AIR SERVICE MEDICAL

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DIVISION OF MILITARY AERONAUTICS
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WHERE PHYSICAL FITNESS, MENTAL ALERTNESS, AND MORAL COURAGE ARE ABSOLUTELY ESSENTIAL.

GIFT

PREFACE.

In each of the countries at war there is a fully established Air Medical Service. Early in the development of the Aviation Service of our Allies. and even earlier in the German Air Service. it was found essential to create a medical department as an integral part of the Air Force. The French and the Italians for the past year have had well-organized Air Medical Services, which include in their personnel many of the foremost specialists of these respective countries. The British, whose Royal Air Force exists as a separate arm of the service, have a separate Air Medical Service with a Surgeon General of Aeronautics. In our own Service, this work has been effectively handled by a division of the Surgeon General's Office, assigned as a part of the Division of Military Aeronautics.

Aviation is new, and the Air Medical Service even newer; so that for educational purposes the director of Military Aeronautics deemed it advisable to issue this book. Its object is to set forth Aviation's debt to Medicine and to make clear the part played by the Air Medical Service in the "winning of the war in the air."

The book is presented in two parts. Part I is a shorter statement of the essential facts which are of immediate general interest. Part II goes into greater detail and is for the information of those who belong to the Air Medical Service or of those who desire to make a more thorough study of this new work.

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CONTENTS

PART I.

PART II.

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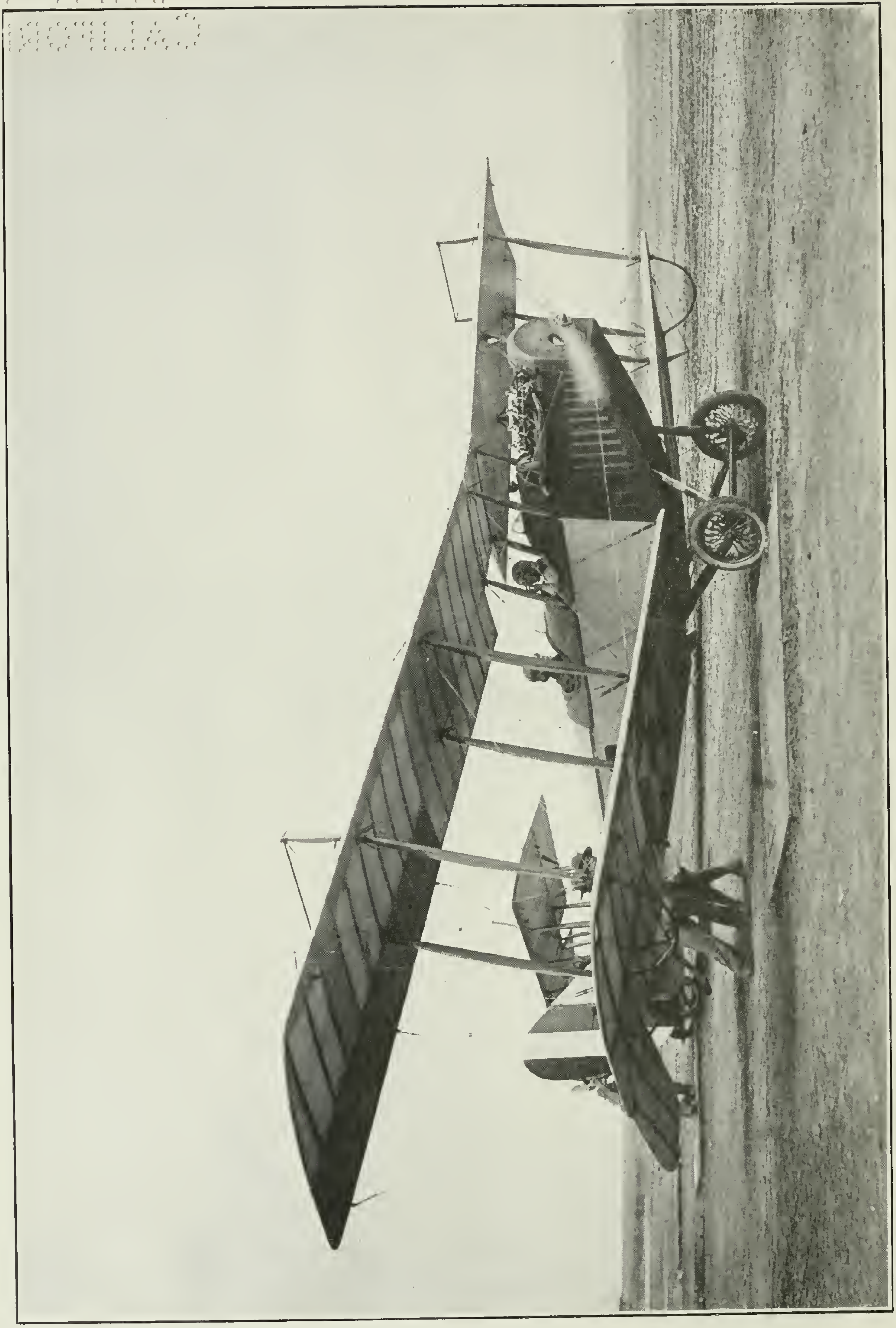
CALIFORNIA



PART I.

