Canadian Research in Aviation Medicine

By C. B. Stewart,

During World War II there was a tremendous increase in the number of men flying at high altitude and in high speed aircraft. This greatly magnified some medical problems which had formerly been of minor importance, and added new hazards never before experienced by man. Numerous Canadian scientists of widely varied background, training and interest were engaged throughout the war period in a concerted effort to solve these problems. A complete account of their work would require a large volume; over one thousand scientific reports have been written. In this article only a very brief description will be attempted of the fields in which Canadian scientists worked and the more important contributions which they made.

Aviation medicine is not, as some have said, a new specialty which sprang into being during the World War II. Extensive and valuable research into the special medical problems of flyers had been carried on between 1914 and 1920. Much basic scientific work had been done and many practical problems solved. But after 1920 medical research workers had other interests. No new work in aviation medicine was reported in scientific literature between 1921 and 1933. In the latter year several significant changes took place in various parts of the world and expecially in the government of Germany. It is not surprising that reports of an increasing interest in aviation medicine began to come from that country within the next few years. Yet, in 1938, there were fewer than a dozen persons engaged in this field of research in the United States and none in Canada.

In 1938 Sir Frederick Banting became interested in the medical problems associated with flight after discussions with Major A. A. James of the R.C.A.M.C., who had for some time been trying to stimulate research in this field. Largely through the efforts of Dr. Banting an inter-departmental committee was established in Ottawa by the Minister of National Defence. This organization later became the Associate Committee on Aviation Medical Research of the National Research Council, with Sir Frederick as Chairman. Financial assistance was given to interested research groups to purchase or construct the special equipment required for many of the aviation medical studies. When war came in September, 1939, the nucleus of an aviation medical research team was already in existence and equipment available or in process of construction. Some of this equipment was of totally new design and permitted investigation of problems hitherto almost untouched. As a result, Canadian research workers were more than a year ahead of American groups in some fields.

Investigation of the special problems of flyers is usually called Aviation Medicine, but it is certainly not confined to Medicine alone. Scientists from many fields have added their efforts to those of the specialists in medicine and the medical sciences. In Canada, as elsewhere, it was a cooperative effort. Psychologists, physiologists, biologists, medical clinicians and experienced aircrew studied the problems involved in selecting the right men for training as aircrew. Physicists, engineers, biologists, physiologists, biochemists and textile experts worked together on the design and construction of oxygen equipment, flying clothing and other protective devices. Nutritionists, chemists, bacteriologists and many others added their ideas and their skills to aid in protecting the airmen from the hazards of flight, to help in the prevention of disease, or to improve the efficiency of R.C.A.F. personnel.

Research projects in aviation medicine were organized by several civilian groups

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at Canadian Universities, especially Toronto, McGill, Western Ontario and Alberta. These were aided by financial grants from the National Research Council. Other investigations were undertaken in research units of the R.C.A.F. Medical Branch at Toronto, Regina, Halifax and Montreal. The work of these service and civilian units was correlated under the Associate Committee on Aviation Medical Research, but co-operation was very close in any event. Most of the projects had some civilian and some R.C.A.F. personnel working together. Close liaison was also maintained with the research workers in Great Britain, the United States, Australia and other allied countries.

The first studies were undertaken in the Department of Medical Research of the University of Toronto under the direction of Sir Frederick Banting. Two of the senior members of his staff, Professors G. E. Hall and W. R. Franks were especially interested in aviation medicine, and both later made extensive and valuable contributions to research in this field. Group Captain Hall, D. F. C. and Legion of Merit, was director of the Research Division of the R.C.A.F. Medical Branch from its organization in 1940 until his appointment as Dean of the Faculty of Medicine, University of Western Ontario, in 1944. Wing Commander Franks, O.B.E., was Director of Aviation Medical Research for the R.C.A.F. overseas, from 1941 to 1943, and succeeded Group Captain Hall as Director of the Canadian program in 1944. He has now returned to his position in the Banting and Best Department of Medical Research at the University of Toronto, but is also Consultant Director for the R.C.A.F. Institute of Aviation Medicine.

