthy".

Rates

9. The number of cases cured by some particular method, or the number of deaths due to a specific cause, are meaningless unless expressed as rates or incidences. A rate or incidence is *the number of occurrences (such as cases, cures, or deaths) expressed as a proportion of the population involved or at risk*, usually for a given period.

10. For example, 100 cases of pneumonia may have been cured by a particular antibiotic, but this fact is not impressive if 1,000 cases have been treated, for the success of the drug is then but 10 per cent. Again 1,000 people may die of a given disease, but the seriousness of this cannot be assessed unless the population in which they occurred is known. This population may be the total of those contracting the disease, the rate calculated from which will be the *fatality rate of the disease*. On the other hand, the population could equally be that of the whole country, of the R.A.F., of the command or of the station to which these people belonged and the rate calculated will be the *mortality rate* from the disease in that population. The rates concerned might be as follows:—

1,000 deaths from disease "X" out of 2,000 cases;
Fatality rate = 50 per cent. or 500 per thousand

1,000 deaths from disease "X" in R.A.F. population 250,000;
Mortality rate = 4 per thousand

1,000 deaths from disease "X" in whole country, population 50 million; *Mortality rate* = 0·02 per thousand.

It is quite clear that rates as well as plain numbers must always be quoted to give such figures meaning.

Morbidity Rates

11. The incidence or rates of diseases are of special value in showing where particular preventive problems exist and in measuring the success of the preventive action taken. They also provide figures upon which can be based the numbers of hospital beds required, the kind and quantity of drugs or equipment needed, and the medical manpower that will be necessary to look after the sick.

12. Once again morbidity rates are expressed as *a number of cases in relation to the population at risk*. For example:—

20 cases at a station of 1,000 strength gives an incidence of 20 per thousand.

20 cases in a group, strength 20,000, gives an incidence of 1 per thousand.

The importance of the occurrence of 20 cases cannot be assessed unless the rates are calculated. To do this it is always essential to define the population at risk.

13. However, rates such as these may still mislead unless the period to which they apply is also defined. For general purposes of comparison, rates are stated on a yearly basis, unless for a particular purpose some other specific period is defined. Thus if in one month at a unit of strength 1,000, 1 case of a disease occurs, the incidence for the month is 1 per thousand, but for purposes of comparison it will be stated as 12 per thousand *per annum*. The final annual incidence for the unit may well be less than this, for only 2 or 3 more similar cases may occur during the remaining 11 months. It is consequently most important always to state the period to which rates refer.

Age Standardization

14. An example of the deceptive impression it is possible to make by using crude rates is given in para. 5. Crude rates are those simply related to a population without the refinement of making allowances for the particular characteristics of that population, such as age and sex distribution. Unless populations are first made comparable by such allowances

erroneous conclusions are bound to be drawn from comparison of the rates; for example:—

Crude death rate	Bournemouth	1935	13·3 per thousand
,, ,, ,,	Bethnal Green	1935	10·3 per thousand.

This does not mean that Bethnal Green is a healthier place than Bournemouth, but that the Bournemouth population contained over twice as many persons of ages over 75 years. In fact 70 per cent. at Bournemouth were between 50 and 74 years; and between 10 and 40 years there were 10 per cent. fewer than at Bethnal Green. A higher proportion of old persons must lead to a higher death rate, as they die off faster than the young. This applies in the same way to morbidity rates, as susceptibility is not standard for all age groups. When comparing rates the age structures of populations must be remembered.

Controls

15. The efficiency of any procedure is best measured statistically by comparison of its effects on one group or population with the effect of different measures on other but comparable groups or populations, known as controls. The validity of the comparison depends on the similarity of the control group to the test population. This similarity should be exact for all characteristics, except the one under test. Unless like is compared with like, no acceptable conclusions can be drawn and it is unsafe to assume that the procedures concerned are responsible for any difference in results. The requirements in controls vary according to the experiment and the choice of appropriate groups is rarely a simple matter. Characteristics which should be similar in test and control populations may include age and sex distribution, trade, geographical situation, past medical history, and length of service or employment. It is a fundamental principle in all statistical and experimental work that controls are essential.

16. Once suitable test and control groups have been selected, it is often necessary to ensure that individuals do not know to which group they belong, so that bias will not affect their response. In testing a drug, for instance, the control group should be given a placebo of identical appearance, taste, and texture. Furthermore, those responsible for assessing the effects of the drug should not also decide to whom the test drug or the placebo is given, nor should they be aware of the selection. This prevents biased or subjective judgments.

Random Sampling

17. A reasonably homogeneous population can be divided into test and control groups by an unbiased method of selection known as *random sampling*. One method of random sampling consists of giving identification numbers to everyone in the population, and then placing them in one or other of the groups by reference to a table of random sampling numbers. These tables are devised to overcome the experimentally proved preference of individuals for certain numbers and number sequences, which could bias selection. Simpler methods may be sufficient, such as the arbitrary allocation by odd or even final digits where individuals can be identified by a convenient serial number, such as the personal service number. Separation of groups may sometimes be conveniently made by taking alternate cases as they occur. Alphabetical methods are usually most unreliable; for example, any selection involving the initial letter M would provide a sample containing a preponderance of Scots and Irish, so resulting in racial bias. The choice of method depends largely on circumstances, but it is essential to adhere rigidly to whatever procedure is finally chosen.

Correlation Tests

18. It is often desirable to measure the relationship between two or more characteristics for a population and the degree of any existing relationship. This is expressed by the *coefficient of correlation*; a text book should be consulted for the method of computation, but the answer always lies between + 1·0 and − 1·0. If the answer is zero it means that there is no observed relationship at all; + 1 indicates absolute correlation in direct proportion; − 1 means absolute correlation in inverse proportion. Intermediate positive and negative answers show direct or inverse relationships of varying degree, those nearest to 0 being least and those nearest to 1 being most closely related.

19. For example, there are more deaths from pneumonia and bronchitis in cold weather and the coefficient of correlation between registered deaths from these causes and the mean air temperature is − 0·9, showing a strong inverse relationship (*i.e.* the lower the temperature the more deaths). Age and height in school children, on the other hand, show a positive correlation.

Tests of Significance

20. It is often necessary to determine whether certain observed results might or might not have been obtained by chance. The tests used measure the probability of this and the answers are expressed in terms of "P". Examples of the meaning of values of "P" are as follows:—

P	*Probability of an Event Occurring*
>0·01	Greater than 1 in 100
>0·1	Greater than 1 in 10
<0·001	Less than 1 in 1,000

It is conventional to establish the level of significance at 0·05. This means that when chance could have brought about any event more than once in 20 times, that event is unlikely to have any significance (*i.e.* it may be due to chance). But the level itself may be chosen according to circumstances. When differences are observed in certain observations and P is stated to be >0·1, it means that such differences might occur by the ordinary intervention of chance at least once in ten times and so are not "significant". If P were <0·001 the chance of occurrence would be less than one in a thousand; this is highly "significant", *i.e.* the occurrence was most probably not due to chance.

21. Tests of significance and of correlation do no more than express probability. Sound statistical opinion should never go further than saying that results are probably due or not due to chance.

Research and Statistics

22. These paragraphs are no more than a brief introduction to the statistical method. For further reading "Principles of Medical Statistics" (the Lancet Press) by Bradford Hill is recommended. Any officer proposing research may obtain guidance on the details of planning experimental work and assistance in the calculation of coefficients of correlation or tests of significance, through the competent medical authority, from the Air Ministry (M.A. 7). It is always better to carry out a small-scale planned experiment, with trustworthy even if limited results, than to perform a wider unplanned survey which may only be equivocal and misleading.

R.A.F. MEDICAL STATISTICS

The Card and Flimsy System

23. The R.A.F. system of medical statistics has always been based on the card and flimsy. All medical records are made in duplicate; the flimsy copy is enclosed in the individual's medical history envelope (F.Med.4) which follows him wherever he is posted during his service career and provides a complete up-to-date history for consultation by the medical officer when necessary; the card copy is sent, through group and command, to the Air Ministry, where it becomes part of the central records.

Central Records

24. Besides statistical advisory functions, Air Ministry (M.A.7) deals with the coding and analysis of medical documents, and with the accessible storage of record cards, which are filed in alphabetical sequence. This central library of record cards numbers some 12 million and constitutes an invaluable pool of statistical data.

Checking of Cards

25. Record cards contain a considerable amount of administrative data about patients, which can be checked at group, command, or Air Ministry. This information must be accurate and complete, otherwise statistical classification is made impossible. For example, from 1946 to 1950 there were 87,000 cards for patients named Brown; unless service numbers and full christian names are correctly entered on the card, errors in filing are inevitable.

26. As important is the necessity for accuracy in recording diagnosis and compiling clinical notes, which of course cannot be checked in the same way as administrative data. The difficulties of coding are greatly aggravated if every card record must be completely read through to discover the truth. The accuracy and completeness of the facts recorded by the doctor are fundamental to the whole system.

Coding

27. Numerical codes are provided for all the facts it is required to obtain from record cards. The code for diseases is that adopted by the World Health Organization in 1948, the International Statistical Classification of Diseases, Injuries and Causes of Death. These code numbers are punched on to small cards, the holes in which permit electrical contacts to control sorting. This punch card method (the Hollerith system) is applied to in-patient, out-patient, and annual medical examination records.

Analysis

28. The central library of medical records may be analysed in two ways once the originals have been correctly filed and the punch cards prepared. Large groups can be quickly segregated and analysed by the punch card machinery, or individual records can be examined in detail. The two are interlinked, cross references to original cards being provided by the machinery. From the punch cards it is possible to obtain, for example, the cases of poliomyelitis among officers of any given age group in any particular year and the number of days sickness these represent. The information is provided by the machine in the form of an

automatically typed list, giving all such cases, their total, the number of days involved, and cross references to individual cases. From the cross references, it is easy to pull out for study the actual histories from the record library. The usefulness of such study depends on the accuracy of the case notes; no statistical system can compensate for any initial deficiencies.

Forms Stats System

29. By the time all record cards have reached the Air Ministry, and have been coded and analysed, a considerable period since their origination will have elapsed. The Forms Stats system is designed to provide more immediate information on the health of the R.A.F. with special reference to diseases amenable to epidemiological control. The information is a rapid and approximate monthly summary and, as many diagnoses must be tentative, no reliance is placed on its accuracy for eventual statistical purposes.

30. **Forms Stats 50, 51, and 550.** Form Stats 50 is the rough working sheet from which units compile Form Stats 51, the Monthly Station/Command Return of Sickness. The latter is forwarded to groups and commands and gives principal medical officers an up-to-date picture of the health of their stations. A consolidated return for all stations is prepared at commands and sent to the Air Ministry (M.A.7 (1 Copy)). From this, Form Stats 550 is prepared by M.A.7 to show the state of health of all commands, at home and abroad, as well as of the whole R.A.F. Form 550 enables the Air Ministry to be rapidly aware of health problems and provides principal medical officers with a means of comparing the health of their commands with others.

31. **Form Stats 58.** Whereas Forms Stats 50, 51 and 550 are a simple series of statistical returns, Form Stats 58 is a nominal roll of patients admitted to sick quarters, hospital, sick in quarters, or sick at home, for over 48 hours. It serves primarily as a local picture of the more serious cases and as a check on the rendering of medical record cards. In addition it may be used as a most useful cross check to the information contained on Form Stats 51.

32. The Forms Stats system, combined with the card and flimsy individual medical records, covers the requirements both for immediate and detailed medical statistical information.

SICKNESS WASTAGE RATE

33. The sickness incidences commonly used and expressed in terms of per thousand per annum are attack rates; their significance is not always obvious to the layman and they give no indication of the loss of manpower from sickness. Such information is of value to the executive and has been usefully supplied in some commands by the use of a sickness wastage rate (S.W.R.) This rate is calculated from the formula:—

$$\frac{\text{Total man-days lost in the month from sickness} \times 100}{\text{Total strength of station} \times \text{Number of days in the month}} = \% \text{ S.W.R.}$$

Information Required

34. The total man-days lost from sickness consist of:—

(*a*) The number of days sickness represented by cases admitted to sick quarters or hospital or sick at home for over 48 hours.

(*b*) The number of days absent from duty represented by those admitted for 48 hours and under.

(*c*) The number of days absent from duty represented by those excused duty.

(*d*) The number of days absent from duty because of sick leave.

35. The information to calculate (*a*) is obtainable from the details normally entered on Form Stats 58. That required for (*b*), (*c*) and (*d*) must be specially collected. The method suggested is to complete the following box, which should be stamped on the reverse of Form Stats 58, weekly and monthly:—

WEEKLY	Flying Personnel	Non-flying Personnel	W.R.A.F.
Number of patients excused duty			
Total number of days absence from duty these represent			
Number of patients admitted for 48 hours or less			
Total number of days absence from duty these represent			
MONTHLY			
Number of patients granted sick leave during the month			
Total number of days sick leave these represent			

Interpretation of S.W.R.

36. The rate indicates the percentage strength of a unit non-effective each month because of being under treatment or convalescing. Owing to a number of variables it is only an approximate rate, and is not an absolute index of the prevalence of sickness. It is best interpreted in conjunction with the orthodox sickness incidence, when it will give some indication of the severity of prevalent illness. For example, if the incidence of sickness rises and the S.W.R. falls it suggests that there is much minor illness occurring. If the opposite happens it suggests that what illness is occurring is more serious. It is emphasized that the S.W.R. should not be used as a substitute for the normal sickness incidence, but rather as method of demonstrating its significance.

CHAPTER 18

RADIATION HAZARDS

INTRODUCTION

History of Radiation Disease

1. Roentgen announced his discovery of X-rays in 1895. They were the first form of man-made ionizing radiation. Their almost immediate and widespread use soon resulted in cases of over-exposure to this type of external penetrating radiation being recorded in the medical literature. Owing to the lack of shielding the tubes emitted rays in all directions and the whole body was thus frequently exposed. It is now known that this is more serious than the irradiation of small portions of the body.

2. In 1896 dermatitis, blistering, ulceration, alopecia and soreness of the eyes were described as consequences of exposure and in 1897 diarrhoea and vomiting were added. The first cure of cancer by X-rays was achieved in 1899 but in 1902 the first radiation induced cancer was reported. By 1904 X-rays were known to be capable of producing sterility and blood changes.

3. By 1914 hundreds of accidental burns had been caused, along with dozens of cases of cancer, several cases of leukaemia and at least one of aplastic anaemia. Most of the patients were either radiologists or their technicians.

4. In all these cases the X-rays had arisen from sources external to the body. However, the alternative mode of irradiation is from within, that is, internal radiation. Since the 16th century about 75% of all the deaths amongst the miners of Scheeberg and Joachimsthal have probably been due to lung cancer following the chronic inhalation of the alpha-emitting gaseous radium decay product, radon. This further decays, depositing on the respiratory epithelium solid radioactive particles.

5. Another famous example of exposure to internal radiation concerns the New Jersey luminous watch-dial painters who in the years 1916–25 had been in the habit of pointing their radium laden brushes with their lips. After passage into the intestinal tract quantities of the alpha-emitting particles were absorbed and deposited in bone. Anaemia, osteitis, bone necrosis, pathological fractures, osteogenic sarcomas and carcinomas of the accessory sinuses occurred. The incubation period of the neoplasms, like that of the X-ray induced cancers, was usually several years.

6. Investigations of the dial painters, and other patients who had ingested radium, made it possible to determine what quantity of radium the body can contain without suffering significant damage. This is known as the maximum permissible body burden (M.P.B.B.) for radium and is set at one ten millionth of one gram (0.1 micrograms). Calculation or animal experiments permit the M.P.B.B. for other radioisotopes which are deposited in bone—the so-called bone seekers—to be derived by comparison with radium.

7. Moreover, it has been possible, subsequently, to establish a rough relationship between the amount of radium excreted in a given time and the quantity remaining in the body. The body burden may thus be determined in life. This technique of biological monitoring has been extended to other isotopes and is now routinely employed as a check on the

efficiency of the measures taken to protect exposed workers. Following accidents involving releases it may be the only method which can be used to discover who has inhaled radioisotopes. (The whole body counter, *see* para. 112, offers an even more modern method for the measurement of isotopes in the body during life.)

8. The radiation casualties of Hiroshima and Nagasaki and the victims of criticality incidents occurring in atomic energy establishments have demonstrated the early and late effects upon the body of sudden, external, whole-body penetrating radiation by gamma rays and neutrons. Since World War II great numbers of animal experiments have given information about the pathological, biochemical and the genetic effects of radiation.

9. Though they have been occasionally exaggerated the dangers of ionizing radiation are thus very real. However, all the evidence suggests that with careful handling the use for peacetime purposes confers benefits that far outweigh its hazards. Nevertheless because understanding of its ultimate effects is not yet complete, caution by those handling it is invariably to be recommended.

BASIC CONCEPTS

Nature of Radiation

10. All radiations take the form either of waves or of particles. Their properties are listed in Table 1(R).

Natural Background Radiation

11. Natural radiation, which originates both from outer space and from the radioactive substances in the ground, is called background radiation:—

(*a*) *Cosmic Radiation*. A variety of radiations arrives from space. Most are charged particles and are therefore deflected towards one or other pole thus causing greater sea level dose rates in the higher latitudes than at the equator. The atmosphere acts as a filter and in consequence the dose rate increases with altitude (*see* Table 3(R)). Interactions occur in the upper atmosphere whereby cosmic radiation leads to the creation of radioactive beryllium 7 and carbon 14 which fall to earth and may become incorporated into living matter.

(*b*) *Terrestrial Radioactivity*. With the exception of a few substances of fairly low atomic number, the most important example of which is potassium 40, the majority of naturally-occurring radioactive substances found in the earth are derived from the high atomic number parent elements, uranium 235 and 238 and thorium 232. Their atoms are unstable and they ultimately decay to stable (*i.e.* inactive) lead by a series of intermediate steps, each of which involves the transition from one radioisotope to another accompanied by the release of ionizing radiations. No less than 45 different radioactive isotopes are listed as members of the three decay series. Traces of them are found in many soils. Their radiations reach man from the ground and from many building materials. They enter food and water obtained from affected soils and are thus ingested. Two of the series are the gases radon and thoron which diffuse from the soil into the atmosphere and are inhaled. Under inversion conditions the radon content of the air increases greatly.

(*c*) *Total Background Dose*. The make up of a typical total annual dose to the gonads and bone marrow attributable to natural radio-

TABLE I(R)

SOME PROPERTIES OF IONIZING RADIATIONS

Type of Radiation	Notation	Normally Regarded as	Mass (Atomic Mass Units)	Electric Charge	Typical Energy in Electron Volts, eV (1 KeV = 1,000 eV and 1 MeV = 10^6 eV)	Range in Air	Range in Tissue	Penetration	Mode of Origin
Alpha	α	Particle	4	+2	5 to 10 MeV	3 cm	25 micron	Because of their relatively large size and charge and low velocity they have little penetrating power and are completely stopped by paper or thin metal foil.	Alpha particles (He^4_2 nuclei) are emitted on the disintegration of certain radioactive isotopes, particularly those of heavy elements (1).
Beta	β	Particle	1/1840	+1 or −1	A few KeV to 5 MeV	Up to a few metres	A few millimetres	Range of majority of beta particles lies between 0·01 mm and 2 cm in tissue; the range in other low atomic number materials is inversely proportional to their density.	Beta particles are emitted by the nuclei of most radioactive isotopes, sometimes alone but more often accompanied by gamma rays (2). Their charge may be positive but is usually negative. They are emitted in a broad spectrum of energies. The maximum (E_{max}) is characteristic of the emitting isotope and is three times as great as the energy of the average particle from the same source.
Neutron	n^1_0	Particle	1	0	Usually described in four bands: Thermal: up to 0·5 eV Intermediate: 0·5 eV to 10 KeV Fast: 10 KeV to 10 MeV High energy: over 10 MeV	Range is energy dependent but always comparatively long, *e.g.* up to hundreds of metres.	Whole body penetration	The absence of charge enables neutrons to pass readily through the electron structure of an atom and they are stopped or deflected only when they come close to a nucleus. Thus they have considerable ranges in all materials.	The most important sources of neutrons are nuclear fission (3), alpha bombardment of certain light elements and the bombardment of a deuterium or tritium loaded target by protons or deuterons in an accelerator (4).
X Rays	X	Electro-magnetic Radiation	0	0	A few KeV to 1 MeV	Long: range is energy dependent	Whole body penetration	The penetration of X and gamma rays is illustrated by the thicknesses which will reduce the intensity to approximately one half, thus:—Half-value thickness in cms: *Energy* — *100 KeV*, *1 MeV*, *10 MeV* Aluminium — 1·5, 4·3, 11·0 Iron — 0·25, 1·5, 2·9 Lead — 0·01, 0·9, 1·2	X-rays are produced in two ways: 1. By the sudden deceleration of fast moving electrons. 2. By a change of energy level of the orbital electrons of an atom. Gamma rays differ from X-rays only in their origin. They result from a rearrangement of a nucleus, as in (1); radioactive disintegration, when there is usually accompanying beta radiation. (2); and capture reactions in which a neutron enters into the nucleus and a gamma photon is emitted (5).
Gamma Rays	γ	Electro-magnetic Radiation	0	0	Energies mostly lie in the range of 0·05 MeV to 3 MeV	Long: range is energy dependent	Whole body penetration		

Examples
(1) $Pu^{239}_{94} \rightarrow U^{235}_{92} + He^4_2$ + energy
(2) $Na^{24}_{11} \rightarrow Mg^{24}_{12} + \beta + \gamma$
(3) $U^{235}_{92} + n^1_0 \rightarrow Sr_{38} + Xe_{54}$ + 2-3 neutrons + energy
(4) $H^3_1 + D^2_1 \rightarrow He^4_2 + n^1_0$ + energy
(5) $H^1_1 + n^1_0 \rightarrow D^2_1 + \gamma$

activity in the U.K. is shown in Table 2(R). Although the total varies it approximates to 100 mrads p.a. (This unit is explained in para. 36.)

TABLE 2(R)

RADIATION FROM NATURAL SOURCES

Source	Dose (mrad) p.a. to gonads and bone marrow
Cosmic radiation UK	24
Potassium 40 in body	20
Carbon 14 in body	4
Ground sources in UK	50
TOTAL	100 approx.

Ground sources vary in their strength. In Cornwall they contribute up to 300 mrad p.a. and in Kerala, India, up to 4,000 mrad p.a. In neither area has the higher background produced detectable harm.

Man-made Radiations

12. Man-made radiations originate from certain machines (*e.g.* X-ray sets and accelerators), from the treatment of stable substances so that they become radioactive and from the management of radioactive elements in such a way that they undergo fission (*e.g.* the use of nuclear weapons and nuclear reactors).

Natural and Man-made Doses Compared

13. The dramatic manner in which ionizing radiation was brought to public notice by the explosion of nuclear weapons in war has led to a risk of over-emphasizing its dangers in peace. It may be helpful to understand that the radiation background has been little increased by man-made radiation (*see* Table 3(R)).

TABLE 3(R)

POPULATION DOSES OF RADIATION TO THE GONADS
(*see* para. 16)

Source	Dose as percentage of natural background
Diagnostic radiology	14·1
Dental radiology	0·01
Mass miniature radiology	0·01
Radiotherapy (non-malignant conditions)	4·5
Radiotherapy (malignant conditions)	0·5
Radiotherapy (using radioisotopes)	0·18
Shoe fitting	0·01
Luminous watches and dials	Less than 1·0
Television sets	Negligible
High altitude flying*	Negligible
Occupational exposure	0·5
Radioactive waste disposal	Less than 0·001
Fall-out from test explosions	1·2

* The actual gonad dose received by an individual in an aircraft at 50,000 feet above the U.K. is, according to the M.R.C., 0·5 per cent. of the annual natural background dose per hour of exposure. Since the natural background is taken as 100 mrads p.a. (*see* Table 2(R)) the dose rate at 50,000 feet is a half mrad per hour.

Genetic Effects and the Population

14. Once a mutation has occurred in a gene it is handed on whenever the cell divides. Although spontaneous mutation in a particular gene is rare there are thousands of genes in each cell and thus mutations arise continually in any population. Exposure to ionizing radiation and to certain chemicals will increase the mutation rate. Mutations which result from high radiation doses may be somewhat more harmful, on average, than those which occur spontaneously. High dose rates may produce more mutations than the same dose given at lower rates. There is no evidence to support the theory that a threshold dose exists; this means that any dose could have some genetic effect although this may be impossible to detect.

15. A mutation in a somatic cell can only result in harm to the individual whereas a mutation arising in a germ cell, or any cell ancestral to it, will be transmitted to subsequent generations if the cell participates in fertilization. It is for this reason that the dose received by the gonads is of particular importance and explains why Tables 2(R) and 3(R) quote gonad dose rates.

16. Subject to the qualifications mentioned in para. 14 and some others, it may be stated that in general a dose of 100 rems (*see* para. 38) to 10 people will result in the same total number of mutations as will be caused by 10 rems to 100 people. Thus, to average the total gonad dose over the population gives some indication of the genetic risk, and this is what has been done in Table 3(R) in respect of various sources. If this average is applied to the portion of the population between conception and 30 years (the mean age of childbearing) the "genetically effective dose" is derived.

17. Subject again to the qualifications mentioned above, a dose of 30–80 r applied to the gonads of a human population is likely to double the mutation rate in a representative collection of genes. Compared with these doses the small contribution from man-made sources is likely to be insignificant.

Late Effects of Radiation

18. The acute effects of radiation are considered in paras. 136–141. They are distinctive and become manifest in anyone who receives a sufficiently large dose to induce them. On the other hand late effects are more uncertain in their origin and can arise from causes other than radiation. In consequence population studies are necessary to investigate them and so they can conveniently be included here.

19. **Leukaemia.** A study of the survivors of Hiroshima and of patients irradiated for ankylosing spondylitis reveals that the high doses received in these cases have resulted in an increased incidence of leukaemia, reaching a peak around seven years after exposure and dying away after a decade or so. In the case of the Hiroshima survivors, the nearer they were to ground zero the greater their liability to develop leukaemia. This evidence, however, does not prove that the steadily rising mortality rates from leukaemia all over the world—a threefold increase in England and Wales over 30 years, reaching 56 deaths per million in 1959—can be wholly attributed to the small increase in radiation exposure which has occurred in recent years. Part of the rise is apparent rather than real and is due to better diagnosis. Factors other than radiation must be mainly responsible.

