THE MEDICAL & SURGICAL ASPECTS OF AVIATION

H. GRAEME ANDERSON

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THE MEDICAL AND SURGICAL ASPECTS OF AVIATION

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WITH CHAPTERS ON

APPLIED PHYSIOLOGY OF AVIATION

BY

MARTIN FLACK, M.A., M.B.

LIEUT.-COLONEL, R.A.F.; DIRECTOR OF MEDICAL RESEARCH TO THE ROYAL AIR FORCE

AND

THE AERO-NEUROSES OF WAR PILOTS

BY

OLIVER H. GOTCH, M.B., Ch.B., M.R.C.P. (London)

SURGEON-LIEUTENANT, ROYAL NAVY; PHYSICIAN, ROYAL AIR FORCE CENTRAL HOSPITAL

AND AN INTRODUCTION

BY

THE RIGHT HON. THE LORD WEIR OF EASTWOOD, P.C.

SECRETARY OF STATE FOR THE ROYAL AIR FORCE

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TO

"THE MUSTARD PLANE"

PREFACE

I AM conscious of the fact that this is the first book of its kind, and forgiveness is asked for its many shortcomings. It is rare in modern times to be given the opportunity to find a new subject upon which to write. Aviation, within the last few years, has undergone such enormous developments in the design and construction of machines, making for increased power, stability, speed and climb, that one might be tempted to think that the human machine—the aviator—had been somewhat overlooked. This has not been the case; on the contrary, to some of us in our profession the choice and care of the aviator have proved a new but interesting subject for investigation, and at the same time an absorbing study.

The vagaries of the Great War have thrown many of us out of our "lonely furrow" to plough afresh a new soil, perhaps along totally different lines. The ophthalmologist may have found himself a battalion doctor, the throat and nose specialist in charge of a field ambulance, and the gynaecologist perchance a naval surgeon. In my own case it meant laying down consulting surgical work for the life of an aerodrome medical officer.

On joining the Royal Navy at the outbreak of war I was attached to the Royal Naval Air Service; and, since then, for the past four years I have lived with aviators, flown with them, and entered for the most part into their interests, studying them alike in war squadrons, in aeroplane, seaplane, and airship stations, and in hospitals specially devoted to their maladies. I have also been associated with aviators of our late Royal Flying Corps, with those of the Royal Air Force, and at times with French, Belgian, and American aviators. I have made many friends among them all, and deeply regret the loss of many who have "gone west." My tribute to our flying men is that nothing is too good for them, and that it is up to us as a profession to strive in every way we can to save them from disaster, and should disaster overtake them to find the means to restore them to health again.

The Royal Air Force Medical Service offers excellent prospects to young medical men who have not seen much of the world.

It is to be hoped that the experiences recorded in this book will prove of some value to others who are interested or engaged in similar work.

I wish to express my thanks to Lord Weir for the great interest he has taken in this book, and for his kindness in writing the introduction. Fortune has favoured me in that my colleagues, Lieut.-Colonel Flack, R.A.F., and Surgeon-Lieut. Gotch, R.N., have each contributed chapters.

Every opportunity to carry out investigations on the medical and surgical aspects of aviation has been afforded me by the commanding officers under whom I have served, namely: Wing-Comm. C. R. Samson, R.N.A.S., Wing-Comm. A. W. Longmore, R.N.A.S., Sqd.-Com. P. Shepherd, R.N.A.S., Lieut.-Col. C. E. H. Rathbone, R.M.L.I., Capt. H. D. Briggs, R.N., and Lieut.-Col. F. F. Muecke, R.A.F. Nor can I forget the facilities given me by my two Staff-Surgeons, H. V. Wells and G. D. Bateman.

But my greatest debt is to those who had the patience to teach me to fly, Sqd.-Comm. Hilton Jones, R.N.A.S., Flight-Lieut. Lloyd, R.N.A.S., and Flight-Comm. McMinnies, R.N.A.S. To the latter especially, during two years of association, many of the hours of which were spent in the air together, I have to express my gratitude for his valuable help in all matters relating to aviation.

My warmest thanks are cordially given to Mr. F. F. Burghard for his kindly encouragement and his never-failing advice on all surgical matters; to Surgeon-Lieut. A. G. Holman, R.N., for furnishing me with notes on the effects of cold at great altitudes; to Capt. Coler, R.A.F., and Capt. Drake, R.A.F., for statistics and reading proofs; to Miss Abbott for secretarial work; and to Mr. H. E. Powell, Sub-Librarian to the Royal Society of Medicine, for able assistance in collecting the literature list.

I am indebted to Major Gamble, R.A.F., for many of the unique photographs of aeroplane accidents; to Dr. Shenton and Miss Thompson for the X-Ray photographs, and to Major Lees-Smith, R.A.F., and Lieut. D. G. Brown, R.A.F., for other illustrations. My numerous flying friends are all reminded of the important part they have played in helping me to lay the fruits of over four years' work with them at the mercy of the reader.

H. Graeme Anderson.

101, Harley Street,
London, W.
November 5, 1918.

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INTRODUCTION

The veil which has covered the activities of the Royal Air Force during the war has at length been lifted, and the public is beginning to recognise the immense progress in aviation which has been made under the intensive cultivation of the last four years. From the facts which have now been disclosed it may seem that the conquest of the air has been achieved, both for military and commercial purposes, but the actual operation of aeroplanes, more especially for commercial purposes, still presents difficulties which are not perhaps generally recognised. Mechanical development has in fact, to some extent, outstripped what may be called operational development.

The wonderful technical progress which has been made during the war, is due to the intimate and whole-hearted co-operation of the aircraft designers and manufacturers with the responsible Government department.

We are to-day witnessing the birth of a new industry, concerning itself with the operation of aeroplanes for commercial purposes. The difficulties which the new industry will have to meet, I am convinced, can be successfully overcome, if in the years following the war this spirit of mutual confidence and of co-operation is maintained between the industry and the Air Ministry.

Arising out of this development of the commercial use of aeroplanes, it appears that among the responsibilities which in the interests of the public, the State, through the Air Ministry, will have to undertake, is that of safeguarding the all round fitness, both technical and medical, of the commercial pilot. Technical fitness can be secured by a sound system of training. Medical fitness is more dependent on the individual himself, but as has been discovered during the war, a great deal can be done by proper methods of selection, supervision and physical training.

Great as is the importance of the work which has been carried out by the Medical Authorities of the Royal Air Force in war time, it seems right to forecast that it will prove of no less value in the years of peace. An account of the methods by which it has been developed to meet the special needs of the Service, will be found in Surgeon-Lieut. Graeme Anderson's book, together with the review of our present knowledge and practice in regard to the medical and surgical aspects of flying in general. The author is himself a pilot, and has had during the war an extensive experience of the subject on which he writes. His present work is the first to deal with this new and important branch of medical study, and will serve to stimulate further research into the many and varied problems which still require elucidation.

WEIR.

January 11, 1919.

THE MEDICAL AND SURGICAL ASPECTS OF AVIATION

CHAPTER I

The History of Medical Interest in Aeronautics and Aviation

At the end of this book will be found a list of the literature relating to the medical and surgical aspects of aviation. It will be seen by the comparatively large number of contributions and contributors how great of recent years has been the interest of our profession in aviation.

There is probably no doctor with such a wealth of knowledge of aeronautics and aviation from the historical point of view as Dr. F. J. Poynton, to whose kindness I am greatly indebted for many of the facts of medical interest relating to ballooning. In 1767 a physician, Dr. Black, of Edinburgh, came within an ace of being the inventor of the first balloon. He suggested that hydrogen gas would be capable of raising a thin bladder in the air. The first serious study of aeronautics made in the autumn of 1783 was marked by investigations on strictly scientific lines, in that various beasts and birds were sent up by the Montgolfiers to test the possibility of existence in the air. At Versailles a sheep, a cock, and a duck were sent up in a balloon which ascended a few hundred feet and came down half a mile away. These animals were found none the worse for their experience except that, for some unexplained reason, the cock was found to have its leg broken. In the *European Magazine* of that date is a quaint engraving of a sheep alighting after a flight, to the joy of the spectators around.

November 21, 1783, saw the first aerial journey in a balloon by De Rozier and the Marquis D'Arlandes. They ascended to 3,000 feet, but in the account given by the latter no mention is made of any physical inconveniences in the flight. In the second aerial journey, however, which was made by Charles and Roberts on December 17, 1783, these pioneers ascended to 6,000 feet and remained up for one and a half hours. On landing Roberts got out and Charles alone ascended to 9,000 feet. He became benumbed with cold, and felt severe pain in the right ear and jaw, but he held on and went to 10,500 feet. This is the first record of physical discomfort suffered in the air.

In this country the first balloon ascent was made by a Scotsman, Tytler, at Edinburgh, on August 15, 1784. In September, 1784, the Italian, Lunardi, became our first aerial traveller. The first Englishman to go up was a surgeon, John Sheldon, then Professor of Anatomy at the Royal Academy. Full of scientific enthusiasm he accompanied Blanchard in his second balloon ascent in England. But history states that science was thrown to the winds, and that the chief concern of these voyagers was to reach the earth in safety. Although no facts of medical interest were recorded, owing no doubt to the good doctor having the " wind up," it is gratifying to us as a profession to know that the first Englishman to ascend was a medical man.

On January 7, 1785, Dr. Jeffreys, an American physician, accompanied Blanchard in a balloon journey across the English Channel. Ascending from Dover they landed in France in the forest of

Guines. This journey was also undertaken with scientific ends in view, and among the gear carried were "Letters for the French, philosophical instruments, a bottle of brandy, biscuits, and two cork jackets." Unfortunately during the flight all these had to be cast overboard; and it is even recorded that the aeronauts had to part with most of their clothing. In June, 1785, an attempt was made by De Rozier and Romain to cross by air from France to England, but the balloon caught fire in mid-air, and both aeronauts perished.

In 1785 another medical man, Dr. Fordyce, accompanied Lunardi in his balloon flights in Scotland, but there is no evidence that he added any observations of medical interest about flying. Blanchard in 1785 first used parachutes, by means of which he lowered dogs from balloons. A few years later he made a parachute descent himself and sustained a broken leg.

Almost the first handbook on aeronautics in the English language was the *Aeropaidia*, by Baldwin, published in 1786. Although he was not a medical man Baldwin heartily recommended balloon ascents for convalescents in the following words:—"The spirits are raised by the purity of the air and rest in a *chearful* composure." In conversation with a pre-war balloonist the other day the fact was elicited from him that during a balloon trip all worries and mental disturbances disappeared as by magic, thus confirming the "chearful composure" described in early days. Baldwin also advised scientific investigations of "tastes and odours at different heights," and commented on the possibility that a change "from hot, putrid, and impure, to cool, pure air, impregnated with the invigorating aerial acid, may contribute without the aid of drugs to the recovery of the sick and invalid." With a grim sense of humour he advised ballooning to promote longevity.

It is interesting to find that the celebrated American aeronaut, John Wise, who was a piano-maker and suffered from dust phthisis, wrote that "From the devouring ravages of such a complicated disease the practice of ballooning relieved me." This rather justifies Baldwin's advice, although it is recorded that Lunardi died of phthisis.

As to the therapeutic value of flying, the future holds great possibilities. Flammarion records that he ascended in a balloon with an attack of influenza on him, and that when he came to earth he was completely cured. In Hamel and Turner one reads that a gentleman at York, while suffering from neuralgia, made a passenger flight in an aeroplane, and on landing found that the pain had gone; and that Hubert Latham, the aviator, suffered from early phthisis, but after taking up aviation enjoyed good health. The sanatorium airship may yet have its day. There is no doubt that flying improves the appetite and health generally.

As a rapid means of rendering first-aid the aeroplane is invaluable. The author was the first to institute this method of travelling to aeroplane accidents, and has now made between thirty and forty such journeys. (See Chapter VI.) The French conceived the idea of having aerial ambulances to convey quickly the wounded—especially gun-shot wounds of the abdomen and chest—from the dressing posts just behind the firing line to hospitals well equipped for dealing with such surgical emergencies, and situated outside the range of hostile artillery. Nemirovsky and Tilmant have lately organised an aeroplane, which they have named the "Aerochir," to carry a pilot, a surgeon, and a radiographer who can also act as assistant surgeon, as well as an equipment consisting of an X-Ray apparatus, a steriliser, surgical instruments, accessories and dressings. The electric current from the aeroplane can be used, with the addition of a transformer and an interrupter, to work the X-Ray apparatus, and also the steriliser. The following advantages are claimed for the "Aerochir":—(1) That by its means surgical aid can be brought quickly; (2) The surgeon is brought to the patient and the latter saved a journey before receiving surgical aid; (3) It does not increase traffic on roads required for purely military purposes; and (4) Formations of these aeroplanes can rapidly transfer surgical aid from one part of the line to another where an attack may have suddenly occurred. In future wars, with the possibility of large formations attacking each other, one may find, hovering on the outskirts of a battle royal in the air, first aid aeroplanes, surgically equipped, distinguished by the Red Cross, and each carrying a surgeon and sick berth attendant, ready to follow down and render aid to a fallen aerial combatant.

With regard to the effects of altitude on the human body it is interesting to study the first accounts amongst the balloonists. At Hamburg, early in 1800, Robertson, with a companion, in a balloon ascent to 21,500 feet, suffered altitude effects. The chest felt enlarged, voices became almost inaudible, and there were noted ear trouble, swelling of the lips, prominence of the eyes, and epistaxis. The Russian aurist, Sakaroff, accompanied Robertson on one of his trips, and made scientific observations. In 1800 Gay-Lussac and Biot, in a balloon ascent in France, were similarly affected. The height reached was 23,000 feet, and Lussac was affected by the cold; his fingers became benumbed, he had laboured breathing, a quickened pulse, parched throat, and headache. In the same year Count Zambeccari, Dr. Grassati, and M. Andreoli made an ascent to a high altitude, and the two former became unconscious. They noted the inaudibility of their voices at great heights, and also the effects of cold. They suffered severely, and were nearly frozen to death over the Adriatic.

These seem to be the first records of altitude effects on the body, and the train of signs and symptoms were known under the name of balloon sickness. Madame Blanchard suffered from severe epistaxis at 22,800 feet. The first detailed records of altitude effects are gathered from the historic ascent of Glaisher and Coxwell to 31,000 feet. The former's records show that at 18,844 feet his pulse was quickened to 100—at 19,415 feet his breathing was affected and he had palpitation—at 19,435 feet his pulse was quicker, his hands and lips bluish in colour, and he could with difficulty read the instruments—at 21,792 feet he suffered from sea sickness, although there was no rolling or pitching of the balloon,—at 24,000 he became unwell—at 29,000 feet he had great muscular weakness; he says, "I seemed to have no limbs," and then he fell back insensible for seven minutes. Coxwell's hands became frostbitten, he was attacked by great weakness in the limbs, but managed to open the balloon valve by pulling on the valve cord with his teeth, and thus to save the situation for both. On descending recovery seems to have been very rapid, as shortly afterwards both aeronauts were able to walk about seven miles.

Gaston Tissandier, Sivel, and Crocé-Spinelli all suffered from altitude effects. Prominent among the signs and symptoms were difficulty in breathing, loss of muscular power, venous congestion, nasal and pulmonary haemorrhage, headache, vomiting and torpor. Even death has resulted, and both

Sivel and Crocé-Spinelli met their fate in this manner. Sivel, in 1875, when at 23,000 feet, wrote, "I am inhaling oxygen, the effect is excellent." At 25,000 feet Tissandier wrote, "I feel stupefied and frozen, Crocé-Spinelli is motionless in front of me; the mind and body weaken by degrees and imperceptibly without consciousness of it; no suffering is then experienced, on the contrary an inner joy."

Dr. A. Berson in 1894 ascended to 30,000 feet, was aloft five hours, but inhaled oxygen all the time and was unaffected. Other physical illnesses have been recorded as occurring in the air; it is said that Blanchard was seized with an apoplectic stroke during an ascent; in 1824 Lieut. Harris, R.N., and Miss Stocks made a rapid balloon descent; the former was killed, but the latter fainted and escaped without injury. Her nerve was not affected, and she made three subsequent ascents. Observations of medical interest on the influence of air pressure on the ear were made by Alt in a balloon ascent. He examined his companion's ear during the flight, and verified the decrease in the power of hearing and such symptoms as pain and buzzing in the ears. He noted that the tympanic membrane became congested and was pushed back during the ascent.

These early pioneer aeronauts are to be greatly admired for their courage, and to them are due many facts of fundamental importance in the medical study of aeronautics. They showed us the qualities and daring temperament necessary for the successful aviator, the possibility of the human body withstanding flight in mid-air and the endurance of long flights (Green in his famous flight from London to Germany was eighteen hours aloft), and they also gave us our first records of altitude effects on the human body. It is gratifying to note the prominence taken by medical men in these early ascents. The names of three—Dr. Sheldon, Dr. Jeffreys, and Dr. Fordyce—should go down in history as the forefathers of our R.A.F. medical service. Another medical man should be mentioned, Dr. McSweeny, who, although he gave us no facts of medical interest, wrote an essay in 1844 on aerial navigation and practical ballooning.

Many investigations have been carried out on the effects of altitude on human and animal life. In Peru in 1890 Viault noted an increase in the number of red blood cells at great mountain heights. This was verified in 1901 by Gaule in a balloon ascent. Abderhalden in 1902 investigated the influence of high altitude on the blood of rabbits—and on Pike's Peak similar investigations were carried out on the human body by Haldane, Douglas, Henderson and Schneider. Armand Delille, André Mayer, and Jolly demonstrated that no change occurred in the blood from the heart in high altitudes, but that the peripheral blood alone showed polycythaemia. Victor Henri investigated the effects of altitude on the gases of the blood. Hallion and Tissot studied arterial pressure and respiratory changes in relation to high altitude. Dreyer and Ainley Walker, in the *Lancet* of October 25, 1913, discussed the effect of altitude on blood volume.

Mention must be made of the work done on altitude effects by Mosso and by Aggazotti in Italy; and also of the investigations on mountain sickness carried out by the Germans Zuntz, Duric, and colleagues. But the wonderful researches of that famous physiologist, Paul Bert, on the effects of diminished atmospheric pressure have remained since that time (the seventies) as the basis of all subsequent work on altitude effects.

In the time intervening between ballooning and aviation came the period of the gliders, in which man made his first attempt to fly, using an apparatus heavier than air. These glides or flights were made from hillsides, from specially constructed towers, and from balloons. This period, which heralded the birth of aviation, gave us no facts of medical interest save the study of the psychology of these daring gliders, and the surgical disabilities which resulted from their daring. Nevertheless it will be found of value to study the work of those pioneer gliders, Montgomery, Lilienthal, Pilcher and others. From 1891 till 1896, when he met his death in a gliding trial, Lilienthal made many glides, and a study of his writings is peculiarly interesting from the psychological point of view. Once in a gliding experiment he fell 65 feet to earth, and he writes thus: "With my senses quite clear, my arms and my head forward, still holding the apparatus firmly with my hands, I fell towards a greensward; a shock, a crash, and I lay with my apparatus on the ground." And again, "I often reach positions in the air which are much higher than my starting point. At the climax of such a line of flight I sometimes come to a standstill for some time, so that I am enabled whilst floating to speak with the gentlemen who wish to photograph me regarding the best position for the photographing." These last few lines reveal to the author more than anything else the psychology of these pioneer aviators. It was Lilienthal's death in a gliding accident in 1896 that caused the Wright brothers, four years later, in 1900, to begin their researches on aviation, which culminated in the first aeroplane flight on December 17, 1903. From that historic date others took up the new art, notably Henri Farman and Leon Delagrange; and in the year 1908 we find aviation well established.

The first Englishman to fly was Moore Brabazon, in 1909. The Services took up aviation in 1912 with the establishment of the Royal Flying Corps and a naval wing—the latter destined to become the Royal Naval Air Service, now of happy memory.

From 1903 till 1907 the author can find no records of medical interest in aviation. In 1907 there was published in Paris a pamphlet of five pages by Dr. Naquet, entitled: *Physiologiques* (*quelques Considérations générals et*) *sur les Ascenscionnistes, Aeronautes, et Aviateurs.*

During the Circuit de l'Est in 1910 in which the contestants were compelled to fly regardless of weather, the German Lindpainter had to give up because of physical and nervous exhaustion; and another candidate on alighting crawled under his machine and went to sleep. In 1910 Moulinier, in France, investigated the arterial tension among aviators at high altitudes. In 1911, in France, Cruchet and Moulinier published their findings on arterial tension, altitude, and aviator's sickness; Bonnier recorded his investigations on the "Capacité manostatique" among aviators; Reymond wrote on the reflexes in aviation, and Rouch on aviation schools and military medicine. In Italy work was published in the same year by Falchi and Nieddu-Semidei, and in Russia by Prof. B. Okouneff on the aural question in relation to aviation. Some military balloonists had consulted the latter on deafness due to ascents, and subsequent compensation. Hence his investigations into the effects of rarefied air on the organs of hearing. The only article of medical interest in aviation in this country appeared in *Flight* on May 6, 1911, by F. I. Wilbur, entitled, "Aviation and Common-sense."

With the formation of the Naval and Military Wings of the Royal Flying Corps in 1912, two Service medical officers were appointed, namely: Staff-

Surgeon H. V. Wells, R.N., to the Naval Wing, and Captain E. G. R. Lithgow, R.A.M.C., to the Military Wing. Both were happy selections, as these doctors developed a keen interest in practical aviation; and it is to their credit that they were the first medical men in this country to learn to fly. Lithgow obtained his Royal Aero Club Aviator's Certificate, No. 414, on February 4, 1913, at Upavon on a Short biplane, whilst Wells obtained his, No. 490, on May 24, 1913, on a Bristol biplane at Eastchurch.

The year 1912 also saw work in France by Crouzon on arterial tension, and by Marquis on practical hygiene of the aviator and aeronaut: in Italy by Falchi, and the first German contributions by Flemming and by von Schrotter. In 1913 we find in this country Wells laying the foundation of his work to be published later, and the late Dr. Adler doing the same by making flights with Hamel. In France a paper was read by Dr. Reymond, a senator, at the Paris Congress, in which he comments on the effects of flying on cardiac disease and pulmonary tuberculosis, pointing out how badly the emphysematous and asthmatic suffer through flying, giving hints on clothing and hygiene, and predicting the great possibilities in the medical investigations into flying; a small article by Legrand completes the French contributions for that year. In the same year there were articles by Cowley in Havana and by Friedlander, Huss, and Von Schrotter in Germany.

In 1914 the late Dr. Adler published the first article in this country on the medical aspects of aviation in a separate chapter in Hamel and Turner's book on Flying, although it must be remembered that Wells had really commenced before him, and also had his first paper completed, although not published. In this year also we find the first contribution from America in Ovington's letter on "the psychic factor in aviation." In Germany contributions were made by Halben, Koschel, Loewy and Placzek, Marx, Suring, and Volkmann.

Just after the outbreak of war the author, in association with Wells, investigated the injuries and destructive effects of aeroplane bombs in Belgium and France. Early in 1915 Wells embodied the results of his invest gations of 1912-1913 in an article on "The Flying Service from a Medical Point of View," which was published in the Journal of the R.N. Medical Service. In this he discussed the questions of high velocity accidents, safety belts, safety helmets and clothing, and dealt with the physical requirements of candidates for the flying service. He found that the researches into pulse rate and blood pressure were unsatisfactory during flight, owing mostly to the vibrations of the aeroplane affecting the pressure recording instruments.

Willcox, Spilsbury, and Legge published the results of their investigations on aeroplane dope poisoning. In Germany an article by Schoppler, of medical interest appeared. In the latter half of 1915 the author was investigating aeroplane accidents.

The year 1916 saw another communication by Wells on "Some Aeroplane Injuries and Diseases, with Notes on the Aviation Service." In this he dealt with injuries to the neck and eye in aeroplane accidents, and cautioned against the danger of sending an apparently unhurt aviator into the air again immediately after a crash to prevent loss of nerve; he gave a detailed account of a case of frost bite occurring in an aviator at 15,000 feet in winter time; he commented on the question of ill effects from petrol vapour and exhaust gases to the aviator during flight; he described the nervous breakdowns of flying pupils and coined the word

"Aerosthenia" to cover these conditions; and he touched on the importance to the pilot of eyesight and free joint movements of the lower limbs. In this country also Knott published an article on aviators' sickness, while from American sources came a contribution from Holloway and one from Cottle, a medical officer of the U.S. Navy, on "Naval Aviation Personnel." Splendid work was also done in Paris by Camus, Nepper, and Binet on the reaction times of aviators and on the physiological reactions to various shocks as a means of picking out the best aerial fighters; while in France also, Ferry published an interesting article on an experimental study of arterial tension in aviators, and articles came from the pens of Vorbe and Rocher.

In 1916, Captain Halliwell, C.A.M.C., graduated as a flying officer, and did war flying as an active service pilot. He is the only medical man of our empire who has earned this distinction, although some medical students were active service pilots, and one at least has since qualified as a doctor. The author obtained the Royal Aero Club Aviator's Certificate, No. 3758, on October 26, 1916, at Eastbourne, on a Maurice Farman biplane.

In October, 1916, there was formed a special Medical Board of the R.F.C., consisting of Dr. G. A. Sutherland, Mr. A. H. Cheatle, and Major Lithgow, to deal with the medical selection of flying officers and also with invaliding and disposing of those injured or broken down. 1917 was a year of great developments. Many contributions to the literature on the medical aspects of aviation were made by American writers, notably those by Small and by Blaauw on visual requirements, by Chamberlain, Connor, and Green on medical examination standards; by Babcock on Barany tests, and by Jones and Guggenheim on otology in relation to aviation.

Lacroix, in France, contributed an article on otology, and Gemelli in Italy one on blood. Delapchier, in France, was the first to record a case of fracture of the astragalus in a parachute descent.

The R.F.C. Special Medical Board did splendid work and had to be considerably augmented. Major Lithgow's long experience of aviation was of very considerable value on the invaliding board, and notable work was done by Cheatle in the elaboration and application of various tests to determine the neuro-muscular stability of aviators, and by Sutherland on the investigation of cardio-vascular debility in those who had broken down through stress of flying.

Early in 1917 a meeting took place between the naval medical authorities interested in aviation, the R.F.C. special medical board, and a body of medical, physiological, and technical experts. Various medical aspects of aviation were discussed, and standards of vision and fitness for flying were drawn up. In April, 1917, Martin Flack, from the Medical Research Committee, was appointed adviser on research connected with the physiological aspects of flying. The value of his work cannot be over-estimated, and has proved of very great help in the selection of candidates for aviation, and in determining those who are on the point of showing fatigue and suffering through stress of flying.

In France Major Birley, R.A.M.C., was superintending all the R.F.C. in the field. In the same country the author was attached to a large flying school where unique opportunities were afforded in the study of the flying pupil, and where also the author carried out his "blindfold" experiments in the air to test the sense of balance in flight. The last item of medical interest in 1917 was the formation of a Central Air Hospital for investigating the ailments of both naval and military flying officers.

The present year, 1918, has been historic in that it has witnessed the fusion of the Royal Naval Air Service and the Royal Flying Corps into a single service, namely, the Royal Air Force. Accompanying this has been the formation of a new Air Force Medical Service. Under the able command of Lieut.-Colonel F. F. Muecke, R.A.F., the Central R.A.F. Hospital has now become well established, and many auxiliary hospitals have been attached to it.

In an address to the Medical Society of London on March 11, 1918, on the selection of candidates for the Air Service, the author suggested the formation of a special medical flying school where the standards of fitness demanded of the aviator could be put to the test, and where also certain "border line" cases of pupils turned down from flying could be investigated. This has since been carried out, and there valuable work has been done by Captain Rippon, R.A.M.C., Dr. Head, and Dr. Rivers.

Mention must also be made of the good work carried on all along by Dr. Atkin Swan and his colleagues at the R.F.C. hospitals. In 1918 four more medical men have learnt to fly, namely :—Captain Tredgold, R.A.M.C., Captain Hearn, R.A.M.C., Lieut.-Colonel Heald, R.A.F., and Lieut.-Colonel Taylor, R.A.F. The year has produced many contributions of medical interest to the literature by French, American, and British writers.

CHAPTER II

The Selection of Candidates for Aviation

The Development of Aviation

All will agree that one, if not the outstanding, feature of this present war has been the remarkable development of aviation. Scarcely ten years ago the pioneer aviators were looked upon as men possessing some supernatural quality—the power to fly. Then man began to teach man, and the institution of dual control instruction, in which teacher and pupil fly in the same aeroplane, each with a set of controls acting in unison, paved the way for many to learn flying. The services—naval and military—organised flying corps, and the possibilities of this new arm in warfare were seriously considered. On the outbreak of war the personnel of the Air Service was increased, and there was a great demand for pilots. As loss and wastage occurred this demand grew and methods of training in flying were intensified. Accompanying this have been the development in aeroplanes of speed, power, and construction, and the institution of long-distance flights, high altitude flying, night flying, and specialisation in different forms of flying—*e.g.*, aerial fighting, reconnaissance, and photography, bombing, testing, and instructing.

The Aviator's Duties

To realise the value of the standards of fitness required it is well to know something of the aviator's duties in war-time. On the one hand, he has usually comfortable quarters, a good bed and food, and has not to undergo the long marches and discomfort of trench life as in the infantry work. He is usually out of range of enemy artillery fire, although subject to hostile aircraft attack. In weather unfit for flying he has much leisure time. On the other hand, in the few crowded hours of his daily work he may come through the most intense strain to which the human nervous system can be subjected. As it has been aptly put, an aviator's life consists of "long spells of idleness punctuated by moments of intense fear." He has to face extremes in the elements, intense cold, the sun's glare, rain, wind, fog and mist, and gusty or bumpy weather. There is the incessant noise of his engine; he may have long-distance patrols, in which the imagination is given free-play to run riot, perhaps over the sea, with no landmarks and the dread of engine failure ever present in his mind. His visual acuity is sharpened, always on the look-out for hostile aircraft, watching for and registering the flash of enemy guns, taking photographs, noting movements of enemy troops, rolling-stock, submarines, or other information of naval or military value, and subjected to more or less accurate anti-aircraft gun fire from the ground. Often he has to reach altitudes where the available oxygen is reduced by one-half. He may have suddenly and rapidly to change height, as in the modern aerial fight in which he may be opposing more than one enemy machine. His judgment has to be most accurate to perform the various intricate aerial evolutions so as to outwit his opponent and gain a favourable position to rake him with machine-gun fire. He may have to loop, spin, dive, or side-slip, apparently out of control, in order to deceive his opponent or to decoy him over a friendly gun or near a friendly formation. There is the subconscious dread of his aeroplane catching fire in the air. Lastly, and most exciting of all, is the nerve-strain of contour chasing or ground strafing, in which he attacks the enemy on the ground from a low height of perhaps 20 to 50 feet.

Basis of Present Investigation

With regard to the views to be expressed on the standards of fitness for such work, these are not to be taken as representative of any particular Service.

We can help in framing standards of fitness for flying by knowing the requirements of the aviator's life, by studying the psychology and physiology of flying, and by investigating the maladies commonly found among flying men. By such means standards of fitness can be drawn up subject to modification from time to time. In eliminating the unfit the author would suggest the institution of a special flying school where border-line pupils could be instructed in flying under patient and sympathetic instructors and with a medical officer, specially interested in aviation, carefully recording the results. Such records would be invaluable to us in confirming or modifying the present standards of fitness required for air work. The modern aviator's work is becoming more and more specialised, and here again we can help by framing standards of fitness graded for the various flying duties.

Physical Requirements

In selecting candidates for the Air Service what is looked for is a sound constitution, free from organic disease, and a fairly strong physique in order to withstand altitude effects, such as cold, fatigue, and diminished oxygen. It is essential there should be normal hearing and good muscle and equilibration sense.

Eyesight.—As the aviator is so dependent on his eyesight, too much importance cannot be attached to this part of the examination.

Temperament.—But next to vision, and most important of all in obtaining the best aviator, is the question of temperament. Undoubtedly there is a particular temperament or aptitude for flying, and its distribution is peculiarly interesting, whether looked upon from its racial aspect and ethnological origin or in relation to previous health, life, and habits. Unfortunately, this temperament is a difficult matter to estimate clinically, and especially so in the examining room. The ideal aviator must have good judgment, be courageous, and not upset by fear, although conscious of the perils of his work. He must be cool in emergencies, able to make careful and quick decisions and act accordingly. His reaction-times must never be delayed—he must be ever alert, as mental sluggishness in flying spells disaster. Whether he should be imaginative or not is a difficult question to settle—one meets many of both types. The author is inclined to think the individual with imagination, yet able to keep it well under control, makes the better pilot.

Previous Training in Sports.—With regard to relation of habits in this special aptitude for flying, the latter is found most commonly among those used to playing games and leading an outdoor life. The yachtsman and the horseman, with their finer sense of judgment and "lighter hands," should make the most skilful pilots. The Germans until recently always selected their aviators from their cavalry. It was thought that the racing motorists would make the best pilots, but this has not always been proved to be so. Every now and then one meets the type with splendid physique and apparently unshakable courage and finds that he learns to fly indifferently or is unable to learn at all, and again one meets the weedy, pale type learning quickly to fly and turning out to be a first-rate pilot.

Family and previous History.—In estimating whether the candidate is likely to stand the strain of war-time flying much help can be given by inquiring into his family history as well as the history of his previous health.

MEDICAL TESTS OF AVIATION CANDIDATES

Candidates for the Air Service should be made to undergo (1) a surgical examination, (2) a medical examination, and (3) a special sense examination, preferably by experts in each line ; the final selection should be made on the total results by a medical selection committee.

(1) Surgical Examination.

General.—In the surgical examination the age, height, weight, and general physique are considered.

Age.—The age should be between 18 and 30 years. Under 18 and up to 20 caution and well-balanced judgment may be lacking ; 24 is about the best age. Over 33 the candidate, although quite able to learn to fly, does not stand the nerve-strain of air work so well. Much depends on the physiological age. Cody learnt flying at 47 and was flying regularly till he met his death when 52 years of age.

Height does not matter much, but the candidate should not be under 5 feet, as he would have difficulty in reaching the rudder bar or looking over the cockpit of the aeroplane.

Weight.—Naturally the lighter the candidate the better, but in modern times with the increased speed and climb of aeroplanes this does not count so much as formerly. Colour, physique, attitude, and tone of muscles should be noted, especially the abdominal muscles, where lack of tone would allow of splanchnic flooding and the possibility of fainting in the air. Any surgical defect, no matter how small, should be recorded in the report, as such may be used and its significance exaggerated later by a pilot who has developed a distaste for flying.

The previous History of Wounds and Injuries.—These injuries have to be carefully considered—especially injury to the head, followed by prolonged unconsciousness of recent origin. The author has known a few such cases, who were all slow to learn, made indifferent pilots, were easily fatigued, and quite unfit for war work in the air. These cases all had symptoms dating from their injury—*e.g.*, headaches, easily fatigued, emotional and subject to vertigo, and physical signs, such as instability of muscle and equilibration sense. Should the head injury not be of recent origin, the candidate have no symptoms and be able to pass the tests, he should be placed in the special school which has been suggested. Any evidence of epilepsy, vertigo, migraine, persistent headaches, lack of concentration, and easily induced fatigue should disqualify. Loss of cranial vault need not disqualify. Recently the author passed such a pilot as fit for flying. He was able to pass all the tests, and had quite a large piece missing from the frontal region of his skull. Trunk injuries may disqualify, depending upon the amount of disablement and deformity. The author has had four cases of fracture of the spinal column without injury to the spinal cord. One has a marked kyphosis and is not allowed to fly. Two have been fitted with light pexuloid jackets, which give considerable help. It has to be remembered that the pilot's seat, unfortunately, is not built for comfort. Though he lacks personal experience of cases of gunshot wounds of the thorax who have returned to flying duties, the author feels sure that these should not be rejected unless they fail to pass the altitude tests as devised by Lieut.-Col. Martin Flack, R.A.F.

Disabilities to Extremities.—With regard to whether disabilities of the extremities should cause rejection or not, their significance depends on the extent to which they interfere with the power to work the controls or use the machine-gun. An aeroplane nacelle with the controls attached to a dynanometer registering the minimum force required to control and fly the machine can be used to estimate disabilities of the extremities.

With regard to the upper extremities, it is important to remember that most movements in controlling the aeroplane are performed below the level of the shoulder. Dr. Head recently asked the author to see a case of a pilot with deficient lower trapezius muscle action on one side, so that he could not use the one arm above the level of the shoulder. It was pointed out that this pilot could quite well control the aeroplane, but would be prevented from freeing a jamb in a gun mounted on the upper planes. It is much more important that the candidate should have both arms intact than both legs. Quite a few with one leg have still been able to fly, and should the amputation be below the knee an artificial lower leg and foot will act quite well on the rudder bar. Should the amputation be above the knee the artificial leg is dispensed with in flying and the normal foot is strapped to the rudder bar, the latter being pressed forward or drawn backward in the aeroplane's control by the sound leg.

Those with orthopaedic disabilities, such as contractures, partial loss of power or limited movements in certain joints, should be tried in the examining nacelle. Those with limitation of movement in the ankle joint should be passed for employment in seaplanes and other types requiring less delicate control than fast single-seaters. The author has known a pupil with congenital dislocation of one hip who had no difficulty in learning to fly.

Old infantile paralysis cases should be rejected, owing to the danger of trophic lesions being produced by the cold of altitudes. Candidates suffering from venereal disease must be temporarily rejected. To fly well one must be temperamentally as well as physically fit; and in venereal disease, with all its attendant worries, full attention and concentration on flying, so important in the tuition stages, cannot be given.

(2) The Medical Examination

Before proceeding with this examination a careful record is made of the candidate's (*a*) previous occupation, habits, and mode of life; (*b*) previous health; and (*c*) family history.

(*a*) *Previous Occupation, Habits, and Mode of Life.*—As a general rule those whose previous occupations have been of an outdoor nature and those who have been accustomed to playing outdoor games make the better aviators, although, as in most things, the exception to the rule is occasionally to be found in the thoughtful, quiet, student type who rarely plays any games yet surprises everyone by his rapidity in learning to fly and in developing light hands; and conversely we meet the type with fine physique, splendid courage, and in glowing health, who learns to fly with difficulty and develops hands like hams as far as piloting the aeroplane is concerned. It should be remembered that all aviation pupils are made to undergo physical training, and are given opportunities to indulge in various outdoor sports at most flying schools. Thus many weedy and flabby individuals are soon licked into shape.

An inquiry is made into the candidate's habits, especially in relation to tobacco and alcohol, although very little real knowledge is gained in the examining room. Most flying men smoke a great deal and very few are strict teetotalers. Excess in smoking certainly leads to palpitation, shortness of breath, and in some cases double vision, and these dangers should be explained to candidates. Very few confess to excess in smoking, and one records with a hidden smile the candidate's statement that he smokes five cigarettes a day, whilst the sunburnt condition of the middle and index finger of his right hand bears silent testimony to a much greater daily expenditure in tobacco. Although the author himself is not a teetotaler, he firmly believes that excess in alcohol will ultimately spoil the aviator. Among pupils at a flying school alcohol should be strictly forbidden and candidates should be warned of its danger. An aviator may fly under the influence of alcohol and yet by instinct perform remarkable aerial stunts. And in one case which was observed the passenger was sick over the side of the machine, while the pilot, who was under the influence of drink, was not affected, though the mere fact of his attempting such evolutions on an old and unsuitable type of machine showed that his judgment was below par. Fortunately, nothing worse happened. The author knows of another accomplished aviator who after a few drinks at a friendly aerodrome did a series of stunts and then made off home, a distance of thirty miles. He felt content but sleepy, made up his mind to do no more stunts in the air, and remembered coming down to land in his own aerodrome. Later he woke up in the sick bay with a doctor stitching a scalp wound. Although he made up his mind to do no more stunts, onlookers saw him loop and roll the machine a number of times when coming down to land. There seems little doubt that the action of alcohol is accentuated in the air.

(*b*) *Previous Health.*—A great deal of help can be given from a careful inquiry into the candidate's previous health. Recent temporary illnesses such as influenza and tonsilitis may hinder a candidate from passing the tests, yet his rejection should only be temporary and a re-examination should be carried out later. A history of untreated or imperfectly treated syphilis should be a cause for rejection. A history of malaria with recent attacks should be a cause for rejection. In the author's experience malarial cases rarely do well in aviation, and he has had to invalid out quite a considerable number. The cold experienced in flying undoubtedly precipitates malarial attacks. If malarial cases are allowed to fly at all they should be made to do so in warm climates. A history of epilepsy or *petit mal* should disqualify a candidate. Elsewhere the author has recorded the case of a pupil who was slow to learn and was on the point of being turned down on that account alone. He was given another chance under another instructor, who reported fairly satisfactory progress, but one day the pupil in one of his early solo flights failed to flatten out, the aeroplane hit the ground at its gliding angle, and he was thrown clear of the crash a distance of 66 feet and found quite unhurt, although a little dazed and mentally slow. A few days later in the mess this pupil was seized with a typical epileptic seizure, which was repeated the same night and the following day. A confession was then forthcoming that he had suffered from epilepsy for the previous five years and that he had taken bromides regularly. An epileptic seizure in the air was undoubtedly the cause of the crash.

Candidates with a history of neurasthenia, nervous breakdown, or mental depression, rarely do well in aviation. Similarly those with a history of shell shock soon develop some form of aero-neurosis. Such histories should be estimated from the standpoint of date, duration, original severity, and the lapse of time with freedom from symptoms. Having made careful inquiry into the value of a history of sea-sickness and train-sickness the author would not reject a candidate on such grounds unless for balloon work. Cases of real air sickness—that is, sickness due to the rolling and pitching of the aeroplane—are comparatively rare. The actual vomiting usually occurs not during the flight, but immediately after the landing. Should a pupil be unduly liable to air-sickness, this tendency is usually discovered quite early in his training whilst under dual control instruction.

A history of recent tuberculosis of the lungs should cause rejection at once. The author knew one pupil who escaped the usual entrance medical examination and who had active pulmonary tuberculosis. The cyanosis and respiratory distress he showed in his trial flight were really alarming. He was taken aside and treated to a good heart-to-heart talk. He confessed to his disease, and said he knew he could not get into the Army, but he was keen on flying and, in his own words, "did not care a damn how he finished up." Examination revealed extensive and advanced tuberculosis of the lungs. Finally he was sent to the south of France. A history of asthma, chronic bronchitis, or pleurisy would cause rejection.

(c) *Family History.*—The family history, especially with regard to diseases of the nervous system, may shed some light on the type of soil with which we have to deal, especially in relation to the strain of war flying.

The Renal, Digestive, Circulatory, Respiratory, and Nervous Systems

In the medical examination these systems are investigated.

(*a*) *Renal.*—The urine is examined for albumen and sugar ; if present the candidate is rejected.

(*b*) *Digestive.*—In examining the digestive system, note is taken of the tone of the abdominal muscles. If the tone is poor and there is some dilatation of the stomach—danger signals that splanchnic flooding and fainting in the air may occur—these cases are sent back for physical training, and if passed for flying duties should be advised to wear an abdominal belt.

(*c*) *Circulatory.*—If any organic disease of the heart is found the candidate is rejected. Equally important is any evidence of instability of the vaso-motor system. Raynaud's disease would disqualify. Candidates showing coldness of the extremities, with signs of defective peripheral circulation, and a history of easily induced chilblains, should not be allowed to fly at great heights but rather graded for low-flying duties. Among some aviators who break down and exhibit some type of aero-neurosis it is found that there are signs of vaso-motor instability—*e.g.*, the radial pulse is not well sustained with the arm overhead, there is a large pulse pressure on examination with the sphygmomanometer, and there are signs of defective peripheral circulation in the extremities. Candidates showing such signs do not last long as aviators. Further investigation is required in such cases. The author would not reject them altogether, but rather place them in the special flying school. Many of these cases may be due to recent temporary illness, and, again, many can be improved by physical training. Personally the author does not attach much importance to the pulse-rate. Of a large number of pupils whose pulse-rate he examined before and after their trial flights the majority showed a rate varying from 96 to 120 before the flight and with an increase of 10 to 20 beats after landing. It has been said that a slow pulse is a good sign, yet in a group of fifteen pupils the one who showed a slow pulse-rate, 80 before the flight and 86 on landing, was the only one of that group to give up flying after his fourth solo. He developed all the signs of pupil's aero-neurosis.

(*d*) *Respiratory System.*—Any evidences of active tuberculosis, emphysema, bronchitis, or pleurisy disqualify for air work. In war-time an aviator may have to fly at any height up to about 22,000 feet ; at this altitude the available oxygen is reduced by one-half, and consequently the respiratory rate is increased. Many aviators feel quite undisturbed at this height, some feel respiratory distress, fatigue, headache, faintness, epistaxis and blurring of vision, and have to descend, whilst some actually faint in the air. The problem why some are affected and some are not at great altitudes has been investigated by Lt.-Col. Flack. His work is of the greatest importance and its value cannot be overestimated with regard to safeguarding our airmen. Much of Lt.-Col. Flack's work cannot be referred to now, but mention can be made of one of his tests, namely, the breath-holding test. In this test the candidate, seated, is told to expire once as fully as possible, then to inspire fully and hold his breath as long as possible. He is told to imagine that he is swimming under water and to hold on as long as he would do there. A clip is placed on the nose. Most good pilots are able to hold the breath for 60 seconds or more—45 seconds is the minimum for the test. During the breath-holding there is a depletion of the alveolar oxygen and the candidate is submitted to a gradually rarefying atmosphere, as in ascending to a high altitude. This test has been confirmed to be of practical value by other more accurate tests in which the accumulation of CO_2 was eliminated, and, moreover, it has been found that pilots who suffer at altitudes cannot hold the breath so long as those who are unaffected. In the absence of organic disease it is difficult to account for this disability, and various theories have been suggested, such as a low vital capacity or an abnormal rate of oxygen usage, or an undue reaction to diminished oxygen. As some fail in the test through lack of resolution, it is important to ask the candidate his reason for giving up. The "oxygen want," cases may reply, "I felt dizzy," "My head began to swim," "Things got blurred"; whilst the normal cases usually say, "I wanted air," "I just had to give in," "I felt like bursting." It is useful also to measure and record the candidates' vital capacity. The candidate should show 3,000 c.c. or more.

(*e*) *Nervous System.*—Any organic disease of brain or spinal cord disqualifies a candidate. The mentality and temperament have to be studied as carefully as possible. Knee-jerks are recorded. An exaggerated knee-jerk may indicate an unstable nervous system. The candidate is tested for tremor by making him stand with the eyes shut, tongue out, arms extended, and fingers slightly flexed and spread apart. An inquiry is made into the usual amount of sleep obtained, and whether disturbed or not. Any signs of restlessness are noted, such as fidgety movements of hands, feet, or face, or biting the nails. These would rather point to an unstable nervous system. Yet the author has in mind one aviator, recognised as one of the very best instructors in our service, who exhibits, when not flying, all forms of restlessness, so marked that it amounts to a destructive habit. Unconsciously he will destroy many articles within his reach; at night he can often be heard talking away in his sleep for quite long periods.

(3) Special Sense Examination

(*A*) *Vision.*—The author has no doubt in his own mind that the aviator should have unaided normal vision in both eyes and in each eye separately, and also normal colour vision. Such is required of an executive officer in the Royal Navy, and such should be the standard for air work. The medical aviation authorities of the French Army and of the American Navy insist on this. He knows perfectly well that there are quite a number of aviators with defective vision who fly well, yet he knows also of many who have come to grief. The pupil with defective vision who attempts to learn flying will probably crash. He would qualify this by saying that should such a pupil have been an observer for some time he will probably learn to fly quite well, his visual judgment having been adapted by his previous air experience. An aviator with defective vision is undoubtedly at a disadvantage in an aerial fight or in reconnaissance work.

The author feels sure he has saved some pupils from disaster by advising them to give up flying on account of their eyesight. Every now and then, in aerodrome life, one runs across incidents that forcibly demonstrate the value of good vision to the pilot. Last summer a pupil with defective vision, but corrected by glasses, was making bad landings. He was on the point of being turned down, but was allowed another chance. He made three attempts to land—in the first two he flattened out too soon and went up again, and on the third attempt he made a good landing. Yet that same evening he met his death in a crash. From the inquiry no doubt remains that his glasses got displaced by his safety helmet, and his uncorrected defective vision was insufficient to save him.

Later to the same school came two pupils, each with defective vision, one corrected and the other not, yet both learned to fly without trouble and became good pilots, but each had over **100** hours to his credit as an aerial observer.

In view of the question of man-power in the supply of candidates for the Air Service, the standard of vision may have to be lowered, although personally the author is strongly against this. At least it should be possible to have vision standards graded for the various flying duties. Candidates should be examined for concealed hypermetropia, which has been found in some cases to be a cause of making bad landings. Should a candidate with each eye read 6/9 with a + 2 lens he is rejected. Similarly, heterophoria, or concealed squint, has been found to be a cause of making bad landings. Such cases are better tested and watched by the aerodrome doctor. The test applied is the red and green light test.

Pilots and observers should have perfect colour vision. The importance of this is seen in picking out the colour or markings of hostile machines, in recognising signal lights, and in judging the nature of landing grounds.

Testing for night blindness is only of importance in grading pilots for night bombing. It must be remembered that there may be a certain amount of adaptation to light perception, and, again, that the ideal conditions for night flying are bright moonlight and no clouds. Under these conditions it is almost impossible to spot an aeroplane from the ground. Thus the pilot can see well but not be seen. Night blindness is tested by reading the ordinary test-type under gradual increase or decrease of illumination. It is hardly necessary to test for stereoscopic vision.

(*B*) *Aural.*—This includes examination of the throat, nose, and ear. The previous history is noted with regard to pyorrhoea, recurring sore throat, earache, deafness, or discharge from the ears. The teeth and gums are examined, as it is essential that the pupils should commence flying dentally clean. Most aviators fly with the mouth slightly open and any minor degree of oral sepsis flares up owing to the cold or rush of air experienced in flying. In one pupil with pyorrhoea the author saw a very severe gingivitis induced through flying. In propeller types of aeroplanes—*i.e.*, with the engine behind—there is little protection from the rush of air. Septic tonsils should be enucleated.

The nose is examined to estimate the amount of clear airway. The Italians lay stress on this examination and even take tracings of the degree of nasal stenosis by means a nasal catheter, plug, and recording manometer. Many pilots with septal deviation and enlarged turbinates have flown without discomfort, whilst others have been returned suffering from headaches induced in the air. Some have had submucous resection performed in the hospital lately and have been returned to flying duties. Reports from them later will help to settle the relationship between nasal obstruction and headaches induced by flying. Further observation on a series of cases is required. Cases with adenoids, and nasal polypi or infective sinuses, are temporarily rejected until treatment has been carried out.

Hearing must be normal and each ear is tested separately by forced whisper at a distance of 20 feet. The author uses terms employed in aviation such as "contact" and "switch off." The aviator's hearing becomes tuned to the sound of his engine and any misfiring is at once detected and action taken accordingly. Defective hearing in the pilot or air mechanic may lead to serious injury or even death to the latter in starting up the engine preparatory to a flight. In this act the mechanic swings the propeller and should the aviator, through defective hearing, fail to catch the words "contact" or "switch off," as the case may be, the engine may unexpectedly start and the propeller injure or kill the mechanic. Chronic suppurative disease of the middle ear is a cause for rejection. Similarly it is well to reject any cases showing perforation of the tympanic membrane or cicatrices. These cases would probably suffer from pain in the ears induced by the incessant noise of the engine and by pressure effects from changing height rapidly. There is also the possibility of permanent deafness ensuing later.

(*C*) *Equilibration and Muscle Sense.*—It has been assumed that a sound equilibration and muscle sense is essential in flying, so that the aviator would be conscious of his position in space, realise at once any deviations therefrom, and correct these quickly. But in fog it has been found almost impossible to detect any deviation during a flight. Time and again aviators coming out of dark clouds or fog have found themselves flying one wing down, and it has been recorded that some have flown upside down without knowing it. Thus, it is obvious that most of the impressions which control balance in flying come through the eyes.

