BRITISH MEDICAL JOURNAL

LONDON SATURDAY JULY 13 1946

PROGRESS OF AVIATION MEDICINE IN THE ROYAL AIR FORCE AND ITS APPLICATION TO THE PROBLEMS OF CIVIL AVIATION*

BY

Sir HAROLD E. WHITTINGHAM, K.C.B., K.B.E., LL.D.Glasg., F.R.C.P., F.R.C.S.Ed.

Air Marshal, lately Director-General of Medical Services, Royal Air Force

In choosing a subject for this lecture in memory of the immortal William Harvey, physician and biologist, I feel that it would be appropriate, so far as the Royal Air Force is concerned, to give you a brief survey of the progress made in the physiology of aviation during the war and its application to the problems of civil aviation. Though aeronautics were unknown in Harvey's day, he was deeply interested in circulatory and respiratory phenomena, and these are much involved in certain important flying problems, particularly those of high acceleration and altitude. Harvey would have rejoiced to see how the experimental method has been applied to the biology of flying and would have marvelled at the progress made in this branch of medical science, also at the way that contemporaries and the public have accepted it and recognized its importance. Although Harvey discovered the circulation of the blood in arteries and veins, his conception of the circulation of the blood to the lungs was very wide of the mark: he thought that the inspired air cooled the blood and so prevented it from boiling at ground level. We know now that the blood actually boils at altitudes of over 60,000 ft. (18,280 metres) if compression is not employed.

Harvey applied the experimental method to gain knowledge for the benefit of humanity. I propose, therefore, to try to indicate to you some of the blessings to man that have accrued from aviation medicine researches in the Royal Air Force during the war and how many of these can be applied to the physiological and psychological problems of civil aviation.

Before the war the control of civil aviation, including licensing for civil flying, was vested in the Secretary of State for Air, and a special department existed at the Medical Headquarters in the Air Ministry to deal with the medical aspects, particularly the assessment of fitness to fly. After the outbreak of war this work still continued to be done by the Air Ministry, but on a diminished scale, as civilian flying was limited to testing and delivering aircraft and to manning a mere handful of passenger aircraft. Very little research in aviation medicine was done specifically on behalf of civilian flying, as practically all new developments were confined to Service types of aircraft. A few *ad hoc* problems were dealt with as they arose, and were common to civil and R.A.F. transport aircraft alike.

With the return of peace and the formation of a Ministry of Civil Aviation the relation of Service to civil aviation medicine has altered somewhat, the position being as follows.

Present Position of Medicine as Applied to Civil Aviation

The Ministry of Civil Aviation does not possess a medical branch of its own, but relies on the extensive knowledge and experience of aviation medicine available at the Air Ministry. A close liaison is maintained between the Ministry of Civil Aviation and the Air Ministry Medical Directorate, which continues to advise generally in this country on aviation medicine matters. The Ministry of Health, however, is responsible for the sanitary control of civilian aircraft and passengers

arriving at or leaving airfields in England or Wales: the Scottish Department of Health is similarly concerned in Scotland. The Royal Air Force Medical Branch has behind it the results of many years of experience and practical observations on medical aviation problems, and has a highly skilled staff of specialists to give appropriate advice and investigate problems as they arise. In addition, the valuable services of the Flying Personnel Research Committee† and its subcommittees are available to the Ministry of Civil Aviation. This committee reports direct to the Secretary of State for Air. It consists of a body of eminent scientists representing physiology, psychology, neuro-psychiatry, neurology, hearing, vision, and statistics; it advises on researches into the medical aspects of all matters affecting personnel which might conduce to safety and efficiency in flying, including problems associated with the scientific selection of flying personnel. The Director-General of Medical Services of the Royal Air Force is an *ex-officio* member of the committee. There are executive members of Air Staff representing operations, training, and research, a medical and an executive member for the Fleet Air Arm of the Navy, and a scientific officer (non-medical) of the Ministry of Civil Aviation. Other medical and non-medical individuals representing the practical interests involved are co-opted as required. The researches carried out under the aegis of this committee are done mainly at the Institute of Aviation Medicine at Farnborough, the Psychological Department of Cambridge University, and in the field by the Flying Personnel Medical Officers of the various flying Commands.

It would not be economical to duplicate these facilities purely to give civil aviation medical independence. Moreover, even if this were considered desirable, it would be some time before a new and separate staff of medical men could attain the knowledge necessary, unless either appropriate personnel were seconded from the Air Force or retired officers were employed. It would be an asset, however, if there were a Medical Adviser in the Ministry of Civil Aviation to make liaison with the medical authorities and scientists engaged in aviation medicine matters—civil, Service, and international—and to help keep the human factor in flying in proper perspective and abreast of progress of the machine. Otherwise there will be a tendency to revert to the pre-war attitude, when man's requirements were a secondary consideration to those of the aircraft. To obtain the best results the machine and its equipment must be designed and built to fit man.

I propose now to review a few of the more pressing problems of aviation medicine that confronted the Royal Air Force during the war. To enable aircrew to handle powerful aircraft of all types it was first necessary to learn how to select the best human material by physiological and psychological

† The composition of the committee is as follows: Sir Edward Mellanby (chairman), Prof. F. C. Bartlett (psychology), Dr. E. A. Carmichael (neurology), Mr. C. S. Hallpike (hearing), Prof. A. Bradford Hill (statistics), Dr. B. H. C. Matthews (physiology), Sir John Parsons (vision), Air Vice-Marshal Sir Charles Symonds (neuro-psychiatry), Surg. Capt. R. C. May (Fleet Air Arm), Air Cdre. T. McClurkin (Chief Executive Officer), and Air Marshal Sir Harold Whittingham (Director-General of Medical Services, R.A.F.).