CHAPTER I.

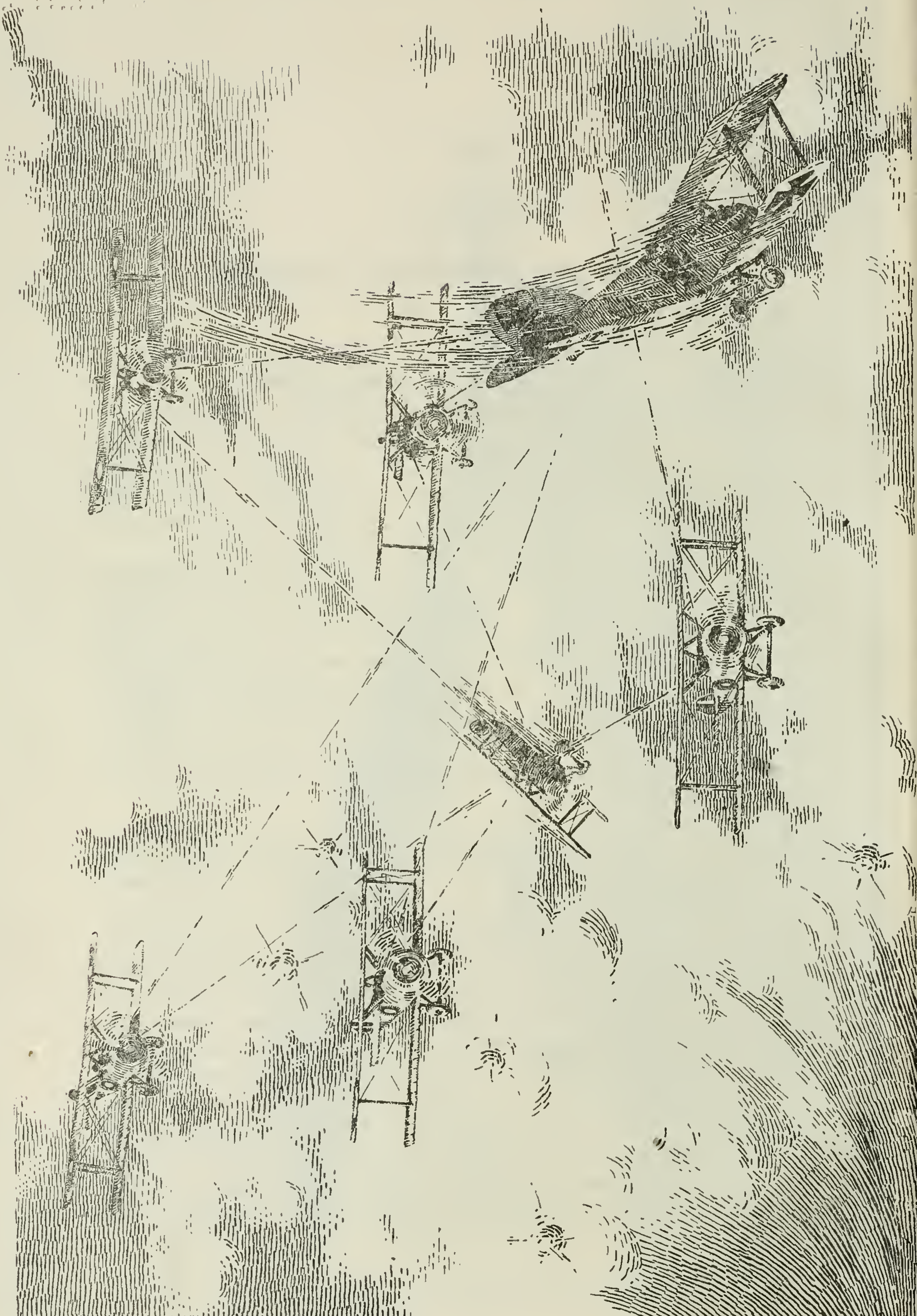
AVIATION AND ITS MEDICAL PROBLEMS.

