United Services Section

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Preventive Medicine in Relation to Aviation

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Schutz der Besatzung gegen die durch das Fliegen bedingte Krankheiten.

(*a*) Sehvermögen—Blendung, Ermüdung der Augen beim Nacht—und Blindfliegen, Schwarzsehen, Nachtblindheit.

(*b*) Gehörsinn—Lärm, Luft-Telephonie, Mittelohrtaubheit und übermässige Vestibularreizung.

(*c*) Atmung—Sauerstoffmange.

(*d*) Ermüdung.

(*e*) Verdauung—Magenaufblähung, Luftkrankheit, Rationen für lange Reisen, Wasservorrat.

AVIATION has progressed to a remarkable degree during the last decade, and more especially in the past three years, when this country, like many others, has become air-minded and record after record has been broken. In 1935, when King George V reviewed his Air Force at Duxford, on the occasion of his Jubilee, the expression that there was " a lot of sky " was common. Now, the picture is entirely changed : aeroplanes are to be seen daily ; there are over 200 Service and civil aerodromes, excluding privately owned ones, in England alone, and all types of aircraft have been greatly improved as regards carrying-power, comfort, speed, and range of flight. To-day Service machines travel at speeds varying between 180 to 350 miles an hour and have flown non-stop for 7,162 miles ; and the new air-liners of Imperial Airways have a top speed of 250 miles an hour and cruise at 200 miles an hour while carrying 40 passengers plus cargo. Many aeroplanes leave this country daily for foreign parts, and air-routes to various parts of the Empire have been opened and speeded up. The popularity of flying and the air-mindedness of the nation have been shown by the King's visits by aeroplane to R.A.F. stations ; the recent holiday trip of the Duke and Duchess of Gloucester to East Africa ; the historic journeying by Mr. Chamberlain to and from Germany during the recent crisis, when time was most important ; the flights of Cabinet Ministers and other high officials to outposts of Empire to help settle some difficult problem by personal contact ; and the wide use of air travel by business men for financial gain, and by Service men to obtain the maximum number of days' leave at home.

This development of aviation is not an unmixed blessing for, though it has greatly

increased the rapidity of transport between one country and another, and between continents—and so has brought various parts of the world closer together as regards time—it is a most deadly implement of war and there is the added danger of aircraft conveying infectious diseases, either by means of passengers or insects. This danger was foreseen several years ago by the health authorities in many countries, with the result that the International Sanitary Convention for Aerial Navigation was drawn up at the Hague, in April 1933, and has since been ratified by practically all countries in the world.

In this paper it is proposed to deal with preventive medicine, as far as it affects aviation, under two main headings :—

I.—The protection of communities against diseases liable to be imported by aircraft.

II.—The protection of flying personnel against diseases due to flying.

I.—The Protection of Communities against Diseases Liable to be Imported by Aircraft

The safeguarding of the masses against infection is of greater importance in public health administration than that of the individual, and it is justifiable, therefore, to consider this matter first. Journeys by air, from countries where the major infectious diseases (cholera, plague, smallpox, typhus, and yellow fever) are endemic to non-infected yet susceptible countries, are so rapid that they are usually completed well within the incubation periods of these diseases. This was pointed out by Air Commodore D. Munro (1925), and Massey (1933), and Table I demonstrates that the danger of importing these diseases to various countries by air is considerable unless adequate protective measures are undertaken by all concerned.

Table I.—Showing the Relationship Between the Incubation Periods for the Major Infectious Diseases and the Time Taken to Complete the Journey by Air Between Endemic Zones and the United Kingdom.

Disease	Incubation period (days)	Endemic area	Time taken to complete journey by air from endemic area to U.K. (days)
Cholera	2–5	India	4–5
		Iraq	2–3
Plague	2–6	India	4–5
		Iraq	2–3
		East Africa	4
		West Africa	3–5
		South America	4–5
Smallpox	10–14	India	4–5
		Iraq	2–3
Typhus	5–12	Central Europe	2
		Russia	2
Yellow fever	3–6	West Africa	3–5
		South America	4–5

The administrative machinery for the health control of air-traffic is based on the International Sanitary Convention for Aerial Navigation, 1933, which specifies the maximum measures that may be imposed for this purpose, but leaves their actual application to each country concerned, the general aim being to make the necessary regulations as uniform as possible to lessen inconvenience to passengers and to cause the minimum of delay to air transport, otherwise the main object of such mode of travel would be defeated. The Office International d'Hygiène Publique, in Paris, through its Air Navigation Quarantine Commission, deals with the application of the Convention and continually keeps matters concerning the sanitary control of aircraft under review, from an international aspect, while through its delegates it maintains a close touch with the various governments who have ratified the Convention ; it is,

in fact, an international health-controlling bureau with the power to draft international agreements. The Health Organization of the League of Nations, on the other hand, provides an international intelligence service which promptly informs the health authorities throughout the world of the incidence of infectious diseases at various ports and airports. This epidemiological information is passed on weekly to the appropriate medical officers of health of each country by the health department of the government concerned, so that they are in possession of up-to-date particulars regarding infectious diseases and epidemics, occurring both at home and abroad. Thus, in the United Kingdom, this information is published and distributed by the Ministry of Health weekly through the agency of their " Weekly Record of Infectious Diseases at Ports, &c. " and by means of notices in the *London Gazette*. From this information medical officers of health of areas containing customs aerodromes furnish the appropriate customs officer and person in charge of each aerodrome with a written list of infected places. In addition, each government has drawn up its own regulations regarding the sanitary control of aviation, and in this connexion the Public Health (Aircraft) Regulations, 1938, issued by the Ministry of Health, are designed to prevent the introduction of infectious diseases from abroad into the United Kingdom by aircraft, and are applicable to all aerodromes officially recognized for customs purposes for the arrival and departure of all foreign-going aircraft, which are not permitted to land elsewhere. In the case of a forced landing of an aircraft entering the country from abroad, the commander must notify the local authority, or customs or police officer, as soon as possible, and the crew, passengers and cargo must not leave or be removed from the vicinity of the landing-place until permitted to do so by the local authority ; then the aircraft, if infected or arriving from an infected area, should proceed to a sanitary aerodrome : if the aircraft is unable to proceed, the passengers and crew may be allowed to continue their journey by other means, provided that they have given their names and addresses of intended destination to the local authority, who forwards the information to the local authority of the intended destination in each instance.

Prior to dealing with the actual working of the International Sanitary Convention for Aerial Navigation, it is convenient to consider the various types of authorized aerodrome. Aerodromes, on which aircraft legally may make their first landing on entering a country, or from which they may depart, are collectively termed " *authorized aerodromes* ", and include customs, sanitary and anti-amaryl aerodromes, as well as certain local areas (*see* Diagram I).