* Harveian lecture delivered before the Harveian Society of London at the Royal College of Surgeons on May 27, 1946.

methods; then to buttress their natural attributes by providing mechanical aids to enable them to withstand the abnormal conditions encountered at higher altitudes, in all climates, by day and night, as well as in manoeuvres of combat involving high acceleration, and to ensure, so far as was possible, survival in emergency—that is, during and after bailing out, ditching, or crashing.

Selection

The general medical examination for fitness for flying, including special tests for cardiovascular stability and neuromuscular and respiratory efficiency, introduced in 1919 and called the "Flack Physical Efficiency Tests," has proved its value. This examination is devised to ensure that those who pass are alert in body and in mind and have accurate vision, good muscle tone, quick reaction time, and a good sense of balance. These tests do not predict the individual's aptitude to learn to fly; they do, however, materially aid in the assessment of general physical fitness to withstand the stress of flying.

During the war additional tests were introduced to select personnel for particular aircrew duties; the chief of these were used to help assess power of co-ordination, cardiovascular stability, tolerance for rarefied atmospheres, night visual capacity, and hearing efficiency in aircraft.

(i) *The sensorimotor test* was devised to judge deftness of hands and feet and co-ordination between the limbs, eyes, and ears. Extensive investigations have validated this apparatus as an effective means of picking out those individuals who would fail to learn to fly on account of poor co-ordination. Approximately 25% of those who fail to learn to fly do so because of being too heavy with their hands and feet, while the other 75% fail chiefly for temperamental reasons. Unfortunately, no satisfactory test for temperamental fitness for flying has proved valid as a sole arbiter in the selection of aircrew on entry, except in the case of severe predisposition to nervous breakdown.

(ii) *The cardiovascular stability test* is done with a tilt-table to detect those who have a low diastolic blood pressure which fails to rise on change from the horizontal to the vertical position, indicating instability for aerobatics.

(iii) *The high-altitude test* is carried out in a decompression chamber, where rarefied atmospheres are simulated up to 40,000 ft. (12,180 metres), or more if necessary, at the rate of climb of a modern aircraft. This test is used to eliminate those who are liable to suffer from decompression sickness or "bends," due to the nitrogen dissolved in the body fluids coming out of solution under greatly lowered atmospheric pressure more rapidly than it can be disposed of by the lungs. It has been found that about 25% of all aircrew tested suffer from "bends" when submitted to this standard test, whereas only 10% of young fit pilots so suffer.

(iv) *The rotating hexagon test*, intended to provide a visual task simulating that performed by a night fighter pilot, has proved to be only a rough guide to the assessment of night visual capacity, owing to uncontrollable factors which affect night vision in degrees varying with the individual. The test has therefore been used only to prevent grossly night-blind individuals from being allocated to night-flying duties: this means the elimination of about 3% of candidates for flying. As regards the remainder, it is considered that the best way to approach the problem is to give them night-vision training, to teach them how to look and to perceive, and to refer to an ophthalmologist for special examination, including a scotometry test, anyone whose night vision appears to be below normal during this training.

(v) *The hearing efficiency test* is performed with a gramophone audiometer, and is designed to measure ability to receive normal speech signals in both ears as transmitted through telephones in the presence of a background of intense aircraft engine noise. This was introduced because the whisper test at 20 ft. (6.1 metres) cannot be standardized, owing to variables such as the tester's voice and noise background. It is also uncertain whether the whisper test passes individuals who would be inefficient in hearing telecommunication messages in the presence of aircraft noise. In addition to the gramophone audiometer, a pure-tone audiometer is used to test pure-tone reception at 5 frequencies (4,000, 2,000, 1,000, 500, and 250 cycles per second in either ear) and at a subjective level of 20 decibels above the normal threshold. Candidates with a threshold hearing loss greater than 20 decibels at any of the frequencies are rejected. These are good tests, but have the defect of needing special apparatus which requires to be kept standardized.

The Royal Air Force, with its vast number of aircrew, opportunities for carefully controlled observations, and accurate personal records, has been in an ideal position to assess the value of various selection tests. Such Service experience has been

used in formulating suitable tests for the licensing of civilian pilots, of whom there are two classes. The private pilot must hold a Class A licence, and pilots and other members of aircrew of public transport or those employed as test pilots must possess a Class B licence, which entails passing a higher medical standard. As civil flying necessitates air travel over many countries, an international standard of medical examination for fitness to fly has been laid down by agreement of the appropriate authorities of the various countries concerned. Until January, 1946, the authority for this was the International Convention for Aerial Navigation (ICAN), with its head office in Paris. Now it is the Provisional International Civil Aviation Organization (PICAO), with headquarters in Quebec. The standard medical examination set for Class B licences is in some respects even higher than that for R.A.F. aircrew, particularly as regards physical fitness and hearing: good physical fitness is essential to help ensure against the fatigue of long flights, and perfect hearing is very important in connexion with modern radio aids to navigation for blind flying at night and in fogs. All aircrew of civilian airlines must be up to the PICAO medical standards for their particular duties (pilot, wireless operator, engineer, etc.), though extra tests and safeguards may be introduced if any company thinks fit. When stratosphere liners become the vogue a decompression test, on the lines of that in use in the R.A.F., will doubtless be included in the routine tests laid down by PICAO, in case mechanical failure or explosive decompression did occur.

There are important branches of aviation other than aircrew that have benefited from the Flying Personnel Research Committee's researches into the problems of selection of personnel. For example, psychological tests were devised to select Fighter Controllers, whose duties included direction of fighters in interception tactics and on offensive sorties, also of patrols on convoy duty. These tests proved successful in picking candidates with the intellectual capacities required, and demonstrated a strong positive relationship between test scores and operational efficiency. The adoption of these tests resulted in a reduction in training wastage of Fighter Controllers. Somewhat similar methods were applied with success to Filterers, who co-ordinated information received from a number of radar stations simultaneously to help plot the position and movements of aircraft. The results of these investigations and a study of Service Air Traffic Control Officers proved of value in determining the standard of candidates to be selected for the very important job of Air Traffic Controller in civil aviation. Thus recommendations were made regarding the qualities required in a Control Officer, also regarding promising sources of recruitment and selection procedure. Recently these tests have been modified and added to with a view to selecting for civil aviation the best pilots for safe flying. Here two tests deserve mention—namely, the *controlled approach* (which is an extension of the Cambridge cockpit test), to pick out those who tend to under- or over-shoot in their landing approach, and the *grid location test* (in which small objects on a grid-scale have to be accurately located), to select those with deft touch, imperturbability in face of delay and error, and the ability to learn the sequence of controlled movements rapidly.