20. **Cancer.** The experience gained from radiology, radiotherapy and from Hiroshima shews that irradiation can lead to an increased chance of developing cancer. Skin, certain abdominal organs and, to a lesser extent, bone appear to be more vulnerable to external penetrating radiation than do other tissues in this context. The mean incubation period is measurable in decades except, perhaps, in children where there is some evidence that it may be shorter.

21. **Reduction of Life Span.** There is little or no human evidence that irradiation reduces the life span unless, of course, the dose is so great that death follows as a direct consequence.

22. **Cataract.** Doses in excess of 200 rads (*see* para. 36) of X-rays to the eye may produce cataract.

23. **Interference with Pregnancy.** Large doses of radiation in pregnancy may lead to miscarriage, still-birth and, very rarely, developmental abnormalities. Low doses may have harmful effects on the foetus especially in the early stages of pregnancy but they have not yet been proved to lead to an increased liability to leukaemia in later years.

24. **Impaired Fertility.** Low doses of radiation do not appear to affect fertility but larger doses of the order of several hundred rads may lead to sterility especially in the female.

Radioactivity

25. **Activity.** Activity, or more precisely, radioactivity, depends upon the fact that the nuclei of radioisotopes are unstable because they have too much energy. This is released in the form of radiations and the process by which stable nuclei are eventually reached is called decay. Several steps may be necessary to achieve this and each one is called a disintegration, *see* para. 11(*b*). Every disintegration is accompanied by the release of one or more forms of ionizing radiation.

26. **Physical Half-Life.** The nuclei of a given mass of a particular radioactive substance (which may be loosely referred to as a radioisotope or a radionuclide) do not disintegrate simultaneously. Disintegrations occur randomly but the time taken for half the nuclei to disintegrate is constant, and characteristic, and is known as the half-life of that particular radionuclide. The daughter product may, of course, be radioactive itself. Half-lives range from 10^{-20} seconds to 10^{20} years.

27. **The Curie.** A radioisotope with a short half-life is very active because the rate of disintegration of its atoms is high. Any quantity of a substance undergoing $3 \cdot 7 \times 10^{10}$ disintegrations per second (*i.e.* 37,000 million d.p.s.) is said to have an activity of one curie. Submultiples in common use are as follows:—

Millicurie	m.c.	1/1000th.	$3 \cdot 7 \times 10^{7}$ d.p.s.
Microcurie	μ.c.	1/1,000,000th.	$3 \cdot 7 \times 10^{4}$ d.p.s.
Micro-microcurie	μ.μ.c.	1×10^{-12}	$3 \cdot 7 \times 10^{-2}$ d.p.s. (2 d.p.m. approx.)

28. **Specific Activity.** The activity per unit weight of a substance is known as its specific activity. It is expressed as curies per gram. The higher the specific activity the greater is the danger from radiation.

1 gram of radium	contains	1 curie of activity
1 gram of plutonium	,,	$6 \cdot 17 \times 10^{-2}$ curies of activity
1 gram of uranium (238)	,,	$3 \cdot 34 \times 10^{-7}$,, ,, ,,
1 gram of tritium	,,	10^{4} (*i.e.* 10,000) curies of activity

29. **Ionization.** Atoms are neutral since the negatively charged orbital electrons are equal in number to the positively charged protons in the nucleus. Any disturbance of this relationship results in ions being created. The simplest example is the case where an orbital electron is removed. The electron becomes a negative ion and the remainder of the atom a positive ion. An ion pair is thus created.

30. **Nature of Radiation.** The type of radiation considered in this chapter should be referred to as ionizing radiation in order to distinguish it from other forms of radiation. It is so called because it has the property of ionizing materials through which it passes. It is their capacity to cause ionization which permits the detection and measurement of ionizing radiations and so far as is known it is the same capacity which causes tissue damage.

31. **Types of Emission.** Radioisotope data books and nuclide charts list the types of radiation emitted by particular isotopes. Some, like tritium, carbon 14, strontium 90 and phosphorus 32, are pure beta emitters. Others, for example plutonium and polonium, are predominantly alpha emitters. Most of the remaining radioisotopes emit considerable quantities of gamma rays in addition to charged particles which, in the majority of cases, are beta particles.

Types of Exposure

32. **External Radiation.** Radiation may emanate from sources outside or inside the body; it may also be penetrating or non-penetrating. Outside, or external, radiation may be partial or complete, the complete form being called whole body radiation. X-rays, gamma rays and neutrons are the chief penetrating radiations whereas alpha particles and most beta particles will not penetrate far into the tissues (*see* Table 1(R)).

33. **Internal Radiation.** Internal radiation occurs after radioactive substances have entered the body by surface absorption, by inhalation, by ingestion or through wounds. Once inside the body the substances are either distributed evenly throughout the tissues or taken up preferentially by a particular organ or tissue. The radioactive isotopes of hydrogen, potassium and sodium, to give examples, become generally distributed but those of strontium tend to concentrate in a particular tissue, the bone. When isotopes have entered the body they irradiate it continuously until they decay to inactive substances or until they are eliminated in the ordinary processes of excretion. Neither event might be completed during the human life span. Alpha emitters are potentially the most dangerous isotopes internally, because alpha particles are the most efficient ionizing agents (*see* Table 3(R)) and therefore do most biological damage to the surrounding cells.

34. **Effective Half-Life.** The time taken to eliminate from the body half the atoms of an internally deposited isotope is called the biological half-life of that element. The combination of biological and physical half-lives is known as the effective half-life and it is always smaller than either. Mathematically the E.H.L. is calculated by the use of the formula:

$$\text{E.H.L.} = \frac{T_b \times T_r}{T_b + T_r}$$

where T_b = biological half-life and
T_r = physical half-life

The biological half-life is best determined by experiment but if this information is not available it can be derived, by calculation, from excretion data if certain assumptions are made concerning ingestion.

TABLE 4(R)

EFFECTIVE HALF-LIVES OF SOME RADIOISOTOPES

Radionuclide (Total body)	Physical H-L Days	Biological H-L Days	Effective H-L Days
Tritium	$4 \cdot 5 \times 10^3$	12	12
Carbon 14	2×10^6	10	10
Iodine 131	8	138	7·6
Strontium 90	10^4	$1 \cdot 3 \times 10^4$	$5 \cdot 7 \times 10^3$
,, (for bone only)	10^4	$1 \cdot 8 \times 10^4$	$6 \cdot 4 \times 10^3$
Uranium 238	$1 \cdot 7 \times 10^{12}$	100	100
Plutonium 239	$8 \cdot 9 \times 10^6$	$6 \cdot 5 \times 10^4$	$6 \cdot 4 \times 10^4$

Units of Radiation

35. **The Roentgen.** In 1928 it was internationally agreed that X-rays should be measured by the ionization they cause in air, and nine years later gamma rays were included in the definition which was amended to read:—

> "The roentgen shall be the quantity of X or gamma radiation such that the associated corpuscular emission per 0·001293 grams of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign". (*Note.* 0·001293 grams of air = 1 cubic centimetre at N.T.P.)

It is denoted by the letter "r" and a submultiple in common use, the milli-roentgen by "mr".

36. **The Rad.** Most X or gamma rays pass straight through a substance unless it is very thick or very dense. Only a proportion of the radiation is "used up" in causing ionization. The roentgen could therefore be supposed to be either the whole emitted quantity of radiation or that portion of the quantity which is absorbed to cause ionization. The latter supposition is usually accepted but to place the matter beyond doubt a special unit, the Radiation Absorbed Dose has been introduced. One gram of an irradiated substance is said to have received a dose of one rad when it has absorbed 100 ergs of energy. One thousandth of a rad is a milli-rad which is denoted by "m rad".

37. **The Roentgen and the Rad Compared.** The roentgen applies by definition only to X and gamma radiation. The rad can be used to measure any form of ionizing radiation. The roentgen is defined in relation to an effect on air whereas the rad can be applied to any substance. The roentgen is a measurement of the *exposure* dose but the rad measures the *absorbed* dose. When soft tissues are exposed to 1r of X or gamma radiation about 95 ergs are absorbed per gram of tissue. Thus, for biological purposes, the two units are virtually interchangeable when X or gamma radiation is considered.

38. **The Rem.** The rad remains unsatisfactory, however, because the same absorbed doses of different radiations have different biological effects. Therefore the Roentgen Equivalent Man has been introduced as a unit of measurement. One rem is the dose of any radiation which causes the same biological effect as one roentgen of X or gamma radiation. The milli-rem, m rem, is a thousandth of a rem.

39. **Relative Biological Effectiveness.** If identical masses of a tissue are each exposed to a dose of 1 rad of one or other of the various types of radiation it will be discovered that the amount of biological damage which results will vary with the type of radiation involved in each case. For example, 10 rads of X-rays will cause the same damage as 1 rad of natural alpha particles. Therefore, in terms of biological damage:—

1 rad of α particles = 10 rads of X-rays.

The ratio between the two is the relative biological effectiveness (R.B.E.) of natural alpha particles. The R.B.E. for other forms of ionizing radiation is given in Table 5 (R).

TABLE 5(R)

RELATIVE BIOLOGICAL EFFECTIVENESS

Radiation	R.B.E.	Biological Effect
X-rays, gamma rays, electrons and beta rays of E_{max} greater than 30 KeV. (*N.B.* E_{max} is explained in Table 1(R))	1·0	Whole body irradiation (blood forming organs critical)
Beta rays of E_{max}, not greater than 30 KeV	1·7	
Fast neutrons and protons up to 10 MeV	10	Whole body irradition (cataract formation critical)
Naturally occurring alpha particles	10	Carcinogenesis

Notes. (*a*) The numbers quoted above are R.B.E. values in general every day use. However, they were originally selected for maximum permissible dose calculations and are sometimes denoted as R.B.E.p. for this reason. It is very difficult to determine the true R.B.E. especially for internally deposited isotopes and the R.B.E. established for one effect may not hold for another.

(*b*) An R.B.E. of unity should be used in assessing the acute lethal effect of a large dose of fast neutrons.

Thus, to derive the dose in rems the following calculation is made:—

(Dose in rads) × R.B.E. = (Dose in rems)

Examples will make the matter clear:—

Q. What is the dose in rems from 10 rads of gamma radiation?

A. $10 \times 1 = 10$ rems.

Q. What is the dose in rems from 10 rads of beta particles of E_{max} not exceeding 12 KeV?

A. $10 \times 1{\cdot}7 = 17$ rems.

PERMISSIBLE DOSES OF RADIATION

40. **History.** In 1921 the first official body to attempt to control radiation exposure was formed. It was the British X-ray and Radium Protection Committee. Other countries followed suit and in 1928 the forerunner of the present International Commission on Radiological Protection (I.C.R.P.) was created to "deal with the basic principles of radiation protection, and to leave to the various national protection committees the right and the responsibility of introducing the detailed technical regulations, recommendations, or codes of practice best suited to the needs of their individual countries". The Medical Research Council's Committee on Protection against Ionizing Radiations have studied the latest I.C.R.P. recommendations and, with certain qualifications, advocate their acceptance. In addition they have made certain recommendations on their own.

41. **Minimizing Exposure.** In the following paragraphs maximum permissible doses are quoted. Though it is believed that these doses carry a negligible probability of causing significant somatic or genetic injury, all exposures should nevertheless be kept as low as possible.

Routine Exposure

42. **Population Groups.** In order to make it possible for society to benefit from ionizing radiation some members of the population must work in close contact with various sources. This group of occupationally exposed radiation workers are allowed higher doses than the rest of the community but, so as to limit population genetic effects, the percentage of the population permitted to be so exposed is restricted. Further fractions of the population are also allowed doses which are higher than those for the population in general but are not as high as for occupational workers. This special group includes adults who occasionally work near or have to enter the controlled areas where occupational workers are employed but who are not themselves radiation workers, as well as members of the public who live in the vicinity of reactors and similar "special" areas where radiation levels may be slightly higher than elsewhere.

43. In addition to listing different maximum permissible doses for each of the three groups of the population mentioned in para. 42 (*viz* occupational workers, special groups, and the general public) the I.C.R.P. lists different maximum permissible doses for different body organs and parts. In this way they take account of the different radiosensitivities of different tissues and also the hereditary damage which can result from the irradiation of the gonads.

44. **Maximum Doses.** Table 6(R) lists the maximum permissible doses. It is based mainly on I.C.R.P.

TABLE 6(R)

MAXIMUM PERMISSIBLE DOSES TO ORGANS AND TISSUES

Exposed Part of Body	Occupational Exposure *i.e.* Radiation Workers *Note:* (*a*)	Special Fractions of the Population (*see* para. 42)	
		Special Workers *Note:* (*b*)	Public in "Special" Areas
Whole body, blood-forming organs, gonads, lens of eye (*c*)	5 (N − 18) rems (*d*) 3 rems/13 weeks (*e*)	1·5 rems/year	0·5 rems/year
Skin, thyroid, bone	30 rems/year 8 rems/13 weeks	3 rems/year	3 rems/year
Other single organs	15 rems/year 4 rems/13 weeks	1·5 rems/year	1·5 rems/year
Hands, forearms, feet and ankles	75 rems/year 20 rems/13 weeks	7·5 rems/year (*f*)	Not specified

Notes. (*a*) An occupational worker (*see* paras. 42 and 45), who is graded under the Factories Acts as a classified worker, works in a controlled area where he could receive doses in excess of 1·5 rems p.a. to the whole body, blood forming organs or the gonads. He works under the supervision of a radiation protection officer and is medically examined, including a blood examination, before and during such employment at periods not greater than 14 months. His name is entered in a "Health Register" and details of his exposure as measured by a film badge or other dosemeter are recorded. He is over 18 years of age and has been instructed in the hazards involved. He is assumed to work 40 hours per week for 50 weeks per year until the age of 65.

(*b*) "Special" workers (*see* paras. 42 and 45), who are sometimes misleadingly referred to as non-radiation workers, are employed on duties where they could not receive more than 1·5 rems p.a. to the whole body, blood-forming organs and gonads. Current regulations specify in effect that this can not be received at a greater rate than 0·0125 m rads (in air) per minute in the case of workers in a factory (as defined by the Factories Acts).

(*c*) Of the parts which are allowed to receive the least doses, the blood-forming organs and lenses of the eyes are mentioned because of their radio-sensitivity, the gonads because of the hereditary genetic effect and the whole body because it contains these parts.

(*d*) The formula D = 5(N − 18) rems, where D is the total dose which has or could have been received by the age of N years, implies a yearly maximum dose of 5 rems. Thus a person who first starts occupational exposure at say 30 years as opposed to 18 years has a reserve of permissible exposure, thus:—

$$D = 5(30 - 18) = 5 \times 12 = 60 \text{ rems.}$$

(*e*) To the extent that the formula permits, however, an occupationally exposed person may only accumulate the permissible dose at a rate not exceeding 3 rems during a period of 13 weeks *i.e.* at a maximum annual rate of 12 rems. According to I.C.R.P. the 3 rems can be given in any interval of time, for example, in a second provided no further exposure occurs in the same period of 13 weeks. Regulations made under the Factories Act in effect limit this maximum rate to 2·5 m rads in air per hour averaged over any one minute *i.e.* 0·042 m rads (approx.) per minute.

(*f*) No value has yet been specified by I.C.R.P.

45. **Genetic Assessment.** In order to assess the hereditary genetic risks to the population of the levels quoted in Table 6(R), in the light of paras. 14–17, it is necessary to add up the total radiation which may be received by the gonads from 0 to 30 years of age (the mean age of childbearing) assuming that occupational exposure starts at 18 years. Everyone receives natural background which on average amounts to:—

$$100 \text{ m rems p.a.} \times 30 = 3 \text{ rems}$$

Most people are exposed to medical radiology and this averaged over the whole population, at current rates of exposure (*see* Table 3(R)), amounts to 19·3% of natural background *viz* 0·6 rems. In addition to this 3·6 rems to the gonads the occupational worker may receive the following maximum gonad dose by the time he is 30 years old:—

$$(30 - 18) \times 5 = 60 \text{ rems}$$

A "special" worker could receive:—

$$(30 - 18) \times 1{\cdot}5 = 18 \text{ rems}$$

The public in special areas could receive a dose to the gonads between birth and 30 years of age of:—

$$(30 - 0) \times 0{\cdot}5 = 15 \text{ rems.}$$

These gonad doses may be compared with the I.C.R.P. view that "the genetic dose to the whole population from all sources additional to natural background should not exceed 5 rems (per 30 years) plus the lowest practicable contribution from medical exposure". They make the following illustrative apportionment of the genetic dose of 5 rems:—

(*a*) Occupational Exposure	1 rem
(*b*) Exposure of Special Groups	0·5 rems
(*c*) Exposure of population at large	2·0 rems
(*d*) Reserve	1·5 rems
Total	5·0 rems

This allocation implies that if the maximum gonad dose is accumulated by the age of 30 years in groups (*a*) and (*b*) then group (*a*) would not exceed 0·7% of the population and (*b*) 3%. In fact both groups are smaller than this and on average receive much less than the maximum permissible gonad (genetic) dose. However, the M.R.C. has commented that occupational workers should only receive a gonad dose of 60 rems by 30 years of age if this averages out at 1 rem or less per head of the whole population. This means that item (*a*) of the I.C.R.P.'s illustrative example is mandatory as far as the M.R.C. is concerned.

46. **Total Radiation Exposure.** The total dose of radiation received is the sum of the external and internal doses. Once they are inside the body many radioisotopes tend to concentrate in certain organs. These organs then receive a higher dose of radiation than the rest of the body. This explains why Table 6(R) refers specifically to the thyroid, bone and other organs.

47. **Critical Organ.** Because the organs and tissues of the body exhibit varying degrees of radiosensitivity it is necessary to consider sensitivity as well as the dose received. When this is done those organs which assume a greater importance are said to be "critical". In cases of uniform whole body radiation the critical tissues are the blood-forming organs, the gonads and the lenses of the eyes. If concentration in a particular organ occurs then it is usually but not always taken to be the critical organ. In certain cases, however, the dose to the organ of entry—lungs or gut—is so high that the organ itself becomes the critical organ. Bone for instance is the critical organ for all soluble plutonium salts but if the salt is insoluble then the lung, if the organ of entry, becomes critical simply because the particles of plutonium lodge there for a prolonged period.

48. **The Maximum Permissible Body Burden.** Permissible levels of radionuclide taken into the body are based either on comparison with radium or on a maximum dose-rate of 300 m rem per week to the critical organ with the exception of the gonads, blood-forming organs, skin, lenses, thyroid and bone. The total quantity in the body at any time is known as the body burden and the allowable quantity as the Maximum Permissible Body Burden (M.P.B.B.), *see* Table 7(R) and paras. 111–117.

49. **The Maximum Permissible Concentration.** Maximum Permissible Concentrations in air and water are related to the M.P.B.B. and are designed to ensure that, assuming a daily intake of 20 cubic metres of air or 2·5 litres of water, the total body burden will never build up to a level greater than the maximum permissible. I.C.R.P. lists the M.P.C.$_a$ and M.P.C.$_w$ for a large number of radionuclides. The M.P.C.$_w$ includes the water content of food and thus radioisotopes in food do not require special consideration unless they are concentrated there. M.P.C. values apply to occupational exposure and are quoted for both a 40 hour week and a 168 hour week. The first applies to 40 hours exposure per week for 50 weeks per year for 50 years and the latter to continuous exposure for 50 years. M.P.C. values are flexible to some extent, and take the exposure period into account. For example, if an occupational worker is receiving no other radiation he could work for one hour per week in an atmosphere containing 40 × the M.P.C.$_a$ of the isotope involved rather than 40 hours in 1 × the M.P.C.$_a$. If he is receiving external radiation then the M.P.C. must be reduced so that the total dose to any organ does not exceed the permitted limit. However, he can receive the full M.P.C. for any number of isotopes provided they do not affect the same organs. If the same organs are affected then each M.P.C. must be reduced in proportion so

that the total permissible dose to any particular organ does not exceed the limit specified in Table 6(R). Special workers may receive 3/10ths of the 40 hour M.P.C. and the population in special areas 1/10th of the 168 hour M.P.C. if, in both cases, there is no external radiation dose. If there is an external dose then the M.P.C. must be reduced in proportion. If the public in special areas come to be exposed to a mixture of nuclides, as in an accidental release, which affect several organs, then the 168 hour M.P.C. values must be reduced by a further one third *i.e.* to 1/30th in all. (The reason for this is that one M.P.C.—or more accurately one M.P.B.B. —gives 15 rems p.a. to the critical organ (unless it is the whole body, blood-forming organs, gonads, lenses, skin, thyroid or bone when other values apply—*see* Table 6(R) for the particular isotope involved. Therefore 1/10th M.P.C. gives 1·5 rems which is the maximum permissible dose to any single organ in a member of the public in special areas. If the mixture affects many different organs then the conditions become equivalent to whole body exposure and therefore the applicable maximum permissible dose is now 0·5 rems p.a. Since 0·5 is one third of 1·5 the M.P.C. must be further reduced by this factor). Some details of the measurement of air and water concentrations are given in paras. 105 and 106. The levels appropriate to the general public are given in para. 54 (*b*). Table 7(R) lists some M.P.B.B. and M.P.C. values for a selection of isotopes taken from the Report of Committee II of I.C.R.P. (1959), as amended by the 1962 supplement.

Accidental Exposure

50. **Occupational Accidental Exposure.** An accidental exposure occurring once in a lifetime and contributing not more than 25 rems should be added to the dose accumulated up to the time of the accident. If the sum then exceeds the maximum value permitted by the occupational formula the excess need not be included in future calculations. Accidental doses higher than 25 rems should be regarded as potentially serious and the medical authorities should decide if subsequent occupational exposure is to be limited. Planned emergency high exposure should be so arranged that the individual does not receive more than 12 rems. Women of reproductive age should not be subjected to planned emergency exposure.

51. **Population Accidental Exposure.** The M.R.C. has stated that the following total doses of external radiation are acceptable for members of the general public as the result of an accidental release of activity:—

(*a*) Gamma dose to the whole body, measured in free air *i.e.* exposure dose:

Children up to 16 years and pregnant women	20 r
Others	30 r

(*b*) A combined beta and gamma dose (subject to (*a*) above) to the whole body:

Children under 16 years	75 rads
Others	150 rads

(*c*) Beta dose to areas such as hands and flexures being in all less than 10% of the total body surface, additional to (*b*) above:

Children under 16 years	75 rads
Others	150 rads

(*d*) Gamma dose additional to (*a*) above to a small group of people performing essential duties, consisting of males preferably of the older age group or of post-menopausal females: 30 r

TABLE 7(R)

M.P.B.B.s and M.P.C.s

Radionuclide	Organ of Reference (critical organ in **bold face**)	M.P.B.B. in total body (μc)	For a 40 hour week (M.P.C.)w (μc/cm³)	For a 40 hour week (M.P.C.)a (μc/cm³)	For a 168 hour weel (M.P.C.)w (μc/cm³)	For a 168 hour weel (M.P.C.) (μc/cm³
Tritium H^3 (Sol)	**Body Tissue**	1×10^3	0·1	5×10^{-6}	0·03	$2 \times 10^{-}$[illegible]
	Total Body	2×10^3	0·2	8×10^{-6}	0·05	$3 \times 10^{-}$[illegible]
(submersion)	**Skin**	—	—	2×10^{-3}	—	$4 \times 10^{-}$[illegible]
Strontium Sr^{90} (Sol)	**Bone**	2	4×10^{-6}	3×10^{-10}	1×10^{-6}	$1 \times 10^{-}$[illegible]
	Total Body	20	1×10^{-5}	9×10^{-10}	4×10^{-6}	$3 \times 10^{-}$[illegible]
	GI Tract	—	1×10^{-3}	3×10^{-7}	5×10^{-4}	$1 \times 10^{-}$[illegible]
(insol)	**Lung**	—	—	5×10^{-9}	—	$2 \times 10^{-}$[illegible]
	GI Tract	—	1×10^{-3}	2×10^{-7}	4×10^{-4}	$6 \times 10^{-}$[illegible]
Iodine I^{131} (Sol)	**Thyroid**	0·7	6×10^{-5}	9×10^{-9}	2×10^{-5}	$3 \times 10^{-}$[illegible]
	Total Body	50	5×10^{-3}	8×10^{-7}	2×10^{-3}	$3 \times 10^{-}$[illegible]
	GI Tract	—	0·03	7×10^{-6}	0·01	$2 \times 10^{-}$[illegible]
(insol)	**GI Tract**	—	2×10^{-3}	3×10^{-7}	6×10^{-4}	$1 \times 10^{-}$[illegible]
	Lung	—	—	3×10^{-7}	—	$1 \times 10^{-}$[illegible]
Uranium U^{238} (Sol)	**GI Tract**	—	1×10^{-3}	2×10^{-7}	4×10^{-4}	$8 \times 10^{-}$[illegible]
	Kidney	5×10^{-3}	2×10^{-3}	7×10^{-11}	6×10^{-4}	$3 \times 10^{-}$[illegible]
	Bone	0·06	0·01	6×10^{-10}	5×10^{-3}	$2 \times 10^{-}$[illegible]
	Total Body	0·5	0·04	2×10^{-9}	0·01	$6 \times 10^{-}$[illegible]
(insol)	**Lung**	—	—	1×10^{-10}	—	$5 \times 10^{-}$[illegible]
	GI Tract	—	1×10^{-3}	2×10^{-7}	4×10^{-4}	$6 \times 10^{-}$[illegible]
Plutonium Pu^{239} (Sol)	**Bone**	0·04	1×10^{-4}	2×10^{-12}	5×10^{-5}	$6 \times 10^{-}$[illegible]
	Liver	0·4	5×10^{-4}	7×10^{-12}	2×10^{-4}	$2 \times 10^{-}$[illegible]
	Kidney	0·5	7×10^{-4}	9×10^{-12}	2×10^{-4}	$3 \times 10^{-}$[illegible]
	GI Tract	—	8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
	Total Body	0·4	1×10^{-3}	1×10^{-11}	3×10^{-4}	$5 \times 10^{-}$[illegible]
(insol)	**Lung**	—	—	4×10^{-11}	—	$1 \times 10^{-}$[illegible]
	GI Tract	—	8×10^{-4}	2×10^{-7}	3×10^{-4}	5×10^{-8}
Fission Products	**Lung/Bone**	—	—	—	1×10^{-6}	$1 \times 10^{-}$[illegible]
Unidentified Isotopes	—	—	—	—	1×10^{-7}	$4 \times 10^{-}$[illegible]

Note. The expression 3×10^{-3} μc means 0·003 μc or 0·000,000,003 of a curie, *i.e.* three thousandths c a millionth part of one curie. Similarly 2×10^3 μc means 2,000 μc or two thousandths of a curie.