To investigate this the author did the following experiment, having Flight-Commander McMinnies, R.N., as pilot, the author's sense of balance and vestibular reactions having previously been found normal by Mr. G. J. Jenkins :—

Blindfolded and with ears plugged he sat in the stern seat of an aeroplane in telephonic communication with the pilot in front. The latter had to perform certain evolutions in the air, and these and his own position in space the author had to describe to the pilot during the flight. At first he was able to describe the flight fairly accurately—the climbing, flying with right wing down, the first spiral downwards to the right; after that he was "all at sea," and thought the machine was climbing up and up continuously, whilst in reality it was spiraling down to the left. He was able to record the latter part of the descent to land.

He thinks this experiment goes far to prove that the aviator is for the most part dependent on impressions conveyed through the eyes for his sense of balance during a flight. Nevertheless, although further investigation is required in this direction, it is his view that every candidate's equilibration, muscle sense, and vestibular reactions should be tested.

The following are the tests generally employed:—

(*a*) Self-balancing at rest and in motion. The candidate with his eyes shut and hands on his hips is asked to stand on one leg. He should do this for 15 seconds on each leg. He then walks in a straight line heel to toe, but with eyes open, and at a given signal he has to pivot round and walk in the opposite direction without losing balance.

(*b*) The muscle sense can be tested in two ways—firstly, by asking the candidate to appreciate difference in weight between articles of a similar size; and secondly, by making him raise a cigar-box lid on which is balanced a tuning-fork, five inches in height and with a small foot-piece, from a table to the level of the shoulder and down again. Those with a good muscle sense can do this without upsetting the tuning-fork. Many can raise the apparatus successfully but in lowering it fail, indicating carelessness and an impulsive nature. It may be pointed out that the muscle sense is called into play quite a lot in flying—especially impressions from the buttocks. In running into air-pockets the aeroplane may be suddenly bumped upwards or downwards as a whole, or rocked in a lateral or fore-and-aft direction. These deviations are often felt in the buttocks, and with a quick reaction time in the pilot the aeroplane is soon on a level keel. In fact, an accomplished aviator seems to anticipate bumps. These tests *a* and *b* were devised by Lieut.-Col. A. H. Cheatle, R.A.F.

(*c*) The vestibular reaction is tested either by means of the rotation test or the caloric test.

In the *rotation test* the candidate sits in a revolving chair fitted with arm-rests, foot-rest, and a head-rest inclined forward at 30°. He is told to close his eyes and the chair is then rotated evenly from right to left six times, each rotation lasting two seconds. The eyes are then opened at a given signal and the candidate looks to his left at the examiner's right forefinger. The nystagmus so induced is noted with regard to its duration, degree, and type. The test is then repeated in the opposite direction. The duration of the nystagmus in normal cases varies from 12 to 25 seconds, anything over 25 indicates an easily stimulated vestibular mechanism. With regard to the degree of nystagmus, the majority show fine rapid oscillations, but some show large and slow oscillations, whilst some exhibit a mixed form. The type of nystagmus is almost invariably in a lateral direction, but the author has seen vertical nystagmus with a curious rotation of the eyeball. Mr. Jenkins has pointed out that in those with a highly trained vestibular mechanism, like the acrobat, the nystagmus induced is of short duration or absent. At present it is difficult to interpret the readings, and investigation is required to find whether the individual with a highly trained vestibular mechanism or the opposite makes the better aviator.

It is essential to have a rotation chair worked electrically, as an uneven rate of rotation alters the findings considerably. Having treated by rotation over a hundred pupils and skilled pilots the author cannot come to any definite conclusion with regard to the value of duration or degree of nystagmus, except that perhaps, if any, the most experienced give a shorter duration. Curiously enough the one pupil who exhibited slow vertical nystagmus with some rotation soon developed aero-neurosis and gave up flying.

In the *caloric test* the nystagmus is induced by a gentle continuous flow of water at 70° Fahr. into one ear. The period of induction and the duration of nystagmus are recorded.

It has been suggested that the sense of *projection* should be tested. In this test the candidate looks fixedly at the bull's-eye of an indoor-range target until he locates its position in space. He then closes his eyes and attempts to place the forefinger of his right hand on the bull's-eye. The readings are noted down as bull, inner, outer, or miss—good pilots are supposed to score bulls or inners. The author has tried this test with a number of aviators, but so far cannot estimate its full value. He has made an attempt to test the aviator's sense of *direction*. In this test the instructor takes the pupil for a flight, spirals him twice, and then through the telephone asks him to point out a certain landmark on the aerodrome—*e.g.*, a particular hangar. By means of a stop-watch the instructor notes the time taken to accurately point out the object. With the few tests that Flight-Commander McMinnies carried out at his request the time taken by the pupil was about 4 seconds.

(*D*) *The Psycho-Motive Reactions.*—It is important that the aviator should possess normal reaction times with regard to vision, hearing, and touch. All parts of the reflex arcs involved must be intact. These reaction-times are tested by means of the D'Arsonval chronometer, which determines accurately at what fraction of a second, after having received a visual, auditory, or tactile stimulus, the candidate under examination reacts. By means of this instrument Dr. Camus, Dr. Nepper, and Dr. Binet have investigated the reaction times among aviators. In early 1917 the author had the pleasure of visiting our French colleagues at the Grand Palais in Paris, and was given every opportunity to witness and study their tests, with the value of which he was considerably impressed. The D'Arsonval chronometer is worked electrically, and has a clockwork movement turning a pointer on a dial, divided into 100 parts, at a speed of one revolution a second. There are two press button switches, one held by the examiner and one by the candidate.

To measure the visual reaction-time the examiner starts the pointer revolving by pressing his thumb-switch, and once the candidate perceives the pointer moving he stops it by pressing his thumb-switch. The time taken is noted on the dial. The normal vision reaction time is 19/100 of a second, but in unsuitable candidates may be slowed down from 22/100 to 48/100 of a second. The visual reflex consists of the impressions carried through the eyes to the brain and from there down to the muscles controlling hands and feet. For example, the aviator perceives one wing tilted up to the right, and this impression is carried through his eyes to the brain, there recorded, and a decision made, which is transmitted to the hands, so that the control lever is pushed over to the right and the aeroplane is made to assume an even keel again. Or, as in landing, when the impression that he is near enough to the ground is transmitted through the eyes to the brain and down to his hands, he pulls back the control lever at the correct moment, and the aeroplane flattens out just as the ground is reached. Should the visual reaction-time be delayed in landing, a crash is likely to ensue.

The auditory reaction-time is tested by the examiner tapping the table with his thumb-switch, which again causes the pointer to move, whilst the candidate facing away from the instrument stops the pointer with his thumb-switch on hearing the tap. The auditory reaction-time usually takes 14/100 of a second, but may be delayed from 17/100 to 33/100. In the auditory reflex the impressions are carried through the ear to the brain and down to the muscles of control. For example, in flying the pilot may hear his engine miss-fire, and the decision to find a good landing-place is at once transmitted to the muscles controlling eyes, feet, and hands.

The tactile reaction-time is recorded in a similar way, the examiner tapping the candidate on the head or hand, and the latter on feeling this stops the pointer. The normal tactile reaction-time is 14/100 of a second, but may be slowed from 20/100 to 39/100. The tactile reflex consists of impressions conveyed from the nerve endings in skin and muscles to the brain and down to the muscles of control. For example, when a pilot feels a " bump " the sensation is carried from the skin and muscles of his buttocks to the brain, and a decision is transmitted to the muscles controlling his feet and hands to correct the effects of the bump. Each reaction-time is tested ten times and an average taken. All these reaction-times are found delayed if the candidate be physically or temperamentally unfit, as in disease, worry, cold, fatigue, and after excesses.

A slow reaction-time, the delay of a second or part of a second in correcting an error in the air or in landing, may mean all the difference between a crash and safety.

In 1915 the author devised the following test, but so far has not had the means of carrying it out. The idea was to measure the candidate's reaction-time in correcting "bumps." Use was to be made of a rocking fuselage fitted with controls and an electrical recording apparatus. In this the candidate was to sit ready as for flying. The examiner was to tilt the fuselage either laterally, or fore and aft, and the pupil had to correct this, and the time taken was to be recorded electrically. This, from the point of view of practical aviation, would be another method of testing the candidate's tactile reaction-time.

(*E*) *The Emotional Reactions.*—In this test, which has been elaborated by Dr. Nepper, the influence of the emotions on the respiratory rhythm, the vasomotor control, and tremor is recorded graphically. It is more a grading test in determining the best type of aviator for aerial fighting rather than an entrance test for aviation candidates.

The aviator has round his chest a pneumograph, in his left hand a trembler, and round two fingers of his right hand a pneumatic "doigtier." All three are connected by rubber tubes to stylets writing on a blackened revolving cylinder, and thus are recorded the respiratory rhythm, any tremor present, and the peripheral vasomotor control. Behind the candidate a revolver shot is fired or a magnesium flare set off, and on the smoked paper a record is made of any variations. In the best type of pilot with good nerves the effects recorded are of short duration, whilst in unsuitable ones the respiratory rhythm remains increased for some time, there is marked tremor, and peripheral vaso-motor constriction. The author saw the graphic records of some of the best French aviators who underwent this test. Much remains yet to be done, and there are many problems awaiting elucidation in the selection of candidates for aviation duties.

CHAPTER III

The Applied Physiology of Aviation

By Lt.-Col. Flack, R.A.F.

"*If men were meant to fly they would have been given wings.*"

But a few years ago such a remark as this was common enough, especially during the period when the brilliant pioneers of flying were making their most fundamental experiments. Now, as a result of their successful efforts, man is able to fly, and indeed flying is a common everyday performance. It is true that man has not developed wings but has provided a motor and wings as an accessory to himself. Nevertheless in flying he and his machine become, to all intents and purposes, a single entity.

Although flying has become possible, not all men can acquire the art of flying. To do this, certain physiological attributes are especially necessary. In addition, if not perhaps even more important, is a psychological attribute, namely, the flying temperament. It is not proposed, however, to treat on this in any detail here. Suffice it to point out that a really successful aviator is still possessed of the temperament characteristic of the pioneers; he is endowed with absolute fearlessness, a love of adventure and sport, and a dogged determination to overcome every difficulty, no matter how insuperable it may appear. In these days of war also, the successful aviator possesses what may be termed the "fighting temperament."

From a physiological point of view, however, it is obvious that since man has added to himself wings and a motor, the most important factor in the art of flying is the nervous control and co-ordination of the reflexes necessary for the successful management of these accessory parts. An insight into the motor side of these "flying reflexes" and their co-ordination is easily afforded by getting into a stationary machine and studying the fundamental effector movements (" effector responses "), necessary to flying. These fundamental effector movements are.

(1) With the arms a fore and aft and a side to side movement.

(2) With the legs a to-and-fro push of the rudder bar.

Careful study of these movements in a stationary machine at once brings home the fact that these "effector responses" are by no means easy to acquire. The combination of hand and foot movement is by no means familiar to the average person, and while attention is directed to one movement, the other movement, equally important, is for the time being neglected. Thus, when the attention is directed to the hand movement the foot movement is forgotten for the time being, and becomes inco-ordinate. This is brought out even more effectively if, instead of being performed in a stationary stable machine, the movements are tried in an unstable apparatus which responds to each movement of the joy-stick and rudder. In these circumstances it is quickly realised that it is a matter of very great difficulty to maintain by appropriate arm and leg movements an even keel while in a state of unstable equilibrium.

In practically no other acquired accomplishment has man to keep so many groups of antagonistic muscles in a state of "static" wakefulness or to perform such a variety of constant co-ordinated leg and arm movements. It is for this reason that the acquiring of the art of flying, even in the apt pupil, is a matter of hours and not of minutes. For this reason also the period of training for flying is relatively long, since it is fully realised that a considerable period of time is necessary before the essential movements in flying have developed into subconscious reflexes.

From the above considerations it is obvious that the successful flier must be one who has power to co-ordinate his limb muscles with a beautiful degree of refinement. By some people it is held that the previous training of a horseman has given him the necessary qualifications. It should be borne in mind, however, that although such horsemanship has given him delicately co-ordinated arm movements, "hands," the more difficult co-ordinated arm and leg movement necessary for flying has not been thereby acquired, since the leg movements of horsemanship are of a different order to those employed in flying. By this it is not intended to infer that the possession of a good pair of hands and of a good sense of balance, acquired in the art of horsemanship, is not a valuable accessory to the acquisition of the art of flying.

The man who has not the power of delicately co-ordinating his arm and leg movements will be deemed "ham-handed," "heavy-footed," or "never able to acquire the art of flying." It is because of the importance of this delicately co-ordinated effector response that great importance is attached to a history of sport in the selection of aviators.

While a history of sport is of great importance, even greater is a history, if it can be ascertained, of acquiring a proficiency in sport easily. In other words, such a man has already shown himself an adept at acquiring rapidly a new series of reflex acts, and other things being equal youth has a great advantage here.

We next come to the consideration of the sensory side of these reflex arcs. By what afferent paths are impulses conveyed to the final effector paths. Putting aside the question of intelligence by which the subject appreciates the information given him by the instructor by oral, and to a certain extent by visual means, through what mechanisms, extroceptive and proprioceptive, is the art of flying acquired? Without danger of contradiction, it can be confidently affirmed that the visual reflex is all important to the aviator. It is for this reason that many authorities pay considerable attention to the determination of the time of the experimental visual reflex, especially in the selection of scout pilots.

Again, the auditory sense is of considerable importance, especially in the detection of any mechanical defect in the running of the engine, and because the flier derives much information as to the position of his machine by the "singing" of the wind through the wires of the machine.

A point of considerable difficulty arises, however, in connection with what may be called "sense of balance." Considerable divergence of opinion exists as to the part played by afferent impulses from the eye, cutaneous nerve endings, "muscle sense," and from the vestibular mechanism.

In regard to the last it is frequently argued that since the vestibular mechanism especially is developed in birds, it is important that men in whom the mechanism is functioning especially well should be selected for aviation. True as this may appear at first sight, the fact must not be overlooked that regarding the man and his machine as a single entity, the accessory parts added to man have, to a considerable extent, their own sense of balance. In other words, it must not be overlooked that most modern machines are possessed of a considerable degree of inherent stability, and on this account there is no reason to suppose that machines cannot be effectively flown by men in whom the vestibular mechanism is not especially sensitive.

This may well be the case, since it is known that cutaneous sensations, especially from the seat and also from the alteration in direction of wind pressure on the cheeks, play with most pilots a very important part in giving them an idea of their projection in space. Much information is also derived from the "feel" of the joy-stick and the joint and muscle sense brought into play in its manipulation.

The sense of vision, however, is here also of the greatest importance. As described elsewhere, the author of this book found that when his eyes were bandaged and his ears were plugged, after the first few evolutions he had little or no idea of his position in space, indeed he had the impression that he was ascending continuously. This has been confirmed by other observers, and it is also a well-known fact that an aviator after flying a long time in a cloud will have but little knowledge of the position in which he will emerge from that cloud with relation to the earth.

A very experienced pilot tried an experiment similar to the one mentioned above. He found that he could tell the kind of evolutions being executed fairly well chiefly because of the "feel" of his seat. When, however, he tried to fly he could not perform correctly even quite elementary movements. Thus in making a turn he "stalled," but was only aware of the fact on account of the feel of the joy-stick. Later he got his nose right down, but again he only became aware of this because of the feel of the joy-stick.

To sum up, in acquiring the art of flying, it is necessary for the would-be flier to be possessed of—

(1) A good sense of vision and hearing, and a quick effector response to impulses thereby received.

(2) A good sense of balance in which impulses derived from the skin, muscles and joints play as important a part as do those derived from the semicircular canals.

(3) A delicate co-ordination of muscular movements, particularly in the interplay between the antagonistic muscles concerned in the various movements performed by those muscles.

Given the above assets, the pupil will during his stage of dual training so perfect his effector responses that after a time his flying will become more or less automatic. If this be not the case, then he will never become an efficient pilot, and will early develop fatigue.

It is absolutely necessary that quite early in his flying career the subject should be able to divert his attention elsewhere than to the arm and leg movements necessary for flying. It becomes necessary for the pilot to find his way across country, to read maps, to practise photography, bomb-dropping and gunnery, during all of which machines should be flown more or less subconsciously. Finally, having acquired such flying sense, it becomes the lot of many pilots to practise almost subconsciously difficult aerobatics, while acquiring what may be known as the "fighting sense."

It must again be emphasised here that, in the acquisition of all these adjuncts to flying, visual acuity is all important.

It is for this reason that during the ground training of the flying officer, and also throughout his career, especial attention should be given to those sports which aid in the acquisition of what may be termed "eye." Of especial value in this connection is fencing. But other sports, such as boxing, shooting, tennis, and badminton are of great service.

Although "eye" is to a large extent an inborn gift, it is to be emphasised that it can also be cultivated to a large extent. Thus no matter how good be the "eye" of a first-class bat, he will not maintain his form except by constant practice. So with the "eye" of the aviator.

Besides playing a part in the acquisition of "eye," sport aids the acquisition of delicate muscular co-ordinated movement and balance. For instance, it is undoubtedly good practice for any one to set himself such a simple task as to acquire the art of bowling a good length ball. Thus a man who can hit a piece of paper the size of half-a-crown six times in six balls has developed a delicate series of co-ordinated reflexes. Fencing, already mentioned, is of especial value in acquiring "eye" balance, and quick co-ordinated movement.

Thus far we have been dealing with the acquisition of the art of flying. It is necessary also to deal with the strain which flying imposes on the body, especially at high altitudes. The increased speed of the machines, their heightened ceiling, the greater rapidity with which they climb, have carried aerial warfare to such an altitude that the aviator has to be able to live and work in an atmosphere where the vital constituent, oxygen, is diminished. Thus superadded to the nervous strain involved in learning to fly, is the physical one, which falls particularly upon the respiratory and circulatory mechanisms. To understand this strain, it should be explained that these mechanisms are called upon to function in an atmosphere of diminished oxygen, where, if anything, an increased supply is required : there is thus the tendency to the establishment of a vicious circle, a demand for increased oxygen supply in an atmosphere in which it is progressively diminishing as the aeroplane mounts. Many of the symptoms from which airmen are liable to suffer are due to the strain thrown upon these bodily systems. For this reason the would-be aviator must start out upon his training with a particularly sound constitution, above all his circulatory and respiratory mechanisms must be perfect, and it is on this account that so great care is exercised in his selection on admission to the service. For this reason also, the flying officer who wishes to be successful should keep himself trained and fit, he should look upon himself as being engaged in a sport necessitating careful habits of life approximating almost to those of hard training, so that his efficiency may not be impaired.

As an aviator climbs, he passes from the normal barometric pressure at ground level to a pressure which diminishes according to the height attained. Thus, his body becomes directly exposed to an alteration in the air pressure, as well as to an atmosphere in which less oxygen is available for the body needs.

The experience gained from a study of " mountain sickness " does not help us greatly in understanding this question, for mountain climbers attain their heights at a relatively slow rate, and the body has an opportunity to adapt itself to its new surroundings. Such adaptation takes generally from seven to ten days. But the aviator on a high flying machine may attain a height of 20,000 feet in 30 to 40 minutes, and remain at that height for but a short time, at the most a few hours, a time so short that the body has little or no opportunity to adapt itself to its new conditions. Even when one considers the case of an aviator flying regularly over a long period, the number of hours at which he has kept at a great altitude are but few compared to the number he has spent on the ground—say, for example, 240 hours (10 days) in 1000 hours flying, spread over two years.

The information gained by balloonists as to the effects of altitude upon the bodily mechanisms has been more helpful. They have been able to attain great heights in a relatively short space of time, and further, have been able to make observations as to the behaviour of the breathing, heart, etc., under these conditions. This knowledge has been supplemented by more recent work in dirigible airships and aeroplanes. Observations have also been made in large steel chambers from which the air has been gradually pumped out, thereby bringing about the conditions of diminished air pressure and lack of oxygen corresponding to definite altitudes. Another and more practical method of observing the effects of diminished oxygen pressure is to get the subject of experiment to breathe air diluted with varying amounts of nitrogen. Professor Dreyer has recently designed a very simple and effective method on these lines. It has the great advantage that the observer is not himself submitted to the effects of the rarefied air.

The diminution of atmospheric pressure has in itself practically no effect upon the human body. The body is composed approximately of 70 per cent. fluid, and any alteration in external pressure is transmitted equally to all parts of the body, so that no effects due to pressure arise within the body.

The question is sometimes raised as to whether the aviator is liable to an "air disease" or "flying sickness" akin to "caisson disease" or "divers' palsy." The cause of caisson disease is now well known. Men who have to do their work under increased air pressure dissolve under this pressure a considerable amount of nitrogen in the blood plasma. If the pressure be diminished too rapidly, *e.g.*, when a diver is brought too rapidly to the surface or men are released too quickly from a caisson, minute bubbles of gas are given off in the blood which, by lodging in the muscles and joints, may produce pains known as "bends," by damaging the nervous system may produce paralysis, or by blocking the blood vessels of the heart or brain may cause death.

In the case of flying there is no corresponding phenomenon, because even at a height of 20,000—25,000 feet the diminution of pressure is not sufficiently great or rapid to produce any liberation of gases dissolved in the fluid portion of the blood.

Diminution of pressure, however, may produce certain effects upon the body through gases more or less pent up within it, namely, in the intestines and in spaces connected with the nose and the middle ears.

With diminishing atmospheric pressure any gases that there are in the intestines will expand and occupy a larger volume, and if this volume is at all great the aviator will experience a distension of his stomach and intestines, which, by pushing up his diaphragm, may cause interference with his respiration. But inasmuch as the amount of this gas is normally not large, and its expansion induces increased contractions of the intestines, it is soon voided from the body and inconveniences from this cause are rare.

Generally speaking, little attention need be paid to the effects due to expansion of the gases in the alimentary tract beyond exercising a certain degree of care in choosing a diet which does not cause any upset of digestion, especially a liberation of gases in the intestines. In this respect it is difficult to specify any particular forms of food, since these vary in gas-producing power with individuals, and each person is more or less aware of his own peculiarity in this respect.

More important from the point of view of the aviator is the air normally enclosed within the middle ear, and in the air spaces connected with the nose. The alteration in pressure in the frontal sinuses causes in many aviators a sense of discomfort amounting, in many cases, to actual headache; but little can be done to alleviate this condition.

In the case of the middle ear, if the Eustachian tubes are not patent and equalisation of pressure is not easily made, a most unpleasant train of symptoms may ensue—noises in the ears, giddiness, and even severe pain. These symptoms are due to unequal pressure upon the ear drum. For this reason it is important that the flying officer be taught how to maintain the pressure equally on either side of the tympanic membranes normally. During ascent the pressure in the Eustachian tubes may be diminished by forcibly swallowing, when a clicking may be heard in both ears, or better still, by imitating the first inspiratory movement of a yawn, when a cracking note is experienced in the ears. By practice it becomes possible to open the tubes without opening the mouth. During descent the pressure may be equalised in much the same way as the above, since each swallowing or yawning movement again momentarily opens up the Eustachian tube and permits an equalisation of pressure to take place. Generally speaking, however, during descent, particularly if very sudden, the pressure within the Eustachian tubes is best increased by holding the nose and gently blowing up the tubes with a forced expiratory movement, the mouth being closed. When planing down steeply, it is particularly important to bring about this regularisation of the air pressure as frequently as possible.

Prior to a flight, especially to high altitudes, these movements may be practised on the ground, namely, by alternately swallowing and blowing up gently, with the nose held and the mouth shut. Any catarrhal condition of the nose and throat such as that due to a nasal cold or to excessive smoking may lead to blocking of the Eustachian tubes. For this reason the flying officer should as much as possible avoid the risk of catarrhal infection.

As a digression, it may be stated for the information of the non-medical reader, that "colds" are not, as their name signifies, due to cold. Scott and his fellow-explorers in no way suffered from common colds even at very low temperatures, excepting when parcels of clothing containing dust and germs were opened. A cold in the head is due to the thriving of certain organisms on the lining membranes of the nose and throat of an individual who has been exposed to infection. These are generally conveyed in minute particles of secretion coughed or sneezed into the air by a person who is infected—the person exposed to infection will not, however, develop a cold unless the microbe is of a peculiar virulent kind or his resistance to infection has been reduced by a low state of health, or unless the mucous membranes have been prepared for infection by previous congestion in a stuffy atmosphere. The great secret in the avoidance of colds is to shun (1) stuffy atmospheres, (2) the neighbourhood of infected persons. Conversely, an infected person should always be careful to sneeze or cough directly into a handkerchief and avoid shouting or loud speaking when near any one.

The chief effects of altitude on the bodily mechanisms are, however, due almost entirely to the diminished oxygen supply in the air. Roughly speaking, at an altitude of 11,000 feet, the air contains relatively only two-thirds of the oxygen tension it does at sea level, at 19,000 feet only one-half. Thus the aviator flying at these heights will have to increase his intake of air in order to obtain the same amount of oxygen that he would get at sea level. This he does unconsciously by breathing more deeply and more quickly. Every one who has flown to any height knows this fact, and has found that after a certain altitude, he is no longer a nose breather, but begins to breathe deeply through both mouth and nose. The breathing and circulation react in the same way as they do when heavy work is being undertaken. When, therefore, an aviator is at a height where the tension of oxygen is considerably reduced, his respiration and his circulation alter in character and rate in order to keep up the supply of oxygen. To do this with any degree of success, an aviator must have both a sound chest and a sound circulatory system, and the examination of successful flying officers has shown that they are possessed of great respiratory and circulatory efficiency.

The effects of diminishing oxygen tension may be mentioned in more detail. In an atmosphere in which the oxygen has been reduced from the normal 20.97 to 17 per cent., although a match will not burn, a man feels little or no discomfort. With 14 per cent. of oxygen the depth of breathing is appreciably increased, the blood pressure slightly raised, and the pulse rate augmented. With percentages from 10 to 12, a form of nervous exaltation appears, approaching in many cases to an intoxication, so that although the subject has the greatest confidence in himself, he is really far below his normal efficiency. This has been conclusively proved both for atmospheres in which the oxygen has been altered at normal pressure, and also by experiments in rarefaction chambers. Persons, however, appear to vary considerably in the degree to which their mental powers are affected. In many, the onset of mental symptoms is also attended by a feeling of giddiness, considerable diminution of muscular power, and less frequently by nausea and vomiting.

Finally, diminution of oxygen tension in the atmosphere leads to paralysis: as in the case of the famous balloon ascent of the aeronauts Coxwell and Glaisher, when both aeronauts became suddenly paralysed. Coxwell, however, managed to pull the safety-valve with his teeth, and thus prevent disaster. In another well-known balloon ascent, Crocé-Spinelli, Sivel, and Tissandier were all paralysed before they began to breathe the oxygen in the bags with which they had been provided, although the famous French physiologist, Paul Bert, had warned them not to wait until too great a height was attained before using these bags. At present there is little danger of the ordinary aeroplane reaching the heights necessary for such symptoms to occur.

From this it will be seen that it cannot be emphasised too strongly that the effects of altitude are in reality due to diminished oxygen tension, and not directly due to diminished pressure, and it is obvious that the first thing that is required in any flier is that he should be able to withstand the strain of frequently repeated exposure to an atmosphere in which the oxygen tension is progressively diminishing. In other words, for high altitude flying, he must be able particularly to withstand wear and tear. Since the strain of altitude flying is thrown particularly on the respiratory and circulatory systems, and the nervous mechanisms controlling them, these are particularly examined in the selection of the flying officer.

A number of the tests employed for these have been worked out by the examination of the successful flying officer. In the main these are of a simple nature. One such test is the breath-holding test referred to elsewhere.

The examination of successful aviators has also shown that a good vital capacity, that is, the amount of air which can be taken into the lungs after the fullest expiration and fullest possible inspiration, shall be sufficiently large. This can be tested by the use of a special modification of an ordinary gas meter. After having filled the lungs, the subject is asked to expire as deeply as possible through the meter and the amount is thereby automatically recorded. The average vital capacity of the successful pilot is about 4,000 c.c., and the vital capacity of any flying officer should preferably not fall below 3,400 c.c., and certainly not below 3,000 c.c. whatever be his physique.

This method of measuring the lung capacity is altogether more satisfactory than that of measuring the chest, which may give quite deceptive results. An apparently narrow-chested individual may often have a larger vital capacity than a subject who apparently has a large chest capacity. It is important also that the candidate for aviation shall have good chest movement, a firm abdominal wall, and be, preferably, a deep breather. By slow, deep breathing more air is taken into the lungs than by more rapid, shallow breathing. It has also been shown that the efficient pilot responds by slow, deep breathing to work, and that quick, shallow breathing is not easily induced.

The advantage of a firm abdominal wall for good respiration and efficient circulation cannot be overstated. Research in connection with successful pilots has shown that those who wear well have good expiratory force. From the examination of successful pilots a standard expiratory force has been found, namely, the height to which a column of mercury can be steadily blown in a U tube manometer. When flying stress is supervening the power to blow up mercury is appreciably decreased.

A variant of this test is to note the time during which a definite pressure of mercury can be sustained with the breath held and nose clipped. The behaviour of the pulse may also be watched, and, from the nature of the response, valuable information is obtained as to the condition of the subject under examination. The U tube test has proved of value in elucidating the condition of the lungs, heart, and medullary centres in successful and unsuccessful officers, and in this way standards have been set.

Soundness of heart is as essential as soundness of wind. Over and above evidence of soundness by the ordinary clinical examination, evidence is sought as to the manner in which the heart will respond to work. In flying it will have increased work thrown upon it, sometimes in a very rarefied atmosphere, and the quicker the heart beats, even at ground level, the more oxygen it requires.

Under stress of work at ground level the heart beat rises frequently to 100, but at great heights the rate is frequently considerably more than this, which means that under these circumstances largely increased oxygen supply is necessary, at the very time when a lessened supply is available.

A standardised test is often employed, which has been worked out by the examination of successful pilots. This consists in raising the body on to a chair five times in fifteen seconds. The standard increase which takes place in good pilots is known, and the rate of return to normal is also known, and, from the response given by the subject, an idea as to whether this is satisfactory or not can therefore be assessed. It has also been found that in good pilots the diastolic pressure is relatively high, and that the difference between this pressure and the systolic pressure is not, as a rule, more than 30 to 40 mm. of mercury. In any case the difference between these pressures should not be too great, and the diastolic pressure should certainly not be low (below 70 mm. Hg.) in any subject passed for aviation.

It will be seen that in the examination of the candidate considerable reliance is placed upon instrumental examination. This is because instrumental examination gives definite results by which another medical officer at a subsequent stage in the career of the candidate can contrast the condition of the subject with his previous examination, and see whether he is wearing well or showing signs of stress, and, if the latter, take appropriate measures to prevent breakdown. For this reason, all such tests should be of the simplest possible nature. It is to be emphasised also that they are designed to aid the examination, and that the results obtained should be judged in the light of the results of the examination as a whole.

The disabilities resulting from flying are due almost solely to the wear and tear on the organism as the result of the repeated and intermittent strain upon the nervous system and the respiratory and circulatory mechanisms. This fatigued condition occurs, although less frequently, amongst men in the line. It is, however, liable to appear earlier amongst flying men, because they are living under conditions which are at times even more abnormal.

The examination of officers suffering from Flying Stress has abundantly proved that in connection with the circulatory and respiratory mechanisms signs of stress supervene. Particularly characteristic is a degree of instability associated with the medullary centres. This is particularly well shown by an examination with the U tube manometer.

The attention of the flying officer cannot be directed too often to the fact that he must keep his respiration and circulation efficient by a process almost akin to that of training. The rower, the mountaineer, the long distance runner, the swimmer, the boxer, in fact any man who wishes to bring off any particular performance, is obliged to train his body. In the same way it is incumbent upon the aviator who wishes to do his best at altitudes more or less to keep himself in training. Thus deep breathing can be cultivated, the expansion and movements of the chest increased, and, to a certain extent, the habit unconsciously formed of breathing deeply and efficiently.

For this purpose slow chest expansion exercises with arm movements, as provided by physical training, are good. At the same time a healthy outdoor life is necessary, with vigorous games, so that the subject may have his muscles, including his heart, in the best condition, ready and fit to undertake any amount of effort.

Of particular value from this point of view are those forms of sport in which the subject performs vigorous work with the breath held, as, for example, boxing and under-water swimming. It is well known that experts in these forms of sport make very efficient high altitude fliers. Cross-country running and football are also to be recommended. Since good belly muscles are important, care also should be taken to preserve the tone of these by suitable exercises.

Attention may also be drawn to the value of the hardening of the body, that is, accustoming it more or less to exposure. The reason that flying officers from overseas are successful in flying at altitudes is largely because they have not "coddled" themselves but have been accustomed to leading a life in the open, wearing often a minimum of clothing. Thus, they have inured their bodies to withstand discomfort arising from cold. This means that when exposed to the cold of high altitudes there is not the same tendency for them to use up bodily fuel extravagantly in order to keep the body warm, and there is a consequent lessening of the oxygen required. The same is true of the athlete generally, and there is no need to emphasise the fact that the true athlete has made, and is still making, the finest type of flier. The man who coddles himself, who likes to live luxuriously, too warmly clad, who shirks a cold dip in the mornings, is not the man who will stand the strain of exposure, or fly well on long-distance flights. Cold baths each morning on arising, the avoidance of too frequent hot baths, and a good tramp across country in all weathers have their value in this hardening process.

The introduction of the use of oxygen on aircraft has proved of incalculable benefit to the service. When administered to aviators after a height of 15,000 feet, in such a manner as to make up for the deficiency of oxygen, it has been found that flying officers are able to keep at great heights in comparative comfort. With no lack of oxygen, there is neither respiratory nor cardiac distress, nor is there any period of exaltation or of confusion of the senses. Before the use of oxygen, aviators sometimes returned to their aerodromes and made fantastic reports as to the numbers and height of hostile aircraft seen; or observers, when confronted with photographic plates showing several exposures on each, believed that the camera was at fault, since they felt sure that they had taken only one photograph on each plate. It is now realised that such performances were probably attributable to lack of oxygen and the consequent confusion of the senses. Without the use of oxygen, many fliers found it difficult, on account of muscular weakness, energetically to work a gun or to release it when jammed.

Oxygen can be carried either in the form of compressed gas in cylinders, or as liquid in a metal vacuum vaporiser. For long-distance machines the latter has the advantage owing to the lightness of the apparatus and the amount of oxygen that can be carried. Oxygen is of especial value in long-distance bombing and high-flying work, when the physical strain upon the airman is great.

If not administered during the flight, the administration of oxygen, when practicable, to aviators on landing after a long flight is also of value. As with the long-distance runner, it quickly relieves any distress, and mitigates after-effects. There is sometimes a feeling amongst aviators, as amongst sportsmen, that oxygen is a "dope." This is not so. Unlike the familiar experiment in which a glowing chip of wood bursts into flame in the presence of oxygen, the human body does not burn at a quicker rate as the result of an extra oxygen supply. Only a relatively small amount of any extra oxygen is taken up from the lungs at ground level. Most of the excess is breathed out again into the surrounding air. The aim of giving oxygen at high altitudes is to supplement the deficit at those altitudes. But even if a little more be given, there is no question of an exhilaration or stimulation of the body with a subsequent reaction, as in the case of certain drugs. There is no danger of the pilot who takes oxygen developing an "oxygen habit" or craving at ground level. The administration of oxygen to normal healthy persons makes a difference, particularly during heavy work, because the heart works more efficiently and with an ample oxygen supply waste products are fully combusted, and do not accumulate within the body. The great service of oxygen in diseases such as pneumonia is so well known as hardly to need mention. This is because, owing to the diseased condition of the lungs, the heart is starved for oxygen. Owing to the rarefied air, the heart and the body are starved at great heights, and the administration of oxygen has similar beneficial results. Oxygen may be taken by means of a mask or a pipe mouthpiece. The mask method is altogether to be preferred to the pipe. With the pipe, care must be taken that the flow is free, that the oxygen is quickly drawn in without the expenditure of unnecessary energy in sucking. A combined mask and pipe may be used advantageously. Oxygen should preferably be taken continuously at heights of 10,000 feet upwards, the delivery being automatically regulated according to the height, or it may be taken intermittently, when a slightly larger amount per minute is taken for several minutes and its use then stopped for a time and resumed again when required. As stated, the continuous method is to be preferred, since thereby the intermittent strain on the bodily mechanisms is obviated.

Another effect of altitude which has to be taken into account is the temperature of the air. Roughly speaking, the temperature of the air becomes 1° F. colder for every 365 feet of climb, so that at high altitudes very extreme cold may sometimes have to be endured. The intensity of the cold varies with the season of the year and with the height attained; it is accentuated also by the speed of the machine through the air. To prevent loss of body heat while flying, special suits have been designed, the cardinal principle of which is to keep the body surrounded by layers of warm air. In most cases this warmth is derived from the body, but the warming of clothing by electric means has also been tried. For warmth purposes great thickness of clothing is by no means necessary. Underclothing should be loose fitting: two thin garments of closely woven texture, either of wool or silk, are better than one thick one. Research has shown that the warmth-giving power of clothing lies in the fineness of the mesh rather than in its thickness. Care should be taken to avoid orifices through which the outside air can permeate. Tight clothing should be avoided, particularly clothing which tends to hamper the movements of the chest or restrict the circulation of the limbs. On active service, the flying suits issued will generally be found to fulfil all requirements.

Frequently, however, it is necessary to employ considerable additional protection for the legs, especially for the feet, and for this reason great care should be taken in providing suitable additional protection in the form of warm, loose-fitting stockings.

For the protection of the face, a fairly close-fitting head and face piece of non-absorbent and non-porous material may be made, the inner surface of which will not absorb the oil or grease with which it is imperative to anoint the face when severe cold has to be endured. Over such, a woollen balaclava may be worn, and then a leather cap of good close-fitting design.

Most flying caps have the defect that the crown of the head is not fur-lined. Many officers, therefore, will find it an increased comfort to extend the fur-lining of the helmet completely over the crown of the head. An adequate head covering should be such that, when the cap, goggles, and oxygen mask are employed, the face is entirely covered. For special purposes, there is being issued a combined helmet fitted with oxygen mask and microphone attachment, which, with the goggles, completely envelopes the head of the aviator, and greatly conduces to his comfort. Leakage of air around the neck is prevented by means of a suitable scarf or fur stole. For the protection of the hands a series of suitable gloves may be employed, for instance thin silk gloves covered by woollen gloves, the whole enclosed in a leather gauntlet, which can be easily removed for delicate work. Gauntlets provided with a specially adaptable finger muff are to be recommended. In certain cases electrically heated gloves have also been employed.

For the protection of the eyes well-fitting, fur-lined triplex goggles should be employed. The fogging of goggles may be prevented by certain preparations which are on the market. Certain pilots prefer to employ tinted goggles, and for this purpose a special issue has been made. It is claimed that such goggles arrest harmful rays which tender to produce inflammation of the conjunctiva and also enable many pilots to observe objects in greater detail. Some aviators take a considerable time to get accustomed to the employment of such glasses.

In conclusion, a few other hints may be incorporated here. Every flying officer, especially when on active service, should endeavour to fill up his spare time in a way which rests his mind and takes away his thoughts from his work. When the flying hours are long, exercise should be particularly directed to employing those muscles which are not fatigued in flying. Such exercises are riding, cross-country walks, and a certain amount of football. A hobby, according to the tastes of the individual, is an excellent mental distraction, preferably one which takes the subject into the open air. When games such as billiards and cards are indulged in, stuffy atmospheres should, as far as possible, be avoided.

Just as in training for sport, the flying officer should endeavour to get regular hours of sleep in a well-ventilated chamber, no matter how great be the temptation to break the rule. Adequate hours of rest are all important. Although every measure should be taken to ensure adequate warmth during sleep, there is frequently a tendency to employ too much bed clothing, which to a certain extent has the same effect as "coddling." As with clothing, it is possible to accustom the body to a minimum amount of protection necessary to preserve the body warmth.

After a flight the recumbent posture is restful to the fatigued bodily mechanisms. If difficulty be experienced in going to sleep, the Medical Officer can give useful advice.

It has already been hinted, in regard to diet, that gas-producing foods are best avoided, but in practice there is little need for the average healthy person to worry about the constitution of his diet. It is important, however, that no flying should under any circumstances take place upon an empty stomach. It is quite probable that a number of the accidents which occur during training are due to the fact that the pupil has not partaken of an adequate meal before venturing into the air.

Before long flights it is advisable not to partake of food of too fluid a nature or of too much liquid. By this means the desire to urinate in the air during a flight is avoided. On very long flights, especially on two-seater machines, a supply of liquid food, such as sweetened cocoa or malted milk, may be carried in special thermos flasks. In addition compressed food in the form of tablets or chocolate may be taken.

Tobacco and alcohol also have their importance as regards the question of training and well-being, and for this reason too much stress cannot be laid upon the importance of over-indulgence in either. Excessive smoking of cigarettes, especially the inhaling of the smoke, produces shortness of breath and quickening of the heart beat. As anything which interferes with the breathing is particularly harmful to the flying man, there is little need to labour this point. Anyone who has become accustomed to inhaling should be advised to give up cigarettes and take to a pipe, and, generally speaking, an endeavour should be made by the flying officer to reduce smoking to a minimum, since any excess impairs the action of the respiratory and circulatory systems, which are of such vital importance to the aviator. Smoking is too often an expression of sociability at the expense of efficiency. The "gasper" or the "yellow peril" are best avoided when the flying officer is hanging around on the tarmac ; indeed smoking is best given up altogether.

The question of alcohol is even more difficult than smoking. Undoubtedly alcohol is best avoided by the flying officer. There is no doubt that on the return from a fatiguing flight, especially during bad weather, there is a great call for a "stimulant." The unsatisfactory things about alcohol are (1) that in many people one drink begets a desire for another, and that a greater amount is gradually necessary to produce the desired effect; (2) that this effect is too evanescent. Experimental work on the effects of alcohol upon the human body show that from the point of view of efficiency the so-called beneficial effects are entirely illusory. The judgment is affected, "reaction time" is slowed, and fine co-ordination of movement impaired. The importance of this to the aviator is at once apparent. To avoid disaster he has always to be on the "*qui vive*" and ready at the shortest notice to put into necessary action, by relatively delicate muscular movements, any message which reaches his brain.

The above applies particularly to what may be termed "steady drinking" of a degree insufficient to produce intoxication. It is not suggested that an occasional convivial evening is in itself productive of great harm to the system, particularly if it is certain that no flying shall take place while the body is still under the influence of the drug. On the other hand, the idea of priming up the system by alcohol before a flight is wholly pernicious and cannot be too strongly condemned. Such a course, even in the strongest, cannot, if habitually persisted in, end otherwise than in disaster.

CHAPTER IV

The Psychology of Aviation

From the point of view of medical interest there is perhaps no more important subject than the study of the psychology of flying, in that the practical issues at stake are so great. From the study of the sensations experienced during flight the medical officer is able to gain a wealth of information of inestimable value to him in dealing with his flying charges. Mention need only be made of its value in selecting the best type of men suitable for aviation duties, in advising and helping the pupil aviator during his period of instruction, in noting any change in his mental attitude towards flying, in intervening where loss of confidence is beginning, and preventing the establishment of a definite aeroneurosis, in detecting the malingerer, in co-operating with the instructors, and finally in the treatment and disposal of those who have broken down through stress of flying.

The spirit of conquest has throughout the ages been found among a certain class of men—pioneers, adventurers, supermen, or even madmen have they been styled, as the fancy pleased.

Handed down from our fighting ancestors this spirit of conquest, unchanged by environment or circumstances, and kept alive by the law of survival of the fittest, finds itself to-day living with renewed vigour in the realms of aviation. Man's fight to conquer the elements has been prompted either by the sense of sport and adventure or by the development of commerce in the spread of civilisation. And ever attendant on this spirit of conquest has been the cry for movement, novelty, and speed. This is exemplified in man's conquest of the sea from the time he embarked on his frail craft to the present-day fast going ocean liner or warship; and again the call for novelty and speed has still further been appeased by man's conquests in the depths of the sea in his development of the modern submarine.

No less have been his conquests on land since the first steam locomotive to the present-day express train doing 60 miles an hour. More speed has been attained in the development of the motor car, in road and track racing, demanding of man very high qualities of courage and alertness.

Even more has been demanded of him in his final conquest, that of the air, necessitating his control of great speed through an element of many of the factors governing the navigation of which he is as yet ignorant. There is no doubt that the early pioneers of flying were regarded as possessing, in their ability to fly, some supernatural power, and were looked upon by many as being mad. But there was so much method in their seeming madness that it has made possible aviation of to-day with the recognition of the vast and terrible powers the Air Force possesses in warfare, and also the possibilities of new developments in commerce and travel.

Although from the first aeroplane flight to the present day covers a period of exactly 15 years, flying has really only been before the public for a little over ten years. In the first six of these years the individuals who had actually flown either as pilots or as passengers were comparatively few. Up to the outbreak of the present war only 862 Royal Aero Club Aviation Certificates in this country had been granted. It is rather difficult to estimate, but the total of half a million probably represents the number up to the present who have actually flown either as pilots or observers. Naturally the various types who have taken up flying are not all equipped with the same amount, range of and control over their imaginations, nor do all come through the same kind of experiences in flying. For example a great difference exists in the sensations experienced in an ordinary quiet passenger flight from those gone through in a first flight with the type of pilot whose one thought is to raise "vertical gusts" in his companion. Again the pupil aviator during his period of instruction may meet with varied types of instructors; and here the author would ask those specially employed as instructors to realise in their speciality, apart from the requisite flying ability, patience and endurance, that success will come to them more readily through a close study of the psychology of flying. Many instructors are young in years, but the nature of their calling tends to make them psychologically mature. If the instructor's mind is solely centred in his pupil's ability to learn either quickly or easily the aeroplane's control during flight his interest and success will never be so great as when he pays equal attention to studying the temperament of his flying charge. Unless he does so he is liable to undermine his own pupil's confidence in him, and once that goes there is little hope of success for the pupil. Indifference, lack of sympathy, difficulty of approach, or bullying methods on the instructor's part may absolutely ruin a pupil's flying career. It is in this early period that opportunities to confide in those more experienced greatly help a pupil, for it must be remembered that he is not only lonely in the air but frequently extremely lonely on the ground. The threshold in flying is often of a frail nature, and to cross it a firm, helping hand may be all that is needed. Failing this, a slip or fall occurs, and the whole mental attitude towards flying may change. The stage of instruction is one in which the impressions gathered may mould the whole future flying life of the pupil.

Similarly the sensations experienced in active service flying may vary greatly, depending upon the type of flying duties. Within the short space of a few minutes, concentrated Hell may be the experience of one pilot, whilst another may carry on for long spells and encounter no such horrors. For example a night bomber may make many raids, fortunate always in weather conditions, a good engine, and the fact that the enemy searchlights have failed to pick him up; on the other hand a machine on artillery observation may be set on fire or partially decontrolled, and have the greatest difficulty in reaching its own lines, being perhaps pursued by enemy aircraft all the way, and made a target for a never ceasing hail of lead. The many and varied experiences recounted of aerial warfare will ever remain a wonderful and glorious epic in history.

In order to study the psychology of flying, the medical officer should have experience of the air, preferably as a passenger. He who would probe the subject more deeply can only do so by having piloted an aeroplane by himself. One does not advocate that all R.A.F. medical officers should learn to fly, but the interest in their work will be heightened by making occasional passenger flights.

Apology must be made by the author, whose work in life has been always in surgery, for venturing to write on such a difficult subject as psychology.

But once one has turned the handle, and pushed the door ever so little ajar to peep within, one must perforce enter this fascinating domain and relate in no matter how crude a way one's impressions of the visit.

As the subject of psychology, even though it be a specialised department of the subject, is apt to lead a writer into generalities, the author proposes, keeping the practical issues mainly in view, to deal with the subject from three points of view; namely (1) from that of the passenger or pupil during his period of dual control instruction; (2) from that of the pupil aviator during his first few solo flights, and (3) from that of the qualified aviator engaged either in the various special duties of war flying or in instructing.

Through these stages one can study the various impressions, sensations, and mental deductions and attitudes in flying, and finally arrive at some points of practical value.

(1) The ordinary individual or pupil views his first passenger flight with mixed feelings, the nature and intensity of which depend on many factors. Firstly there is the motive which prompted him to go up in the air. The investigation of this motive is an important one, and the reason why flying was chosen formed one of the stock questions in selecting candidates for aviation duties. The pioneer aviators were undoubtedly prompted by the spirit of conquest, those immediately following them by a sense of adventure or a demand for excitement, whilst in others later by scientific curiosity or perhaps financial possibilities. With the outbreak of war came the motive of conquest not of the air but in the air. The following is a record made of the reasons why flying was chosen, from 100 consecutive pupils at a large flying school.

1.	Because of their interest in flying	30
2.	Because of the attraction or fascination of flying ...	16
3.	Because of a desire for excitement	10
4.	Because of the novelty of flying	8
5.	Because of a mechanical interest	6
6.	Because of a desire for change from the infantry or trench life	6
7.	Because of a desire for experience or new study ...	4
8.	Because of the possibilities for individual action ...	4
9.	Because aviation was thought the best branch of the service	4
10.	Because of no particular reason	4
11.	Because of a liking for speed	3
12.	Because of a financial reason	3
13.	Because of physical disability	1
14.	Because the individual felt best suited for flying: ...	1
		100

In reviewing these one finds that the majority, 46 in number, take up flying either because they are interested (30) or because they are attracted (16). Those that take it up for excitement (10), for novelty (8), for the love of speed (3), for the opportunities for individual action (4), form another group, 25 in number; and these for the most part turn out to be the best fighting pilots. Those taking it up for the sake of mechanical interest (6), for experience or as a study (4), or for service reasons (4), form another group numbering 14. Those taking it up for purely self reasons may be grouped together, such as those desiring a change from trench life (6) or on account of financial possibilities (3), numbering 9 in all.

Reasons 13 and 14 may be passed over without comment, but it is difficult to understand the mentailty of those who take up flying for no particular reason.

When the time for the actual flight approaches the motive is probably relegated to the background of the mental picture, but later and throughout the flying career it may continuously assert itself.

The second factor that comes into play is the question of confidence in the pilot. This is of importance, as to the ordinary individual in his first flight there is a sense of danger, conscious or subconscious. This may assert itself or not, depending on the amount of confidence or lack of it in his pilot or instructor. Happily confidence in the machine is of little import, as ignorance with regard to construction and aerodynamics proves a wonderful analgesic. The question of confidence in his pilot having been more or less settled, the intending passenger finds himself tuned up to a varying state of excitement, as evidenced by an increase of 10 beats or so in the pulse, consciousness of the heart's action, and perhaps abdominal sinking sensations. He tries to answer to himself the questions what will the flight be like, and has he any knowledge of what he is about to "buy." As most people now-a-days have seen an aeroplane in flight, the memory of previous observations is awakened, and by a process of association the two first attributes that will enter his mind are height and speed. The number of aeroplane flights he has seen and whether he has viewed these from near or far will determine the character of his perceptions of these. It is at first difficult for the onlooker in aerodrome life to estimate with any degree of accuracy either a machine's height or speed at a given moment. As most people dislike looking down from a height and suffer from more or less vertigo and other unpleasant sensations, one of the main introspective difficulties will be with regard to how he can withstand this. Again memory of speed sensations is stimulated by past experiences as in switchback and mountain railways, waterchutes and lifts. As he approaches the aeroplane his thoughts are to a certain extent diverted from speed and height for the moment to the efforts made in climbing into the passenger seat, fixing the safety belt and generally making himself comfortable in his new surroundings. As the propeller is swung and the engine started his impressions become mostly auditory. These increase as the hum of the engine mounts to a roar when the pilot opens the throttle to test the engine and gain the proper number of revolutions. Mixed with the auditory impressions are tactile ones from the vibration of the whole machine, and from the rush of air from the propeller. The aeroplane is still prevented from moving forward by the *chocks* placed against the undercarriage wheels. Then the engine is throttled down for the moment, the *chocks* are removed, and as the throttle is again opened the aeroplane moves forward to commence its flight. As it progresses on and over the ground the passenger is conscious of the augmented speed and vibration, but just as the aeroplane leaves the ground these impressions are suddenly and almost completely withdrawn. The ground and objects thereon appear to be moving away but this perception diminishes as the machine gains height. On looking over the side, the passenger is agreeably surprised to find that he can view the ground with equanimity from a height and experience no giddiness or other unpleasant sensation. This is due to the fact that the aeroplane is not connected with the ground and thus the observer's sense of perspective is altered.

Although the aeroplane may be flying level at from 60 to 120 miles an hour, the passenger is not conscious of any such speed and can only partially realise this by projecting his face or hand over the side, from under cover of the wind screen.