The wide Service experience gained with the decompression test to assess fitness for high-altitude flying has also proved of value in helping to formulate instructions for employees engaged in testing pressure cabins on the ground in aircraft works, to exclude those not suited for such pressure changes, and to ensure a safe rate of pressure change for a normal individual. It has been recommended, therefore, that all intended employees on this work should be medically examined to exclude disease of the alimentary, circulatory, or respiratory system, including upper respiratory tract infections; also that they should be instructed how to ventilate their middle ears during ascent and descent, and, where possible, should be given a decompression-chamber test. The rate of pressure increase should not be greater than 1/2 lb./sq. in. (0.035 kg./sq. cm.) per minute for inexperienced operatives, and gradually increased up to 2 or even 3 lb./sq. in. (0.14 kg.–0.21 kg./sq. cm.) as experience is gained; decrease in pressure can be at the rate of 5 lb./sq. in. (0.35 kg./sq. cm.) per minute for the healthy.

It is convenient now to consider the problems of high-altitude flying, particularly those of adequate oxygen supply, decompression sickness, and explosive decompression.

Altitude Flying

In this country at the outbreak of war neither those engaged in Service nor in civil flying were really oxygen-minded. Moreover, the continuous-flow system of oxygen supply then in use allowed two-thirds of the oxygen to go to waste. The Medical Branch was therefore faced with two urgent problems: first, to make every member of aircrew oxygen-minded, and, second, to devise an oxygen supply system and mask that would prevent oxygen waste, give the maximum of comfort to the user, and be reliable in the severest cold when sitting or moving about the aircraft or on baling out. To make aircrew oxygen-minded, demonstrations of the ill effects of oxygen want were given in low-pressure chambers in which all flying altitudes and current rates of ascent and descent could be simulated. As regards improvement of oxygen supply, an economizer and mask were quickly designed and developed to prevent oxygen going to waste during expiration, and to be foolproof against stoppage of flow should the breathing of the wearer be minimal, as during shock or unconsciousness. This new system more than doubled the operational range of aircraft from the oxygen point of view.

Several improved types of mask were subsequently developed as the result of operational experience, so that the latest mask (Type H) is practically ideal, combining the qualities of comfort, smallness, lightness, and perfect fit even during strenuous aerobatics.

To assess the relative merits of oxygen masks and systems under various conditions an anoxia meter was designed and produced to estimate the amount of oxygen in the blood for any length of time without puncture of an artery, as had to be done formerly. The apparatus is simply clamped lightly to the ear and the oxygen content of the blood is measured by means of two photo-electric cells.

This provision of good oxygen equipment was vain unless aircrews and passengers co-operated by using it to the greatest advantage. All aircrew and passengers therefore had to be instructed regarding the value of oxygen in maintaining normal cerebration, vision, and hearing at altitudes over 10,000 ft. (3,045 metres), as well as its role in delaying the onset of fatigue and the ill effects of cold. In addition, a mask-leak tester was developed and introduced to check the fit of oxygen masks before all flights in which oxygen was likely to be used.

Other oxygen equipment developments were mobile decompression chambers for testing and instructional purposes, a plant for separating oxygen from the air during flight, a portable oxygen set (weighing 5½ lb. (2.38 kg.) and containing 10 minutes' supply of oxygen) to enable aircrew to move about away from their station at oxygen-requiring heights, and a very light bale-out oxygen bottle (weighing 3½ lb. (1.47 kg.) and containing 10 minutes' supply) fitted into the parachute pack as a stand-by for those who might have to bale out at altitudes above 30,000 ft. (9,140 metres): this emergency oxygen supply is permanently connected with the oxygen mask and can be turned on immediately by pulling a release handle on the side of the parachute pack.

These Air Force oxygen researches, developments, and experiences have been a boon to civil aviation, and have provided all the data required to fix the necessary rates of flow of oxygen at various altitudes for crew and passengers, including invalids. The new civil aviation mask for passengers was designed and developed at the R.A.F. Institute of Aviation Medicine, and it is a direct descendant of Type H, modified to meet civilian needs. It is extremely light (weighing only 1½ oz.: 42.5 g.), is a good fit (being made in four sizes), and is of aesthetic appearance: it had also to be of the cheapest possible construction compatible with proper function, as the policy is to make these masks an individual issue of the "throw away when finished with" type, owing to difficulty of sterilization. The portable oxygen set is being adopted for use by stewards and passengers to enable them to move about in aircraft at oxygen-requiring heights, also as a stand-by for invalids at even lower altitudes: in this case the bottle is slung over the arm of the passenger's seat. Some of the Service decompression chambers will probably be utilized in the near future by civil aviation organizations to train members of aircrew, especially with the advent of stratosphere flying.