LONG RANGE FALL-OUT FROM NUCLEAR EXPLOSIONS

Origin

52. **Source of Fall-Out.** Fall-out consists of active particles derived from:—

(*a*) The original materials in the weapon or device.

(*b*) Products created when they undergo fission (or fission/fusion).

(c) Substances from the casing and the environment activated by neutron irradiation. One of the most important of these, biologically, is carbon 14 created from atmospheric nitrogen when the burst occurs in air.

53. **Return to Earth.** The weapon itself, the conditions under which it is exploded, the season and meteorological factors all influence the pattern of fall-out. When low yield explosions take place close to the earth about half the fall-out descends in rainfall during the first month. High-altitude, high-yield explosions inject many of the particles into the stratosphere and these may take months or years to return to earth. The discussion here refers to the world wide deposition of fall-out, rather than to its descent in the locality of an explosion.

Fall-Out and the Body

54. Radiation arising from fall-out reaches the body in three main ways:—

(*a*) *External Radiation.* Gamma-emitting isotopes collecting on the surface of the earth can lead to dose rates of three to four, or even more, μ rads per hour a metre above the ground shortly after tests. These rates quickly fall to low levels (less than 1 μ rad per hour) when testing ends. In any case shielding by buildings reduces the dose to human beings by four-fifths, while the gonad dose (the significant one), is further reduced by the overlying tissues. The short-lived isotopes such as zirconium 95 and niobium 95 are the chief contributors to the dose rate initially but as they decay the long lived caesium 137 (half-life 30 years) becomes relatively more important.

(*b*) *Inhalation.* It is difficult to assess the role of inhalation. However, the average air concentrations of constituents of fall-out are hundreds of times lower than the appropriate M.P.Cs.$_a$ set by I.C.R.P. to protect the general population* against the dangers arising from the peaceful use of atomic energy. Moreover, most of the particles taken into the lung are not retained there. In the absence of specific data I.C.R.P. makes the assumption that 25% of any inhaled particles are exhaled, 50% reach the gastro-intestinal tract owing to ciliary action and 25% are retained in the lung. If the compound is soluble this last percentage passes into the body but if it is insoluble a further 12½% is ultimately swallowed. Remaining particles may be kept in the lung, may be passed to the lymph nodes or may be dissolved in blood and carried round the body. Inhalation is probably of only minor importance; for example, the quantity of strontium 90 inhaled daily is about 1/20th of that ingested.

**Note.* The limiting M.P.C. for the general population is one hundredth of the appropriate 168 hour M.P.C., *see* para. 49. The reason for this is that the 2 rem average genetic dose allowed to the population in 30 years, *see* para. 45, is made up of 1·5 rems internal and 0·5 rems external radiation dose to the gonads. Since the 168 hour M.P.C. permits 5 rems p.a., one hundredth of it gives 1·5 rems after 30 years exposure. Because of the significant risk to gonads the total body M.P.C. is used rather than the M.P.C. for the critical organ.

(*c*) *Ingestion.* Any constituent of fall-out may be ingested by man or animals after deposition on plants. In addition strontium isotopes are taken up by the roots to a much greater extent than other fission products. Strontium, caesium and iodine are transferred into milk fairly readily and caesium is also retained in meat. Plutonium is only sparingly taken up by plants or by the gastro-intestinal tract. Strontium, caesium and iodine are well absorbed into the body but most other fall-out components are poorly absorbed. Any ingested isotope irradiates the gastro-intestinal tract even if it is not absorbed.

Constituents

55. **Strontium 90.** Strontium 90 is a beta emitter with a physical half-life of 28 years and it is biologically similar to calcium. In times of relatively high fall-out (*e.g.* 0·68 mc/km²/month early in 1959 at Milford Haven) the quantity entering the human diet depends more on deposition on leaves than on root absorption. Thus the rate of fall-out is important. In times of low fall-out (*e.g.* 0·16 mc/km²/month early in 1960) the situation is reversed and the cumulative amount available in the soil to the roots is more important. In the soil the stronium 90 is taken up by the roots in proportion to the strontium 90 to calcium ratio. Plants in low calcium soils take up a greater proportion of strontium 90. Adding lime to such soils will reduce the absorption of strontium 90. In passing through animals the strontium 90/calcium ratio is reduced by discrimination against the former; for example, the ratio in milk is only one-tenth of the ratio in the diet of the animal. The ratio of strontium 90 to calcium in the total diet is about 1·4 times that in milk in countries where milk is the main source of calcium. Therefore milk measurements give a good guide to total strontium 90 intake in such countries. About 90% of the total internal strontium enters by ingestion. The strontium 90 to calcium ratio in plasma and new bone is about one-quarter of the ratio in the diet owing to discrimination against strontium mainly in its absorption from the gut. Similar discrimination occurs in the placenta, and the ratio in foetal plasma is only half that of the maternal plasma. Thus, in times of rising fall-out the bones of newborn children contain a lower strontium 90 to calcium ratio than those of infants and young children who have been laying down new bone in large quantities. Adolescents and adults who are exposed for the first time take up very little strontium 90 into their bones. The ratio is expressed usually as $\mu\mu c$ (or picocuries) of strontium 90 per gram of calcium. Typical bone values in the first half of 1961 were, newborn children 0·74 picocuries/g Ca, infants and children 0–5 years old, 2·07 picocuries/g Ca, children and adolescents 5–20 years old, 1·0 picocuries/g Ca and over 20 years, 0·36 picocuries per gram of calcium. Strontium is taken into the crystal structure of bone and irradiates it and those bone- and blood-forming cells lining bone surfaces. It is feared, but not proved, that this may lead to enhanced induction rates of leukaemia and bone tumours in the population. Any such increase could only amount to a fraction of the existing rates.

56. **Caesium 137.** Caesium 137 irradiates the body externally and thus the total accumulated deposit on the ground is the important factor. Owing to its being washed away by rain and to its redistribution in soil by cultivation it disappears from the surface with an apparent half-life of 10 years. It also enters the body by ingestion following direct deposition on leaves. Unlike strontium it is readily redistributed in the plants on which it falls. Once in the soil it is largely inaccessible to plants and therefore the quantity in which it is found in the diet is even more dependent upon the rate of fall out than is strontium. *Via* the diet of cattle it readily enters milk, the more important dietary source in western countries, and

meat. In the body, unlike strontium, it irradiates the whole body instead of one organ and has an effective half-life of about 4 months as opposed to more than 15 years. Again, unlike strontium 90 which emits beta particles which are hard to detect it decays to barium 137 which emits a gamma ray of characteristic energy which can be measured outside the body in a whole body counter (*see* para. 112) and thus the total quantity of caesium 137 in the body can be deduced directly.

57. **Carbon 14.** Weapon tests up to 1960 had added 20–30% to the natural background carbon 14. It has a half-life of 5,568 years and enters biological matter *via* the carbon cycle. It contributes only a small dose to the whole body of exposed individuals but, owing to its very long half-life, it will contribute a greater total dose to human gonads (over thousands of years) before it finally disappears than all the other components of fall out added together. It has considerable genetic significance since 37% of the atoms of the chromosome material D.N.A. (desoxyribonucleic acid) are carbon. If carbon 14 becomes incorporated in the molecule damage may result from the beta particle released when the atom decays and also by the fact that it is transmuted to nitrogen when this occurs.

58. **Iodine 131.** Iodine 131 has a physical half-life of 8 days and is thus only important for a very short period after a test. It is ingested mainly in milk and is concentrated in the thyroid gland.

59. **Dose Commitment.** The foregoing paragraphs show some of the difficulties in estimating the doses of radiation received by the world population from fall-out. The amounts and proportions of the constituents vary in time and place and therefore the breakdown of the total dose received by the average individual in any one year is almost meaningless. However, the total dose contributed by each component, before it finally disappears, to an average member of the world population is most informative and is known as the dose commitment. Table 8(R) gives the dose commitment, as calculated by the U.N. Scientific Committee, for tests carried out over the 8 years ending in 1961. The average gonad dose from natural background radiation received during these 8 years in the U.K. was approximately 8 × 100 m rems. Thus the 111 m rems delivered to the gonads over all time by fall-out is about 14% of background in the years of the tests.

TABLE 8(R)

DOSE COMMITMENT (m rem) FROM ASSUMED PRACTICE OF TESTING 1954–61

Source	Gonads	Cells Lining Bone Surfaces	Bone Marrow	Fraction of Dose Commitment Reached by 2000 A.D.
External	30	30	30	0·97
Internal				
Sr. 90	N/A	79	40	0·91
Cs. 137	11	19	14	1·0
C 14	70	116	70	0·10
TOTAL	111	244	154	0·42 for gonads 0·54 cells lining bone 0·56 for marrow

Note. Thus, the carbon 14 released during the eight year period will have delivered 0·1 of 70 m rems (*i.e.* 7 m rems) to the gonads of the average individual by 2,000 A.D. leaving 70–7 (*i.e.* 63 m rems) to be delivered to future generations.

EFFECTS ON CELLS AND SOME ORGANS

Cells

60. **General.** The effects of radiation upon cells vary according to total dose, time intervals between doses, total exposure time, dose rate and the nature and energy of the radiation. They may be considered under the following headings:—

(*a*) *Genetic Changes*. Genetic damage to somatic cells may lead to the later appearance of cancer. Abnormalities may appear in subsequent generations if the damage occurs to a germ cell (*see* para. 15).

(*b*) *Chromosome Abnormalities*. Visible breaks may occur in chromosomes. Reunion usually takes place but sometimes the pieces are permanently detached from one another or deleted altogether. Occasionally the pieces are wrongly reunited giving rise to translocation or inversion. Gross damage kills the cell but small changes are compatible with survival and even with reproduction. The chromosomal abnormalities detected in certain cases of acute and chronic myeloid leukaemia are possibly related to these effects.

(*c*) *Interference with Cell Division*. A large dose of ionizing radiation stops cell division. A smaller dose may inhibit division for a few hours. When it does take place the division may appear normal and be followed by a second apparently normal division before the daughter cells die. The full effect of radiation injury is thus in some cases delayed. Nevertheless, inhibition of mitosis is amongst the earliest effects of radiation.

(*d*) *Cytoplasmic Effects*. Cytoplasmic effects appear more slowly than do changes in the nucleus. Large doses cause vacuolation and eventual disappearance of cytoplasm. It is not yet certain whether the effects are brought about by the free radicles formed when cell enzymes are exposed to radiation or whether they are simply the cytoplasmic response to nuclear damage.

61. **Cell Death.** Injured cells may suffer immediate or delayed degeneration and death. The death of many adjacent somatic cells leads to necrosis and to ulcer formation, and the death of germ cells to sterility. The cells of different species, the cells of different individuals within that species, the cells of different tissues and the apparently identical cells in the same piece of tissue all differ in their susceptibility to radiation damage.

62. **Recovery.** Small doses of radiation inhibit cell division for a time but soon mitosis takes place again, often more rapidly than before. Larger doses may kill a few cells but these are soon replaced in tissues capable of regeneration. The total biological effect is thus the sum of damage and recovery.

63. **Biological Factors.** The younger and the more complex, the more active and the less healthy, the less ischaemic and the less differentiated the cell, the more will it be damaged by radiation. If cell activity is depressed by certain drugs or by cold before irradiation, less than the expected damage ensues.

Organs

64. **Skin.** The ionizing radiations most likely to damage skin are high-energy alpha particles, beta particles and low-energy X and gamma rays. The pathology is similar to that following over-exposure to ultraviolet light. The energy and nature of the radiation, the duration and manner of the exposure (continuous or intermittent), the intervals between doses, the total dose, the colour and moistness of the skin, the site, the

race, the sex and the age of the patient all alter the effect of ionizing radiation upon the skin. The dose required to affect skin is high. Acute doses in excess of 600 rads are necessary to cause erythema. Doses between two and four thousand rads will result in early erythema in one day and skin breakdown in one to two weeks. If the whole body were exposed to such doses of penetrating radiation the Acute Radiation Syndrome would result. Cancer of the skin, occurring after an interval of years, is an occasional late effect of over-exposure.

65. **Alimentary Canal.** The alimentary canal is affected either by external penetrating ionizing radiation or by the radiation from ingested radioactive particles. Large doses cause increased peristalsis, vomiting, erythema, ulceration and haemorrhage. Gangrene and fibrous stricture may follow later. All parts of the canal do not appear to be equally affected, perhaps because different recovery potentials exist.

66. **Blood.** Blood-forming organs are affected either by external penetrating radiation or by the emissions from radioactive particles lodged nearby. The effects depend upon the life cycle of each of the blood cells. Lymphocytes are first affected, their numbers declining within a few hours. The granulocyte count falls within a few days and the platelet and red blood cell counts within a few weeks. Agranulocytic angina, petechiae, bruising, haemorrhage and anaemia follow as secondary effects. Eventually, where the dose is not too large, the blood-forming organs recover and the blood picture returns to normal. Sometimes there is an excess of repair activity, immature cells making their appearance. Where differentiation is affected abnormal cells are found. Possible late effects include leukaemia, lymphosarcoma and aplastic anaemia.

67. **Bone.** Alpha emitters, such as radium and plutonium, when deposited in bone affect the osteogenic connective tissue lining endosteal surfaces and resorption cavities of bone trabeculae. Beta emissions, like those from strontium 90, and external radiation affect loose connective tissue in the bone marrow spaces between bony trabeculae. There is no obvious relationship between the degree of radiation damage and the incidence of sarcoma and it may be that gross damage is protective owing to the resultant reduction in the capacity of the tissue to proliferate. In animal experiments the induction of leukaemia by the administration of bone-seeking internal emitters is overshadowed by the far greater induction of bone tumours.

THE PRINCIPLES OF PROTECTION

Radiation Shielding

68. Radiation received from external sources may be reduced by the interposition of a suitable material (such as lead in the case of X or gamma radiation) between the source and the subject. After having placed a shield in position measurements with a suitable instrument should be made in order to show that radiation is not being unduly reflected from walls, floor or ceiling and to check the adequacy of the shield itself. (*See* para. 108.) It is necessary to ensure that people are not inadvertently exposed by radiation penetrating walls. Although the trunk may be shielded by a wall of lead bricks the head, arms and perhaps legs are often exposed. In such a case an extra dosimeter and/or film badge should be fixed to the exposed part. Large sources of ionizing radiation are best used in the quiet hours to reduce the chance that other people will be irradiated accidentally. (*See* para. 157).

69. Adequate shielding, as defined in the "Ionizing Radiation (Sealed Sources) Regulations, 1961" is the provision and proper maintenance, round the source, of shielding or a demarcating barrier outside which the dose rate averaged over one minute does not exceed 2·5 m rads in air per hour for occupational workers or 0·75 m rads per hour for all other workers. The limitation of the dose rate to one minute is largely for the convenience of the Factory Inspector who may occasionally wish to measure it.

Effect of Distance

70. The intensity of radiation from a point source varies inversely with the square of the distance. It is possible to reduce the dose received, therefore, by the use of remote handling tools such as tongs or window-dressing arms. Radiation from plane surfaces and collimated beams falls away more slowly. (*See* para. 152.)

Effect of Time

71. Because the activity of all radioactive substances is subject to decay, it is sometimes convenient to await the reduction in activity of short half-life radioisotopes and this technique may be employed to deal with contaminated clothing where an "active laundry" is not available or with contaminated aircraft.

Protective Clothing

72. Persons handling highly contaminated objects or unsealed sources should wear protective clothing in order to prevent contamination gaining access to the body and personal garments. One or more of the following items, all of which should be clearly marked, may have to be worn:—

(*a*) Plastic, linen or paper hat.

(*b*) Rubber, canvas or linen gloves.

(*c*) Washable or disposable overgarments such as denims, laboratory coats or surgical gowns.

(*d*) Eye shields or safety glasses. (These may be especially necessary for work on beta emitters in order to keep the dose to the lens below permissible limits.)

(*e*) Rubber boots or overshoes made of linen or plastic.

(*f*) Respirator (Respirator Antigas Light Interim Pattern).

(*g*) Rescue breathing apparatus.

(*h*) Completely enclosed "frogman suit" with piped air from a compressor.

73. The particular clothing required depends upon the nature and degree of risk. Overalls or laboratory coat with overshoes are the minimum. Complete enclosure and an independent air supply are required where the levels of airborne activity are well in excess of the $M.P.C._a$ and exposure is prolonged. The matter is considered further in paras. 78–84.

74. Clothing changes should take place at a foot barrier between the active and inactive areas. All procedures at the barrier should be planned so as to keep the contamination on the active side of the barrier. For example in an active area the soles of the overshoes pick up contamination from the floor. Therefore, when leaving, one overshoe is first removed (by inserting fingers inside the overshoe thus avoiding hand contact with the active exterior) and is placed in a receptacle provided on the active side of the barrier. In the meantime the foot has been lifted across the

barrier without touching the floor on the active side, otherwise the shoe would carry contamination into the inactive area. The other overshoe is now removed before that foot in turn is lifted across the barrier.

75. **Removal of Clothing.** After use protective clothing should be monitored before its removal in a "no-contact-with-the-outer-surface" manner similar to that employed when surgical garments are donned. It should not be shaken because particles thus released may be inhaled. Gloves should be washed with soap and water before removal. Very active items should be disposed of as "active waste" but the remaining items may be laundered, if necessary, at an "active laundry". In most cases time decay should be permitted before laundering is attempted. Contaminated fabric may be sent to a normal laundry provided it does not exceed the contamination limits set in Table 9(R).

TABLE 9(R)

MAXIMUM PERMISSIBLE LEVELS OF SURFACE CONTAMINATION

Type of Surface	Principal alpha emitters (*see* para. 91)	Low toxicity alpha emitters	Beta and beta/gamma emitters (*see* para. 98)
Articles and surfaces in:—			
Inactive and low activity areas	10^{-5} μc/cm²	10^{-4} μc/cm²	10^{-4} μc/cm²
Active areas	10^{-4} μc/cm²	10^{-3} μc/cm²	10^{-3} μc/cm²
Personal clothing hospital bedding	10^{-5} μc/cm²	10^{-4} μc/cm²	10^{-4} μc/cm²
Protective clothing	10^{-4} μc/cm²	10^{-3} μc/cm²	10^{-3} μc/cm²
Skin	10^{-5} μc/cm²	10^{-5} μc/cm²	10^{-4} μc/cm²

Notes. (*a*) Averaging is permitted over inanimate areas of up to 300 cm² or, for floors, walls and ceiling, 1000 cm². Averaging is permitted over 100 cm² for skin or, for the hands, over the whole area of one hand, nominally 300 cm².

(*b*) Principal alpha emitters are all other than those listed in note (*c*).

(*c*) Low toxicity alpha emitters are uranium isotopes, enriched and depleted uranium, natural uranium, natural thorium, thorium 232, thorium 228 and short-lived nuclides such as the daughters of the isotopes of radium.

(*d*) The method by which readings from a variety of instruments can be converted to contamination levels is given in paras. 99–101.

(*e*) Contamination levels should be kept as low as possible and usually within the above limits, although some relaxation may be authorized in the case of surfaces where the activity is mainly fixed (*see* paras. 80 and 102–104). Loose activity levels must never exceed the above limits. The maximum tolerable fixed activity depends upon the dose it delivers to those working in its vicinity. It may be possible to reduce this (*see* para. 125).

Personal Protective Measures

76. Unsealed sources should not be manipulated with the unprotected hand and special precautions should be taken to avoid punctures or cuts of the skin. Persons with open skin wounds should not work in contaminated areas. The welding, brazing, soldering, *etc.*, of radioactive metals should not be permitted unless it is carried out in a specially ventilated place and by special techniques designed to prevent the inhalation of active dust. Disposable paper handkerchiefs and paper towels

should be provided together with "active waste" containers into which they may be thrown after use. Hands should be well washed after leaving the controlled area and, together with the shoes and clothing, they should be monitored. Food, drink, cutlery, crockery, handkerchiefs, smoking items, cosmetics and barrier creams should not be introduced into a contaminated place since the use of any of them might provide a means by which contamination could enter the body. In order to reduce decontamination operations, tools, *etc.*, should not be taken in unless they can be left there until the job is completed.

General Measures

77. All operations should be planned to limit the spread of radioactive material. Air flow should always be from the uncontrolled to the controlled area. The unnecessary movement of persons or materials should be avoided. Equipment used in an active area should not be used elsewhere until the level of activity upon it has been reduced below the limits quoted in Table 9(R). Small contaminated objects for disposal should be placed in paper, or preferably, polythene bags. If necessary they should then be placed in containers of lead or other metal. A label should be fixed to the container stating the nature of the contents, their physical condition and total activity, and the dose rate at the surface of the container. The label should only be destroyed when the contaminated item is in the charge of a person who is aware of the hazards.

Practice in the Atomic Energy Authority

78. The organization of the protective practices in a typical A.E.A. establishment is based upon a system of colour coding for the "controlled" areas where special precautions are necessary. Entrances are specially marked so that those entering see quickly what kind of precautions are required. The markings also serve to warn unauthorized personnel against entry. One such system of coding is described below.

79. **Blue Areas.** Where there is a risk from penetrating radiation such as neutrons, beta radiations, X or gamma rays from machines or from enclosed or sealed sources the area is designated a blue area. It is a *radiation* area. A film badge and/or some other form of dosimeter must be worn but protective clothing is unnecessary. A dosimeter and a film badge would be worn if an operation involving exposure to high dose rates (*e.g.* 75 mr. per hour or more) were being undertaken so as to permit the operators to make a rough check on their dose at frequent intervals. The monthly reading of film badges provides a ready method of ensuring that safe practices are being followed in such areas but this is supplemented by surveys with instruments.

80. **Red Areas.** Red areas are *radioactive* areas where there is a possibility of alpha or beta/gamma-emitting particles becoming airborne. Also there may be an additional risk from penetrating radiation. Normally the levels of surface contamination are kept below the levels shown for active areas in Table 9(R). They are controlled by regular area surveys, with probe and/or smear, followed by cleaning if necessary. Higher levels may be permitted particularly if most of the activity is fixed *i.e.* cannot easily be removed (*see* para. 102), or if an isotope of low radiotoxicity is involved. The levels of airborne activity are found by the use of air samplers (*see* para. 105) and are compared with the M.P.C.$_a$ values issued by I.C.R.P. If they are found to be consistently higher than the permitted concentrations, the processes in use are modified. Biological

monitoring is used to supplement air sampling. Film badges, laboratory coats and overshoes are minimum requirements but, depending upon the work to be done, gloves, hats, boiler suits, *etc.*, may be used. The decision as to the wearing of a respirator is a matter of judgement. If levels of surface contamination are high and a dust-disturbing activity is to be undertaken it may be advisable to wear one. However, an air concentration which is higher than the M.P.C.$_a$ is not necessarily an indication for using a respirator (*see* para. 49).

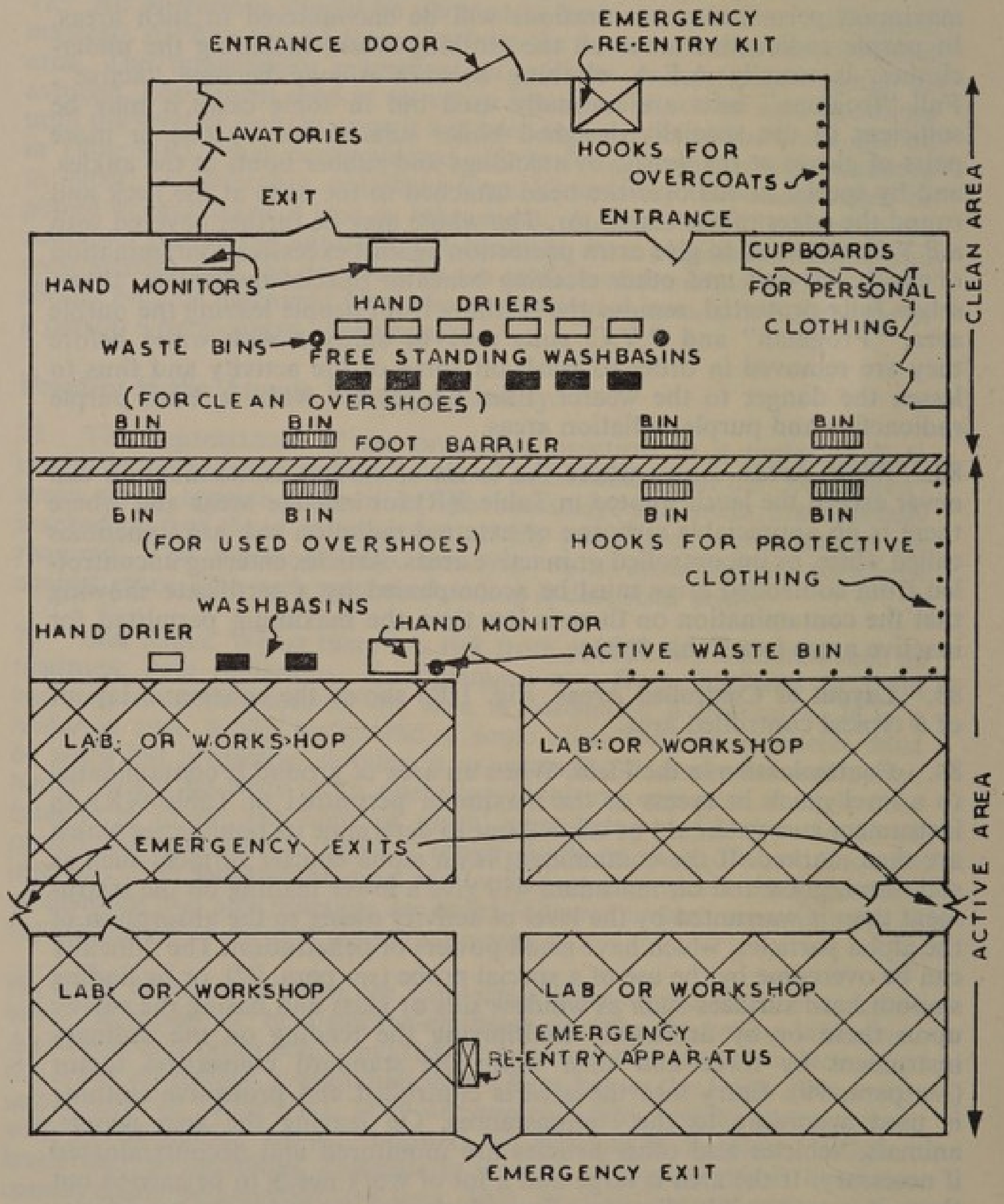
81. **Purple Areas.** A purple area is an *exclusion* area where access is restricted to specially trained people under the strictest supervision and control. Extremely high dose rates or airborne levels well in excess of maximum permitted concentrations will be encountered in such areas. In purple radioactive areas all the clothing worn, including the underclothes, is usually A.E.A. clothing because it may become "active". Full "frogman" suits are normally used but in some cases it may be sufficient to use specially designed boiler suits sealed by one or more pairs of gloves at the wrists, by stockings and rubber boots at the ankles, and by special hoods over the head attached to the suits at the neck and round the edges of the respirator. The whole may be further covered with a P.V.C. suit so as to give extra protection against excessive contamination of the boiler suit and other clothing beneath. Special undressers, themselves fully protected, remove the clothing from people leaving the purple area. "Frogman" and P.V.C. suits may be sprayed with water before they are removed in order to wash off some of the activity and thus to lessen the danger to the wearer. Film badges are worn in both purple radioactive and purple radiation areas.