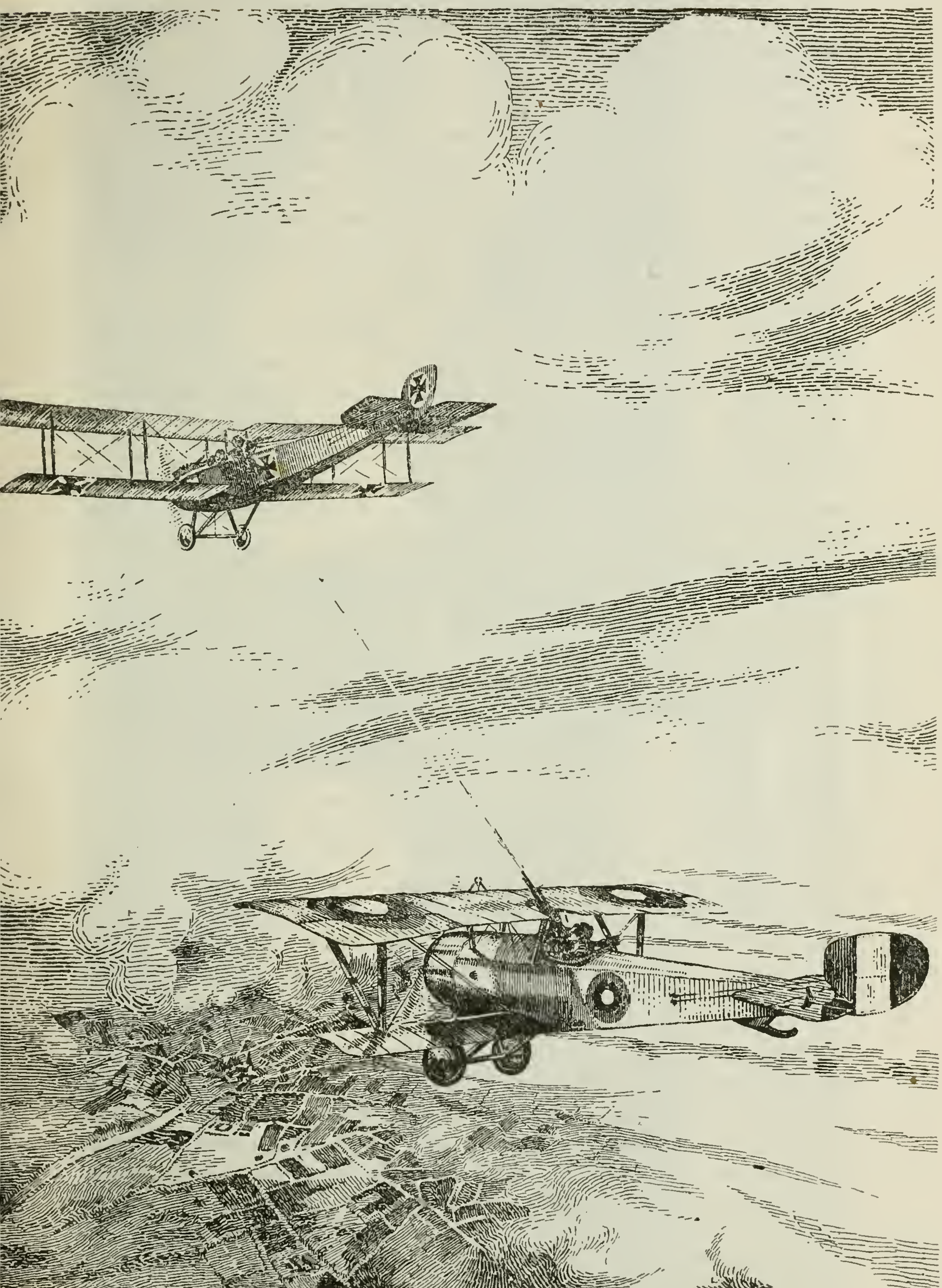
Wonderful has been the development of the airplane—inconceivable has been the neglect of the MAN in the airplane.

Aviation began in the United States of America. The genius of Langley, Chanute, and the Wright brothers made it possible to maintain in the air a machine heavier than air. Starting as a scientific experiment, aviation has developed with such gigantic strides that to-day, in the defense of our Nation, the Air Force has a place comparable in fighting importance with the land and sea forces.

Ever since the time that man lived in a cave and was obliged to chase his food or be chased by it, he has dreamed of flying. He has racked his brain and bruised his body in futile attempts to emulate the bird. At various stages in his history we see him climbing to the top of precipices, trees, bridges and houses, and from these heights projecting himself into space, with nothing to break his fall except a modified kite, parachute, or some similar contrivance, and landing below with many regrets and broken bones. Gravitation was not to be defied by such rudimentary methods.

Through all time man has been speeding up. The savage, finding himself upon a snow-capped height and desiring to go to the valley below, was wont to set himself upon a piece of bark and slide down to his destination; or, desiring to go down the valley, he stepped into a hollow log and shot the rapids of some swiftly flowing stream. Desiring to cross the plain, he subjugated the horse and used him as a more rapid means of transportation. Later on civilized man, astride a pair of wheels, propelled himself along the highway by means of a mechanical device. Then the steam engine was invented, and with it the steamboat and locomotive, which enabled man to travel with increased speed. The electric trolley car appeared soon after the perfection of the electric motor. Eventually came the gas engine, and with that the automobile, capable of even greater velocity. It is not surprising that in the United States, the least mature of the progressive nations of the world, this speed mania broke all bounds