His anxieties with regard to height and speed having been relieved, there supervenes a feeling of exhilaration and more attention is now paid to the scenery below. He now finds mental occupation in trying to adapt his new perceptions of objects on the ground and comparing and contrasting these with his previous perceptions at ground level. As the aeroplane's course is altered he is conscious of one wing going gently up as the whole machine is banked in turning. Then after a while he may become a little apprehensive of the descent, and wonder as to whether he will experience water-chute or lift sensations. Again in this he is greatly surprised. As the aeroplane's nose is gently pointed downwards and the engine throttled down, auditory impressions are diminished, but there is no sensation of rapid descent or falling. Nearing the end of the glide the earth seems to be coming up rapidly to meet the aeroplane and the sensation of speed is again increased. As the wheels touch the ground with an almost imperceptible jar, the vibrations increase for a little, and then subside as the aeroplane slows down and comes to rest. When the passenger steps out he is conscious of a marked sense of exhilaration as though he had partaken of a glass of good champagne. The pulse is found increased from 10 to 20 beats above normal and there may be a certain amount of difficulty in hearing and buzzing in the ears. The mental summing up of most passengers after a flight is a sense of exhilaration, a feeling of having accomplished something, agreeable surprise at the absence of sensations of height and speed, mixed with mild disappointment that all previous apprehensions were needless.

As more flights are taken the passenger gains what is known as air experience, adapting himself to the various evolutions and deriving therefrom more or less pleasure as the case may be.

With the pupil under instruction the case is different. As well as accustoming himself to being in the air he has gradually to learn how to control the aeroplane in flight. This takes a varying time from $2\frac{1}{2}$ to 9 hours' flying. During this time he is fully occupied mentally in adapting himself to a new and complex set of co-ordinated movements, as in working in unison the rudder bar with his feet and the control lever with his hand. He has to develop "hands" or delicacy of touch. To a few this seems to develop easily and naturally. Most pupils expend too much muscular energy on the controls, "squeeze juice out of the joy stick," and are apt to over-correct any errors in the air. A drowning man will clutch at a straw, and the author is inclined to think that where the subconscious element of fear is more marked there will be found less delicacy of control. Confidence in his instructor and a sense of rivalry and competition with his fellow-pupils greatly help the would-be aviator at this stage—on the other hand the difficulty of estimating how far he himself, and not his instructor, is really controlling the machine often raises doubts in his mind as to his progress in flying. A few may give up at this stage, realising their inability to learn, or finding themselves unhappy in the air, losing confidence in themselves and recognising that their nervous system is not equal to the strain. Happily most are keen and determined and enjoy their lessons in flying, and here the original reason why flying was chosen exerts no little influence on the whole problem. In the tuition period, confidence as a rule grows daily until the pupil realises that it is nearly time for him to be sent up alone. This is a critical period and in some cases quite a mental strife goes on; a fight on the one hand between determination and a desire to get it over, and on the other a feeling of uncertainty as to one's ability to really bring it off successfully.

Sooner or later the momentous day in the pupil's flying career arrives, and this brings us to study.

(2) The psychological aspects from the point of view of the pupil on his first solo.

A thorough insight into this side of the question can only be obtained by having flown solo oneself. The author's own effort was amply repaid, and from a careful analysis of it immediately afterwards he was enabled more easily to pick out the salient psychological points for investigation and to draw up a scheme for such accordingly. The following is a brief résumé of his own experiences. " I had no intimation that I was to go solo, but had been going round doing landing practice with my instructor, Flight-Commander McMinnies, when after the fourth landing he got out of the machine, as I thought, to examine a tyre, but instead said, 'Go on, " doc," push off, you'll be alright.' I knew that debate and delay would raise doubts in my mind, so, to avoid this, thankful that I had not been given long to ponder, I pulled down the mental blind on my imagination and opened the throttle slowly. My effort at taking off the ground was not exactly classical and I found the machine slewing off to the left." Although torque is mainly responsible for this, and one should correct against it by keeping on a little right rudder, the author is convinced that lack of co-ordinated movement was also responsible. In the forward movement of the left arm to open the throttle there is inclined to be a similar automatic action of the left leg, and so more pressure is exerted on the left rudder bar, causing the whole machine to move to the left. " Once in the air my mind was fully occupied all the time in attention to flying, watching controls, instruments, etc., and I can honestly say that fear had no time to assert itself. The element of fear was lurking somewhere at the back of the head, but acting rather as a guardian spirit in making me conscious of danger and concentrate on avoiding errors. I found actual flight fairly easy, in fact the aeroplane seemed to do it all, and all I had to do was to concentrate in case any emergencies should arise." Of course the machine feels much lighter, easier on the controls and inclined to climb more quickly than during a dual instruction flight. In a first solo there is no time to notice any sense of loneliness. A remnant of the old spirit of conquest reasserts itself in that one has time to feel one has at least achieved something new and wonderful. In a double sense one feels well above one's fellow-creatures below. "After two circuits I determined to land—a long experience of aerodrome life told me that here difficulties arise, but I was too occupied mentally to worry. My flying friends who witnessed my first flight will all agree that my effort to land was not according to the book of words. I made many errors in the descent and realised that stimuli in rapid succession were being sent to the higher centres. There was no time to be afraid. Each stimulus of difficulty or error had to be met by a rapid and correct response. On landing there was a feeling of happiness at having achieved something new, but also a feeling of disappointment at not having made a better performance. There was no mental fatigue afterwards, but I felt conscious of slight muscular tiredness in both upper and lower limbs. Owing to bad weather intervening, my second flight did not take place till a week later. Then my sensations before going up were anything but pleasant, but once in the air these completely vanished owing to the mind being fully occupied in attention to flying. This time I felt much more confident during the flight and better able to control the machine. Instead of the machine flying me there was the feeling that I was flying the machine." The realisation of this fact in the air changes the whole mental attitude towards flying, and in it originates the awakening of self-confidence in flying. In the second flight no difficulties were encountered and a good landing was made.

"In reviewing my solo experience I was struck by the following facts :—

(*a*) That by receiving little or no intimation until just before going up I had no time to be troubled with anxieties and apprehensions or the mental turmoil of repressing these.

(*b*) That actually during the flight I had no feelings of fear.

(*c*) That the element of fear was present but subconscious.

(*d*) That if there is a long interval between the intimation and the actual flight then actual signs and symptoms of fear may occur.

(*e*) That there is a fair expenditure of mental and bodily energy during a first solo flight.

(*f*) That stimuli may be sent up to the brain in rapid succession, so much so that I venture to think in some cases a state of mental inertia supervenes, and may possibly account for a proportion of crashes on the first few solo flights."

A series of questions was drawn up relating to these points amongst others. Each pupil immediately he finished his first solo was asked to fill up one of these forms under the author's guidance. It is important that this should be done almost immediately after the flight as delay alters one's impressions considerably. At first the author made pupils write out their confessions in letter form, but found they often strayed from the real issues required. If a set series of questions has to be answered the investigation is rendered more simple and accurate. Again, it is of importance that the questions should be filled in under personal supervision. The following is a copy of the form he used for investigating the points in question as well as others not of purely psychological interest.

1st SOLO EXPERIENCES

Name................ Age........ Rank........

Previous Occupation......................

1. Previous air experiences.—
2. Why flying was chosen.—
3. Time on dual control before solo.—
4. Imaginative or not.—
5. Proficiency in sports, if any.—
6. Estimate of one's own courage.—
   (*a*) no fear, naturally brave.
   (*b*) ordinary courage, cautious, fear controllable.
   (*c*) naturally nervous.
7. Previous health.—
   (*a*) any serious disease, *e.g.*, heart, lungs or accident.
   (*b*) any ear or eye trouble.
   (*c*) any disease of nervous system.
   (*d*) liability to sea or train sickness.
   (*e*) ability to look from a height (not flying), *e.g.* from cliffs, tower, etc., without feeling giddiness.
8. Family history.—
   Any evidence of disease of nervous system, *e.g.*, fits, epilepsy, etc.
9. Medical examination.—
10. Instructor's report.
11. Later progress.

DESCRIPTION OF SOLO

Entry from log book.

Time after intimation of having to do first solo.

Sensations before going up :—

(*a*) Quite confident.
(*b*) A little uncertain.
(*c*) Uneasiness in knees.
(*d*) Trembling or abdominal sensations.

In describing solo, state course.

Line of direction, and did you keep this line in getting off ?

The "get off the ground" and any error in doing so.

In the air, was the mind occupied all the time in attention to flying, watching controls, instruments, etc. ?

Or did the element of fear come in ?

Or was fear only at the back of the head ? (subconscious).

Did actual fear assert itself at any particular moment of flying, *e.g.*, in "bumps," turning, coming down, or flattening out to land—or in errors of flying, such as stalling, nose too far down, too much bank, flying on uneven keel, inability to steer a straight course ?

Did you lose your head at any time and in what manner ?

Describe the coming down and the landing: any errors ?

Do you honestly think the attention of the mind is so taken up in watching controls, instruments, etc., during the first solo that fear can rarely assert itself ?

Do you think that the mind (brain attention) can become so tired on a first solo that the pilot would give up—his attention power being finished—and let the machine do as it liked ?

Any further description and remarks.

As each pupil completed his first solo flight he was sent immediately to the author and under personal supervision each filled in the above form. An analysis of 100 of these shows some facts of psychological interest.

(*a*) Age :

The average age was $21\frac{1}{2}$ years, the youngest 19 and the oldest 34. Undoubtedly youth with all its elasticity is best suited for flying and more especially for war flying. As far as school flying goes a man between 30 and 40 years of age can learn to fly just as well as one between 18 and 20. The veteran Cody learnt to fly when 47. But after 30 years of age the strain of war flying is in most cases too much to withstand, at any rate for long. Of course much depends on the physiological age. Personally the author thinks 24 to 26 the best age, as then the judgment is more mature for actual flying, for tactical flying, and for the employment of aerial gunnery.

(*b*) *Previous Occupation :—*

As the majority were youthful previous occupation proved of little importance. These ranged from student to diamond merchant, from bank clerk to rancher.

(*c*) *Motive for taking up flying :—*

This has already been discussed.

(*d*) *Imagination :—*

64 confessed to have imagination, whilst 36 confessed to have little or none. The author is inclined to think that those with marked powers of imagination may make the more skilful pilots as far as actually handling a machine goes, but those with little or no imagination make the better fighting pilots. Much depends on the will power to keep imagination from running riot.

(*e*) *Estimate of one's own courage :—*

None confessed to being without fear.

Ninety-seven said they had ordinary courage, were cautious and could control fear.

Three said they were naturally nervous but could control fear and keep a grip on themselves.

None confessed to being actually of a nervous disposition.

(*f*) *Liability to sea sickness or train sickness :—*

37 confessed to being subject to this whilst 63 said this did not inconvenience them.

The rolling and pitching of an aeroplane in gusty weather may produce a feeling of nausea, but actual vomiting rarely takes place in the air. But in some pupils, especially after a bumpy cross country flight, actual vomiting may occur after landing. Again some otherwise quite good pilots are unable to stand aerobatics on this account.

(*g*) *Ability to look from a height without feeling giddy :—*

An enquiry into this elicited the fact that 60 were able to withstand looking from heights such as cliffs, towers, etc., while 40 confessed to vertigo or unpleasant sensations.

(*h*) *Interval of time after intimation of having to go solo :—*

This varied from a few seconds up to a week. From his own experience, the author feels convinced that it is better not to warn the pupil till the last minute that he has to go up alone. Then he has no time for apprehensions. If he has already been flying with his instructor and the latter gets out and tells his charge to go on alone, the pupil's " blood is usually up," and he takes off in a much better frame of mind. This is a point of extreme practical value and in discussing it with a great many pupils and instructors, the majority heartily agreed with the author.

(*i*) *Sensations before going up* :—

The extent of these depends very much on the time the pupil has to think over it. Most are anxious to get it over. After all it is probably the most momentous event of all in a flying man's career.

Seventy felt quite confident.

Thirty felt a little uncertain as to their ability to do it successfully. And of these, 3 had a feeling of uneasiness in the lower limbs, whilst 8 had abdominal sensations.

(*j*) In the air was the mind occupied all the time in attention to flying, watching controls, instruments, etc.?

To this question 80 answered yes, whilst 20 said that during the flight they had time to think of other things not actually connected with flying.

(*k*) Did the element of fear come in during the first solo flight?

To this 86 replied no, whilst 14 said they actually felt afraid in the air, not all the time, but at certain moments when they were conscious of having committed errors in flying.

There is no doubt the mental concentration is so great during the first few solo flights that there is little time for fear to assert itself.

(*l*) Or was fear only at the back of the head (subconscious)? 37 confessed to this, whilst 63 said they were not aware of this condition at all.

(*m*) Did you lose your head at any time and in what manner? 97 gave a negative answer whilst 3 confessed to momentary loss of head. Of those three, two said that during the flight they momentarily forgot how the controls acted and committed errors of flying, in putting on opposite bank to the rudder action. There was a temporary block in the new and complex co-ordinated response requisite for flying. Happily in both cases the loss of head was only momentary and the errors were corrected in time.

The third case confessed that in gliding down to land he stalled and commenced to side-slip. He writes: " I can remember instinctively stretching out my left hand to try to right the machine by grabbing something outside the nacelle (he caught hold of a strut). Then I thought to myself, " You damned fool, you're losing your head and will crash if you don't do something." I seemed to regain my self-control and opened the throttle, at the same time keeping the nose down a little, and pushing the control to port. The machine came back to her normal level and I went off again on another circuit."

(*n*) Do you honestly think that the attention of the mind is so taken up in watching instruments, controls, etc., during the first solo that fear can rarely assert itself? 76 said they were convinced this was so, whilst 24 replied that they thought the attention was not so taken up, and that it was possible during the flight to become really afraid.

(*c*) Do you think that the mind can become so tired on a first solo, that you might have to give up, and let the machine do as it liked?

34 said yes to this and 66 said no. There is no doubt that the first solo flight is a great strain on the nervous system. There is the varying stage of excitement before the flight and the great mental concentration during the flight.

If many errors of flying or difficulties are encountered, and especially if the first solo flight be of long duration then the repeated stimuli in rapid succession to the higher centres produce dilemma and mental inertia. In this state the pupil is not affected by panic but simply is unable to do anything and the machine may get into a position from which it cannot be recovered.

It is wise therefore to make first solo flights of short duration.

A few may give in after the first two or three solo flights, but the majority rapidly gain confidence, and soon make rapid progress. Some are apt to grow over-confident and a little careless—especially about the seventh solo flight, and here a word of caution from the instructor may be necessary.

After about 30 hours of solo flying the pupil becomes a qualified aviator and gains his " Wings." He is then selected according to his ability or fitness for one or other special set of flying duties, trained accordingly, and is then ready for war flying.

From the study of the passenger, dual instructional, and early solo flights the following is the summary of conclusions of practical value.

That the pupil need not fear height giddiness, the sensation of speed, loneliness, air sickness, or breakage in the air. That instructional flights should not be of long duration so as not to induce mental fatigue and the loss of knowledge gained in the early part of the flight. Nor should first solo flights be of long duration, in case dilemma and mental inertia should supervene.

That everything should be done to instil confidence in the pupil.

That after the intimation that the pupil is to go on his first solo, the time should be as short as possible before the actual flight. It is better " sprung " on him suddenly. That it is comforting to know that fear in the air rarely occurs on the first few solo flights.

In his progress towards qualification the aviator adapts himself to a new set of co-ordinated movements in response to stimuli in the aeroplane's control. He acquires air experience, develops "hands," and so flying becomes more or less automatic. A few never get beyond the pupil stage and flying to them is always more or less an effort—others again, although slow and not very promising, as pupils suddenly take a turn, make rapid progress, and prove splendid pilots in the end.

Rippon has shown that the married man is slower to learn and does not prove such a capable pilot, at least for war purposes, as the unmarried.

(3) *From the point of view of the Qualified Aviator* :—

In the earlier days of the war the overseas aviator was called upon to do any odd job in aviation for military purposes. Nowadays naval and military aviation is divided into various special sections, each requiring different types of aeroplanes, and to a certain extent different types of aviators.

Depending on his flying ability, his perfection in aerial gunnery, his physical fitness and temperament, he is chosen for one of the following special aviation duties :—

(*a*) Scout Pilot :—for offensive or defensive patrol, for trench strafing, or for special roving commissions.
(*b*) Artillery Observation Pilot.
(*c*) Reconnaissance or Photography Pilot.
(*d*) Night Bombing Pilot.
(*e*) Day Bombing Pilot.
(*f*) Instructor Pilot.
(*g*) Ferry Pilot.
(*h*) Test and Experimental Pilot.
(*i*) Seaplane Pilot.

All are subject to the stress of flying but the first five have the added strain of enduring anti-aircraft fire from the ground, and attack in the air from hostile machines. Engine failure may be disastrous enough in testing, ferrying, or instructing, but it is a thousand times more so over enemy lines. Fire in the air is a constant dread in aerial warfare—while another factor inducing mental strain is the danger from fog and loss of direction.

(*a*) The Scout Pilot, from the very nature of his calling in being mostly on the offensive, and from the fame derived from bringing down enemy machines, is the one most often in the limelight. He must have the physique to withstand the effects of high altitude, and also of sudden and rapid change of heights. Called upon in most aerial duels to perform all sorts of aerobatics he must possess "fine hands," be adept in flying tactical manœuvres, and above all an expert in aerial gunnery and a deadly shot. If a formation leader, he has to make rapid but accurate decisions, otherwise he may lead not only himself but perhaps his whole formation to destruction. Temperamentally he is better with no imagination, or with one well under control. He is more apt than anyone to suffer from a feeling of loneliness, and often welcomes a fight to prevent distraction. Happily in an aerial combat he has full mental occupation in jockeying for position, and only later perhaps when he is safely home does he realise the danger he had come through. In an aerial "dog fight" there is always the danger of collision. In the days before formation flying and aerial mêlées were common the scout pilot often met his opponent alone. The thrill of danger often obsesses him momentarily before giving battle. Experience in air fighting gives birth to a new flying confidence. At first through eagerness he may open fire at too long a range. Later he learns to sum up his opponent before the duel commences. If he finds the latter opening fire at a long range he is comforted in the fact that he is up against a beginner, or one who has the "wind up."

Many combats in the air are indecisive. In the mental tension of disappointment, rage often seizes him at his adversary's escape, and here his judgment may be clouded for the moment and his fit of temper lead him to break formation or make him fail to notice other sources of danger. The sight of an enemy machine going down in flames rarely unnerves him, he finds exultation in the fact that another enemy aeroplane has been beaten, but rarely thinks of its previously living occupants. The sight of a comrade going down may unnerve him but it often spurs him on to revenge. The author has been struck by the fact that our most successful aerial fighters are all very clear thinking men. They all recognise the super-importance of accurate aim and all pay special attention to developing this by constant target practice. Again most of them figure out all the chances in an aerial fight and act accordingly. Ill luck has always to be reckoned with, and the probable extinguishing of a meteoric career.

The successful aerial fighter tries to approach his opponent rapidly and without being seen, and does not open fire till he is fairly near. Then his opponent, quite unconscious of danger, may meet instant death from an unseen hand.

Many scouts prefer this diving method of attack, and should they fail in the first attempt, clear off rapidly, gain height again and await another unsuspecting prey.

(*b*) The artillery observation pilot's duties impose a great deal of nerve strain on him, and he, more than any other pilot, is apt to become too introspective whilst in the air. His work never takes him to a very great height and he is constantly under more or less accurate anti-aircraft fire, and at times subject to aerial attack by hostile scouts. He has always an observer with him and thus wards off feelings of loneliness. Confidence in each other is a factor of supreme psychological importance. The very fact that they can speak to each other by telephone, or exchange notes or even a smile, unconsciously softens the nerve strain. His work may be of two kinds. If on an artillery observation patrol he has to fly up and down a certain stretch for a given time looking for enemy gun flashes. On some days there may be little to note and the work becomes deadly monotonous, especially as he is all the time a moving target for "Archie." If a beginner he may become at first horribly afraid, and unless possessed of a strong will is much tempted to kick the rudder bar over and make for home. The natural response to fear is flight, and with the means so ready at hand it is a wonder that the animal instinct does not more often assert itself. But again there is another response or lack of it to fear. This depends on the subject's temperament and also on the intensity of the stimuli producing fear. Instead of the flight response there occur dilemma and mental inertia for the time. His other work consists of doing counter-battery shoots, *i.e.*, ranging a friendly battery's fire on an enemy battery. Here he finds more mental occupation in that he has to locate his own battery, watch for ground signals, get out his wireless, and watch for and correct the fall of shot. As a rule the work is not of such long duration. In this duty he is not nearly so apt to become introspective. He need not possess the flying ability of the scout pilot, nevertheless he must possess an adequate nervous system.

(*c*) The pilot on Reconnaissance and Photography has to fly well into enemy country. He carries a companion and has a definite mission. He may be called upon to defend himself, but is often escorted by a fighting scout. His dread is that of engine failure over enemy country, and also the sudden onset of bad weather. He may hide from " Archie " in friendly clouds but has to keep a sharp outlook for enemy scouts.

(*d*) The Night Bombing Pilot in his training period may suffer apprehensions as to his landings, but once accustomed to this and when actually on night bombing raids he rather welcomes the friendly darkness. Most agree that it is the least nerve racking work of all. He is usually blessed with a good engine, is conscious of the fact he can see and not be seen. He knows that " Archie " is more or less haphazard, unless perhaps over his object, whilst attack from the air is mostly a matter of luck. He knows it is difficult for a searchlight to pick him up, at least keep on him for any length of time, and he derives a great deal of glee from diving on it with machine gun fire. All these facts give him a great deal of comfort and one finds that his nervous system does not give way easily.

(*e*) The Day Bomber has to fly in formation which he must rigorously keep or else disaster will befall him. "Archie" may be troublesome at times, but dread of engine failure is his chief worry. He is as a rule escorted. Formation flying is the great salve to his feelings. In the earlier days when day bombing was more or less haphazard, then many a one, just before facing the barrage over a town, was much tempted to release his bombs anywhere and make back for safety. Aerial mob psychology plays a great part now-a-days in the complete execution of a daylight bombing raid.

(*f*) The Instructor Pilot has not the nerve strain of flying under war conditions but nevertheless the responsibilities of his work are very great. He has to face long hours, and in good weather may be doing six hours a day in the air. He must be both physically and temperamentally strong. Besides possessing flying ability he must have the power to impart it to others. He has to be continuously studying his pupils from the psychological point of view, ever keeping in mind the supreme importance of the psychic factor of inspiring confidence in others. He must have the patience of a saint and keep an unruffled temper. He has always to face the possibility of a pupil doing something extraordinarily stupid in the air—an error at an insufficient height to prevent disaster. This could certainly be obviated by equipping all instructional machines with a means of rapidly rendering neutral the pupils' controls.

How great is the strain on the instructor of sending off pupils on their first solo flights can only be realised by those with long experience of flying school life. His judgment as to when his charge is ready to fly alone must be fine to a degree. The responsibility of a life often rests on his shoulders. The author has been repeatedly impressed by the fact that most successful instructors are men of unusually strong physique. It is a mistake to send good instructors on war flying. They may lose the glory, excitement, and rewards connected therewith, but it is on the results of their work that reliance is placed on maintaining a supply of the very finest aviators.

On the other hand it is a mistake to impose instructor's duties on the pilot from overseas—by way of giving him a rest. Let him have his rest in a proper manner. He may be getting stale, easily made irritable, and not at all interested in instructing. To make him do so is to court disaster.

(*g*) The Ferry Pilot's life is probably the easiest of all. There is little nerve strain, and this is an excellent way, for those who wish it, of giving overseas pilots a rest, and yet maintaining their interest in aviation.

(*h*) The Test and Experimental Pilot must possess the requisite "hands" for flying. Should apprehensions arise they mainly revolve round the amount of confidence he has in the designer and constructor of the particular machine he is flying. It is to the good if he is of a mechanical turn of mind and better still if he so acquaints himself with the details of construction and design as to consider himself an expert in these matters.

(*i*) The Seaplane Pilot's duties expose him to a peculiar strain not found in other aviation duties. The fact that he has to carry out long patrols over the sea, with perhaps for hours on end no visible landmarks, gives him much time for reflection. He is apt to suffer from a peculiar sense of isolation and ponder over the thought of engine failure, a much more serious occurrence over the sea than over the land. As one seaplane pilot explained it—"If you have a forced landing even in the desolate country you can always get to a friendly pub for the night, but 'in the ditch' there are no pubs." Again should he have a forced landing and the sea become at all unsettled he has to face the worst form of sea-sickness known.

In the psychological study of the aviator one is struck by the importance of the motive in taking up aviation. This gives more or less driving power to the conscious endeavour to overcome the obstacles in learning to fly—and supplies the determination to surmount difficulties throughout the whole flying career. The author places determination, grit, "guts," call it what you may, as the most important factor in flying.

At the commencement of the flying career attention is called into play and kept fully occupied in the acquisition of responding to new stimuli with a new series of muscular contractions in correct proportion and sequence. At the outset execution often falls short of intention. Some of the motor responses are excessive or superfluous, others are omitted at the proper time or in proper sequence and disturbing factors arise.

In attaining progress and success the proper control is gradually gained over the requisite muscular responses. Attention is fixed on what alone is necessary. This is retained and the rest forgotten. When this control is thoroughly organised then conscious effort is no longer necessary and flying becomes automatic.

Perception, Discrimination, and Retentiveness are important factors in learning to fly. When flying becomes more or less automatic then arises the question of the adaptability of the aviator to particular flying duties. The law of survival of the fittest as a rule answers this question, but the psychologist and physiologist may supply a more economical answer.

A great deal of practical psychology has been carried out in connection with aviation, especially with regard to the study of reaction times and emotional responses; and also in connection with tests of the attention, behaviour, and motor responses at atmospheric pressures corresponding to high altitudes.

Loewy and Placzek in 1914 reported a series of tests of the attention and other psychic phenomena on themselves, and two others, in a cabinet with an atmospheric corresponding to that of an altitude of 4,000 metres. Objective findings were comparatively slight although mistakes in additions were more frequent the more rarefied the air. The sensation of being incapable of giving close attention, of being unable to act promptly and with precision, these subjective factors were prominent, and exerted a certain amount of paralysing effect. The subjects were quiet, warm, and free from responsibility—and therefore were not exactly under the conditions as in actual flight.

In America similar but more elaborate tests have been carried out. One would suggest that similar tests should be done under the effects of cold—a most important factor at altitudes.

Psychological investigation helps considerably in determining deterioration or staleness in the aviator. The latter may be fit for a particular flying duty or even flying in general but the question arises how long can he remain fit.

Unhappiness in the air, introspection, morbid thoughts, and the feeling that the dangers connected with flying are developing into an obsession, are danger signals that the psychologist alone can discern and can take action accordingly.

This leads us to the domains of mental pathology, and the study of the various nervous breakdowns occasioned by the stress of flying.

CHAPTER V

The Aero-Neuroses

The term, The Aero-Neuroses, is used by the author to cover the various types of nervous breakdown that may arise in those engaged in flying. Fleet Surgeon H. V. Wells, R.N., coined the word " Aerosthenia," to designate these conditions, but this word, although euphonious, is altogether incorrect. Various other terms have been used, such as Flying Stress, Flying Sickness and Aviators' Neurasthenia, but " Aero-Neurosis " is a better term to use, including as it does any type exhibiting manifestations of functional disease of the nervous system brought on by flying. The subject is a very large one, and one of the most difficult to be faced by the medical officer, as more cases of this nature than of any other present themselves in Air Force work. The questions of prevention, diagnosis and treatment are of equal importance alike to the aviator himself and to the service. Nervous breakdowns have been noted since the early days of flying; in fact they may be classed as an occupation neurosis—a comparatively new occupation, namely: flying. Aero-neurotic conditions may be brought on, firstly, simply by the strain of learning to fly. Loss of confidence and a fear of going up in the air arise, a neurasthenic condition develops, the chief characteristic of which is one of the phobias, namely: aero-phobia. Again, the condition may follow an aeroplane accident at any time in the aviator's career; it is commonly of a more severe type if induced early in his flying life. The shock of the crash alone may do it, or it may follow where concussion supervenes, or where bodily injury has been sustained in a flying accident. Finally, neurasthenia may follow the added strain of war-time flying with its attendant long flights, great altitudes, night flights, aerial fighting, and anti-aircraft fire. It is an extremely difficult matter to say beforehand which individual is likely to break down in flying. Temperament is very difficult to estimate clinically. More rigorous examination in admitting candidates to the Air Force has certainly eliminated a number of candidates whose nervous systems would have been likely to give way. No tests or series of tests have proved of much value in picking out such individuals, but a study of the psychology of flying helps greatly in estimating the temperament of the aviator. Along psychological lines will be found the guide to eliminating the types likely to break down in flying; and also in many cases the means of treating such cases. The aerodrome medical officer interested in flying has the best opportunity of studying the various Aero-Neuroses. Given such a doctor in conjunction with an experienced senior flying officer or instructor we have a powerful combination at an air station for speedily eliminating the unfit, for preventing many from breaking down, for stopping a wave of Aero-Neurosis amongst others, for reducing a number of preventable flying accidents and thus saving both personnel and material for the good of the service. Of the various Aero-Neuroses the most common are those with either neurasthenic symptoms or symptoms pertaining to hysteria; but one and all of the various manifestations of functional disease of the nervous system may be found. Before discussing the etiology and various clinical types that are met, it will be well, from the practical point of view, to divide these cases into two great classes:—(I.) The Aero-Neuroses found among pupils from the commencement of their flying career up to the time when they become qualified aviators, roughly after about thirty hours' solo flying. And (II.) The Aero-Neuroses found among qualified aviators and for the most part those engaged in war flying.

Class I. the author will deal with himself in Section A of this chapter, whilst Class II. in Section B of this chapter has been written by his friend and colleague, Surgeon Oliver H. Gotch, R.N., to whom he is greatly indebted. During the past year Surgeon Gotch has had under his care a large number of flying officers whose nervous systems have broken down under the strain of war flying. His investigations into these conditions have been most complete, and from an independent point of view purely as a medical officer interested in flying, the author is in hearty agreement with all the views he expresses.

SECTION A

THE AERO-NEUROSES OF FLYING PUPILS

During two years as medical officer at flying schools about 600 pupils passed through the author's hands. They arrived in small batches from time to time, and he had every opportunity of getting to know them and watching them through the pupil stage of their flying career. The great majority went on to qualify and then passed out to other schools for special training or else on to war squadrons. About 10 per cent. gave up or were made to give up owing to some type of Neurosis supervening. The pupil may come to consult the medical officer himself or he may be brought by his instructor. In some cases no more difficult problem can face the aerodrome medical officer. Much depends on the opinion he shall form, and this must therefore be based on a careful examination, backed by experience and a sound knowledge of what is required of the aviator. Great help can be obtained by working hand in hand with the instructors. The type of Neurosis mostly found in pupils is of the neurasthenic variety but occasionally the hysterical variety is found. It is of importance to know the time of onset of the Neurosis. It may occur (*a*) during the period of dual control instruction; (*b*) more commonly during the first few solo flights; (*c*) less commonly later, when the pupil is either transferred to another flight or has to fly faster types of aeroplanes; (*d*) again, the onset often dates back to a flying accident either without injury or after sustaining shock, concussion, or bodily injury. (*e*) Moreover, it has been found to follow where the pupil has not actually been in a flying accident but has been the witness of one. (*f*) Finally there is the case following a crash, usually with severe bodily injury, in which, very late, Aero-Neurosis supervenes. If the pupil develops Aero-Neurosis, and it remains undetected he may infect other pupils; sometimes quite a wave develops, one pupil who has given up flying being followed in this course by two or three more in the same week. As will be seen later, prompt measures are required to deal with the situation. After enquiring into the time of onset, one notes from the clinical point of view whether a case is of the neurasthenic or hysterical variety. Often one variety merges into the other. All symptoms are carefully noted, and a physical examination carried out, but the latter, in pupils, usually returns negative results. What are the usual types of Aero-

Neuroses the medical officer has to deal with? Let us take the simplest case first: the pupil will come along to consult the medical officer—he may or may not have had a minor crash and escaped physical injury, but he will say honestly that he does not want to continue flying. His nervous system is not strong enough to bear the strain of flying, and luckily he himself recognises it and is manly enough to confess it. Such a pupil one has to admire for his moral courage, as it has to be remembered that pupils are very sensitive to their fellow-pupils' opinion. The treatment is easy; his wishes are granted and he is detailed to another branch of the service. As an instance of such a case, the author has had a pupil come to him for advice after having done only one hour's dual control instruction. This pupil said that honestly he could not go on with it. Another made a very erratic first solo, landed safely, stepped out of the machine and said that nothing on earth would induce him ever to go up again. Another came after having done four solos, and another after five hours' flying, and both confessed to their inability to go on with it. The next type of case is one who comes either just near the end of his dual control period of instruction, or perhaps after his first or second solo and complains of headaches, usually worse after flying, and as a rule attended by gastric symptoms, often nausea, but no actual vomiting; or perhaps he may have difficulty in getting to sleep, or his sleep may be broken or fitful. Dreams connected or not with aviation may be reported. In some cases the chief symptoms may be giddiness in the air. No mention as a rule is made of any distaste for flying, the mental attitude towards flying is studiously avoided in the history given. Some appropriate treatment is ordered, and the pupil is placed on the "Excused Flying" list. In a few days, sometimes depending on the state of the flying weather, he will reappear with the story that he is not much better or that the symptoms have recurred; perhaps there may be some new symptom added, and usually if a trial flight has been undergone, vertigo is complained of. A consultation with the instructor at this stage will throw some light on the subject. Of course physical examination and treatment are not to be excluded but much can be gained by a good heart to heart talk with the patient. Some confess that they are unhappy in the air and give in; others stoutly deny that they want to give up flying, and say that they would very much like to carry on with flying if they could only get well again physically. In these latter cases the medical officer may have great difficulty in deciding. The physical signs are few or absent; he may only find an increased knee jerk, there may or may not be tremor, and similarly with evidence of equilibration instability. It may be doubted if even physiological tests would help one at this stage. What is lacking is that one has not the instrument for probing or laying bare the subject's temperament. Sooner or later the truth comes out, and these cases give up or are rejected as unfit for further flying. These cases are of the neurasthenic variety, and the chief symptom, though in many cases denied, is aerophobia. If they go on undetected great harm may be caused not only to themselves, in that they become unhappy, depressed, shun their comrades and suffer in general health, but also to their fellow-pupils, some of whom may become changed thereby in their mental attitude towards flying. Another class of case of Aero-Neurosis with onset similar to the above, takes on the character of hysteria. Some show quite notable signs such as marked tremor of limbs, lips, etc. Functional paralysis, contracture or a hyperaesthetic condition may develop. The author was called in consultation to a case lately in which with no history of injury a painful contracture of the knee was present. The knee was kept semi-flexed and the gentlest touch caused excruciating pain. There was a glove area of hyperaesthesia. There was no fluid in the joint, no extra-articular swelling, no redness or local increase of temperature, whilst X-Rays showed nothing abnormal. There was no evidence of tuberculosis in himself or family, and no history of gonorrhea or syphilis. On enquiry it was found that he had nearly finished his dual control period of instruction and would soon be ready for his first solo. Under an anaesthetic the knee relaxed. This was undoubtedly a case of hysterical joint and the cause was made plain. In another case complaint was made of excessive tenderness and pain over the middle of the sacrum, no evidence of organic disease was found, and in this case on searching enquiry there was elicited a marked distaste for flying, although he had gone as far as twenty hours' solo flying. It is rather a ticklish point whether to turn down a pupil who begins to suffer from a form of neurosis and who has done say, twenty to thirty hours' flying. So far as his own experience goes the author has never yet found a case of this kind do well. It is well to keep in mind always the question of malingering; it is an undoubted fact that some individuals are admitted who never intend to fly; and others discover either that they have no liking for flying or that they are not up to it and try to avoid it on medical excuses. In the earlier days these individuals on one or other excuse managed to spend quite a time in the service without doing much flying. They often tried the doctor with symptoms both weird and varied, but if the doctor has any knowledge of flying it is fairly easy to diagnose these cases and treat them accordingly.

Now one turns to the class of case in which a Neurosis follows a flying accident. In these a morbid condition follows the shock of the crash, and may present symptoms of neurasthenia or hysteria or both. The condition is absolutely the same as the Traumatic Neurosis knows as "Railway Spine" or a "Railway Brain." In the crash the pupil may sustain more or less severe bodily injury—he may sustain more or less severe concussion—he may receive bodily shock without apparently physical injury, or finally he may simply be affected by the profound mental impression of the crash. After one or all of these conditions the Aero-Neurosis may supervene. As in an accident of any sort with danger to life one rarely feels the mental side of it until the next day, or perhaps not till some time later, and then the enormity of the danger that has been escaped spreads itself before one. Those with little imagination or with imagination well under control can or may dismiss the whole problem from the mind almost immediately, but in others less fortunate, the picture repeats itself, becomes more and more developed mentally until it finally becomes fixed. Such a fixture presents itself as a temperamental breakdown, and any form of Aero-Neurosis may develop. For example, after a crash the pupil often, if apparently unhurt, is now-a-days excused flying for a day or two. Should a Neurosis develop he will probably complain of headache, or insomnia, or may suffer from dreams in which flying accidents predominate. Again he may exhibit some form of irritability or simply complain that he feels out of sorts. Should he have sustained a minor injury, such as a bruise, sprain, or a trifling wound, the significance of such will be unduly dwelt on. One finds that the symptoms do not decrease with the physical signs of such injuries. After appropriate surgical treatment these cases are usually sent on leave for a week or two. Should a Neurosis develop the pupil on returning to duty will say that he does not feel fit and detail any or all of the symptoms described above. They often complain of being easily fatigued, with inability to concentrate on reading, study, lectures or games. Some confess that their confidence in flying is lost whilst others stoutly aver the opposite. Others say their confidence will return as soon as they feel all right again. It is interesting to note that after a crash, usually in which severe physical injury has been sustained, Aero-Neurosis may supervene as a late development. This has been noted where even although the injuries were severe there was no loss of consciousness. After such a flying accident the pupil is laid up for weeks or perhaps months under surgical treatment. He may have been very keen on flying, and during his treatment and convalescence he does not mind much his injuries, but rather frets over the fact that he is losing time and that his brother pupils are forging ahead of him in flying. But later on the details of the occurrence of his crash begin to get hold of him, and a kind of slow mental cancer sets in, and as time goes on and he is ready to return to duty all keenness on flying has disappeared, and a real traumatic neurosis has developed. For example, a pupil on his second solo crashed, was thrown out and sustained a telescoping fracture of his seventh thoracic vertebra without involvement of spinal cord; there was no loss of consciousness, but surgical shock and pain were very severe. For two months he lay in a special spinal frame ; his daily conversation was on his speedy return to flying and how he must make up for lost time. Convalescence took another two months, and then all keenness for flying had gone. Such is a brief description of the types of Aero-Neuroses that occur.

Having noted the time of onset in the pupil's flying career, consulted with the instructor, carried out as far as possible a thorough physical, psychological and physiological examination and diagnosed the clinical type of Aero-Neurosis, the aerodrome medical officer is faced with the problem of treatment. Earlier in this chapter a division was made of Aero-Neuroses from the practical point of view into two classes, namely : (1) among pupils, and (2) among qualified pilots and those engaged in daily flying or war-time flying. The importance of this distinction from the point of view of treatment will be seen below. In the early days of flying before there was much medical interest in or supervision over flying, if a pupil crashed and was apparently uninjured, he was ordered to go up again in another machine almost immediately. This was supposed to prevent loss of nerve or if momentarily lost by the crash to facilitate the immediate recovery of it. The author has seen the results of this method of treatment, and can say emphatically it is a method to be condemned ; he is sure that most experienced instructors will agree with him in this. Bullying treatment with pupils never pays in a flying school. It must be remembered that pupils are usually young, some having practically just left school. A nervous breakdown sets in early in their career and some must go through a terrible mental struggle between giving up or going on with flying ; and, therefore, a great deal of firm sympathy is required. Some are afraid to confess to their instructor, and, therefore, if they receive friendly help and advice from the doctor a great deal of their mental anxiety is relieved. The very fact that they can unburden their troubles to some one relieves them considerably. Symptomatic treatment must be carried out, *e.g.*, headaches must be treated, and for this the author usually prescribes

Ammon. Bromide	gr. xx.
Phenacetin	gr. viii.
Cæffein Citrate	gr. ii.

This will relieve most ordinary headaches and should the pupil report no relief from this powder then one suspects malingering. Gastro-intestinal disturbance must receive appropriate dietetic and medicinal treatment. One rarely finds evidence of organic disease in pupils, at least now-a-days with the rigorous methods employed before the candidate is admitted to the Air Force. Most of the pupils who give up or are turned down from flying should be re-examined as for admittance to the Air Force. In the majority of these so dealt with little evidence of vaso-motor disturbance or equilibration instability was detected. About ten per cent. give up or are rejected. In treating these from the point of view of flying, the author at first worked in the dark and had gradually to feel his way. Some were simply excused flying for a day or two, and were given ground duties, and some were given short leave, perhaps a week-end or up to a week. The results were unsatisfactory, for no sooner were they back to flying than symptoms reappeared. Some were put back on dual control instruction again, the "Slow Recovery" method mentioned by Wells, whilst others were turned over to another instructor. But the results were no better. Some who had sustained minor injuries in a crash were given from fourteen days to two months' leave away from everything connected with flying, but even this did not restore their flying confidence. As an example, a pupil on his second solo made a bad take off the ground, lost his head and crashed. The machine turned over, and the pupil sustained a fracture of the nose with very slight displacement and a few minor bruises. He was in hospital two weeks, and was then given a week's leave, but on return to duty he said he did not feel quite fit to resume flying, but thought that later his confidence would return. He was a keen engineer, and well up and interested in all connected with engines. As an experiment permission was obtained for him to go on three months' leave to his own home and to avoid all connection with flying. He was forbidden to read flying papers, discuss flying subjects, or mix with any other flying officers. On his return he looked physically fit and well, but on examination he said his mental attitude to flying had not changed since his crash, and that his " nerves " did not feel up to it. Similar results were obtained with several other cases. After trying the various methods detailed above no good results were obtained, and as it was noticed that one case of Aero-Neurosis might affect others one was forced from the point of view of value to the service, to look upon the infective side of the condition, and prevent that at all costs. The conclusion come to, which was supported by the C.O., the senior flying officer and all instructors alike was, that as soon as a pupil showed loss of confidence in flying and exhibited any of the signs or symptoms of Aero-Neuroses, he must be discharged from the air station as unfit for further flying, and the sooner this was done the better for all concerned. This is a drastic statement to make and treatment to carry out, but experience has convinced the author that not one single pupil who loses confidence in flying and develops an Aero-Neurosis ever regains that confidence or goes on to become a qualified aviator. By this method of eliminating such cases at once, the service loses a certain number of pupils (10 per cent. the author has found, some of whom might have succeeded after prolonging instruction); but to counterbalance that and more than counterbalance it, this rapid elimination method saves instructors' time and patience (the latter being very important), saves machines, material and money, prevents a wave of Aero-Neuroses spreading, and saves the pupil himself from perhaps serious disturbance to his after-health. Some flying officers break down even after they have qualified and are ready for overseas. Some of these have probably had a mental struggle during their pupil days which has remained undetected or unconfessed. Perhaps some of these with appropriate treatment could be relieved, but even this is doubtful. Throughout all his experience the author has always found that the earlier the stage of onset of the Neurosis in a flying man's career the more hopeless is it to deal with or cure. When a flying officer has done fifty to one hundred hours' flying it is always worth while making an effort to save him should a Neurosis set in. Before deciding finally on the nature of the case it is well to remember that there are a few malingerers who try to get out on medical grounds as soon as they have qualified; they have their "wings" and like to retire, retaining these without doing any more serious flying.

To summarise, an aerodrome medical officer should treat all cases on their merits, consult as much as possible with the instructor, classify the clinical type of Aero-Neurosis, carry out investigation with regard to further tests that might detect such cases earlier and incidentally prove or disprove the tests for admittance to the Air Force. He should remember that the earlier the onset of the Aero-Neurosis the worse the prognosis. Perhaps some medical officers may find the treatment proposed of rapid elimination of such cases too severe. Any method of treatment even to save for the Service the ten per cent. who are rejected would be welcome. Some time ago a suggestion was made to one medical officer to carry out hypnotism in some of these cases, but so far nothing has been heard of the results.

The "Aero-Neurosis" of War Flying

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The following remarks and suggestions are based on the notes of 200 selected cases of flying officers who have broken down with respect to flying whilst on war service, and is a summary of the year's work whilst at the Central Royal Air Force Hospital, Hampstead.

The main purpose of this article is to give an account of the "Neuroses" of war flying from a purely practical standpoint, and to describe the examination and treatment and prognosis of the patient in a way that might serve as a guide to an Air Force Medical Officer who has had no previous experience.

In the first place, the most essential point to realise in any single case is the paramount importance of taking a very detailed and full history of the patients. Quite often, after a laborious questioning of the patient with respect to his history and symptoms, one fails to elicit anything of value which can explain his breakdown until some point reveals itself,—maybe quite a trivial one—which throws a most unexpected light on his case. Naturally such a procedure is often exceedingly tedious, and in any case is laborious, and will mean that it will be only possible to examine a few cases in one day. Apart from the time spent, the question of fatigue on the part of the medical officer is obviously an important one. Repeated personal experience has shown that a sketchy, hurriedly-taken history is generally useless.

History

Firstly, there is (1) *Family history.* The number of persons in any community who have a completely *negative* family history seems to be, generally speaking, small. How great a part heredity plays in our lives may be indeterminable, but certainly a large proportion of the patients studied at the Royal Air Force Hospital, Hampstead, gave evidence of some hereditary "nervous instability" either on the paternal or maternal side, or both. The worst cases almost invariably showed some. (Out of 200 cases, 167 had a positive history in this respect.)

The patient is asked to give as complete an account as he is able of his family :—their ages, nationalities (particularly as to any Celtic or Hebrew blood), and habits ; whether there is any alcoholism or evidence of definite mental instability or eccentricity in one direction or another—their attitude toward worries and troubles of all kind : whether or no they have ever suffered from any nervous breakdown.

Any constitutional disease such as pulmonary or other forms of tuberculosis, diabetes, etc., are of less importance, apart from epilepsy—but the existence of "rheumatism" has, in a few cases, been revealed in the family of a patient (26 out of 200). A family history of epilepsy or of asthma should, of course, be mentioned.

A thorough investigation of the family history in officers who have failed nearly always brings out facts which fully explain his failure and might, if previously known, have prevented his acceptance. On the other hand, those cases studied of "Star Fliers" who have withstood the greatest strain in war flying without any symptoms beyond those of physical and mental fatigue, have nothing in their family history for debate.

In ordinary civil practice so many fine points in the family history as the above would scarcely be worth mentioning, but in the case of the flying officer this is different. The experiences he daily undergoes whilst on war flying probably involve the greatest strain on his nervous system that is possible in any human being, and it is reasonable to suppose that any slight "kink" in his hereditary nervous disposition might give way.

During his civil life this "kink" would never perhaps show itself. Again, the average age of war pilots is that during which hereditary influences become most obvious. In some cases it will be found necessary to interview the parents themselves on points which the patient has no exact knowledge or which, perhaps, he is holding back from the medical officer (such as alcoholism, delirium tremens, insanity, etc.).

Secondly, there is the history of the patient before he joined the army. To find out as much as possible of his infancy and childhood is important. In the first place there is his up-bringing, his behaviour at home and at school, the nature and extent of his work and play, the age he left school. His health as a child should be made the object of a very careful inquiry; whether he suffered from any of the so-called "functional nervous disorders," such as pavor nocturnus, somnambulism, habit spasms, lienteric diarrhoea and nocturnal eneuresis, etc., or from any of the two diseases which stand in commonest relationship to them—rickets and rheumatism. A history of chorea as a child should, of course, receive special attention. In such a case it will be necessary to write to or to interview the parents.

Most flying officers seem to be derived from that class engaged in some industrial business. If the patient was in business before he joined the army, a brief history should note the time spent in it, whether he was easily or difficultly placed, his interest, opportunities for exercise, sport, and other recreations, etc. An account of the general health of the patient should include any nose or throat trouble, chronic coughs, colds, asthmatic attacks, etc. (any operations performed), etc. Of the specific infections, "rheumatism" should hold the first place in the medical officer's mind. Thus, a previous complaint of chronic headache, growing pains, transient sore throats with pain in the sides and epigastrium, etc., etc., are of an equal degree of importance as a history of frank rheumatic arthritis.

(A history of "rheumatism," either in the patient or his family, was noted in fifty-one out of 200 cases.)

Then there is the question as to whether or no the patient ever suffered with the same symptoms as the present, or whether he ever, in any way, broke down under strain before.

Sometimes at first a negative reply is given when really there has been an instance, many years back, now forgotten. This is overlooked until a leading question happens to recall it. The following is an example:—

Lieut. R., *aet.* 21, sent back after three and a half months' duty as a balloon officer observer. Total hours war observing—twenty-one. He had been forced to take to his parachute at 800 feet, owing to a threat of fire (the balloon had escaped damage); landed quite safely; no injury; no shock and thought nothing of it. The descent in a parachute amused him, he said. Up again the next day. Two nights later he began to dream of the experience, but also that he was severely burned and landed in a trench in a dying condition. For several nights in succession this same type of dream occurred, but gradually the dream took on a different character, and the flying portion of it disappeared and was replaced by unpleasant dreams connected with his life at home—that he had burned his home to the ground through having dropped a lighted cigarette. Finally he became exceedingly "nervy," continually apprehensive, worried, and ill at ease. He was sent home as a case of "debility," following an acute influenza attack. On enquiring into his pre-war history, nothing could be elicited of importance until, after much hesitation, he remembered that, when a boy, aged nine, he had had a great dread of fireworks, since the time he had set his sister's hair on fire with a Roman candle and burnt his hand as well. He remembered being extremely upset at the time and of dreaming bad nightmares. Later, as he got older, and after joining the army, he had entirely forgotten all about the incident, until a few leading questions were put to him, when he recalled it. Another exactly similar type of case has been recorded.

A recent history of a nervous breakdown of any kind is obviously of great moment.

If the patient joined some infantry regiment, or other branch of the Service, before joining the R.A.F., a brief account of his military history should be given. Often, in fact in the majority of cases, whatever the previous history in civil life, good or bad, the patients generally admit that they never felt so well as during the first few months of their service training. Enquiry should be made about habits, food, drill, discipline, etc.; how much active service they underwent, and finally their reasons for joining the R.A.F. Naturally, most of them say that they have been attracted to flying for its own sake. Some may have had a previous interest in it, practically or theoretically; others frankly admit that their original motive was to escape the routine military life, either at home or abroad, and that they had no real genuine interest in flying apart from the novelty and change. (Number of cases with previous military or other Service experience—**106.**)

The health of the patient during this time should include accurate dates as to any sickness, the names of any hospitals to which he was sent, and the time he was officially on the sick-list. A history of any "fever," whether termed "trench fever" or "pyrexia of uncertain origin," or any specific fever, an acute, sub-acute, or chronic diarrhoea or gastric complaint should be noted and taken into account during the physical examination. A history of bleeding gums at any time, however trivial, should never escape attention. The next part of the history should contain an accurate account of his flying experience.

In the case of a pilot under instruction;—

(1) Number of hours dual control.
(2) What machine he first flew solo.
(3) His sensations whilst performing aerobatics.
(4) Any doubts or apprehension about any flight.

(5) His landings.
(6) His relations with his instructor.
(7) Any crashes or accidents of any kind.
(8) His confidence when graduated, etc.

In the case of a qualified pilot on active service :

(1) Types of machine flown.
(2) Total hours flown over the lines (and the number of hours flown apart from war flying).
(3) Average height.
(4) Greatest height.
(5) Work done whilst flying.
(6) Experience with enemy aircraft.
(7) Whether forced down, shot down, or crashed (and a detailed description of same if occurred).
(8) Any "high altitude" sensations before or after landing, etc.
(9) Whether he saw any machines crash (especially machines from his own squadron), catch fire, etc., and his impressions at the time.
(10) His confidence over the lines, and in handling emergencies, etc.
(11) His landings.
(12) His present flying confidence.

These and other minor points connected with his flying experiences deserve a detailed description.