The design of protective equipment on sound physiological principles occupied the attention of a considerable group of Canadian research scientists. Flying exposes man to environmental conditions that are far beyond the range within which the body is adapted to function. A buffer must be placed between him and the unfavourable environment, or he must have some means of carrying a suitable medium with him. For example, ascent to high altitude involves exposure to progressively decreasing atmospheric pressure, and this results in a smaller amount of available oxygen. The airman must be provided with an additional oxygen supply by a mask on all flights above 10,000 feet. At still higher altitudes, above 25,000 feet, there is a new hazard, that of decompression sickness, as the low pressure permits nitrogen to be evolved into the tissues in the form of bubbles. It is manifested by severe pain in the arms or legs which may make it necessary for the airman to descend to a lower altitude for relief. The newer types of aircraft avoid this danger by having sealed pressurized cabins. The crew inside may be at a pressure equivalent to 10,000 feet when their aircraft is flying at 40,000. Another hazard is the extreme cold which is always encountered at high altitude regardless of season or climate. This is expecially important in military aircraft since the weight of heating equipment must be kept to a minimum to provide a larger bomb load or to permit higher flight. A fighter pilot may leave his base on a hot summer day at 85° F., or a Libyan aerodrome at 110° F., and in five minutes he may be flying in an atmosphere of −20° F. or lower. High speed, noise, vibration, glare, air-sickness and many other factors must also be contended with.

In 1939 the oxygen masks used by British, American and Canadian airmen were very inadequate. They were extremely wasteful of oxygen, and many a mission had to be completed after the supply was all gone. In addition, the cold often made them useless at high altitudes. At 25,000 feet where a man cannot remain conscious for more than a few minutes without oxygen, the external temperature is about -40° F. Most of the military aircraft at that time were unheated or very inadequately warmed. Oxygen masks became caked with ice from the condensed moisture of the expired breath, and frequently the oxygen line was completely blocked. The small amount of moisture always present in commercial oxygen was also a hazard, since ice might block the tiny orifices of the valves on the oxygen cylinders. On the recommendation of Sir Frederick Banting and Dr. G. E. Hall the National Research Council provided the first experimental unit on this continent where the effect of low temperatures and low pressure could be tested simultaneously. This unit was installed at No 1 Clinical Investigation Unit, R.C.A.F., Toronto. The installation consisted of a large cold room in which the temperature could be lowered to -65°F., with a low pressure chamber inside the room in which the pressure could be reduced to the equivalent of 50,000 feet. Studies were conducted jointly by R.C.A.F. personnel and members of several departments of the University of Toronto. The first oxygen mask which did not freeze up at low temperature was designed by this research team in 1941. These masks were used throughout the war on most of the Trans-Atlantic flights by R.A.F. Ferry Command and by R. C. A. F. aircrew in Canada. In addition essential features of the design were incorporated in later British and American models. About the same time a practical method of producing dry oxygen was developed in the Department of Physics of the University of Toronto. Ice blockage of the oxygen pipe lines and valves was prevented, and the solution of the problem was then complete. Another joint project of the Department of Physics and the R. C. A. F. was the development of an "Oxygen Demand Valve." This provided an airman with oxygen in direct proportion to the rate and depth of his respiration, avoiding the earlier waste and providing an automatic increase in oxygen to compensate for any additional needs produced by exercise, cold or other factors.

To this low temperature low pressure chamber at Toronto, American investigators brought equipment and models for testing while similar installations of their own were being built. The scientists of the neighboring countries worked in close harmony on all such problems, and the Canadians were not by any means simply recipients of vital information and methods developed south of the border. The arrangement was one of mutual aid which was of distinct advantage to both.

In the same cold room extensive investigations were carried out on the physiological effects of low temperature on man and protection from the harmful effects. Complete new outfits of clothing for ground-crew and aircrew were scientifically designed and tested to provide the maximum of comfort and efficiency as well as protection from the elements. An excellent electrically heated aircrew suit was developed, which was used in patrol aircraft off the Canadian coasts. Many of the features of its design and the physiological data on which they were based were also used by the air services of our Allies.