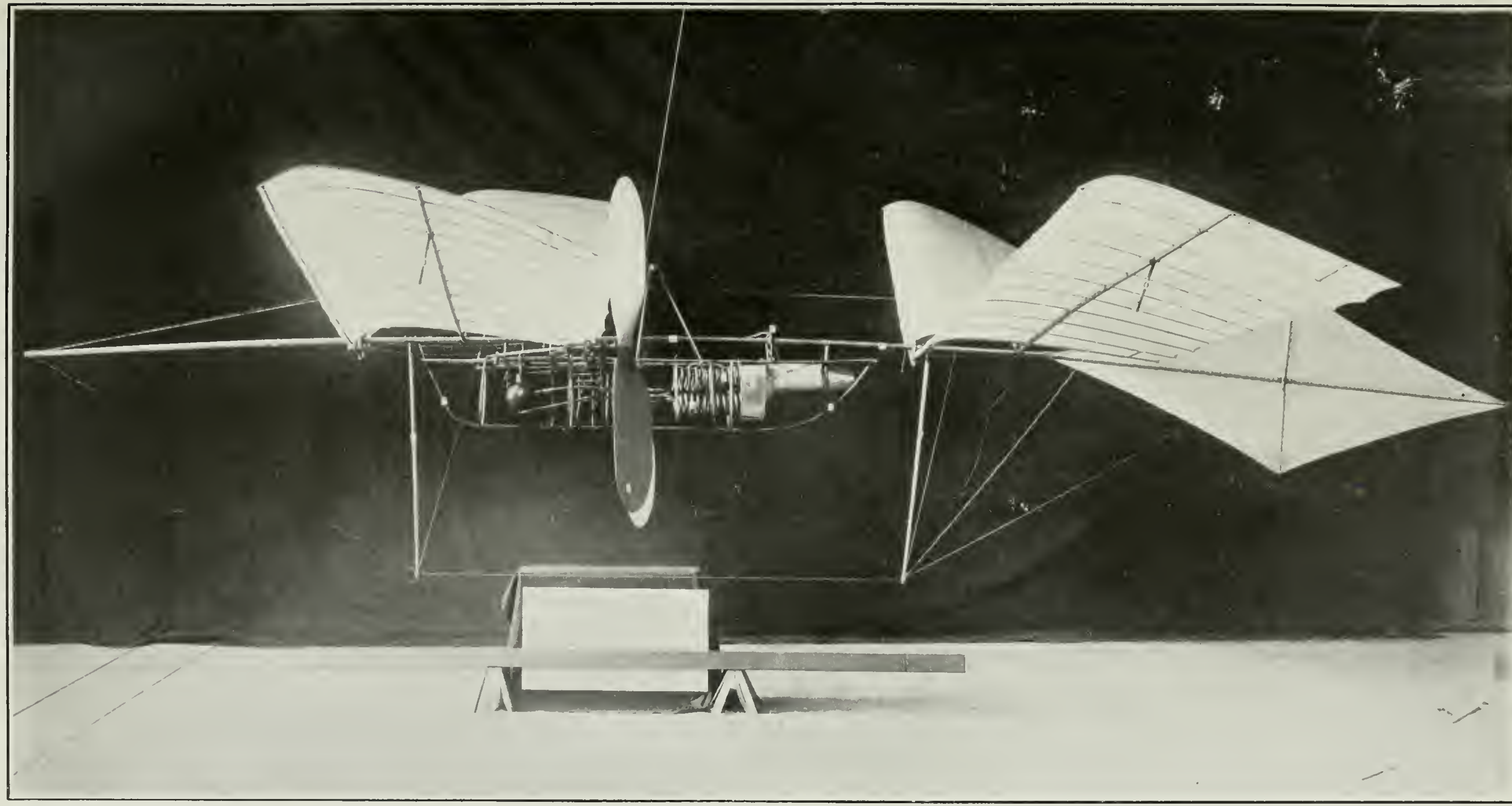


A SITTER.

and man flew off at a tangent into space. The Wright airplane had set a new pace.

Each new mode of travel has evolved its own new and peculiar human ills and medical problems. Reverting to the savage, we can picture a new variety of accidents coincident with rudimentary tobogganing. With water transportation came seasickness and drowning, with the various methods of resuscitation. Railroading developed a new category of ills, from caisson disease to "railroad spine;" railroad signaling emphasized the importance of normal color perception. With the development of the electric railway there opened up a new chapter of ills in the form of electric shocks and burns. With the gas engine came Colle's fractures from cranking and an increasing number of collision accidents with the ever-increasing speed. Now with the airplane come the new problems of air-sickness, oxygen-want, and the unprecedented demands on the special senses, the nervous system, and the heart.

While American genius made possible the birth of the airplane, its extraordinary development in such a short space of time is directly due to the drive of necessity arising from actual warfare in Europe. Prof. Langley's theories of heavier-than-air machines were correct; the producers of airplanes have converted them into realities. After the appearance of the Wright biplane, however, flying in this country made little progress; we Americans were slow to appreciate the possibilities of this new invention. The Wright brothers took their machine to Europe, where an immediate keen interest developed in its sporting possibilities, which appealed particularly to the French, Italians and English. The German, ever watchful of anything calculated to enhance the value of his war equipment, immediately took notice and began airplane experiments. Thus the French, Italian and English interest had its root in the appeal of the plane to sporting instinct; the German interest, on the other hand, sprang from "Kultur," in recognition of its possibilities as an additional weapon of war. The development of the airplane among the Allies is a story of sportsmanship; among the Germans it is part of the secret annals of war preparation. During the early stages of the war air superiority lay with the Germans and was represented mainly by their development of the Zeppelin. During this period the Germans placed their trust in the lighter-than-air type of machine; at the same time they did not neglect the heavier-than-air type. It was not until 1916 that, under the spur of war conditions, both belligerents came to a full realization of the immense possibilities of the airplane as a factor in battle. It is, therefore, the other nations who have developed the airplane, and we now look to these nations for advice and instruction in aeronautics; it is a case of the pioneer taking the position of a novice in his own field of endeavor.