(i) *A customs aerodrome* must have an appointed medical officer, on call as required, in addition to a customs officer. There must be a well-lighted room for medical inspections, together with a room for the temporary isolation of infectious cases, and separate lavatories for the two sexes. An assistant health officer or local facilities for disinfection and deratization are not necessities.

(ii) *A sanitary aerodrome* takes the health control a step further, as, in addition to the requirements of a customs aerodrome, there must be an organized medical service with one or more sanitary inspectors to supervise such duties as disinfection ; equipment for taking and despatching material for laboratory examination, if the examination cannot be done on the aerodrome ; facilities nearby for the isolation, transport, and care of infectious cases, as well as for the isolation of contacts, separately ; apparatus for carrying out disinfection, disinsection and deratization ; and an adequate supply of good drinking water, and safe disposal of excreta, refuse, and waste water. In addition, the aerodrome must be protected against rats.

(iii) A sanitary aerodrome may be designated a " *local area* " if it is so sited as to be beyond all probable risk of contamination from without ; in addition, no one must enter or leave such an aerodrome except with the permission of the competent authority. If cholera, plague, smallpox, typhus, or yellow fever is present in the surrounding district, then, except for persons working on the aerodrome, no one is permitted to enter except by air.

(iv) In districts where yellow fever exists, either clinically or as proved by mouse-protection tests, preventive measures are taken still a step further, as an *anti-amaryl aerodrome* must, in addition

to conforming to the requirements of a sanitary aerodrome in a local area, be situated at least a mile to the windward of habitations, especially those of natives ; it must be kept free from yellow-fever-carrying mosquitoes, and provided with mosquito-proofed quarters for aerodrome staff, aeroplane crew and passengers ; quarters for the last-named must be separate, as passengers may require surveillance for a period up to six days before embarkation to ensure freedom from yellow fever.

Authorized Aerodromes

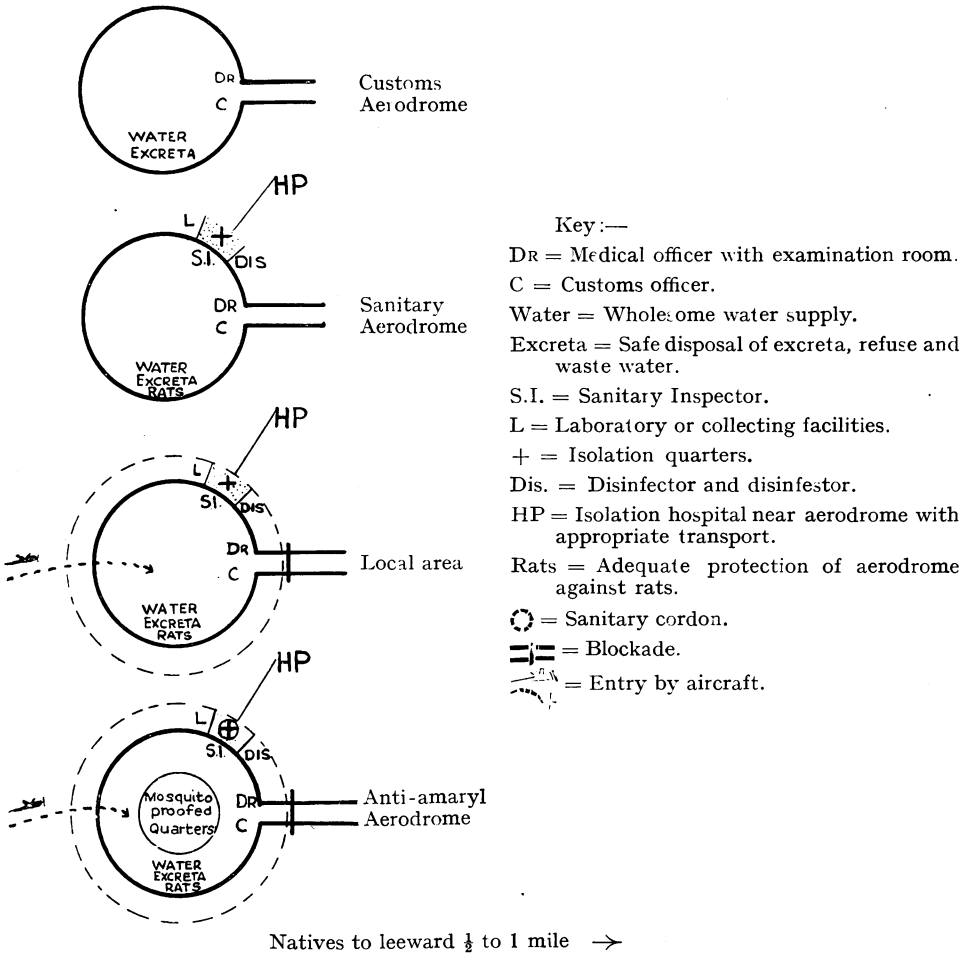

DIAGRAM I.—Diagrammatic representation of various types of authorized aerodromes : there is a gradual transition from one to the other in the order—customs aerodrome, sanitary aerodrome, local area, and anti-amaryl aerodrome.

THE SANITARY CONTROL OF AERODROMES

In the case of aircraft arriving from abroad, if a death other than an accident occurs, or if there is a case or suspected case of infectious disease (other than tuberculosis or venereal disease) on board, the commander of the craft must notify the aerodrome medical officer or customs officer, preferably by wireless before arrival : if the person in charge of the aerodrome gets this information first, he must notify the medical officer and customs officer immediately.

Infected aircraft or those coming from places infected with cholera, plague, smallpox, typhus, or yellow fever, or those with rodents dying aboard, must not discharge passengers, crew, or cargo until after the medical officer has inspected them and declared them free from infection. The usual procedure is to isolate in hospital persons showing definite evidence of infection, while the contacts may be liberated (depending on the disease and the locality) after giving their names and addresses of destination, so that the appropriate local authorities are able to keep the contacts under surveillance during the incubation period of the disease. The customs officer is usually the first person to visit an aircraft on arrival and, if it is infected or suspect, he orders its detention and forthwith notifies the medical officer and the person in charge of the aerodrome of the fact. If the medical officer does not inspect an aircraft within three hours it is free to leave, and, should he not consider it necessary to inspect any aircraft and passengers, he may give a liberation certificate in writing to the customs officer concerned. It should be noted that no mail can be detained, disinfected, or destroyed, except packages containing fish, shell-fish, fruit, or vegetables coming from a cholera-infected area.