High speed results in several serious problems in flying. The body can stand unlimited speed on a straight course, but rapid starting and stopping or any change in direction provide special stresses on the occupant as well as on the aircraft. Much research has been done on the design of safety belts, crash harness and parachute harness, which will hold an airman without themselves causing physical injury on sudden decrease in speed. The protection of pilots on extremely rapid take-off is also important, as in aircraft propelled from the decks of merchant ships. But the most interesting problem of high speed flying is that of "blacking-out". In pulling out of a dive or doing a high speed turn the airman is pushed down against his seat with increasing force and a consequent increase in dead weight. The greater the speed and the smaller the arc of the plane's change of course, the greater will be his increase in weight. The effect of these forces is usually measured in terms of the airman's normal weight, this being represented by the symbol "g". A 150 pound man temporarily weighs 750 pounds at 5g, a 175 pound man 525 pounds at 3g, and so on. Terrific effort is required to move the arms and legs to control the aircraft but a more serious problem is a sudden loss of vision. Under this force the blood becomes so heavy that very little of it gets back from the lower part of the body to the heart. There is then an insufficient supply of oxygen carried to the eyes by the arterial blood and the vision fails. A few seconds later, if the manoeuver is continued, the blood supply to the brain becomes inadequate, and the man collapses. Consciousness and vision return when the pressure is relieved by "levelling off."

In order to study the problem of "blacking-out" more scientifically, the National Research Council financed the design and construction of a human centrifuge, which was installed at No. 1 Clinical Investigation Unit, Toronto. This was the first installation of its kind in any allied country, the only other one being in Germany. This was another vital piece of equipment which would not have been obtained except for the efforts of Dr. Banting. It is very similar in principle to an ordinary laboratory centrifuge. A vertical shaft bears a horizontal arm from which is suspended a car or gondola somewhat resembling an airplane cockpit and large enough to hold a man. When the vertical shaft rotates the car is swung in a circle 32 feet in diameter. The airman inside is pressed down against the seat and experiences the same sensations as occur in high speed manoeuvers in an aircraft. The first practical means of preventing "blacking-out" was a suit containing water-filled bladders over certain areas of the legs and abdomen. It was designed and tested by Wing Commander W. R. Franks, and his associates. Similar suits were later developed in the United States and were much publicized by stories in *Life* and other popular magazines in 1945, while the Canadian and British equipment was still officially rated as "secret." But the initial discovery, freely shared with the services of the allied countries, was made by a Canadian. In addition the American investigators used the Canadian centrifuge to test their first air-filled "anti-g" suits (that is, suits designed to counteract the physical effects of high speed turns and pulling out of power dives), and thereby were enabled to complete them a full year earlier than would otherwise have been possible. Sir Frederick Banting was killed in an airplane crash in Newfoundland while on his way to England to present the details of the Canadian anti-blackout suit to the R.A.F. Wing Commander Franks was already on his way across the Atlantic by ship when his "Chief" was lost.

Many other studies were made on problems relating to the protection of the airman during flight. Non-fogging, wide-vision goggles were designed at No.1 Clinical Investigation Unit to protect the airman's eyes from wind, glare or flash burns in the event of an accident. Rapid methods were developed for detecting small amounts of the insidious carbon monoxide gas, should exhaust fumes find their way into the fuselage. Greatly improved intercommunication equipment was evolved, and helmets to protect against the incessant aircraft noise. Search for a preventive agent against the embarrassing and disabling airsickness occupied the attention of several investigators. They used various types of swings to determine the kinds of motion which may be upsetting to the occupant. Valuable studies to determine the effect of "blacking-out" on the brain were carried out on monkeys at the Montreal Neurological Institute. A pressure-breathing oxygen mask and vest were developed in Toronto which allowed our fighters to reach altitudes higher than 40,000 feet, and to bring down German reconnaissance aircraft whose pressure cabins had hitherto permitted them to fly unharmed above the highest levels which our men could reach without oxygen failure.

After Sir Frederick Banting's tragic death Dr. Duncan Graham, C.B.E., Professor of Medicine, University of Toronto, was appointed Chairman of the Associate Committee on Aviation Medical Research. He had been a member of the Committee from the time of its organization, and was fully acquainted with the work. The aviation medical program in the Department of Medical Research of the University of Toronto, came under the direction of Dr. H. C. Bazett, C.B.E. The Canadian group was especially fortunate in obtaining the services of this outstanding scientist, who was one of the few survivors of the group which first developed research in the new field of aviation medicine during World War I. He obtained leave of absence from his post as Professor of Physiology at the University of Pennsylvania, Philadelphia, to come to Toronto. He was a very active member of the Canadian research group for over two years, then went to England for some months. He finally returned to the United States where his extensive experience from World War I and from the work with Canadian and British groups was of tremendous assistance in the rapidly expanding program of aviation medicine in that country.