Or, in the case of an observer, in addition to most of the points mentioned above, it will be necessary to know :—

(1) His confidence in, and relations with, his pilot.
(2) Whether he had the same pilot during the whole of his service in France.
(3) Whether he flew with different pilots.

It is generally admitted that an observer has a far greater strain imposed upon him than a pilot, for the following reasons :—

(*a*) Any loss of confidence in his pilot will mean a correspondingly greater degree of anxiety in that observer.

(*b*) A crash (especially if the machine is falling from some height) will give him sufficient time to anticipate the fall in his imagination (whilst the pilot has his attention occupied in handling his machine).

(*c*) An observer has to keep a constant look-out for enemy aircraft, etc., during the time he is taking photographs, or making other observations (not to speak of handling his gun at a moment's notice).

The above points explain why it is that observers generally break down sooner and to a much greater degree than pilots. In the case of a balloon observer it is important to know whether (and how many times) he had to take to his parachute or whether the balloon was attacked or set on fire—and of any psychical sequelae that may have followed from such experiences.

The patient's habits and general health whilst on active service should next be studied, viz. :—

(1) How much alcoholic drink he took, and when he took it : whether he took stimulants before going up "to nerve himself for a fight," etc.
(2) The amount of tobacco smoked (*i.e.* number of cigarettes and pipes smoked in a day).
(3) Exercise taken whilst off duty.
(4) Whether he ever suffered from any venereal disease and if so the treatment he underwent.

(5) Whether he was ever ill with fever, etc.
(6) Whether he suffered from bleeding gums or dry mouth whilst flying.
(7) Any temporary ailment, however trifling, which may have thrown him off his balance for a day or two.
(8) His present symptoms.

With such facts as these one will be, in some measure, capable of forming a decision on the history of his breakdown, its bearing on his present condition and on his future prospects.

If the breakdown followed a crash, it will be necessary to know the exact circumstances in which the crash occurred, as far as he can remember them, whether he felt quite well or "off colour" on the day he crashed, whether he had taken sufficient food, etc.

There is no need to describe the method of clinical examination, but it may be permissible to emphasise one or two points.

(1) It is advisable to make a routine clinical examination prior to employing any of the valuable physiological tests in use at present, since several cases have come to my notice in which patients with florid secondary syphilis and active pulmonary tuberculosis have been tested with physiological apparatus before a clinical examination has been made, with a possible risk of infection to others.

(2) The teeth and gums and naso-pharynx and auditory apparatus should be most carefully inspected, especially noting the presence or absence of any oral sepsis, however slight. It is obviously important to eliminate any possible toxic element in a case which might be aggravating the condition of "breakdown."

Types of Cases

The cases, judging from personal experience, seem to fall into six main groups.

(1) Those who are merely physically or mentally tired—" stale "—with nothing to complicate the condition.

(2) Those in whom the breakdown as regards flying has a purely mental origin, *i.e.* something unpleasant, some experience has impressed itself on them giving rise to a persistently disagreeable memory. In time the impression may act subconsciously and gradually give rise to symptoms or signs referable to the cardio-vascular, central nervous, respiratory, or abdominal systems (to be discussed later). The writer is convinced that the vast majority of all the cases of " breakdown " with respect to flying (in which the toxic element can be excluded) start purely *mentally*, from an impression, an experience, or an act, etc., and that the symptoms and signs found later are secondary to the primary mental cause.

(3) Those cases in which the toxic element has been the deciding factor in the " breakdown." Of these, the commonest seen at this hospital have been (in order of frequency)—(*a*) oral sepsis; (*b*) influenza; (*c*) malaria; (*d*) dysentery; (*e*) syphilis; (*f*) obscure rheumatic-like infections, termed collectively as " trench fever "; (*g*) tuberculosis; (*h*) chronic nephritis. The purely toxic patient, when the toxic factor has been removed, has made an apparently complete recovery, with resumption of full flying duties under war conditions.

(4) Those who suffer from a psychopathy, *i.e.* from a disorder of conduct. Such a flying officer is generally sent home with a history stating that he is quite untrustworthy, though brave and some-

times capable, and that under certain conditions of service he is entirely inefficient. For example, such a patient may be found to do good work at one squadron, but if transferred to another may be found unsatisfactory. He will take a dislike to his commanding officer, or to members of his mess: he will refuse to carry out his work unless allowed to do as he pleases. When examined at this hospital such a patient may be found to be abnormal in many ways. He has little regard for truth; will state that he has done 500 hours' flying when in reality he has only done 50, or record incredible adventures in the air. His private life may be also found to run on similar lines (*e.g.* one patient told the writer that he was twenty-one and unmarried, when in reality he was a married man of twenty-nine with a child and had recently been charged with bigamy). To say that such cases belong to the criminal type is, perhaps, too strong, but from the flying point of view at any rate they can hardly be counted as satisfactory flying officers except when placed under very special conditions of service which happen to suit their temperament. That they are occasionally supernaturally brave and daring (and hence, often invaluable as "roving pilots") is undeniable, but otherwise they appear to be quite unsuited to lead a formation or to be entrusted with any responsible command. They should, of course, only be allowed to fly single-seaters, out of consideration for the observer or passenger they carry.

(5) Those cases whose flying disability has been ultimately traced to a purely "physical" cause (as opposed to a psychical origin) the result of (*a*) true oxygen want at high altitudes; (*b*) air sickness; (*c*) giddiness in the air; (*d*) "concealed squint," etc. A good many cases of true oxygen want have been described; personally the writer has only seen

one genuinely proved case. All the other cases of supposed oxygen want have been ultimately traced to a psychical foundation and proved by actual testing.

(6) Malingerers. This class may be more numerous than is supposed, but it is exceedingly difficult to prove that any patient is definitely malingering. Nevertheless, one must always be on one's guard against the type of flying officer who really does *not* want to fly and who knows that the medical officer thinks him unfit for flying. Such an officer will stoutly maintain his keenness to continue flying, hoping thereby that he may retain his flying pay, should he be able to persuade the medical officer to prescribe "limited flying."

At this point it is necessary to add that "mixed" classes of the types 2 and 3 are extremely common, *i.e.* in which an aviator has mentally broken down and whose condition is complicated by some toxic factor such as influenza, oral sepsis, etc. In such cases a cure of the toxic element, though improving the general condition and particularly the symptoms of exhaustion, fatigue, loss of power, of mental concentration, etc., will not restore confidence in flying.

The above classification is only intended to be a preliminary attempt as a practical guide to the medical officer who examines a number of patients for the first time. Further experience will no doubt improve this classification.

Clinical Signs

(1) In the first type of case there are no physical signs of any objective importance. The patient will merely state that he is tired and "stale," and would appreciate a rest from flying. On questioning a patient as to his symptoms, he will often admit that the first intimation he had of his staleness was

a failure to make his usual good landings. He accuses himself of carelessness, and will often get depressed about his loss of skill in this respect. "I do everything as usual," he says, "but for some reason or other I can't help making 'dud' landings, or "I might be only just beginning to learn flying, judging by my performances lately," and so on.

There is no "apprehension" factor in this type of case, no real loss of confidence The patient is merely physically and mentally tired, and is manifesting his condition in a perfectly normal fashion.

His depression is natural, but it may, of course, bring with it a more serious condition of things, viz. :—broken sleep, loss of interest, and ultimately of confidence in flying.

(2) In the second type of case the clinical symptoms and signs are exceedingly complex and difficult to unravel and explain. In such cases a complete history is essential to discover the starting point in the breakdown.

With his present experience the writer is forced to admit that the starting point is practically always a *mental* one. The clinical signs in these cases seem to be the expression of some disturbance of the central nervous system as a whole, which, in their turn, are secondary to a *mental* disturbance. In what way and by what steps this secondary disturbance of the central nervous system arises it is impossible to say, but the clinical signs in a typical case are very interesting, and appear to point to a hyper-irritability and instability of the central nervous system, and in particular of the medullary centres governing the action of respiration, the vaso-motor system, the vagal system, and even other cranial nerves.

It is not within the scope of this article to offer any explanation of this type of case and the physical signs connected with it. One would only be led into an attempt to explain the cause of the ailments from which the majority of the whole human race suffer.

It seems extremely unlikely that the physical signs as found in this type of case are confined to flying officers, *i.e.*, congestion of the face and poor pulse response during the "fatigue test," failure to hold the breath beyond a certain limit, "gastric splashing," rapid pulse, high pulse pressure, headaches, increased tendon reflexes, digital tremor, etc., etc. We should expect to find them all in any individual suffering from an "occupation neurosis" or a "traumatic neurasthenia," where a mental shock or strain seems to have set in motion a whole number of concrete signs and symptoms formerly described, for want of a better word, as "functional."

In examining this type of flying officer patient, one need not go far afield to prove that his central nervous system as a whole is in a state of disturbance.

He complains of a great depression, apprehension, extreme irritability, change of character, a morbid desire to be alone, a lack of power to concentrate on any subject at any given time, a failure of memory, lack of energy, lack of interest, loss of the natural pleasure of being alive, sleeplessness, dreams and nightmares, all pointing to a morbid condition of his higher centres. There is also a complaint of breathlessness and an undue sense of fatigue on exertion, of an unpleasant consciousness of the heart's action, perhaps palpitation and intermittency; of headache (particularly of a paroxysmal nature—probably vaso-motor in origin), etc. We find a flushing of the face (sometimes unilateral—four cases) to a very slight stimulus, of excessive perspiration, digital tremor and marked increase of the tendon reflexes (in others, an extremely sluggish condition of the tendon reflexes—eighteen cases). Nine cases have shown curious pupil abnormalities, presumably of central origin. The pupils were unequal, and one or both reacted sluggishly to light and accommodation (four cases only showed these signs when the eye had become dark-adapted). Seven of the above cases were seen again five months later, and the pupils reacted perfectly normally. Incidentally, the general condition of these patients had returned to normal. Stammering has been noted in twenty-eight cases; two cases were apparently totally amnesic on admission; twelve cases showed general tic-like movements of head and limbs. It would, perhaps, not be out of place to quote a few of the cases under discussion, thereby demonstrating their complexity.

(1) Lieut. Pilot, *aet.* twenty-one, complained of a tight feeling in both nostrils of a month's duration; he said that he could not breathe through them properly. He was anxious for an operation to cure the condition. Flying history:—260 hours' war flying. Two recent crashes, no injury but slight shock. Flew twenty-six hours after the last crash. No loss of confidence in flying, but admits to having dreamed of the crashes ever since they had occurred (last crash—six weeks ago). On examination:—no abnormality could be discovered in the naso-pharynx, and he was assured that there was nothing the matter; but his reflexes, however, were increased, and there was some slight digital tremor. His previous history was unimportant, save that ten years previously a nasal polypus had been removed from the right nostril, and his health at that time was poor. Previous to the operation he had had a nasal discharge and difficulty with nasal breathing.

He failed in the physiological tests instituted by Lieut.-Colonel Flack, and his general condition seemed to point to an early fatigue of the central nervous system. His complaint about his nose might be put down to a re-awakening of the by-gone memory of his former nasal trouble, and was an expression of his "central fatigue." In three months he was perfectly well and declared that his nose complaint must have been pure imagination.

Captain Y., *aet.* 27, pilot.

Sent home as a case of oxygen want, with a recommendation to fly at low altitudes only. Complained of feeling exceedingly faint when flying at 12,000 feet, but not at lower altitudes. First noticed symptoms six weeks ago. Previously had had no symptoms. Total hours, 250. Excellent flying record. At the time of examination complained of no symptoms, except those of faintness, breathlessness and giddiness, and loss of power to control the machine at high altitudes. Otherwise was feeling quite well, but admitted sleeping badly since the symptoms started. Dreamed a good deal of flying, but not unpleasantly. Had also noticed himself sometimes utterly unable to find his word when addressing a fellow officer or his C.O., and that his hands shook when holding a knife and fork. Previous history negative, but his flying history had been full. Has had several forced landings and twice sustained very slight flesh wounds from shrapnel, but not bad enough to send him to hospital. Three months ago his engine failed at 12,000 feet when he was six miles over the lines, and he admitted being nervous after the incident. On examination, there was some digital tremor, and tendon hyper-reflexia. His general appearance was that of a somewhat highly-strung individual. Talked rather aimlessly about his condition and had a slight stammer. On testing his condition at high altitudes by means of physiological apparatus, it was found that his oxygen want must have been entirely the result of auto-suggestion, since he was made to breathe in an atmosphere of 18,000 feet without any symptoms whatever. The neurosis from which he was suffering seemed to have arisen from the day his engine failed at 12,000 feet. A great many similar cases have been seen at the hospital. In the case of the above patient an ulcer was present on the right tonsil resembling a Vincent's Angina, which eventually healed under treatment. There was a great deal of chronic oral sepsis which was also treated very thoroughly and a relapse prevented. When seen three months later at an Appeal Board, he wished to start flying "scouts" again, and did not complain of any symptoms, and had done some high flying as a passenger.

(2) Lieut. Z., *aet.* 28, pilot.

Canadian by birth; complained of a feeling of great exhaustion, sleeplessness, and apprehension as regards flying over the lines, though denying any loss of confidence in flying apart from this. His machine had been hit by anti-aircraft fire at 19,000 feet whilst on patrol with other machines a fortnight before the onset of symptoms. There had been no previous warning of any anti-aircraft barrage, and the "hit" in his case must have been a chance shot. His machine fell to 5,000 feet, but he managed to regain partial control, and eventually landed before the machine caught fire. He was thrown out, but did not hurt himself, and walking to a hut a few yards away found it belonged to a regimental mess. He received immediate attention, and offered to fly back to his squadron, but was taken back in a lorry. Felt quite well the next day, but was prohibited flying by his C.O., who said that he looked very unfit. Three days later he complained of sleeplessness and nightmares of an extremely vivid character. He kept thinking about his extraordinary ill-luck at being hit at 19,000 feet, above the clouds. Was finally sent home as unfit, though he himself wished to fly and get his nerve back again. Total hours—100 (in France). His previous and family history were not altogether satisfactory. His father had had several attacks of delirium tremens, eventually left home and had never since been traced. The patient admitted that whilst in France he had taken drink to excess, "to keep his end up," so he said, and had latterly taken "several whiskeys" during the night to make him sleep. He had been in the cinematograph business before joining the army. On examination, his general physique appeared very good but he appeared restless, ill at ease, and constantly walked about whilst he talked. There was a distinct antero-posterior tremor of the tongue, and a fine tremor of the lips and fingers; the tendon reflexes were not exaggerated. He was kept in bed for a week and given ammonium bromide mixture 20 gr. t.d.s., and his general behaviour and condition carefully watched from day to day. His mental condition became very much better, though the tremors increased for a few days after treatment had been instituted. The question naturally arose as to what part the alcoholic factor played in his condition, and whether he would have broken down through that alone, supposing he had had no flying accident. He seemed a stout-hearted individual, and could not properly be called a neurasthenic. His work in France had apparently been very satisfactory until the accident. The prognosis in such a case was obviously a matter of some difficulty. He was very seriously warned about the dangers of alcoholic excess and finally sent on leave, and "limited flying" recommended.

Many more examples showing the individual character of the cases seen might be given, but without quoting any further cases it is obvious that each patient must receive a very individual attention and a painstaking examination, otherwise the whole origin of the trouble might be entirely missed.

(3) In the third type of case the outstanding symptoms are a continuous feeling of fatigue, weariness of the limbs after a little exertion, a feeling of general lassitude and exhaustion, and of mental dullness, particularly towards the end of the day. A patient with a preponderance of such symptoms, especially where there appears to be no direct cause for the breakdown with respect to flying, should be assumed to be suffering from some toxic factor unless this is proved to be otherwise. Steps must be taken to discover what is the nature of the toxicity. The teeth should be carefully examined; account should be taken of any temporary ailment, etc.; in short, a thorough medical examination will be necessary.

(4) In the fourth type of case the physical signs are rather characteristic. The patient appears objectively normal. He does well in all the physiological tests—perhaps too well. There are no demonstrable signs of any moment; a few minutes' conversation, however, with such a patient will be enough to settle any doubts as regards his condition. The writer remembers one of such patients who, seeing him for the first time, offered a cheque for five pounds (which he had already made out in his name) if he could get him a special job in France away from his C.O., whom he detested. Another patient, under the care of Surgeon Anderson, insisted on his false teeth being sent out to France, as he could not wait for them to be fitted in hospital. He declined leave, and refused to do any other form of duty except flying in France. Such patients have been termed "Impulsifs" by French neuro-

logists, and are quite incurable. They will go through life in this fashion. How far, and to what extent, war conditions accentuate their abnormality it is hard to say. Suffice it that such patients are quite recognisable at first glance, and the only difficulty will be to determine whether or not they should continue flying. All persuasion and influence or any sort of treatment is generally quite useless.

(5) The fifth type of case is recognised by demonstrating the presence of oxygen-want, "concealed squint," etc., and the tests carried out with physiological apparatus. This is not the place to describe such cases, since they do not belong to the present discussion.

Treatment

The ideal aim of treatment in the above cases is obviously to make a broken-down flying officer fit again for war service with the same confidence as he had had previously (reference to the classification of cases will assist discussion on this point).

In the case of type (1)—Here we have a normal individual who is temporarily "stale" and requires rest—mental and physical. Treatment in his case is a comparatively simple matter. After a thorough clinical examination whereby all complicating factors should be excluded, he may be given the maximum amount of leave permissible under R.A.F. regulations, or if this is not deemed sufficient, a month's stay at a suitable convalescent home (of which those attached to the Royal Air Force hospital are ideal in every respect), with a further period of four weeks' leave.

In the case of very special "long service colonial cases," three months' leave to Canada, South Africa, or Australia, may be advisable, but this is rarely necessary.

In our experience, it is a distinct mistake to extend the leave away from any form of duty connected with flying beyond a certain limit, as several patients who have reported themselves at the end of an extended leave for a Medical Board have shown a total loss of flying confidence.

This can only mean that too much unemployed time away from any form of duty connected with flying has a deleterious effect on the flying confidence of an officer who, when given leave, was merely tired, but with his flying confidence unimpaired. In other words, care should be taken not to convert the tired officer into a chronic convalescent.

Just sufficient unemployed time should be given according to the case to enable a satisfactory bodily and mental rest and no more. The minimum is three weeks, and the maximum is ten weeks (except in very special cases of officers of exceptional ability who have seen a great deal of flying service).

Too much time off duty is just as great a mistake as too little rest away from duty.

At the end of the leave Home Service for a certain amount of time is advisable.

It is not possible to give any figures of very much value, since comparatively few merely tired flying officers have been seen as in-patients. Out of twenty-eight cases, nineteen have reported themselves back at flying duties either in England or in France apparently well and with full flying confidence. Of the remaining nine cases, five lost their confidence and gave up flying; the remaining four have not been traced.

(2) In the case of the flying officer who has broken down in the manner described under the second type of case, treatment is a matter of considerable difficulty. In the first place, any officer who has been rendered unconscious through a blow or injury

to his head following an accident, should be *strictly* kept in bed from two to three weeks following the accident, no matter how quickly he may seem to improve. We have seen a great many cases of officers with no physical signs of organic injury complaining of headaches, depression, nervousness, and loss of flying confidence, some, indeed, totally unfit for any form of duty, who stated that they were in bed only two or three days following a serious crash with loss of consciousness. They had been allowed up and sent on leave, and the symptoms had developed after a certain variable latent period.

Other patients whose symptoms have not been the immediate result of concussion should invariably receive a thorough medical examination before sending them away on sick leave. The process of a thorough history taking and examination followed by a sympathetic conversation is often a great relief to the patient who, perhaps, was afraid to open his mind fully before. Incidentally, a complete sympathy between doctor and patient is, of course, absolutely necessary. The patient should feel that he is receiving the most individual care and attention.

Any " repression " connected with the mental condition of the patient should receive special examination, and an attempt be made to relieve the mental distress and worry.

To send a patient away on sick leave who complains of sleeplessness, headaches, nightmares, and shows signs of general nervous instability without any further word or examination, is to condemn him to a great deal of mental and physical suffering and might end in seriously impeding his chances of improvement for fitness in any capacity whether military or otherwise.

Every patient sent from France with a history of " Flying Neurasthenia " should be under medical supervision until the medical officer is satisfied that he will improve without any special medical attention.

In a case of average severity with broken sleep, nightmares, irritability, apprehension, depression, and well-marked signs of "nervous instability," such as a stammer, increased reflexes, tremor, and inco-ordination, it is generally wise to adopt the plan of rest in bed for a week (according to the symptoms and signs) and to prescribe an ammonium bromide mixture to be taken t.d.s. The following gives the best results :—

Ammon. brom.	gr. xx.
Liq. arsenicalis	m. iii.
Tinct. calumbae	m. x.
Ferri et ammon. cit.	gr. x.
Aq. chloroform add	oz. i.

Small doses of the bromide are not of much service. It is best to give not less than 15, or more than 30 grs. t.d.s.

On the whole, ammon. bromide is the best bromide salt, and it is seldom necessary to resort to any other drug. For troublesome insomnia, trional grs. v.- grs. x. at night is the most certain remedy. It gives the quickest and most certain results. In cases with severe headaches and distressing insomnia accompanied by feelings of apprehension and nightmares when the patient falls asleep, cannabis indica with bromide has been exceedingly useful, but should be used with caution, owing to its somewhat uncertainty of action. The length of time during which treatment is necessary varies with the severity of the case. In 60 per cent. of the cases some definite improvement was always noticeable.

After a little experience, it is generally possible after a few days' observation to pick out those patients who will eventually return to flying under war conditions from those who will be permanently unfit.

No patient whom the medical officer considers permanently unfit for any further flying should be sent to a convalescent home where there are other flying officers who are only temporarily unfit; in other words, a permanently unfit officer of "nervous type" is a source of danger to others in that he "infects" his fellow-officers with his own troubles. He is, so to speak, an "infectious case," and should be removed as quickly as possible from the other patients. The writer has known two or three instances where one patient with severe neurasthenia was sent to a convalescent home and appeared to be ultimately responsible for the "breakdown" of several other patients in that home. In short, a patient whom the doctor considers permanently unfit for any further flying should be boarded as soon as possible (as far as medical circumstances will permit) and marked "unfit for any flying duties" for six months. The relief that this decision affords to the patient is considerable, and the writer can give sixteen instances of patients who have regained their confidence after six months' complete rest from flying. A definite decision either one way or the other, according to the type of case, has a very definite "therapeutic" value.

Prognosis

At the present moment it is unfortunately impossible to give any statement of much value on the prognosis of the cases in detail. The difficulty of tracing the patients is great, and we are only beginning to discover the final history of them.

Consequently the question of prognosis can only be discussed on the broadest basis.

The most important single factor in prognosis is :—*the length of service and the amount of flying experience obtained before the breakdown occurred.*

An officer who has badly broken down after a few hours in France, or who has sustained a slight crash and is sent home soon afterwards as unfit, has a poor flying future, and will probably be best advised to give up flying. Whereas the officer who has done a great deal of flying and who has had a very full and varied experience of aerial warfare and who breaks down late in his flying career should make an ultimate recovery and return to flying. The shorter the flying experience the worse the prognosis. The longer the experience the better the prognosis. On the whole there is no better prognostic basis in the writer's experience.

Three flying accidents have a very adverse bearing on the prognosis. The three accidents are :—

(1) The machine catching fire.
(2) A breakage in the air.
(3) A direct hit by anti-aircraft fire.

In any patient who has broken down and who has had the misfortune to experience any of these, the prognosis is, at the best, uncertain.

These accidents, the most dreaded by flying officers, create the deepest impression on the mind. Personally the writer has not seen such a patient (whose lot it was to be involved in such an experience) regain his *full* flying confidence, however much he improved as regards simple flying.

Summary

The conclusions on the neurasthenia of war flying from a practical standpoint (based on a year's experience and necessarily requiring further expansion and modification in the light of more experience) are as follows :—

(1) A detailed history of the case is of outstanding

importance, and *contains the key to the subsequent treatment and prognosis.*

(2) The cases fall into six groups :

(*a*) Simple fatigue, physical and mental, as the result of prolonged stress in a normal individual.

(*b*) " Neurasthenia," *i.e.*, a complex group of symptoms and signs in a patient who has lost his flying confidence and whose personal and family history are not entirely satisfactory. Such a patient will show evidence of a general nervous instability, and his cortical, bulbar, and medullary centres are in a condition of hyper-excitability (as is shown by his symptoms and the clinical signs). The condition in the first place arises from a mental impression and later gives rise to the symptoms and signs which are found on examination. He has lost confidence in flying and is, therefore, in his present state, useless as a flying officer.

(*c*) This class comprises those flying officers who have broken down through some toxic factor in their history. They have not lost their flying confidence, but are unfit to fly until this toxic factor is removed. When they are well they return to flying with unimpaired confidence.

(*d*) Those patients termed " Psychopaths " for want of a better word are unsatisfactory for all flying service except under very special conditions. They are assumed to be suffering from a disorder of conduct, and as a rule do not show any physical signs. Their family history is generally bad, and their upbringing and education faulty.

(*e*) These patients have not lost confidence in flying, but are unable to fly at high altitudes owing to symptoms of oxygen want, or sickness in the air, etc. They are mentioned in this article since their symptoms may be wrongly attributed to " neurasthenia."

(*f*) Malingerers.

(3) Mixed types of cases are common, especially of (*b*) and (*c*).

(4) All patients should receive a thorough examination and an adequate treatment, and should not be sent away on leave or to a convalescent home until the medical officer is satisfied that no further special treatment is necessary.

(5) The essence of prognosis is :—The shorter the flying experience the worse the prognosis, the longer the experience the better the prognosis. In such case, the most important patient is the experienced officer, and every effort should be made to restore to him his former confidence.

(6) Hopeless cases, *i.e.*, those patients who appear permanently unfit for further service should *never* be allowed to mix with cases whose breakdown seems to be only temporary. They should be discharged from the flying service as soon as medical circumstances will permit.

The writer wishes to take the opportunity of thanking Surgeon-General Sir Humphrey Rolleston, K.C.B., for much valuable criticism in the writing of this article.

It is gratifying to know that Surgeon Gotch has in the main come to the same conclusions as the author of this work himself, especially as to the mental or central origin of most aero-neuroses and also as to the prognosis depending on the time of onset. The author is more hopeful of getting a flying officer back to duty if the latter has already over 100 hours to his credit. During the last year the author has had to deal with surgical cases only, either from local accidents or returned wounded from overseas, and in quite a number of these one of the aero-neuroses supervened, but many got over the conditions and returned to flying again.

CHAPTER VI

Aeroplane Accidents

In the early days of flying there were necessarily many accidents, owing firstly and unfortunately to structural weakness in the aeroplanes, and secondly to the fact that the pioneer pilots had to experiment, and were mostly unacquainted with many of the factors governing aerial navigation. When man began to teach man, and as improvements in the construction of aeroplanes increased, so accidents diminished in number proportionately; but on the other hand, many more took up flying, and the total of accidents was increased. The pre-war methods of teaching were slow and sure, and first solo flights were made in stages and after prolonged tuition, thus tending almost to obviate accidents altogether. As the war advanced, and the importance of aviation was recognised, so more pilots were required, and the methods of teaching had to be accelerated. Thus a few hours' dual control instruction—three and a half to seven hours—were given, and pupils sent off to do their first solo flights. Naturally many more accidents occurred, and as nowadays tuition is on faster and more powerful aeroplanes, so have the total number of accidents increased. Every accident teaches something new, and all should be investigated thoroughly, so that a preventable cause or error can be eliminated in the future. In this connection the reports of the Public Safety and Accidents Investigation Committee of the Royal Aero Club are very instructive and should be studied.

The total number of accidents due to school work

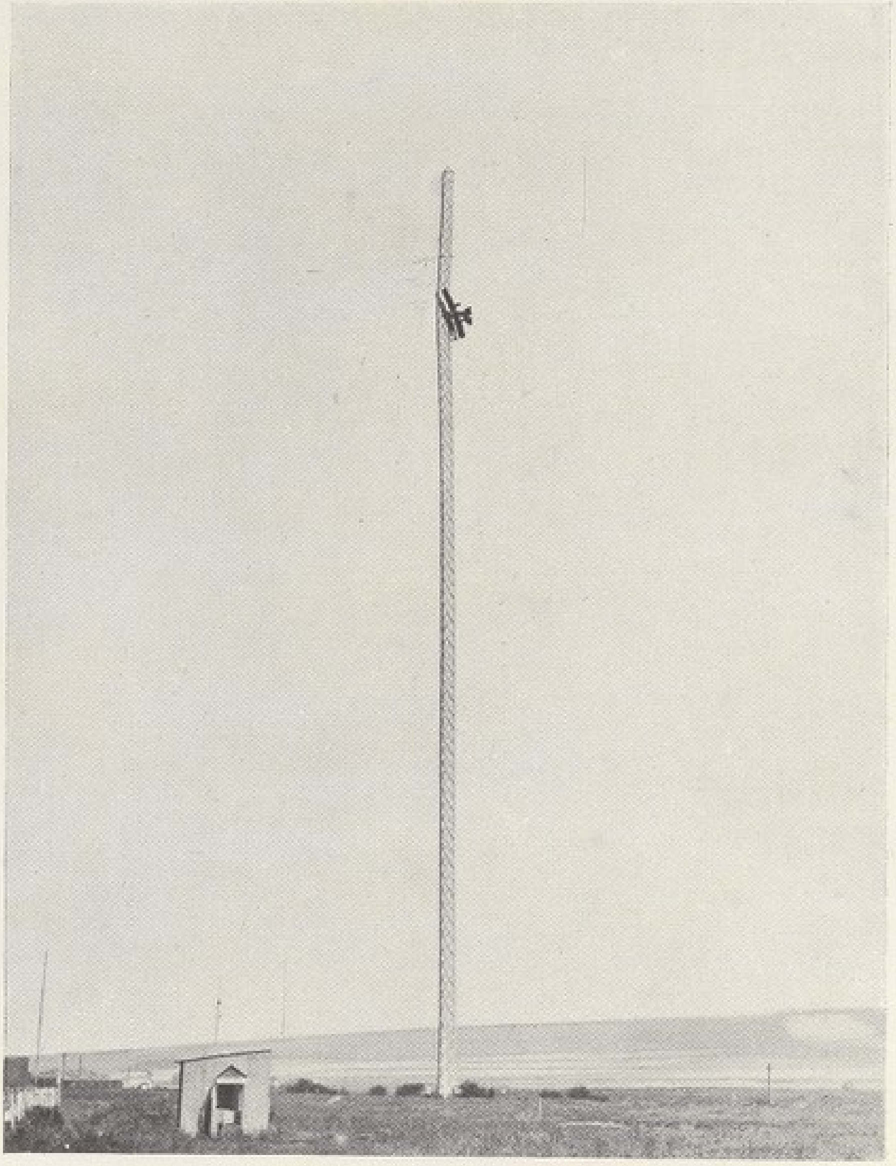

PLATE 1.—A seaplane collided with and stuck in the mast of a large wireless station. The pilot was saved.

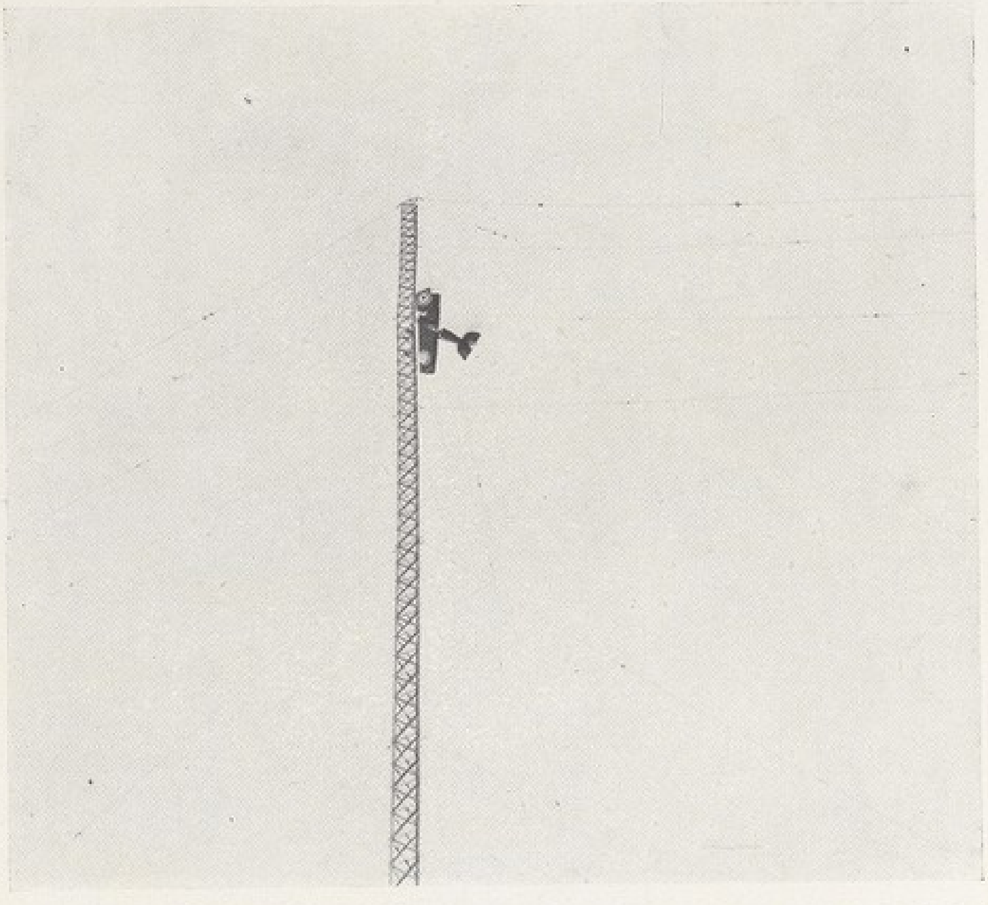

PLATE 2.—Probably the most unique aeroplane accident that has ever happened.

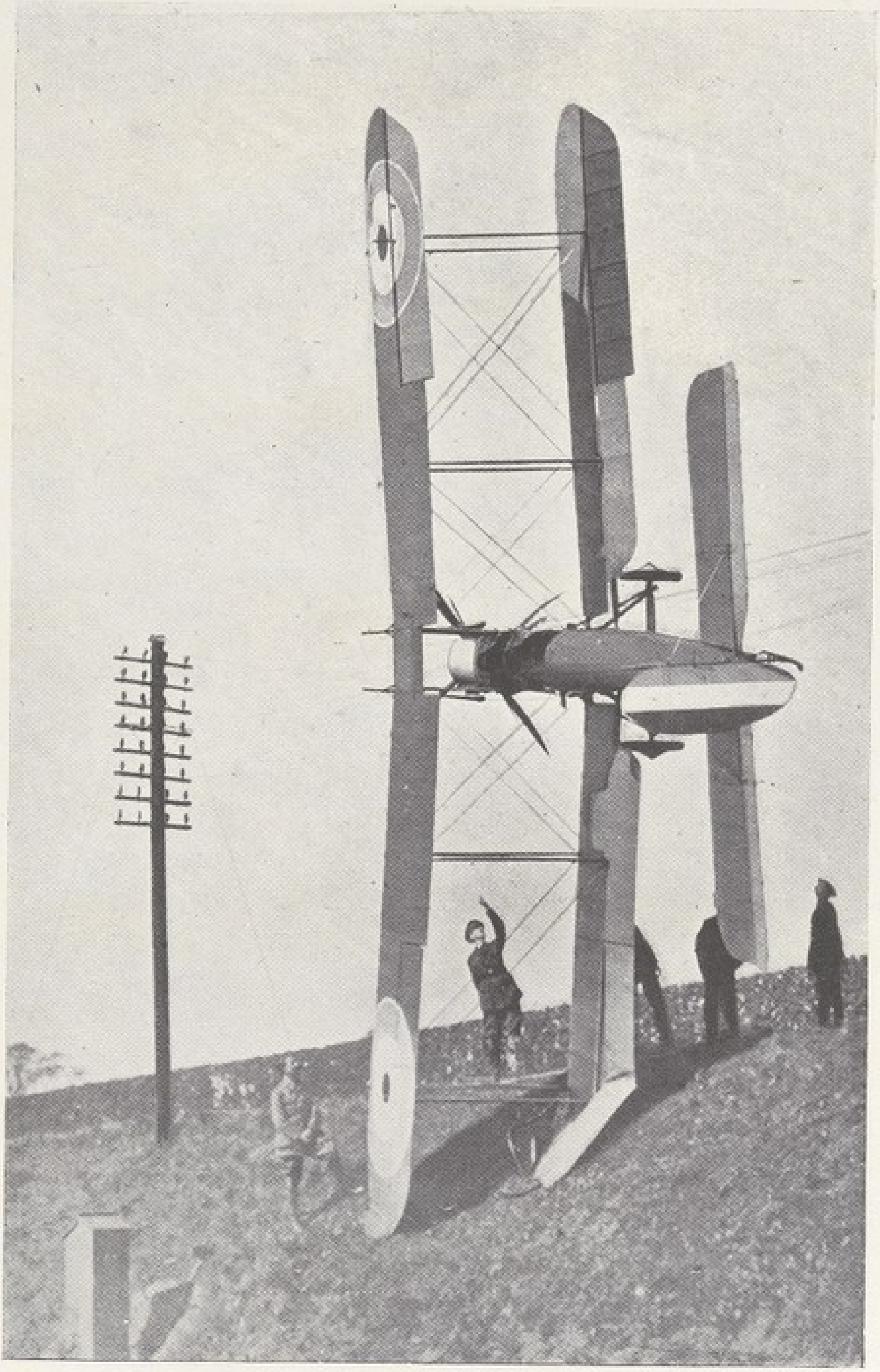

PLATE 3.—An aeroplane caught in telegraph wires—landed on one wing tip—occupants uninjured.

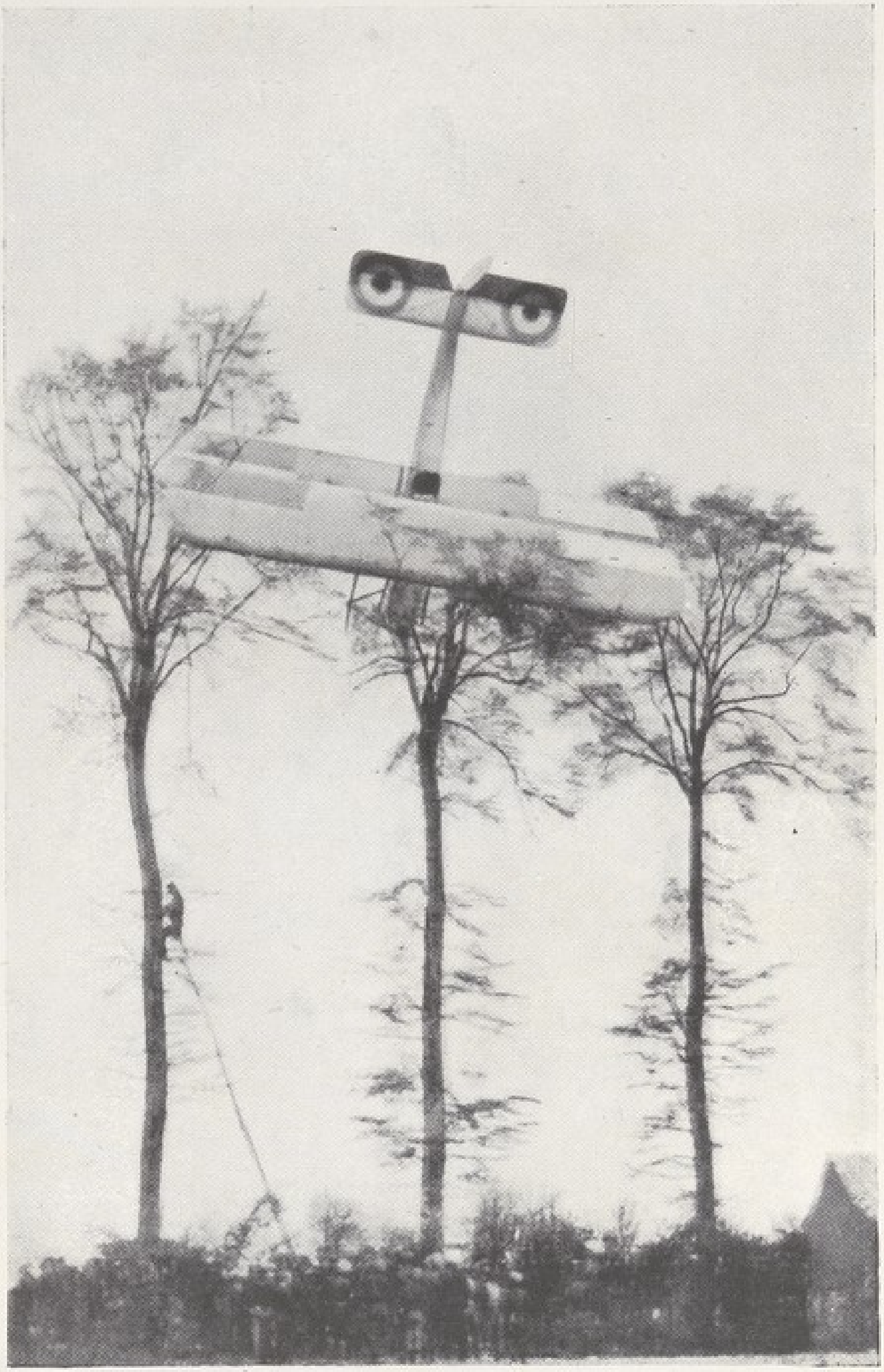

Plate 4.—A landing in the tree tops.

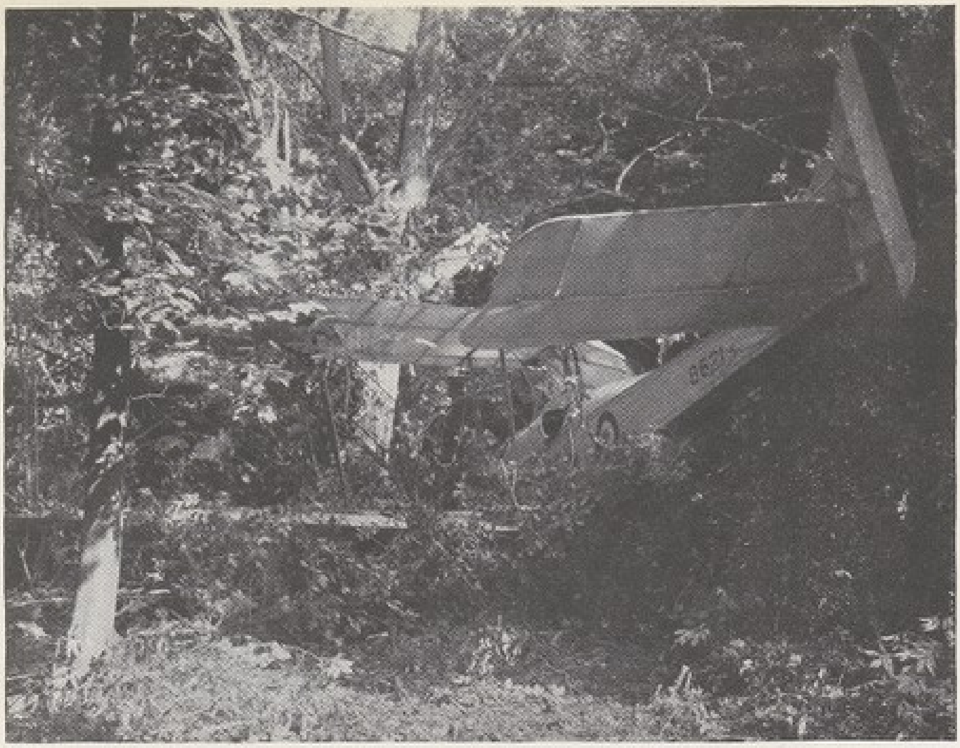

PLATE 5A.—A crash in a forest.

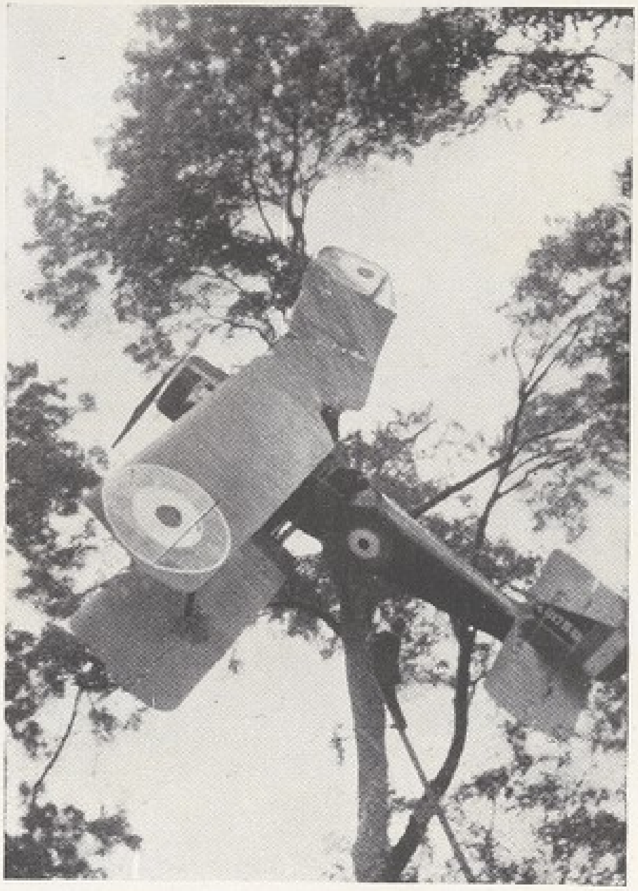

PLATE 5B.—An imitation of how a bird lands on a tree—pilot uninjured.

Plate 6.—A nose dive into a wood.

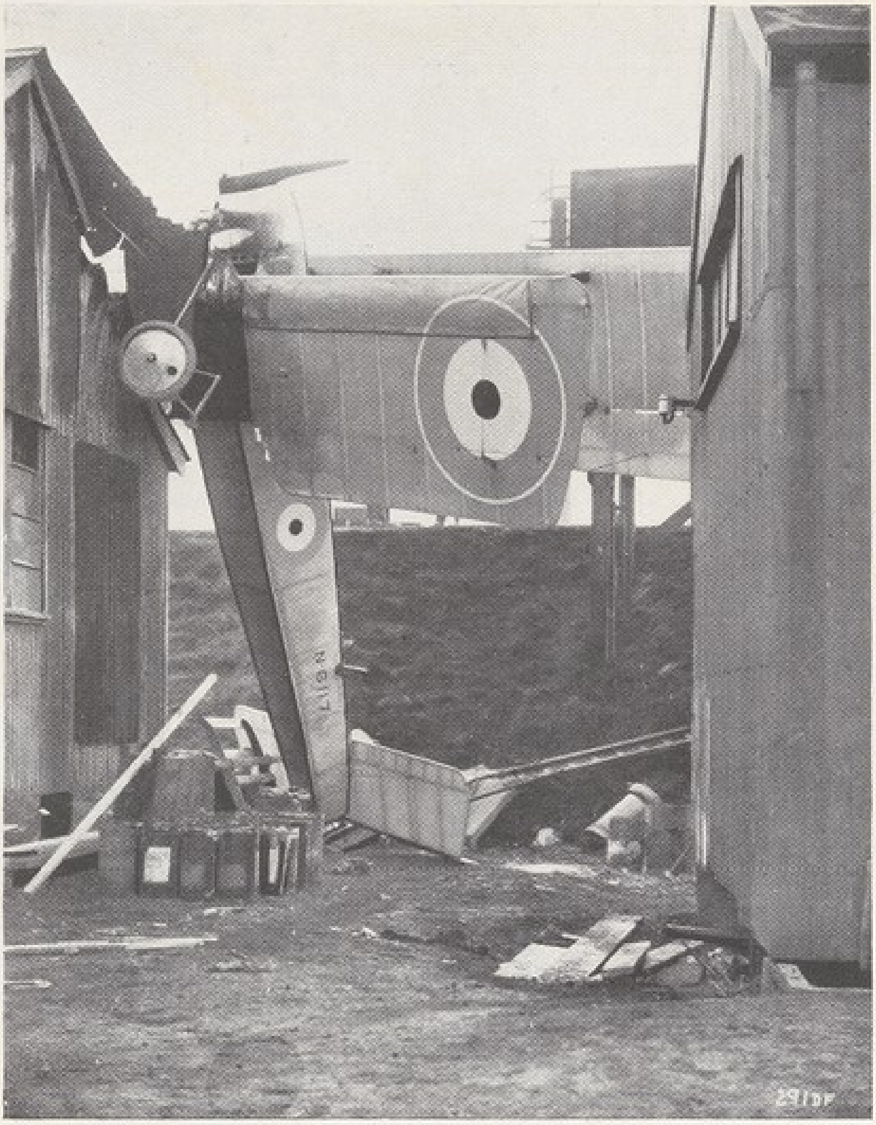

PLATE 7.—A crash between hangars showing difficulties in reaching the injured occupant.

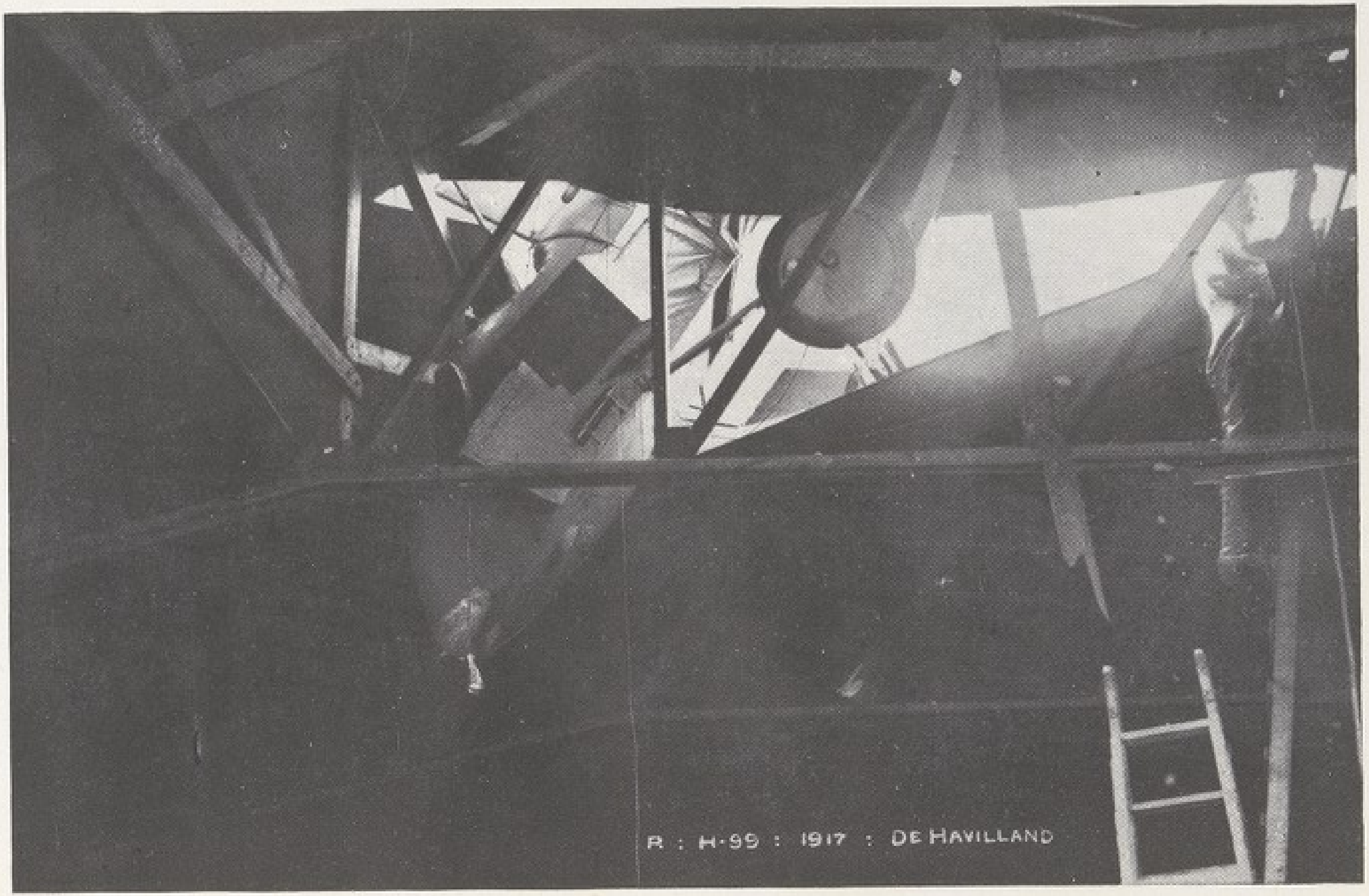

Plate 8.—A crash through the roof of a hangar, taken from within.