In brief, the sanitary control of arriving aircraft is along the following lines :—

(i) Medical inspection of passengers and crew ;

(ii) Isolation in hospital of infectious cases, other than tuberculosis or venereal disease ;

(iii) Surveillance of contacts, usually at home, during the incubation period of the disease, after de-lousing in the case of typhus contacts, and ridding of fleas of plague contacts ; adequate vaccination against smallpox or inoculation against cholera or yellow fever exempts from isolation ;

(iv) Disinfection of aircraft and infected articles in cases of cholera, plague, smallpox, and typhus ;

(v) Disinfestation of aircraft and personal belongings in cases of plague and typhus ;

(vi) Disinsection of aircraft in the tropics and subtropics to prevent yellow fever, dengue, and malaria-infected mosquitoes from being introduced into the country ;

(vii) Deratization of aircraft in case of plague or death of rodents on the voyage ;

(viii) Proper disposal of excreta on arrival, as it is forbidden to discharge excreta from the air, except over the open sea ;

(ix) The provision of a safe drinking-water supply, protected against mosquito breeding and, in the case of cholera, the water stored on board the aircraft must be disinfected and emptied out, then the tanks must be further disinfected before filling with wholesome drinking water ;

(x) Prohibition of the unlading of fresh fish, shell-fish, fruit, and vegetables, if there is a case of cholera on board or if the aircraft has come from a cholera-infested area.

As regards departing aircraft, passengers and crew are medically examined, if necessary, especially in areas where cholera, plague, smallpox, typhus, and yellow fever are prevalent. The aerodrome medical officer may prevent any person, who shows evidence of suffering from an infectious disease, from travelling by aircraft. He may also stop the embarkation of close contacts of any of the infectious diseases mentioned above, unless such contacts have been successfully vaccinated against smallpox within three years, or inoculated against cholera recently or against yellow fever within two years,[1] and, in the case of typhus, disinfested if necessary. In addition, he must ensure that no infected bedding, clothing, or articles, are taken on board, and that the aircraft itself is free from infection, e.g. freed of rats in a plague area or disinsected in a yellow-fever zone.

This leads to a consideration of the *journey log-book*, which all aircraft engaged on international flights must carry, and in which public health matters concerning aircraft and passengers must be entered. Such entries should include any sanitary action

[1] No definite period is stated for yellow fever, but the yellow-fever antibody content of the blood of those inoculated with virus vaccine is considered to be sufficiently high at the end of two years to ensure immunity in the majority of instances.

taken in regard to the aircraft at the port of departure or at places of call *en route*, as well as any health items that occur on the voyage, such as the presence in the aircraft of any person who requires surveillance. To facilitate the medical examination at the aerodrome of arrival an entry must be made if cholera, plague, smallpox, typhus, or yellow fever, has occurred in the area of departure within fifteen days; in certain countries, especially in the yellow-fever zones of the Americas, a "Certificate of origin of passengers" is demanded as an additional aid.

One hiatus in the International Sanitary Convention for Aerial Navigation is the fact that it does not apply to Service aircraft of any nation. Thus, as far as we are concerned, unless the Royal Air Force falls into line with the principles and spirit of this Convention, preventable disease may be spread by air to civilians and Service personnel alike, especially by aircraft moving from one command to another in tropical and subtropical countries. The matter is now under consideration at the Air Ministry and appropriate Service regulations will shortly be issued.

Yellow Fever and Aviation

Yellow fever merits a section to itself, for special precautions have to be taken against this disease, as the mosquito vector (*Aëdes ægypti*) is so prevalent throughout the tropics and subtropics that, if the disease were introduced by means of a human case or by infected mosquitoes, a severe epidemic would result, especially as the infection would occur among highly susceptible peoples. In fact, the fear of this dread disease spreading to India by air traffic within the incubation period is so great that the Government of India has taken additional precautions to those laid down in the International Sanitary Convention for Aerial Navigation. Thus, passengers by aircraft from yellow-fever or suspected yellow-fever areas in Africa, are not permitted to enter India until nine days have elapsed since their departure from the affected area, and aircraft are not permitted to fly direct to India from such an area unless in possession of a certificate issued by the Egyptian Quarantine Board stating that the aircraft has been adequately disinsected. In common with the Dutch East Indies and the Sudan, India has prohibited the importation of yellow-fever virus, even for research purposes. As a further safeguard, India, Iraq, and Egypt, have mutually agreed to inform each other by telegram of any air-passenger coming from a dangerous area, while India further demands that a wireless message, stating the health condition of the aircraft, be sent to Karachi two hours before arrival.

That there has already been a recent spread of yellow fever from the endemic zones in West Africa eastwards is strongly suggested by Findlay's (1938) findings in the Malakal district of the Southern Sudan, for in 1933 only 1% of the population tested gave a positive yellow-fever response to the mouse-protection test, compared with 21% positive in 1938. As *Aëdes ægypti* is present in this district, it is assumed that the infection is of the urban and not the jungle type. Recently, there was a fatal case of yellow fever in a European, at Kouy, in the Sudan. It is evident, therefore, that yellow fever is occurring as far east as the Anglo-Egyptian Sudan, without classical symptoms, and only awaits suitable soil and exaltation of virus to produce a severe epidemic. Though this spread of yellow fever coincides with the opening up of the air-routes from West Africa to the Sudan, it cannot be affirmed that this has been the mode of spread of the infection, as motor traffic has also greatly developed at the same time, and anti-yellow-fever measures are more easily enforced in the case of aircraft than with motor-car traffic.

Nowadays, air-travel is so rapid that an aeroplane departing from the yellow-fever zones of West Africa reaches the Sudan in two days, Mozambique in four days, Durban in five days and, by another route, Karachi in five and Calcutta in six days, respectively; all these places are heavily infected with Aëdes. There is, therefore, great danger of yellow fever being spread by air-passengers incubating the disease

or by infected mosquitoes in the aircraft, unless special precautions are taken. Anti-yellow fever precautions are carried out on the following lines :—

(i) The provision of anti-amaryl aerodromes ;
(ii) A campaign against *Aëdes ægypti* ;
(iii) Control or isolation of intended air-passengers in yellow-fever areas before embarkation ;
(iv) Change of aircraft during journey to prevent direct transport of insects infected with yellow fever ;
(v) Destruction of mosquitoes in aircraft ;
(vi) Protective inoculation.

(i) It is desired to create *anti-amaryl aerodromes* in all yellow-fever and suspected yellow-fever districts ; such aerodromes have been established at Kano and Malakal : Khartoum, being a junction and clearing place for air traffic, is also an anti-amaryl aerodrome, though not situated in a yellow-fever district.

(ii) A *campaign of destruction* has been instituted against *Aëdes ægypti* and other yellow-fever species, especially in anti-amaryl aerodromes and their vicinity. Since this campaign began the *Aëdes ægypti* indices in many places along the air routes of Africa have markedly declined, especially in West Africa.

(iii) Intending passengers may be required by health authorities to go into *isolation*, if necessary, for six days before embarkation. In Nigeria, seven days' notice of proposed flight is demanded, so that it can be decided whether quarantine in a mosquito-proofed hut is necessary before embarkation.

(iv) A *change of aircraft* during journeys lessens the risk of missed, infected insects being transported beyond a certain point. Land 'planes operate between West Africa and Khartoum : here, other 'planes complete the journey to East or South Africa, or to Egypt, where another change is made at Alexandria before travelling on to India.