Stratosphere flying at altitudes above 37,000 ft. (11,270 metres) brought two further problems—namely, how to prevent the occurrence of decompression sickness or "bends," and the best means of compressing the oxygen breathed so as to maintain the normal sea-level amount in the blood. The obvious answer to both was to supply the right amount of pressure. Exactly how this could best be done required much

FIG. 1.—Oxygen mask designed and developed at the R.A.F. Institute of Aviation Medicine for use in civil aviation.

research. First, pressure suits were developed, and it was in one of these, filled with oxygen under a pressure of 2½ lb. per sq. in. (0.176 kg. per sq. cm.) that Fl. Lieut. M. J. Adams in 1937 attained the altitude of 54,000 ft. (16,450 metres): such suits were clumsy to wear and greatly hampered movements, so they quickly fell into disuse. The next step was the development of pressurized cabins to give full freedom of movement with adequate comfort and warmth. Researches in pressure-cabin design were based on applying a pressure of 7½ lb. per sq. in. (0.51 kg. per sq. cm.), so that at an altitude of 44,000 ft. (13,200 metres) the pressure within the cabin would be equivalent to that of the atmosphere at 18,000 ft. (5,480 metres). The question arose of the effects of sudden decompression on the occupants if the cabin pressure were lost owing to mechanical failure or to puncture by shellfire or to a port blowing out. From the results of experiments on animals it was assumed that the sudden change of pressure from the equivalent of the atmospheric pressure at 18,000 ft. inside the cabin to that of 44,000 feet outside would cause such violent expansion of the lungs, stomach, and intestines that serious bodily damage or death would result. This was disproved in the Physiology Laboratory at Farnborough in 1942. The experiment has been repeated hundreds of times since, and it is quite clear that a fit man suffers little or no ill effects from such explosive decompression, provided that at the time of the explosion he is breathing oxygen, as he should be for an atmospheric pressure equivalent to that of an altitude of 18,000 feet.

These researches have provided the knowledge necessary for civilian pressurized aircraft for altitudes envisaged at present. In fact, the present aim is for an internal pressure of 6½ lb. per sq. in. (0.46 kg. per sq. cm.), so that at 20,000 ft. (6,100 metres) the cabin pressure would be equivalent to that of the

atmosphere at 8,000 ft. (2,400 metres), and oxygen would not normally be needed except to turn on in emergency.

While awaiting the production of pressurized-cabin aircraft it was necessary, in answer to the appearance of the German pressurized JU86, to devise some temporary measure to permit operations between 38,000 and 44,000 ft. (11,570 and 13,200 metres). A pressure breathing equipment was therefore developed in conjunction with the Royal Canadian Air Force. By this means positive pressure is applied to the lungs so that the total pressure in them is greater than that of the surrounding atmosphere. This is done by increasing the pressure in the mask while a counter-pressure is applied to the thoracic and abdominal walls to make expiration less of an effort. The equipment consists of a "Mae West waistcoat," which also serves as an oxygen reservoir. It maintains a continuous pressure of 1/4 lb./sq. in. (0.0175 kg./sq. cm.) to chest and abdomen: greater pressure cannot be applied in this localized manner without seriously impeding the return flow of blood to the heart. This device therefore has a ceiling of about 46,000 ft. (15,000 metres). It is reasonably comfortable to wear, was used during the last year of the war by photographic reconnaissance units, and proved to be a valuable interim measure.

Aircraft were not only attaining to higher and higher altitudes but were reaching greater and greater speeds, which kept ever to the fore the problems of the effects on man of high acceleration and deceleration.

Acceleration and Deceleration

During the war extensive researches were carried out on problems of acceleration and deceleration in relation to aerobatics, crash landings, ditchings, and baling out and ejection from aircraft.

As aerobatics play little part in ordinary civilian aviation only brief reference will be made to this problem. Blacking-out during a tight turn or loop at high centrifugal acceleration leads to momentary loss of control of the aircraft by the pilot, maybe during a critical manoeuvre. It was therefore necessary, during the early stages of the war, to introduce anti-measures without delay and with the minimum of interference with the pilot and the structure of the aircraft, as every man and every machine were needed in the air. Researches had already shown that blacking-out was due to the blood, under the force of high centrifugal acceleration, being drained to the lower part of the body, particularly the legs, so stopping the circulation of the blood to the eyes and brain, and that this usually occurred in the normal sitting position after exposure to a force of about 5 "g" for 4 seconds. It was found that abdominal belts alone did not prevent blacking-out, but interfered with the return of blood from the lower part of the body to the heart when the force of "g" was released, and so did more harm than good. The immediate answer to the problem was the introduction of the crouch position, which raised the individual's blacking-out threshold by about 2 "g": thus the average pilot can withstand up to 7 to 7½ "g" for 4 seconds, which was sufficient at that time. To achieve this crouch posture all that was necessary as regards structural alteration to aircraft was to raise the rudder-bar position 6 in. (15 cm.) by fitting a simple stirrup with a heel support to prevent the foot slipping during tight turns.

Further developments were hydrostatic and pneumatic anti-"g" garments designed to equalize automatically the internal pressure built up in the body fluids by the accelerating force, so preventing the blood from pooling in the lower part of the body. During the past three years great progress has been made, by close liaison between U.S.A. and British workers, in the development of a pneumatic suit of light type capable of being put on or taken off almost as easily as an ordinary pair of trousers. The latest suit weighs only 3 lb. (1.36 kg.), can be worn either as underclothing or over slacks, and can be put on within two minutes and taken off in half that time. These suits apply pressure as required by means of inflatable bladders to the lower abdomen, thighs, and calves, and so prevent pooling of blood in the lower half of the body. The air pressure is derived from a source within the aircraft, such as the instrument pump, and, by means of a regulating valve, is increased or decreased proportionately to the force of "g"

applied. The valve can be set to cut in at a predetermined force of "g," as it is uncomfortable to have the pressure functioning for low forces of "g," such as are encountered when flying in bumpy weather and while taking certain evasive action. This type of suit raises the threshold for blacking-out by at least 2 "g," and in addition, by ensuring good circulation of blood to the head, lessens fatigue and helps to maintain good reaction time even in long and arduous flights. It is unlikely, however, that such suits will be required by pilots of civil air lines, except possibly to prevent fatigue on very long journeys.

There are problems of linear acceleration, however, that are applicable to civil flying, particularly those connected with crash landings, ditchings, and baling out and ejection from aircraft.