82. **White Areas.** Areas where the levels of surface contamination can never exceed the levels quoted in Table 9(R) for inactive areas and where there is no appreciable airborne or external radiation risk are sometimes called white, or uncontrolled or inactive areas. Articles entering uncontrolled from controlled areas must be accompanied by a certificate showing that the contamination on them is less than the maximum permitted for inactive areas (*see* Table 9(R)).

83. **Layout of Controlled Areas.** Fig. 1(R) shows the schematic layout of a typical controlled area.

84. **Contamination in the Field.** When an area of ground is contaminated to a level much in excess of the maximum permitted in Table 9(R) an instrument survey should be carried out to determine its boundaries which are then marked. If the contaminant is an alpha emitter surfaces such as soil, sand, grass and tar macadam will give a lower reading on the instrument than is warranted by the level of activity owing to the absorption of the alpha particles, which have small powers of penetration. The difficulty can be overcome by the use of a special probe (*see* para. 92), or by finding smooth hard surfaces such as window sills or glass and basing the survey upon these or by arbitrarily multiplying the reading on the ordinary instrument by three and then using the standard conversion factor (*see* para. 99). Entry into the area is controlled and protective clothing is used according to the circumstances. On leaving the area people, animals, vehicles and other articles are monitored and decontaminated if necessary. If the area is large and a lot of work needs to be carried out there, it is worthwhile allotting a few vehicles for use inside the boundaries only, thus saving the effort of decontaminating many vehicles at the end of the operation. Clean vehicles are parked outside. The aim to be followed in dealing with contamination in the field is the same as in a controlled area, *viz* the contamination must be contained and not allowed

to spread to clean areas. This may be impossible when contaminated casualties have to be removed but the use of polythene sheeting inside the ambulance, on the stretcher and inside the sick quarters or hospital will help to minimize the spread. Because of the danger of isotopes gaining entry to the body through a non-intact skin it is vital to prevent the spread of contamination to M.I. rooms, casualty departments and operating theatres in order to avoid the time-consuming process of decontaminating them before subsequent use by uncontaminated patients.



LAYOUT OF ACTIVE AREA

FIG. 1(R)

Protection in Laboratories

85. **Facilities.** The facilities listed below should be available in any laboratory handling radioactive materials:

(*a*) Washing facilities with knee- or foot-operated taps.

(*b*) A floor strong enough to support heavy shielding materials. It should have a smooth, continuous, non-absorbent surface which can easily be cleaned or removed. Floors should be cleaned by moist mopping; and to reduce the spread of contamination excessive water should not be used. Dry sweeping should be avoided in order to reduce the inhalation hazard.

(*c*) Walls and ceilings finished with a non-porous washable surface such as certain hard-gloss paints.

(*d*) Work surfaces of waxed wood, stainless steel, plastic sheets, glass or enamel. They should be protected by a disposable cover such as a polythene sheet since it only has to be replaced when decontamination is necessary.

(*e*) Drip trays where wet processes are involved.

(*f*) Fume cupboards which may be constructed of wood and glass if the wood is painted with a special hard gloss or strippable paint. The base of the cupboard should be of slate or covered with linoleum. These cupboards should not be used for handling more than one millicurie of any alpha emitter. The air exhaust system in a fume cupboard should be sufficient to produce an air flow of at least 200 linear feet per minute through the window of the cupboard when it is open to the working position when solids are handled and twice this velocity when radioactive gases are handled. An air flow as low as this is sensitive to the movement of air in the laboratory. Smoke tests should therefore be carried out to ensure that the draught is adequate under all conditions of ventilation. This is a task for ventilation experts. The exhaust air must not be discharged at a point where it could enter the air intakes. It will need to be filtered if it results in anyone being exposed to more than the maximum air concentration permitted to his group of the population or if it results in activity being deposited in the area in excess of the maxima for inactive areas given in Table 9(R). However, further special considerations may apply (*see* para. 147).

(*g*) Tongs, forceps, trays and, where necessary, remote handling equipment, all of which should be confined to the active area.

(*h*) Equipment and protective clothing (including gloves and respirators) which should be inspected frequently.

(*i*) Pyrene and fire fighting equipment which should be readily available outside the door of the laboratory.

MONITORING INSTRUMENTS AND PROCEDURES

Instruments

86. Radiation instruments used to protect health fall into one of two categories:—

(*a*) Survey meters for the measurement of external penetrating radiation.

(*b*) Contamination monitors which are used to measure contamination levels.

Survey meters are fairly straightforward; paras. 68–69, 79, 107–110 and 150 indicate their mode of use. Most of the following account—up to para. 106—is concerned with the use of contamination monitors.

87. All instruments are either ratemeters or integrating dosimeters. A ratemeter measures the rate at which radiation is being received. Survey ratemeters are calibrated in the form of roentgens per hour or m rem per minute or some similar unit and contamination monitors in counts per second. Integrating dosimeters, of which film badges and quartz fibre dosimeters (Q.F.D.) are examples, record the total dose received whilst the instrument was in use.

88. **Service Instruments.** The working principles of all types of instruments used in the service are described in A.P. 4687 "Basic Physics and Radiation Hazards and Detection" to which reference should be made for any information additional to the following list of the differing methods of detection:—

(*a*) Ionization chambers are used for beta, thermal neutron, X and gamma measurements. The Meter Survey Radiac No. 3 and the N.I.S. 221 Gas Monitor are based on ionization chambers. The Q.F.D. is a special form of ionization chamber sensitive to X and gamma radiation.

(*b*) Proportional counters are mainly employed for detecting neutrons. The Fast Neutron Monitor Type 1262 is an example of this use.

(*c*) Geiger counters are designed especially for the purpose for which they are to be used but the geiger principle can be employed to detect alpha or beta and gamma radiation. The beta/gamma probe used with either the Radiation Monitor Type 1257 or the Radiac Set Type 1320 X is a geiger counter and the Meters Doserate Portable No. 1 and Contamination No. 1 are based upon them.

(*d*) Scintillation counters can be used to measure any radiation but in practice they are mostly confined to alpha or X and gamma radiation measurements. The alpha probes supplied with the 1257 and 1320 instruments employ zinc sulphide scintillation phosphors and the X probe of the 1320 uses a sodium iodide crystal to measure the X-rays emitted by plutonium.

(*e*) Solid state detectors are becoming increasingly important in many roles but instruments using the principle are not available in the Royal Air Force.

(*f*) Film badges can be used to provide a permanent record of the integrated dose of X or gamma rays and of slow or fast neutrons. For the last a special type is required. When needed in the Royal Air Force they are supplied by the Radiation Protection Service on demand through Ministry of Defence (M.A.3 (RAF)).

The Use of Alpha Scintillation Counters

89. An alpha scintillation probe can be used to measure the total alpha contamination on a surface directly. Alternatively, when incorporated into a drawer assembly, a 1320 alpha probe can be used to count alpha activity on filter papers which have been used for smear surveys (*see* para. 103) or in air samplers (*see* para. 105). In either role it is important to prevent contamination being deposited on the sensitive end of the counter as it will add to the background reading.

90. **Light Sensitivity.** The zinc sulphide screen is light sensitive. When used in the drawer assembly this does not matter since the drawer excludes light when it is shut and thus only the activity on the filter paper inside the drawer is counted. However, when the probe is used in the usual way, *i.e.* to measure surface contamination directly, the screen is covered by a layer of tough plastic material over one or two layers of thin aluminium

FIG. 2(R). THE 1320 MONITOR WITH ALPHA DETECTOR IN OPERATION
In the field the whole assembly would be polythened as a protection against contamination. The insert indicates the ground to probe-face distance.

foil in order to exclude light. The whole is further protected by a metal grille. Before use the probe should be explored with a light bulb in order to see if the count rate rises owing to light sensitivity and in use care should be exercised to prevent the foils becoming perforated *e.g.* by grass. The probe must be changed (or repaired) if it becomes light sensitive. When the probe is changed the operating voltage of the instrument must be adjusted (by a trained person) to suit the new probe otherwise inaccurate readings may result.

91. **Contamination Survey Technique using an Alpha Probe.** Alpha counters give a low background reading, unless the probe unit is light sensitive or contaminated, and it is not usually necessary to subtract it from subsequent readings. In use, the probe should be held as close as possible to the contaminated surface. The count rate can then be noted. If the count rate is too low to be accurately read from the meter (less than 1–2 c.p.s.) then the actual counts must be counted over a known period of time. In the case of the 1320 the clicks in the earphones occurring in one minute are counted. A G.P.O. mechanical counter is incorporated in the 1257 and this will add the counts automatically. The background count must be previously determined and subtracted from the final count in such cases. This is simply done by operating the probe in an area free from radioactivity and noting the count rate. Alpha counters are slightly sensitive to gamma rays. If alpha contamination has to be measured in the presence of gamma radiation a piece of uncontaminated paper placed over the sensitive end of the probe will stop alpha particles entering and any count rate noted thereafter will be due to gamma rays (plus background). The maximum count rates of both the 1257 and the 1320 are 1,000 c.p.s. If high levels of alpha contamination are to be measured the range of the instruments can be extended by covering a part of the probe surface with cardboard. For example, if it is half covered then all subsequent readings are multiplied by two. The limit to this procedure in practice is a hole of 4 sq. cms. in the centre of a piece of cardboard over the screen of the 1320 alpha probe. Since this is 80 sq. cms. in area subsequent readings are multiplied by 20 thus extending the range of the instrument to 20,000 c.p.s. The method for converting count rates into contamination levels is given in para. 99 and smear surveys are considered in para. 103. Once the contamination level is known it can be compared with the maximum permitted levels quoted in Table 9(R). Owing to absorption of alpha particles, it is necessary to multiply the results obtained, when the ordinary alpha probe is used, by 2 if clothing is being surveyed and by 3 if a ground surface (*e.g.* concrete, grass, *etc.*)—*see* para. 84.

Plutonium Contamination Survey Technique Using the X-ray Probe

92. The use of the 1320 alpha probe to survey ground contaminated with alpha emitters is a laborious and tiring task since the probe has to be held close to the ground. In the case of contamination by plutonium this difficulty can be overcome by making use of the fact that 4% of its disintegrations are accompanied by the release of X rays which have far greater range and penetrating power than alpha particles.

93. The X-ray probe unit has been designed for use with the 1320X instrument. It is mounted on the extension rod supplied and when used in the manner illustrated in Fig. 2(R) it permits the operator to walk upright and yet hold the probe about 10 cms. from the ground. The conversion factor is given in para. 101.

94. Since alpha particles are absorbed by a layer of liquid such as water or blood it may be impossible to determine with an alpha probe whether

wounds or wet clothing are contaminated. The 1320 with the X-ray probe attached can be used as a detecting, rather than a measuring, instrument under these circumstances. The probe is held close to the surface and the presence of contamination is shown by any reading above background.

Beta/Gamma Contamination Surveys

95. The beta/gamma probe supplied in the service may be used either with the 1257 or the 1320. The geiger tube is mounted in a metal cylinder one portion of which is a moveable window. When the window is open the counter measures any beta and gamma radiation which reaches the probe. With the window shut gamma rays only are counted since the beta particles are excluded. When measuring contamination which emits both beta and gamma radiations, for example fission products, both types of reading are taken and subtracting the latter from the former gives a measure of the beta dose.

96. The probe may become light sensitive if the substance painted on the geiger tube wears away. Therefore before use the probe, with its window open, should be offered up to a lighted 60 watt bulb in order to determine whether this causes the count rate to rise.

97. It is necessary to determine the background count rate before use. This is done by switching on the instrument and holding the probe, with the window open and facing downwards, about a metre above the ground. Since natural radiations are random in their occurrence the meter should be observed over a period of a few minutes and the average count rate obtained. The true count is the count measured in the presence of activity minus the background count. Again, owing to random emission, only approximate measurements of levels less than three times background will be obtainable with service instruments.

98. In use the probe should be held one inch from the surface being monitored and moved slowly over it. Factors for converting the true count into a contamination level which can then be compared with the values in Table 9(R) are given in para. 100 and smear surveys are considered in para. 103.

Conversion Factors

99. **Alpha Probe Conversion Factors.** The use of conversion factors is a convenient and quick method of converting count rates into contamination levels. They may not be completely accurate in all circumstances but are sufficiently so for all practical purposes. When held close to a smooth (*see* para. 84), dry surface uniformly contaminated with a high energy alpha emitter such as plutonium or polonium, the 1320 alpha probe with two foils (additional to the sheet of plastic) and the 1257 alpha probe with one foil (additional to the sheet of plastic) will give readings on their instruments of 50 and 15 c.p.s. respectively when the contamination level is 1×10^{-4} $\mu c/cm^2$.

(*Note*. The use of only one foil on the 1320 alpha probe makes little difference to the conversion factor.)

The 1257 and the 1320 give readings of 100 and 400 c.p.s. respectively when the contaminant is a low energy alpha emitter such as uranium or thorium and the level is 1×10^{-3} $\mu c/cm^2$. The conversion factors for the B.N.110 are the same as for the 1320. Appropriate multiplication or division permits other count rates to be converted and the result can be compared with the permitted levels quoted in Table 9(R). For example in the first case quoted:—

50 c.p.s. = 1×10^{-4} μc/cm² (= 1 μc/m²)

Therefore:— 75 c.p.s. = $1{\cdot}5 \times 10^{-4}$ μc/cm² (= 1·5 μc/m²)

350 „ = 7×10^{-4} „ „ (= 7 „)

500 „ = 1×10^{-3} „ „ (= 10 „)

5 „ = 1×10^{-5} „ „ (= 0·1 „)

100. **Beta/Gamma Probe Conversion Factors.** When the beta/gamma probe supplied with the 1257 and 1320 instruments is held, with its window open, one inch above a uniformly contaminated surface greater in area than 8″ × 3″ the instrument will record 5 c.p.s. above background if the contamination level is 1×10^{-4} μc/cm². Other count rates can be converted in the manner shown in para. 99. Soft tissues in close contact with this level of contamination receive about 1 m rad per hour. Once derived the level may be compared with the permitted maximum quoted in Table 9(R).

101. **X-ray Probe Conversion Factor.** When the X-ray probe unit is held about 10 cms. above a surface uniformly contaminated with plutonium the 1320X instrument will give a reading of 20 c.p.s. if the level is 60 μc/m² (= 6×10^{-3} μc/cm² or 1,000μ grams/m²) provided that no X or gamma emitter (other than the plutonium) is present.

Contamination with Loose Activity

102. Activity on a surface is considered to be part loose and part fixed. Loose activity is that amount of activity which can be removed by moderate pressure. It is important to know what portion of the total contamination is loose since this may be transferred *via* the hands and clothing into the bodies of those who come into contact with it and furthermore it may become airborne if disturbed and thus present a possible internal hazard. Activity fixed to a surface can be dangerous as a source of external radiation only, whereas loose activity is both an external and an internal hazard (*see* note (*e*) under Table 9(R)). When work is being carried out on a large contaminated surface, such as an aircraft contaminated with fission products, the loose activity will be transferred to the overalls and will present a hazard until they are removed. Fission products emit beta and gamma radiations and the dose contribution from the latter can be significant in this context.

103. **Estimation of Loose Activity.** There are two methods which can be used to assess loose activity:—

(*a*) *Subtraction Method.* An area of about one square foot is selected and the total activity is measured with the probe held over the centre. The area is wiped and the procedure is repeated. A subtraction gives the loose activity reading which can be converted to a contamination level by use of the appropriate conversion factor. The method is useful in the field and has the small advantage that the background count may be ignored.

(*b*) *Smear Method.* A hard filter paper (Whatman No. 1) is placed on the contaminated surface and is worked along a spiral path towards the centre of a circle 6″ in diameter using light pressure applied by two fingers, in such a way that the loose activity is collected in the central area of the paper. If it is more convenient to smear an area of any other shape or size, this is satisfactory providing that its approximate area is known and it is not in excess of about 300 cm². A circle of 6″ diameter is about 200 cm² in area. When smearing a surface contaminated with an alpha emitter it is best to avoid very dirty patches since dirt on the filter paper will absorb the alpha particles, which will not then be counted.

104. **Smear Counting.** The filter paper is placed in an alpha or beta/gamma counter as appropriate. The drawer assembly for alpha counting supplied in the service can be connected to either the 1257 or 1320 instrument. The count rate is observed. If this is low the low rate counting methods given in para. 91 are used. Not all the disintegrations occurring on the paper will be "seen" by the counter. The proportion that is counted will depend upon the efficiency of the counter. (*Note.* The efficiency of any counter is determined by noting the count rate which results when a source of known activity, in disintegrations per second (d.p.s.), is presented to it. Then the % efficiency = the c.p.s. observed × 100 divided by the d.p.s. of the source.) The efficiency varies with the radioisotope involved. The disintegrations occurring on the filter paper are calculated by multiplying the count rate (minus the background count in the case of beta/gamma counters) by a hundred and dividing by the % efficiency of the counter. The drawer assembly has an efficiency of 30% when counting the principal alpha emitters provided the grille, plastic film and foils have been removed. Once the d.p.s. on the paper have been derived, division by $3{\cdot}7 \times 10^4$ (the number of d.p.s. in a μ.c.) converts the disintegrations into microcuries. This now divided by the area smeared gives an average of loose activity picked up by the paper per cm². Thus:—

$$\text{c.p.s.} \times \frac{100}{\%\ \text{efficiency}} = \text{d.p.s. occurring on the paper}$$

$$\frac{\text{d.p.s.}}{3{\cdot}7 \times 10^4} = \mu\text{.c. of activity on the paper}$$

$$\frac{\mu\ \text{c}}{\text{areas smeared in cm}^2} = \text{average activity removed/cm}^2$$

This assesses, rather than accurately measures, loose activity. Multiplication of the result by 10 is taken as a measure of total loose activity. This usually causes an over estimate which is, however, in the interests of safety. Self absorption of alpha particles (*see* para. 105 (*a*)) is ignored in smear counting. The reasons for this are firstly that a hard paper is used to reduce the effect and secondly, smear counting is used only to assess loose activity, *i.e.* great accuracy is neither claimed nor sought.

Air Monitoring

105. Air samplers are used to determine the level of particulate airborne activity in order that it can be compared with the appropriate M.P.C._a—*see* para. 49. The working principle most commonly consists of drawing a known quantity of air through a filter paper. The paper is then placed in a counter and the quantity of activity is determined. When alpha emitters are involved and great accuracy is required, the paper is left for 48 hours before it is counted in order to allow the daughters of the naturally occurring, alpha emitting gases radon and thoron (*see* para. 11 (*b*)), which will have been absorbed on to it, to decay. Normally the paper is counted an hour or so after collection. The activity divided by the number of ccs. of air drawn through the filter paper gives an average concentration (in μ.c./c.c.) of the isotope in the air during the period the sampler was operating. After reference to the M.P.C._a of the isotope involved the concentration can be expressed as a fraction or a multiple of the M.P.C. The various steps in the calculation are as follows:—

(*a*) The activity is calculated in the same manner as given in para. 104 but conventionally in time units of minutes rather than seconds. However, in this case two correction factors must be applied. The first allows for the self-absorption of alpha particles. It is assumed that half the particles are absorbed and thus multiplication by two is necessary when alpha emitters are involved. The second is the collection factor. Not all the airborne contaminant is collected and some passes through the filter paper. Fourstone Mill A paper is 60% efficient and therefore multiplication by 1·66 is necessary; Whatman 41 is 80% efficient and the multiplication factor is therefore 1·25 but a glass paper such as Whatman GF/A collects nearly all the particles and therefore no multiplication is necessary. The calculation is therefore:—

$$\text{Count rate (c.p.m.)} \times \frac{100}{\%\ \text{efficiency of counter}} \times \text{self-absorption factor} \times \text{collection factor} = \text{d.p.m.}$$

$$\frac{\text{d.p.m.}}{2{\cdot}22 \times 10^6} = \mu\text{c. of activity on the paper}$$

(*Note.* $2{\cdot}22 \times 10^6$ is the number of d.p.m. occurring in one microcurie).

(*b*) The next step is to determine the air flow through the sampler in cubic centimetres. The A.E.R.E. Air Samplers type 1640A and 1651A have meters showing the air which has flowed through them in litres. The Portable Dust Sampling Units 1195A and 1355B are equipped with meters which show the linear flow in feet. The air flow can be calculated by assuming that 10,000 linear feet of air is 7 cubic metres. The Vacandair Samplers should be calibrated to determine the air flow through them but this is between 16 and 18 litres per minute of operation. Thus the time that this unit is working must be known. Simple calculation now gives the average air concentration:—

$$\frac{\mu\text{c. of activity on paper}}{\text{volume of air in ccs.}} = \mu\text{c./c.c.}$$

(*c*) It is important to select the correct type of air sampler. Low flow-rate samplers are placed in a central position in a room and work undisturbed for a day or more, thus giving an estimate of the overall activity level. To gain a better impression of the activity at a particular spot a high flow-rate sampler is used for a short period. Personal air samplers attached to the clothing may also be used and may give an even better estimate than does the high flow-rate sampler of the risk to a particular individual. The average flow rates of the various samplers are:—

1640A.	100	litres/min. using a Whatman GF/A paper
1651A.	60	,, ,, ,, ,, ,, ,, ,,
1195A.	120	,, ,, approx. ,, ,, ,, ,,
1355B.	,,	,, ,, ,, ,, ,, ,, ,,
Vacandair	16	,, ,, ,, ,, ,, ,, ,,

The 1651A is a battery operated version of the 1640A. The 1355B is a complete sampling assembly incorporating a sampler, an alpha-counting drawer assembly of the type supplied in the service and an integrating ratemeter to record the counts. The counter efficiency is about 30%. A castle for beta/gamma counting is also available and has an efficiency of about 12–15% when counting fission products.

Assessing Activity in Liquids

106. The Meter Contamination No. 1 has a liquid counting facility which is intended to measure fission products in water and involves the use of the water contamination calculator. Full instructions are issued with the

instrument. The presence of beta/gamma emitters in a liquid can be detected by removing the metal screen from the beta/gamma probe supplied for use with the 1257 and 1320 instruments and immersing it up to (but not beyond) its neck. Provided the sample is large enough—a bucketful or more—it may be assumed that 5 c.p.s. (above background) $= 5 \times 10^{-5}$ μc/cm³ for fission products between a few hours and a few weeks old. Alpha emitter concentrations are usually determined by evaporating a known quantity of the liquid, after removing the non-radioactive solid content in order to prevent self-absorption, and then counting the alpha residue. A field method which can be used is to select a container, such as a tin lid, of about the same base dimensions as the alpha probe, evaporating from it a measured quantity of about 20 ccs. of water and then measuring the alpha activity with the probe in the usual way (*see* para. 91). The total quantity of contamination in the container can then be calculated (para. 99) and the concentration of activity in the original sample estimated. The result should be multiplied by two in the case of waters of medium hardness to allow for self-absorption. The levels of contamination in water are considerably reduced (50% or more) by the conventional methods used to treat raw water.

Monitoring of External Exposure

107. The methods used to measure contamination on a surface may be used to detect and measure external contamination on the skin, hands and clothing.

108. Instruments such as the Meter Survey Radiac No. 3 are used to survey the X and gamma dose rates at particular points and if the duration of exposure of a person at such a point is known his total exposure dose can be easily calculated.

109. **Quartz Fibre Dosimeters.** Personal dosimeters give a record of individual exposure. When exposed to X or gamma radiation which is or may be in excess of 75 mr. per hour a quartz fibre dosimeter (Q.F.D.) should be worn. Since the charge will gradually leak away—and thus lead to a false reading—the dosimeter should be charged immediately before use. It may be partially discharged for the purpose of accurate zeroing by shorting the central electrode to the case. The type of Q.F.D. appropriate to the anticipated dose should be selected and the user should be instructed at what intervals to read it and at what total dose to evacuate the area. The types available in the R.A.F. are:—

62/911/0001	Dosimeter Q.F. No. 1	0 – 0·5 rads.
,, ,, 0101	,, ,, ,, 2A	0 – 5 ,,
,, ,, 0003	,, ,, ,, 3	0 – 50 ,,

110. **Film Badges.** People who are exposed to an occupational radiation hazard that may be greater than 1·5 rems in a year or who work in a controlled area should wear a film badge. These should be worn continuously and are usually developed at monthly or quarterly intervals, unless exposure to large doses is known or suspected when they should be developed and read at once. To measure the whole body dose they are best worn attached to the clothing on the front of the body at waist level. Film badges may also be used to measure partial exposures by wearing them on wrists, fingers or any other particularly exposed part. Expert film readers can deduce the total beta, the total gamma, the total X-ray and the total slow neutron doses received by the wearer and the energies of the X and gamma rays can be estimated. If the film badge is likely to become contaminated with beta/gamma emitters it should be enclosed in a P.V.C. envelope which is wiped clean at least daily. This reduces the beta dose to the film but prevents the gamma dose from being overestimated.

Monitoring Internal Contamination

111. The body burden of contamination inside the body can be measured directly or indirectly. Para. 56 refers to an example of the former and para. 7 to an example of the latter. The thyroid counter and the whole body counter employ the direct method of measurement and biological monitoring, the indirect. The direct method can only be employed for measuring gamma emitters since gamma rays are the only radiation sufficiently penetrating to be detected at the surface of the body. Once the body burden has been determined it can be compared with the Maximum Permissible Body Burden (M.P.B.B.) of the isotope involved as recommended by I.C.R.P. (*see* para. 48).

112. **Whole Body Counter.** Whole body counters are now available at a number of centres in this country. Since they are used to measure very low rates of gamma emission they are usually well shielded against natural background radiation, thus improving the threshold of detection. One or, usually, more than one sodium iodide crystal is used to scan the body. The response of the crystal makes it possible to determine the location and quantity of the isotope and, by measuring the energy of the gamma rays, its identity. The body burdens of isotopes such as iron 59, cobalt 60, zinc 65, ruthenium 106, iodine 131, caesium 137 and radium 226 can be measured by this means. The body surface must be free of contamination when the measurement is made.