(v) The *destruction of mosquitoes in aircraft* has occupied the attention of many public health experts and aircraft constructors in various countries during recent years. Difficulties as regards the type of sprayer and insecticide to be used have had to be overcome. First, the ordinary " Flit " gun was used but proved of little practical value, as the spray produced was neither sufficiently fine nor penetrating. Pressure sprayers, driven by petrol engine or electric motor, were found suitable for aerodrome work but were too heavy and cumbersome for use actually during flight, which is the ideal method of disinfesting aircraft as it ensures destruction of insects before landing, as well as saving valuable time : disinfestation should be done just before or after taking-off and again from a quarter to half an hour before landing.

Park Ross, of South Africa, suggested building tracheal ducts into aircraft so that insecticide could be diffused through all internal compartments, but this idea was rejected, mainly on account of the great increase of weight involved. His visit to England in 1937, in connexion with this matter, however, brought to light the Larmouth carbon dioxide sparklet method of diffusing insecticides under pressure in the form of a very fine spray, which could penetrate all corners of the compartment treated, even behind curtains ; this result is attained by the pressure of carbon dioxide liberated by a sparklet bulb forcing the insecticide from a 50-c.c. metal container through fine copper tubing to jets in the compartment requiring to be treated. This year, an equally effective apparatus, the Phantomyst Nebulizer (made by André (Components) Ltd.) has been used for disinfesting aircraft ; by means of this apparatus, which weighs only 17 lb. and can be easily transported from one compartment to another, a dry and penetrating mist is formed by compressed air forcing the insecticide through fine jets to atomize it, then on to high-speed rotors, where it is pulverized ; the machine is calibrated to disperse 1 c.c. of insecticide a minute, and ten to fifteen minutes' action is required for a compartment of about 500 cubic feet. The sparklet ejector apparatus and the Phantomyst have been widely

experimented with by Imperial Airways, and for this purpose were fitted to their flying-boats *Cassiopeia* and *Cambria* on the Southampton-Durban run ; the results have been most satisfactory. A full report of these researches has been published recently by Mackie and Crabtree (1938), who stressed the necessity of placing the disinfesting apparatus in different positions in the compartments, depending on the normal continuous but slow flow of air currents from behind-forward in the aircraft, due to aerodynamic forces exerted on the outside of the machine. In flying-boats the sparklet ejector apparatus has been found most suitable for freight compartments and the Phantomyst Nebulizer most suitable for passenger compartments.

The choice of suitable insecticides for aircraft work is of prime importance for, as Mackie (1938) states, it should be :—

(*a*) Highly toxic to insects ; (*b*) innocuous to passengers ; (*c*) non-inflammable ; (*d*) non-corrosive and non-staining ; (*e*) stable in all climates and readily miscible with water.

Therefore, " Deskito ", which is a water-soluble pyrethrum concentrate, requiring to be diluted 10 to 14 times its volume with water immediately before use, has been adopted by Imperial Airways : the dosages which have been found essential (acting for ten minutes) to kill all mosquitoes in aircraft are from 50 to 150 c.c. of 1 : 14 Deskito per 1,000 cubic feet of space for the ejector apparatus, depending on the parts of the aircraft to be treated, and 30 c.c. of 1 : 10 Deskito per 1,000 cubic feet for the Phantomyst Nebulizer. Professor J. W. Munro recommends a 1 : 30 dilution of Deskito in water, using 150 c.c. for each 1,000 cubic feet of space to be treated and allowing the insecticide to act for fifteen minutes.

Pyrocide 20 is another very effective insecticide and is used widely in America, Egypt, and India, but as it contains a paraffin base, which with repeated application gradually saturates the walls and furniture of the aircraft, it so increases the risk of fire that it is considered inadvisable to use it.

Recent investigations by the Pan-American Airways, reported on by Cumming (1938), suggest that the present method of disinfesting the interior of aircraft is inadequate, as infected mosquitoes and other insects can find safe harbourage in the space between the outer and inner linings of the aircraft, or in the hollow wings, and can thus be transported to other aerodromes or forced landing grounds. In addition, he states that the exterior of the aircraft offers many hiding places for mosquitoes and instances the space which accommodates the retracted under-carriage, various grooves in the structure, and innumerable rivet holes. It is felt, however, that air currents during flight will dislodge most of these insects, but should later experience confirm Cumming's views, steps will require to be taken to disinfest these remote spaces and crannies.

As regards the prevalence of insects in the cabins of aircraft, the incidence varies with the site of the aerodrome, especially whether it is on land or water, and, in the latter case, the distance from the shore ; flying-boats usually moor well out at a floating pontoon. C. B. Symes found that of 52 aircraft arriving at Kisumu from the north, approximately 50% harboured insects, including culicine and anopheline mosquitoes, muscidæ, tabanidæ, and chironomidæ ; the insect population in these aircraft would doubtless have been far greater, but for the antimosquito measures practised at aerodromes. From Kisumu south to Durban, the local authorities have taken the additional precaution of trying to limit the entrance and exit of insects by hanging overlapping curtains, impregnated with para-di-chlor-benzine, over the doorway of aircraft. It would appear advisable to fit these curtains on all aircraft travelling over yellow-fever districts, especially in view of the possibility of such aircraft using re-fuelling aerodromes, which are mere clearings in the jungle, placed a reasonable distance from human habitations and supposed to be kept Aëdes-free. Incidentally, passengers are not permitted to embark at re-fuelling aerodromes without a special health certificate from the local medical officer of health.

(vi) *Protective inoculation with virus vaccine* has proved a most valuable preventive medicine measure against infection with yellow fever; protection begins about a week after inoculation and is fully developed in 90% of cases within three weeks, persists apparently for about two years, and is equally effective against urban and jungle types of the disease. Prior to 1937, the virus was given in conjunction with hyper-immune human serum with the result that, in about 3% of cases, infective hepatitis occurred three to four months after inoculation; at times the incidence was higher; thus, in Egypt, of 54 R.A.F. personnel inoculated against yellow fever with immune human serum plus attenuated viscerotropic virus, 7 men (i.e. 13%) developed jaundice three to four months later, whereas jaundice did not occur in any of the 996 R.A.F. personnel living under identical conditions, but not given this inoculation: the blood-sera of the jaundice cases following inoculation were tested and found to be free from yellow-fever-immune bodies in every instance. During the past fifteen months, however, an attenuated pantropic virus grown on chick embryo minus its central nervous system has been used; this virus has lost much of its viscerotropic and neurotropic properties, yet it produces a high degree of immunity to yellow fever; already 3,500 injections of it have been given in this country to people proceeding abroad and over 800,000 in Brazil, without the occurrence of a single case of jaundice. The assumption is, therefore, that the delayed hepatitis, which occurred previously after inoculation with certain batches of yellow-fever virus plus human immune serum, was due to the virus of infective hepatitis being present in some batches of human sera, analogous to the hepatitis, at times fatal, which has followed inoculation with measles and encephalitis-immune sera (Findlay and MacCallum (1937) and Propert (1938)). This defect has now been overcome by using only sufficient human serum to suspend the virus, that is 0·25 c.c. at each inoculation instead of about 30 c.c. as previously. The protective power of this virus inoculation is manifested by the fact that there has not been a case of yellow fever among 5,700 Britishers so inoculated before going to yellow-fever zones, whereas during this period there have been 40 cases of yellow fever among Britishers who were not immunized; moreover, nowadays, yellow fever does not occur among research workers in this field, though before the introduction of protective inoculation many distinguished workers, including Noguchi, Stokes, and Young, contracted the disease and died.