LANGLEY STEAM-DRIVEN AERODROME WHICH MADE NEAR QUANTICO, VA., MAY 6, 1896, THE FIRST SUSTAINED FLIGHTS UNDER ITS OWN POWER EVER MADE BY A HEAVIER-THAN-AIR FLYING MACHINE.

LANGLEY STEAM-DRIVEN AERODROME IN FLIGHT OVER POTOMAC RIVER NEAR QUANTICO, VA., MAY 6, 1896.

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QUARTER-SIZE GASOLINE MODEL, LANGLEY AERODROME, IN ONE OF ITS FLIGHTS OF AUGUST 8, 1903, ON THE POTOMAC RIVER.

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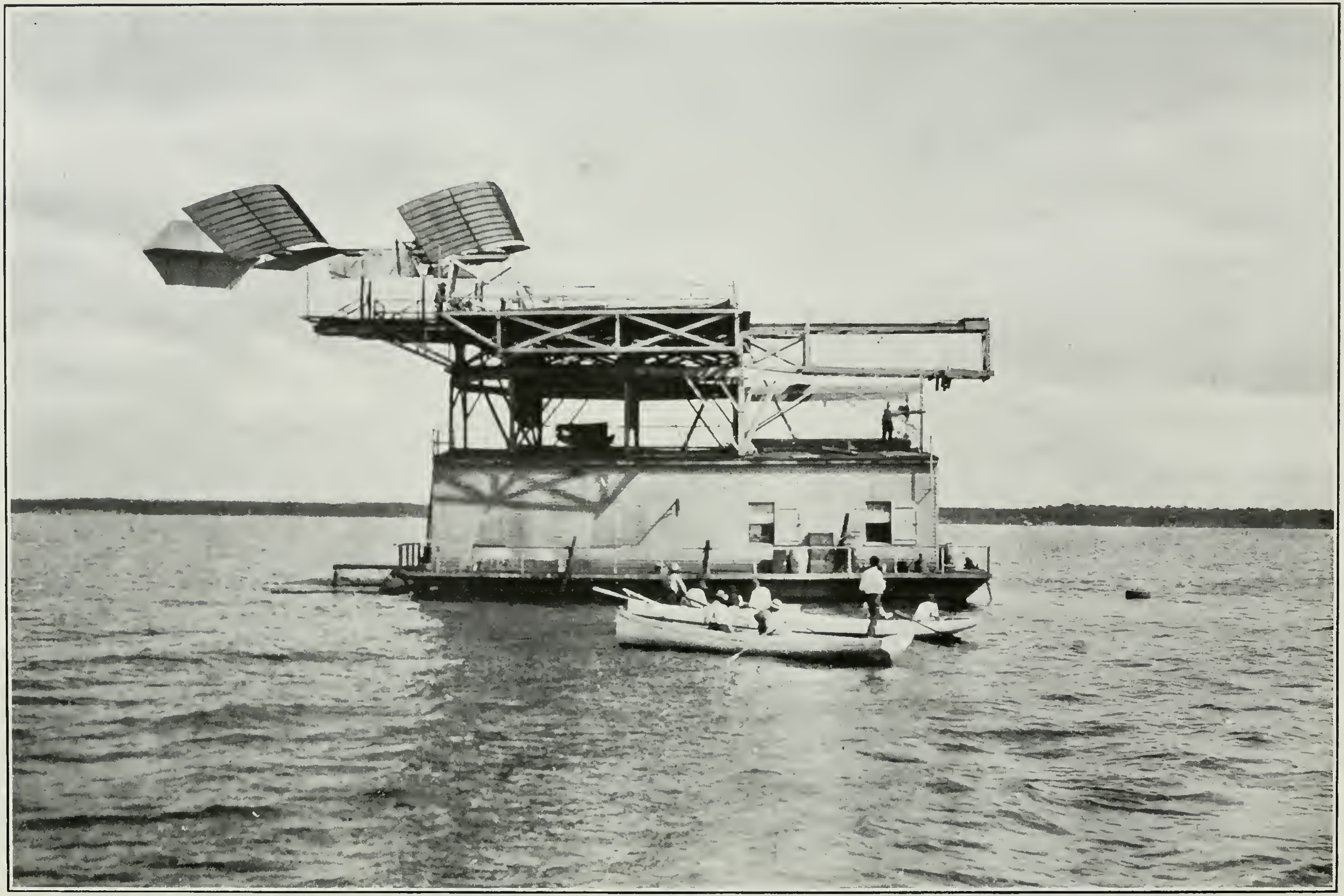
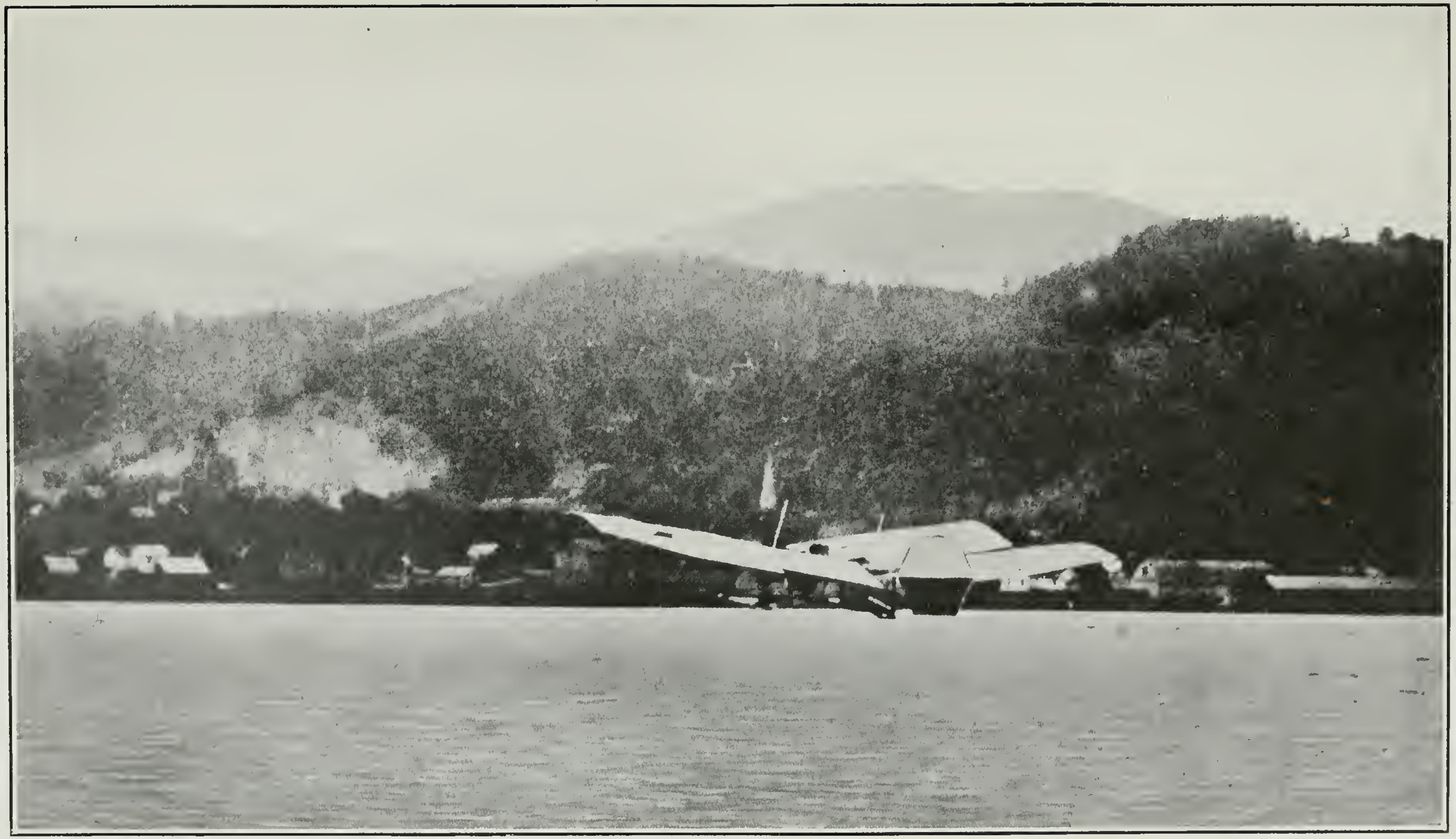