113. **Thyroid Counter.** The thyroid counter may be a Geiger-Muller tube but is usually a sodium iodide crystal scintillation counter. The probe unit is encased in a considerable thickness of lead to restrict the view of the crystal so that it "sees" only the gland at which it points. A bar across the end-window positions the instrument a standard distance from the gland. The counter assesses the quantity of radioactive iodine in the thyroid gland and finds its greatest worth when there has been an accidental release of I 131. It has been used after the intravenous injection of radioiodine for medical purposes.

114. **Biological Monitoring.** Biological substances, particularly excreta, are examined to determine the presence or absence of radionuclides. If a radionuclide is present its quantity can be measured and, if the metabolism of the element in question is known, the total body burden can be estimated. The technique of biological monitoring is used as a routine check upon persons who work in conditions where the entry of radioactive substances into the body is possible. It is also used following accidents involving radioactive substances. It is the only practicable ante-mortem method of estimating the body burden of a radionuclide which does not emit gamma rays of sufficient energy to register on the whole body counter. When sending specimens to a competent laboratory it is necessary to state on the Form F. Med. 12 the isotope involved, the time of entry (if possible) of the isotope and the time of collection of the specimen. In addition to the three following paragraphs the subject is discussed in paras. 126–135.

115. **Urine Assay.** The body burdens of uranium, plutonium, tritium and other radionuclides are estimated by urine analysis. A routine check demands the collection of an eight-hour sample and for an accurate estimation one or more 24 hr. samples are required. It is important that the urine should not become contaminated from external sources. The collecting bottle should be scrupulously clean and should be placed in a

clean area. No sample should be passed into the bottle until protective clothes have been removed and the hands washed and monitored.

116. **Faecal Assay.** In the first weeks after exposure the body burden of any insoluble radioisotope is best estimated by faecal assay. All faeces should be saved for a week and each day's sample should be sent separately to a competent laboratory. This is particularly useful for plutonium.

117. **Expired Air Assay.** Expired air may be monitored for the presence of radon gas produced in the body by ingested radium.

DECONTAMINATION

Decontamination of Skin

118. The position and level of the contamination should be established by monitoring the patient. The "hotter" areas should be dealt with first and perceptible damage to the skin should be avoided. If after a thorough decontamination some residual contamination remains, the area may be covered and the patient sent home with instructions to return next morning. A fresh check for contamination should then be made however successful the initial treatment appeared to be. The maximum permissible level is that level of contamination which will cause no harm if it is present throughout the patient's life and therefore such a level may be allowed to remain upon the skin (*see* Table 9(R)).

119. As a rule, except for the decontamination of hands and in emergencies, all decontamination procedures should be carried out under the supervision of the Medical Officer. Attempts to remove contamination which resists mild procedures should always be made under such supervision.

120. The immediate washing of the contaminated skin with soap and water is the method of choice for removing loose contamination, subject to the following precautions:—

(*a*) Do nothing which would cause an uncontaminated wound to become contaminated.
(*b*) Tepid, not hot, water to be used.
(*c*) Soap to be neither abrasive nor highly alkaline.
(*d*) A swab to be used. The skin not to be abraded.
(*e*) The skin to be washed for a few minutes at a time, then monitored.

Washing may be repeated if necessary and provided the skin remains undamaged. If the above procedure fails a mild detergent such as "Teepol" may be used, it being understood that frequent applications might injure the skin and render it permeable. Special attention should be paid to creases, folds, hair and finger nails. After each decontamination the treated place should be dried with a fresh, non-contaminated towel or swabs which should themselves then be treated as contaminated waste.

121. Where mild attempts have failed and where the skin shows no evidence of irritation the following measures may be used under medical supervision:—

(*a*) Immerse for 30 seconds in saturated potassium permanganate solution then decolourize in 5% sodium bisulphite.
(*b*) "Sweat out" the hands by enclosing them in rubber gloves for one to two hours at a time.
(*c*) Wash with 10% citric acid.

(*d*) Immerse for 20 min. in 10% aluminium sulphate solution to remove fission products.

(e) Use titanium dioxide paste as an abrasive, until a "whiteness" of the skin appears which indicates that the application has been thorough.

Many other substances have been suggested for use as decontaminants. The use of soap and running water is still best.

Decontamination of Particular Parts

122. Special areas of the body require special treatment:—

(*a*) *Hands*. All the above methods are applicable. Trim the nails.

(*b*) *Face and Scalp*. Rub with small cotton wool swabs. Avoid the spread of contamination to eyes, nose or mouth. Shampoo the scalp with "Cetavlon" or "Teepol" while the head is extended over the end of a couch so that drainage from the scalp will not pass over the face. It may be necessary to cut or shave the hair.

(*c*) *Nose*. Contamination of the face or the possibility that large quantities of airborne activity may have been inhaled demands investigation for nasal contamination. The patient should blow his nose into a disposable swab. Each nostril is then swabbed with a folded filter paper which is afterward opened, dried and counted for activity. If the level is very high ephedrine should be instilled and the nares irrigated. The patient's head is held forward so that he will not swallow much of the fluid. Dust heavy enough to be deposited in the nostrils will not be inhaled.

(*d*) *Eye*. The eye is irrigated for ½ to 1 hr. after adrenaline 1:2000 has been instilled into the eye and ephedrine 1% into the nose.

(*e*) *Gastro-Intestinal Tract*. H_2O_2 mouth washes. The administration of small (non-purgative) doses of sodium sulphate may reduce the absorption of plutonium. Purging is contraindicated.

After an incident causing contamination of the mouth, nose, eye or skin eight-hour urine samples (with no added preservative) should be sent within 24 hrs. to the Senior Royal Air Force Representative at A.W.R.E., Aldermaston, Berks. An appreciable body intake requires that 20 ccs. of blood should be taken into a heparinized tube and dispatched after 4 and before 12 hours. All samples should be accompanied by a Form F. Med. 12.

Wound Decontamination

123. The procedure for dealing with contaminated wounds is as follows:—

(*a*) Irrigate with tap water for ten minutes while encouraging blood flow by inducing congestion. Direct pressure close to the wound is not desirable.

(*b*) Save and monitor the object which caused the injury. Spread blood from the wound over a filter paper and monitor it for contamination. Spread it thinly on to a glass slide and after drying monitor it for contamination.

(*c*) Abrasions seldom give rise to absorption. Ordinary surgical toilet after irrigation is adequate. Where the wound is deep or punctured excision should be considered. Excisions must be large enough to avoid cutting into the contaminated area and should be carried out in a bloodless field where possible. Excised flesh and all soiled swabs should be sent to A.W.R.E., Aldermaston for estimation.

(d) A plain blood sample should be collected and sent to Aldermaston after 4 hours but before 12 hours and an eight-hour urine sample within 24 hours to A.W.R.E., Aldermaston for estimation. If the first urine sample is negative a second should be sent four days later. All samples should be sent with a Form F. Med. 12

Decontamination of Equipment

124. The decision to decontaminate must take into account the continuing value of the article compared with the cost of decontamination. Equipment should be decontaminated as soon as possible after its use for in many cases this prevents the fixing of the radioactive particles. All surfaces should be cleaned by wet methods if possible. Vacuum cleaning may only be attempted if there is proper filtration of the ejected air. The method used to remove dirt from a particular surface will, in most cases, be the best method of removing contamination from it.

125. Paint may be cleaned with detergent solution or removed with a paint remover. Polished linoleum may be washed and the wax polish removed by a solvent. If the contamination is by alpha or soft beta emitter the radiation may be reduced by overpainting. The paint should be applied in two coats of contrasting colours so that any wearing of the outer coat becomes immediately apparent. Food in dustproof containers is fit for consumption if any contamination on the container is removed before opening. If equipment has to be contaminated its subsequent decontamination can often be facilitated by the prior application of preparations such as strippable paint which can be easily removed later.

RADIOISOTOPES DEPOSITED INTERNALLY

Plutonium

126. Plutonium may enter the body by inhalation, ingestion or through wounds. Even if inhaled a greater fraction reaches the gut than is retained in the lung (*see* para. 54 (*b*)). Uptake from the gut is poor, especially in the case of insoluble compounds, but the gut is irradiated as the plutonium passes through. The plutonium which is absorbed by any route is deposited early on in the lymph nodes, liver, kidney and spleen but eventually most of it is deposited in bone (*see* para. 67). Plutonium dioxide, produced by combustion in air, is extremely insoluble.

127. **Estimation of Body Burden.** The body burden shortly after intake is estimated from faecal samples. All faeces voided during the first seven days should be sent to a suitable laboratory. It may be inferred that a patient has inhaled plutonium if it is found upon a high nasal swab. Urine samples do not give reliable quantitative information until three months have passed since the time of plutonium inhalation.

128. **Treatment of Pu Inhalation.** Plutonium inhalation is best handled in the following manner:—

(*a*) *Primary*. The patient should gargle and spit repeatedly and blow his nose. After the instillation of some agent to close the vascular bed the nose should be irrigated until high swabs no longer reveal the presence of plutonium. Purging is of no value. Faeces should be collected.

(*b*) *Secondary*. If the M.P.B.B. is likely to have been exceeded a chelating agent may be administered. If used it should be given as soon as possible. To be really effective treatment should be started within 24 hours. The best chelating agent at present available, Diethylene Tetramine Pentacetic Acid, may be made into a physiologically normal solution for slow intravenous transfusion. Its affinity for calcium may cause death in tetany if the transfusion is precipitate. Safety may be assured by the intravenous administration of calcium gluconate during the transfusion. The dose of D.T.P.A. is $\frac{1}{4} - \frac{1}{2}$ gram daily in 250 or 500 ml of normal saline administered as slowly as possible. D.T.P.A. increases the normal excretion rate of plutonium about one hundred times. Strong solutions damage the renal tubules and cause thrombophlebitis at the site of injection.

129. **Plutonium Injection.** Over ninety per cent of soluble plutonium remains in the wound during the first 24 hours, and sixty per cent or more is still there ten days later. Some sixty per cent of the plutonium which finally enters the system is deposited in bone. As little as one microgram, when injected into the subcutaneous tissue of a rat, will cause the growth of a fibrosarcoma at the point of injection. The treatment is as for wound decontamination (*see* para. 123).

Uranium

130. The effective half-life of uranium, like the body distribution, is uncertain but is probably about 100 days. Even enriched uranium is more dangerous to the body as a simple poison, damaging the convoluted tubules, than as a radioactive substance. It is excreted so rapidly that no trace of a single exposure is left after a few weeks. The assessment of body burden, carried out by urinalysis, proves unreliable. It is also wise to test for the proteinuria which follows kidney damage by uranium.

131. **Treatment of Uranium Inhalation.** The urine should be alkalinized and fluids pressed. Eight hour urine samples should be sent to A.W.R.E., Aldermaston for analysis.

132. **Uranium Injection.** A wound into which uranium may have been injected should be irrigated after having been encouraged to bleed. In view of the relatively harmless nature of uranium the wound should be excised only if a very considerable quantity of the contaminant remains embedded. The urine should be alkalinized and samples sent to A.W.R.E., Aldermaston for analysis.

Treatment of I 131 Inhalation

133. There is no known way to hasten the excretion of internally deposited I 131. When there is risk of I 131 inhalation, as there may be after a reactor accident, personnel likely to be exposed should be given 200 mg potassium iodide by mouth. This satiates the thyroid gland and prevents the uptake of further iodine for two or three days. The dose may be repeated when required.

Tritium

134. As is shown in para. 28 tritium has a very high specific activity. The gas itself is poorly absorbed by the lungs or skin but its oxides (HTO and T_2O, *i.e.* tritiated water) are well absorbed through both and are about 400 times more dangerous. The oxides are equally well absorbed by the skin and lungs. Thus, an air line respirator without impervious clothing only gives half protection. Inside the body it is evenly distributed throughout the body water and thus leads to whole body exposure.

135. **Treatment.** After exposure to tritium the patient should wash all over with soap and water. Copious fluids should be administered for several days so as to replace the body water as quickly as possible. The effective half-life can be reduced from 12 to 4 days by this means.

THE RADIATION SYNDROME

Acute

136. The time it takes for a previously unexposed individual in good health to sicken (*i.e.* to become combat ineffective) or die depends primarily upon the total dose received, the rate at which it is received and on individual variations. Some men have greater resistance to radiation injury than others. Circumstances of exposure, and therefore the dose received, will vary. Individuals who have been previously exposed are likely to become ineffective with smaller doses than those exposed for the first time. The human body can repair some of the injury. A given dose received in a short period will generally be more harmful than the same dose received over a longer period. Radiation doses received in less than 24 hours are called acute doses. Those received over a longer time are called protracted doses.

137. The complex of symptoms brought about by an excessive exposure of the whole body, or a large part of it, to ionizing radiation is called radiation sickness. The earliest symptoms are nausea, vomiting and diarrhoea. Haemorrhage, inflammation of the mouth and throat, and lassitude may follow. The time of onset of radiation sickness depends mainly upon the dose received. Several hours will normally elapse before persons become unfit for combat. Thereafter there will generally be a latent period of variable length during which the individual shows no signs of sickness but may feel some malaise. After about a week the more serious phase of the illness begins. It may last several weeks before either recovery or death occurs. As the dose received is increased the pace of the illness quickens, the onset being more rapid and the latent period shorter. The larger the dose the higher the probability of death and the quicker its onset.

138. Figure 3(R) (prepared by the U.S.N.) gives the expected times of onset and duration of combat ineffectiveness as functions of acute and protracted doses.

139. The following examples illustrate the use of Fig. 3(R).

(*a*) 1000 *rads received in less than a minute*. The dose will most probably produce combat ineffectiveness 4 to 5 hours after exposure (estimated at the middle of the broad band curve) although the onset of ineffectiveness could be as early as 2 or as late as 8 hours after exposure. Death may be expected in about 7 days.

(*b*) 600 *rads received over a* 30 *minute period*. This acute dose is expected to produce combat ineffectiveness in about 12 hours although the onset of ineffectiveness might be as early as 4 or as late as 24 hours post-exposure. There will be a latent period between the second and fourth days after exposure. Death for many of those exposed may be expected in 3 to 5 weeks.

(*c*) 500 *rads received over a* 3 *day period*. This protracted dose will product combat ineffectiveness on the 6th day, although in some cases it could begin on the 3rd day, the end of the exposure period. Death for many of these exposed can be expected in 4 to 7 weeks.

140. Radiation injuries may conveniently be divided into five groups:

Group I (100 to 200 rems.) Short-lasting nausea and vomiting followed by slight leucocytosis.

Group II (200 to 300 rems.) Transient nausea and vomiting and mild clinical manifestations of haematopoietic derangement. Recovery is usual but delayed effects may appear.

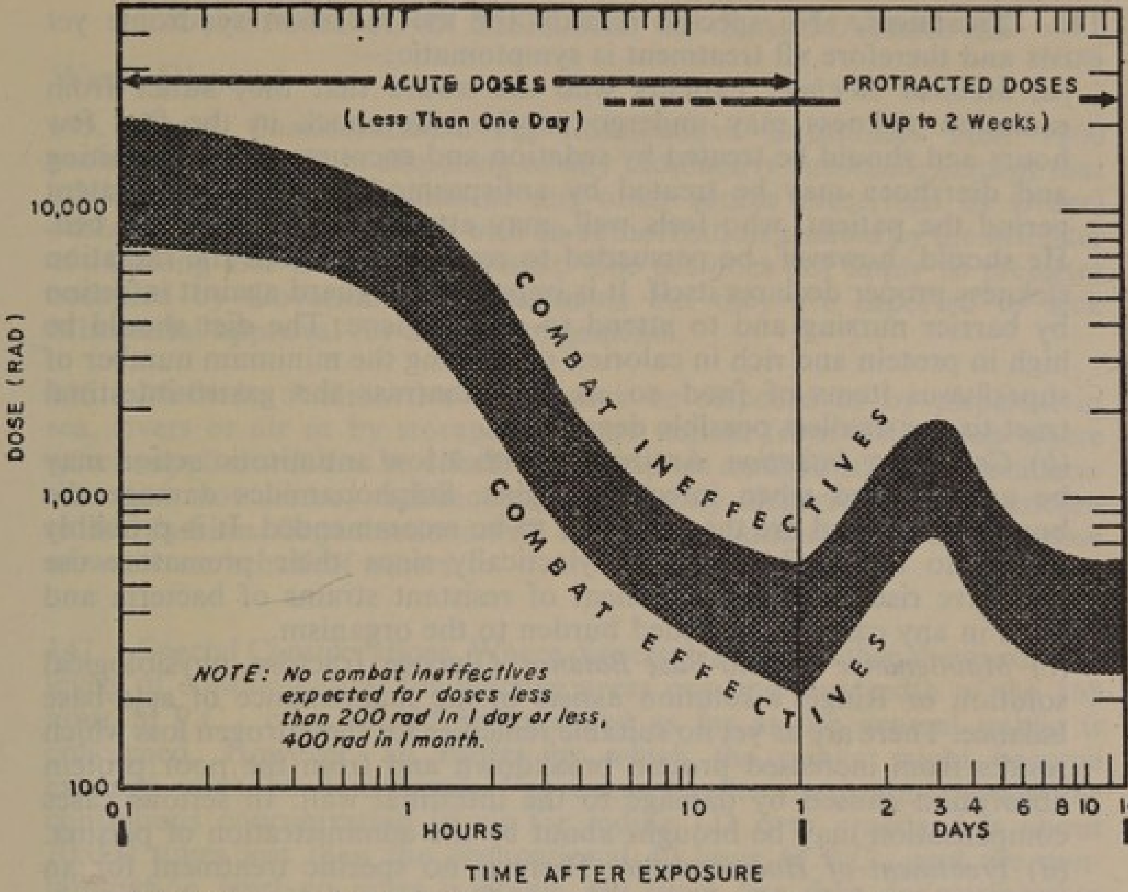


FIG. 3(R). EXPECTED TIMES OF ONSET AND DURATION OF COMBAT INEFFECTIVENESS FOR WHOLE-BODY ACUTE AND PROTRACTED DOSES (NO MEDICAL TREATMENT)

Group III (300 to 500 rems.) Between these doses lies the L.D. 50 for man: correct treatment is therefore of great importance. The illness is severe. Grave haematological changes may be accompanied by gastro-intestinal haemorrhage.

Group IV (500 to 1,000 rems.) An accelerated version of the Acute Radiation Syndrome occurs and the complications of gastro-intestinal injury are dominant. The severity of the haematopoietic disturbances is related to the duration of survival. The outcome is usually fatal.

Group V (More than 1,000 rems.) Gastro-intestinal injury predominates. There is massive damage and dehydration of the body. Death occurs in 3 to 6 days. Doses of several thousand rems bring about neuromuscular symptoms which may occur within 2 minutes, having a "knock-down" effect. Death takes place in a few hours.

141. Where injury is caused by a dose of 300 to 500 rems the following clinical picture may ensue:—

(*a*) Nausea and vomiting.
(*b*) Fatigue, inability to concentrate.
(*c*) Rise in granulocyte count on the first day followed by a rapid fall in the count.
(*d*) Fall in the lymphocyte count during the first 24 to 48 hours.
(*e*) Rapid fall in sperm count.
(*f*) Erythema on the first day, remaining for several days.
(*g*) Epilation during 2nd to 3rd week.
(*h*) Weight loss from 2nd or 3rd week.
(*j*) Haemorrhage from 4th to 5th week.
(*k*) Death between 1st and 6th week, except where the patient is successfully treated.

142. **Treatment.** No specific remedy for the radiation syndrome yet exists and therefore all treatment is symptomatic:—

(*a*) *Medical Regime*. Patients who are aware that they suffer from radiation sickness may undergo psychogenic shock in the first few hours and should be treated by sedation and encouragement. Vomiting and diarrhoea may be treated by antispasmodics. During the latent period the patient, who feels well, may attempt to rise from his bed. He should, however, be persuaded to remain there until the radiation sickness proper declares itself. It is important to guard against infection by barrier nursing and to attend to oral hygiene. The diet should be high in protein and rich in calories, containing the minimum number of superfluous items of food so as to embarrass the gastro-intestinal tract to the smallest possible degree.

(*b*) *Combating Infection*. Antibiotics with a low antimitotic action may be administered when infection begins. Sulphonamides damage the bone marrow and are therefore not to be recommended. It is probably unwise to use antibiotics prophylactically since their premature use may give rise to the development of resistant strains of bacteria and may, in any case, be an added burden to the organism.

(*c*) *Maintenance of Acid-Base Balance*. Glucose, fructose, physiological solution or Ringer's solution assists in the maintenance of acid-base balance. There are as yet no suitable remedies for the nitrogen loss which results from increased protein breakdown and from the poor protein absorption caused by damage to the intestinal wall. In serious cases compensation may be brought about by the administration of plasma.

(*d*) *Treatment of Haemorrhage*. There is no specific treatment for an increased tendency to haemorrhage. The use of blood platelets in suspension is of doubtful value.

(*e*) *Restoration of Haematopoiesis*. During radiation sickness proper transfusions of whole blood, packed cells and of plasma are important. Bone marrow transplants may be attempted but immunological complications render success uncertain. The worth of the measure has not yet been fully assessed.

(*f*) *Treatment of Skin*. Skin hygiene is essential. Infected skin may be treated by the intramuscular injection of long-acting penicillin. After large doses of radiation, skin erythema may become exudative and defy treatment.

(*g*) *Convalescence*. Convalescence is slow, taking approximately three months after a 300 rem dose and six months after a 500 rem dose.

143. **Clinical Records.** Whenever a patient has been exposed to radioactivity or has been contaminated by radionuclides or has suffered injury by irradiation the most detailed notes should be made and preserved.

Chronic

144. **The Syndrome.** Chronic radiation injury may follow as the delayed effect of a single large irradiation or after persistent small dose irradiations. Many of the effects have already been considered in paras. 18—24. Others include:—

(*a*) *Haematological Changes:*—

(i) Persistent leucopaenia (under 3,500 cells per cu.mm.)
(ii) Persistent neutropaenia (under 2,400 „ „ „)
or (iii) Persistent leucocytosis (above 15,000 „ „ „)

(*b*) *Chronic Skin Changes*. Pigmentation, dryness, telangiectasis, fissures and atrophy leading, in some cases, to squamous cell epithelioma, all occur as possible chronic consequences of skin exposure to radiation.

TRANSPORT AND DISPOSAL OF R.A. MATERIALS

Waste Disposal

145. **Legal Considerations.** The Radioactive Substances Act, 1960 prohibits anyone from disposing of any radioactive substance (except that arising from clocks, watches or any other source prescribed by Order) otherwise than in accordance with an authorization granted by the Minister of Housing and Local Government. The act does not apply to premises occupied by Government Departments but they are expected to seek Ministerial approval for their arrangements.

146. **Methods.** Radioactive waste may be disposed of by dispersal in sea, rivers or air or by storage. In areas remote from civilization where water supplies will not be affected the simplest method is burial. Incineration does not destroy radioactivity but merely disperses it in an uncontrolled fashion. Organizations with Ministerial authorization may dispose of waste on behalf of others.

147. **Special Considerations.** Where dispersal is used neither the maximum levels of contamination for inactive areas nor one hundredth of the 168 hour M.P.C.$_a$ or $_w$ should be exceeded as far as the general public is concerned. However, all routes by which the public might become exposed must be considered. For example, the maximum permissible continuous concentration in air for iodine 131 over grassland is about 10,000 times less than the occupational 40 hour M.P.C.$_a$ and the contamination level on grass is about 250 times less than for surfaces in inactive locations. These reductions are applied since iodine is transferred *via* cattle to milk and thence to the thyroid glands of children. Similarly the sea disposal of strontium is limited by the fact that fishes concentrate it to 1·5 times the level in sea water.

Transport and Transfer

148. Active materials being moved from one building to another on a station should be moved in suitable containers and should be delivered to the receiver personally, not being left in an office for him to find. The dose rate at the surface of the container and at one metre from it should be measured with an instrument such as the Meter Survey Radiac No. 3. Multiplying the rate by the likely duration of exposure will give a measure of the risk involved to those transporting it. As a rule a rate of 200 m rems per hour should not be exceeded at the surface and 10 m rem/hour at one metre. The minimum safe distance for undeveloped film from a package emitting X or gamma radiation at this rate is 15 feet for 20 hours exposure. Active solutions should be transported in leak-tight secondary outer containers packed with sufficient chemically inert absorbent material to absorb the whole content should it escape. In all cases the outer container should be free from detectable contamination.

149. The movement of radioactive materials by public carriers is subject to a variety of strict regulations to protect their employees, the general public and other goods. Reference must be made to their rules before the dispatch of radioactive materials. Packages for transmission through the post must be approved by the G.P.O. Engineering Section and the radiation at any point on the surface should not exceed 10 mr/24 hours. A.P. 3150 gives instructions concerning the movement of radioactive materials by service aircraft.

CALCULATIONS

150. When radioactive materials are to be routinely handled the risk involved should first be assessed by calculation. A plan is then made on the basis of the risk thus revealed. Radiation measurements should be made during handling and these may or may not indicate that some change in routine is necessary.

Sources

151. **Specific Gamma Ray Emissions.** In the case of gamma emitters the easiest method of determining the risk (another is given in para. 153) is to use a specific gamma ray emission table (*see* Table 10 (R)). This lists the dose rate in roentgens per hour at 1 cm. from 1 millicurie of an unshielded point source of a number of isotopes. Dose rates for other distances can be derived by the application of the inverse square law (*see* para. 152) and for other times and sources of other strengths, by multiplication or division as appropriate. For example:—

Q. What dose would be received from an unshielded source of 1 curie of cobalt 60 at 1 yard in 15 minutes?

A. Dose at 1 cm from 1 mc is 13·2 r in 1 hour

∴ „ „ 1 cm „ 1 curie is 13,200 r in 1 hour

∴ „ „ „ „ „ „ 3,300 r in 15 minutes

∴ „ „ 1 yard (90 cms) „ $3{,}300 \times \frac{(1)^2}{(90)^2}$ in 15 minutes

which is equal to 0·4 r in 15 minutes or 400 mr in 15 minutes

TABLE 10(R)

SPECIFIC GAMMA RAY EMISSION (r/hr 1 cm from 1 m.c.)