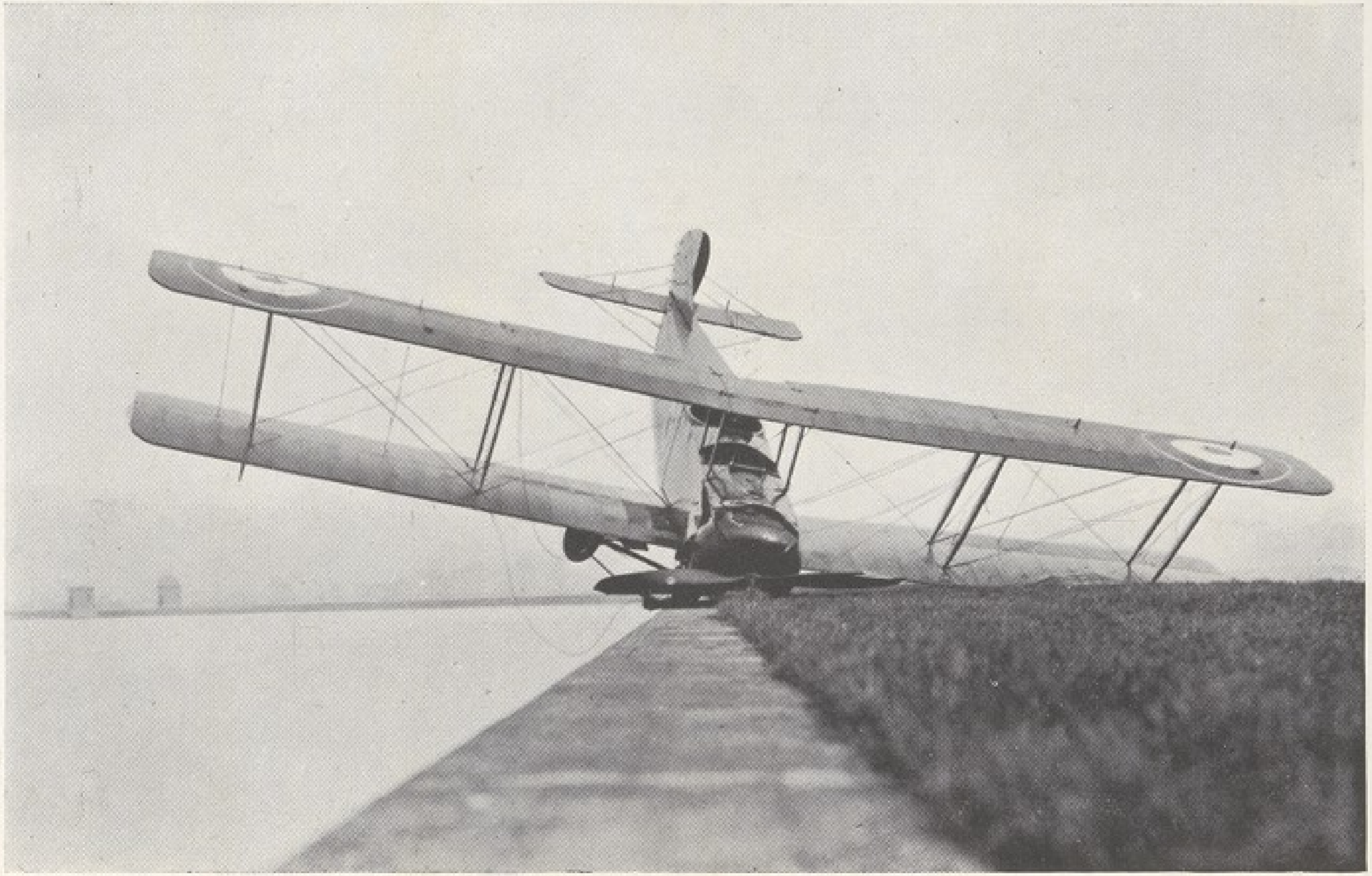

PLATE 9.—A crash between land and water.

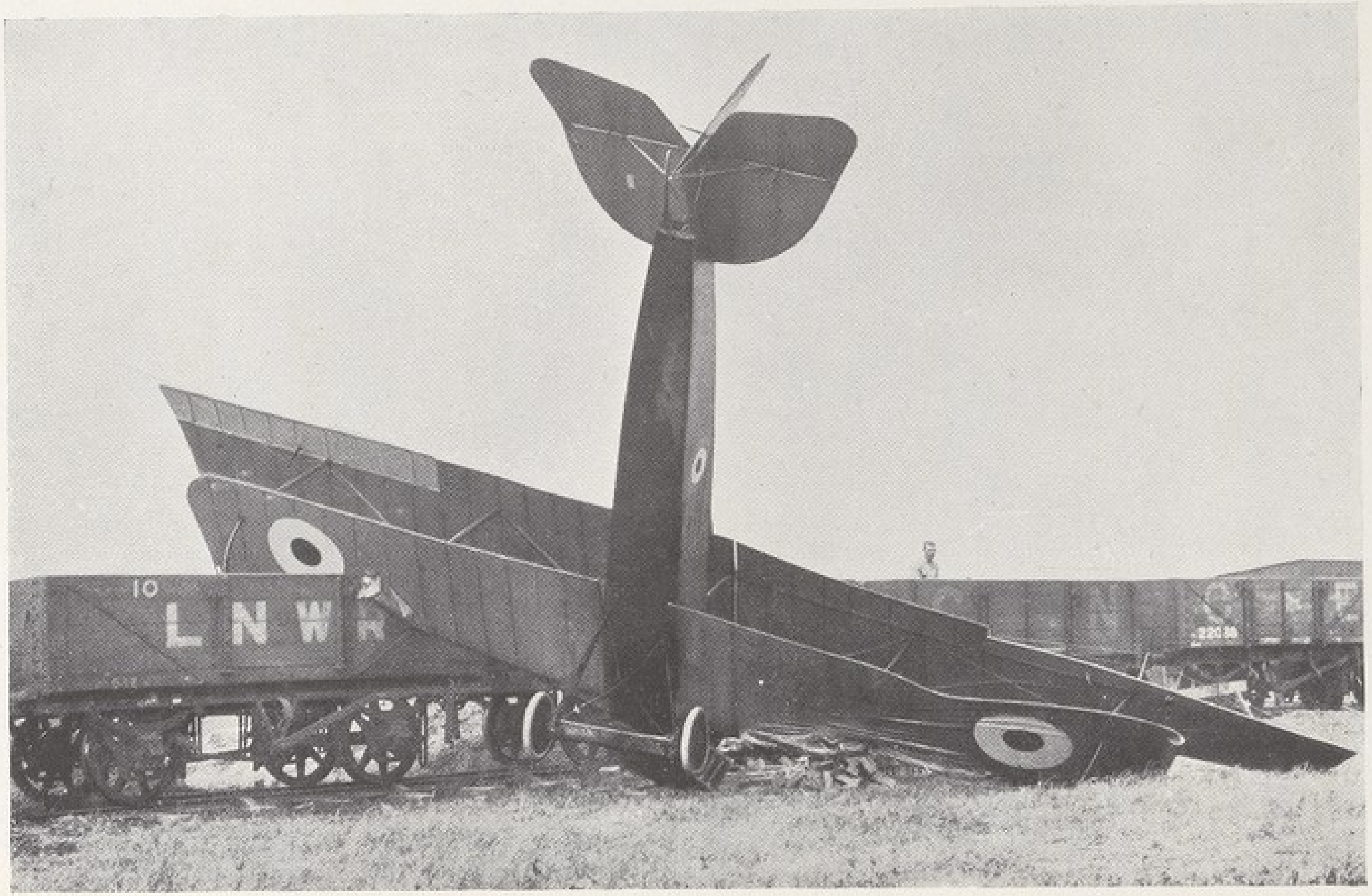

Plate 10.—A crash into a goods train.

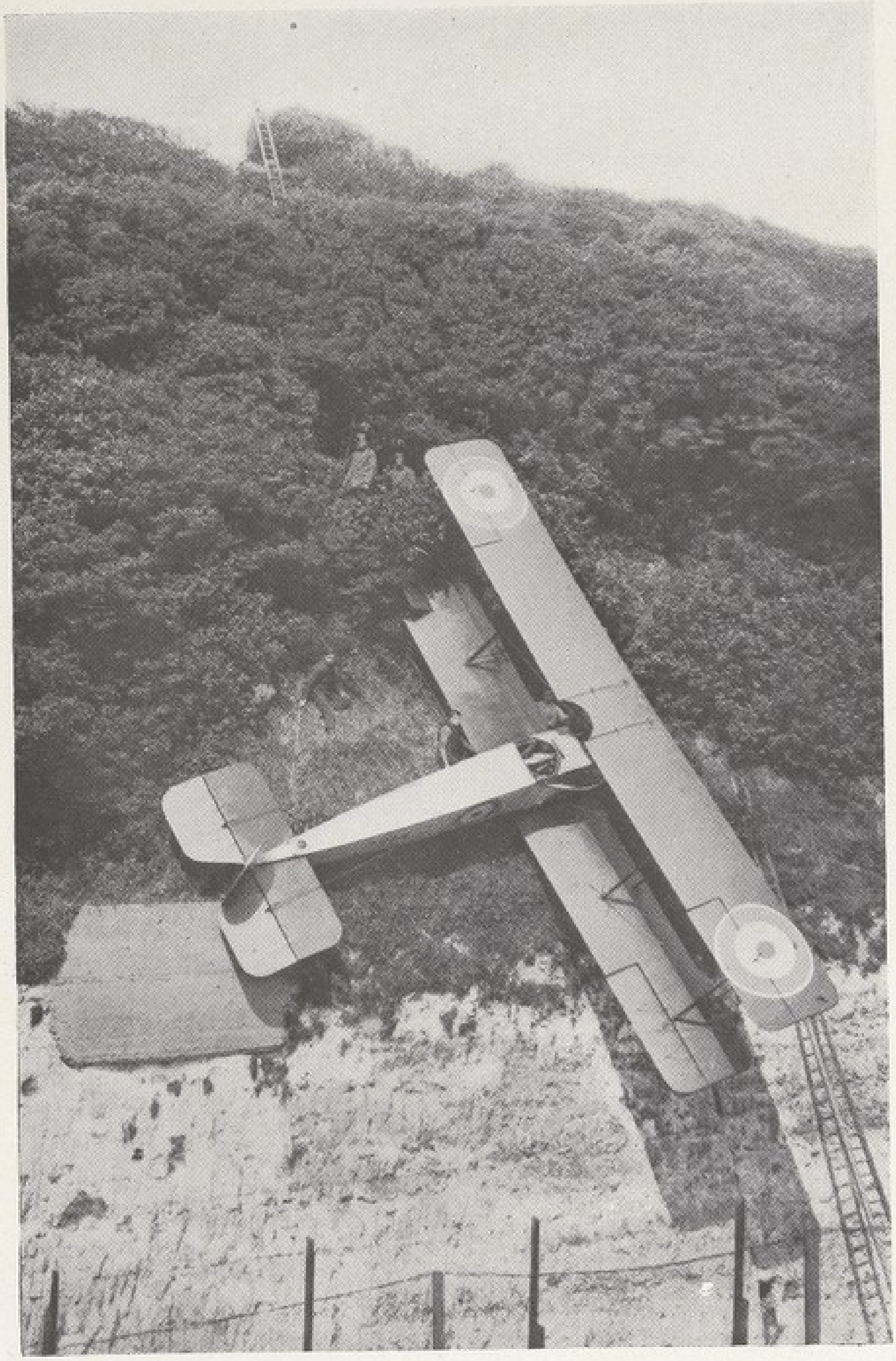

PLATE 11.—An unique landing—on the side of Dover Castle.

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and experimental flying is greatly augmented by the number due to war flying, either as the result of aerial duels or anti-aircraft fire from the ground.

Classification of Aeroplane Accidents

An attempt has been made to classify accidents at one station covering a period of six months, and these are referred to as the " V " series. In a general review of accidents the author has also drawn from fifteen months' experience whilst at another school,

FIG. 1.—A typical crash—occupants uninjured. Aeroplane has to be sent into workshop for repairs.

and these are referred to as the " E " series. In the " V " series during six months 4,000 hours' flying were done, consisting of 9,000 flights; and during that time fifty-eight aeroplanes were wrecked or crashed. The suggested definition of a crash is an aeroplane so damaged in a flying accident that it has to be deleted or sent in to the workshops for repair or rebuilding. (Fig. 1) This is in contradistinction to the effects of a bad landing or get off where the ensuing damage is small, *e.g.*, broken wires, landing wheel, tail skid, or bent axle, and can be repaired by the flight mechanics. (Fig. 2.) Fifty-eight crashes in 9,000 flights represent one crash in every 155 flights. In these fifty-eight crashes sixteen were injured, which is equivalent to twenty-eight being injured in every 100

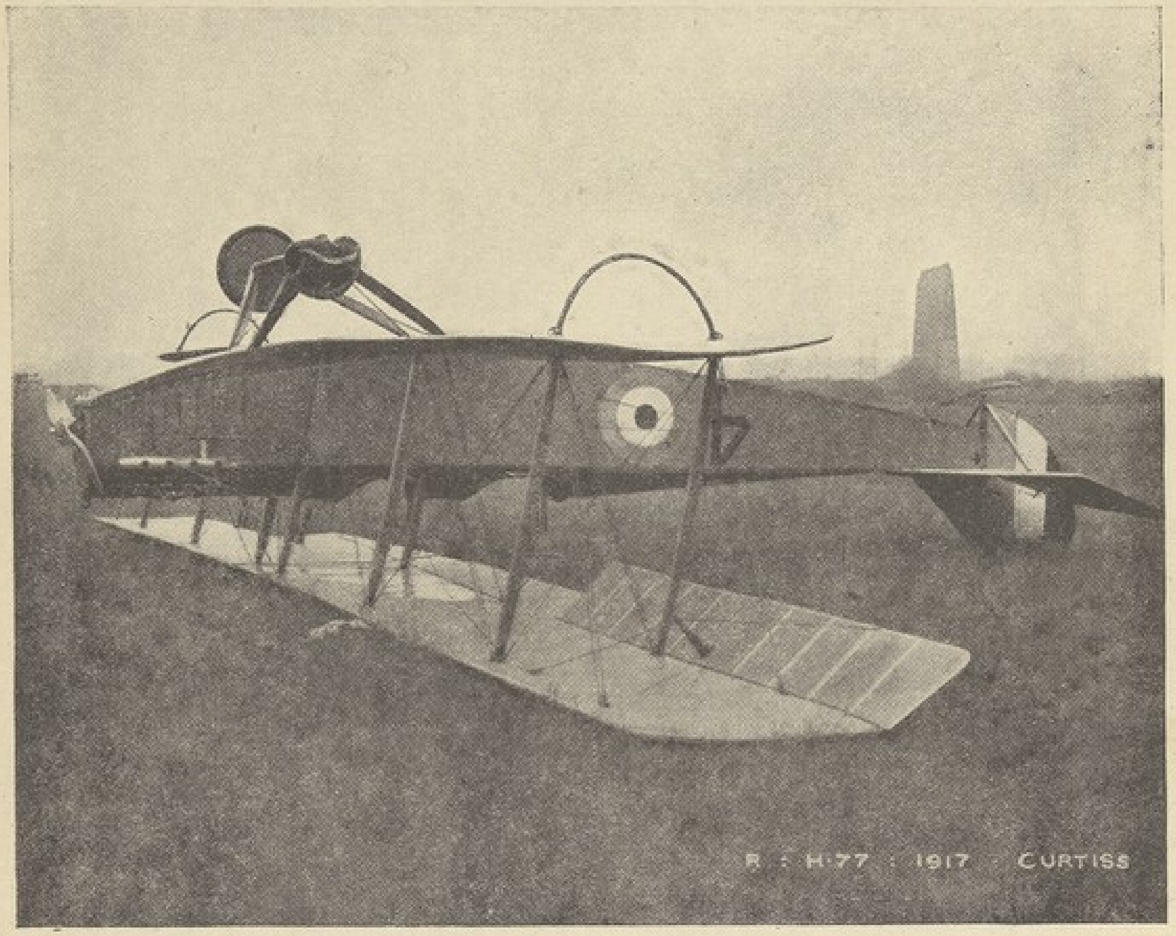


FIG. 2.—A bad landing—gentle turn over—occupants uninjured—landing wheel broken.

crashes; or one pupil injured in every 560 flights. From these figures one can see that school flying is fairly safe and compares favourably with other high velocity forms of transit. In the table which the author has drawn up flying accidents have been classified, firstly with regard to the cause, secondly the type or in which part of the flight the cause was initiated, thirdly the subtype or actual damaging cause, *e.g.*, the ground, trees, houses, other aeroplane, fire, etc., and fourthly the region or regions injured. To each record are also added remarks on the value of the safety-belt, safety-helmet, or other detail.

TABLE OF CRASHES

"V" Series. (1) *With Injury to Pilot.*

No.	Number of flight	Cause	Type	Subtype	Region injured	Remarks
1	3rd ...	Loss of head	Getting off	Collision with ground	Trunk ...	Belt held.
2	Dual ...	Unavoidable	Landing	Collision with tree	Shoulder; face	"
3	2nd ...	Loss of head	Getting off	Collision with ground	Face ...	Belt gave way.
4	2nd ...	Brain fatigue	Landing	Collision with ground	Back ...	" "
5	1st ...	" "	"	Collision with ground	Elbow and foot ...	" "
6	5th ...	Loss of head	Getting off	Collision with ground	Back ...	Belt held.
7	2nd ...	Error of judgment	Landing	Collision with ground	Wrist ...	Belt gave way.
8	12th ...	Loss of head	In the air	Collision with ground	Multiple	Fatal accident, belt gave way.
9	13 hours	Error of judgment	Landing	Collision with ground	Elbow ...	Belt gave way: forced landing.
10	12 hours	Error of judgment	"	Collision with ground	Wrist ...	Belt gave way: forced landing.
11	7th	Loss of head	Getting off	Collision with tree	Face ...	Belt held.
12	2nd ...	Brain fatigue	Landing	Collision with ground	Back ...	Belt gave way.
13	2nd ...	Engine defect	"	Collision with ground	Neck and back ...	Belt held: forced landing.
14	7th ...	Loss of head	In the air	Collision with ground	Face ...	Belt gave way.
15	7th ...	Error of judgment	Landing	Collision with ground: fire	Arm ...	" "

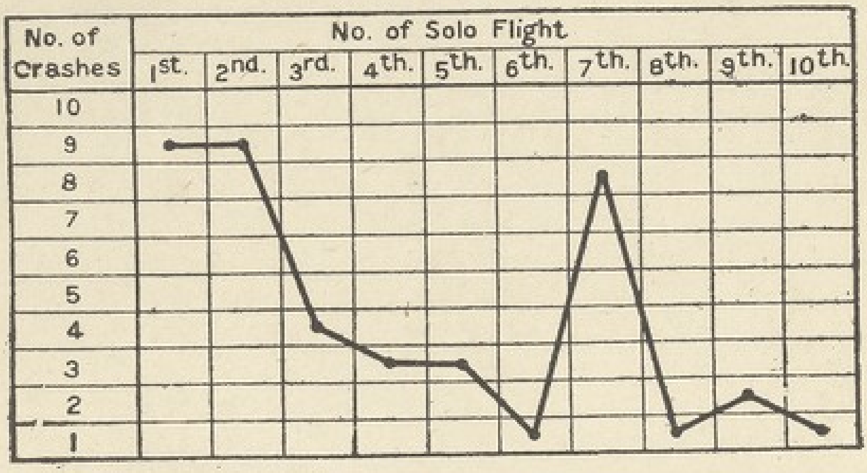
(2) *Without Injury to Pilot.*

No.	Number of flight	Cause	Type	Subtype	Remarks
16	1st ...	Error of judgment	Landing	Collision with ground	Belt held.
17*	⎧1st ...	" "	"	" "	Belt gave way.
18	⎩3rd ...	" "	"	" "	Belt held.
19	2nd ...	" "	"	Collision with tree ...	"
20	1st ...	Brain fatigue	"	Collision with ground	"
21	1st ...	Loss of head ...	"	" "	"
22	2nd ...	Error of judgment	"	" "	"
23	1st ...	" "	"	" "	"
24	1st ...	" "	"	" "	Belt gave way.
25	1st ...	" "	"	" "	Belt held.
26	3rd ...	" "	"	" "	Belt gave way.
27	7th ...	" "	"	" "	" "
28	7th ...	" "	"	" "	" "
29*	⎧10th ...	" "	"	" "	Belt held.
30	⎩20th ...	" "	"	" "	Belt gave way.
31*	⎧7th ...	" "	"	" "	Belt held.
32	⎩17th ...	" "	"	" "	"
33	12th ...	" "	"	" "	"
34	7th ...	" "	"	" "	"
35	3rd ...	" "	"	" "	"
36	4th ...	Unavoidable ...	Getting off	Collision in air with another aeroplane	"
37*	⎧5th ...	Error of judgment	Landing	Collision with ground	Belt gave way.
38	⎩7th ...	" "	"	" "	" "
39*	⎧1st ...	" "	"	" "	Belt held.
40	⎩5th ...	" "	"	" "	"
41	4th ...	" "	"	" "	"
42	4th ...	" "	"	" "	Belt gave way.
43	9th ...	Unavoidable ...	"	Collision in air with another aeroplane	Belt held.
44*	⎧8th ...	Error of judgment	"	Collision with ground	Belt gave way.
45	⎩9th ...	" "	"	" "	" "
46	16th ...	" "	"	" "	" "
47*	⎧2nd ...	" "	"	" "	" "
48	⎩6th ...	" "	"	" "	Belt held.
49	After 10 hours	" "	Getting off	Collision with tree ...	Belt gave way.
50	"	" "	Landing	Collision with ground	Belt held.
51	"	" "	"	" "	"
52	"	" "	"	" "	"
53	"	" "	Getting off	" "	"
54	"	" "	"	" "	"
55	"	" "	Landing	" "	"
56	Instructor	" "	Getting off	Collision with aeroplanes on ground	"
57	"	Unavoidable ...	"	Collision with hidden boulder	"
58	2nd ...	Error of judgment	Landing	Collision with ground	"

* Those starred and bracketed refer to the same pilot.

From this list of fifty-eight crashes the following table and chart are compiled to show the frequency of crashes on early solo flights :—

	Number of Crashes.		
Number of solo	With injury to pilot	Without injury to pilot	Total
1st	1	8	9
2nd	5	4	9
3rd	1	3	4
4th	0	3	3
5th	1	2	3
6th	0	1	1
7th	3	5	8
8th	0	1	1
9th	0	2	2
10th	0	1	1
12th	1	1	2
After 10 hours	2	12	14
Dual control	1	0	1
Totals	15	43	58



The above chart shows a greater frequency of crashes on the first and second solos, then a diminution from the third to the sixth inclusive and a rapid rise again on the seventh. The inference suggested is that by the time the pupil arrives at his seventh solo he often becomes over-confident and a little careless.

Causes of Aeroplane Accidents

The causes of aeroplane accidents are as follows :—

(1) Defect in the aeroplane.
(2) Error of judgment in flying.
(3) Loss of head.
(4) Brain fatigue or lethargy.
(5) Fear.
(6) Physical illness.
(7) Unavoidable causes.

In an analysis of the fifty-eight crashes in the "V" series the following table shows the frequency of these causes :—

Cause	Number of Crashes. With injury to pilot	Without injury to pilot	Total
(1) Aeroplane defect	1	0	1
(a) Breakage			
(b) Engine failure			
(2) Error of judgment	4	38	42
(3) Loss of head	6	1	7
(4) Brain fatigue	3	1	4
(5) Fear	0	0	0
(6) Physical illness	0	0	0
(7) Unavoidable	1	3	4
Totals	15	43	58

(1) *Defect in Aeroplane.*—This cause amounts to mechanical failure of some part of the aeroplane, and can be subdivided into (*a*) breakage in the air, and (*b*) engine failure.

(*a*) In the early days of aviation breakage or giving way in the air of some vital part of the aeroplane, *e.g.* the folding back of a wing, was unfortunately fairly common, and was due to faulty design or weakness in construction. Happily to a great extent this has been corrected, and at the present time very few accidents are due to this cause. In three years' experience with the R.N.A.S. the author has not seen a machine actually break in the air. In one case in the " E " series an elevator control wire jammed and caused the aeroplane to nose-dive with fatal results to both occupants.

(*b*) Engine failure, *per se*, may be a direct cause of an aeroplane accident, for example, if the engine fails just as the aeroplane is leaving the ground, and there is unsuitable landing ground and obstacles in front, and the pilot has not sufficient height or air space to avoid these. Or, for example, in landing if the pilot finds in his glide downwards that he has undershot or overshot the mark, and his engine will not " pick up " or respond to carry him on further to suitable landing ground.

On the other hand engine failure may not be a direct cause but may be a strong contributory or indirect cause of an accident. In all cases if the engine fails in the air a forced landing is compulsory, but given a fair height—2,000 feet or more—the pilot can usually select a good field for landing and arrange his descent accordingly. Of course on approaching the field to land it may be found not quite so good as was imagined from a greater height, *e.g.*, sloping ground, long grass, etc., and thus the pilot may make an error of judgment on actually landing. This quite often occurs with a pupil but rarely with an experienced aviator who knows exactly how to " pancake " his machine. But even in the case of experienced aviators, engine failure just after leaving the ground is a strong contributory cause to the real cause of an accident, namely, an error of judgment in flying. Authorities cite as one of the commonest examples of aeroplane accidents, engine failure just after leaving the ground when the pilot tries to turn back to his original starting place, loses height in the turning and in trying to prolong his glide, loses flying speed, stalls

—and the aeroplane falls to the ground out of control. In the " V " series engine failure was the direct cause in one case and was a contributory cause in two cases.

(2) *Error of Judgment.*—Error of judgment in flying is the commonest cause of aeroplane accidents. This error may occur in getting off the ground, in the air, or on landing. Of the fifty-eight crashes in the ' V " series this cause accounted for forty-two—four in getting off the ground, and thirty-eight on landing. Of the many examples of error of judgment in flying, perhaps the commonest is that in which the pupil in landing misjudges his distance from the ground, and either " flattens out " too soon and " pancakes " with a crash, the occurrence of which depends on the height he is above the ground, or else " flattens out " too late and strikes the ground at a varying angle, usually over-turning and wrecking the machine. (Plate 12.) Other examples of errors of judgment in the air are putting on too much " bank " with insufficient " rudder " or *vice versa* ; climbing on a turn ; and, as in engine failure, prolonging a " glide " so that the machine loses flying speed. It is difficult to estimate and account for these errors of judgment. In some cases they may be due to insufficient instruction. In other cases, even after prolonged instruction, the pupil may still misjudge distances, and on examination one occasionally finds that his standard of vision is below normal ; but, on the other hand, the pupil may be found to be physically fit, to have normal vision and good balancing power. In the latter cases it may be a question of delayed reaction times, especially the visual reaction time on which the aviator is so much dependent. Normally this takes $\frac{19}{100}$ or $\frac{20}{100}$ of a second. It may be delayed by fatigue, drugs and excesses ; but, on the other

PLATE 12A.—Showing result of flattening out too late. Aeroplane photographed in the act of overturning—occupants uninjured.

PLATE 12B.—Showing result of flattening out too soon, and pancaking. Undercarriage broken—occupants uninjured.

hand, in some individuals who are otherwise physically fit, it is found to be much slower than normal, so that it is evident that in the selection of candidates for aviation the visual and other reaction times must be up to the normal standard. By the French medical authorities on aviation, candidates are rejected if the reaction times are found to be of the delayed type.

(3) *Loss of Head.*—Loss of head occurs fairly frequently in a greater or less degree and accounts for a fair proportion of accidents—seven in the present " V " series. The pupil in his new occupation of flying for the first time has all his mental faculties on the alert at extreme high tension; the sense of danger, although not asserting itself, is ever present but subconscious. Under the sudden strain of an emergency the power to reason and act synchronously may momentarily lapse, resulting in what is known as loss of head. In a critical position the pupil has to think, decide, and act quickly; but in loss of head the mental balance becomes upset—there is no mental inertia—so that the wrong decision is taken and acted on. In flying, seconds and parts of a second count enormously and may mean all the difference between safety and danger. After actual loss of head there is seldom time to correct the error made. As examples of loss of head in the air, the pupil in an emergency may move the throttle the wrong way, may keep his engine full on when he should throttle down, or may switch off his engine at a moment when he requires all the flying speed possible. Loss of head is very much allied to the two following causes of accident, brain fatigue and fear.

(4) *Brain Fatigue.*—In contradistinction to loss of head the pupil in brain fatigue reaches the stage where he has neither the power to reason, decide

nor act. A state of mental inertia supervenes. This is due to repeated stimuli received by his brain in rapid succession in his flight; he feels alone; a succession of errors occurs in the air; he feels he cannot manage to control the aeroplane; fear does not seize him, but the enormity of the whole thing appals him; he feels helpless and a state of brain fatigue occurs in which, in a stupor, he awaits events and takes little part in the aeroplane's control. After a careful study of 100 of the first solo flight confessions of pupils, and of many pupils who have had crashes, whether with or without injury, the author is convinced that brain fatigue is a cause of a fair proportion of aeroplane accidents. Four occurred in the fifty-eight of the "V" series. As a rule in brain fatigue, the error the pupil makes is that he fails to flatten out, and the aeroplane strikes the ground at its gliding angle and becomes wrecked. If one questions a suspected case of brain fatigue immediately after his flight one finds usually that the pupil has very little recollection of what he did in his flight. Memory seems to become partially stunned. It is difficult to make a diagnosis of those liable to brain fatigue. As a rule, if it occurs, the pupil, even should he escape injury, soon gives up flying. He is not of the temperament suitable for flying. As a preventive the pupil's first few solo flights should always be of short duration.

(5) *Fear.*—Fear, at least in a degree sufficient to disturb one's flying, is rarely experienced in the air on the first few solo flights, whatever the sensations may be before going up or in the intervals between flying. The mind is far too much occupied and concentrated on details of flying, watching the various instruments that record air speed, height, levels, and engine revolutions, and in judging one's

position and direction in the air relative to the ground. From an analysis of the confessions of the first solo flights of 100 pupils, and of his own, the author notes that very few experience fear in the air, at least not in a degree sufficient to disturb one's flying. Many confess that fear is subconscious —that there is a sense of danger lurking somewhere at the back of the head, but that it rarely if ever asserts itself. In the " V " series no crash occurred through fear. One case was related by an officer in which he said that the pilot was seen in the air to throw up his hands and was heard to shriek; the machine fell out of control, and the pilot died shortly afterwards from the injuries received.

(6) *Physical Illness.*—In the series of crashes under consideration none was attributable to physical illness. At an air station medical inspection of the pilots and pupils at regular intervals reveals any organic disease that might lead to loss of consciousness in the air. Flying on an empty stomach may cause faintness in the air. In schools, flying begins at dawn, and all pupils are provided with a good meal of cocoa, tea, bread and butter. Similarly on long flights pilots are provided with tabloid forms of nourishment. The effects of cold and fatigue may produce faintness or stupor in the air. There are many instances on record of pilots fainting in the air either through being wounded or from high altitude effects. Some have been known to recover consciousness before reaching the ground and have been able to make successful landings. Two pupils in the " E " series suffered from attacks of malaria in the air and both were made to discontinue flying. Another pupil in " E " series, although slow to learn, was making fair progress, but one day he was noticed to descend rather steeply; he made no attempt to flatten out, the aeroplane

struck the ground at its gliding angle, and the pilot was thrown out, clear of the machine, a distance of 66 feet, and escaped with only a slight sprain of one ankle. A few days later in the wardroom this pupil was seized with a series of typical epileptic fits. On enquiry a history of epilepsy for the previous five years was elicited. This was undoubtedly a case of an epileptic fit taking place in the air.

(7) *Unavoidable Causes.*—From time to time unavoidable causes of accidents arise. Every precaution is taken at a flying school to prevent collisions in the air or on the ground. Set signals are made with regard to the direction of circuits and landing areas for different flights. The terrain in certain areas may be unsuitable and conceal obstacles; again, in some aeroplanes the view of the air or ground in certain positions may be limited. These conditions may cause unavoidable accidents. In the "V" series four accidents were unavoidable—two were due to bad terrain with obstacles concealed in the grass—in the case of the other two a collision took place in the air. One machine was landing and one was getting off, but neither saw the other, with the result that both machines collided 10 feet from the ground and were wrecked, but both pupils escaped unhurt.

Type of Accidents

The term "type of accident" is suggested to describe the part of the flight in which the cause of the accident was initiated. It is possible to have an arbitrary division of a flight into three parts: first, the getting off the ground into the air up to 50 or 100 feet; second, in the air with the various turns, figures of eight, climbs, spirals, etc.; and, third, the landing, which includes the descent from the time the throttle is closed to the time the aeroplane is brought to a standstill on the ground.

The following table gives an analysis of the types in the " V " series :—

Type of accident	Number of Crashes. With injury to pilot	Without injury to pilot	Total
(1) In getting off	4	6	10
(2) In the air	2	0	2
(3) In landing	9	37	46
Total	15	43	58

Some of the errors which the pupil may make in getting off are raising the aeroplane's tail too high, slueing to one side, or getting off with one wing down.

In the air a pupil may lose flying speed or stall, or may sideslip, or spin.

The commonest type of accident is in landing, the pupil's *bête noire*. He may either flatten out too soon, lose flying speed some feet from the ground, and the machine " pancake," or else he may be too late in attempting to flatten out, and the aeroplane strikes the ground at an angle, turns over and is wrecked. (Fig. 3.)

Scheme for First-Aid at an Air Station.

The Sick Bay or Dressing Station should be in full view of the aerodrome, with a lookout man supplied with field glasses always on duty during flying hours. Should the Dressing Station not be situated on the aerodrome, the former should be connected by telephone to the lookout man whose position commands a good view of the flying area. Immediately a crash or forced landing occurs the lookout man telephones to the Sick Bay, notifying the Steward the exact site of its occurrence. A map of the aerodrome numbered in quadrants can be conveniently arranged in the Sick Bay. The lookout man then leaves his post and proceeds to the scene of accident, taking the hand stretcher on wheels, on which is carried a first-aid dressing bag and an emergency tool kit case. The latter consists of an oblong box containing the following :—

(1) Two crowbars.
(2) Two strong wire cutters.
(3) Saw.
(4) A long stout knife.
(5) A hammer.
(6) Strong cloth cutting scissors, and
(7) A fire extinguisher.

Experience of aeroplane accidents teaches one that the above set of implements is very necessary, as in some crashes where the pilot is pinned under the wreckage it may be difficult to reach him. In such cases one feels helpless without these emergency tools. (Plate 13.) An injured aviator should never be dragged out of a crash except in the case of fire, but rather the wrecked machine should be cut away from him. In many cases this prevents simple fractures from being converted into compound ones. (Plate 14.) The Steward on being notified of an accident despatches the ambulance, which stands always in readiness by the Sick Bay, to the scene of the accident. The ambulance should be provided with twin wheels aft in order to facilitate movements on soft earth, etc. Two sick berth attendants go with the ambulance and with them is a bag containing the following articles :—

(1) Morphine solution and two Wildey's hypodermic syringes.
(2) A bottle of chloroform and face mask.
(3) Brandy.
(4) A bottle of sterilized water.
(5) Six first-aid field dressings and slings.
(6) Picric acid dressings.
(7) A tourniquet, cloth cutting scissors and a knife.

These articles can easily be packed into a small bag 10 in. by 8 in. by 3 in. This has been found most useful as it contains all that is necessary, is light,

PLATE 13.—A bad crash showing necessity of having emergency tool kit to cut away wreckage and reach the injured aviators.

PLATE 14.—The injured should not be dragged out from the wreckage, but the latter should be cut away first.

can be easily carried, and does not take up room if one has to go by air to an accident. The surgeon on duty is on the aerodrome during flying hours

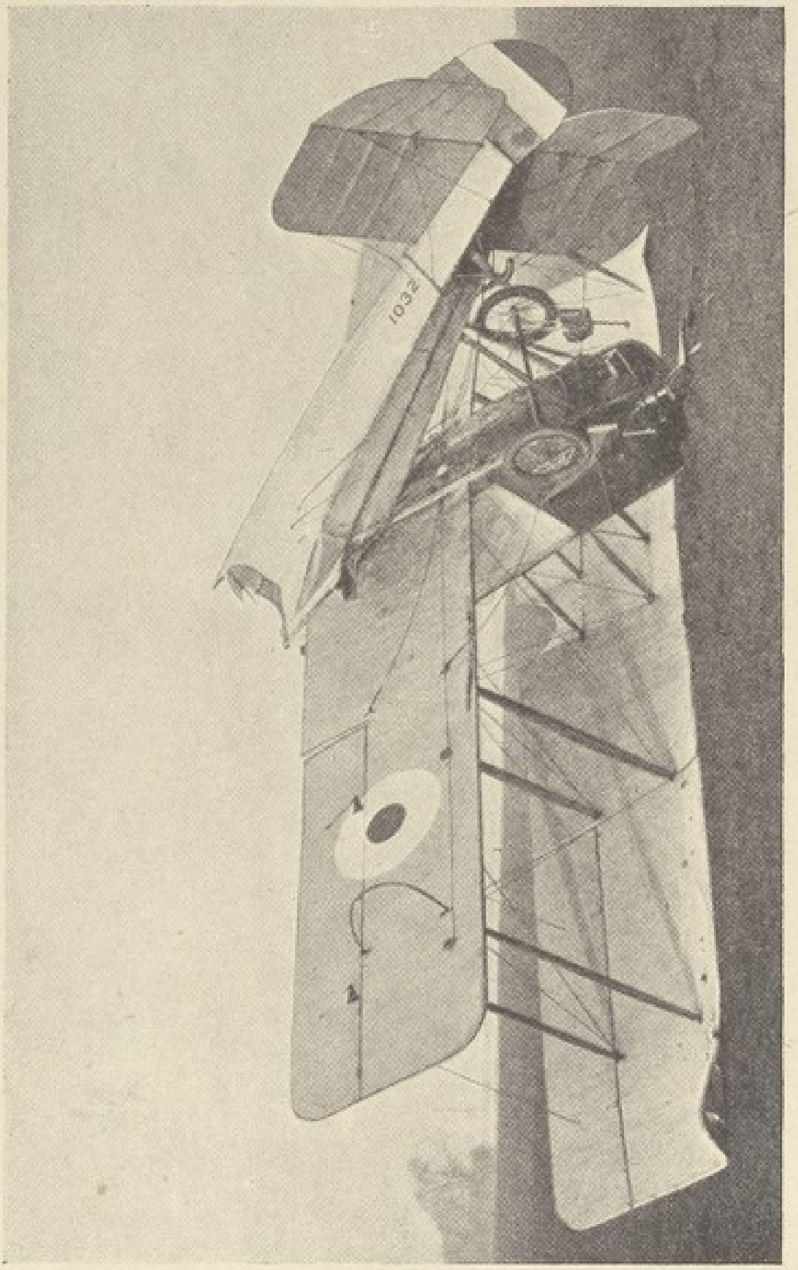


FIG. 3.—A crash result of flattening out too late. Machine overturned and wrecked.

and proceeds to the scene of the accident by car or foot. If the accident is at a distance, a mile or more, it is better to go by aeroplane. The author has now gone by air to over thirty forced landings and accidents at a distance and is convinced of the utility of this method in arriving quickly and not otherwise tired and out of breath as after a long run. In connection with the discovery of the site of forced landings and accidents at a distance from the aerodrome much depends on the condition of the country around. Should this be flat country these accidents are fairly easily discovered, but in some flying schools the surrounding land may be uneven, intersected with dykes and high hedged roads. Thus it may be extremely difficult for the search party to find the wreck. The author suggests under these conditions at an air station that an aeroplane be sent up and ordered, on discovery of the crash, to circle round it; to fire a Verey's red light if it is thought that the pilot is injured; a green light if is thought that the pilot is uninjured; and a white light to signify that it is possible to land near the crash. Officers and flight mechanics who arrive or are sent out to the scene of accident should be trained in first aid with special reference to aeroplane accidents. Flying pupils should not be allowed to come near or help unless under exceptional circumstances.

In many cases the crash is so severe that the wreckage has to be cut away from the injured aviator. In other cases the machine is upside down with the pilot held head downwards by his safety belt. The latter must be cut and the pilot slid gently out. The emergency tools are used to cut wires, remove wreckage and lever away the heavy parts, *e.g.*, the engine, and thus easily to reach the injured person. The aeroplane seat cushion is taken from the machine and placed under the injured pilot's head, whilst his body rests on a flying coat spread out on the ground. A rapid examination is carried out to determine the injuries received. If the injured

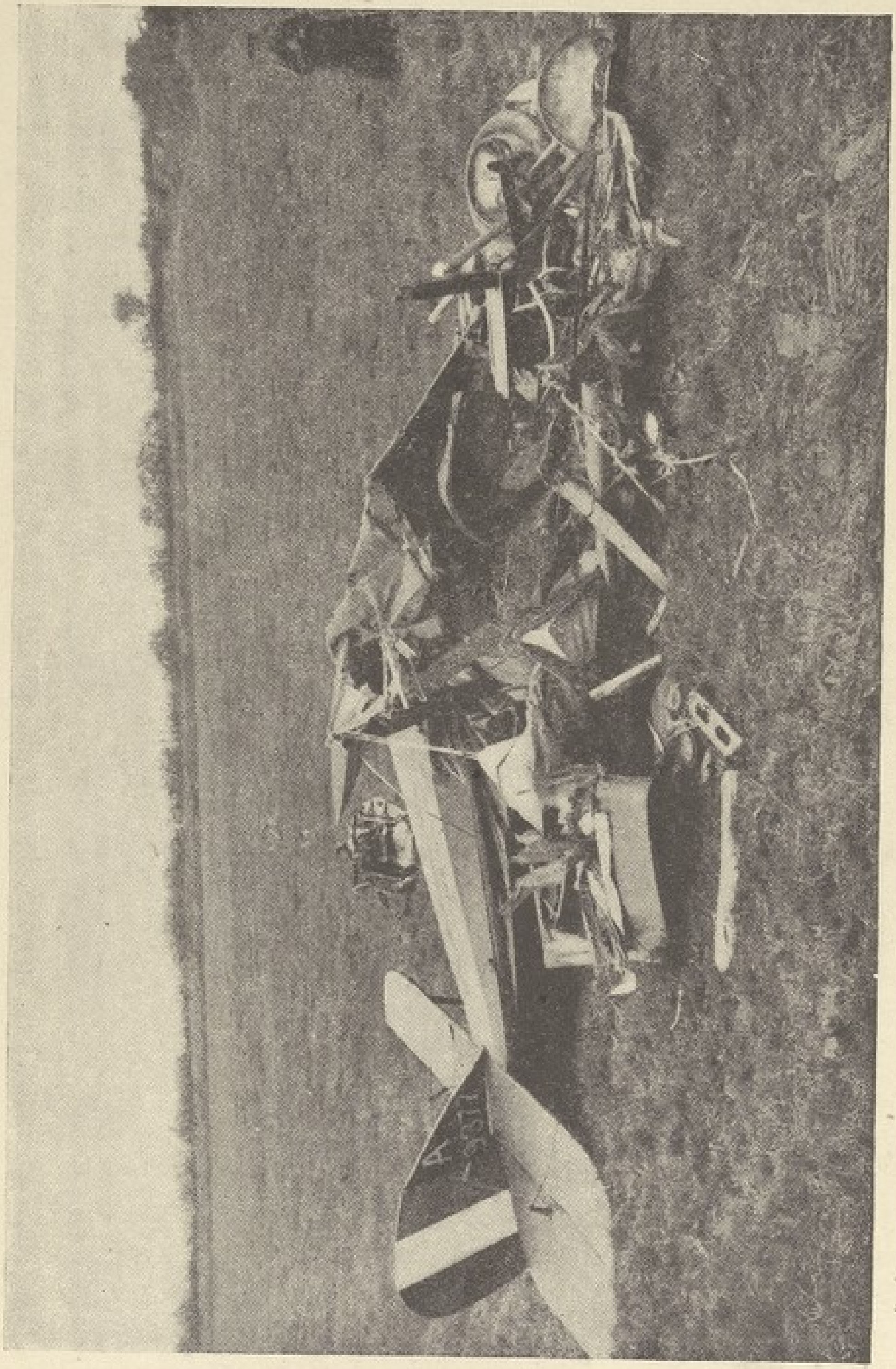


Fig. 4.—Fatal result due to crushing effects.

person is conscious and in much pain morphine should be injected and he should be conveyed quickly to the dressing station, where clothes can be cut away, injuries examined and treated. If unconscious, some cutting away of clothing can be done on the field, injuries examined, and perhaps a dislocation reduced or a fracture accurately diagnosed during the unconscious period. In cases of fire, unless the pilot is thrown clear, the fire extinguishers must be used; but if there is any wind blowing they are of little use, as an aeroplane on fire is destroyed completely within a few minutes. (Plates 15 and 16.) The pilot's leather clothing usually protects the body for a time, but the face and lower limbs rarely escape. As the pain is very severe (and this applies to other injuries apart from those caused by fire) it is better to give chloroform on the field, and this administration is kept up on the way back to the dressing station. Morphine should also be given, but it takes some time to act.

Some Factors Relative to Aeroplane Accidents

The injuries sustained are akin to those apt to be associated with most high velocity accidents, but are usually more severe, as greater speed is used in aviation. They may be divided into: (1) Injuries due to crushing, where some part of the pilot's body gets crushed between parts of the wrecked aeroplane, *e.g.*, between the engine and the woodwork, or between different parts of the woodwork in tractor (engine in front) types of machines; (Fig. 4) or between the engine and the earth, as in propeller (engine behind) types of machines. Crushing injuries are very severe in nature and mostly fatal in the latter type of aeroplane. (2) Injuries due to collision with the ground, as when the pilot is thrown out or hits the ground with his

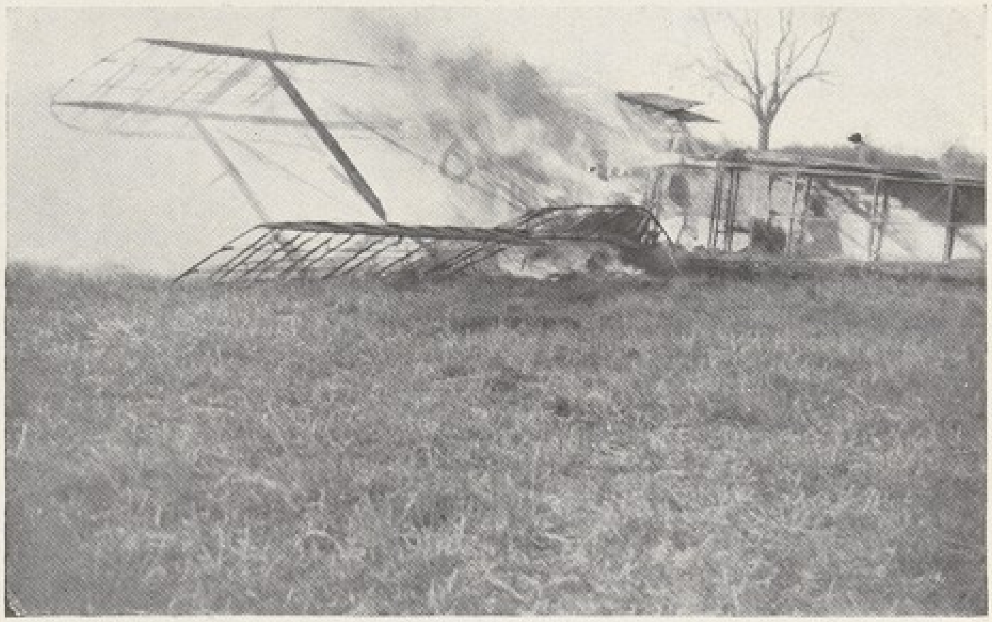


PLATE 15.—An aeroplane crashed and on fire.

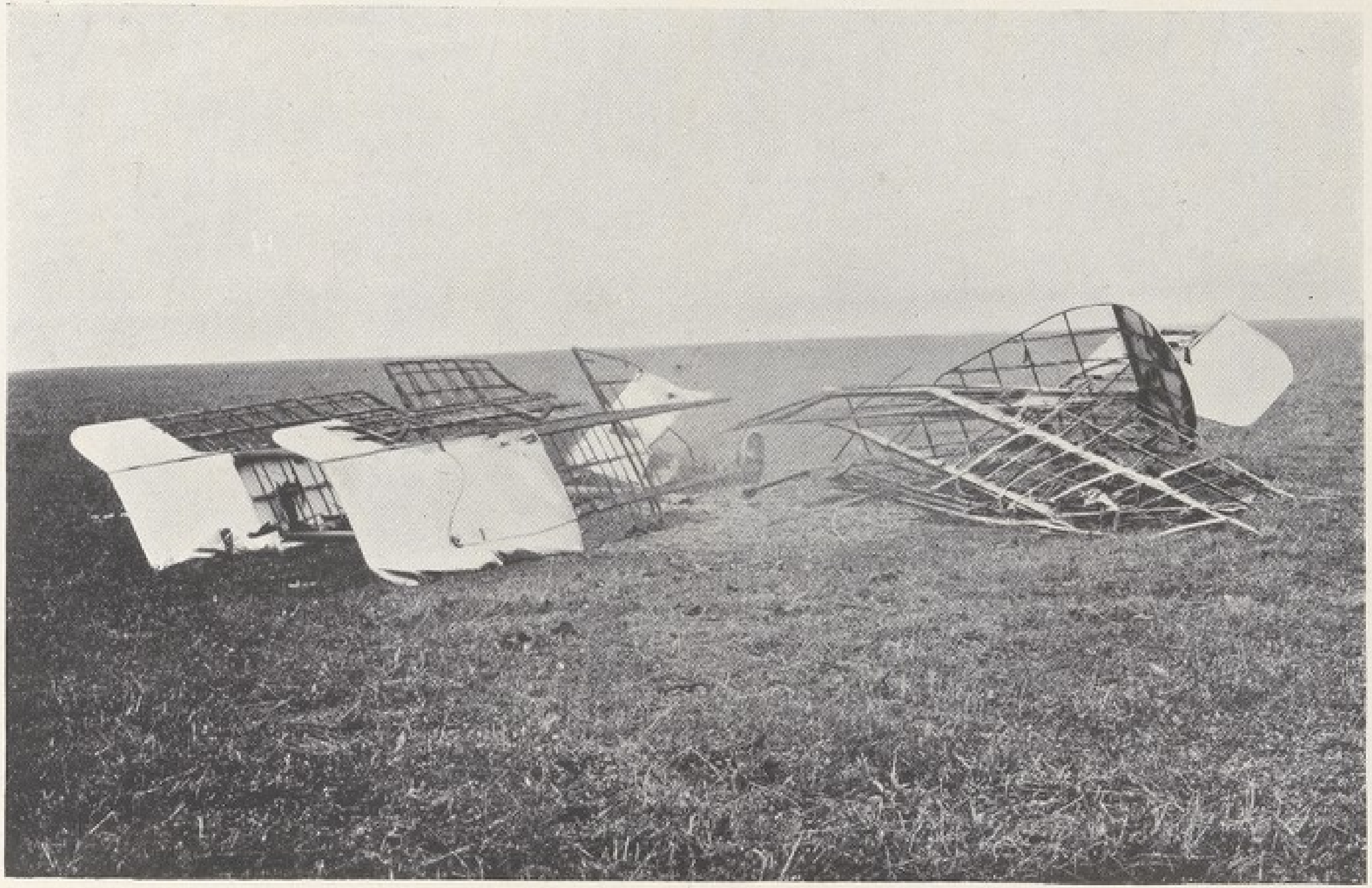


Plate 16.—Aeroplane destroyed by fire in the course of a few minutes.

head in turning over in and with the aeroplane. (3) Injuries due to impact with different parts of the aeroplane, as when the head is violently jerked forward and strikes the edge of the nacelle on the aeroplane's impact with the ground. (Fig. 5.) Flying débris such as broken struts and wires may cause local impact injuries. (4) Injuries from fire. (5)

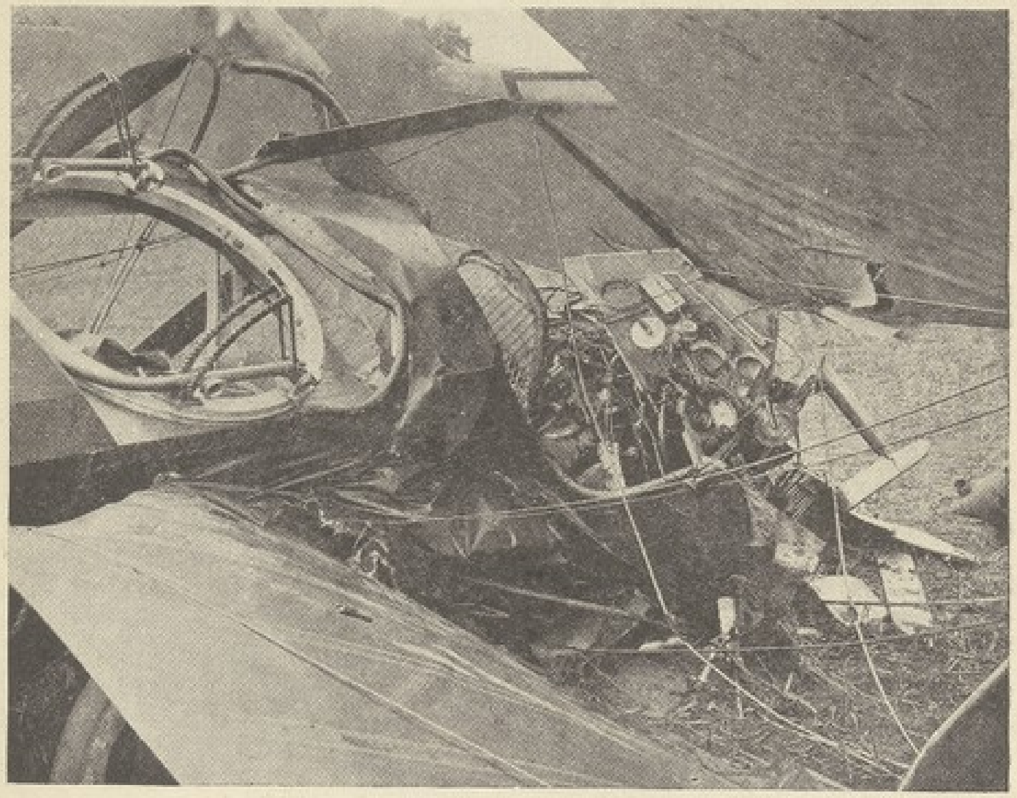


FIG. 5.—Showing how impact injuries occur. Aviator's head may strike cockpit edge or instrument board.