FULL-SIZE MAN-CARRYING FLYING MACHINE READY FOR LAUNCHING, 1903.



FULL-SIZE MAN-CARRYING LANGLEY FLYING MACHINE IN FLIGHT JUNE 2, 1914, OVER LAKE KEUKA, N. Y. FLOWN BY GLENN H. CURTISS.

10a-5

UNIV. OF CALIFORNIA

AIR SQUADRON IN BATTLE FORMATION.

AIR SQUADRON IN BATTLE FORMATION.

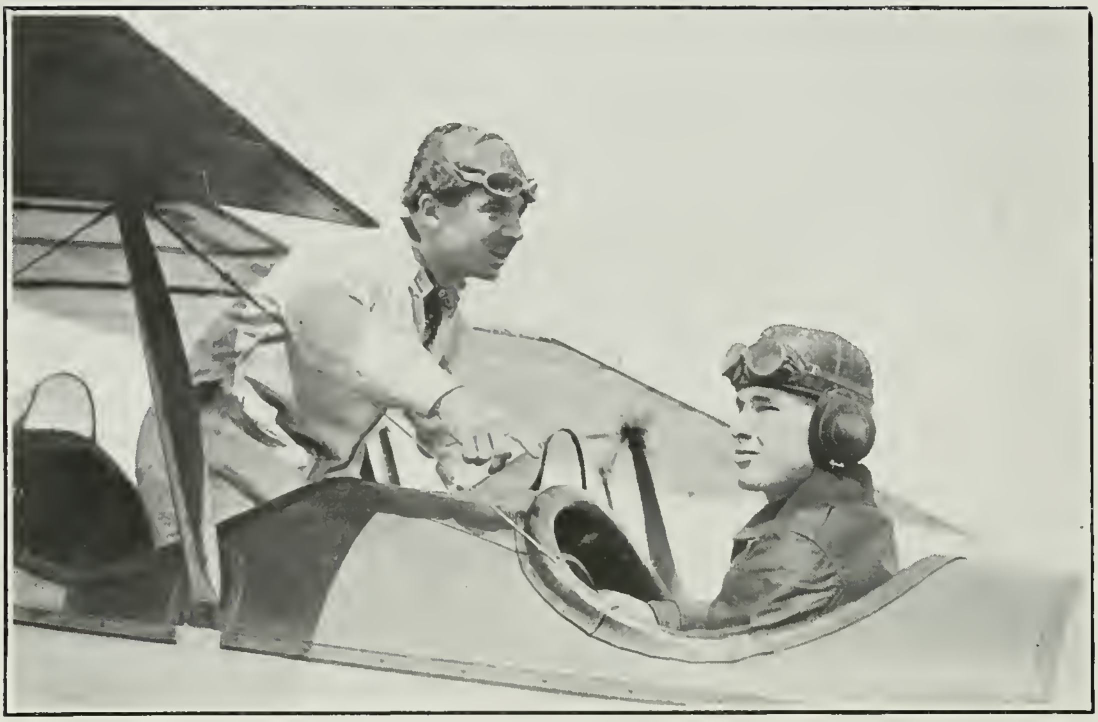
10a-7

AIR SQUADRON IN BATTLE FORMATION.

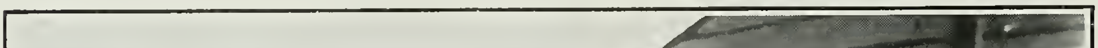
Each pilot must possess a wide field of vision to enable him not only to keep his position with his command but to detect enemy planes which have a habit of slipping up on a pilot for an attack.

CADET APPROACHING PLANE WITH INSTRUCTOR ON HIS FIRST TRIP. THE CADET IS MERELY A PASSENGER.

A CADET AND HIS INSTRUCTOR.

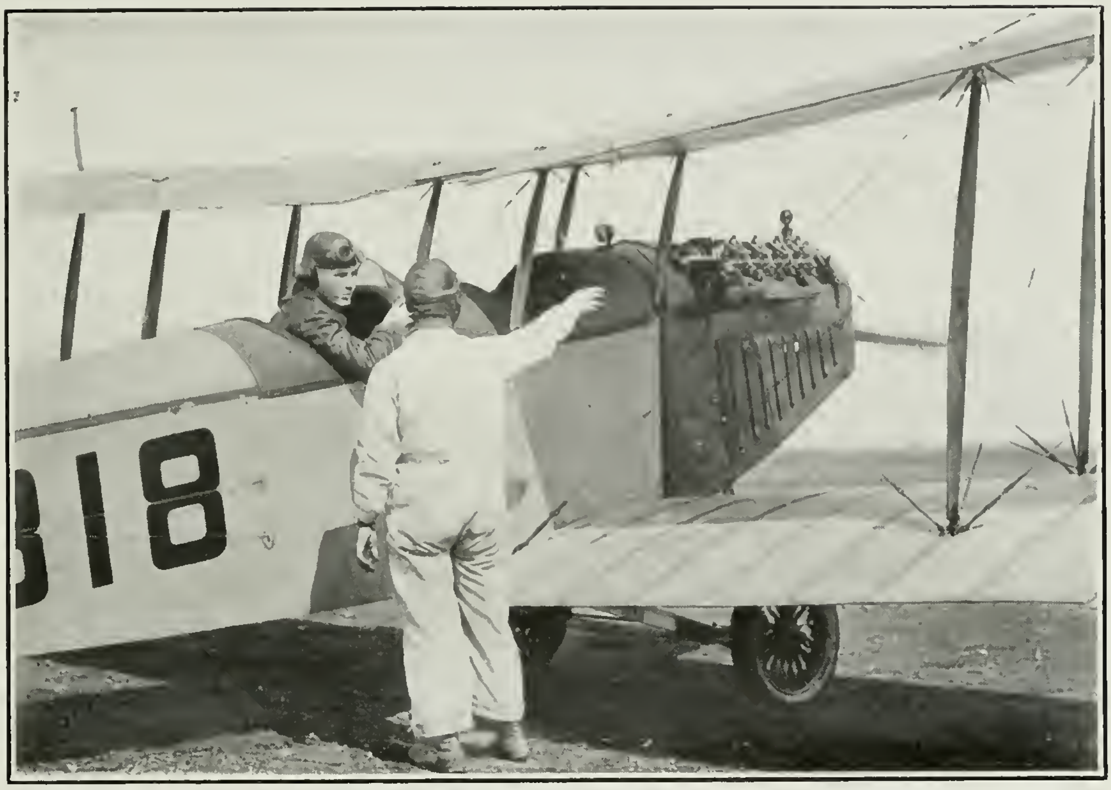


INSTRUCTOR IMPRESSING UPON THE CADET THE USE OF THE RUDDER.



CADET AND INSTRUCTOR IN THE MACHINE.

The instructor is assisting the cadet who is experiencing an air trip for the first time.



CADET RECEIVING FINAL INSTRUCTIONS BEFORE GOING ON A FLIGHT ALONE.

