PREVENTIVE MEDICINE IN RELATION TO AVIATION.

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(Continued from page 228.)

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 counter-acting 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).

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
Preventive Medicine in Relation to Aviation

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 connection 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’ manoeuvre. 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.
Preventive Medicine in Relation to Aviation

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 sound-proofed.
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-sound-proofed 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 meatuses 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, dyspncea, 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>
<thead>
<tr>
<th>Height above sea-level (feet)</th>
<th>Partial pressure of oxygen in inspired air (mm. of Hg)</th>
<th>Partial pressure of oxygen in alveolar air (mm. of Hg)</th>
<th>Oxygen saturation of the blood in normal persons (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>160 Dry 151 wet</td>
<td>98</td>
<td>96</td>
</tr>
<tr>
<td>15,000</td>
<td>90 Dry 81 wet</td>
<td>50</td>
<td>82</td>
</tr>
<tr>
<td>20,000</td>
<td>78 Dry 64 wet</td>
<td>88</td>
<td>63</td>
</tr>
<tr>
<td>25,000</td>
<td>59 Dry 50 wet</td>
<td>50*</td>
<td>50*</td>
</tr>
<tr>
<td>30,000</td>
<td>47 Dry 38 wet</td>
<td>50*</td>
<td>pressure at this altitude is insufficient to support life</td>
</tr>
</tbody>
</table>

* 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 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.**

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

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 per cent. 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.

REFERENCES.

Preventive Medicine in Relation to Aviation