Drowning and immersion effects in seaplane work. (Fig. 6.) And (6) suspension effects, as when the pilot is suspended head downwards in an overturned aeroplane and is unable to loosen his safety belt. (Fig. 7.) In many crashes the sudden impact of the pilot's body on the safety belt causes abdominal injury.

The injuries sustained vary a good deal and depend on the type and power of the aeroplane, and the cause and type of accident (see classification). An experience of three years attached to the Royal Naval Air Service has impressed the author more and more with the element of luck in crashes. The present day school aeroplane is much stronger

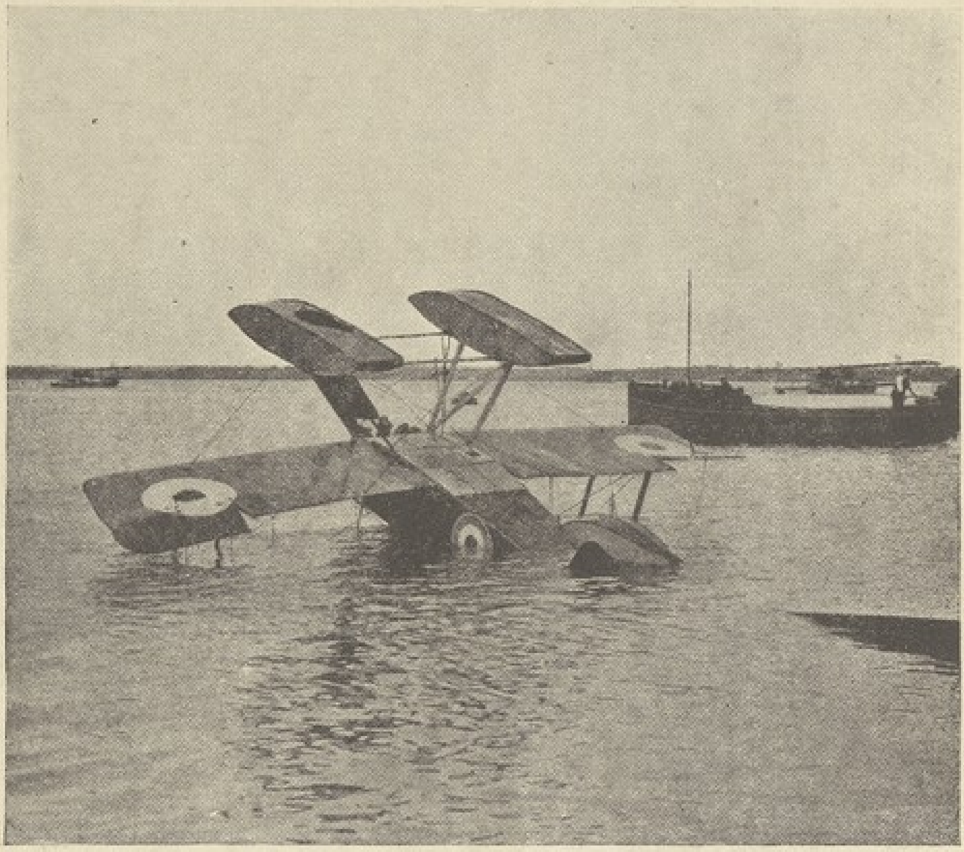


FIG. 6.—Showing how drowning may occur as result of seaplane crash.

in construction and more powerfully engined than in earlier days, thus providing for a greater margin of error on the pupil's part. The propeller type of school machine (for example, the Maurice-Farman) is considered very safe. It can be landed slowly and has a powerful engine to cover errors. In a crash it has a strong under-carriage and a great deal of woodwork to absorb the shock before actual

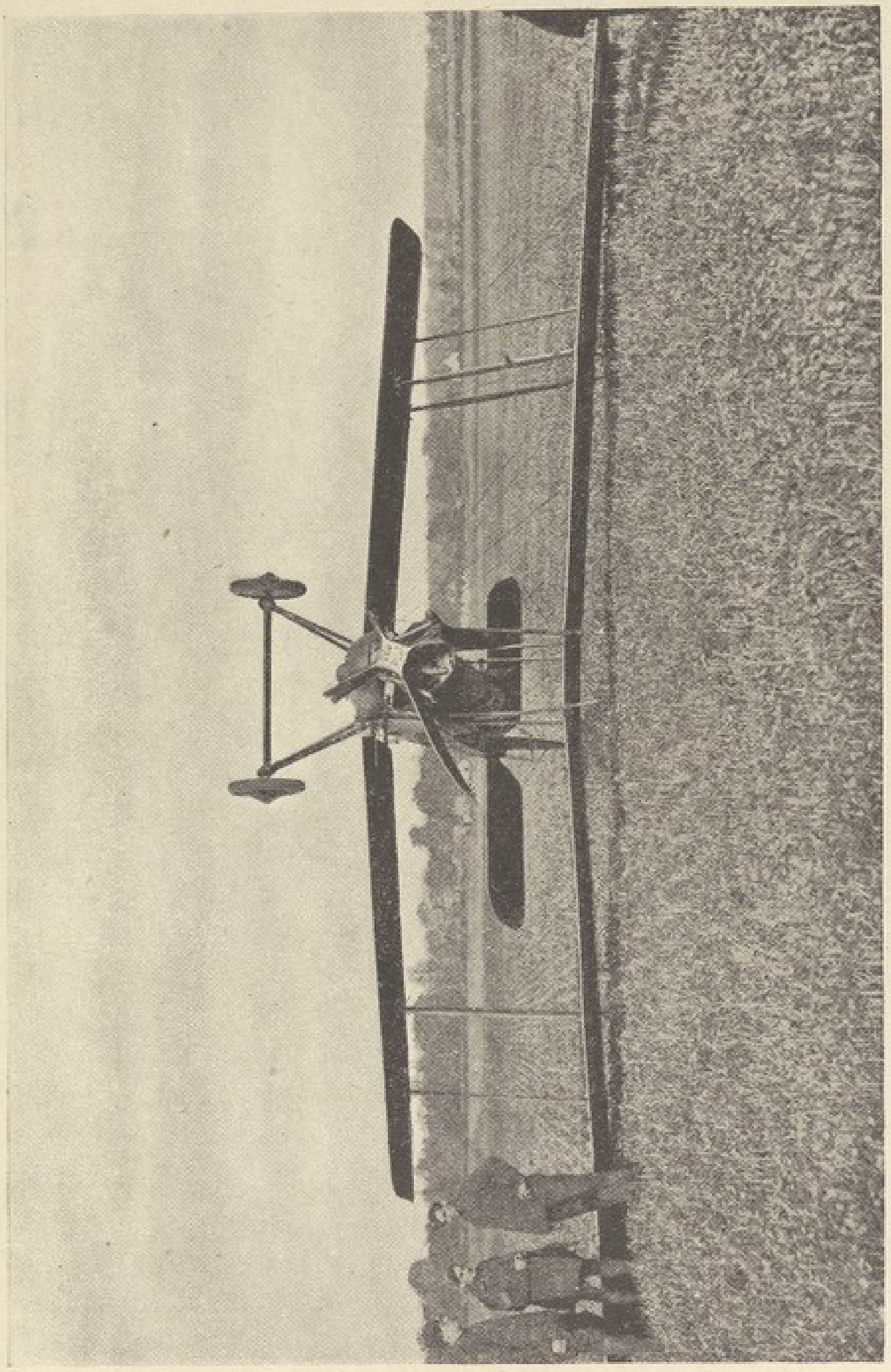


Fig. 7.—Showing how suspension effects may be produced if aviator is unable to loosen his safety belt.

injury occurs to the pilot. On the other hand, in a nose-dive in this type of machine the engine, being behind, is likely to crush the pilot severely, and this usually proves fatal. In tractor machines the engine in front takes most of the shock in a crash, but the

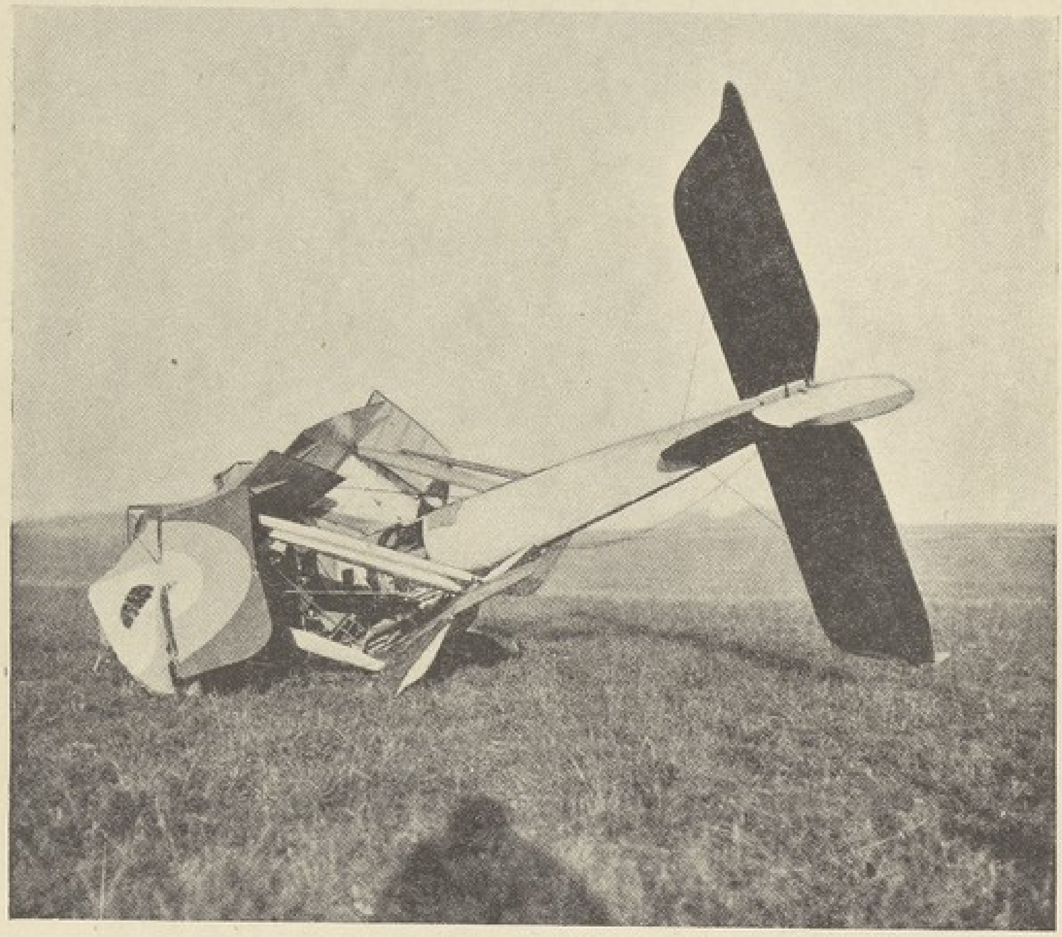


FIG. 8.—Showing in a crash in a tractor machine how the front seat cock-pit gets crushed.

observer's seat just behind the engine usually gets telescoped or crumpled sideways. (Fig. 8.) The pilot's seat, which is behind these, usually escapes crushing effects. (Fig. 9.) If the pilot receives injury, this occurs either from his being thrown out or from his head being violently jerked forward and hitting the nacelle edge, wind-screen or instrument board.

Should the safety belt hold the sudden impact of the pilot's abdomen and lower part of chest against it may cause internal injuries. Nowadays most nacelle edges are padded and safety belts are stronger and broader.

Safety Belts.—With regard to the use of safety belts endless discussion has taken place amongst aviators. The author's own opinion is that before leaving

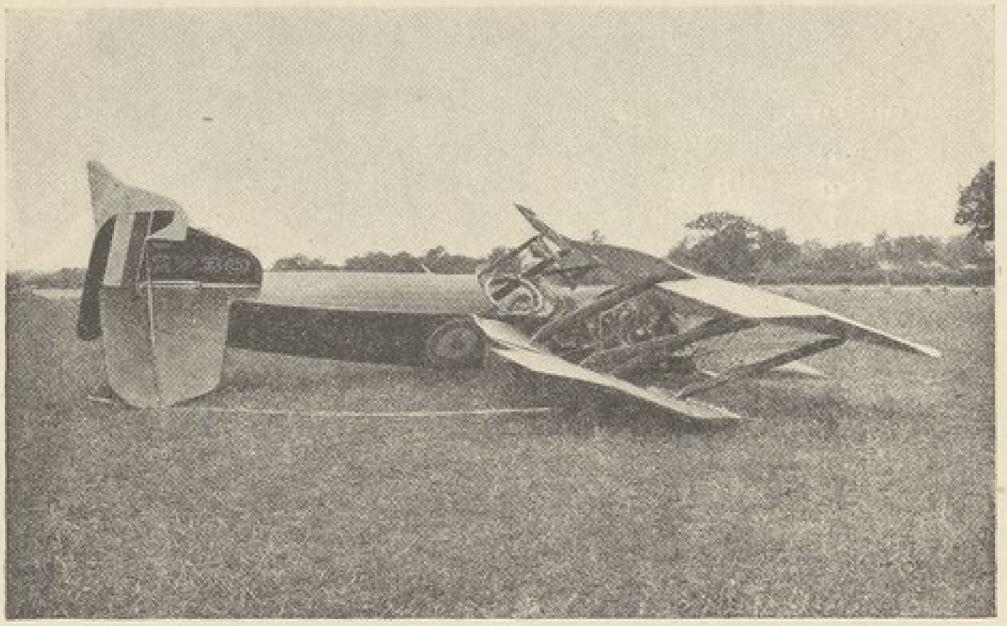


Fig. 9.—Showing how the pilot's cockpit escapes crushing effect.

the ground all aviators should see that their safety belts are fastened, and should be familiar with the method of their quick release. The belt should never be undone in the air. Thus the pilot, in the event of fainting, losing consciousness, or being wounded, or encountering gusty and bumpy weather or fog, has a safeguard to prevent him either being thrown out in the air, or thrown forward on to his control lever (thus causing the aeroplane to nose dive), or having his feet jerked off the rudder bar (thus losing steering power). All probably are agreed on the above, but the difficult question arises whether to release the belt near the end of a glide before landing. This the author would advise in the propeller type of aeroplane, but in the tractor machines it remains an open question, as the following figures show. In seventeen crashes on tractor machines with seventeen injured, the belt held on seven occasions and gave way in ten. In forty-two crashes without injury to the pilot the belt held in two-thirds of the cases and gave way in a third.

AEROPLANE CRASHES—" V " SERIES.

Number of injured when safety belt held	7
,, uninjured when safety belt held	28
,, injured when safety belt gave way ..	10
,, uninjured when safety belt gave way ..	14
Total	59

Certainly if the aeroplane catches fire in a crash little hope can be entertained of the pilot if he be strapped in. Safety for him depends on his being thrown out clear of the machine. The author has seen only one school accident where fire occurred, and happily the belt gave way, the pilot being thrown out and sustaining nothing more than a fractured clavicle, whilst the aeroplane was destroyed by fire in less than five minutes. (Fig. 10.) A narrow belt is to be condemned. The ideal safety belt should be broad and resilient, attached to the framework of the aeroplane and not to the pilot's seat, should be made to release easily and quickly, not at the centre of the pilot's body but at the side, where it is attached to the aeroplane. This release should be effected by means of a small hand lever. It is advisable for all pilots to carry a stout knife in the outside pocket of their flying coat in order to cut the belt should they be held in upside down in a crash.

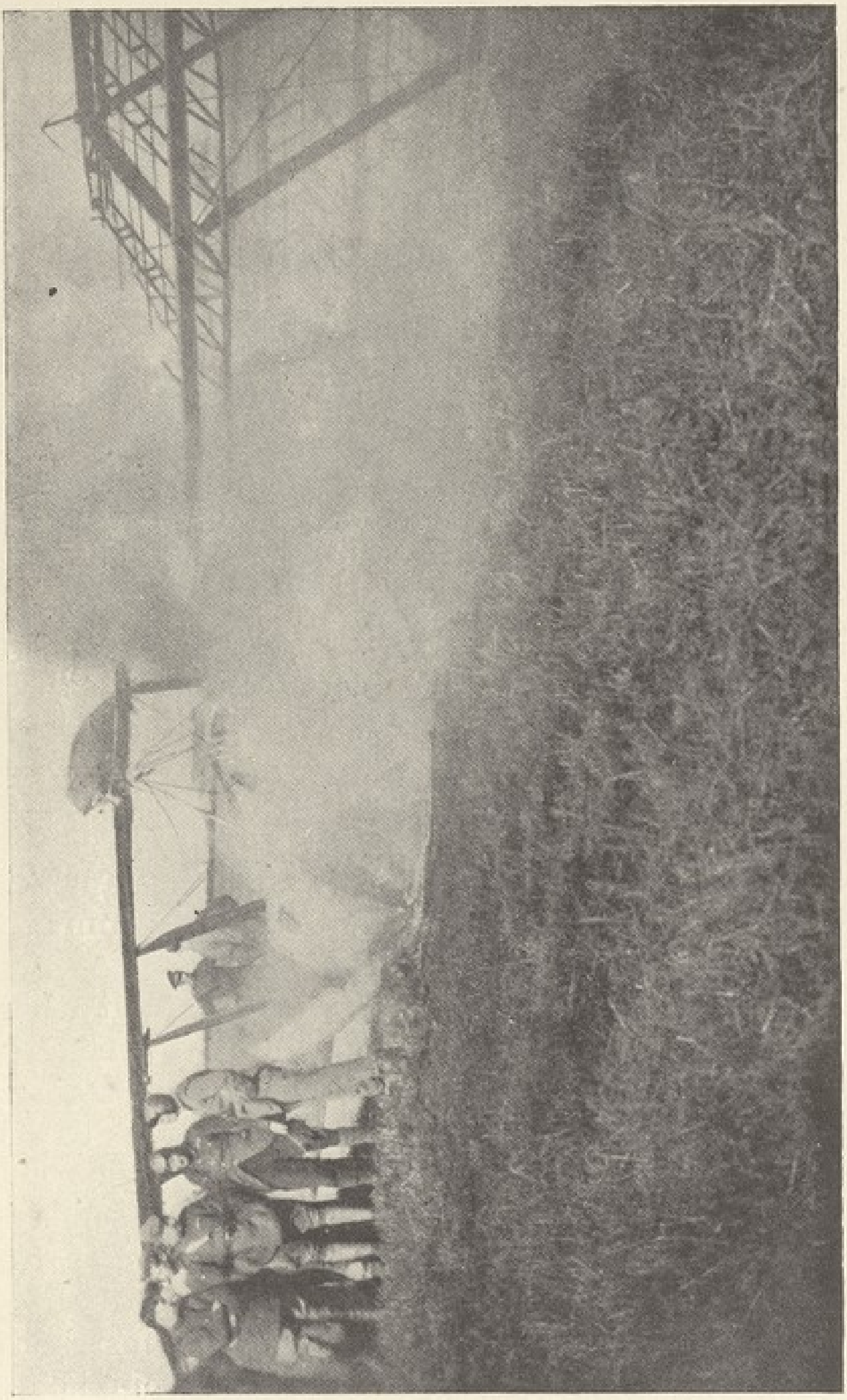


FIG. 10.—Aeroplane on fire after a crash.

Safety Helmets.—Safety helmets are of undoubted value in school work and should be worn by all pupils. They should fit properly and not be easily dislodged from the head whilst flying. The modern ones are much lighter and less high in the crown than the earlier ones used. In a crash they certainly prevent scalp wounds from broken struts and wires, and the side flaps protect the ears from injury. Over and over again the author has seen pilots thrown out who owe their escape from more or less serious head wounds, to their safety helmets.

Cases 5, 7, 9, 12, 13, 14, 15, 22, 28, 30, 31, 32, 37, 44 and 47, were certainly saved from head injury by their safety helmets. On the other hand in a turn over, the added height of the crown may catch the ground and wrench the head either forwards or backwards, causing fracture dislocation of the neck or severe strain and possible rupture of the muscles of neck and back. Case 13, although escaping head injury, had his head violently forced forwards in turning over and sustained severe strain of the muscles of back and neck.

As pointed out by Fleet Surgeon Wells, an ideal safety helmet would take its support from the shoulders.

Goggles.—Most aviators wear goggles but there are still some who prefer to fly without them. The question arises, would the continuous rush of air, at from 50 to 120 miles an hour, do damage to the eyes if flying were carried out for a considerable length of time without goggles? It has been said that as the air, especially at flying heights, is free from dust and foreign bodies it would therefore do no harm to the eyes. The author knows of one instructor who after a year continuously instructing pupils and wearing no goggles, began to suffer from a form of conjunctivitis. He certainly thinks that goggles should

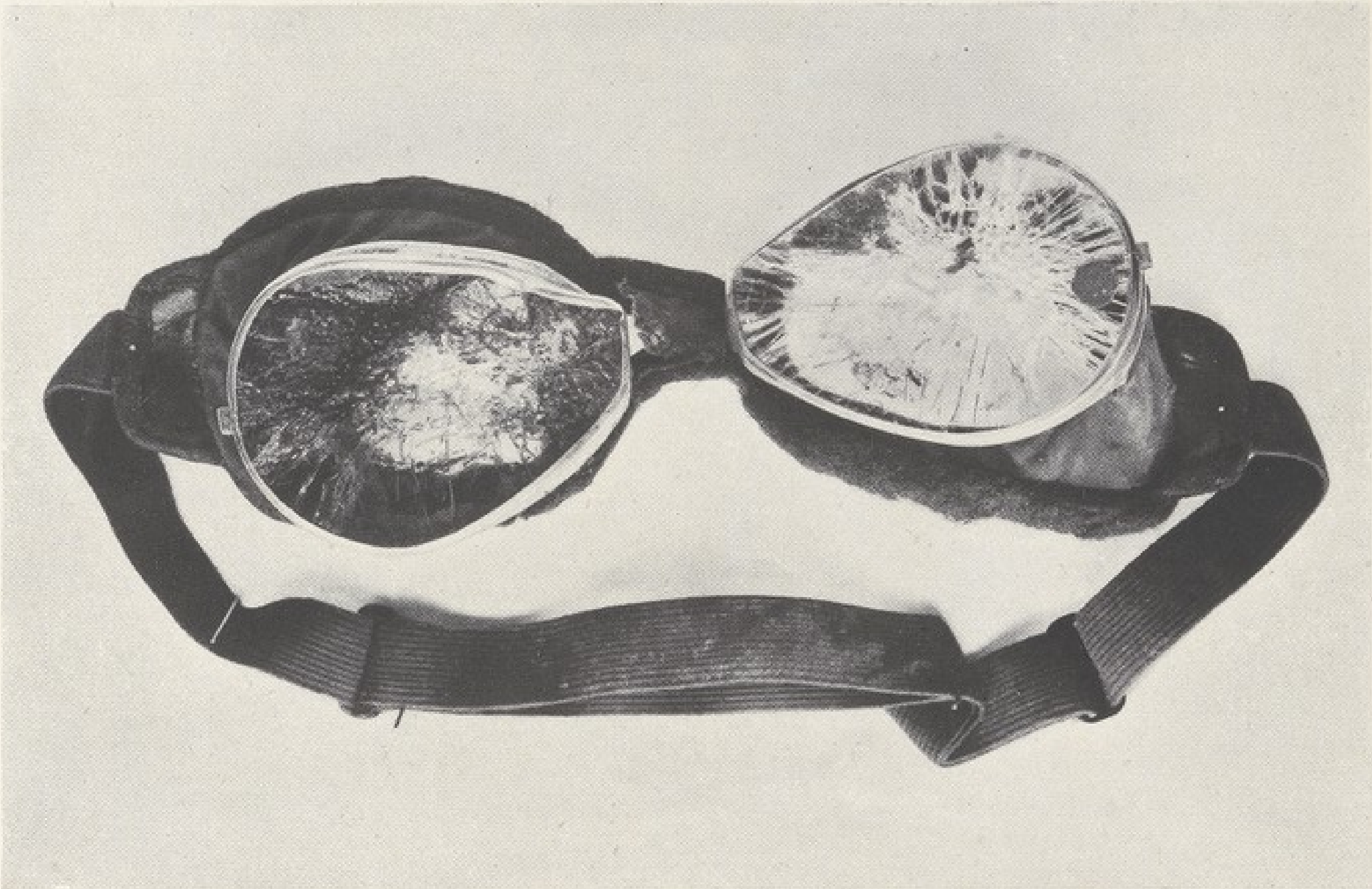


PLATE 17.—Triplex goggles—the result of a crash showing how pupil escaped injury to eyes.

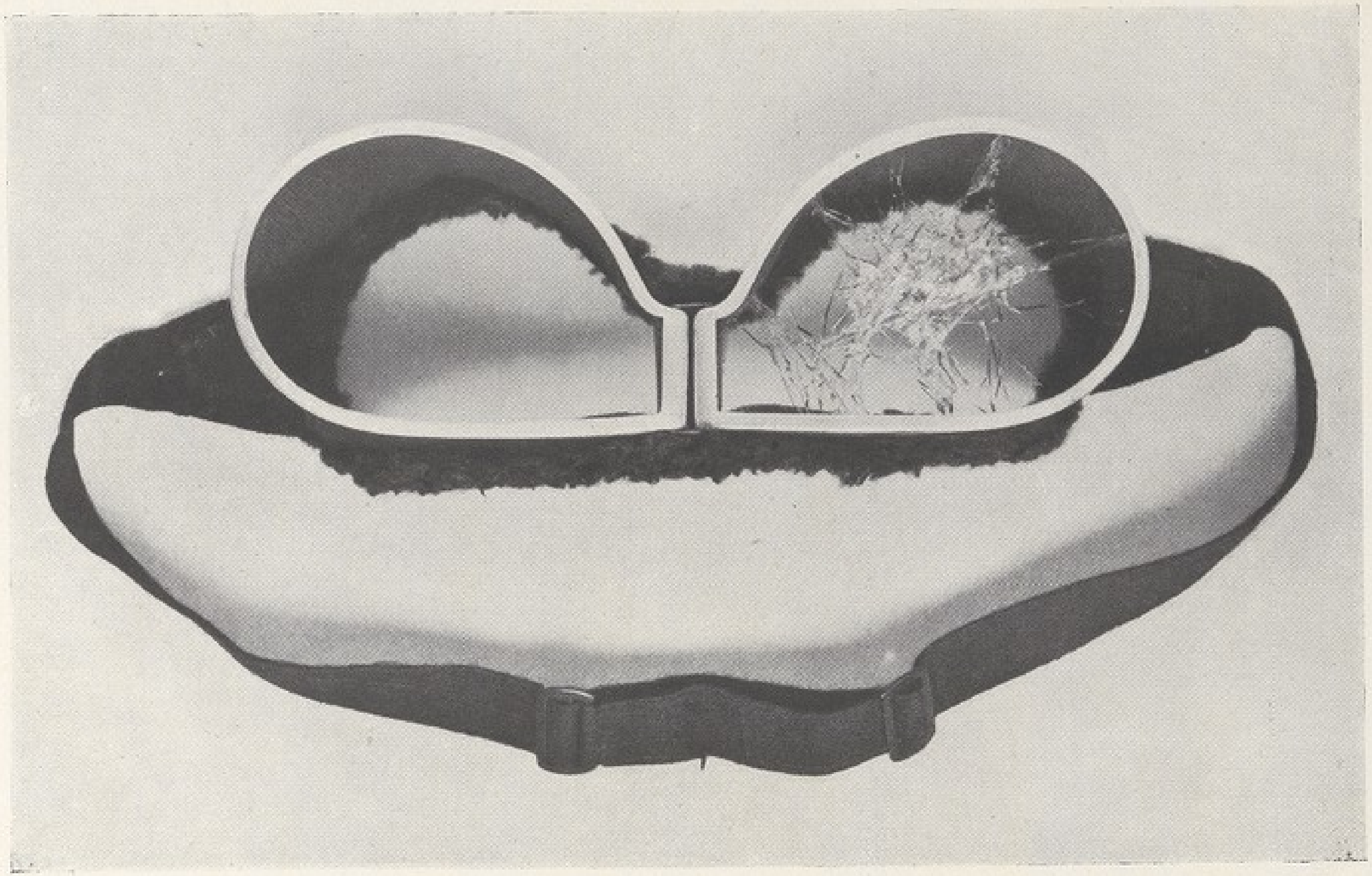


Plate 18.—Triplex goggles. Right lunette hit by shrapnel. Aviator's eye escaped damage.

always be worn. There is no doubt that flying without goggles is apt to set up a spasm in the eyes which in the long run is bound to do harm. Triplex or non-splintering material is now almost universally used instead of glass in the manufacture of aviation goggles. Thus, rarely in a crash do we get any injury to the eyes. (Plates 17 and 18.) The nose-piece connecting the two lunettes should have no metal in its composition. He has seen some cases where wounds of the nose were caused by the metal connecting part of the lunettes.

Accidents under Dual Control

Accidents under dual control are not common, as the instructor has usually time to correct in the air any of the pupil's errors in flying. One occurred in the "V" series, and was unavoidable owing to the nature of the ground. In the "E" series three occurred. One was due to defect in the aeroplane whereby the elevator control wire had jammed, causing the aeroplane to nose-dive and resulting in the death of both pupil and instructor. A second occurred in a propeller machine where the pupil stalled the machine at forty feet from the ground, the instructor being unable to correct the error in time; the aeroplane was wrecked and the instructor escaped with superficial wounds of nose and chin, but the pupil sustained a fracture dislocation outward of right ankle; the internal malleolus of right tibia was fractured and also the fibula in two places at its lower and upper thirds. X-rays revealed fracture of the os calcis. A plating operation was carried out, and the pupil returned to flying eight months afterwards and is now a seaplane pilot. In the third case, a propeller type of aeroplane was stalled thirty feet from the ground and was wrecked; the pupil escaped uninjured, but the instructor sustained a lacerated wound of the knee involving the knee-joint. In this case the pupil held on too firmly to the control lever. All dual control machines should be fitted with a mechanical device for throwing out of action quickly the pupil's control of the machine. The author has seen three other crashes under dual control but without injury to either instructor or pupil.

Fatal Accidents

In two years of school work the author has only seen three fatal accidents, occurring in roughly 200 crashes. Four deaths occurred of which three were instantaneous and one after four days. All were due to multiple injuries. The following are short accounts of the cases :—

No. 8. " V " Series. B. (R.F.C.). In a tractor machine on landing, this officer, when 50 feet from the ground, lost his head and put his engine full on without attempting to alter the glide. The aeroplane struck the ground at its gliding angle with engine full on and was completely wrecked. The belt gave way and the pilot was thrown out but death was instantaneous from the multiple injuries received. The latter consisted of : (1) Fracture dislocation of the neck ; (2) fracture of base of skull ; (3) fracture of nose ; (4) subglenoid dislocation of right shoulder and (5) multiple abrasions. This officer's vision was $\frac{6}{8}$ in each eye but he had goggles fitted to correct his vision.

" E " Series.—In a propeller machine one of the elevator wires slipped off its pulley and jammed, causing the aeroplane to nose dive from 200 feet. The instructor and pupil were both crushed into the earth by the engine and death was instantaneous in each case. Multiple injuries occurred as follows : Instructor : (1) Fracture dislocation of the neck ;

(2) fracture of the nose ; (3) fracture of first, second, third, and fourth ribs on left side ; (4) large lacerated wound of left side of chest ; (5) lacerated wound of perineum and scrotum, and (6) multiple abrasions. Pupil : (1) Fracture of base of skull ; (2) fractures of lower jaw and upper jaw of right side, right radius, first metacarpal of right hand, lower third of right femur, lower third of left tibia ; (3) lacerated wounds of face and right eye, and of posterior aspect of right ankle exposing the joint.

"E" series.—In a forced landing with a propeller machine in wooded country, the aeroplane struck a tree and was wrecked. The instructor sustained a sub-glenoid dislocation of the left shoulder, but the pupil received the following injuries : (1) Fracture of base of skull ; (2) fracture of lower third of left femur ; (3) multiple contusions of trunk and limbs. In spite of a decompression operation this officer died on the fourth day.

Regional Injuries

(1) *Multiple Injuries.*—These usually prove fatal and have been referred to under fatal accidents.

(2) *Head and Neck.*—Five cases of head and neck injuries occurred in the "V" series, and three in "E" series. The following are short accounts of the cases :—

(*a*) "V" Series, No. 3. C. (R.N.A.S.), aged 24. On second solo in a tractor machine, stalled on leaving the ground—lost his head and switched off the engine—machine hit the ground at a sharp angle, turned over and was wrecked. The belt gave way and the pilot was thrown out and rendered unconscious for two or three minutes. He sustained a fracture of nose without displacement and showed concussion symptoms for a few hours. Subconjunctival hæmorrhage appeared next day, but otherwise the case did well and left hospital in a fortnight. On examination at that date insomnia, headaches, nightmares, and loss of confidence in flying were present. The fracture had healed but the knee-jerks were increased. Two months' leave was granted away from all connection with aviation. Two months later the same signs and symptoms were present and as his confidence had not returned he gave up aviation—diagnosis "aero-neurosis."

(*b*) "V" Series, No. 2. C. (R.N.A.S.), aged 18. As a pupil receiving instruction, this officer had a crash with his instructor in a tractor machine whilst making landing practice. The aeroplane hit a small tree and overturned. The belt held, but the pupil sustained a fracture of the nose from a broken strut, and also a triangular shaped wound under the right eye and a wound of forehead. In hospital three weeks and then sent on leave.

(*c*) "V" Series, No. 11. C. (R.N.A.S.), aged 21. Made a bad landing on his seventh solo, lost his head and put the engine full on to go up again—saw he was unable to clear the trees so shut off engine and awaited events. The aeroplane was wrecked—the belt held but the pilot's head was jerked forward and struck the nacelle edge—the back of the head also receiving injury from broken strut. Severe contusion of forehead, with abrasions of left side of face, and contusion of right lower posterior parietal region were sustained. There was no surgical shock or cerebral injury. In hospital for fourteen days, then returned to flying, was given instruction on a slow type of machine, but as progress was slow he was transferred to another flying school.

(*d*) "V" Series, No. 14. S. (R.N.A.S.), aged 20. On seventh solo when gliding down to land stalled at 200 feet, side-slipping and wrecking aeroplane. The cause, loss of head, was initiated in the air. The belt gave way and pilot was found stunned amongst the wreckage. Contusions and abrasions of chin and nose and of left hand were sustained. In hospital one week, but this officer was advised to give up flying.

(*e*) " V " Series, No. 13. C. (R.N.A.S.), aged 26. On second solo—engine failure caused a forced landing—when 100 feet from the ground white smoke was emitted from the engine clouding the pilot's vision and obscuring his view of the ground so that he was unable to flatten out. The machine was turned over and wrecked, the belt held but pilot's head was forcibly jerked forward in the turn over. The safety helmet saved scalp injury. Pilot walked into camp from the wreck, a distance of two miles. In hospital five weeks with severe strain of muscles of back and neck. X-rays revealed no fracture, but there was great tenderness over the region of the fourth and fifth cervical vertebræ; the knee-jerks were greatly increased. Was sent on leave for six weeks and had massage to neck daily. He has now returned here to flying; the knee-jerks are still greatly increased but there is no evidence of aero-neurosis.

(*f*) " E " Series. N. (R.N.A.S.). An instructor. Failed to correct a pupil's error in the air; the aeroplane was stalled and side-slipped from 40 feet. Instructor received wounds of nose and chin, but resumed flying a week later.

(*g*) " E " Series. D. (R.N.A.S.). Got off the ground in a tractor machine with one wing down, this increased till the machine side-slipped and was wrecked. The belt held but pilot's head was jerked forward and hit the nacelle edge, he sustained superficial wounds of nose and left cheek. This officer continued to fly in three weeks' time.

(*h*) " E " Series. F. (R.N.A.S.). In a tractor machine climbing on a turn, lost speed, and nose-dived from 100 feet. Pilot got out of the wreckage unassisted but fainted immediately afterwards. He sustained an incised wound from one canthus to the other, exposing nasal bones, which were uninjured, a lacerated wound 1 inch long of left eyebrow and eyelid, and a wound 1 inch long of conjunctiva of left eye. Eyeball at the time apparently uninjured and vision unimpaired. Later, hæmorrhage occurred into the anterior chamber with some retinitis produced by concussion of eyeball. This gradually cleared up and in two months' time vision was $\frac{6}{6}$ in each eye. However, there was a great deal of scarring of the wounds of eyelid and nose. Fibrolysin and radium treatment were carried out.

None of these injuries proved fatal. Five continued flying, and three gave up. In three of these cases the injuries were caused by the head being violently jerked forward and striking the nacelle edge; three were caused by the head striking the ground, and two were caused by broken struts.

(3) *Trunk.*—Five occurred in the "V" series and none in the "E" series:—

(*a*) "V" Series, No. 4. McK. (R.N.A.S.), aged 21. On second solo; had flown very badly for some twenty minutes; in landing failed to flatten out; hit at gliding angle; belt broke and pilot was thrown 20 feet and sustained injury to mid-dorsal spine. The cause was undoubtedly brain fatigue or lethargy. X-rays revealed telescoping of sixth into seventh thoracic vertebræ, and a sub-luxation of sixth right rib at its vertebral end. There was no injury to spinal cord; movements, sensations and reflexes of lower limbs being undisturbed. Surgical shock was very marked and lasted forty-eight hours. Treatment consisted in lying flat in a spinal bed splint for three months. Then a spinal jacket was fitted and patient allowed to move about. At present this case is doing well. There is some general kyphosis in mid-thoracic spine and also some limitation of spinal movement in that region. At present in hospital but will probably be able to fly again.

(*b*) " V " Series, No. 6. A. (R.N.A.S.), aged 18. On fifth solo; got off the ground with one wing down and climbing; when 50 feet up shut off engine through loss of head and side-slipped to the ground. The machine overturned and pilot was crushed, but the belt held. He sustained a large contusion around left eye but no injury to eyeball except some sub-conjunctival hæmorrhage, vision unimpaired. Strain of upper part of abdomen with a belt of hyperæsthesia over epigastrium. Injury to mid-thoracic spine which an X-ray examination proved to be a fracture of the body of seventh thoracic vertebra but with no injury to spinal cord. There was severe surgical shock and a great deal of pain, the shock passed off in forty-eight hours, but the pain continued for two weeks. The area of hyperæsthesia cleared up in five weeks' time. Treatment: flat on back for three months, then a spinal jacket was fitted. It is not likely that this officer will fly again. There is marked kyphosis with a boss over the seventh thoracic spinous process.

It is curious that the above two cases both had fracture of the seventh thoracic vertebra, in both cases of a telescoping nature: in (*a*) the one centrum evenly telescoped into its neighbour, and in (*b*) the one centrum unevenly and partially telescoped into the one below. In both cases also the spinal cord escaped injury.

(*c*) " V " Series, No. 12. B. (R.F.C.), aged 26. On second solo. Pilot remembers commencing the glide to land from 1000 feet but can remember nothing more of the accident. He was physically fit before flying and there is no evidence to show that he fainted in air. It is probable that he suffered from brain fatigue and was unable to think quickly enough to flatten out. Machine was wrecked: belt gave way and pilot was found in the wreckage. Loss of consciousness for five minutes followed by a degree of surgical shock. There was a severe strain of muscles of back, but X-rays revealed no fracture. There was a contusion of lower part of chest and upper part of abdomen due to impact on safety-belt; abrasions of nose, lips and chin. He improved under rest and massage, but is not likely to re-continue flying.

(*d*) "V" Series, No. 2. S. (R.F.C.), aged 26. Whilst instructing a pupil in landing practice, owing to an unavoidable cause overturned and wrecked the machine. He sustained a contusion of right side and back of chest, sprain of right shoulder and abrasion of right knee. There was slight hæmoptysis which ceased after admittance to hospital. Under rest, massage and movement, this case did well and in a few weeks returned to flying duties.

(*e*) "V" Series, No. 1. M. (R.F.C.), aged 27. When getting off on his third solo lost his head and put the machine's nose down to earth with engine full on. The machine overturned and was wrecked. The safety belt held but the impact of the pilot's body caused compression of lower part of chest with severe dyspnœa which lasted for about two hours. No evidence of fracture of ribs, but pilot sustained a severe sprain of left shoulder. Uneventful recovery. Granted three months' leave.

Of these five cases, one is still flying; one gave up; one's subsequent history unknown; and two are in hospital, of which one will probably be unable to take up flying again, and the other may probably re-continue flying.

Injury to the trunk occurs from crushing effect between different parts of the wrecked aeroplane, or between the wreck and the ground. It is curious that more severe injuries did not occur.

It has been noted that sudden chest and upper abdomen compression can occur from the sudden impact on and tightening of the safety-belt around the pilot's body in a bad crash; dyspnœa, rigidity of muscles, tenderness and hyperæsthesia, are amongst the ensuing symptoms from this cause.

(4) *Upper and Lower Extremities.*—Five occurred in the "V" series, and four in the "E" series. Six with injury to the upper extremity, and three to the lower extremity :—

(*a*) "V" Series, No. 5. K. (R.F.C.), aged 18. On his first solo flight saw another machine crash on the ground beneath him. In coming down to land this crash seemed to hypnotise him and he failed to flatten out. Machine turned over and was wrecked. Belt broke and pilot was thrown out a distance of 30 feet. He sustained a backward dislocation of right elbow and an inward dislocation of left foot. Unconscious for five minutes, followed by severe cerebral irritation which lasted for half an hour. The dislocations were easily reduced. This officer returned to flying duty in three months' time.

(*b*) "V" Series, No. 7. N. (R.F.C.), aged 19. On his second solo through error of judgment did not flatten out soon enough. Belt broke and pilot was thrown out. He sustained an impacted fracture of lower end of right radius with broadening of wrist but no antero-posterior displacement. Some pain and rigidity over upper part of abdomen from impact on belt. This case did well under massage and movement and returned to flying six weeks later.

(*c*) "V" Series, No. 9. W. (R.F.C.), aged 19.

This officer had done thirteen hours' flying. On a forced landing came down on ploughed land and did not flatten out soon enough through error of judgment. The machine overturned. Belt broke and pilot was thrown out, sustaining a severe sprain of left elbow. There was considerable pain, swelling, and limitation of movement, but these rapidly disappeared under massage and movement. This officer returned to flying in three weeks' time.

(*d*) " V " Series, No. 10. H. (R.F.C.), aged 27. This officer had done twelve hours' solo flying. On a forced landing on ploughed land failed to flatten out enough through error of judgment. The machine overturned. Belt broke and pilot was thrown out sustaining an injury to right wrist. X-ray examination revealed no fracture. This case did well and returned to flying in three weeks.

(*e*) " V " Series, No. 15. N. (R.F.C.), aged 19. On his seventh solo. Had just got off the ground when he saw two aeroplanes crossing his path. He pulled back the control lever to clear the other machines, but stalled and side-slipped, striking the ground with engine full on. Belt broke and pilot was thrown out clear of the machine which immediately burst into flames and was rapidly destroyed by fire. Pilot was unconscious for five minutes and sustained a fracture of left clavicle at junction of middle and outer thirds. Treatment consisted in allowing the injured arm to hang over the bed with a pillow between shoulders.

(*f*) " E " Series. J. (R.N.A.S.), aged 26. On a cross-country flight had engine failure, had to do a vertical bank low down to avoid some trees; one wing tip hit a tree and aeroplane was badly wrecked. This officer sustained a subglenoid dislocation of left shoulder and a wound 2 inches long underneath lower lip and penetrating the mouth; an incised wound under chin, with severe bruises of both arms and legs. Unconscious for three-quarters of an hour but ultimately did well and returned to flying in six months' time.

(*g*) "E" Series. W. (R.N.A.S.), aged 24. This pupil whilst under instruction on a dual control propeller machine stalled through an error in judgment and machine side-slipped from 40 feet and was wrecked. He sustained a fracture dislocation outward of right ankle; the internal malleolus of tibia, and the upper and lower thirds of fibula were fractured. A plating operation was performed a month later. This officer returned to duty in six months and is now a seaplane pilot. Ultimately good movement was obtained in the ankle-joint, although a weakness occurred after prolonged walking or exercise.

(*h*) "E" Series. L. (R.N.A.S.), aged 18. In a propeller machine on first solo overbanked on his first turn, the machine stalled and side-slipped 200 feet to earth. Pilot was found in the wreckage and sustained a simple fracture of middle third of right femur with 2 inches of shortening; there were abrasions of left leg, right forearm, forehead and chin. Superficial wounds of right eyebrow and bridge of nose. Surgical shock was severe. The fracture was set and retained in position by means of a traction splint, and a good result was obtained. This officer returned to flying in eight months' time.

(*i*) "E" Series. E. (R.N.A.S.). An instructor, giving dual control instruction to a pupil, had just left the ground when the control lever jammed or was held too tightly by the pupil, causing the machine to stall when 40 feet from the ground and side-slipped to earth. The pupil escaped unhurt, but the instructor sustained a lacerated wound 5 inches long over the right knee, exposing the patella and penetrating knee-joint. The belt held but the front of the nacelle was crushed in; impact with the instrument board had caused the wound. The case did well and returned to flying within five months.

Of these cases eight have returned to flying duties, and one is still under treatment. The usual cause of injuries to the upper extremities in crashes is due to the pilot being thrown out. Usually a hand is thrown out as a safeguard and injury to the upper arm ensues. In six of these cases the safety belt gave way and the pilots were thrown out, all sustaining injury to the arm; in the three other cases the pilots were not thrown out but all sustained injury to the leg. It is safer not to drag the injured aviator out of the wreck but rather to cut the wreckage away from him. In three of the cases engine failure and subsequent forced landing was a contributory cause of the accidents.

The author trusts that the scheme which he has outlined for the classification of aeroplane accidents will be taken up and improved by other medical officers attached to air stations. It is only by having a large number of reports that reliable statistics can be obtained.

There is no doubt that much can be done to prevent loss of life in flying accidents, and also to minimise the severity of injuries sustained both in school and active service flying. The means of saving life is by parachute descent; but it is essential that the parachute be carried so arranged that when required it can be liberated from the aeroplane without fear of entanglement, and also that it will open fairly quickly. Lately on the western front several instances have been reported of successful parachute descents by enemy aviators from aeroplanes either set on fire in the air or so damaged by gun fire as to be uncontrollable.

By some device during the aeroplane's descent the parachute is liberated and forcibly draws the attached aviator from his seat clear of the damaged and falling aeroplane. The use of the parachute is more essential for war flying than for school flying. In the former, machines are more often damaged in the air, and there may be both time and height to escape by parachute. While in the latter, most accidents occur on landing or leaving the ground, and the causes are initiated a few seconds before so that there would neither be time nor height to escape by parachute. Although it is quite possible a proportion of school accidents might occur in the air, such as fire or breakage, etc., and that there would be both time and height to escape by parachute. Probably the difficulties of attachment and design may be overcome, so that in the future all aeroplanes, whether employed for tuition, commerce or war, will carry parachutes.

In quite a large proportion of aeroplane accidents the occupants receive injuries to the face, due to the impact throwing their heads forward. Thus the face may strike the edge of cockpit or nacelle, gun mounting or instrument board, resulting in fracture of skull, nose, upper or lower jaw, or else severe wounds of face with subsequent disfigurement. Death may ensue from such injuries, or they may disable the aviator for some considerable time. A fractured lower jaw means at least eight months before return to flying duties. The eyes fortunately usually escape injury, as apart from natural bony protection they are usually closed in by non-splintering material such as Triplex. The edges of the cockpit are usually padded in most modern machines and gun mountings are placed laterally. There is no reason why a padded face piece should not be added to the safety helmet.

There is a natural disposition on the part of most pilots to feel they want to be free and unimpeded whilst flying. In the old days many used to scoff at goggles, safety helmets or belts; but at present most aviators realise the value of these things, and

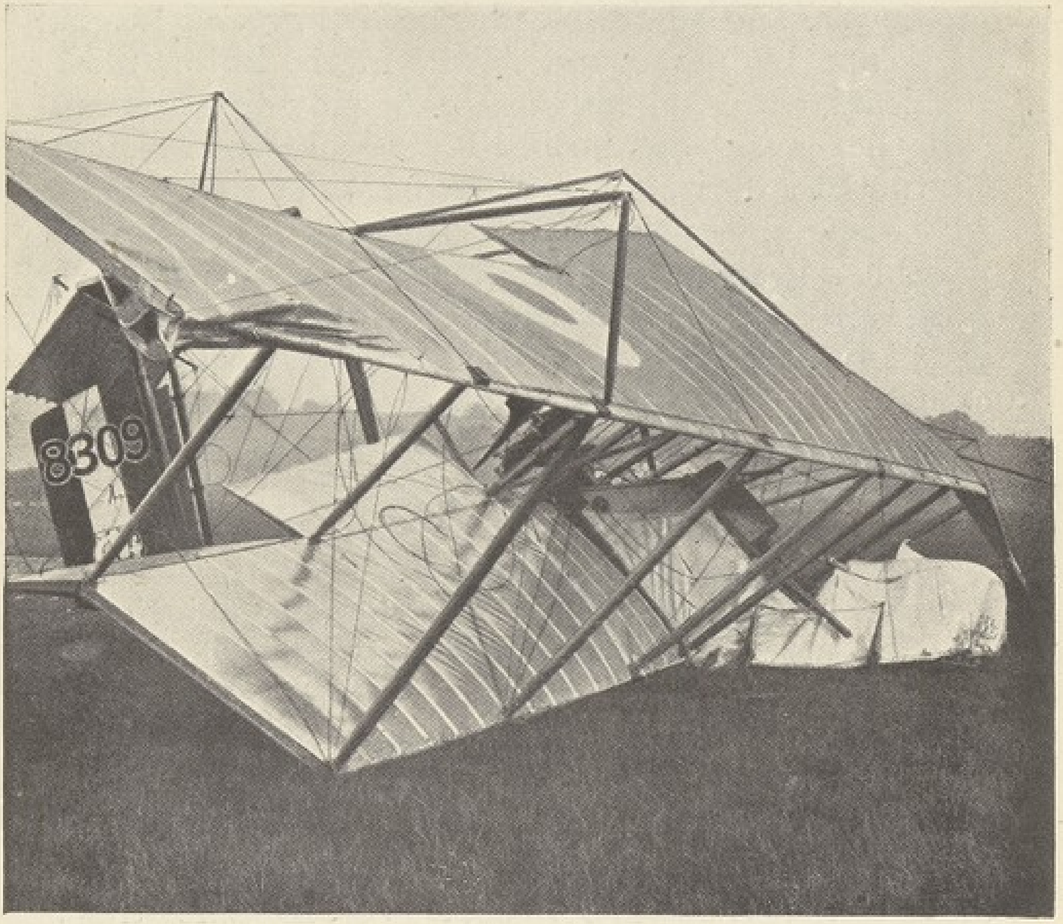


Fig. 11.—Showing the aeroplane's nose striking the ground first, and how the aviator's feet and legs are likely to be injured.

are more inclined to welcome the investigations of medical officers concerning aeroplane crashes and adopt their suggestions of apparatus and methods for preventing or minimising bodily injuries. As the forepart of the aeroplane usually strikes the ground first, it follows that should the occupant not

PLATE 19A.—A fatal crash.