Isotope	Dose	Isotope	Dose
Aluminium 28	8·5	Oxygen 15	5·8
Argon 41	6·6	Potassium 42	1·4
Caesium 134	8·7	Potassium 43	5·6
Caesium 137	3·1	Radium 226	8·25
Chromium 51	0·15	Sodium 22	12
Cobalt 60	13·2	Sodium 24	18·4
Iodine 131	2·2	Strontium 85	3
Iodine 132	11·8	Tungsten 187	3
Iron 59	6·4	Zinc 65	2·7

152. **Reduction of Radiation Intensity with Distance.** The dose rate from a radioactive source varies inversely as the square of the distance according to the formula (but *see* para. 70):—

$$D_2 = D_1 \times \frac{(d_1)^2}{(d_2)^2}$$

where D_1 is the dose rate at a distance d_1 from the source and
D_2 is the dose rate at a distance d_2 from the source

Q. The dose rate at 1 metre from 1 curie of iodine 131 is 0·225 rads per hour. What is the dose rate at 2 cms?

A. Dose rate at 2 cms $= 0{\cdot}225 \times \frac{(100)^2}{(2)^2}$

$= 562{\cdot}5$ rads per hour.

This formula applies only to point sources. A source may be considered to be a point source when its dimensions are small compared with the distance involved. The ratio between the two should exceed 1 to 5. When a source is not a point source it is assumed to be a segment of a spherical shell with the centre at the point at which the dose rate (D) is required. Then, if D_s is the dose rate of the surface of the source and φ the solid angle subtended by the source at the point of interest:—

$$D = \frac{D_s \times \varphi}{2}$$

153. **Point Source Approximations.** The full calculation of dose rates is rather involved and in practice approximations are used:—

(*a*) *Gamma*. The following approximation may be used for gamma emitting point sources:—

Dose rate at 1 foot = 6 × C × E rads/hr.
where C is the source strength in curies and
E is the total energy of the gamma radiation (MeV) released on each disintegration. The formula only holds for gamma rays between 0·3 and 3 MeV energy.

The dose at 1 metre may be obtained by using 0·54 instead of 6 in the formula. The total energy is obtained from a radiosisotope data book or nuclide chart. For example, sodium 24 emits two gamma rays (both below 3 MeV), one of 1·37 and the other of 2·75 MeV, with each disintegration. The total energy is therefore 4·12. Sometimes only a certain proportion of disintegrations are accompanied by the release of gamma rays. For example, potassium 42 releases gamma rays of 1·52 MeV in 18% of its disintegrations. The total energy, therefore, to be inserted in the formula is:—

$$\frac{18}{100} \times 1{\cdot}52$$

(*b*) *Beta*. The dose rate per hour from a beta source of C curies at 1 foot is given by the following formula if self absorption and air absorption are neglected (neglecting these over estimates the dose and is therefore safe):—

Dose rate at 1 foot = (approx.) 300 × C rads/hour

Fission Products

154. **Radiac Calculator No. 1** In the area of intense fall out from a nuclear weapon explosion the gamma dose rate should be measured about a metre above the ground. If the time that has elapsed since the explosion occurred is known, the Radiac Calculator No. 1 will make it possible to determine the dose rate in the same spot at any future or past time, the dose that will be received by staying in the area between two stated times and how long it is possible to remain before any specified dose is received. The instructions for use are given on the reverse side of the calculator.

155. **Fission Product Decay.** The radionuclides formed in the fission chain reaction which occurs when a nuclear weapon is detonated decay by beta emission, accompanied in the majority of cases by gamma radiation. The gamma activity in roentgens per hour at t hours after the explosion is given by the use of the formula:—

Dose rate at time t hours = dose rate at 1 hour × $t^{-1\cdot2}$
An approximation which can be used if a calculator is not available is that a sevenfold increase in time is accompanied by a tenfold decrease in activity. Thus if, at a given point:—

Gamma dose rate at 1 hour = 100 r/hr
Then ,, ,, ,, ,, ,, 7 hours = 10 ,,
,, ,, ,, ,, ,, 49 ,, = 1 ,,
,, ,, ,, ,, ,, 14 days = 0·1 ,,

Q. The dose rate 3 miles from ground zero at 2 hours after burst is 150 r/hr. What will the dose rate be at 98 hours (*i.e.* 4 days later)?

A. Dose rate at 2 hrs = 150 r/hr
∴ ,, ,, ,, (2 × 7) 14 hrs = 15 r/hr
∴ ,, ,, ,, (14 × 7) 98 ,, = 1·5 r/hr

Dose rates at intermediate times can be obtained by plotting the points obtained in this fashion on log/log paper, joining them with a straight line, and reading off the rates at other times. Less accurately it can be assumed that the decrease between two of the time intervals is linear and a rough calculation will give an approximate answer.

156. **Dose to Infinity from Fission Products.** In a fall-out field where decay is following the $t^{-1\cdot2}$ law the total dose to infinity may be calculated by the means shown below provided that the dose rate at the time after burst when the field is entered is known. The dose to infinity means the dose that would be received by staying in the area until all or most of the fission products had decayed. The steps are:—

(*a*) Measure the dose rate at time t after burst.
(*b*) Express this as roentgens/t *i.e.* t is made the unit of time.
(*c*) Multiply this dose rate by 5 to obtain the dose to infinity.

Q. The dose rate at 3 hrs. after burst is 17 r/hr. What is the total dose to infinity that a person would receive by remaining in the area?

A. 17 r/hr gives (3 × 17) *i.e.* 51 r/3 hours (at 3 hours)
∴ The dose to infinity = 5 × 51 = 255 r.

157. **Shielding.** Shielding against radiation is best left to experts if circumstances permit. In all cases the efficiency of any shielding arrangement should be checked by instruments before first use and occasionally thereafter. Table 11(R) gives shielding values which may be used to reduce the gamma radiation dose from a point source to 1%. Half the quoted thickness of any of the materials listed will reduce the dose to 10%.

TABLE 11(R)

THICKNESS IN INCHES TO REDUCE GAMMA DOSE BY A FACTOR OF 100

Material / Energy MeV	Water	Soil	Concrete	Iron	Lead
0·3	34	22	14	3·5	0·5
0·5	37	25	15·5	4·2	1·2
0·7	40	28	17	5·0	2·0
1·0	43	32	20	5·9	3·1
1·5	50	38	23·5	6·9	4·2
2·0	56	43	27	7·7	4·7
Density g/cc.	1·00	1·5	2·35	7·8	11·2

FURTHER READING

1. The current Air Ministry Order/Defence Council Instruction (RAF) on "Health Control of Workers Exposed to X-rays and Radioactive Materials."
2. The current Air Ministry Order/Defence Council Instruction (RAF) on "Storage and Use of Radioactive Sources Installed in Aircraft and Used in Servicing Certain Equipment."
3. Air Publication 4687. Basic Physics and Radiation Hazards and Detection.
4. Assay of Strontium 90 in Human Bone in the United Kingdom. Medical Research Council Monitoring Report Series. H.M.S.O. 1/6d.
5. Code of Practice for the Protection of Persons Exposed to Ionizing Radiations. H.M.S.O. 8/-.
   Records: Use of X-rays for diagnosis and therapy, use of radioactive isotopes, protection against ionizing radiations.
6. Hazards to Man of Nuclear and Allied Radiations. H.M.S.O. 7/-.
   Records: A second report of the Medical Research Council.
7. Glossary of Atomic Terms. H.M.S.O. 3/6d.
8. Notes on Atomic Energy for Medical Officers. H.M.S.O. 6/-.
   Records: Elementary physics, medical effects, protection.
9. Radiation Hazards and Protection by D. E. Barnes and Denis Taylor. George Newnes Ltd. 30/-.
10. Radioisotope Data, United Kingdom Atomic Energy Research Group (1961). H.M.S.O. 8/-.
    Records: Tables of energies, half-lives, specific activities.
11. Recommendations of the International Commission on Radiological Protection, I.C.R.P. Publication 1. Pergamon Press 3/6d.
    Records: Permissible dose for external radiation (1958).
12. Recommendations of the International Commission on Radiological Protection, I.C.R.P. Publication 2. Pergamon Press 35/-.
    Records: The report of Committee II on permissible dose for internal radiation (1959).
13. Recommendations of the International Commission on Radiological Protection, I.C.R.P. Publication 3. Pergamon Press 21/-.
    Records: Protection against X-rays up to energies of 3 MeV and beta and gamma rays from sealed sources.
14. Recommendations of the International Commission on Radiological Protection (As amended 1959 and Revised 1962) I.C.R.P. Publication 6. Pergamon Press 25/-.
15. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. H.M.S.O. 35/6d.
16. Safe Handling of Radioisotopes, International Atomic Energy Agency, Vienna:

    Safety Series No:

1.	Safe Handling of Radioisotopes	6/-
2.	Health Physics Addendum	9/-
3.	Medical Addendum	9/-
4.	Safe Operation of Critical Assemblies and Research Reactors	9/-
5.	Radioactive Waste Disposal into the Sea	15/-
6.	Regulations for the Safe Transport of Radioactive Materials	9/-
7.	Notes on Certain Aspects of the Regulations	9/-
8.	Use of Film Badges for Personnel Monitoring	9/-

17. The Effects of Nuclear Weapons, edited by S. Glasstone, United States Atomic Energy Commission 1962. $2.
18. The Ionizing Radiation (Sealed Sources) Regulations. H.M.S.O. –/9d.
19. United Kingdom Atomic Energy Authority Health and Safety Code. Authority Code No: E1.2 H.M.S.O. 3/6d.
    Records: Maximum permissible doses from inhaled and ingested radioactive materials.

FURTHER READING

1. The current Air Ministry Order/Defence Council Instruction (R.A.F.) on "Health Control of Workers Exposed to Ionising Radiations".
2. The current Air Ministry Order/Defence Council Instruction (R.A.F.) on "Storage and Use of Radioactive Sources Installed in Aircraft and Used in Servicing Certain Equipment".
3. Air Publication 4017. Basic Physics of Radiation Hazards and Detection.
4. Assay of Strontium 90 in Human Bone in the United Kingdom. Medical Research Council Monitoring Report Series. H.M.S.O. 1/6d.
5. Code of Practice for the Protection of Persons Exposed to Ionising Radiations. H.M.S.O. 4s.
   Records: Use of X-rays for diagnosis and therapy, use of radioactive isotopes, protection against ionizing radiations.
6. Hazards to Man of Nuclear and Allied Radiations. H.M.S.O. 7s.
   Records: A second report of the Medical Research Council.
7. Effects of Atomic Power. H.M.S.O. 1961.
8. Basic Radiation Safety for Technical Officers. H.M.S.O.
9. Radiation Hazards and Protection by D. W. Barnes and Denis Taylor. George Newnes Ltd. 25s.
10. Radioisotope Data. United Kingdom Atomic Energy Research Group (1955). H.M.S.O. 3s.
    Records: Tables of constants, half-lives, specific activities.
11. Recommendations of the International Commission on Radiological Protection. I.C.R.P. Publication 1. Pergamon Press 1959.
    Records: Permissible dose for external radiation.
12. Recommendations of the International Commission on Radiological Protection. I.C.R.P. Publication 2. Pergamon Press 1960.
    Records: The report of Committee II on permissible dose for internal radiation (1959).
13. Recommendations of the International Commission on Radiological Protection. I.C.R.P. Publication 3. Pergamon Press.
    Records: Protection against X-rays up to energies of 3 MeV and beta and gamma rays from sealed sources.
14. Recommendations of the International Commission on Radiological Protection (As amended 1959 and Revised 1962). I.C.R.P. Publication 6. Pergamon Press 25s.
15. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. 1958.
16. Safe Handling of Radioisotopes. International Atomic Energy Agency. Safety Series:
    1. Safe Handling of Radioisotopes
    2. Health Physics Addendum
    3. Medical Addendum
    4. Safe Operation of Critical Assemblies and Research Reactors
    5. Radioactive Waste Disposal into the Sea 15/-
    6. Regulations for the Safe Transport of Radioactive Materials 9/-
    7. Notes on Certain Aspects of the Regulations 6/-
    8. Use of Film Badges for Personnel Monitoring 9/-
17. The Effects of Nuclear Weapons, edited by S. Glasstone, United States Atomic Energy Commission 1962. 41s.
18. The Ionising Radiations (Sealed Sources) Regulations. H.M.S.O. 1961.
19. United Kingdom Atomic Energy Authority Health and Safety Code, Authority Code No. H.M.S.O. 1961.
    Records: Maximum permissible doses from inhaled and ingested radioactive materials.

SCHEDULE OF UNIT HYGIENE INSPECTIONS

Item	*Points of Attention*	*Notes*
	BUILDINGS—GENERAL ITEMS	
STRUCTURE	1. Walls and ceilings.	Repair, decoration, and cleanliness.
	2. Floors.	Repair and cleanliness.
	3. Surrounds.	Cleanliness and tidiness.
PHYSICAL ENVIRONMENT	4. General ventilation.	Adequate opening area of windows.
	5. General lighting.	Good general lighting both by daylight and artificial light. Cleanliness of windows and lighting fittings. Presence of correct electric bulbs—regular replacement of unserviceable bulbs.
	6. Heating.	Adequacy of heating arrangements in winter to ensure satisfactory ventilation.
SANITARY FITTINGS	7. Sanitary conveniences.	Cleanliness, good repair, and function of fittings. Adequate supply of toilet paper. Adequacy of hot water supply. Presence of receptacles for razor blades and refuse. Adequacy of supply of waste plugs. Proper daily cleansing and drying of duckboards.
	8. Ablutions.	
	KITCHEN AND ANCILLARY PREMISES	
	As under "Buildings—General Items" and in addition the following:—	
STRUCTURE	1. Floors.	Soundness of concrete and avoidance of dirt traps; adequate slope to drainage channels and absence of puddling.
	2. Yards and surrounds.	Cleanliness and good drainage, especially swill compound; good repair of hard standings.
	3. Grease traps.	Cleanliness, regular clearance, and fly-proof covers.
FITTINGS	4. Shelves, slabs, table-tops, and chopping blocks.	Good repair and cleanliness of surfaces. Note all working surfaces in preparation rooms, stores, and butchers' shops.
	5. Storage racks.	Good repair and cleanliness of racks in vegetable stores and plate and pan washups.
	6. Sinks and pan wash.	Soundness of surface and cleanliness; good repair of draining boards; evidence of misuse of sinks as knife sharpeners. Adequacy of hot water and detergent supplies.
EQUIPMENT	7. Machinery.	Mixing, mincing, and slicing machines—thorough cleansing after use, including surrounding walls and floors; presence of effective guards and warning notices; earthing of electrical machinery and display of electric shock first-aid poster.

KITCHEN AND ANCILLARY PREMISES (*contd.*)

Item	*Points for Attention*	*Notes*
	8. Washing-up machines.	Serviceability of temperature gauges; adequate training of operators; correctness of operating temperatures; correct dosage of compound detergent emulsion. Enforcement of air drying of crockery; sufficiency of serviceable plate racks.
	9. Personal cutlery wash-up.	Ensure use of two-tank system; correct dosage of detergent in wash tank; adequate sterilizing temperatures in rinse tank during use; frequent change of wash water; protection from weather.
	10. Implements and utensils.	Adequacy of supply; good repair and cleanliness; proper storage facilities.
	11. Refrigerators.	Cleanliness and proper use; use of drip trays in meat refrigerators; maximum utilization for prepared food.
PHYSICAL ENVIRONMENT	12. Lighting.	Correct position of lights over equipment to avoid shadows. Adequacy of illumination.
	13. Special ventilation and steam extraction.	Adequacy of window opening without disturbance of fly-proofing where fitted; effectiveness of hoods over cooking apparatus; proper functioning of extraction fans; through ventilation in butcher's shop, bread, bacon, and dry rations stores.
PERSONNEL ARRANGEMENTS	14. Clothing.	Availability of proper scale of personal issue of white and working clothing and rubber boots or clogs; use of appropriate clothing for clean and dirty jobs; adequacy of laundry arrangements.
	15. Sanitary and rest-room accommodation.	Provision of hand-basin, hot and cold water, soap, nailbrush and clean towels in main kitchen and in lavatories; cleanliness and adequacy of lavatory accommodation and provision of handwashing notices. Provision of clean, well furnished rest room equipped with clothing lockers.
	16. Personal hygiene of food-handlers.	Enforcement of hand cleanliness and nail cutting; pre-shift hand checks by N.C.O. i/c; absence of septic cuts, coryza, gastro-intestinal disturbance, and skin disease; absence of dressings on hands.
	17. Training of food-handlers.	Knowledge of hygiene of food-handling and appreciation of its importance; sense of responsibility.
	18. Kitchen organization.	Systematic division of clean and dirty jobs; absence of muddle; good housekeeping.

KITCHEN AND ANCILLARY PREMISES (*contd.*)

Item	*Points for Attention*	*Notes*
REFUSE DISPOSAL	19. Swill.	Provision of covered bins in kitchen and washups; prompt removal to compound after each meal; cleanliness of bins after use; adequacy of bins in compound; soundness of lids and clear labelling; easy access and regular clearance by contractor.
	20. Dry refuse and tins.	Provision of separate, labelled bins in compound; adequate cleansing of tins before discard.
	21. Vegetable preparation room effluent.	Provision of trapped gullies outside kitchen for ease of cleansing.
PEST CONTROL	22. Insects.	Absence of flies and cockroaches; adequacy of control measures, and prevention of breeding places; denial of food wastes to insects and regular spraying with residual insecticides; fly-proofing of windows of preparation and storage rooms.
	23. Rodents.	Absence of evidence of rats and mice and adequacy of control measures; rodent proofing of doors, windows, and all other points of entry.
FOOD STORAGE	24. Bread.	Provision of slatted shelves; open stacking of loaves for ventilation; muslin protection for stacks.
	25. Meat.	Provision of adequate, cool handling space and offal bins.
	26. Cereals and dry rations.	Provision of adequate covered bins.
	27. Edible fats and perishable foods.	Adequacy of refrigeration and cold storage.
	28. Milk.	Provision of covered churns and dippers, washed and sterilized by scalding daily.
	29. Vegetable.	Sacks and boxes raised off floor; adequate containers for prepared vegetables; adequacy of ventilation.
FOOD SERVICE	30. Hotplates.	Cleanliness and good repair; special attention to absence of cockroaches.
	31. Serving implements.	Adequacy and cleanliness of implements to avoid unnecessary handling of food.
	32. Staff.	Cleanliness of white clothing and hands; wearing of hats—cook adequacy of supervision.

N.A.A.F.I. AND CIVILIAN-RUN CANTEENS AND INSTITUTES

As for "Kitchens and Ancillary Premises" and in addition the following:—

STRUCTURE	1. Staff quarters.	Cleanliness and good repair.
FITTINGS	2. Display cabinets.	Adequate protection of displayed food.

DOMESTIC ACCOMMODATION

As for "Buildings—General Items" and in addition the following:—

Item	*Points for Attention*	*Notes*
STRUCTURE	1. Overcrowding.	Particular attention to floor area per bed in dormitories.
	2. Bars—officers' and S.N.C.Os.' messes.	Adequacy of glass-washing facilities; efficiency of ventilation, natural and/or artificial.
FITTINGS	3. Incinerators—W.R.A.F. barracks only.	Presence of and correct function of.
	4. Laundry facilities.	Adequacy of sinks, electric irons, drying racks in W.R.A.F. blocks.
EQUIPMENT	5. Beds and bedding.	Serviceability of bed springs; cleanliness and freedom from damp of mattresses and bedding; head staggering in winter time.
	6. Wardrobes and lockers.	Adequacy, cleanliness, serviceability; absence of food.
	7. Sanitary bins—W.R.A.F. barracks.	Presence and cleanliness of bins; regular clearance.
	8. Refuse containers.	Adequacy of supply in barracks.
PHYSICAL ENVIRONMENT	9. Ventilation.	Special attention to ventilation of dormitories.

MISCELLANEOUS PREMISES

As for "Buildings—General Items" and in addition the following:—

GUARDROOMS

STRUCTURE	1. Cells and detention rooms.	Presence of A.O.C.'s certificate of fitness; adequacy of floor area; absence of wall projections providing suicidal opportunities.
	2. Dog kennels.	Suitability of siting to prevent noise and smell nuisance; cleanliness and tidiness; presence of hygienic fly and rodent proofing; food stores labelled "dog food—not for human consumption".
PHYSICAL ENVIRONMENT	3. Heating.	Provision of flush-fitting heating panels; presence of wall thermometer in secure place.
	4. Lighting.	Provision of secure bulkhead type fittings.
	5. Ventilation.	Adequacy of window opening without fouling bars.
	6. Sanitary fittings.	Cleanliness and good repair; presence of toilet paper.
	7. Washing facilities.	Cleanliness and good repair; availability of facilities for dog-handlers.

BEDDING STORE

STRUCTURE	1. Bedding storage.	Separate storage for clean and soiled bedding.
PHYSICAL ENVIRONMENT	2. Heating.	Adequacy of heating to ensure dryness of bedding.
PEST CONTROL	3. Prevention of infestation.	Adequacy of arrangements for disinfection of blankets and bedding; serviceability of steam disinfestor; particular attention to cleanliness of returned laundered articles; regular laundering of blankets.

CINEMA

Item	Points for Attention	Notes
STRUCTURE	1. Exits.	Adequacy in case of fire.
SANITARY ARRANGEMENTS	2. Lavatories.	Provision of adequate lavatories.
PHYSICAL ENVIRONMENT	3. Ventilation.	Adequacy of ventilation.
EQUIPMENT	4. Fire-fighting appliances.	Adequacy of provision.

TELEPHONE EXCHANGE

Item	Points for Attention	Notes
STRUCTURE	1. Sleeping accommodation for shift operators.	Presence of satisfactory rest room.
SANITARY ARRANGEMENTS	2. Lavatories.	Provision of lavatories near at hand.
PHYSICAL ENVIRONMENT	3. Ventilation.	Adequacy of artificial ventilation when necessary.
	4. Lighting.	Particular attention to lighting of switchboard.
PERSONNEL ARRANGEMENTS	5. Feeding arrangements.	Provision of satisfactory meals for shift workers.
	6. Seats.	Provision of switchboard chairs of satisfactory design.

BARBER'S SHOP

Item	Points for Attention	Notes
HYGIENE REQUIREMENTS	1. Linen	Cleanliness and regular laundering of linen.
	2. Water supply.	Availability of adequate hot and cold water.
	3. Instrument sterilizing and cleansing.	Availability and use of antiseptics approved by medical officer; regular cleansing and hygienic storage of combs and brushes.

CARAVAN SITES

Item	Points for Attention	Notes
SITING	1. Surface.	Suitability, grass or hard standing preferable; sand or gravel soils provide best drainage.
	2. Area.	Absence of crowding of vans.
	3. Access.	Adequate width of gate; presence of hard paths throughout site.
SITING	4. Water supplies.	Presence of pure and adequate piped supply, protected against frost and provided with a drain.
	5. Conservancy.	Particular attention to arrangements for disposal of human excreta and sullage water.
REFUSE DISPOSAL	6. Swill and dry refuse.	Provision of separate bins; regular clearance by Service, Local Authority, or contractors.

PIG FARMS

Item	Points for Attention	Notes
STRUCTURE	1. Siting.	Suitability of site, to leeward of buildings; particular attention
	2. Floors.	to soundness and adequate drainage, and to properly covered and fly-proof soakage pit.

PIG FARMS (*contd.*)

Item	*Points for Attention*	*Notes*
FEEDING ARRANGEMENTS	3. Storage.	Availability of rodent and insect-proof containers.
	4. Swill processing.	Enforcement of swill boiling to prevent pig disease.
SANITARY ARRANGEMENTS	5. Water supply.	Availability of adequate water supply to maintain cleanliness.
	6. Conservancy.	Satisfactory arrangements for disposal of faeces by tight packing on impervious base or removal by contractor.

SEWAGE FARMS

STRUCTURE	1. Capacity of works.	Adequacy of plant in relation to new buildings since installation.
EFFLUENT SAMPLING	2. Daily.	Ensure daily samples kept; maintenance of satisfactory standard.
	3. Annual.	Satisfactory quality of last annual sample.

WATER SUPPLIES

SUPPLY	1. Adequacy.	Adequacy of supply for all unit purposes throughout the year.
	2. Potability.	
TREATMENT	3. Purity.	Adequacy of filtration and chlorination; satisfactory bacteriological report on last examination and after any new work of source or supply pipes.

REFUSE DISPOSAL

STRUCTURE	1. Access road.	Satisfactory approach road for vehicles.
	2. Siting.	Suitability of siting to leeward of habitations.
	3. Tipping.	Particular attention to hygenic maintenance of tip.
	4. Incineration.	Serviceability of incinerator; thorough destruction of refuse; hygenic disposal of ash.
EQUIPMENT	5. Vehicles.	Satisfactory design of vehicles with cover and tail board.
	6. Tools and implements.	Adequacy of supply of spades, rakes, pokers, and brooms.
	7. Fire-fighting equipment.	Presence of adequate appliances and water supply.
PEST CONTROL	8. Rodents, flies, and mosquitoes.	Adequacy of control measures; prevention of breeding places in heaps of refuse and tins.

TECHNICAL ACCOMMODATION

As for "Buildings—General Items" and in addition the following:—

STRUCTURE	1. Rest rooms and cloakrooms.	Adequacy for W.R.A.F. and civilians; locker accommodation.
	2. Floors.	Cleanliness and good repair; proper drainage; prevention of slipping hazards in oily and wet processes; daily cleansing.
	3. Working area.	Absence of overcrowding.

TECHNICAL ACCOMMODATION (*contd.*)

Item	*Points for Attention*	*Notes*
PHYSICAL ENVIRONMENT	4. Heating.	Adequacy of heating arrangements; good repair of doors and windows to prevent draughts and chilling.
	5. Lighting.	Adequacy and good arrangement of general and local lighting; particular attention to levels of illumination for fine and moving tasks, and in passageways; avoidance of glare from local lighting.
	6. Ventilation.	Particular attention to design and proper function of exhaust ventilation in dope shops, battery charging rooms, and occupations generating dust, fumes, vapour, or gas.
SANITARY ARRANGEMENTS	7. Washing facilities.	Adequacy of provision with hot and cold running water; presence of soap and clean towels.
	8. Drinking water.	Presence of pure and adequate supply of drinking water and hygienic means of consumption.
SANITARY ARRANGEMENTS	9. Lavatories.	Provision of adequate accommodation separate for the sexes, and not opening directly into workrooms; cleanliness and adequacy of illumination.
DANGEROUS HAZARDS	10. Machinery.	Presence of effective guards for cutting edges, moving parts, and driving belts.
	11. Hoists and lifting tackle.	Security and regular checking.
	12. Dust.	Efficiency of suppressive measures; presence of fire appliances; visual warning of toxic and explosive risks.
	13. Toxic vapours, gases, fumes, and solvents.	Adequacy of ventilation; correct use of respirators and lifelines; exclusion of untrained workers; provision of barrier substances.
	14. Electroplating.	Knowledge of the hazards of salts of chromium and cyanides; use of ointment prophylactic; safe storage of poisonous substances.
	15. Battery charging.	Separation of acid and alkaline charging; provision of appropriate antidotes; wash bottles for eye burns; presence of warning and first-aid notices; correct use of protective rubber aprons, boots and gloves and of goggles; acid-proof painting of benches; adequacy of exhaust ventilation.
GENERAL SAFETY MEASURES	16. First-aid boxes.	Correct maintenance of first-aid boxes; current first-aid training of box holder; correct maintenance of accident book.