Crash Landing.—In crash landings various injuries, lethal and otherwise, are apt to occur as the result of the body being carried forward with the momentum of the aircraft and striking against some hard object or bending on itself to such a degree as to cause a wedge fracture of the spine. The commonest injuries are fractures of the skull or simply bruises and lacerations of the scalp and face, and fractures of the bones of the lower limbs and of the spine. The wearing of a safety belt low down near the pelvis is unsatisfactory, as it allows of so much forward flexion that fracture is apt to occur in the dorso-lumbar region, with serious immediate and after results: whereas a safety harness which supports the shoulders allows only slight forward flexion of the spine, and if fracture does occur it is in the upper dorsal region and the prognosis is therefore more favourable. Compression fractures of the spine are not so common in aircraft crashes as in parachute descents.

During the past three years extensive study has been made of the forces which the human frame can withstand without injury or without injury sufficient to endanger human life, with the aim of collaborating with aircraft makers in the stressing of airframes and the design of safety devices to reduce crash injuries to the minimum. The extent of injury sustained during aircraft crashes depends on the magnitude of the force applied, the area and site over which the forces are spread, the duration of the forces, and the relative movement between supported and unsupported parts of the body. For example, if the skull receives the first impact the area of contact is usually small owing to the curve of the skull, so that the pressure per square inch is high. The skull is strong, but the deflection which it can withstand without fracture is small: if fractured, the chances of survival are much lower than for fractures of other bones. The mortality rate for fracture of the skull in flying accidents is 94%. If the back and buttocks receive the first impact the area of contact is much larger, and appreciable deformation of tissues may result. Injuries to aircrew and passengers during crashes can be reduced by supporting the body over as large an area as possible, and by preventing the skull from hitting unyielding objects of small size. A posture facing backwards therefore gives better protection from serious injuries than one facing forwards, whether supported by harness or not. Harness gives relatively poor protection against injury, as the area of the body covered is small compared with support of the whole back by the seat. From the physiological aspect, the ideal posture during crashing or ditching is to lie or crouch with arms and legs flexed, the back and head fully supported, facing towards the rear of the fuselage. These postures reduce the effects of vertical deceleration on the spine, and are the basis of crouch positions adopted with success in various types of R.A.F. aircraft. A new safety-type harness has recently been developed to withstand the stresses liable to occur under existing conditions. A survey is being made of the important aircraft types, including jet-propelled machines, to find the maximum forward deceleration which can be withstood, and the anchorages of seats are being reviewed. The immediate aim is to produce a safety harness and seat which will withstand 25 "g."

A simple protective measure for passenger aircraft would be to place all seats facing to the rear instead of to the front; then, in the event of a forced landing, the passengers should be instructed to lean back in a crouched position with the head pressed firmly against the soft back of the seat and protected by the hands clasped tightly round the back of the neck. Generally speaking, the passengers' view from an aircraft would not be materially affected by this back-facing arrangement of seats. A special safety cell has been designed for crashes, but to carry these would occupy valuable space and unnecessarily increase the pay-load, for the padded seat reversed as suggested functions as a safety-cell.

Baling Out and Parachute Descents.—A considerable amount of research has been done to assess the decelerating forces involved when parachutes open at various altitudes and speeds: the higher the altitude and speed the greater is this force. The decelerating force applied to the parachute harness attached to a man of about 10 st. (63.5 kg.) in weight, at the moment of opening of the canopy, at altitudes up to 25,000 ft. (7,620 metres) is usually less than

25 "g," and the standard parachute with its rigging is capable of withstanding this degree of stress: the harness is stressed to withstand over 40 "g." This decelerating force acts for only a second or so—the greater the force the shorter the duration—so that blacking-out rarely occurs unless the parachutist is anoxic at the time, as well he may be. Experiments with dummy men fitted with accelerometers indicate that forces up to 30 "g" occur at altitudes of 35,000 to 40,000 ft. (10,660 to 12,180 metres) if the parachute is opened almost immediately after baling out. Such decelerating forces may seriously damage the parachute and its rigging. It is essential at these higher altitudes, therefore, for the user to allow the rate of fall to slow down to terminal velocity before pulling the rip-cord: this takes about 12 seconds.

It is convenient to consider here the danger of unconsciousness and even death from anoxia resulting from baling out in the stratosphere. Members of the staff of the R.A.F. Institute of Aviation Medicine took part in a number of experiments to find out how long a man could live at altitudes varying between 44,000 and 25,000 ft. (13,200 and 7,620 metres) during parachute descent, even though unconscious. These experiments were done in the laboratory, the subject being suspended in the air by the standard parachute harness. In this way, by simulating the atmospheric oxygen conditions from 40,000 ft. (12,180 metres) down by the use of nitrogen-air mixture, at the rate of descent of an open standard parachute, it was found that man could remain unconscious and yet live up to a period of 7½ minutes. This is not adequate to ensure a safe descent, as it would take 7½ minutes to reach 20,000 ft. (6,100 metres) if baling out took place at 35,000 ft. (10,660 metres). Moreover, the unconscious parachutist would become limp and the head would fall forward and so be liable to cause respiratory embarrassment; while the cold is intense ($-55^{\circ}\text{C}.$) at these altitudes and would materially reduce the chances of survival. A quicker descent could be made by doing a delayed drop from 35,000 to 20,000 ft. (10,660 to 6,100 metres), which would take 1½ minutes; by this time the individual might be so anoxic as to fail to pull the rip-cord. For this reason the emergency bale-out oxygen set was introduced, and has added greatly to the confidence of those flying at higher altitudes.