It is a wise precaution, therefore, for all those who intend to travel by air through yellow-fever districts to be inoculated with attenuated pantropic virus, to give them protection against infection and to facilitate their journey, as those so protected are not held up in quarantine.

The practical points concerning anti-yellow-fever inoculation are:—

(*a*) The virus is issued solidified in ampoules, which should be kept in a refrigerator or on ice at about 4° C.;

(*b*) When required for use, 1 c.c. of cold sterile water is added to the ampoule to dissolve the virus; the solution is complete in one minute;

(*c*) The inoculation needle must be cool and free of alcohol, otherwise the virus may be killed;

(*d*) The inoculation is given in the deltoid region at least fourteen days before the expected date of arrival in a yellow-fever zone;

(*e*) There may be a slight reaction about a week after the inoculation, the symptoms being headache, backache, lassitude, and low pyrexia (99° F.), which disappear in twenty-four hours and may be relieved with aspirin; there are no ill-effects such as jaundice;

(*f*) A certificate of inoculation should be given in each instance, as it may be required by the passenger on the journey;

(*g*) It is advisable to be reinoculated after a period of two years, if further exposure to infection is likely;

(*h*) In Aëdes-infected districts a mosquito-proof net may be kept around an inoculated person for three days after the inoculation, as the virus may be circulating in the blood, but this precaution is not essential as the amount of circulating virus is so minute and the virus itself so attenuated that it is unlikely to infect *Aëdes ægypti*;

(*i*) Persons performing inoculations should be immunized.

II.—The Protection of Flying Personnel against Diseases due to Flying

The safe piloting of aircraft under all conditions of weather, especially while landing and taking-off and during the performance of aerobatics at high speed, necessitates that pilots should possess a high degree of physical fitness. In the Service all flying personnel—pilots, observers, air-gunners, photographers, and wireless operators—should be alert in body and mind, with good muscle tone and quick reaction time, and should possess as well accurate vision and a good sense of balance. For these reasons, there is a continual endeavour on the part of the medical branch, working in close co-operation with aircraft constructors and various research workers, to improve any conditions of flying, whether connected with the aeroplane, flying equipment or man himself, which are proving detrimental to the well-being and efficiency of the personnel. In this connexion there have been many problems to solve concerning glare, ocular fatigue, blacking-out, noise, excessive vestibular stimulation, oxygen want, mental and physical fatigue, and air-sickness.

Vision

As regards affections of the eyes due to flying, the problems of counteracting glare, the ocular fatigue of night and blind flying, and blacking-out, arise.

Glare is specially liable to affect the eyes of aviators, when engaged in flying over clouds, desert, or water, also when flying towards the sun or when looking towards the sun in aerial warfare, real or mimic. Wing Commander P. C. Livingston, from 1930 to 1938, has done much valuable research on glare and its prevention, and, as a result, has been mainly responsible for the design and perfection of the present-day flying goggles and glasses, which give a full field of vision both in front and laterally as well as permitting binocular vision while landing—these were defects in previous designs. These goggles have been specially designed to fit and remain fixed at any speed to the flying helmet complete with oxygen mask, and to allow of immediate and easy adjustment to any desired position, as well as any width of nose. They are so constructed that triplex glass filters of various tints, appropriate for day or night flying, or suitable lenses for visual correction, can be instantaneously slipped in as required while flying. In addition, there is a dark visor which can be tilted into position in front of the goggles to enable the pilot to fly, or the air-gunner to take aim, if necessary, direct towards the sun with the minimum of glare effect. The antiglare value of these flying glasses has been highly spoken of by members of the long-distance flights in Vickers-Wellesley bombers, which took place to Egypt, via the Persian Gulf, early this year, and to Australia on last month's record-breaking flight. Recently, glasses have been made containing spluttered platinum or aluminium which, by their high refractive power, materially decrease glare and heat from the sun and at the same time give improved visual definition.

Ocular fatigue occurs during night or blind flying and is due to the rapid to-and-fro movements of the eyes while observing the various instruments on the illuminated instrument board. This has been overcome by a practical placing and grouping of instruments so that those most frequently looked at are concentrated in the line of vision. In addition, a weak plus lens is provided for insertion in the flying goggles or glasses for magnifying purposes, and any individual refraction errors are corrected.

Blacking-out.—Another problem which concerns both ophthalmologist and physiologist is that of *blacking-out*, a condition first encountered by aviators during the period of training for the Schneider Trophy race in 1929, at the time when aeroplanes had developed sufficient speed to produce centrifugal forces greater than 4 ' g ' while performing sharp turns. It also occurs when an aeroplane is being pulled out from a steep dive at high speed ; the sharper the turn, provided the speed is kept constant, the greater is the centrifugal force and its effect on the human body. The onset of blacking-out is sudden, but it does not occur immediately an excess over 4 ' g ' is applied, as there is a period of delay lasting a variable number of seconds,

depending on such factors as the amount of ' g ' applied, the general physical and vasomotor tone of the person concerned, and the anticipation of or unpreparedness for the manœuvre performed (*see* Diagram II).