TECHNICAL ACCOMMODATION (*contd.*)

Item	*Points for Attention*	*Notes*
GENERAL SAFETY MEASURES	17. Protective clothing.	Correct use of prescribed clothing and goggles; regular laundering of clothing contaminated with oils and greases.
	18. Warning notices.	Provision of appropriate warning notices.
	19. Meals in workshops.	Enforcement of ban on feeding in workshops.

LAYOUT OF UNIT OR STATION HYGIENE DIARY

(a) Medical Officers Report		(b) Action Taken	
(i) Date and Place of Inspection	(ii) Report	(i) Remarks by O.C. or S. AD. O.	(ii) Remarks by O. i/c Section or by A.M.W.D. (Station Engineer/Clerk of Works)

THE ROLE OF LABORATORIES IN THE CONTROL OF INFECTIOUS DISEASES

The R.A.F. Institute of Pathology and Tropical Medicine

1. This Institute is a laboratory, with additional teaching functions, situated at R.A.F. Halton. It accepts, from units at home and abroad, specimens the examination of which is beyond the scope of local laboratories. In addition the Institute carries out all pathological examinations required by R.A.F. Hospital, Halton.

2. ~~The Institute performs all water and sewage analysis for units in the United Kingdom. Directions for the forwarding of such specimens are contained in Chapters 2 and 4 of this publication.~~ (A.L.4)

3. All other pathological specimens should be sent to the laboratory at the nearest R.A.F. hospital, where the pathologist will decide whether he can perform the tests required. When, however, Halton happens to be the nearest hospital, specimens should be sent direct to the Institute.

4. The R.A.F. Consultant or Principal Specialist in Pathology and Tropical Medicine is resident at the Institute. Patients may be admitted under his care to R.A.F. Hospital, Halton. Appointments for consultations must be made by letter directly with the Consultant.

5. The address of the Institute, which operates a 24-hour service, is:—

R.A.F. Institute of Pathology and Tropical Medicine,
R.A.F. Halton,
Aylesbury, Bucks.
Telephone: Wendover 2261 Consultant Ext. 44
Commanding Officer Ext. 38.

Major Laboratories

6. R.A.F. laboratories of major calibre are situated at the larger R.A.F. hospitals at home and abroad. These laboratories are equipped to perform any pathological procedure normally required in the investigation and control of infectious disease. Water and sewage analysis are also undertaken locally by such laboratories abroad.

7. Advice may be obtained from officers in charge of major laboratories on the specimens and methods required in the investigation of an outbreak of infectious disease.

Minor Laboratories

8. Minor R.A.F. laboratories are situated at stations and lesser R.A.F. hospitals at home and abroad as well as at the Central Medical Establishment. These are equipped to carry out all routine pathological investigations, but forward for examination to major laboratories or the Institute material that is beyond their capacity. Abroad the scope of such laboratories may be wider. Help in the investigation and control of outbreaks of infectious disease from minor laboratories is likely to be limited.

Other Pathological Facilities

9. Laboratories of the Royal Navy or Army may be used on the authority of the competent medical authority, when R.A.F. facilities are unavailable or for other special reasons. Should difficulty occur in arranging adequate pathological facilities, the advice of the Consultant may be sought, through the usual channels.

10. The Public Health Laboratory Service should be used under certain circumstances and always when an epidemic of virus disease is being investigated. The specimens required for the investigation of influenza and the technique of their collection are described subsequently. Special investigations are also required when smallpox is suspected and the collection of appropriate specimens is also mentioned below.

11. The Public Health Laboratory Service may also be utilized in cases of urgency, particularly by units remote from R.A.F. hospitals or other service facilities. Civilian organizations are not, however, to be used for the examination of water or if there is any prospect of litigation following a test result.

Laboratory Help in the Investigation of Infectious Disease

12. The competent medical authority should be consulted when it is considered that laboratory help is required in the investigation of an outbreak of disease. The competent medical authority will make the necessary arrangements with the appropriate laboratory, the officer in charge of which should advise on the number and type of specimens to be examined. If this officer considers that the investigation is beyond his resources, he should advise the Commanding Officer of the Institute of Pathology and Tropical Medicine, who may make arrangements for extra staff and equipment to be made available.

13. If the competent medical authority (in the United Kingdom) considers that a full-scale laboratory investigation should be made at the unit concerned, notification should be sent to the Consultant in Pathoogy and Tropical Medicine and to Air Ministry (D. of H. & R.). If the need for such an investigation is agreed, arrangements will be made for a team of investigators to visit the unit. Abroad, principal medical officers should arrange for such investigations with the officer in charge of the nearest major laboratory.

14. Laboratory assistance may be required in either an exploratory or confirmatory role. The occasions when it is necessary in the investigation of an outbreak depend on many variables in the form of causal organism, extent, danger, and circumstances in general; whether or not help should be asked must remain a matter of individual judgement. The following list, however, is a guide to the diseases in which help might be enlisted and to the specimens normally required.

DISEASE	SPECIMENS FROM PATIENT	OTHER SPECIMENS
Food poisoning	Stool Vomit	Samples of suspected foods.
Enteric fevers	Stool Blood (for culture) Serum	Stools and urine from food-handlers. Selected water samples.
Dysenteries	Stool	Stools from food-handlers. Selected water samples.
Influenza	Saline gargle Serum	
Poliomyelitis	Cerebrospinal fluid Serum	
Cerebrospinal meningitis	Cerebrospinal fluid	Occasionally post-nasal swabs from contacts.
Streptococcal sore throat	Throat swab	Sample of milk supply.
Diphtheria	Throat swab	Throat swab from contacts. Swab from cutaneous lesions in contacts. Sample of milk supply.
Smallpox	Serum Throat swab Scrapings, smears, fluid and scabs from lesions.	

COLLECTION AND TRANSMISSION OF SAMPLES

Post Office Regulations

15. There are strict regulations on the sending of articles for medical examination or analysis by post. These can be found in full in the Post Office Guide, from which the following is an extract:

> "Deleterious liquids or substances, though otherwise prohibited for transmission by post, may be sent for medical examination or analysis to a recognized medical laboratory or institute, whether or not belonging to a Public Health Authority or to a qualified medical practitioner or veterinary surgeon, within the United Kingdom, by letter post, and on no account by parcel post, under the following conditions:—
>
> Any such liquid or substance must be enclosed in a receptacle, hermetically sealed or otherwise securely closed, which receptacle must itself be placed in a strong wooden, leather or metal case in such a way that it cannot shift about and with a sufficient quantity of some absorbent material (such as sawdust or cotton wool) so packed about the receptacle as absolutely to prevent any possible leakage from the package in the event of damage to the receptacle. The packet so made up must be conspicuously marked 'Fragile with Care' and bear the words 'Pathological Specimen.'
>
> Any packet of the kind found in the parcel post, or found in the letter post not packed and marked as directed, will be at once stopped and destroyed with all its packings and enclosures. Further, any person who sends by post a deleterious liquid or substance for medical examination or analysis otherwise than as provided by these regulations is liable to prosecution.".

16. Specimens must not be registered. It is not permissible to destroy registered articles by burning, and this may be necessary as a precaution if the container has leaked.

17. To avoid postal delays over the week-end, samples should be sent by special messenger or not at all during this period.

Apparatus and Containers

18. Apparatus and containers for sending pathological specimens may be demanded from 248 M.U. in the normal way. Special containers for virus specimens may be obtained when necessary from the Public Health Laboratory Service. It is important, particularly with bacteriological specimens, that containers should allow easy access to the contents. For example, when McCartney screw-capped bottles are used, the wide-necked type should always be chosen in preference to the narrow.

19. The nature of the container should always be written on the top left-hand corner of the Form Med. 12 which accompanies specimens to the laboratory. This enables the laboratory to return with the report the same or a similar piece of sterile equipment to the unit concerned, which conserves the unit stock of laboratory equipment and saves voucher action each time an item is dispatched.

Form Med. 12

20. This form is forwarded with all specimens except water and sewage, for which a special form is used. Form Med. 12 is completed in duplicate and it is most important that it should supply full information. In order to enable the pathologist to formulate an intelligent opinion from the examination of specimens, it is essential to supply him with clinical details even in cases apparently of routine nature only.

Food and Beverages

21. With the exception of milk (see para. 26) samples of food and beverages should be sent to the nearest major R.A.F. laboratory. When, however, arrangements have been made by the competent medical authority, such samples may be forwarded direct to I.P.T.M. Samples should be sent, packed in ice, by the quickest possible means; the use of aircraft or dispatch rider may be advisable. Duplicate samples may be sent to the nearest Public Health Laboratory in urgent cases where bacterial or viral disease is suspected.

22. The following particulars should be included on the Form Med. 12 accompanying the specimen:—

- (*a*) Name of unit.
- (*b*) Date of forwarding specimen.
- (*c*) Nature of article of food sent.
- (*d*) Source of the article.
- (*e*) Date of purchase or issue of the article.
- (*f*) Exact examination required.
- (*g*) Reason for requesting examination.
- (*h*) Any batch number or other identifying mark if available.

23. In cases of suspected food poisoning, specimens of the patient's vomit and faeces should also be forwarded, with a concise case history stating:—

(*a*) Name of patient or patients.

(*b*) Estimated time between ingestion of suspected food and onset of symptoms.

(*c*) Synopsis of symptoms in order of occurrence.

(*d*) Condition of other people who have eaten the suspect food.

Method of Collecting Food Samples

24. Food samples should be collected under the direct supervision of the unit medical officer. An average sample of the food concerned should be obtained; for example, both crust and crumb of bread or rind and interior of cheese. Wrappings and original food containers should also be sent if available. If it is necessary to use containers other than the original, clean, sterile glass-stoppered bottles or jars of suitable size should be employed. These should be sterilized by boiling for one hour. Examples of minimum quantities required for examination are:—

(*a*) *Tinned Foods*. One unopened tin together with a partially consumed tin from the suspect batch.

(*b*) *Bottled Foods*. As for tinned foods.

(*c*) *Wrapped Foods*. One package with wrapping undisturbed and 4 ozs. of unconsumed suspect article issued for consumption.

(*d*) *Foods Issued in Bulk Unwrapped*. 8 ozs. of unissued food and 8 ozs. of unconsumed material issued for consumption.

(*e*) *Bread*. One unused loaf together with 8 ozs. of bread issued for consumption.

(*f*) *Meat*. 8 ozs. of uncooked meat, if possible from the same carcase, with 8 ozs. of issued cooked meat if available.

(*g*) *Sausages*. A representative sample of 16 ozs. from the string as issued, with 8 ozs. of cooked sausage if available.

25. If there is a possibility of the good name of a supplier being in question, identical duplicate samples should be taken, in case an independent check is demanded. If such a demand is received, the duplicate samples are not to be handed over without the permission of the competent medical authority.

Milk Samples

26. It is essential for the medical officer to be present when milk samples are taken. The milk must be thoroughly mixed before sampling. The minimum quantity required for examination is one pint. Samples suspected of being below the legal standard of fat or solid non-fat content, or of containing pathogenic organisms, are normally sent for analysis to I.P.T.M. If an adverse report is received, the help of the local Medical Officer of Health should be enlisted without delay. It is most important that medical officers should not express any opinion on the wholesomeness of the milk to the supplier or any other unauthorized person.

Serum Examinations

27. Serum is required for all tests of the presence of antibody. In epidemiological work antibody titres often give valuable information,

particularly in the enteric fevers and in almost all virus and rickettsial diseases. Antibody estimations are useless in the dysenteries and food poisoning, but may assist in the diagnosis of infectious mononucleosis.

28. It is always essential to provide two specimens: the first should be taken early in the disease and the second some 14 to 21 days later. This enables the behaviour of titre to be assessed. Outside the laboratory it is not practicable to separate the serum. A blood sample of 5 to 10 mils should be obtained by venepuncture and delivered into a dry sterile container. The whole-blood sample should be sent to the nearest R.A.F. laboratory or in cases of virus and rickettsial disease to the nearest Public Health Laboratory Service.

29. The following points are of particular importance in the taking and transmission of blood samples for serological investigation:—

(*a*) The venepuncture syringe and needle should preferably be dry sterilized, but if boiling is the only practicable method of sterilization the syringe and needle must be rinsed before use in sterile normal saline.

(*b*) The container must be sterile and a suitable type should be obtained from the nearest R.A.F. laboratory. If this is not possible, a container sterilized by boiling must, before use, be well rinsed with sterile normal saline. Corks should never be used as stoppers for containers. The most convenient method for taking and transmitting blood samples is to use a venule.

(*c*) Transmission of whole clotted blood through the post, except in carefully packed venules, is often unsatisfactory; whenever possible samples should be sent to the nearest laboratory by hand.

(*d*) Full clinical details must be included on the accompanying Form Med. 12, otherwise the results of tests are difficult to interpret. The inclusion of information on previous active immunization and on the results of previous tests, with dates, are essential to the pathologist.

Blood Culture

30. Blood cultures are generally unsatisfactory unless undertaken under optimum conditions. When a blood culture is required, the pathologist at the nearest R.A.F. laboratory should be consulted. He will either supervise the test personally or arrange for the admission of the patient to hospital.

Cerebrospinal Fluid

31. In the great majority of cases where diagnostic lumbar puncture is required, the patient should be admitted to hospital. If this is impracticable, the specimen must be sent to the laboratory by special messenger with full precautions as outlined below and it must arrive at the laboratory within 1½ hours of being taken. For this reason the nearest laboratory should be used, whether it is service or civilian.

32. The following are the precautions that must be taken:—

(*a*) The laboratory should be informed that such a specimen is to be expected.

(*b*) The fluid must be collected in at least two sterile containers without anti-coagulant. A minimum of 10 mils. fluid is required for full examination.

(*c*) The fluid must be maintained at body temperature until it is in the laboratory. The containers must be warmed to body heat before use, then wrapped in several layers of warm cotton wool. The messenger must carry the package in his inside pocket.

(*d*) The messenger must be impressed with the importance of the specimen and be ordered to hand it personally to the laboratory technician or pathologist and to no one else.

(*e*) The accompanying Form Med. 12 must give full clinical details including the pressure of the fluid. In addition the container holding the initial efflux of fluid must be clearly marked.

Faeces—Bacteriological Examination

33. For the diagnosis of bacillary dysentery or enteric fevers, a minimum of six daily stool specimens should be examined. Positive results are to be expected early in cases of bacillary dysentery, while in the enteric diseases stool culture is most likely to be positive in the second or third weeks.

34. When the investigation is designed to exclude the enteric carrier state, a purge of magnesium sulphate (½ oz.) given in the morning before the specimen is taken, increases the chance of isolating organisms. Portions of stool, especially those containing blood and mucus in bacillary dysentery cases, should be transferred to a faeces container-pot and sent to the laboratory with minimum delay.

35. If enteric specimens cannot be delivered immediately or dysentery specimens within two hours, they may be preserved in glycerine-saline and sent by post. Glycerine-saline can be obtained from the nearest R.A.F. laboratory or can be made up as follows. Two parts of sterile normal saline are mixed with one part of glycerine and sufficient saturated solution of phenol red is added to colour the mixture. Saturated solution of sodium dihydrogen phosphate is then gradually stirred in until the colour changes to purple. Approximately 3 mils of the resultant solution is dispensed in screw-capped bottles and, provided the solution is kept in a refrigerator, sterilization is not required. When required, up to an equal amount of faeces is added and a high percentage of successful isolations can be expected from such specimens, even when transmitted by post.

36. Form Med. 12 accompanying a faeces specimen must include a concise clinical history together with a note of previous active immunization. In cases of acute diarrhoea it is important to stress any clinical suspicion of cholera or of staphylococcal food poisoning, as different cultural techniques are adopted in these infections.

Faeces—Amoebic Dysentery

37. The diagnosis of amoebic dysentery by identification of *E. histolytica* is very difficult except on fresh specimens. A portion of stool containing blood and mucus should be sent by special messenger to the nearest R.A.F. laboratory and must arrive within two hours of being passed. The diagnosis of chronic amœbiasis is assisted by a saline purge before the sample is taken.

38. Cyst carriers of amœbiasis can be diagnosed on older specimens of stool, which can be sent by post. *E. histolytica* cysts are more common in the formed part of the stool, portions of which should be included in the specimen for examination.

Sputum

39. Specimens of sputum should be derived from the lower, not the upper, air passages, and should not be contaminated with organisms from the buccal cavity. Hence the early morning sputum should be collected, after the patient has cleaned his teeth and washed his mouth out several times with boiled water. The sputum should then be expectorated directly into a sterile sputum pot, which must contain no disinfectant if a culture is required. When the sole object of the examination is the identification of the tubercle baccillus from smears, a little 5 per cent. phenol solution may be added to the container.

40. The specimen should be forwarded to the laboratory in the sterile container, the packing of which requires extra special care to prevent leakage. It is stressed that tuberculous sputum is possibly the most dangerous specimen arriving at the laboratory by post.

41. Form Med. 12 must state whether the sputum is to be examined purely from the point of view of tuberculosis or for the predominance of other pyogenic organisms. It must be stated whether disinfectant has been added to the sputum. It may take the laboratory as long as six weeks before a firm statement can be made on the presence or absence of tubercle bacilli.

Throat Swabs

42. No local antiseptic should be applied to the throat during the 12 hours before a specimen is to be taken. The swab should not be allowed to touch anywhere except the ulcer or chosen mucosa. A second swab should be taken from the deeper part of an ulcerated area.

43. In suspected cases of cerebrospinal meningitis, a posterior nasopharyngeal swab should be taken, using an ordinary swab bent to an obtuse angle or a West's swab. These must be kept at body temperature as for specimens of cerebrospinal fluid.

44. For the most accurate results throat swabs are best sent by hand to the nearest laboratory. When diagnosis is urgent, as in diphtheria and cerebrospinal meningitis, the use of the Public Health Laboratory Service is fully justified. The accompanying Form Med. 12 should give a clinical summary, including history of contact, and state the exact location from which the specimen was taken.

Urine

45. For bacteriological examination of urine, a mid-stream specimen of 8 ozs. is required from men, a catheter specimen from women. Such specimens are best sent to the laboratory by hand, but provided full precautions to prevent contamination during collection are taken postal transmission is satisfactory.

46. Form Med. 12 accompanying the specimen must give clinical details, the exact nature of any tests required, and the results of previous tests.

Investigation of Influenza

47. The specimens required are serum for antibody tests and throat washings for virus identification. Two specimens of serum are required,

the first in the acute stage (up to the fifth day of illness), the second during the convalescent stage (14th to 21st day). Approximately 5 to 10 mils of blood are required. If the specimens are stored before dispatch, care is required to prevent the blood freezing. The specimens should be sent to the nearest laboratory of the Public Health Laboratory Service.

48. To collect throat washings, which must be obtained within 36 hours of the onset of the disease, the patient gargles with 10 mils of sterile normal saline and transfers this direct to a sterile bottle containing 1 to 2 mils serum broth. The bottle must then be placed at once in the freezing coil of a refrigerator. If the latter is not available the bottle should be put in a thermos on ice. Sterile bottles with serum broth can be obtained on request from the Public Health Laboratory Service. When such a request is made the size of the bottles should be specified as suitable for transmission in "Onazote" insulated containers, which can be obtained from 248 M.U. for the transfer of virus specimens by post. The specimens should be sent either to the nearest laboratory of the Public Health Laboratory Service, or to the Virus Reference Laboratory of the Central Public Health Laboratory, Colindale.

49. Form Med. 12 accompanying the specimens must give full clinical details, especially with reference to the time of onset relative to the taking of the specimens.

Investigation of Smallpox

50. When smallpox is suspected on clinical grounds, immediate notification must be made without awaiting laboratory confirmation, as detailed in Chapter 9. The local Medical Officer of Health will call in the Regional Smallpox Consultant if necessary, but meanwhile specimens must be taken and forwarded by the quickest means available to the Virus Reference Laboratory, Central Public Health Laboratory, Colindale, in order that an early and accurate diagnosis may be made.

51. For the collection and transmission of the necessary specimens special outfits are available from all major R.A.F. laboratories. These "Outfits, specimen collecting, smallpox" (stores reference 8C/2130) consist of a cardboard box inside which is a metal container holding 1 mounted needle, 4 clean glass slides, 1 large screw-capped bottle with capillary tubes in it, and 1 small screw-capped bottle.

52. The specimens required and the method of their collection are as follows:—

(*a*) *Maculo-Papular Rash Stage*. The skin should be cleaned with ether or methylated spirit. With the mounted needle at least six lesions should be scraped and six thick smears should be made on each of the four glass slides. These should be allowed to dry in air, without heating, and when dry the slides should be placed face to face separated by paper to prevent sticking. The slides should be put in their box, the needle in its tube, and the whole outfit sent to the laboratory.

(*b*) *Vesicular and Pustular Stage*. The tops of 6 to 10 lesions should be removed with the needle and placed in the small bottle. Fluid should be collected in the capillary tubes and put back in the large bottle. After scraping, the bases of 4 to 6 lesions smears should be made on the slides. The slides and needle should be packed as above and, with the bottles, the whole outfit should be sent to the laboratory.

(*c*) *Crusting Stage*. Up to 12 scabs should be removed with the needle and placed in the small bottle. The needle should be replaced in its tube and the bottle, together with the rest of the outfit, should be dispatched to the laboratory.

(*d*) *At All Stages*. In addition, at all stages, 10 mils of blood should be taken and two throat swabs. These should be sent to the laboratory at the same time as the other specimens and the outfit.

53. The greater the quantity of material collected the better can results be interpreted. With maximum amounts results will be available in 2 to 24 hours of receipt of the material, with minimum amounts 48 to 72 hours.

54. Containers and Form Med. 12 accompanying the specimens must show the patient's name, age, and previous vaccination history.

THE PREVENTION OF ALIMENTARY INFECTIONS MEDICAL SUPERVISION OF INFECTED PERSONS

Introduction

1. Carriers are generally considered to be the main reservoir for the alimentary infections, but unfortunately their detection by microscopic and bacteriological examination of faeces is extremely time-consuming. Moreover, the results are disappointing since many carriers pass the organisms intermittently, and the methods available for their detection are relatively crude.

2. Investigations in the R.A.F. have shown that direct microscopical examination of three consecutive specimens of faeces, performed under the best conditions by expert technicians, will only detect 60 per cent. of the true number of carriers of *Entamoeba histolytica* in a population. The figure is reduced to about 20 per cent. under ordinary routine conditions. For a simple examination under routine conditions the figure falls to 13 per cent. This method of control is, therefore, ineffective and uneconomical. Moreover, the rate of reinfection has been shown to equal the rate of detection.

General Policy

3. The number of food-handlers, R.A.F. or native, who are infected with worms, directly transmissible from man to man, is too small to justify routine examination of faeces. Furthermore, routine bacteriological examination of faeces is unrewarding except at times of epidemics.

4. The exact policy to be adopted in any particular area must depend on local conditions, so must be at the discretion of principal medical officers. The following recommendations are, however, considered to be the best compromise between the ideal and the practical:—

(*a*) Native food-handlers in tropical and sub-tropical areas should be given mass out-patient treatment for *Entamoeba histolytica* infection on first employment and at regular intervals thereafter. Details of the recommended treatments are issued by Air Ministry from time to time.

(*b*) Native food-handlers should have three specimens of faeces examined bacteriologically before initial engagement.

(*c*) The appropriate faecal examination of all food-handlers should be considered as a control measure on the outbreak of an epidemic.

(*d*) Patients suffering from specific alimentary infections should be dealt with in accordance with the following paragraphs.

Amoebiasis and Giardiasis

5. All food-handlers known to be infected with *Entamoeba histolytica* or *Giardia lamblia* must be treated. They may be re-employed on food-handling duties when, after completion of treatment, six consecutive stools have been found negative. A further three consecutive stools must be examined one month after returning to duty. Where adequate treatment of native food-handlers cannot be ensured, those found to be suffering from active amoebiasis should be permanently suspended from food-handling. The same criteria of cure should be applied to non-food-handlers.

Helminthic Infections

6. Only four helminths are of epidemiological importance in food-handlers: *S.strongyloides*, *T.solium*, *H.nana* and *E.vermicularis*. *S.strongyloides* is very resistant to treatment and, until satisfactory therapeutic reagents have been developed, infection with this worm necessitates permanent suspension from food-handling. The other infections should be treated and the same criteria of cure be applied to food-handlers and non-food-handlers as for amoebiasis.

Typhoid and Paratyphoid A

7. Any person infected with these organisms is unfit for food-handling for nine months after the last positive specimen. Native food-handlers infected with either of these organisms should be discharged as permanently unfit for food-handling, owing to the difficulty of adequate bacteriological clearance. All R.A.F. patients and European civilians must be detained in hospital until 14 consecutive specimens of both faeces and urine have been cultured and found negative. In the case of food-handlers, three further specimens of faeces and urine must be examined on each occasion at the end of the third, sixth and ninth months after discharge from hospital before re-employment on food-handling. A positive specimen is the indication for readmission for a further course of treatment. If no cure follows this second course, the patient is to be admitted to P.M. R.A.F. Hospital, Halton, and notification of this is to be made to the Principal Specialist in Pathology and Tropical Medicine and Air Ministry (D. of H. & R.).

All other Salmonella Infections, Bacillary Dysentery, and Cholera

8. All food-handlers must be symptom-free and have had 14 consecutive faecal specimens found negative before re-employment on food-handling duties.

9. Surveillance of non-food-handlers may cease once the patient is symptom-free and has had six consecutive faecal specimens found negative.

Infective Hepatitis

10. Food-handling should not be resumed until six weeks after the onset of the disease.

Poliomyelitis

11. All patients should be isolated for at least three weeks. In addition the following regulations apply to food-handlers:—

(*a*) *Convalescents*. Food-handling should not be resumed for 12 weeks from the onset of the disease.