Early in 1939 and 1940 considerable emphasis was placed on the development of better methods for the selection of aircrew. Medical standards were appraised, some modified and others discarded. Visual standards are especially important in aviation, and much work was done in this field. Psychologists investigated a number of tests which were designed to differentiate the potentially successful airman from the less promising candidate. Some of the procedures developed by Canadian psychologists proved of definite value. Others were tried and discarded.

In addition to the primary differentiation between potential ground crew and aircrew, selection was necessary for various aircrew positions and for different types of aircraft. For example, pilots of high altitude fighter interceptors, reconnaissance and meteorological aircraft often reached altitudes above 30,000 feet where there was danger of decompression sickness—the agonizing pains in the arms or legs which divers here called "the bends." Early in the war it was also expected that our bomber aircraft would soon be pounding Germany from the stratosphere, and decompression sickness would then threaten increasing numbers of airmen. The first extensive studies undertaken anywhere on altitude decompression sickness were in London, Ontario, and Regina. Low pressure chambers were used to simulate the effects of altitudes of 35,000 to 40,000 feet with occasional hazardous ascents to even greater heights. Much basic information was collected at London on a group of volunteer medical students. In Regina a practical selection procedure was developed which separated the men who were susceptible to decompression sickness from those who had a natural resistance. A unit with twelve low pressure chambers was established at Halifax in 1942 to test all aircrew before they went on to operational flying overseas, and some of the staff of the Regina Unit were transferred to carry out this work. Airmen who were resistant to the "bends" were recommended for the extremely high altitude aircraft, and those who were susceptible were suitable for aircraft that did not usually fly above 25,000 feet. As the air war progressed and tactics changed, it became obvious that the majority of flyers would not reach "bends" altitudes, and selection was then limited to the prospective crews of stratosphere aircraft. The major part of the selection methods worked out by the Canadian group was adopted by the R.A.F. as well. A tremendous amount of work was also done on the prevention of this condition in susceptible men, the results of which will continue to be of value to divers and other compressed air workers as well as to stratosphere flyers in non-pressurized airplanes.

It might be mentioned that airmen are in a more fortunate situation than divers if they develop the "bends." In an airplane the cure is simple and permanent, consisting merely of a descent of a few thousand feet. But a diver or other compressed air worker develops the pain after he comes to the surface, and for him a descent is not so easy. Compression tanks are usually available wherever extensive work is being done a hight atmospheric pressures. Anyone who develops the "bends" is relieved by increasing the pressure, and then a very slow decompression is necessary to prevent recurrence.

An extremely valuable part of the low pressure chamber program was the training which it gave the airmen in the effects of oxygen lack and the proper use of oxygen equipment. It was very difficult in the early part of the war to convince the airmen that they all needed oxygen when flying above 10,000 feet, because most of them felt absolutely no discomfort. This insidious effect of oxygen lack is its greatest danger. A man flying above 10,000 feet, or in a low pressure chamber, without oxygen will gradually become more stuporous, while all the time insisting in an alcoholic manner that he is perfectly well and capable of any activity. Sudden collapse finally occurs if the oxygen is not provided. A harmless demonstration of the insidiousness of anoxia usually convinced the most hardened sceptic that his oxygen mask was his best friend.

In addition to the studies aimed at developing the best procedures for selecting aircrew personnel and for protecting them with special equipment while in flight, extensive research was also conducted on procedures to be followed and equipment needed in the event of emergencies. Considerable basic physiological research was done on the effect of exposure under different conditions. Emergency kits were designed to aid the crews of crashed aircraft. Extensive field trials of emergency equipment were carried out both in the Canadian northland and at sea.