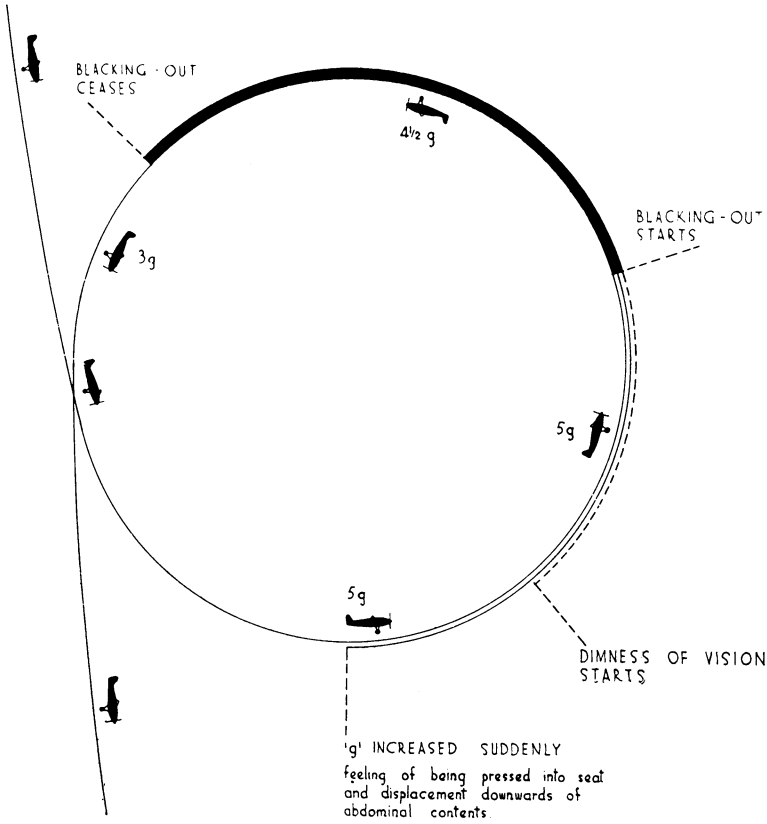

DIAGRAM II.—Diagrammatic representation of the process of blacking-out occurring during a steep dive or turn in aircraft at high speed.

The main effects of high 'g ' on a healthy man are, first a feeling of being forcibly pressed into the seat of the aeroplane, then of the abdominal contents being displaced downwards ; this is quickly followed by a gradually increasing dimness of the whole visual field, then sudden blindness or " blacking-out " occurs, but consciousness is retained, except in highly susceptible persons such as those with poor cardiovascular tone. The blacking-out period lasts a varying length of time, usually about two to five seconds, depending on the force and duration of the ' g ' applied ; it passes off as suddenly as it occurs while the loop or turn is being completed at a force less than 4 ' g '. There may be a certain lack of mental concentration for a few hours subsequent to a blacking-out, but in the trained and fit pilot blacking-out does not occur readily and after-effects are not evident. The great danger of blacking-out is the momentary loss of control of the machine, which is liable to cause a collision with a neighbouring aeroplane during formation flying and tactics which are the order of the day.

To prevent or ameliorate this condition it is first necessary to understand the cause. In this connexion a considerable amount of research work has already been done, especially in Germany, and more recently in this country by Wing Commander

H. W. Corner and Flight Lieutenants J. B. Wallace and D. J. Dawson in high-speed aircraft. From these researches it would appear that the centrifugal force, acting from head to feet, causes most of the blood to flow in that direction, producing splanchnic pooling and increased volume of the lower limbs, as demonstrated by means of X-rays on monkeys by Fischer (1937). Thus, the head and heart are drained of much blood during the application of high ' g ', leading to a fall of the systolic blood-pressure, as shown by Ruff (1938) in Germany, by means of a centrifuge, and by Corner (1938) in this country, in high-speed aircraft. This lowering of the blood-pressure reduces the pressure in the central artery of the retina, which is normally about half that in the brachial artery (Magitot and Bailliart, 1922), to such a degree (Andina, 1937) that the balance between intra-ocular and vascular pressure is upset and as a consequence the circulation of blood in the central artery of the retina is stopped and thus causes complete blacking-out of vision until the said balance is readjusted by the return of the normal blood-pressure when the centrifugal force falls below 4 ' g '. At forces of less than 4 ' g ' the action of the carotid sinus reflex is sufficient, apparently, to prevent the blood-pressure falling low enough to cause blacking-out, as shown on dogs by Koenen and Ranke (1937).

Preventive measures were introduced first by the personal experience of pilots, who found that a certain amount of relief was to be obtained by yelling loudly during a steep turn or sharp pull-out, so as to contract the muscles of the abdominal wall and raise the diaphragm. This procedure brings to mind the observations of Flack and Bowdler (1920), who advocated that aviators should keep themselves physically fit and practise exercises to develop and maintain a firm abdominal wall. All flying personnel should keep physically fit, as this is a simple and effective means of lessening the ill-effects of high ' g '. The natural sequence of thought led to the trial of various types of belt to give increased support to the abdominal wall and so lessen splanchnic pooling. Flack (1929) provided members of the British Schneider Trophy team with a simple elastic belt, but this was soon discarded as being useless. Group Captain G. S. Marshall (1933) suggested the use of a safety-belt fitted with a spring-loaded scoop to inflate the belt with air under pressure of high ' g ', but its production has been delayed until recently. Flight Lieutenant J. B. Wallace carried out several experiments at North Weald in 1937 and 1938 with a specially designed abdominal belt fitted with a pneumatic bag to increase the pressure on the abdomen, and he found that it helped to prevent or delay the onset of blacking-out up to a force of 6 ' g ' in some individuals ; whereas Ruff (1938) in Germany, did not consider that abdominal belts were very successful in counteracting the centrifugal movement of blood to the dependent parts of the body. Instead, he suggested a form of folding chair, so designed as to bring the bodies of pilot or crew into a crouching position, so that the chest is pressed horizontally against the upper thighs, while the lower legs are drawn in under the thighs, as was recommended by von Diringshofen (1934 and 1936), at one time a German war pilot, after he had shown the benefit of this crouching attitude with regard to the higher endurance of powerful centrifugal forces ; this procedure materially reduces the difference in height between brain and heart, and so alters the axis of the body exposed to the centrifugal force that a sufficient blood volume is retained in the head and heart to prevent the occurrence of blacking-out. Wing Commander P. C. Livingston has suggested that the seat should be provided with an oleo fitting so that the first intense force could be dispelled by the seat sinking away as the gravity factor comes on, and thus, by neutralizing the effect of 1 or 2 ' g ' in this manner, no ill-effects might be felt as the result of a 5-' g ' manœuvre. Flight Lieutenant J. B. Wallace (1938) proved that the administration of oxygen does not delay or prevent the onset of blacking-out ; while Ruff (1938) showed that the administration of carbon dioxide raised the limit of endurance to centrifugalization.

Night blindness of mild degree is found occasionally in aviators, who not only find difficulty in seeing in the dark, but have a delayed visual adaptation rate when looking

from a lighted area into the dark, for example, looking from the illuminated cockpit to outer darkness or landing at night with flares. Squadron Leader J. C. Neely is at present investigating this subject with special reference to its incidence among flying personnel and its amelioration by the administration of vitamin A, which apparently plays an important part in the regeneration of the visual purple as shown by Mutch and Griffiths (1937), Maitra and Harris (1937), and Haines (1938).

A good eye lotion has been found very useful in relieving the tiredness of eyes during long flights.

Hearing

Noise in aeroplanes is mainly derived from engine explosions, from revolution of crankshaft and propeller, and from aerodynamic turbulence; this noise is greatest near the engine and is radiated in closed machines from walls, floor, and roof, but not in equal degree; thus radiation is greatest below the front windows and noise is least in the centre of the cabin.