(*b*) *Close Contacts*. If contact has been domestic, *e.g.* a food-handler with an infected wife or child in his quarter, suspension under surveillance is advisable for three weeks.

SUMMARY OF INTERNATIONAL SANITARY REGULATIONS APPLICABLE TO AIR TRAVEL

(1951 AS AMENDED 1955–1959)

INTRODUCTION

Articles of the Regulations

Aim

1. The regulations aim by international co-operation to ensure the maximum security against the international spread of disease with the minimum interference with world traffic. The regulations apply only in those States which have bound themselves, with or without reservations, to observe them. A.1

Definitions

2. Correct interpretation of the regulations calls for precise knowledge of the meaning of the terms used throughout them, as follows:—

(*a*) *Aëdes Aegypti Index*. The ratio, expressed as a percentage, between the number of habitations in an area in which breeding places of Aëdes aegypti have been found, and the total number of habitations in that area. If it is not practicable to examine all the houses in an area, random sampling and examination will conform to the proportions given in Table I at the end of Appendix "D".

(*b*) *Aircraft*. An aircraft making an international voyage.

(*c*) *Airport*. One designated by the State, in whose territory it is situated, as an airport of entry or departure for international air traffic.

(*d*) *Direct Transit Area*. A special area where, without leaving the airport, transit passengers and crews can be accommodated under the direct supervision of the health authority concerned.

(*e*) *Epidemic*. The extension of a quarantinable disease by a multiplication of cases in a local area.

(*f*) *Health Administration*. The governmental authority of a territory, responsible for the implementation of the regulations. In relation to these regulations the health administration represents the State vis-à-vis W.H.O. (*e.g.* the Ministry of Health in England and Wales).

(*g*) *Health Authority*. The authority immediately responsible for the local application of sanitary measures permitted or prescribed by the regulations.

(*h*) *Imported Case*. Means a case of a quarantinable disease introduced into a territory from outside that territory only. It does not apply to a case moving from one local area to another within the same territory. Cases which are found or treated in one local area but which originated in another local area of the same territory should be described as "originating in a local area (which should be specified) within the territory". Where the source of infection is unknown use of the word "imported" should be avoided.

(*j*) *Infected Local Area.*

(i) A local area where there is a non-imported case of plague, cholera, yellow fever or smallpox; or

(ii) one where there is an epidemic of typhus or relapsing fever; or

(iii) a local area where plague infection among rodents exists on land or on craft which are part of the equipment of a port; or

(iv) a local area where activity of yellow fever virus is found in vertebrates other than man.

(*k*) *Infected Person.* One suffering from a quarantinable disease, or who is believed to be infected with such a disease.

(*l*) *International Flight.*

(i) For an aircraft, a flight between airports of more than one State; or a flight between airports in the territory or territories of the same State if the aircraft has relations with the territory of any other State on its flight, but only as regards those relations.

(ii) For persons it means a flight involving entry into the territory of a State other than that in which that person commences the flight.

(*m*) *Isolation.* Means the separation of a person or group of persons from other persons except the health staff on duty, in such a way as to prevent the spread of infection.

(*n*) *Local Area.* The smallest area, within a territory, having a well-defined boundary and a health organisation competent to apply the sanitary measures permitted or prescribed by the regulations. Also, a sanitary airport or an airport having a direct transit area.

(*o*) *Medical Examination.* Includes visit to and inspection of an aircraft and preliminary examination of those aboard. Preliminary examination may include questioning travellers on their movements prior to disemplanement.

(*p*) *Quarantinable Diseases.* Plague, cholera, yellow fever, smallpox, louse-borne typhus and louse-borne relapsing fever.

(*q*) *Suspect.* A person who, in the opinion of the health authority, has been exposed to quarantinable disease infection and may be capable of spreading that infection.

(*r*) *Valid Certificate of Vaccination.* Means a certificate conforming to the regulations and model laid down by the World Health Organisation.

(*s*) *Yellow Fever Endemic Zone.* An area where Aëdes aegypti is present but not obviously responsible for the maintenance of the virus, which persists in jungle animals over long periods of time.

(*t*) *Yellow Fever Receptive Area.* An area where yellow fever does not exist but where conditions would permit its development if introduced.

Nature of Regulations

3. Certain of the regulations are permissive, others mandatory. Their purpose is not to define what a signatory state must do to control the spread of the six quarantinable diseases but rather to lay down maximum measures beyond which members will not go without notifying W.H.O. and thus their fellow members. The object is to facilitate safe travel rather than to achieve safety by obstructing travel.

ORGANIZATION AND ADMINISTRATION

Exchange of Information

4. The effectiveness of the International Sanitary Regulations depends primarily on the rapid exchange of information. This is the responsibility of health administrations and of W.H.O. A.2

5. Health administrations are bound to notify W.H.O. by signal, within 24 hours, of the occurrence of a local infected area. They must further send immediate notification as soon as the area is free from infection. A.3

6. Similar information must be sent when evidence is found of yellow fever virus in an area where it was not previously recognized. Notification may be made that a local area in a yellow fever endemic zone has had an *Aëdes aegypti* index continuously less than one for a year; W.H.O. will then consider whether to declare it outside the yellow fever endemic zone. A.7

7. Initial notification by the health administration of a local infected area must be supplemented later by detailed information and follow-up reports as to source and type of the disease, the number of cases and deaths, conditions affecting spread of the disease and the prophylactic measures taken. Cases of quarantinable diseases, and deaths from them; the presence or absence of either from towns or cities adjacent to airports must be notified by health administrations to W.H.O. at least weekly by signal. A.4.5.9.

8. Each year health administrations are bound to supply W.H.O. with a summary of their vaccination requirements and the quarantine measures they propose to apply. Any changes, or the intention to apply or remove quarantine restrictions must be notified to W.H.O. by signal, if possible in advance and stating relevant dates. A.8

9. Health administrations are bound to make available, on request, to diplomatic missions and consulates in their territories, any information passed to W.H.O. in accordance with these regulations. A.10

10. W.H.O. is bound to pass on to health administrations all the information received in accordance with these regulations. A.11

Infected Local Areas

11. The definition of an infected local area is given in para. 2. After control measures have been taken, freedom from infection may be assumed when twice the incubation of the quarantinable disease concerned has elapsed since the last case and no other cases have occurred in adjacent areas. For plague, however, the period is one month after the supression of the epizootic. A.6

12. A yellow fever infected local area may be part of a yellow fever endemic zone, or one outside such a zone where there is a case of yellow fever. In the former case freedom from infection may be assumed three months after the last case, or one month after the last case if the Aëdes aegypti index has been continuously maintained below one per cent. In the latter case freedom from infection may be assumed after three months if there has been no evidence of activity of the yellow fever virus. A.6

Airports

13. Health administrations are bound to provide W.H.O. with lists of sanitary airports and of airports having direct transit areas in their territory. Any changes in these lists must be notified. A.21

14. Health administrations are bound to ensure that their airports have organizations and equipment sufficient to implement the regulations. Airports must have pure drinking water, an effective sewage disposal system, and satisfactory means for the disposal of refuse and other matter dangerous to health. Where necessary direct transit areas should be provided. A.14 A.18

15. At airports, designated by the health administration as sanitary airports, there must be an organized medical service, with adequate staff, equipment and premises, facilities for the transport, isolation and care of infected or suspect persons, facilities for disinfecting, disinsecting, destruction of rodents and other sanitary measures, facilities for laboratory examinations and for vaccination against cholera, yellow fever, and smallpox. A.19

16. In yellow fever endemic zones and receptive areas, health administrations have to ensure that the area within the perimeter of every airport is kept free from *Aëdes aegypti* (adults and larvae). The perimeter means a line surrounding the area containing airport buildings and any land or water used (or to be used) for the parking of aircraft. Sanitary airports in endemic yellow fever zones are also to be surrounded by a protective area, extending 400 metres around the perimeter, kept free from all types of mosquito (adults and larvae). A.20

17. In yellow fever endemic zones or receptive areas, all buildings in the direct transit area of an airport must be mosquito proof. At sanitary airports in yellow fever endemic zones all dwellings and sickquarters, for passengers, crew and airport personnel, must be mosquito proof. A.20

18. In a yellow fever receptive area the health authority is A.81
responsible for ensuring that any isolation accommodation provided is mosquito proof.

Documents

19. No sanitary document other than those permitted by the A.100
regulations may be required of international traffic.

20. Health authorities may not require any aircraft bills of A.95.97
health, with or without consular visa, or any certificate, however designated, concerning conditions of health at an airport. Health information, as required by the regulations, must be accepted if entered on the part of the Aircraft General Declaration provided for the purpose.

21. Vaccination certificates have to be printed in English and A.98
French (and the official language of the issuing territory as well if desired). The certificates are to be completed in English or French. The regulations lay down the format of the certificates, and these only are valid with the following exception.

22. A vaccination document issued by the Armed Forces to A.99
a serving member is to be regarded as acceptable in lieu of an international certificate, provided it embodies the same medical information and contains a statement in English or French giving the nature and date of the vaccination and to the effect that it is issued in accordance with Article 99.

23. Health authorities are bound to supply on request to A.26
carriers, travellers and consignors, certificates specifying the sanitary measures (including methods and reasons for application) applied to aircraft, individuals or their baggage, and to goods. The dates of arrival and departure must be stated if applicable.

Application of Quarantine Measures

24. States are bound not to impose more stringent measures A.23
against the introduction of quarantinable diseases into their territory than are permitted by the regulations. Such measures are the maximum applicable to international traffic.

25. Sanitary measures and health formalities must be com- A.24.25
pleted without delay and applied without discrimination. All sanitary measures must be carried out without causing discomfort, injury to health, or damage to aircraft. Precautions must be taken against fire and damage to goods or baggage. Disinsecting of aircraft must be so arranged that no delays are caused to take-off. Medical examinations before departure must be fitted in with customs and other formalities to facilitate departure and avoid delays.

QUARANTINE REGULATIONS APPLICABLE TO AIRCRAFT

Landings

26. States may not prohibit from landing at a sanitary airport any aircraft disinsected in accordance with the regula-

tions. But an aircraft from a yellow fever infected local area arriving in a receptive area may be required to land only at an airport designated by the State for this purpose.

27. Health authorities may not, for sanitary reasons, prevent an aircraft from calling at any airport. If, however, the sanitary facilities required to carry out quarantine measures are not available at an airport, the aircraft may be ordered to proceed to the nearest suitable and convenient airport where there are such facilities. A.41

28. Health authorities may not, except in grave health emergencies, prevent aircraft, which are not suspect or infected with a quarantinable disease, from fuelling, watering, and loading or unloading cargo. A.28

29. If an aircraft is unwilling to submit to sanitary measures, immediate departure must be permitted, provided no landing is intended subsequently at another airport in the same territory. Before departure the aircraft may take on fuel, water, or stores, while remaining in quarantine. The exception to this is yellow fever infected aircraft at an airport in a receptive area; in this case sanitary measures are compulsory before departure. A.44

Arrival

30. Any aircraft on an international voyage may be medically examined on arrival. The sanitary measures that may be applied depend on conditions aboard during the voyage and at the time of examination, and on whether arrival is from a local infected area. Special measures relating to each quarantinable disease are defined in the regulations, varying according to whether the aircraft is classified as healthy, suspect, or infected. A.36

31. Health authorities may not class as from an infected local area an aircraft which has landed therein at a sanitary airport not itself being an infected local area. A.42

Pratique

32. Wherever practicable States shall authorize the granting of pratique by radio before arrival to any aircraft providing in advance information which will enable the health authority to determine that it will not, on landing, cause the introduction or spread of quarantinable disease. A.35

33. A healthy aircraft on arrival must be given free pratique. Suspect or infected aircraft must be regarded as healthy and given free pratique once the special sanitary measures, for the quarantinable disease concerned, have been carried out.

Infected, Suspect and Healthy Aircraft

34. The criteria by which aircraft are classed as infected, suspect or healthy vary according to the quarantinable disease concerned. They are contained in the regulations specifically relating to each such disease (see para. 48 *et seq.*).

QUARANTINE REGULATIONS APPLICABLE TO PERSONS

Medical Examination

35. The health authority at an airport may medically examine any person before departure on an international voyage. It is in addition the duty of health authorities to take all practicable measures to prevent the departure on an international voyage of infected or suspect persons. (This does not apply to transients under surveillance.) A.30

36. The health authority may medically examine any person arriving on an international voyage. A.36

37. No measures other than medical examination may be applied to crews and passengers in healthy aircraft in transit, provided they remain in a direct transit area or other similar area of segregation approved by the airport health authority. The same applies if they transfer from one airport to another adjacent in order to continue their journey, provided they do so under the supervision of the health authority. The exception to this rule is that a person from a yellow fever local infected area, not having a valid yellow fever immunization certificate, in transit to a receptive area where there are no means of segregation, may be prevented from travelling. A.34

38. Except for medical examination, health authorities may not repeat sanitary measures already applied at a previous airport, unless there is good evidence that such measures were inefficiently carried out, or unless since departure from the previous airport circumstances have arisen making repetition necessary. A.40

Surveillance

39. The health authority may place under surveillance any suspect arriving aboard an aircraft on an international voyage from an infected local area. (This is apart from the special regulations for the specific quarantinable diseases.) But a person is not to be classed as from an infected local area if aboard an aircraft which has flown over infected territory but has not landed therein, or has landed without the person disembarking, or has landed where there was a direct transit area or other suitable segregation arrangements and the person has not been outside them. A.39.43

40. Surveillance must not exceed the incubation period of the quarantinable disease concerned, as recognized by the regulations, The incubation periods are:— A.39

Cholera	5 days.
Yellow fever	6 days.
Smallpox	14 days.
Typhus	14 days.
Relapsing fever	8 days.

41. Health authorities may require persons placed under surveillance to report at specified intervals. Such a person may not be isolated and must be permitted free movement. He may A.27

be subjected to medical investigation (with the exception of rectal swabbing. Article 69). The person concerned must notify the health authority on departure to another place, in order that the information may be passed to the health authority at his destination, where surveillance may be resumed.

42. A transient under surveillance may not be prevented from continuing on an international voyage. The carriage of a passenger under surveillance must be recorded on the Aircraft General Declaration. A.30

Isolation

43. On arrival of an aircraft health authorities may remove and isolate an infected person. They must do so if requested by the captain. A.38

Immunization

44. Immunization requirements are described in the special regulations for each individual quarantinable disease (see para. 48 *et seq.*).

SANITARY MEASURES APPLICABLE TO GOODS AND BAGGAGE

45. Sanitary measures may not be applied to goods unless the health authority is satisfied that they are infected with or liable to spread a quarantinable disease. Other than live animals, goods in transit without transhipment are exempt from sanitary measures. (For the exception to this see para. 67 under Cholera.) A.46

46. Only the baggage of infected or suspect persons, or of a person carrying infective material or quarantinable disease insect vectors, may be disinfected or disinsected.

47. Mail, books, newspapers and printed material are exempt from sanitary measures, with the exception of postal parcels containing certain foods (see para. 67 under Cholera) or containing soiled linen, clothing, or other material to which special quarantinable disease measures are applicable. A.48

SPECIAL QUARANTINE AND SANITARY MEASURES

PLAGUE

General Provisions

48. Each State is bound to employ all possible means to prevent the spread of plague by rodents and their ectoparasites. Health administrations must collect and examine rodents and their ectoparasites systematically, in any local area, particularly airports, infected or suspected of infection by rodent plague. A.49-59

49. Every suspect, before departure on an international voyage from a local area where there is an epidemic of pulmonary plague, must be isolated for 6 days from last exposure to infection.

50. In exceptional epidemiological circumstances, any aircraft suspected of harbouring rodents may be deratted.

51. For the purpose of the regulations the incubation period of plague is 6 days.

Immunization

52. Vaccination against plague is not to be required as a condition of admission of any person to a territory.

Infected Aircraft

53. **Definition.** An aircraft is to be classed as infected if on arrival there is a case of human plague aboard or a plague-infected rodent is found on board.

(*Continued on page 413*)

54. Health authorities may apply the following measures on the arrival of an infected aircraft:—

(*a*) Any suspect may be disinsected and placed under surveillance. Surveillance may not last more than 6 days reckoned from date of arrival.

(*b*) The baggage of an infected or suspect person may be disinsected and if necessary disinfected.

(*c*) Any other article, such as used bedding or linen, and any contaminated part of the aircraft, may be disinsected and if necessary disinfected.

55. If a rodent, which has died of plague, is found on board, the aircraft must be deratted, if necessary in quarantine.

Suspected Aircraft

56. In terms of the regulations, no aircraft are classed as suspected of plague infection.

Healthy Aircraft

57. Even when coming from an infected local area, or having on board a person from such an area, an aircraft must be classified healthy, so long as it is not infected (see para. 53).

58. An infected aircraft is to be classed as healthy, and free pratique given, after any infected person has been removed from it and the sanitary measures described in para. 54 have been effectively carried out.

59. On the arrival of a healthy aircraft from an infected local area, health authorities may place under surveillance any suspect who disembarks. Surveillance may not last for more than 6 days reckoned from the date of departure from the infected local area.

CHOLERA

General Provisions

60. The incubation period for the purpose of these regulations is 5 days.

61. Only a person on an international voyage, arriving from an infected local area within the incubation period of cholera, and having symptoms of it, may be subjected to stool examination. No person shall be required to submit to rectal swabbing. A.60-69

Immunization

62. Health authorities must take into consideration the possession of a valid certificate of vaccination against cholera in applying the permitted quarantine and sanitary measures against cholera.

63. Any standard for cholera vaccines in force in the territory where the vaccination is performed must be accepted by all health administrations.

Infected Aircraft

64. **Definition.** An aircraft must be regarded as infected if on arrival there is a case of cholera aboard.

65. Health authorities may apply the following measures when an aircraft is infected:—

(*a*) Passengers and members of the crew having valid cholera vaccination certificates may be placed under surveillance for not more than 5 days reckoned from date of disembarkation.

(*b*) All persons in the aircraft without valid cholera vaccination certificates may be isolated on disembarkation for a like period.

(*c*) The baggage of an infected or suspect person may be disinfected.

(*d*) Any other article, such as used bedding or linen, and any contaminated part of the aircraft may be disinfected.

(*e*) Any water aboard the aircraft thought to be contaminated may be removed and the containers disinfected.

66. Excreta, waste water, waste matter, and any other possibly contaminated material, must be disinfected before being discharged or unloaded from the aircraft. The health authority is responsible for their safe disposal.

67. The health authority may prohibit the unloading of, or may remove, any fish, shellfish, fruit, vegetables to be consumed uncooked, or beverages, provided none is in a sealed container and the health authority has reason to suspect contamination. Arrangements for the safe disposal of any such items removed must be made.

68. Only the health authority at the airport where it is to be unloaded may order the removal of food or beverages carried as cargo in the aircraft freight compartment. But the aircraft captain has the right to demand their removal at any airport.

Suspected Aircraft

69. An aircraft must be regarded as suspected if a case of cholera has occurred aboard during the voyage but has previously been disembarked.

70. Health authorities may apply the following measures when an aircraft is suspected:—

(*a*) Any passenger or member of the crew may be placed under surveillance for not more than 5 days reckoned from the date of arrival.

(*b*) Any person on a suspected aircraft arriving on an international voyage from a cholera infected local area, within the incubation period, and having a valid cholera vaccination certificate, may be placed under surveillance for 5 days reckoned from departure from the infected local area.

(*c*) Any such person having no valid cholera vaccination certificate may be isolated for a like period.

(*d*) The measures described in paras. 65(*c*), (*d*) and (*e*), 66, 67 and 68 may also be applied.

Healthy Aircraft

71. If the health authority is satisfied on medical examination that no case of cholera has occurred on board during the voyage, the aircraft must be regarded as healthy even though from an infected local area or having on board a person from such an area.

72. An infected or suspected aircraft is to be classed as healthy and free pratique granted as soon as any infected persons have been removed from it and the prescribed sanitary measures have been effectively carried out.

73. If a healthy aircraft has arrived from an infected local area, the measures described in para. 70 (*b*) and (*c*) may be applied to passengers or crew disembarking.

YELLOW FEVER

A.70-81

General Provisions

74. For the purpose of these regulations the incubation period of yellow fever is 6 days.

75. Every aircraft leaving an airport in an infected local area, and bound for a yellow fever receptive area, must be disinsected under the supervision of the health authority, as near as possible to the time of its departure. This also applies to aircraft, leaving a local area where *Aëdes aegypti* exist, bound for a yellow fever receptive area already freed from this insect.

Immunization

76. Any person leaving an infected local area on an international voyage to a receptive area must be vaccinated against yellow fever. He may be permitted to leave after vaccination even though his certificate is not yet valid.

77. Every person working on an airport in an infected local area, and every member of the crew of an aircraft using any such airport, must be in possession of valid yellow fever vaccination certificates.

78. A person with a valid yellow fever vaccination certificate must not be treated as a suspect, even if he has come from an infected local area. A person from such an area, on an international voyage, unable to produce a valid certificate, may be isolated by the health authority until it has become valid, or for 6 days reckoned from the last possible exposure to infection.

79. A person from an infected local area, having no valid yellow fever vaccination certificate, due to proceed on an international voyage to a yellow fever receptive area where there are no segregation facilities, may be prevented from leaving an airport which has segregation facilities. This will occur only when a specific agreement exists for the implementation of the regulation between the health administration of the territories concerned.

Infected Aircraft

80. **Definition.** On arrival an aircraft must be classed as infected if it has a case of yellow fever aboard.

81. Health authorities may apply the following measures when an aircraft is infected:—

(*a*) Any passenger or member of the crew disembarking in a yellow fever receptive area, without being in possession of a valid yellow fever vaccination certificate, may be isolated until the certificate becomes valid or for not more than 6 days, reckoned from date of last possible exposure to infection.

(*b*) The aircraft may be inspected and any *Aëdes aegypti* on board destroyed.

Suspected Aircraft

82. **Definition.** An aircraft must be regarded as suspected if the health authority is not satisfied with a disinsecting carried out as provided for in para. 75, and live mosquitoes are found aboard.

83. The measures that health authorities may apply when an aircraft is suspected are the same as when an aircraft is infected (see para. 81).

Healthy Aircraft

84. Any aircraft that does not fall within the definition of infected or suspected must be regarded as healthy.

85. An infected or suspected aircraft must be regarded as healthy and granted free pratique as soon as any infected person has been removed and the measures described in para. 81 have been applied.

86. When a healthy aircraft arrives from an infected local area the measures described in para. 81 (*b*) may be applied before free pratique is granted.

SMALLPOX A.82-87

General Provisions

87. For the purposes of the regulations the incubation period of smallpox is 14 days.

Immunization

88. A health administration may require any person on an international voyage, not showing sufficient evidence of protection by a previous attack of smallpox, to have a valid smallpox vaccination certificate.

89. Any such person, not having a valid certificate, may be vaccinated. Refusal of vaccination may be followed by surveillance for not more than 14 days, reckoned from departure from territory last visited before arrival.

90. A person, on an international voyage, who during a period of 14 days before arrival has visited an infected local area, may be considered to be insufficiently protected by vaccination or by a previous attack of smallpox. (A valid smallpox vaccination certificate is evidence of sufficient protection.) Such a person may be offered vaccination, or may be placed under surveillance, or may be vaccinated and placed under surveillance. If he refuses vaccination he may be isolated. Surveillance or isolation must not exceed 14 days, reckoned from departure from the local infected area.

Infected Aircraft

91. **Definition.** An aircraft must be regarded as infected if, on arrival, it has a case of smallpox on board, or if such a case has occurred on board during the voyage.

92. Health authorities must apply the following measures when an aircraft is infected:—

(*a*) Offer vaccination to any person aboard considered insufficiently protected against smallpox.

(*b*) Disinfect any baggage of an infected person, any other baggage or article, such as used bedding or linen, or any contaminated part of the aircraft.

93. The health authority may, under the same circumstances, for a period of not more than 14 days, reckoned from last exposure to infection, isolate or place under surveillance any person disembarking. Health authorities are, however, to take into account the person's previous vaccinations and the likelihood of infection when prescribing the period of isolation or surveillance.

Suspected Aircraft

94. So far as these regulations are concerned the term suspected aircraft is not used relative to smallpox.

Healthy Aircraft

95. Any aircraft, other than an infected one, is to be classed as healthy, even though there are suspects on board. On arrival a healthy aircraft is to be given free pratique, whether or not it has arrived from an infected local area.

96. An infected aircraft must be regarded as healthy and given free pratique, as soon as infected persons have been removed and the measures prescribed in para. 92 have been effectively carried out.

97. Suspects arriving aboard a healthy aircraft may on disembarking be subjected to the measures described in paras. 92 and 93.

TYPHUS A.88-92

General Provisions

98. For the purpose of these regulations the incubation period of typhus is 14 days.

99. On departure from an infected local area on an international voyage, any person considered to be liable to spread typhus must be disinsected by the health authority. The person's clothing, baggage, and any other possession likely to spread typhus, must be similarly disinsected and if necessary disinfected.

100. Any person on an international voyage, who has left an infected local area within the previous 14 days, may be disinsected on arrival and put under surveillance for not more than 14 days, reckoned from the date of disinsecting. His clothes, baggage, and any other possession likely to spread typhus, may be similarly disinsected and if necessary disinfected.

Immunization

101. Vaccination against typhus is not a permissible requirement as a condition of admission of any person to a territory.

Aircraft

102. On arrival all aircraft must be regarded as healthy, even if there is an infected person aboard. But before free pratique is granted, any suspect may be disinsected, and the accommodation occupied by the infected person and by any suspect, together with their clothes, baggage, and any other possession liable to spread typhus, may be disinsected and if necessary disinfected.

RELAPSING FEVER A.93-94

General Provisions

103. For the purpose of these regulations the incubation period of relapsing fever is 8 days.

104. Other than that the period of surveillance must not be more than 8 days, the regulations for relapsing fever are identical with those for typhus.

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CONFIDENCE INTERVAL FOR THE AËDES AEGYPTI INDEX OF ONE PER CENT IN RELATION TO SIZE OF LOCALITY AND SAMPLE (95 PER CENT. PROBABILITY LEVEL)

Number of houses		Confidence interval
Locality	Sample	
700	500	0.7 to 1.7%
1,000	700	0.7 to 1.5%
1,500	1,000	0.7 to 1.5%
2,000	1,000	0.7 to 1.6%
Over 2,000	1,500	0.6 to 1.6%

NOTE. 1. If it is not practicable to examine all the houses in an area, examination should be made of a random sample of a size not less than that indicated in the table above.

2. A minimum of two inspections should be carried out; any additional inspection would increase the validity of the results.

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