The R.C.A.F. was the first service to provide its airmen with a satisfactory "ditching suit." Airmen who were forced down at sea—who, in service parlance, "ditched" their airplane—were provided with rubber dinghies which were released and inflated at the touch of a lever. But in the frigid climate of the North Atlantic their survival time was short if they got their flying clothes wet before getting into the dighy, or if forced to stay in the water. In some areas where our patrols were on constant watch a man could live only 10 or 15 minutes if forced down in the water. The answer was provided by a simple, waterproof, rubber-coated nylon suit weighing only a few ounces, that could be donned in a few seconds over all flying gear and drawn tight with a zipper or draw-string at the neck. Tests were made by volunteer airmen and medical research workers in the sea off Halifax in the winter of 1943. The practicability and value of the suit were proven. The men with the suits were still perfectly comfortable, warm and dry, when those without such protection had to be taken off the dinghies to avoid excessively dangerous exposure. But a great deal of work by physiologists, clinicians, textile experts, aircrew men and others had gone into this project before the "simple" solution was found.

Incidentally, while much of the testing of new equipment was done in the laboratories, final trials required human "guinea-pigs." This work was on a voluntary basis. No one was "detailed" by a senior officer. In tribute to the R.C.A.F. airmen it should be reported that there were always far more volunteers than could be used, no matter how unpleasant or dangerous the experiment might be. It might also be mentioned that the scientist did not ask an airman to undertake anything that he had not already tested on himself, usually on more than one occasion.

Extremely valuable research on

night vision was carried out in Montreal. A training unit was developed to allow airmen to increase their proficiency in discerning and identifying objects in very low illumination such as experienced on night flights. Test equipment was also developed to select those with better night vision for aircrew positions where it was most needed.

Studies on the effects of exposure to heat and other tropical conditions were undertaken when it appeared that the R.C.A.F. would send a contingent to the Far East. Excellent work was done throughout the war on preventive medicine by adequate immunizations and other measures. Some of the medical officers in R.C.A.F. hospitals also made great contributions to medical knowledge especially in the treatment of burns, and in plastic surgery.

With the end of the war most of the research personnel, both civilian and R.C.A.F., have returned to peace-time occupations. However, a determined attempt is being made to retain a working unit. The several R.C.A.F. research organizations have been united in the Institute of Aviation Medicine under the direction of Wing Commander W. R. Franks. Headquarters of this unit are at the former No. 1 Clinical Investigation Unit, Toronto, where the major pieces of research equipment are located. But there are provisions also for assisted research grants to universities throughout Canada, and their research workers can have access to neighboring R.C.A.F. establishments and the use of special equipment. The Institute of Aviation Medicine has a research plant which is unsurpassed on this continent or elsewhere. Facilities include the human centrifuge, in which any high speed manoeuvers can be duplicated; low pressure chambers, where altitudes as high as 50,000 feet can be simulated; the combined cold room and low pressure chamber, already described; a sonic laboratory with simulated aircraft noise of 120 decibels, where physiological effects of noise can be studied and intercommunication equipment tested; a tropical room, where temperatures as high as 160° F. and a very wide range of humidity can be duplicated; a pool for testing flotation jackets, etc.; a laboratory, well-equipped for biochemistry and bacteriology; and many other sections. There are ample facilities for extensive physiological and medical investigations, and it is hoped that the equipment will be used to full advantage. It will be equally available for basic scientific research and for problems of immediate practical importance.

If we should judge the future in the light of the past, we might not be too optimistic regarding aviation medical research. But it is to be hoped that the complete cessation of activity which occurred after World War I will not be repeated. Many exceedingly important and practical problems are still unsolved and require close collaboration between the physician, physiologist, and biochemist on one hand and the aeronautical engineer and physicist on the other. We, in Canada, have the facilities to make a worthwhile contribution. Our scientists solved or aided in the solution of many problems of aviation medicine during the war. Their record has been applauded by their American and British allies. The future holds considerable promise that other problems of peace-time aviation medicine will be solved, and long range investigations undertaken, which had to be "shelved" during the war.

We all hope that there will never be another great war, but if it does come, success will depend on the knowledge and equipment developed by basic and applied research during the intervening period. In any event the knowledge gained by a continuation of research in aviation medicine will have direct and important bearing upon our Canadian peace-time flying program, which is growing and should continue to develop with our great northern country.