An R.A.F. medical officer, an expert parachutist, was installed at the Airborne Forces establishment in this country when the training of air-borne troops was first taken seriously in 1941, and remained there throughout the war. His duties were to advise on parachuting from a medical aspect, and, for this purpose, to make liaison with the Army Airborne Forces and the R.A.F. Institute of Aviation Medicine. Researches he undertook show that liability to injury on landing by parachute varies with age, weight, force of wind, and type of terrain. Statistics revealed that injuries were more frequent in those over 25 years of age than in younger persons; that the injury rate rose rapidly in those over 12 st. (76.2 kg.) in weight; and that the stronger the wind the greater was the risk of injury from wrong stance on landing. The commonest parts to be injured during training jumps were the legs (64% of those injured) and the head (24% of cases). The incidence of injuries during training was initially 4% of jumps, but, subsequent to improved attachment of parachute harness and landing stance, as suggested by this parachutist medical officer, it was reduced to 0.5% of jumps. In addition, a considerable amount of research has been done with different kinds of parachute to ascertain the most foolproof type, as regards both certainty of opening and the minimizing of the final deceleration on touching down. For this purpose visits have been paid to the parachute-training establishments in the United States of America and in Canada, also in Germany.

Critical analysis of rates of survival after baling out from multi-seated aircraft has given valuable information regarding difficulties of escape, such as the angle of the aircraft, the force of "g" resulting from spinning, jamming of hatches, and temporary amnesia. The findings stress the necessity for aircraft to be designed so that all occupants can leave within two seconds of the order to abandon aircraft. In this connexion anthropometrical research has given valuable information to aircraft designers regarding the size and shape of exits necessary to prevent fouling or injury.

All this information is applicable to civil aviation, for, when stratosphere flying becomes a commonplace, passengers and crew will very likely have to be provided with parachutes for use in emergency even if it becomes possible in future to eject the cabin complete with occupants.

Ejection.—As the result of a fatality in January, 1944, when a pilot tried to escape from a jet-propelled aircraft which was out of control, it became evident that the force of the slipstream in aircraft of very high speed is so great that the unprotected human body cannot withstand it for more than a fraction of a second, else limbs are evulsed against the machine. The problems involved were whether quick ejection of the man plus his seat would avoid this evulsion, and whether man could withstand the high force of positive "g" necessary to eject him clear of the tail of the rapidly moving aircraft.

It was first necessary to ascertain what was the maximum force that can be applied vertically to the spine through the seat without

injuring the spinal column, spinal cord, skull, or brain. The Martin-Baker test rig, at an angle of 30° off the vertical, proved best for this purpose. It was found that a man could tolerate in this way up to 20 "g" for a period of a tenth of a second, provided he was well strapped in with safety harness and that there was an appropriate device to prevent his head flexing forcibly and

FIG. 2.—Diagram to show how a man, strapped down with safety harness and provided with a canvas hood device to activate explosive ejection as from an aircraft, can tolerate a force up to 20 "g" applied vertically through the spine for 1/10 second. (The Martin-Baker test rig.)

acutely as the force of "g" was applied. Unless the head is protected it will fall violently forward on the chest, owing to the centre of gravity of the head being in front of the line of thrust of the spine. Trials with dummies in aircraft have shown that it is necessary to arrange for a 40-ft. (12.2-metre) ejection, with an ejection stroke lasting for one-tenth of a second at between 15 and 25 "g" upwards through the seat. This is attained by means of an explosive charge under the seat; the charge is activated by the pilot pulling a roller-blind affair of heavy canvas over his head by means of two rubber handles. When the handles reach the level of the diaphragm the pull activates the cartridge, and the resulting ejection with its high force of "g" makes the hands pull the protecting hood tightly down over the head. In addition to holding the head in position to avoid injury, the hood is intended to protect the eyes and prevent the oxygen mask being torn off by the force of speed.

FIG. 3.—Ejection from aircraft in flight of a dummy man complete with seat as a result of a 40-ft.-per-second explosive charge. The parachute, which operates automatically, is just opening. (Crown copyright photograph of official test done on Oct. 5, 1945.)

It is envisaged that civilian flying in the near future will be in very fast aircraft travelling in the stratosphere, and that arrangements will have to be made for the whole cockpit or cabin to be ejected in emergency. The detached cabin will require to be fitted with suitable parachutes to land it intact or to retard its speed so that

occupants can escape individually by parachute in the usual way at a convenient altitude.

This leads to a consideration of aircraft accidents in general, their causes and prevention.

Aircraft Accidents

It has often been stated that flying accidents are due to human error in at least 80% of cases, but this statement has never been validated: it can be assumed, however, that the human factor plays a very large part in the majority of air accidents. It is of prime importance, therefore, to eliminate from flying duties those who are accident-prone and to provide aids to increase safety in the air, particularly for blind flying, landings, and take-offs.

With these aims in view, researches were instituted to devise tests to predict the accident-prone individual. It was conceded that heavy-handed and leaden-footed individuals, or those visually defective owing to eye-muscle imbalance or gross night-blindness, were accident-prone as regards flying, and they are eliminated by appropriate tests on entry, as already indicated. There still remain a large group who are labelled temperamentally unsuitable to fly, and many of these are accident-prone. Attempts to predict these individuals by psychiatric and psychological methods have been disappointing, except in the case of the Cambridge cockpit test. In researches with this test, pilots were set a relatively complicated task analogous to flying an aircraft, and many aspects of their performance were scored and rated. It was found that those who sustained accidents or became casualties on operations had obtained high error scores in the test, and had been predicted unfavourably. The incidence of non-fatal accidents was highest in those who, though they obtained normal scores, had been rated unfavourably in one or more aspects. The rating was intended to indicate the stability and skill of the individual when obliged to carry out, for a relatively long time, a task in which he was unable to achieve a high degree of accuracy. Stability under stress is regarded as a more important attribute in avoiding accidents than the ability to learn the skill of flying.