PLATE 19B.—Result of a collision in the air.

Plate 20.—A crash due to a forced landing.

be thrown out, his feet and lower legs are most likely to sustain injury. (Fig. 11.) Fractures of both bones of leg and those involving ankle joint are very common. The author would suggest that double light steel supports fitted in the boots and carried to just below the knee, as used in orthopædic practice, would prevent or minimise the severity of fractures to feet and legs that might occur in a crash. This apparatus would not interfere in any way with rudder bar movements. In aerial warfare, and particularly in low bombing or ground "strafing," there is a need for some form of protective armour to save the pilot from bullet wounds.

CHAPTER VII

The Surgery of Aviation

The question of the preparation of the candidate by surgical procedures to fit him for aviation duties may or may not arise in peace time, but during war, when man power may be a difficult problem to solve, it is certainly part of the Air Force surgeon's duties to carry out such measures.

Surgical work in connection with aviation in general differs but little from that found in military and civil life. The difference is mainly one of degree in that one is mostly called upon to deal with the results of high velocity accidents associated with falls at varying angles, and from varying heights. These accidents are not common in civil life, except in such occupations as those of mason, steeplejack, window-cleaner, shipbuilder, etc. Again, in the latter, the recipient of the injuries usually falls by himself, unaccompanied by any protective material. On the other hand, the aviator falls with and in his aeroplane, and therefore a good deal of the shock of impact is taken up by the woodwork of the machine. This may explain the luck that ofttimes befalls the occupants in sometimes the most appalling crashes.

Certain surgical conditions are found in aviation, the result of thermal causes. Of these the most severe result from the outbreak of fire, occurring either in mid-air or on crashing. As the whole aeroplane is reduced to a mere framework in the course of a few minutes, unless the aviator is lucky enough to be thrown out or extricate himself quickly, the resulting burns are often severe if not fatal. The cold at high altitudes is extreme, and aided by the rapid transit through the air, is apt to induce easily frostbite. This may occur in spite of all precautions. Immersion effects as in seaplane accidents may give rise to conditions allied to trench feet.

The projectile wounds received in war flying are much the same as those found in ordinary military surgery, except that added to them and complicating them may be other injuries should the aeroplane be decontrolled or so badly damaged that, on landing, a crash is inevitable. Surgical work in connection with aviation may, therefore, be conveniently arranged in three departments, as follows :—

I. *The Surgery of Preparation for Aviation.*
II. *The Surgery of Aviation in General.*
III. *The Surgery of War Aviation.*

I. *In the Surgery of Preparation for Aviation* we have to deal with by surgical means—operative or non-operative—the various defects, the cure of which will render fit an individual for flying duties.

(*a*) Dental treatment is of special importance before commencing flying. It is a well-known fact that the cold experienced at altitudes combined with the rush of air soon lights up any dental sepsis. Therefore the aviator should commence dentally clean. All cases are carefully examined for pyorrhoea and appropriate treatment carried out.

(*b*) Throat and nose conditions are of equal importance ; septic lacunar tonsils are removed by enucleation ; such foci are apt to be raised into activity by flying. At altitudes where the oxygen tension is lowered, most aviators become mouth-breathers. A dryness occurs, and this encourages the growth of sepsis. To give as free an airway as possible any adenoids present should be removed.

For the same reason any deflection of the nasal septum or hypertrophy of the turbinates causing nasal obstruction should be corrected by performing submucous resection and partial turbinectomy. There is reason to believe that cases of enlarged turbinates and deflected septa are more liable to suffer from headaches on reaching high altitudes. A colleague of mine, Capt. Guthrie, R.A.F., is keeping records of such cases, before and after operation, with regard to this question.

It is essential that there should be no obstruction of the airway to the middle ear and accessory sinuses. Otherwise with the sudden changes of height in flying and the consequent differences in atmospheric pressure, there are liable to appear such symptoms as earache, headache, and vertigo.

(*c*) General defects, such as varicose veins, hernia, varicocele, etc., that would form an inconvenience in flying, should be remedied by operative measures.

(*d*) Ophthalmic work may be necessary as in correcting visual defects. Much can also be done to remedy heterophoria (concealed squint) by ordering and supervising exercises for the ocular muscles in such cases.

(*e*) Orthopaedic Surgery plays its part in the correction of deformities which interfere with the movements of upper or lower limbs, and would otherwise prevent an individual from taking up flying. As quite a number nowadays fly, having only one lower limb, it is essential that the surgeon should advise in each case. He should also see that the artificial limb is light, strong and reliable in every way. Recently the author passed fit for flying an officer who had had both legs amputated below the knee, but is so fitted with artificial limbs that he can easily and with safety perform all rudder bar movements.

II. *The surgery of aviation in general* is concerned mostly with the results of high velocity accidents. These consist of aeroplane accidents and propeller accidents. But it is concerned also with conditions resulting from thermal causes, such as frostbite produced by the cold of high altitude flying; and "waterbite" or a condition allied to trench feet, and produced by immersion in seaplane accidents.

Naturally from such accidents the Air Force surgeon is called upon to deal mostly with fractures, dislocations, lacerated wounds, intracranial injuries, frostbites, and burns.

Much has already been discussed on the results of aeroplane accidents in the preceding chapter, but it is well to keep in mind the following factors which determine the type and severity of the injuries received.

(*a*) The height of the fall—naturally the greater this is the more severe are the resulting injuries.

(*b*) The angle of the fall, upon which so much depends. In vertical dives the injuries are more severe and often fatal. In falls more approaching the gliding angle the less severe are the injuries.

(*c*) Whether with engine on or off. With the engine on the injuries are much more severe, and there is more chance of the outbreak of fire.

(*d*) The type of aeroplane. In propeller machines or "pushers" (engine behind) the injuries received are much more severe and more likely to be fatal than in tractor machines (engine in front).

(*e*) The position of the pilot's seat. In tractors the nearer this is to the engine the more likely is he to be injured.

(*f*) Whether the pilot is thrown out or pinned in the wreckage. If thrown out the injuries are usually of the upper limbs or head. If pinned in the wreckage the lower limbs or face usually suffer.

(*g*) If the pilot falls out of the aeroplane, gravity alone acts, and the injuries are often severe or fatal.

(*h*) Much depends on how the injured pilot is extricated from the wreckage. A simple fracture may be converted into a compound one by trying to extricate the pilot from the wreckage instead of cutting the latter away from him.

First aid falls to the lot of the aerodrome medical officer, and should be carried out as described in the preceding chapter.

Surgical shock resulting from aeroplane accidents is often severe and prolonged. It may tax all the surgeon's ingenuity to combat this.

Concussion of more or less duration occurs in most crashes. During this period a great deal can be done in accurately diagnosing fractures or reducing dislocations before much swelling arises.

Of the various fractures all varieties are found. Fractures of the skull are usually fatal. Fractures of the upper or lower jaw or nose are very common in aeroplane crashes. This is due to the fact that the impact of the crash causes the pilot's face to be jerked violently forward in contact with the cock-pit edge, gun-mounting or instrument board.

Fractures of the upper limbs are not common, and are mostly found in those who have been thrown out clear of the wreckage.

Fractures of the lower limbs are very common. The femur often gives way by indirect violence, the tibia usually by direct violence. At the Central R.A.F. hospital we have had excellent anatomical and functional results after the plating of simple fractures carried out under Lane's technique. (Fig. 12.)

The feet and ankles, being the foremost part of the pilot to take the shock and the least easily drawn out of danger, are the regions in which fractures most often occur. The author has found that the bone most often affected is the astragalus. Fracture of the astragalus is so comparatively rare in civil life that one might say this form of injury is peculiar to aviation accidents. So much so that the author has ventured to name it "aviator's astragalus." Within the past year he has personally seen or had under his care thirteen cases, and has notes of other five cases, making eighteen in all.

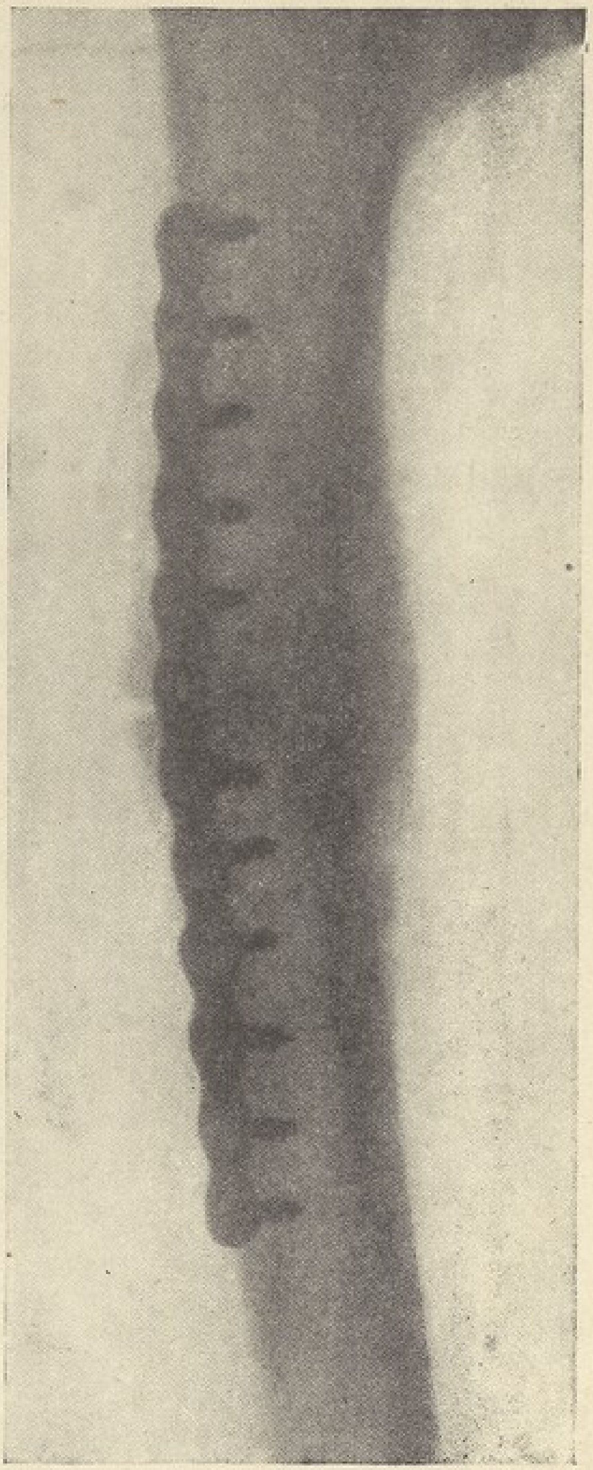


FIG. 12.—Plating of right femur. Perfect anatomical and functional result.

As the fracture is so common and peculiar to aviation, it is of interest to go into the matter in some detail. The comparative rarity of fractures of the astragalus in civil life is borne out by the fact that at general hospitals only one or two cases are seen in the course of a year. There is also scanty reference on the subject in text-books on fractures. Falls from heights on to the feet are fairly common in certain civil occupations, but in these cases the os calcis is the bone that usually sustains fracture. In the latter the patient usually falls by himself, and the impact is taken on the heels. The force is exerted in a vertical direction through the lower limbs. If the material landed on is fairly solid there is no give and the force is distributed through the nearest bone, the os calcis, resulting in its fracture.

On the other hand the aviator usually falls within his machine, and strikes the ground at an angle. The sole of the foot rests on the rudder bar, but with the impact the latter gets pressed into the instep just in front of the heel. Thus the force is exerted through the lower limbs at an angle, and the astragalus takes most of it, and becomes the seat of fracture.

The anterior edge of the tibia acts as a cutting wedge on the astragalus. There is also a certain amount of torsion exerted on the ankle joint due to the momentum carrying the pilot forward, sometimes out of the machine. Again, the machine may not strike accurately nose on, and thus one side gets more crushing effect than the other. The engine may be driven back more on one side than the other. Often one side alone of the rudder bar is bent backwards and only one foot is injured. Before the actual fracture occurs the foot may be in a position of acute dorsi-flexion, plantar-flexion or may be inverted. The author has investigated the majority of these cases with regard to details of the crash, examination of wreckage, etc., and in order to throw some light on the mechanism producing the fracture. In many cases the facts are obscured by the pilot having been rendered unconscious at the time of occurrence. Bilateral fracture may occur.

Varieties of Fracture of Astragalus.

I. Compression and Crushing Types.

The whole astragalus may be simply compressed without actual fracture—a skiagram shows the bone somewhat flattened and elongated in a fore and aft direction. This fact is revealed by comparison with a skiagram of the normal foot. There is no clinical deformity, but there is tenderness on pressure. There may be some limitation of range of ankle joint movements. The most severe types show a complete crushing of the body of astragalus, with pain on pressure and limitation of movement.

II. Fractures of the Neck of the Astragalus.

In these cases the anterior articulating edge of the tibia acts as a wedge, cutting or crushing the neck of the astragalus. Two subtypes are found. (*a*) The neck may be simply fissured with no displacement or deformity. This is revealed by skiagram, and a localised area tender on pressure. (*b*) The neck may be split through and the head and neck of the bone displaced upwards or inwards. In some cases impaction is found. A varus deformity may result.

III. Fractures of the Body of the Astragalus.

The body may be simply fissured without displacement, or it may be split and rotated in the mortice. On the other hand the body may be divided in two, and the following displacements occur. (*a*) The posterior half of the body may be dislocated backwards out of the ankle joint and lie in front of the Tendo-Achilles. Here it can be felt, and there is limitation of ankle joint movements, especially dorsi-flexion. Danger arises from the displaced fragment pressing on the posterior tibial vessels and nerve. (*b*) The anterior half of the body with the head and neck may be displaced forwards and inwards, causing a marked varus deformity, or it may be displaced outwards causing valgus.

IV. The Posterior Process may be broken off. Radiographic comparison must be made with the other foot, as in about 10 per cent. in adult life the posterior process may be found as a separate bone, the os trigonum.

V. Complicated Fractures of the Astragalus.

All varieties may be found—the fibula may be fractured at its lower end, or the internal malleolus of the tibia carried away. The lower end of tibia may be separated from its lateral attachment to the lower end of fibula, and the fractured astragalus may be found separating and making its way upwards between the two bones. Owing to the rupture of ligaments the fractured bone may be dislocated either from the ankle joint or subastragaloid, resulting in all types of dislocation of ankle or foot as described in text-books. The fractured astragalus may be shot completely out of the ankle joint, through the skin, and found lying by itself. (Plates 21 to 24 inclusive.)

Signs and Symptoms.

Unless one is on the spot at the time of the crash it is impossible to make an accurate clinical diagnosis, owing to the very rapid onset of swelling and oedema of foot and ankle. Now that attention has been called to the frequency of this fracture in flying accidents, it is hoped the examiner will keep the astragalus more in mind. Even marked displacement may be obscured by the swelling. If the injured aviator is unconscious more

PLATE 21A.—Fracture through neck of astragalus.

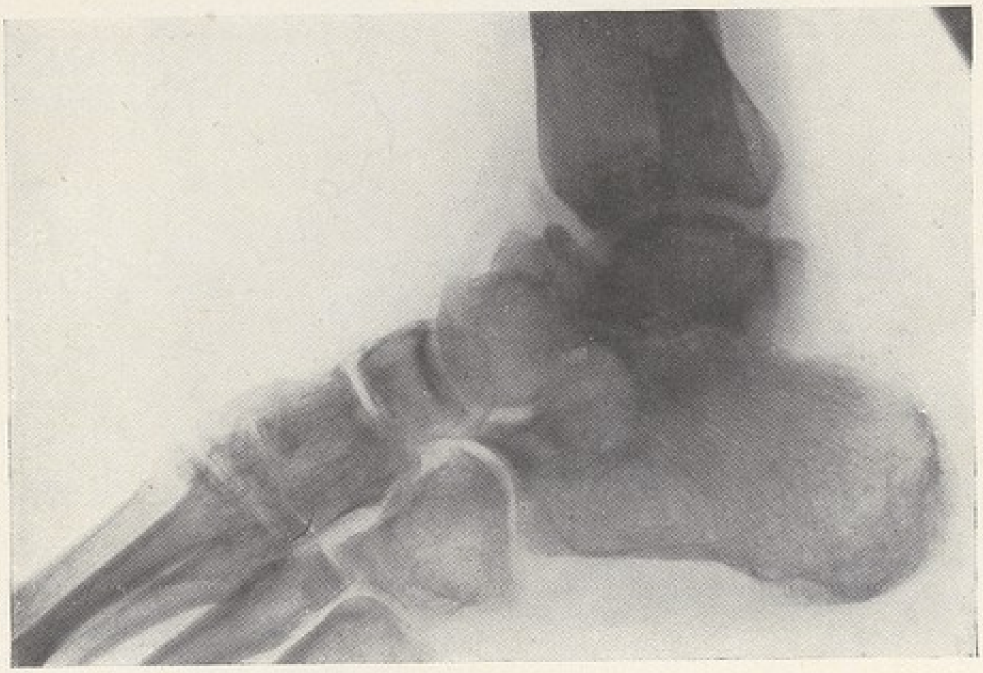


PLATE 21B.—Fracture of astragalus. Compression of body and fracture through neck.

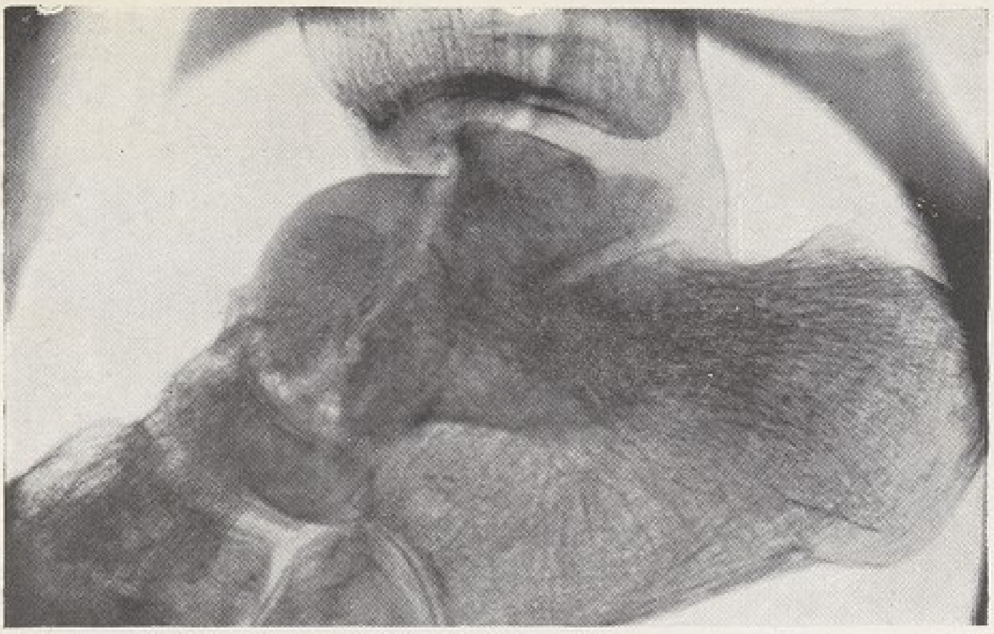


PLATE 22A.—Fracture of body of astragalus.

PLATE 22B.—Fracture of body of astragalus with dislocation of posterior fragment.

PLATE 23.—Fracture of body of astragalus, with dislocation forward and outward of posterior fragment.

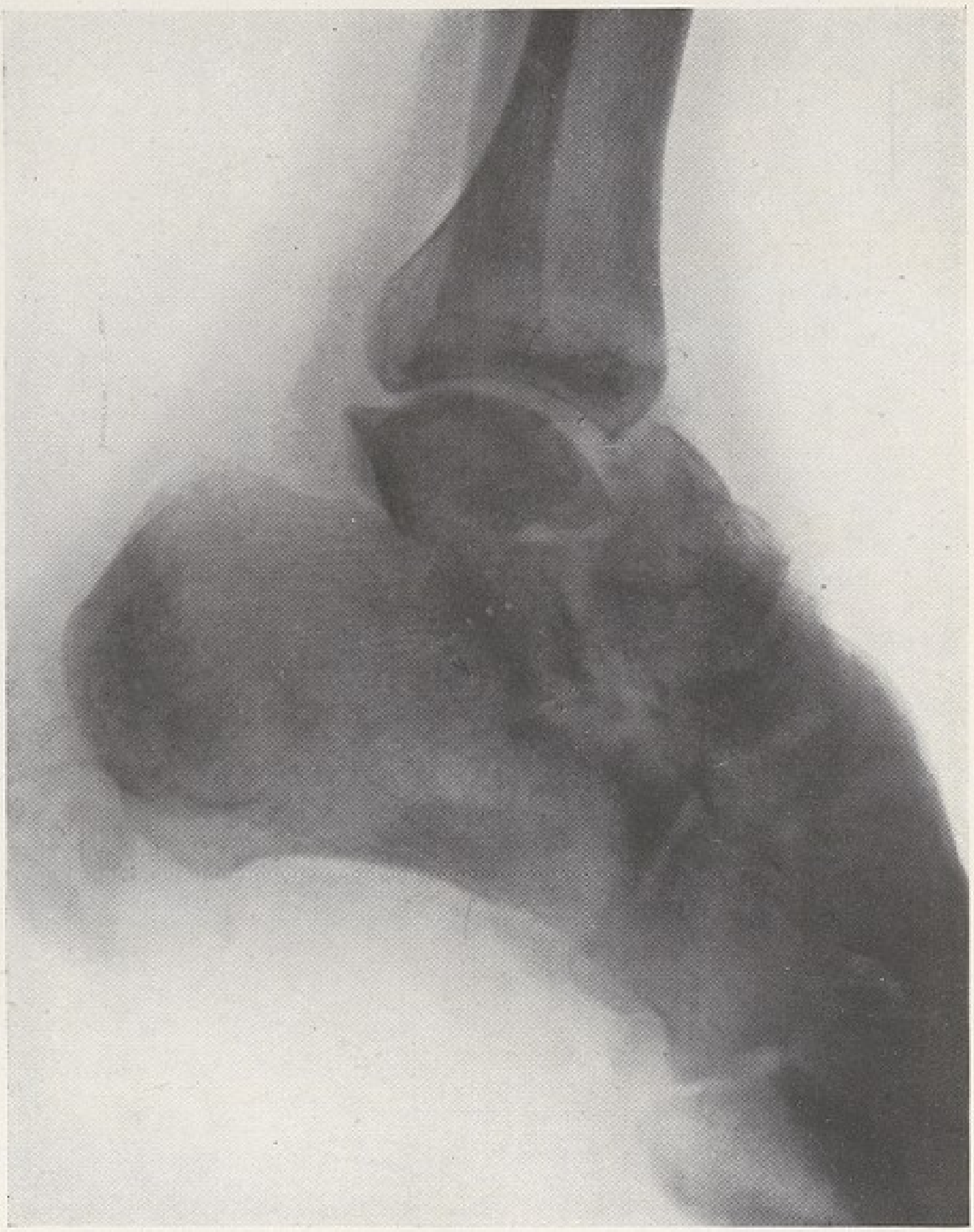


PLATE 24.—Fracture of body of astragalus, with dislocation forward and inward of anterior fragment.

accurate clinical diagnosis can be made. Reliance is placed chiefly on good skiagrams, and the author insists that the normal foot should also be skiagraphed. Stereoscopic views are essential.

A study of the uninjured astragalus reveals great variations in length, breadth, size, shape of articular surfaces, and angle of neck to body. Seymour Sewell, in the *Journal of Anatomy and Physiology*, April, 1904, gives an exhaustive account of a study of over 1000 specimens of the normal astragalus. The bone is an extremely important one, forming as it does the keystone to the arch of the foot. It is of the nature of a block and pulley, and many tendons pass over it. It takes part in two movements, a hinge movement in the mortice of the ankle joint, and a rotary movement with the scaphoid.

Treatment.

The first-aid treatment consists in preventing the injured aviator from attempting to walk or stand. The boot has to be quickly but gently removed; and may have to be cut away. If the injured person is unconscious an attempt must be made at accurate diagnosis and perhaps a reduction attempted in some cases. Lint soaked in strong lead lotion should be loosely applied, and the foot placed gently in a right angled tin shoe and elevated. Skiagrams should be taken as soon as possible, as the subsequent treatment will depend on what is revealed by them. Morphine is usually required to allay pain. As soon as possible the form of light massage, as advocated by the late Dr. Lucas-Championierre, should be carried out.

In the types of fracture where there is little or no displacement, compression types, fissured fractures of neck or body, or fractures of posterior process, the light massage should be followed by strapping of the foot and ankle as carried out by the late Dr. Wharton Hood. The foot is placed in a tin shoe with quadrant, and the whole elevated. The massage, which becomes firmer daily, is applied over the strapping, and as the latter becomes loose, it is not removed but fresh strapping applied over it. In a week's time the tin shoe is taken off during the day, but must be reapplied at night, and passive and active movements at the ankle are encouraged. The patient is allowed up on crutches at the end of a fortnight, but should not be allowed to bear weight on the injured foot for at least sixty days since the occurrence of the fracture. These cases should all do well, and all disability forgotten in six to nine months.

Where there is marked displacement and deformity resulting, open operation should be performed. Accurate anatomical reposition is impossible without open operation. The surgeon may have to choose one of three operations, open reposition of the fragments, partial astragalectomy, or total astragalectomy. The choice will depend on the type of case, and whether it is a recent fracture or one of old standing.

The route for exposing the fractured bone will depend on the nature of the displacement, and the resulting deformity. The external incision over the lower end of the fibula, curving forward a little at its lower end, gives a good exposure either for reposition or astragalectomy. The internal incision is of value in some cases. In very complicated cases of old standing both routes may have to be adopted. If the posterior half of the body is dislocated backwards an incision is made over it, parallel to the Tendo-Achilles. (Fig. 13.) The technique is carried out as advocated by Lane, except that sutures are employed instead of skin clips. Immediate operation may have to be done to relieve the pressure of a fragment on the vessels and nerves around the ankle joint, but it is better if possible to postpone the operation for at least a week. This is done to allow the swelling to go down and also that blebs and excoriations may be treated. Careful attention must be given to the preparation of the foot and leg for operation. Iodine is applied each day, the leg is shaved, and special attention is

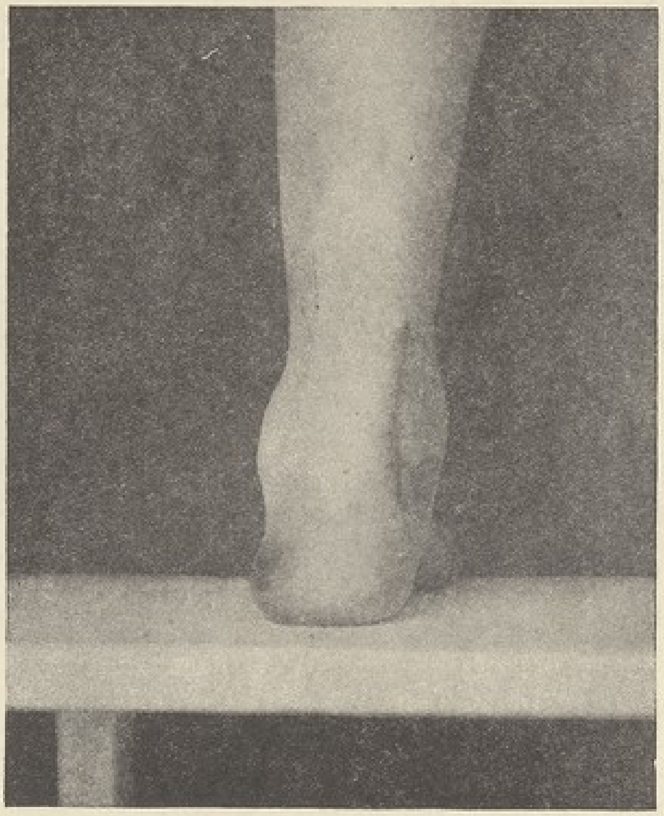


Fig. 13.—Showing incision parallel to Tendo-Achilles for removal of posterior fragment.

paid to the intervals between the toes. No tourniquet is used at the operation, and no vessels are ligated if possible.

A free exposure is made of the fractured bone by one of the routes described above. There should be little haemorrhage and no important structures are divided. An assistant can give great help by manipulating the foot as required. Lane's levers are useful in manipulating fragments. In attempting reposition great difficulty may be encountered, especially if it is an old standing case. The displaced portion is manipulated into position, and an attempt made at impaction. This operation is only of value in recent cases.

In partial astragalectomy it may be that the posterior half of the bone has to be removed, or it may be the head and neck. The latter if displaced often forms a bony block to dorsi-flexion, and often produces a varus deformity. Partial astragalectomy is performed to relieve these conditions. After the operation the foot and leg are put in plaster at a right angle. The plaster is removed in ten to fourteen days, the stitches are removed, and massage, passive and active movements, commenced. The foot is retained at night in a tin shoe with quadrant and the foot gradually screwed up each day beyond the right angle. The patient is allowed up on crutches three weeks after the operation, but no weight is to be borne on the injured foot for at least sixty days.

In some cases, especially where the whole bone is involved, or if there s much rotation of the fragments, or of old standing, it is better to perform total astragalectomy. If the tibial mortice is not injured much, then a very good result is to be expected, both as regards range of movement and weight bearing capacity. The same after-treatment is employed as for partial astragalectomy. (Fig. 14.)

It may be necessary to aid the position of the foot when walking is commenced by ordering a surgical boot with light double steel supports to below knee and with valgus and varus T straps. An upraising toe-spring is added if necessary. A valgus or varus wedge is applied to the boot as required. Fracture of the astragalus is a serious crippling injury, and history and past experiences show that the results in many cases are unsatisfactory. Each case must be treated on its merits.

The following is a short account of the cases of fracture of the astragalus as the result of flying accidents either under the care of, or investigated by the author :—

Case 1.—Lt. McL., age 22, tractor machine, crashed 6/1/18, belt held, not thrown out, engine crushed into cock-

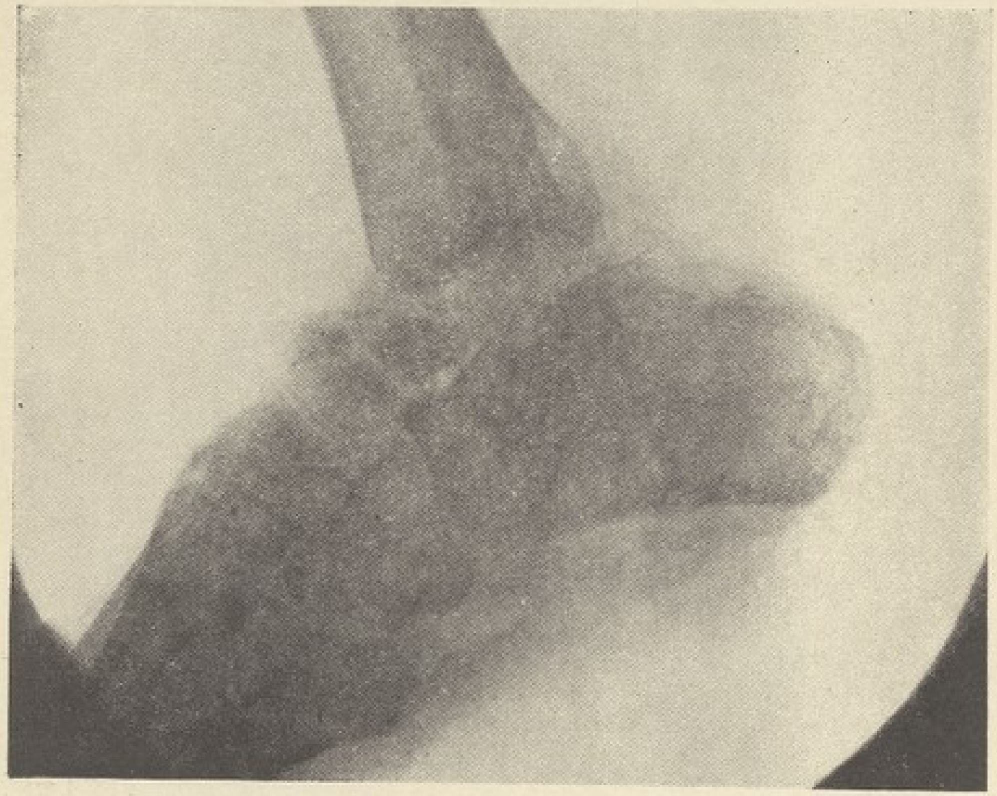


Fig. 14.—Skiagram after total astragalectomy.

pit injuring right foot. Fissured fracture of neck of astragalus. Pain, swelling, could not bear weight or dorsiflex beyond right angle. Tin shoe with quadrant, massage, passive and active movements. Good anatomical and functional result. Walking well in three months from injury.

Case 2.—Lt. G., age 22, tractor machine, crashed 16/2/18, pinned in wreckage, unconscious, bilateral injury of feet. Fracture of neck of right astragalus, compression of left astragalus with fracture of posterior process. Considerable swelling, limitation of ankle movements, valgus deformity.

Treatment as in Case 1, valgus pads and straps added, also given radiant heat. In three months valgus overcome, walks well, but feet easily tired.

CASE 3.—Lt. B., age 24, shot down 26/12/17. Unconscious 14 days, severe multiple injuries, including fracture of left astragalus. Marked varus deformity with little movement at ankle. Fracture through body of astragalus with anterior half, head and neck displaced outwards and lying in front of external malleolus. Partial astragalectomy, 19/3/18. Varus considerably reduced and fair movement at ankle, wears tin shoe at night and short varus walking apparatus during day.

CASE 4.—Lt. B., age 22, tractor machine, crashed 29/2/17. Unconscious, fracture of upper jaw and left astragalus. Fracture through body just posterior to neck. Latter displaced outwards, causing varus deformity with inability to dorsiflex, bony block. Admitted 3/3/18. Forcible manipulation, and plaster, later tin shoe and varus boot and walking apparatus. To return for partial astragalectomy.

CASE 5.—P.F.O. McD., age 20, tractor machine, crashed 7/4/18, thrown out, great swelling around ankle. Fracture through body of left astragalus with dislocation backwards of posterior half. Foot in equinus, cannot dorsiflex. Posterior fragment removed 25/5/18, good anatomical result, fair range at ankle, walks with a limp four months after injury.

CASE 6.—Lt. R., age 34, observer, tractor machine, thrown out, fissured fracture of neck of right astragalus, tip of internal malleolus fractured, no deformity but stiffness of ankle. Tin shoe with quadrant, massage and movements, good result in two months from injury.

CASE 7.—Lt. C., age 25, tractor machine, crashed 5/6/18, partial nose-dive, rudder bar twisted back injuring right foot, fracture through body of astragalus, rotation of anterior fragment with displacement forward causing talipes equinovarus, cannot dorsiflex to right angle. Total astragalectomy 10/9/18, not allowed to walk for 60 days, good anatomical and functional result. (Plates 25 and 26.)

CASE 8.—Lt. M., aged —, decontrolled and crashed 12/8/17. Pinned in wreckage, unconscious, fracture through neck of right astragalus, also tip of external malleolus. Two manipulations, massage, electrical treatment and movements, good functional result but requires a valgus wedge in right boot.

CASE 9.—Lt. S., age 25, tractor machine, crashed 26/1/18. Unconscious, fracture of right astragalus through body with

PLATE 25.—Clinical deformity of Talipes Equino-Varus due to fracture of body of right astragalus (Case 7).

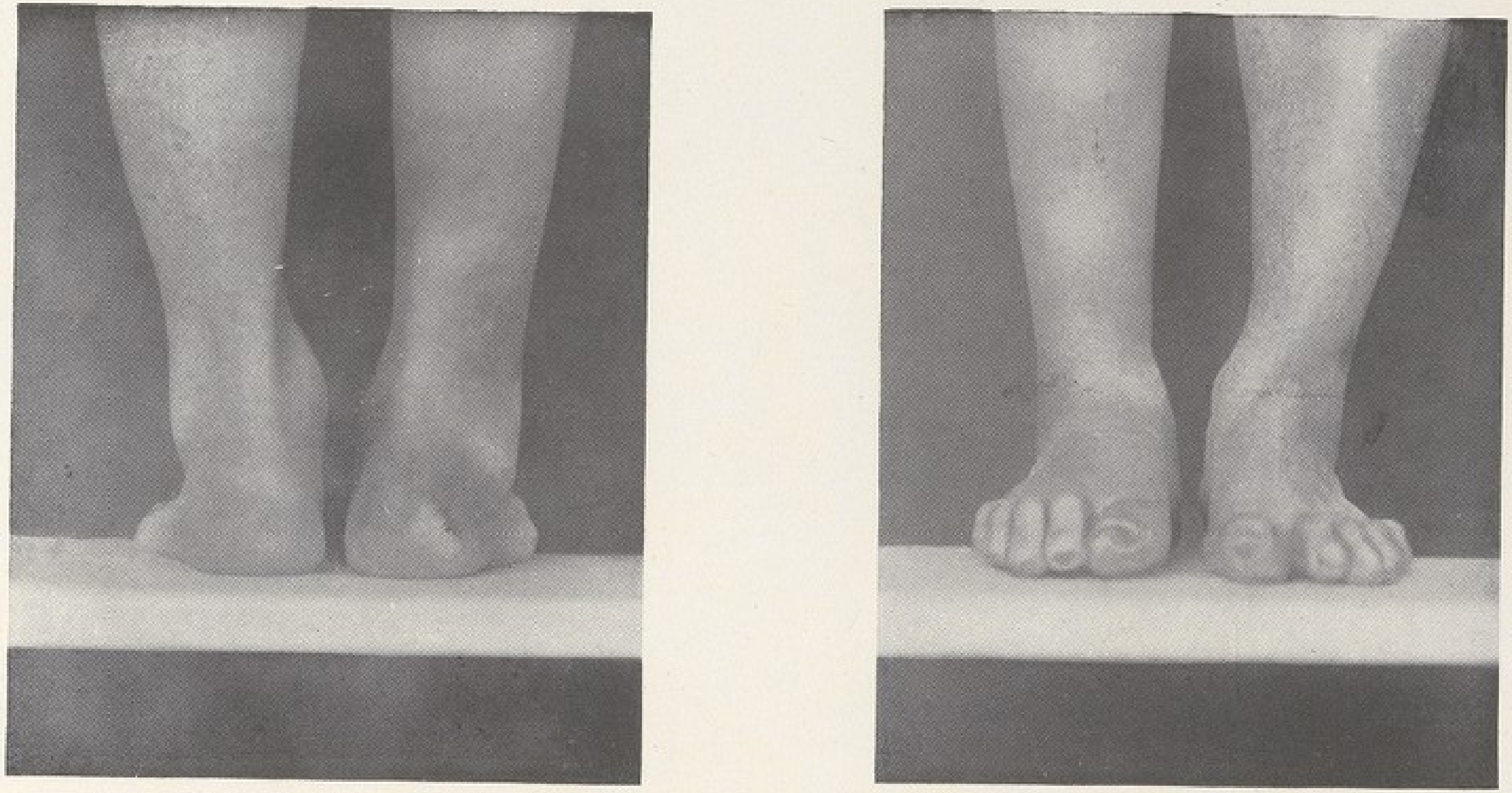


Plate 26.—Result after operation of total astragalectomy, right foot (Case 7).

dislocation of fragment forwards and outwards in front of external malleolus. Foot in varus with limited movement at ankle, partial astragalectomy on 4/4/18. Four months later good anatomical result, fair range at ankle but walks with limp.

Case 10.—Lt. M., age 27, observer, tractor machine, crashed 6/12/16. Unconscious, pilot killed, pinned in wreckage, fracture lower third left fibula, dislocation inferior tibio-fibular joint, fracture of upper surface of body of astragalus. Proposed operation: exposure of ankle joint, freshen inferior tibio-fibular joint to obtain bony union and aid this by inserting a bone peg through lower ends of tibia and fibula, total astragalectomy depending on condition of that bone.

Case 11.—Mr. K., age —, pusher machine, crashed 23/2/14. Not thrown out, unconscious, fracture of right femur, fracture of right astragalus, displacement of anterior portion outwards in front of external malleolus, deformity is valgus. Now wears a valgus walking apparatus, can walk three miles, good range at ankle.

Case 12.—Capt. B. I., age 24, shot down, multiple injuries, unconscious, fracture of left astragalus, crushing of body, deformity varus, excision of posterior half of astragalus. Wears a varus wedge, and T strap, movement at ankle, to right angle only, bony block.

Case 13.—Maj. A., age —, crashed, fissured fracture of neck of left astragalus. Good anatomical and functional result.

Mr. F. F. Burghard has kindly furnished the author with the notes of this case, No. 14, which was under his care.

Case 14.—Lt. T., age 19, crashed 28/5/16, fracture of neck of right astragalus, head and neck being displaced forwards, upwards and inwards, fracture of internal malleolus and varus deformity. Operation on fifth day, inner route, open reposition of head and neck of astragalus, internal malleolus plated. X-Ray shows perfect position, good anatomical and functional result. Killed in France early 1917.

The author is indebted to Mr. Paul Bernard Roth for notes of cases 15 and 16, and also for asking him to see Case 16.

Case 15.—Lt. G., age 25, crashed on 4/2/15, sustained fracture of right ulna, left astragalus and internal malleolus, fracture was through the body of the astragalus and the posterior fragment was dislocated backwards and lying in front of Tendo-Achilles. Posterior fragment removed by Mr. English ten days later; seen by Mr. Roth on the 15/7/15, deformity talipes equinus due to bony block, and could only walk 300 yards. Remainder of astragalus removed by Mr. Roth; good result. In 1917 was doing full duty, playing tennis, etc., killed later.

Case 16.—Air-Mech. F., age 20, observer, jumped from an aeroplane just before the crash. Compression fracture of body of left astragalus, with fissures radiating from inferior aspect, developed a neurosis, functional equinus, atrophy of muscles of leg and hyperalgesia over ankle, subcutaneous lengthening of Tendo-Achilles by Mr. Roth; good result.

The author has to thank Col. Openshaw for allowing him to include this case, No. 17, in the present series.

Case 17.—Lt. , crashed summer, 1918, bilateral fracture of astragalus, immediate operation by Col. Openshaw, who removed a large dislocated fragment pressing on posterior tibial nerve and vessels. The other foot did not require operation.

Case 18.—Name unknown, reported to me by Capt. Denny, U.S.M.R., nose dive, crash, killed outright. Among other injuries one astragalus was fractured and shot clean through the skin and free from the body.

The only other fracture of peculiar interest in the surgery of aviation is telescoping fracture of the spine without involvement of the spinal cord. The author has now seen five such cases. They result from severe aeroplane crashes. There may be other complicating injuries and the spinal condition at first may be overlooked. The pain is severe, and lasts for some time. Deformity of the spine may or may not be present. Surgical shock is extreme. The severe and localised pain should lead one to suspect this type of injury. A good skiagram will reveal the condition. The lower thoracic spine is the part usually involved. The centrum of one vertebra is found telescoped into the one below it. If this occurs evenly there is little resulting deformity. If the telescoping is uneven, and one half of the centrum is driven down laterally more than the other then a

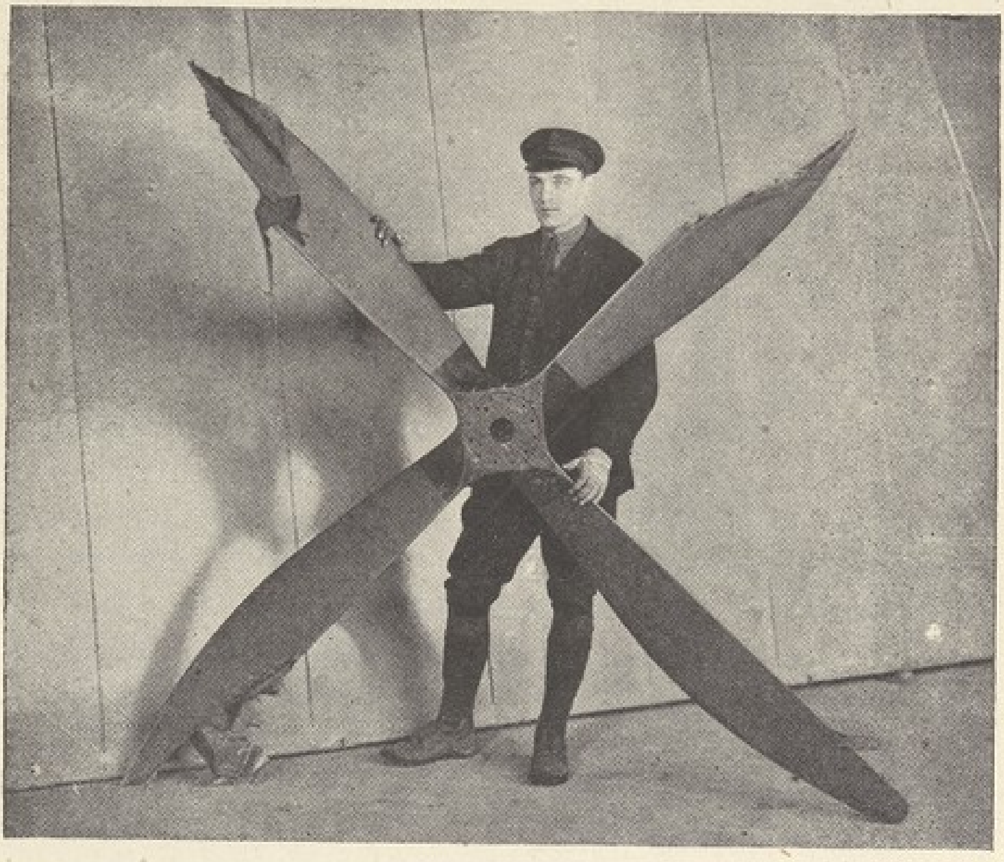


Fig. 15.—Showing broken propeller blades which severely injured a mechanic through a "backfire."

scoliosis is produced. In other cases the anterior half of the centrum gets driven down more and a kyphosis results.

Pain and surgical shock have to be combated at first. The patient must be nursed in a special spinal bed. At the end of three months he is allowed up, but should be fitted with a moulded leather or pexulloid spinal support with arm crutches. Skiagrams should be taken from time to time to watch the progress of the case. If the kyphosis increases it may be necessary to perform Albee's operation. Neurasthenia is apt to follow this type of injury.

Propeller accidents often result in severe injuries mostly to the upper limbs or head. In swinging the propeller to start the engine a backfire may occur, and the propeller suddenly revolves in the opposite direction. Contusions, lacerated wounds, or fractures may occur. (Fig. 15.)

Surgical Conditions due to Thermal Causes.

I. Burns.

The outbreak of fire may occur in mid-air, and is then usually the result of an aerial duel, or it may occur on landing in certain aeroplane crashes. There is less danger of fire in these crashes if the engine is switched off beforehand. In a two-seater machine if an observer be carried, the latter, by means of the Pyrene extinguisher, can do much to quell an outbreak of fire in mid-air. The pilot, by side slipping the aeroplane the whole way to earth, may prevent the fire damaging the vital parts of the machine, and also save his observer's life as well as his own. This manœuvre throws the flames outboard in the direction opposite to the sideslip. A very sudden and steep nose dive might quell the outbreak, but on the other hand the flames may be carried back and damage such vital parts as the rudder and elevator. The parachute is the best means of escape, and these should be provided in every aeroplane. Those who have experienced fire in the air or have witnessed such sights, the most distressing in aviation, will readily endorse this view. On the event of fire occurring in mid-air, safety belts should be at once released. If fire breaks out on crashing, the occupants may escape if thrown clear of the wreckage. If in the machine they are not likely to escape.

Asbestos blankets are extremely useful as a means of first aid. By wrapping them round the injured persons the spread of fire on clothing, etc., can be limited. If asbestos blankets are not available, leather flying coats can be used. Picric acid dressings are applied, or " carron " oil if it is available. Morphine is injected, and chloroform should be administered if there is much pain. The chief difficulty is in combating shock and chest complications. When the shock passes off the original dressings are changed under an anaesthetic, and are replaced by the application of ambrine, once the burns are gently but thoroughly cleansed.

Red lotion and scarlet red ointment are useful in the later stages.

Burns of the first, second, and third degrees are the usual ones encountered. The author has seen one case of burns of lower limbs and abdomen caused by petrol. The rapid transit through the air increased its action as a vesicant.

In the after treatment in these cases it may be found very difficult to prevent contraction. It may be impossible to apply extension. Much can be done by gentle passive movements during the healing stage. And again postural methods may be of use. Once the burn has healed, the resulting cicatrix goes on contracting for quite a long time, but it must be remembered that the young fibrous tissue composing it is distensile as well as contractile. Advantage should be taken of this fact to carry on with oil massage, kneading, and gentle stretching as soon as the burns have healed. Skin grafting and plastic operations may have to be carried out to complete the treatment.

II. Aerial Frostbite.

In school flying, except in some cases attempting height tests in winter, frostbite conditions are rarely seen. But in a bombing squadron, where the formation, in order to reach its objective, has to keep at high altitudes perhaps for some hours, to avoid detection or the attentions of "Archie," the cold experienced is extreme, and from time to time cases of frostbite occur. At such squadrons the pilots are provided with warm and suitable clothing, and precautions are taken by smearing the exposed parts with some greasy preparation. Many efforts have been made to provide electrically-heated garments, but some of these have not proved a very great success. The author was well satisfied with one type of suit which he tried. Frostbite is a form of gangrene brought on by exposure to cold, and the parts usually affected are the face, fingers, and toes. The condition is more likely to supervene where the circulation is enfeebled or where any constriction is present interfering with the circulation. The tissues do not die when frozen, but in the subsequent thawing, in which intense capillary congestion sets in. The affected parts become dead white, accompanied by loss of sensation, due to stasis of the circulation. This is followed by a reactionary period when the full extent of the mischief becomes revealed. In slight cases an erythema follows accompanied by slight swelling, and hyperaesthesia, and later followed by a period of desquamation.

In other cases the swelling and oedema become very marked and bullae form. Certain areas may die and form necrotic patches. In more severe cases a finger tip, a toe, or tip of the nose may be lost through death of the parts. The reaction period is usually accompanied by great pain. The oedema takes some time to subside and convalescence is often protracted. As the swelling subsides, the tissues undergo repair and desquamation occurs. For some time afterwards a peculiar sensitiveness to cold persists in the affected parts. The author has only seen a few cases of aerial frostbite, mostly slight and affecting the fingers and nose, but was impressed by the slow recovery in these cases.

Surgeon-Lieutenant A. G. Holman, R.N., who has had a long experience with a squadron which had to carry out high altitude flying in very cold weather, has very kindly furnished me with the following notes of four cases of aerial frostbite, and appended are his views on prophylaxis and treatment of such cases.