The effect of noise on man depends on its level in the sound scale. Sounds between 80 and 90 decibels are disturbing, the degree depending on individual sensitivity; whereas sounds above 90 decibels are deafening, the more so as the scale is ascended, and at or above 120 decibels they produce the feeling of pain. Continued exposure of the unprotected ears to sounds above 80 decibels will eventually lead to various degrees of nerve deafness; such deafness would be occupational, leading to claims for attributability, except that all Service pilots are provided with special ear-pads to exclude noise, the onus to wear them being on each individual who enters Service machines. The progressive deterioration of auditory acuity in pilots, who have flown over a hundred hours without wearing ear-pads, has been demonstrated by Wing Commander E. D. D. Dickson (1938). Noise also leads to fatigue.

Examples of sound values.

80 to 90 decibels: Police whistle at 15 ft.; motor horn at 23 ft.; fire syren at 75 ft.

90 to 100 decibels: Pneumatic drill at 10 ft.; newspaper press room; inside cabin of aeroplane not soundproofed.

100 to 110 decibels: Boiler shop; whistle of steam engine; steel riveting machine at 15 ft.

110 to 120 decibels (this is the threshold of painful feeling): Thunder (overhead); heavy gun-fire (close proximity to); unmuffled aeroplane engine (close proximity to).

In the non-soundproofed cabin aeroplane there is noise between 90 to 100 decibels in intensity. Aeroplane constructors, both in Europe and America, including Dryden (1930), Spain, Loye and Templin (1936), have studied the problem of the reduction of aeroplane noise and vibration and, as a result of the insulation of walls against sound and the provision of internal surfaces that give good sound-absorption, noise has been so decreased that conversation in an air liner of to-day is as easy as in a modern train.

In Service machines it is not practicable to reduce noise in this manner, owing to the question of weight. Instead, special ear-pads are provided as part of the flying helmet, at any rate for pilot, navigator, and wireless operator; whereas, other occupants of the 'plane, e.g. personnel being transported in troop-carriers, usually just plug the external auditory meatus with cotton-wool. This latter procedure does not prevent the conduction of a certain amount of noise, both by air and by bone conduction; the wearing of a flying helmet, if strapped under the chin, lessens this conduction.

Telephony between pilots and other members of crews in Service aircraft raises another problem of preventive medicine. The continued presence of a microphone in front of the mouth is annoying and therefore helps to hasten the onset of fatigue. Conduction of voice sounds by means of a microphone fixed either over the larynx

or sternum has been tried, but, so far, the results have been poor owing to distortion of voice sounds and absence of labial sounds.

Wing Commander E. D. D. Dickson is at present working in conjunction with Dr. A. W. G. Ewing of Victoria University, Manchester, and the Air Ministry Research Staff at Farnborough, to eliminate the effect of aeroplane noise on the ear and to perfect, if practicable, voice transmission and reception by bone conduction by means of a moving-coil microphone fitted over the sternum and an oscillator applied to the region of the mastoid process or over the brow while the external auditory meati are occluded.

Middle-ear deafness and excessive vestibular stimulation have also to be guarded against while flying. During steep and long ascents and descents, the balance of air pressure on the two sides of the tympanic membrane is so affected, especially by very rapid descents, that it is necessary to open the Eustachian tubes frequently by swallowing, aided perhaps by chewing gum, or forced blowing against the closed nostrils, so as to readjust the pressure to that of the atmosphere, otherwise tinnitus aurium, deafness, pain in the ears, or vertigo, result. Flying personnel should not be permitted to fly while suffering from cold in the head, owing to the danger of mucus or swollen mucous membrane occluding the Eustachian tubes and thus preventing the normal adjustment of the intra- and extra-tympanic pressures. Rapid descents, while there is obstruction of one or both Eustachian tubes, will either cause rupture of the ear-drum or excessive vestibular stimulation, leading to vertigo and vomiting with the possibility of serious consequences.

Respiration

Oxygen want or anoxæmia in altitude flying has been dealt with in considerable detail by various medical officers who served in the R.A.F. during the Great War, namely by Birley, Dreyer, Corbett, Bazett, Flack and Heald (1918), and their articles were revised and published in the Medical Research Council's Special Report, Series No. 53, in 1920. Group Captain G. S. Marshall (1933 and 1937) has brought the subject up to date in connexion with modern high-altitude flying. It has been proved that in the fit individual, as far as aviation is concerned, symptoms of oxygen want, such as dulling of the judgment and intellect, unwarranted sense of well-being and security, delayed reaction time, dyspnœa, and muscle weakness, do not usually occur until the height of 15,000 ft. has been reached and then only after the occupants of the aircraft have been at that height for about half an hour, though the time period varies greatly with apparently normal persons ; of course, the symptoms occur much quicker if moderate exercise, such as air gunnery, is indulged in. Experiments in the decompression chamber have confirmed experience in the air and have shown that at 20,000 to 25,000 ft. without oxygen definite respiratory distress occurs rapidly as the result of such movements as operating a machine gun ; heights above 25,000 ft. cannot be attained without the use of oxygen, as unconsciousness and death would quickly occur, owing to the low percentage of oxygen in the blood and tissues.

Table II

Height above sea-level (feet)	Partial pressure of oxygen in inspired air (mm. of Hg) Dry	Wet	Partial pressure of oxygen in alveolar air (mm. of Hg)	Oxygen saturation of the blood in normal persons (percentage)
0	160	151	98	96
15,000	90	81	50	82
20,000	73	64	36	63
25,000	59	50	30*	50*
30,000	47	38	pressure at this altitude is insufficient to support life.	

* Presumed figures.

R.A.F. personnel are not permitted to fly at heights above 16,000 ft. without the use of oxygen, as man's mental and physical output is definitely reduced at this height, and correspondingly more so as greater heights are attained. Even at much lower altitudes, during long flights such as patrols, the administration of oxygen diminishes or abolishes the fatigue or staleness and increases the mental alertness and muscular vigour of the aviator, as was shown by Flack and Heald (1917 and published 1918). These important facts should be impressed on flying personnel, especially in war time, when the keenest judgment is needed on all occasions.

The present policy is to supply an increased percentage of oxygen in the inspired air for flights at heights between 16,000 and 35,000 ft., and for this purpose oxygen masks are fitted to all Service flying helmets and connected by suitable tubing to an oxygen cylinder so that each individual can turn on his oxygen supply as required ; the oxygen flows constantly and mixes with inspired air in the mask, two-thirds being always lost as inspiration occupies only one-third of the respiratory cycle. Further research is now being planned to improve, if practicable, the present wasteful method of giving oxygen. For altitude flying above 35,000 ft. it is usual to supply pure oxygen under a pressure of 130 mm. of mercury to an individual enclosed in an airtight pressure suit somewhat resembling that of a diver (Marshall 1933) ; in this manner Flight Lieutenant M. J. Adams, in June 1937, reached an altitude of 54,000 ft., a record only recently broken by the Italian, Colonel Pezzi, when he reached 56,000 ft. in October 1938.