Investigations have shown that *fatigue* is conducive to flying accidents, and a considerable amount of research has been and is still being done to assess the relative importance of the many factors involved in flying fatigue and the best means of overcoming or mitigating them. There are various causes of fatigue in aviation, such as the stress of taking-off with heavily laden machines or landing under adverse conditions and at high speed; the mental anxiety of night flying or flying through fog; the discomfort of a cramped and confined position; the effect of noise on the auditory sense; loss of vitality as the result of exposure to cold; and oxygen lack to the body cells when the supply is inadequate. As the cumulative effect of even small irritations is a potent cause of fatigue, there has been a constant endeavour to improve the design and fitting of all flying equipment so as to give the greatest efficiency with the maximum of comfort.

Researches into measures to abate these fatigue-producing factors have resulted in improved radio apparatus and direction finders to simplify night and blind flying without straining the eyes; improved cockpit and instrument lay-out, including dial markings and the best position for all controls so as to obtain the maximum human efficiency with the least fatigue; proper design of seats from an anthropometrical and physiological aspect, to avoid cramping and to lessen vibration; sound-proofing of cockpits and cabins to minimize engine noise; air-conditioning of cabins to maintain an agreeable temperature in all climates and at all altitudes; and the provision of an adequate oxygen supply, including design of mask to give maximum efficiency and comfort. The results of all this work have been passed on for use by civil aviation, including designers of aircraft, and it is hoped that the various improvements suggested will materialize in the new civilian aircraft now under construction and development.

Fatigue in aircrew has been shown to be usually of the skill variety, and results mainly from prolonged repetition of highly skilled performance. The individual concerned is often unaware of his condition and tends to blame the flying instruments for his mistakes. Researches have proved that this liability to make mistakes when fatigued can be countered if the individual has been instructed that fatigue is a normal

sequence of long periods of concentrated mental or physical effort, and that his performance can be almost as effective as when fresh if he realizes he is open to errors and exercises special care, particularly towards the end of the task.

The "beam approach" may be cited as one example of aids to flying and the prevention of accidents in which medical research has played an important part. This is one of the blind-flying devices on which a pilot has to rely in homing at night or in bad day visibility—that is, at a time when he is fatigued and liable to make errors. In addition to the beam approach indicator, a pilot has ten instruments on his blind-flying panel which have to be read and their meaning fitted into one whole before he can make a safe landing under blind conditions. It is of the greatest importance, therefore, that all instruments should present their messages as simply and clearly as possible. The beam approach briefly consists of a radio beam which gives two types of clue to the pilot—one auditory, the other visual. At first these clues were wrongly presented. The auditory clue, which was Morse, did not use the letters that could be picked up with least error; and the visual clue, which consists of a small luminous plan of the aircraft and its relation to the beam, was confusing, as the pilot had to remember to reverse the signal for right and left turn when coming in to the airfield in the opposite direction to the normal approach. Pilots, especially when tired, found this confusing, and often made a wrong response which resulted in a landing accident. The logical visual presentation is that which necessitates the minimum of thought. As a result of these psychological researches, correct aural and visual clues were introduced. The application of this to civil aviation needs no stressing.

Intensive researches into the causes and prevention of flying accidents are being continued by the Air Ministry: every crash is thoroughly investigated. From a medical point of view, statistics are collected covering such data as the type of aircraft involved; estimated speed of impact; posture adopted by each occupant before the crash, whether standing, sitting, facing fore or aft; parts of the aircraft which caused injuries to occupants; sites and nature of injury in each case; and any precautions taken to prevent injury. Appropriate action is taken to correct any faults found either in the structure or design of aircraft or equipment, or in the crash position or the drill of the occupants. It is hoped that, as a result, the incidence of air accidents will become progressively less, and that in those that do occur the survival rate will be high.

Survival after Crashing or Baling Out

Researches in connexion with problems of survival after baling out or ditching in the sea have been carried out by members of the Institute of Aviation Medicine in European waters. Some of these problems were tackled and solved in conjunction with the Admiralty, such as the production of drinking-water from salt water, the provision of the best type of survival ration, and general measures to preserve life when cast away at sea.

The first problem tackled was the development, in 1942, of an *immersion suit* for pilots of aircraft in the catapult armed merchant ships operating with convoys in North Atlantic and Arctic waters. The catapulted aircraft could not land on these ships, and the pilots had to bale out into icy waters, so that a suit was needed to enable them to withstand the severe cold on immersion for at least half an hour before they could be picked up. A suit was produced that was comfortable at stand-by on the ship and yet watertight. Immersion trials of this garment were carried out in Icelandic waters by a member of the physiology team to enable it to be perfected. It was made of a light waterproof gaberdine which allows perspiration to take place through it, yet by virtue of its texture and the arrangement of its fibres holds back water applied to it in the form of rain or during immersion. This suit, modified to meet requirements, was adopted by the Fleet Air Arm. Following the success of this garment, a watertight suit was developed to protect crews of high-speed launches of the Air-Sea Rescue Service against wind and spray.

In 1945 a lighter, inflatable suit to guard against exposure was designed and developed for aircrew to don either just before baling out or ditching, should time permit, or after entering the dinghy. It is made of balloon fabric, has a double

lining for inflation purposes, and is quilted to loculate the air to ensure that there is always a layer of air even at points of pressure. It weighs only 2½ lb. (1.25 kg.), and rolls up to form a stole for the "Mae West." There is a short tube at the neck for inflation by the mouth, and a hood to complete the protection. Even if it is not put on until the dinghy is boarded, it will protect the wearer against further loss of body heat despite wet clothing underneath.

Researches were also carried out with various *life-saving jackets* to assess their efficiency to prevent an injured or unconscious man from drowning. For this purpose a member of the physiology team was kept continuously anaesthetized while immersed in a swimming-bath wearing various types of life-saving jackets in turn, the body being pulled face down from time to time to see if it would right itself. Artificial waves were created to imitate rough water. Though the R.A.F. "Mae West" kept the nose and mouth of the unconscious individual clear of the water, it was improved for use in rough seas by a 2-lb. (0.9-kg.) lift in the back. A new jacket was therefore designed incorporating this and other improvements.