" Case 1.—Flight Sub-Lieut. K., aet 22. Returned from bombing raid after two hours' flying at an average altitude of 10,000 feet. Temperature on the ground 13° F. He did not complain of any pain or discomfort at the time, and his condition was only discovered during a routine examination of all pilots as they landed. He was found to have some brawny swelling of the cheeks. Treatment consisted only of keeping the patient away from excessive warmth until the face had thawed, and application of a mixture of equal parts of lanoline and vaseline.

" There was very little swelling next day and no vesication, and forty-eight hours afterwards, except for a very slight desquamation of the cheeks, there was no further trouble.

" Case 2.—Flight Sub-Lieut. M., aet 27. Returned from bombing raid of about two and a half hours' duration. Face very swollen though not particularly painful. Next day the face was enormously swollen, the cheeks being almost in line with the tips of the shoulders, and in addition there was much redness and some vesication of the skin below the right angle of the mouth. This latter developed into a fairly superficial necrotic patch about the size of a crown piece.

" Treatment consisted of keeping the face warm by wool and bandage, and dusting powder to the necrotic patch. Later a zinc oxide ointment dressing was applied to this latter. The swelling gradually decreased, and the slough turned black and separated, leaving a healthy base about the fifteenth day. The face was very painful for some weeks after this whenever exposed to the cold.

"CASE 3.—Flight Sub-Lieut. D., aet 32 (a mouth-breather). Returned from the same flight with marked swelling of the cheeks and intense inflammation of the lower lip. Next day there was some vesication of the lower lip and later extensive superficial necrosis of the lip. The swelling subsided without further trouble in a few days. The necrosis of the lip was treated with zinc oxide ointment dressing, and sloughs separated about the fifteenth to the twentieth day, leaving rather a painful inflamed surface, which later healed well and gave no further trouble.

"CASE 4.—Air-Mechanic Gunlayer F., aet 21, whilst fighting at 10,000 feet, was forced to remove his gloves to clear a jambed Lewis gun. In doing this he lost both gloves, and had to continue fighting for three-quarters of an hour without gloves. The temperature on the ground at this time was 5° F.

"He was discovered a few minutes after landing, warming his hands before a fire. The hands were intensely swollen, and brawny though there was hardly any pain. They were immediately placed in snow, and very slowly thawed out. There was then found to be some vesication of the fingers. The vesicles were incised, and the whole hands immersed in dilute picric acid solution, and finally covered with lint wrung out in the same solution.

"Next day there was vesication of the whole of the dorsal surface of both hands. These vesicles were incised and treated with the dilute picric acid dressing. The nails were very discoloured, and there was complete anaesthesia to touch from the wrists downwards.

"Picric acid dressings were continued for ten days, when the bases of the vesicles had healed, and a dusting powder and gauze dressing then substituted. The anaesthesia gradually disappeared, remaining longest at the tips of the fingers. There was extensive superficial necrosis, which separated, leaving perfectly clean underlying surfaces after some twenty-three days. The patient complained of stiffness of his fingers for several weeks, but was able to return to ground duties after five weeks' treatment from the time of his first being frostbitten. Ultimately he had a perfectly good pair of hands with very little scar tissue.

"The above were the only cases of aerial frostbites that came under my notice, although I have seen a great deal of flying in very cold weather. Several pilots of my early acquaintance used to smear a little vaseline on the exposed portions of their faces, and this undoubtedly did much to prevent frostbite, though Cases 1 and 3 both had vaseline on their faces. During cold weather I made a point of anointing every pilot's face with equal parts of lanoline and vaseline mixed, and not one of those so treated ever developed frostbite. Whether or no the lanoline becomes to a certain extent absorbed by the skin, and thus makes a more protective covering, I cannot say, but the mixture seems much more effective than vaseline alone. There is one more point in the prophylaxis of aerial frostbite that appears to me important, and that is the kind of fur used in the manufacture of face masks, goggles, etc. North American trappers have found that the only fur that will not become frosted by the breath in the coldest weather is wolverine, and this is the fur that they always select for their own headgear and face protection. Case 3 above was a mouth-breather, and the chin band of his helmet was quite frozen stiff with his breath when he landed, and frozen to his lower lip. I used to make a point of examining every pilot on his return from a flight in cold weather, immediately he got out of his machine, to ensure that no one who should happen to be frostbitten should go into the hot atmosphere of the mess or cabin before being previously slowly thawed out. One point that particularly struck me was the almost entire absence of pain, particularly with more severe cases. And this alone in my opinion calls for the routine examination described above, as the pilot is generally completely unaware of his condition."

III. Waterbite.

This is the name applied to conditions allied to trench feet and due to the effects of prolonged exposure to cold water. It is found in seaplane work, and therefore it is essential that all seaplane pilots going on patrol should be adequately clothed and protected. Lanoline ointment should be applied to the lower limbs, long woollen stockings worn, and over the ordinary trousers there should be sea-boots extending to the hips. The lower and upper limbs are the parts usually affected. At first they become benumbed and white in colour. There is no complaint of pain. There is usually some swelling of the parts, then large bullae form, and the colour becomes mottled. Pain sets in about the third day, is usually intense and may last for weeks. Painful cramps in the muscles are a distressing feature. With the local reaction, soon a line of demarcation forms, and depending on the treatment, the clinical picture is one of moist or dry gangrene. Loss of fingers or toes may occur, and owing to the devitalised condition of the tissues, the wounds are slow to heal. The affected parts should be bathed with spirit, dried, powdered, wrapped loosely in cotton wool and elevated. Gentle massage with oil may be tried in the reaction stage. Opium is given to relieve the pain, and exerts a local influence in that it causes dilatation of the peripheral vessels. Preventative orthopaedic measures should be carried out during the treatment.

The following is an account of a case of "waterbite," at present under the author's care :—

Flight Sub.-Lieut. M., age 24, observer, with Lt. S., pilot, in a seaplane in foggy weather were forced to land, owing to engine failure ; and in doing so the tail float was broken. Slowly the whole machine sank, tail first, and turned right over, so that pilot and observer found themselves seated on what had been the under surfaces of the main floats. Fortunately the submerged seaplane broke adrift from the floats and sank. (Fig. 16.) M. and S., each on a float, were in this position for three nights and four days, without food or drink, and exposed to the action of cold water for most of that time. M. was in ordinary uniform, slacks and ordinary boots, while S. had on leather field boots. The former's feet and legs were benumbed the whole time, and his hands became swollen. In an exhausted condition they were rescued

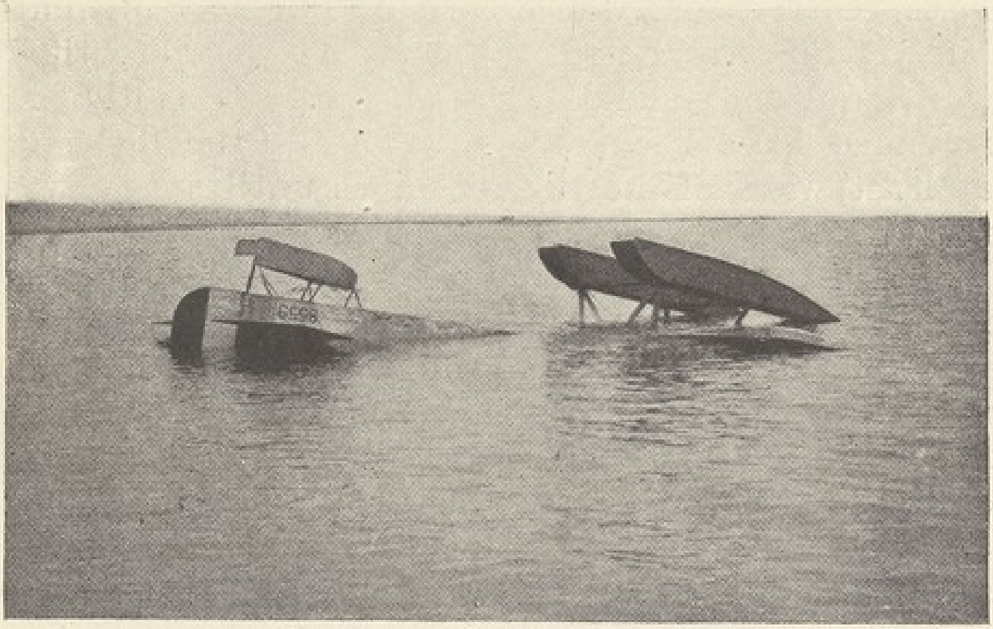


Fig. 16.—Showing a sinking seaplane with under surface of main floats now uppermost.

near the end of the fourth day. S. did not suffer so badly, but was unable to walk for many weeks. M. suffered severely from pain in the feet and cramps in the legs for over three weeks. The parts became mottled, large bullae formed on the soles, leaving raw granulating surfaces. In both feet a line of demarcation formed at the bases of the third, fourth and fifth toes, which, in a condition of dry gangrene, were removed.

The accompanying illustration (Fig. 17) shows the condition nine months after the onset. Preventive orthopaedic measures have been employed to prevent pes cavus arising, by having the patient wear right-angled tin shoes at night.

IV. The Surgery of War Aviation.

In the earlier days of the war the majority of projectile wounds sustained in flying were due to shrapnel or fragments of high explosive shell. Later, with the institution of low bombing, and low flying attacks on infantry, and the great increase in the size and number of aerial fights, the wounds sustained were mostly due to bullets. There are many instances of pilots who have been wounded in mid-air, yet able to control the aeroplane back to their own aerodromes ; and also of observers who although wounded have been able to continue the fight, or at least ward off hostile machines until safety was reached. " First aid " dressing packets should always be carried by pilots and observers engaged in war flying. Much could be done to safeguard both by providing armour-plating around the cockpits. All varieties of gunshot wounds are seen. As aerial fighting is carried on at close range explosive effects on the tissues are often produced by bullets.

Early attention is, as a rule, given to most wounded aviators, and the wounds generally are fairly clean and tend to heal quickly. The wounds seen at the R.A.F. Central Hospital during the past year have been mostly due to bullets, and the parts affected have been mainly lower and upper limbs. There has been a noticeable absence of severe infections, and no cases of gas gangrene have occurred. This is explained by the fact that the wounds rarely come in contact with the earth as in trench warfare. In the latter, especially in the present war, fighting has been carried on over highly fertilised and cultivated land, the soil of which is a good medium for the growth of anaerobic and gas-producing organisms.

One case of bullet wound of buttock developed septicaemia, and the streptococcus was grown from the blood. The wound was thoroughly opened up and excised. Carrel's tubes and Eusol solution were used locally. Anti-streptococcic serum was injected subcutaneously every fourth day. Intramuscular injections of collosal manganese were given, and thyroid extract gr. ii. was taken by the mouth twice a day. Recovery was slow but complete, but at the expense of arthritis of both wrists, one knee and the opposite

FIG. 17.—Showing result of "waterbite" to both feet—nine months after occurrence.

hip joint. Although now these complications have improved greatly.

Compound fractures have been frequent, and in these the best results have been obtained by means of extension and Eusol solution locally. No attempts have been made to plate these cases. Sequestrotomies form a large part of the operative work, and the use of B.I.P.P. has given excellent results in the completion of these operations. The latter are not to be performed in a haphazard way, which often consisted in a mere scraping of a sinus. Good stereoscopic X-ray negatives are essential, and after a careful study of these, the affected bone should be freely exposed. Only in this manner can all dead bone be removed. B.I.P.P. may be rubbed in thoroughly, but it rather interferes with the interpretations of subsequent skiagrams. Eusol solution for two days, followed by saline for two days, gives excellent results.

The most difficult problem to solve is the treatment of bone cavities. All sequestra must be removed, and the cavity curetted, dehydrated with alcohol, and B.I.P.P. rubbed in. At a later operation a muscle flap should be turned into the cavity if possible. In all compound fractures, and this applies to wounds of soft parts as well, special attention must be paid to preventative orthopaedic measures to avoid contractures.

CHAPTER VIII

Injuries and Destructive Effects of Aeroplane Bombs and of Aeroplane Arrows, with Suggestions on the Precautions to be taken during hostile Aerial Raids

A large part of the work in this chapter is based on experience of air raids in Belgium and France during the first year of the war. In conjunction with Fleet Surgeon H. V. Wells, R.N., the observations, up till February, 1915, were collected together by the author, and published in the "British Medical Journal," August, 1916.

Since that time aerial bombing became more and more developed, due especially to the advancement in night flying, and to the construction of heavier bombs and types of aeroplanes to carry such; and also to the specialisation in bomb practice, and the invention of more accurate sighting methods.

Types of Bombs

The bombs the effects of which were observed were of two kinds:

(*a*) *High Explosive Percussion Bombs.*

The high explosive bombs weigh from 10 to 20 lb., and consists of a metal case $\frac{1}{4}$ inch thick, filled with high explosive only. It is presumed that no shrapnel bullets are contained in them, as the author has never been able to demonstrate such either in the wounds or in the wreckage of property produced. By visiting the spots immediately after the explosions he has been able to secure various pieces of the bombs—for example, the handle, the base, and pieces of the casing of various size, as shown in Fig. 18.

Depending on the object to be destroyed the modern aeroplane bomb may weigh anything up to many hundred pounds. The destructive effect is

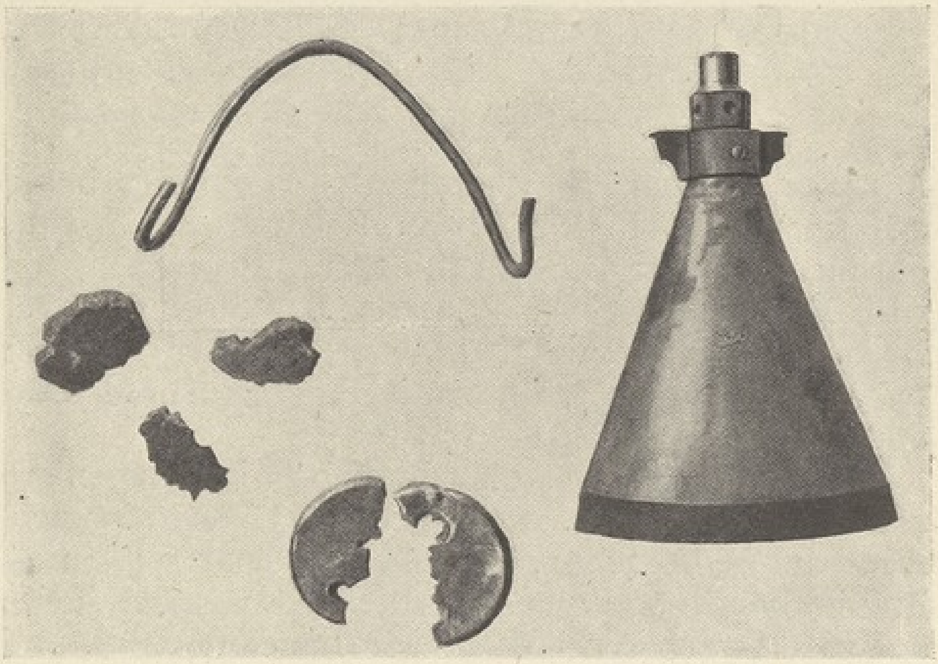


FIG. 18.—Showing to left, handle and fragments of percussion bomb; to right, part of an incendiary bomb.

due to the high explosive and to the metal case being broken up into fragments of various sizes, which are propelled in all directions at tremendous velocity. The bombs may be released from the aeroplane by hand, either over the side of the machine or through a hole in the floor of the fuselage, or by a special bomb-dropping device, by means of which the bombs are released by hand levers or foot pedals from a special bomb-rack.

As the bomb leaves the aeroplane a pin is withdrawn, which allows a small metal propeller to unscrew itself; this sets the internal mechanism ready for explosion on contact. As a precautionary measure the mechanism is not set ready for detonation until the bomb has fallen about 200 feet. Fixed steel vanes keep the bombs steady on their downward flight. Sometimes these bombs fail to explode on percussion, and have been found intact. An aero-

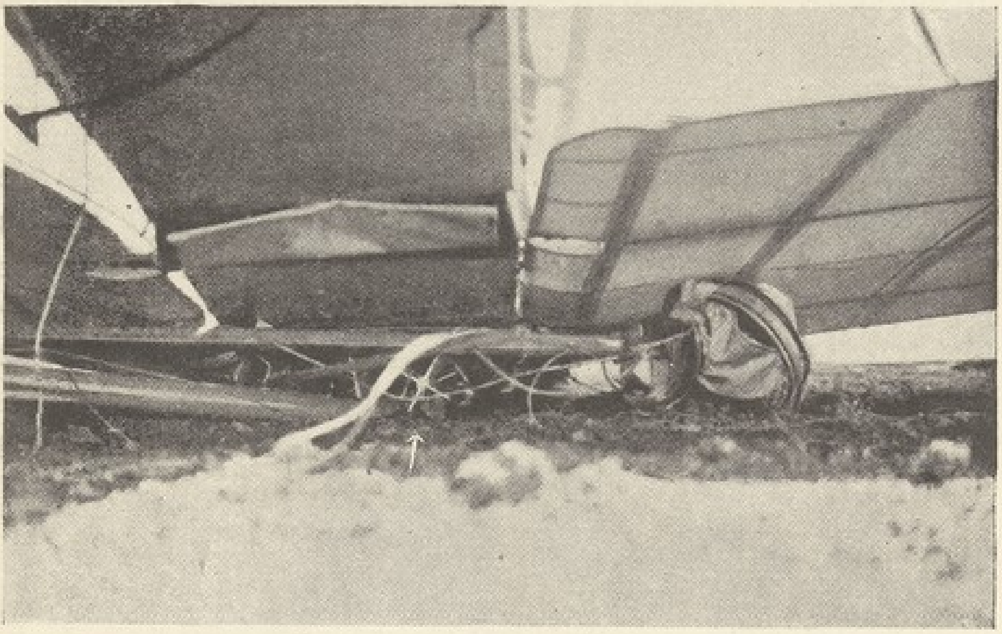


Fig. 19.—Showing a crash after a bombing raid. The arrow points to an unreleased bomb.

plane may return from a raid with an unreleased bomb on its rack. Should a crash occur or fire break out explosion may occur. (Fig. 19.)

(*b*) *Incendiary Bombs.*

The incendiary bombs used to set fire to collections of stores, etc., consist of a thin metal casing containing a medium soaked in some highly inflammable substance, such as petrol. A percussion device in the bomb ignites the inflammable contents.

Flight of Bomb

Bombs are dropped from aeroplanes usually at a height varying from 4,000 to 7,000 feet. Below this the machine comes well within the danger zone from anti-aircraft guns. The forward speed of the aeroplane determines the first part of the bomb's flight, which will be in a forward direction until gravity asserts itself, and then the course will be directed downwards. But from experience the author ventures to make the statement that there is a certain amount of forward deflection, perhaps small, in the whole course of the bomb's flight. Lateral deflection in the bomb's flight may also occur, and this may be due to one of two causes. First, if the wind is across the aeroplane's path some lateral deflection of the bomb's flight must be expected, depending on the wind velocity and the height of the aeroplane from the ground. Secondly, if a bomb is released as the machine is being banked centrifugal action comes into play and will cause some lateral deflection.

A bomb was dropped from an aeroplane at about 6,000 ft. A cross wind was blowing and the bomb fell, as estimated by competent observers, at a spot 200 yards lateral to the aeroplane path.

A bomb was dropped from a height of 6,000 ft. and struck the front of a house in a narrow street. The house was struck at the level of the first floor; to do this the bomb must have had either forward or lateral deflection.

The accuracy of bomb dropping is thus influenced by many factors—for example, height of aeroplane from ground, its air speed, its ground speed, wind velocity, gravity, etc.; thus the chances of obtaining a direct hit on a particular object, unless this be large such as a collection of troops or transport, large buildings, massed shipping, etc., are rather small.

When a bomb is dropped it comes rapidly to earth with a peculiar hissing shriek, quite unlike the whistle of a shell. On explosion it sends up a cloud

Plate 27.—Showing the explosive effect of a large aerial bomb.

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of smoke and débris many feet high. For some time past low bombing has become quite a feature of aerial warfare.

Injuries.

These are much akin to the injuries produced by common high explosive shells. Death or more or less severe injuries may be due to the following causes :—

From the Actual Shock of the Explosion.

That is the effect produced on the individual by the disturbance in the air, created by the sudden expansion of the contents of the shell.

(*a*) The shock may actually kill without producing any visible destruction of tissue.

Two civilians were found lying dead 5 ft. from a hole in the street made by a bomb. There was slight frothing at the mouth, but no wounds, fractures, burns, or any visible injuries.

(*b*) The explosion may blow off limbs, or shatter them severely, or cause multiple wounds. The traumatic shock in all these cases is very severe, and many cases never rally.

A number of civilians were standing round one of the Allies' aeroplanes when a bomb, which was being handed up by a mechanic to the observer, fell and for some unexplained reason exploded. Six people were instantly killed. All had compound fractures, some severely shattered limbs, whilst others had the whole or a portion of an extremity blown off. Curiously enough, the mechanic escaped with nothing more than a wound of the forehead, whilst the observer, who was thrown 30 ft. in the air, came down unharmed, except for slight wounds of face and arm, due to small fragments of the bomb. He suffered in no way from shock, and was able to walk into hospital unaided.

A bomb exploded 5 ft. from a Belgian officer. He sustained a compound comminuted fracture of the left leg and two deep wounds on the front of both thighs. The shock was very marked, and he died the same night. On opening up the thigh wounds, no fragments of bombs or shrapnel bullets were found. The wounds were due to explosive effect alone.

A bomb exploded a few feet from the following cases, the injuries received being due to explosive effect : A civilian, aged 40, had a wound exposing the muscles of the neck and trachea, and a compound comminuted fracture of the left leg. Amputation of the leg was performed, but he died shortly afterwards. A boy who had compound fracture of femur and severe shock never rallied, and died the same night.

From Flying Fragments of Bomb.

The pieces into which a 20 lb. bomb bursts are never very large, the largest being 2 inches by 2 inches, whilst many are quite small. Persons standing within 30 feet of the explosion are likely to be injured. Beyond that range the chances of escape are much increased, but a flying fragment may injure severely at 150 feet from the explosion.

A civilian standing 30 ft. from a bomb explosion received a large wound in the abdominal wall from a flying fragment. Viscera protruded, and he died a few hours after admission to hospital.

A woman, about 20 ft. distant, had a perforating wound of thorax and penetrating wounds of abdomen and right thigh. She died on the way to hospital.

A man, about 40 ft. distant, received a penetrating wound of abdomen. No exit wound discovered. He was operated on, but the fragment was not found at the time. He died later of general peritonitis.

A woman, 30 ft. distant, received a flying fragment in the left side of the chest. Further history unknown.

A woman, standing 30 feet from a bomb explosion, received multiple wounds from small fragments as follows: Small penetrating wounds of left foot, left thigh, right arm, left breast, and left eyelid. A left metatarsal bone was fractured.

At a distance of 50 to 60 feet from where a bomb exploded flying fragments entered a cellar (many of the Continental cellars, although underground, have part of the door, window, or grating above the street level) and wounded three people—

A woman received a wound on left breast.
A woman received a deep wound of thigh.
A child received a slight wound of breast.

From Burns.

Signs of burning and charring are rarely found alone, and are usually accompanied by other more serious injuries. When present they only occur to those in close proximity to the explosion.

A bomb exploded about 5 feet from a soldier, shattering his left leg, fracturing the right tibia, cutting his lip and nose, and causing superficial burns all over the body. He died soon after admission.

A soldier in a stooping position a few feet from where a bomb fell had his left buttock blown off and the wound absolutely charred. This case did extremely well.

From Fumes.

Although the author has no cases among his records it is quite possible that the fumes given off at the time of the bomb explosion might have a fatal or stupefying effect on those in the near vicinity.

From Chemicals.

As far as can be ascertained no evidence of the use of chemicals in aeroplane bombs dropped by the enemy exists up till June, 1917. Then after certain hostile air raids in that month many cases of dermatitis were reported due to contact with a brownish powder either coating the bombs or liberated by the bomb explosion. Cases were reported in the "British Medical Journal" of July and August, 1917, by Drs. Sequeira, J. W. Tyson, H. G. Adamson, and J. M. H. MacLeod.

Dr. Sequeira saw fifty-nine cases of dermatitis—thirty-five in males and twenty-four in females—due to their coming in contact with a brown powder which was scattered about in the neighbourhood of bombs dropped during a certain hostile air raid. In his cases the initial staining was of an orange tint—well seen on the palms, followed about nine days later by intense irritation and itching which interfered with sleep. Closely set discrete vesicles, about the size of hemp seeds, appeared, more especially on the palms and sides of the fingers. Not much redness was noted, but the backs of the hands were swollen. The eruption increased, and reached its height about the fourth day from its appearance. Blebs, filled with clear fluid, occurred—some as large as a hen's egg. Infection followed and pustules formed. The epidermis separated, leaving raw, rather dry, red surfaces. There was slight pyrexia in some cases to 100° F. From the bacteriological examination the fluid in the early vesicles was found sterile. Dr. Panton found an eosinophilia present. The chemical irritant in the brown powder was found to be hexa-nitro-diphenyl-amine, which is recognised as an explosive agent often mixed with tri-nitro-toluene.

Dr. Sequeira found the best treatment was the application of calamine liniment to the affected parts; and he advised the use of wet alkaline rags in the handling or removal of the powder, and the avoidance of ordinary gloves as a protective measure.

From Wreckage Displaced by Bombs.

The injuries thus received so far have been slight, and have been due to falling stones, bricks, mortar, etc. The usual 20 lb. aeroplane bomb is not sufficiently powerful so to wreck an ordinary house that the wreckage falling would cause severe injuries. Most of the injuries have been slight bruises, and no deaths have been recorded, but with the much heavier type of bomb used the wreckage displaced may be considerable, resulting in severe or fatal injury.

From Accidents.

These occur to individuals in their hurry to escape from danger from above.

A bomb fell in the narrow street of a French town, when a woman with a child in her arms (some 50 yards away) made a wild leap for safety, fell down some cellar steps, and crushed her child to death.

In the stampede and panic among an alien mob many deaths from crushing have ensued. Again, there is no doubt that the crowding together of many individuals in underground areas has increased the spread of zymotic diseases.

From Anti-aircraft Missiles.

During hostile aerial raids the air positively teems with metal from all kinds of anti-aircraft guns, and the danger to curious and ignorant onlookers from falling missiles is very great. It is surprising that so few have been injured from this cause, and the number of escapes have been truly wonderful. The base of a 75 mm. shell, weighing $3\frac{3}{4}$ lb., came down very close to one of our officers, and had it struck would have caused instant death. The missiles that are likely to return from the air during the defence are :

1. Bullets from rifles and machine guns. These come down with surprising velocity, sufficient to kill or injure severely. Some have been found imbedded in woodwork, and others with their noses turned or flattened, due to the tremendous impact on the ground.
2. Pieces of shell, of varying size, and shrapnel bullets from proper anti-aircraft guns.
3. Bases and pieces of common shell, solid shell, and unexploded shell.

Fig. 20 shows the base of a French 75 mm. shell and a large portion of a shrapnel bursting shell. They came down together with French mitrailleuse bullets in the outskirts of a town during a hostile aerial raid.

Range of Bomb Fragments

The author's observations on the first series of 20 lb. bombs dropped showed that most of the fragments were driven upwards at about an angle of 30 degrees, so that an individual lying flat on the ground in the neighbourhood would probably escape unhurt. These bombs also made a fairly deep hole in the ground, as a rule about 2½ feet deep. Latterly the bombs dropped have exploded so that the fragments have been driven along parallel to the ground, as well as upwards to an angle of 60 degrees. Bomb fragments have been found embedded in walls at a distance of 150 feet from the explosion.

Destructive Effects

These have been noticed on streets, houses, sheds, sand, and shipping:

(*a*) *Streets.*—With regard to the effects of 20 lb. bombs the hole produced is 2 or 3 feet wide and 1½ to 2 feet deep. Windows in the neighbourhood for 50 to 100 yards around are shattered. A plate-glass window 40 feet from a bomb explosion showed multiple stellate fractures, a frost-like, arborescent appearance being produced. Wooden shutters and doors at 30 feet distance have been perforated, while in others bomb fragments have been found embedded. Pieces have been driven along parallel to the ground in through (Continental) cellar doors and windows, injuring people within. A bomb bursting in the street would send fragments through the ground floor and first floor windows, but not through the masonry. Safety lies in keeping against the wall, indoors on the ground floor, out of the line of windows.

(*b*) *Houses.*—The usual 20 lb. bomb employed from an aeroplane will go through an ordinary roof and explode in the top room. We have not found one which has penetrated further. A wire splinter-proof netting would cause the bomb to explode outside, and only some fragments would probably come through the roof. Sand also acts as a good protective, but its weight precludes its use on most roofs. Very few houses could withstand a direct hit from a heavy bomb.

A bomb came through the roof of an ordinary dwelling-house and exploded in the top room, wrecking everything in it, but no fragments penetrated the floor below.

A bomb struck the projecting ledge of a house roof and burst, dislodging some tiles and bricks, blowing in the windows, damaging property in the upper rooms, and the fragments spent themselves in the street below, killing two soldiers who had taken protection in a doorway. Such doorways and passages afford little protection.

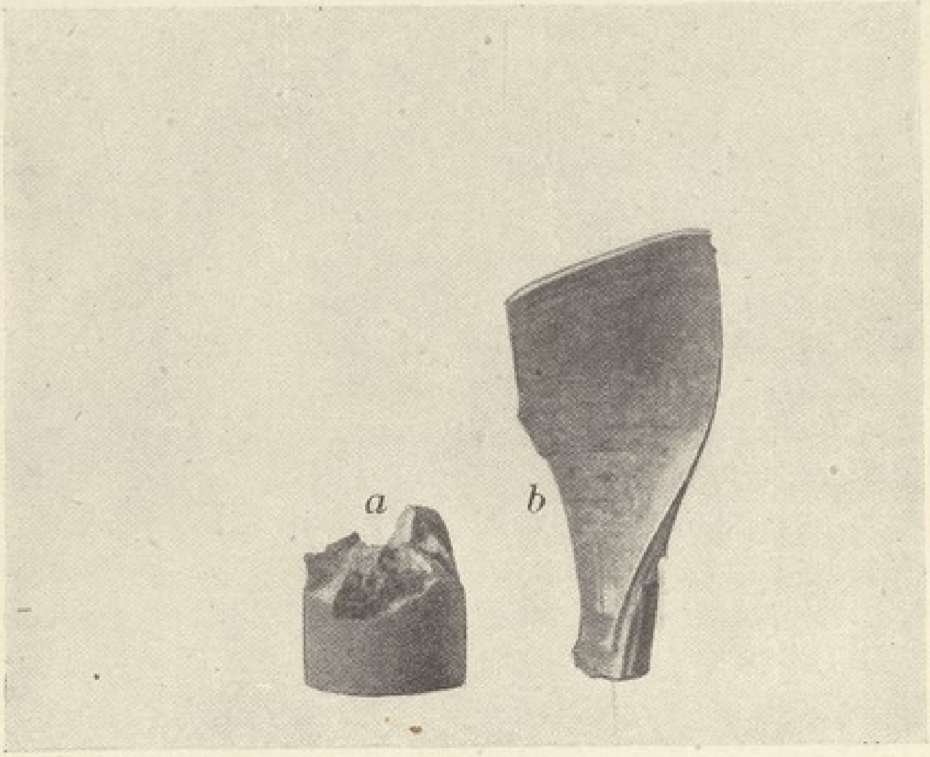

Fig. 20.—Showing pieces of anti-aircraft missiles which fall during an air raid and may produce serious injuries.

A bomb, with either a forward or lateral deflection, struck the front of a house and destroyed a good deal of the masonry, and wrecked furniture, etc., within. Fortunately no one was injured.

(*c*) *Sheds.*—The glass and wooden roof of a large shed (a hangar) was pierced by a bomb, which must have exploded just after entry. The fragments were driven downwards, perforating in many places a canvas covering, and killing two people below. No others were injured.

(*d*) *Sand.*—We have records of six bombs exploding on a sandy beach. The hole produced is usually

$3\frac{1}{2}$ to $4\frac{1}{2}$ feet wide, and 1 to 2 feet deep. Case fragments are found embedded in the sides of the crater. On explosion a spray of wet sand is carried laterally for a distance of 30 feet. Bags full of sand form an ideal protection on a bomb-proof shelter.

(*e*) *Shipping.*—A bomb fell on a barge, and, exploding, made a hole in it, causing it to sink rapidly.

Precautions to be taken during Hostile Aerial Raids

On headquarters being notified of the approach of enemy aircraft, warning signals should be given to the community, such as the firing of a gun, or maroons in the case of air raids at night, hoisting of a flag on the town-hall, blowing of a ship's siren, use of a military rattle, etc. Orders should be given beforehand that all except those connected with anti-aircraft defence must seek cover indoors, preferably in basement cellars, or, failing these, on the ground floors, away from the line of windows. "Get in and get under" is the motto for safety. It must be remembered that it is extremely difficult for the onlooker below to gauge with any accuracy the position of the aeroplane relative to his position on the ground. The danger zones are, as a rule, immediately in front of, and lateral to, the approaching aeroplane; the areas of safety lie directly behind its flight. But it must not be forgotten that a well-banked turn may quickly alter the aeroplane's direction and so place an individual below in the danger area. Fire stations should be notified, and doctors, first-aid crews, and ambulances made ready on telephonic communication. School children should not be sent home from school but congregated on the ground floors out of the line of windows. If people flock into the streets to watch events, they are exposed to as much danger from falling anti-aircraft missiles as from the enemy's bombs, and needless casualties will ensue. On no account must unexploded bombs be handled or touched; a guard should be put over them and the nearest authorities notified. Houses that require to be specially protected should have a splinter-proof netting arranged over, and some feet above, the roof. This would cause some bombs to explode outside the roof, and only a few fragments would probably penetrate the roof. Sand in bags can be used if its weight can be sustained. As hospital ships must at times be in ports which are liable to aerial attacks, we recommend that such ships as have their wards directly under the upper deck should make use of a similar splinter-proof netting. In houses the best protection is afforded by underground cellars, especially those built under the footpath and not directly under the house. In Continental cellars, which are partly above the street level, people are safe if they keep away from the cellar window, door, or grating, as the case may be. The same applies to the ground-floor room of an ordinary house. Avoid upper rooms, windows, and doorways. In the street, passages and entrances to shops, etc., afford no protection, and are to be avoided. If a passage open at both ends is one's only shelter, it is better to take the centre of it and lie down.

The precautions to be taken in buildings where there are more or less large collections of people, such as factories, schools, works, barracks, etc., depend upon the size and type of the building. When there are upper stories the individuals should be collected on the ground floor, with the same precautions as for a house. When there are no upper stories and the building has a ground floor only—for example, a hangar or some hospitals—those locally in authority should see if there is in the neighbourhood another building affording protection.

If so, arrangements should be made for occupying this on hearing the warning signal, and this should be practised and carried out as for fire drill, to avoid panic, especially so with school children. If no such safety building exists, the best measure to adopt is to build beforehand some type of bomb-proof shelter within the building. We have seen a very good one made in the large shed of a works from the available material present. The sides consisted of tins or drums containing sand or non-inflammable merchandise, the roof was of timber supported by powerful props, and on the top of this were placed bags of sand 1 foot thick. This is almost certain, we think, to keep out all fragments of a bomb exploding, as it would, just inside the roof of the shed. Provision should be made for the interior lighting of all bomb-proof shelters, as a dark place crowded with people, who may be already in a high state of excitement, is conducive to panic. Inhabitants in towns subject to air raids paste broad strips of paper diagonally over the inside of their windows, thus preventing glass falling outward and injuring people below.

Aeroplanes, as well as airships, can be and have been used on many occasions during this war for making aerial attacks by night. The author has had the experience of such enemy raids. A point worth remembering is that on a bright, clear, moonlight night an aeroplane is extremely hard to see, and almost everything is in the enemy's favour. The pilot can see well and cannot be seen; he can fly fairly low and thus make more accuracy in bomb-dropping.

Injuries from Aeroplane Arrows

During the time the author was working on the effects of aeroplane bombs he tried to find cases with injuries resulting from aeroplane arrows or flechettes. He could only find one doubtful case in an Indian hospital where one patient said he thought "something came down from above and pierced his hand."

Very early in the war Dr. J. Volkmann read a paper on aeroplane arrow injuries before a special meeting of the Stuttgart Medical Society. It seems that three companies were bivouacking at intervals of eight paces whilst two of our aeroplanes were overhead at a height of 3,000 to 5,000 feet, when suddenly one soldier felt a stabbing pain in his foot, and found that a small steel arrow had penetrated it. Cries of pain arose all around, the horses became restive and two were hit. About fifteen soldiers in all were hit. Fifty arrows had been dropped so that one in every three found a mark. One soldier was pinned to the ground by an arrow passing through his foot, another required an incision for liberation of the arrow from the leg. In one case a penetrating scalp wound was caused without injury to skull. In another instant death was caused by the arrow entering the left temple, and out again by the right coronary suture. Another death was caused by the arrow entering at the shoulder and passing into the thoracic cavity. In one case there was a wound of cheek penetrating the mouth. Most of the cases did well under iodine and dry dressings.

CHAPTER IX

Aeroplane Dope Poisoning

Although the prevention, early recognition, and treatment of aeroplane dope poisoning are of more importance to the medical officers attached to aircraft production factories than to those stationed at aerodromes it is nevertheless well that the latter should be informed on the subject. In factories for the production of aircraft, doping is employed on an extensive scale, being carried on more especially by female labour—at an air station or flying school on the other hand the aeroplanes that survive any length of time have to be redoped every now and then. A certain number of mechanics are detailed off for this work, and the medical officer is usually consulted with regard to their selection. He must have them continually under observation in order to step in at the earliest possible moment when dope poisoning symptoms appear; and he also has to inspect and advise on any matters relating to construction, ventilation, or general hygiene of the doping sheds.

Aeroplane varnish, or dope as it is commonly called, is applied to the fabric covering the wings and body of an aeroplane, in order to keep the fabric smooth, evenly stretched and impervious to air and especially moisture. The wing fabric of a new aeroplane receives about six coats, and each coat is allowed to dry before the next one is applied.

The doping has to be done in a warm atmosphere, about 65° F., so that the fabric may not be affected by dampness and subsequent rotting.

Dope consists of acetate of cellulose dissolved in acetone, carbon tetrachloride, benzene, methylated spirit, and tetrachlorethane. The various dopes employed vary in the proportions of their constituents. Dope is a syrup-like, colourless liquid, smelling somewhat like chloroform. When applied to fabric it dries, leaving a firm, flexible, waterproof, and airtight coating. Dope vapour is heavier than air.

During the latter part of 1914, and owing to the stimulus applied to aircraft production by the war, quite a number of cases of illness with a definite train of symptoms were noted amongst those engaged in aeroplane doping, and some deaths were recorded. It was found by the researches of Drs. W. H. Willcox, B. H. Spilsbury, and T. M. Legge that the poisonous constituent of dope was tetrachlorethane. This was proved by exposing animals to the fumes of dope, acetone, methylated spirit, benzene and tetrachlorethane separately. The animals that were exposed to dope and tetrachlorethane were the only ones affected. Those exposed to tetrachlorethane showed more marked signs and symptoms than those exposed to dope.

Tetrachlorethane $C_2H_2CI_4$ is a colourless liquid with a specific gravity of 1.614 and a boiling point of 147°; it has strong anaesthetic properties, and is a powerful tissue poison, especially selecting and attacking liver and kidney tissues. It is a solvent of resins, is not inflammable, and is commercially fairly cheap. These latter properties, combined with the fact that if tetrachlorethane is eliminated from dope, the resulting coating on the fabric is not nearly so tight, flexible, and durable, explain its value as a constituent of dope. As a rule dope contains about 12 per cent. of tetrachlorethane.

Those employed in doping may suffer from a definite train of signs and symptoms due to inhalation of tetrachlorethane vapour; and it is possible that the toxaemia and tissue changes so set up may end in fatal results. The author has never had any fatal cases, but by bi-weekly inspection of the mechanics employed he has been able to diagnose the early onset of poisoning in some cases. His experience has been that one of the earliest symptoms is loss of appetite with a marked distaste for food, accompanied by constipation, and a feeling of nausea, especially noticed in the early morning. Dr. F. Barlow, on the other hand, insists that pain in the back is one of the earliest symptoms. In his cases this pain was persistent and increased in severity as the day went on so that in some cases work had to be interrupted. The urine as a rule becomes darker in colour each day, and albumen may be noted. A common symptom is dryness of the mouth and a peculiar taste at the back of the throat, whilst the tongue is usually noted to be heavily coated. Malaise, drowsiness, and gradually increasing weakness follow. Headaches may be prominent among these symptoms. Jaundice sets in, is progressive, and is usually noticed first by the worker's comrades. The stools become clay-coloured, and vague abdominal pains, tenderness and feeling of heaviness over the hepatic area may be found. If the patient is at this stage removed from doping and appropriately treated all signs and symptoms may disappear. The clearing up is gradual, and may take some weeks. On the other hand if doping is continued the signs and symptoms increase in severity; the jaundice is progressive, there is increasing weakness, itching of the skin, vertigo, and delirium, and the patient passes into a comatose state and finally death ensues. Willcox, in his valuable work on

Dope Poisoning, noted in the early stage of the disease a slight enlargement of the liver with later on a contraction; bile, a trace of albumen and numerous casts in the urine, but no acetone or diacetic acid. He states that if marked jaundice is present the prognosis is bad, and points out the following interesting clinical and diagnostic features.

(*a*) The insidious onset of the symptoms.

(*b*) The comparatively long duration of the acute stage when marked jaundice has supervened, thus distinguishing the cases from acute yellow atrophy of the liver.

(*c*) The absence of marked pyrexia, thus distinguishing the cases from infective jaundice.

(*d*) The absence of anaemia, thus distinguishing the cases from poisoning by poisons which cause marked blood destruction, *e.g.* arseniuretted hydrogen.

(*e*) The marked character of the jaundice, which is much deeper than is usually seen in cases of delayed chloroform poisoning.

Barlow raises the question that there may be a pseudo form of dope poisoning of a hysterical or auto-suggested type, especially amongst female workers. In Germany quite a distinct type of dope poisoning was noted, chiefly characterised by nervous symptoms, such as headache, tremor, numbness, etc.

Many individuals have worked at doping for quite long periods without being affected; and there is no doubt that some are much more susceptible than others to the poisonous effects of tetrachlorethane.

The pathological aspects of dope poisoning have been investigated by Dr. B. H. Spilsbury, both in the human body and in animals. In one case the internal organs were found bile stained, whilst this was absent in other two cases. The chief pathological changes were found in the liver, kidneys, and heart; and the changes found especially in the liver varied with the duration of the disease. Microscopically there was found fatty degeneration of liver cells commencing in the central zones and spreading peripherally through the lobules and followed by necrosis. Depending on the duration of the disease the necrosis was followed by fibrosis—an attempt at repair—but the fibrotic changes so interfered with the function of the liver that a fatal result ensued. The heart showed dilatation and fatty degeneration of the cardiac muscle. The kidneys were enlarged, and fatty degeneration had occurred.

Treatment.—As these cases show symptoms similar to acidosis, Barlow treats them by attempting to obtain alkaline saturation of the tissues—an alkaline mixture is ordered, containing sod. bicarb., magnes. carb., bismuth carb., and liquid paraffin. The patient is removed from doping, put to bed on a milk diet, and given saline aperients. The patient should not be allowed to return to work, if at all, until at least a month after the complete disappearance of the jaundice.

Prophylaxis.—This is of the utmost importance, considering the seriousness of the disease. In selecting mechanics for this work the medical officer should see that they are all healthy and that they are dentally clean. These workers should be inspected twice a week or oftener if possible—a special dope book should be kept in which the examination results are noted each time. There is no reason why a prophylactic dose of sodium bicarbonate and glucose should not be given to these dope workers each day. They should also be instructed as to the necessity of preventing constipation. They should be given a short lecture on the salient points connected with dope poisoning so that they can take all precautions and report immediately if they feel out of sorts. The author has never found any of the mechanics employed in doping abuse this knowledge.

There should be a special doping shed, fitted with exhaust fans at the ground level, so as to carry off the dope vapour, which is heavier than air. The doping of a plane should be begun at the end nearest the fan—no other work should be carried out in the doping shed—and strict orders should be issued that no meals are to be eaten there. If weather permits doping is better carried on out of doors in the summer-time.

If possible it is better from the administrative point of view not to allow a certain batch of mechanics to work at doping over too long a period, but to have them, say after a two months' spell, detailed for other work, and a new batch put on doping, thus working in bi-monthly relays.

GLOSSARY OF AVIATION TERMS

Aerobatics.—The performance of trick or exhibition-flying, such as looping, spinning, rolling, cartwheels, etc., also known as stunting.

Aeroplane.—A heavier-than-air flying machine, supported by the action of air on fixed planes.

Ailerons.—Hinged flaps, at the trailing edge of the wing tips, and part of the main planes. They are used to maintain the aeroplane on a level keel, and to bank the aeroplane in turning. They are put in use by movements of the control lever.

Air Pocket.—A disturbance in the air causing the machine to undergo a bump or drop.

Air Speed.—The speed of the machine through the air.

Air Speed Indicator.—An instrument for registering the speed of the machine through the air.

Altimeter.—An instrument for indicating the height of the machine from the ground where it started from.

Backwash.—The disturbed air in the wake of a machine in flight.

Bank, To.—To raise one wing for the purpose of turning.

Belt.—The harness or strap used for keeping the pilot secure in his seat.

Biplane.—An aeroplane fitted with two pairs of wings; a monoplane has one pair; a triplane, three pairs.

Bumps.—The sudden rise or fall of an aeroplane when it passes through disturbances in the air such as air pockets or currents. Usually experienced at comparatively low heights and also at mid-day.

Cabre.—Flying with the aeroplane's tail slightly down.

Chocks.—Wooden blocks placed in front of the wheels of a machine to prevent it moving when the engine is started.

Cockpit.—The part of the aeroplane in which the pilot or observer is seated.

Conk.—The engine is said to "conk" when it misfires and fails.

Contact.—Word used to denote that the switch is on.

Control Lever.—This is a vertical lever in the centre of the pilot's cockpit by means of which he controls the fore and aft and lateral movements of the aeroplane. It is commonly called the "joy stick."

Control Wires.—Wires connecting the rudder bar and control lever with their respective controlling surfaces.

Crash, A.—A flying accident in which an aeroplane is so badly damaged that it has to be deleted or sent to the workshops for repair and rebuilding.

Crash Helmet.—A flying headgear, with a stiffened raised crown and projecting edge, in order to prevent head injuries in the event of a crash.

Dive.—When the aeroplane descends steeply.

Dope.—A varnish used to render the fabric of aeroplane wings impervious to air and moisture.

Dual Control.—A double set of controls, acting in unison, fitted in an aeroplane, one for the instructor and one for the pupil.

Fin.—A small fixed vertical plane fitted in front of the rudder to render the aeroplane more stable.

Flattening Out.—This occurs at the end of a glide preparatory to making a landing. The pilot by means of the control lever gradually decreases the aeroplane's gliding angle, until it is level with the ground. This should occur a few inches from the ground. If the act of flattening out is performed too late, the machine hits the ground forcibly, and either bounces into the air or turns over. If performed too soon the machine loses flying speed too high up, and falls to the ground out of control.

Flying Speed.—The speed of a machine through the air necessary to maintain its support.

Forced Landing.—When a pilot has to land through engine failure.

Fuselage.—The body of a tractor machine.

Gadget.—A term applied to any instrument attached to an aeroplane.

Glide.—To descend with the engine cut off with the machine under control and at approximately the flying level speed.

Gliding Angle.—The angle that the fore-and-aft line of the machine makes with the horizon in order to make a correct gliding descent.

Ground Speed.—The speed of the machine relative to the ground, which may be equal to, greater, or less than the air speed.

HANGAR.—A shed for housing aeroplanes.

HAM HANDED—HEAVY HANDED.—A pupil is said to be such when controlling an aeroplane he makes rather forced and jerky movements. He lacks the finely co-ordinated movements necessary for flying.

HOIK.—This occurs when a machine is made to suddenly climb steeply.

INSTRUMENT BOARD.—This is situated in front of the pilot and has attached to it the compass, spirit level, altimeter, inclinometer, clock, and revolution counter.

INCLINOMETER.—An instrument in use which reveals the angle of the aeroplane to the ground in a fore and aft direction.

LOOP.—An aerial manœuvre in which the aeroplane is made to perform an upward and backward turn, and emerge from it flying level.

MACHINE.—Often used to denote the whole aeroplane.

NACELLE.—A boat-shaped body in some aeroplanes, usually but not necessarily of the propeller or pusher type.

NOSE.—The front part of a machine.

NOSE DIVE.—A very steep descent with or without engine.

NOSE HEAVY.—Backward pressure required on the control level to make the machine fly level.

PANCAKE.—The term applied when a machine after losing flying speed, drops level to earth from a height of a few feet. This occurs through flattening out too soon.

PILOT.—The individual who works the aeroplane's controls. Pilot aviator is a better term or simply aviator.

PROPELLER.—The airscrew driven by the engine which forces the machine through the air. Also known as the "prop," the breeze club, or wind stick.

PROPELLER OR PUSHER TYPE.—An aeroplane with the engine and propeller fitted behind the main planes.

ROLL.—An aerial manœuvre in which the machine is made to turn over sideways in a circle, and then continue flying straight as before.

RUDDER.—A vertical controlling surface set parallel with the fore and aft line of the aeroplane, and situated at the latter's tail. It is controlled by the pilot working the rudder bar, and its function is to steer the machine to right or left.

RUDDER BAR.—A cross bar attached to the rudder by control wires, and controlled by the pilot's feet.

SCOUT.—A small single-seater machine.

SIDESLIP.—A sideways movement of a machine through the air either outwards or inwards.

SHOCK ABSORBERS.—Devices for taking the shock of the machine in landing.

SKID.—An inclined portion of the undercarriage or attachment to the tail which helps to take the shock of landing and drags along the ground in doing so, thus slowing up the machine.

SLIPSTREAM OF PROPELLER.—The " wash " set up in the wake of a revolving propeller.

SOGGY.—Slow on the control and heavy to handle.

SPAN.—The measurement of a machine transversely from wing tip to wing tip.

SPIN, OR SPINNING NOSE DIVE.—To go round and round in a small circle with the nose of the machine pointing directly downwards. A corkscrew descent.

SPIRAL.—A steeply-banked, continuous-gliding turn (with engine off).

STABILITY.—The property of a machine whereby it tends to return to its normal flying position if left uncontrolled.

STALL.—To lose flying speed.

STREAMLINE.—A shape designed to offer the least resistance to the passage of a body through the air.

STRUTS.—Wooden uprights uniting the upper and lower planes.

STUNTS.—See Aerobatics.

SWITCH.—An apparatus for cutting off and on the electric current to the sparking plugs.

TAIL-HEAVY.—A machine requiring the control lever always kept forward a little in order to maintain level flight.

TAXYING.—This occurs when an aeroplane is made to travel on the ground by means of its own engine.

THROTTLE.—A device for controlling the amount of explosive mixture entering an engine.

TO TAKE A TICKET.—An aviator's certificate granted by the Fédération Aeronautique Internationale.

TORQUE.—An automatic action of the propeller making the whole aeroplane, while in flight, tend to rotate around its longitudinal axis. This action is in the opposite way to that in which the propeller is revolving.

TRACTOR.—A machine in which the propeller is fitted in front of the main planes.

TRAILING EDGE.—The rear edge of the wing.

Trestle.—Wooden frames or scaffolds designed to support the tail or wings of a machine when repairs are being carried out.

Triplane.—An aeroplane with three pairs of wings, set one above the other.

Trueing Up.—Adjusting the rigging of a machine so as to correct its balance in the air.

Undercarriage or Underchassis.—That part of a machine which carries the weight of the aeroplane on the ground, and also takes the shock of landing.

Vertical Bank.—A loosely-applied phrase referring to any bank over 45 degrees.

Very's Light.—A coloured light fired as a signal from a special form of pistol.

Volplane.—A glide.

Windscreen.—A transparent screen mounted in front of the pilot and passenger to shield them from the rush of air by the machine in motion.

Wings.—The planes or chief surfaces of support.

Zoom.—To ascend very steeply after flying level at full speed.

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