Fatigue

Fatigue in aircraft crews, leading to diminished work performance, was dealt with by Air Commodore A. V. J. Richardson (1935) in his presidential address to this Section. He drew attention to the nervous exhaustion resulting from the cumulative effects of daily fatigue, which causes a continual drain of nervous energy, so that day after day the individual becomes less refreshed by sleep and less fitted for work ; this is apt to lead to psychological trouble. As regards aviation, there are various factors at work in causing fatigue, such as the stress of taking-off and landing at high speed, the mental anxiety of night flying or flying through cloud and fog, the discomfort of a confined and cramped position, vitality lowered through cold and draughts, the effect of noise on the auditory nerve, anoxæmia at higher altitudes, and the injurious effects of carbon monoxide if fumes enter the cockpit or cabin.

Preventive measures to combat these fatigue-producing factors have been conducted along the following lines. Robot-pilots, artificial horizon, aerial compass, and wireless, have done much to simplify night and blind flying. Attention to the design and positioning of seats has overcome cramping, especially in civil passenger aeroplanes. Air-conditioning of air liners has provided an agreeable temperature in the various compartments, in all climates, without draught ; owing to undesirable extra weight, this has not been found practicable in Service machines as yet, but for everyday flying in this country a special flying suit, consisting of a linen fabric outer cover, waterproofed inside and lined first with linen fabric, then with wool, has been provided, together with a lambskin collar, dyed nutria, but free from phenylene diamine, which is apt to cause dermatitis. In addition, there are flying boots and flying gloves ; the latter consist of three glove layers, the inner of silk, the second of cotton, and the outer of leather, to suit varying temperature conditions and permit of adequate cleaning. Of equal importance is the provision at all squadrons of well-ventilated drying rooms to ensure that flying kit is dry and warm before being put on. A so-called " thermally insulated " suit, consisting of leather outside, lined with a heavy sheepskin inside, is issued for conditions of extreme cold. Sound-proofing in air liners and the provision of special ear-pads in Service machines, as already described, have largely overcome the noise factor. Oxygen is provided to counteract anoxæmia, as already described. Attention to the positioning of the exhaust has done much to overcome the fume nuisance, though the occurrence of persistent

headache, not relieved by aspirin, in closed machines on long flights, suggests the possibility of carbon monoxide poisoning in mild degree: this requires further investigation.

Digestion

Ballooning of the stomach or intestines, due to expansion of the contained gases, tends to occur at high altitudes, especially in those who have lax abdominal walls and suffer from fermentative indigestion: this is increased by a too-liberal carbohydrate diet. The ballooning may seriously embarrass the heart and respiration. Relief may be obtained by proper dieting before flights and by the administration of a hydrochloric acid mixture during meals to aid digestion, as the hydrochloric acid content of the gastric juices is often low in such cases.

Diet of persons on long-distance flights has been experimented with, chiefly by means of trial and error, on the various long-distance flights, and one consisting mainly of carbohydrates has been found to be the most suitable, as muscular movements and exercise during flight are very limited and the main requirements are to maintain bodily heat and energy; in fact, as the flight progresses, especially in warm climates, it is found that the appetite is materially decreased. Table III shows a suitable flying ration for one person for a three-days' flight.

Table III.

Item	Quantity
Dried meat (e.g. pemmican or biltong)	2 lb.
Sandwiches, whole round	6 lb.
Chocolate, milk or plain	¼ lb.
Oranges (bottled fresh juice)	12
Apples	6
Bananas	6
Dried dates	¾ lb.
Dried figs	¾ lb.
Dried raisins	¾ lb.
Sugar, lump	¼ lb.
Sugar, barley	¼ lb.
Chewing gum	¼ lb.
Coffee, black, unsweetened	1 gallon
Malted milk tablets	¼ lb.

In addition a bottle of glyco-thymoline, diluted 1 : 10, to rinse out mouth to lessen dryness.

Water is provided on desert flights on the assumption that it may be required for a minimum period of three days in case of forced landings. For this purpose water is carried on the scale of one gallon per man per day, that is, a quart in each water bottle, the rest being stored in tanks and, as already mentioned, these tanks require special treatment in cholera-infected areas.

In addition, for detached aircraft on flights abroad, a small meta-filter, complete with semi-rotary pump and 30 ft. of tubing, weighing 23 lb. in all, is supplied, together with sufficient bleach and ammonia to chloraminate the water filtered by means of this pump. For detached squadrons a small motor-driven plant for mechanically chloraminating water is provided; the whole apparatus packs neatly into two cases, each case being a 2-ft. cube and weighing 150 lb., so that it can be readily transported by aeroplane, motor car, or motor boat; the apparatus can be assembled for action within fifteen minutes and is capable of delivering 250 gallons of filtered, sterilized water an hour. One or more collapsible " sportapool " tanks complete the equipment.

Air-sickness, like sea-sickness, is considered by most authorities to be due to the abnormal excitation of highly sensitive vestibules leading to vagosympathetic disturbance and hypertonus of the stomach, as shown by Gwynne Maitland (1931) and Flack (1931). Liability to this condition can be assessed in the medical room by the type of response to spinning in the Bárány chair. By repeated exposure to these abnormal

stimuli the vestibule becomes adapted to them, as far as flying is concerned, at least in a certain number of cases. Wing Commander E. D. D. Dickson thinks that the adaptation rate is as high as 80%. On these grounds it is intended, as a temporary measure, to accept a limited number of candidates who show varying degrees of air-sickness and to send them to a particular flying training school, where they will receive a special course of training. There are other means of educating the vestibules to adapt themselves to aerobatics; thus in Russia and Germany use is made of rotating wheels. In addition, there are the usual aids for the " bad sailor ", that is, drugs of the barbiturate group, which act as sedatives on the nervous system and reduce muscle tone, including that of the stomach, but which, unfortunately, cause an uncomfortable dryness of the mouth. These remedies must, of course, be taken about half an hour before the intended flight and may require to be repeated during long flights.

As regards flying in warm climates, aluminium fabric sunproof blinds have been fitted in the roof of the cockpit of certain Vickers-Wellesley bombers and have proved of practical value as a protection from the sun; and at the present time the flying-helmet is being reconstructed so that it can be used in two layers, a light inner webbing layer for use in the tropics and in closed-cabin aircraft, over which can be worn a thick outer layer for use in open aircraft and under conditions of cold.

In conclusion, I wish to express my deep gratitude to the Ministry of Health, particularly to Drs. T. Carnwath, P. G. Stock, and M. T. Morgan, for their courtesy in inviting me to various departmental meetings dealing with aviation and general public health matters; to Imperial Airways, especially to Colonels H. Burchall and F. P. Mackie, for their ever-ready help, information, and co-operation on many occasions: and to the various R.A.F. medical officers who have permitted me to refer to their researches, some of which have not been published as yet.

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