The immersion suit and the "Mae West" life-saving jacket, which are light and easily stowed, will be welcomed by civil air lines, particularly now that land planes are replacing flying boats on most, if not all, cross-sea and ocean flights.

Some Flying Problems

Time does not permit of more than passing mention of many other problems tackled, and solved, to improve man's efficiency in flying, whether in a Service or a civil capacity—for instance:

(i) The protection of vision against *sun and searchlight glare* by special glasses and other devices.

(ii) Means of obtaining and maintaining the *maximum night visual acuity*, by pre-adapting with red goggles, and using red or ultra-violet lighting reduced to the minimum to illuminate instruments and maps.

(iii) Improved design of *microphones* and *earphones* to increase acoustic reception and so lessen fatigue.

(iv) Design and development of *flying helmets* to give perfect fit with comfort even when worn for hours.

(v) Proof of the occurrence of *high-tone deafness* as the result of flying for 100 or more hours without ear protection in non-sound-proofed cabins.

(vi) Means of preventing and treating acute *otitic barotrauma* by x rays or gamma radiation.

(vii) Study of the causes of *dental pain at altitude* and its prevention by proper conservative dentistry, using cement of the correct pH and avoiding undue heat near the tooth pulp.

(viii) Study of *air-sickness* and its prevention, and discriminating between true air-sickness and emotional tension.

(ix) *Design of cockpits and seats* for comfort; removal of projections likely to cause injury; placing of all controls in the most favourable position. The problem is whether the controls most often used or those needed in emergency should have place of vantage.

(x) Simplification of *instrument dials* for ease of reading; grouping of instruments so as to cause the minimum of error and fatigue.

(xi) The *disinsectization of aircraft*, and the *control of mosquito* breeding by aerial spraying of D.D.T.

(xii) The *cooling of aircraft* on the ground in hot climates and protection of those servicing aircraft.

It is evident from the foregoing that the majority of aviation medicine researches carried out on behalf of Service flying have a direct or indirect bearing on civil aviation problems. For this reason, when considering the establishment of the new Institute of Aviation Medicine at Farnborough, it was decided to design, equip, and staff it to meet the requirements of civil aviation as well as of those of the Services—Royal Air Force, Fleet Air Arm, and airborne troops. Throughout the war there has been the closest liaison in all this work not only between the Services but also with the Dominions and our Allies: their scientists have worked alongside ours in the Institute, and in some instances still continue to do so. No less important has been the liaison with aircraft designers and scientists on the material side. It was by this whole-hearted co-operation and fine team spirit that such excellent and rapid progress was made in aviation medicine during the war; it is sincerely hoped that this friendly collaboration will continue

in peace to ensure the fullest support for aviation in general so as to make it the safest, most comfortable, and quickest mode of travel.

This is a high-speed aerial review of the progress made in aviation medicine during the war, and, as in an aerial view, the ground covered is extensive but detail is lacking: you get only glimpses of this new country through the clouds of obscure description and so your imagination must fill the gaps. Likewise, as you cannot see the whole world in an hour, even in the fastest of aircraft, so this picture of aviation medicine covers only a small portion of the valuable work done by as fine a team of scientists and medical officers as anyone has ever been privileged to direct.

I wish to pay high tribute to all those who have given so much and often risked so much in these researches—physiologists, psychologists, Flying Personnel Medical Officers, and Squadron Medical Officers, and to those who gave all—Group Captain Hugh Corner and Squadron Leader D. A. H. Robson.

INADEQUATE FEEDING IN HOSPITALS

A STUDY OF CONTRIBUTORY FACTORS*

BY

J. A. F. STEVENSON, M.D. McGill

Major, R.C.A.M.C.; Nutrition Officer, C.M.H.Q., London

JOAN WHITTAKER, B.Sc. McGill

Capt., R.C.A.M.C.

AND

ROBERT KARK, M.R.C.P. Lond.

Lieut.-Col., R.C.A.M.C.; Consultant in Medical Research

Loss of weight, which is sometimes considerable, is not an uncommon occurrence in patients admitted to hospital. In Royal Canadian Army Medical Corps hospitals in Canada losses of weight have been noted in over half the patients observed, and ranged from 10 to 60 lb. (4.53–27.2 kg.).^{1,2} Lyons³ has reported similar losses of weight in soldiers in U.S. Army hospitals. Such findings are certainly not confined to those treated in military establishments, for Elman,⁴ Taylor,⁵ and others have recorded similar observations in civilian hospital patients. At the end of 1943 this state of affairs in Canadian military hospitals in Canada was surprising, since the raw food-stuffs available for hospital use were, according to accepted standards and practices, more than ample.

In this paper, therefore, we record measurements made on actual food intakes of patients in Canadian military hospitals in Canada, and we report observations made during the past few years on factors which have contributed to inadequate protein and caloric intakes. We will also discuss briefly the relationship of so-called "toxic destruction" of protein to loss of body mass and to protein and caloric requirements. Finally, we will present some data to illustrate the effects of a campaign planned to maintain high standards of nutrition in the sick.

Methods

Dietary histories were taken and measurements were made of the food consumed by patients in Army hospitals in Canada. These men were subsisting on the ordinary ("full") hospital diet; they had normal gastro-intestinal tracts and were convalescent after surgical procedures. Over a three-day period all food actually offered to each patient was weighed before and after the meal. Hospital supplementary feedings were measured, and all patients kept a list of extra food supplied by friends or obtained from the Red Cross or the hospital canteen. Food platters were chosen at random so that the servings would represent those usually given by the nursing sister. The caloric, protein, fat, and carbohydrate values of the ingested food were calculated from National Research Council tables of food composition. The results were analysed statistically.

Various aspects of hospital catering which might affect intake of food were studied in over 30 hospitals. Observations were made on supplies of food available in depots, the ordering of

* From the Research and Development Division, Directorate General of Medical Services, Canadian Army, Ottawa.