This cadet has completed his preliminary course and is about to start on a solo flight.

STARTING OFF ON A FLIGHT.

10a-11

PILOT AND CADET SLOWLY AND CAREFULLY DESCENDING TO A LANDING PLACE.

CADET DESCENDING FOR HIS FIRST LANDING.

CADET EXPERIENCES FIRST HALF HOUR IN AN AIRPLANE.

The instructor made a perfect landing without bumping, much to the satisfaction of the student.

10a–13

A CADET READY FOR HIS FIRST SOLO FLIGHT.

A CADET AFTER HIS FIRST SOLO FLIGHT.

Having had his first ride he smiles all over upon landing.

10a-14

It is easy to see how the necessity for attention to the physical efficiency of the pilot came to be overlooked; the world over, everyone has been so absorbed in the one effort—to increase the mechanical efficiency of the airplane. Every thought has been directed toward making each successive model safer and faster.

During this period, representing the first two and one-half years of the war, the pilot was not selected because of any peculiar fitness for flying; it was simply a question of whether he "had the nerve." At one time circumstances made it necessary to place men in the Aviation Service who were "all worn out by the more trying work" of the Infantry or Field Artillery. The viewpoint was: "This man is no longer fit for ground fighting; therefore he will do for the air service." The result of this policy was that the average aviator had a very short time of usefulness and there was, to this extent, some truth in the persistent rumor that the "active life of the aviator at the front was only a certain number of hours." There was enormous avoidable wastage. Little by little the Aviation Services of our Allies have come to realize that the advice of their medical officers was sound; the mental and physical requirements for entering the Air Service were raised, with an immediate saving of an unlimited amount of money and personnel. This is the great lesson we have learned from the bitter experience of our Allies.

The popular idea that a flier must be a "superman" is utterly absurd. It would be much nearer the truth to say: "Anyone can fly." Flying itself is now just as prosaic and commonplace as riding in a motor car, and not more dangerous. To consider that the aviator at the front is in greater danger than his brother in the trenches is ridiculous; actual statistics prove that it is far safer in the air. Further than this, instead of living in the filth of the trenches, the fighting pilot returns to a comfortable airdrome well behind the lines, where he sleeps in comfort and one might even say in comparative luxury.

Nevertheless, aviation is not merely spectacular; it does have its unique problems and makes its unique demands upon those in this service. Nature never intended that man should fly. From the time that he leaves the ground until his return, he is living under unnatural conditions. Although it should be emphasized again and again that the flier at the front is safer than the infantryman in the trenches this does not mean that we should belittle the conditions which the aviator faces. He flies in an atmosphere lacking in that oxygen which is the "breath of life"; subjected to the shells of anti-aircraft guns, or encountering enemy aircraft at any moment; with his body at a dizzy height and hurtling through space at the rate of 125 miles an hour—this represents the daily life of the fighting pilot. The aviator himself is serenely unconscious of the effect of these conditions upon his nervous system; he naturally regards it as "all in a day's work." Yet in attaining altitudes and spending much of his time in rarefied air, the flier is defying nature.

The conquest of the air represents man's maximum achievement. There is no combination of wood and wire which is subjected to such a variety and intensity of strain and stress as the airplane; there is no living combination of muscle and nerve which, consciously or unconsciously, may be subjected to such a variety and intensity of strain and stress as the aviator.

To-day thousands of trained mechanics are working day and night upon the engines of our airplanes; thousands of expensively trained riggers and sailmakers are tuning the wires and mending torn fabric; thousands of hangars are provided to house the planes when they are not flying. A striking discrepancy is noted when we look about to see what is being done to take care of that infinitely more delicate organism—the man who flies the machine.

The pilot of the airplane is the heart and brain of the whole flying apparatus. The engine may fail through lack of care, but the pilot brings the machine safely back to the airdrome. A carelessly inspected wire may snap in the air, but nothing serious results. When the pilot breaks, even momentarily, nothing is left to direct the flight, and the plane and engine, no matter how well they have been cared for, crash and are lost.

The mechanic who looks after the troubles of the engine must be an expert. Work like this is not for the mediocre. No less an expert must be that man who supervises the condition of the pilot. Flying, especially in the military service, coupled with the temperament peculiar to the man choosing this kind of work, develops a most extraordinary series of problems and complications. Many an aviator in a short time becomes a subject over which a genius in medicine might easily become discouraged.

The establishment by our forefathers of the West Point Military Academy was a wise forethought. In this institution a curriculum of four years' intensive study prepares our young men for the profession of the soldier. In this war, however, an important and novel military situation has arisen; even West Point does not offer a solution of this problem. The Air Fighting Force is without military precedent to furnish instruction in all its details. The problems of this war on the ground, while new in many aspects, still could be met by the skill of the engineer and the tactician with fundamentals furnished by years of military experience and study. The problems of the present war in the air lack the accumulated experience of previous wars to indicate their solution; those difficulties, which early made it apparent to our Allies that an air-fighting force has its own potentialities of disaster, presented the immediate problems of our Air Service.

To the Air Medical Service the problems were presented of overcoming all those conditions affecting the physical fitness of the man who, leaving his natural environment, the ground, straps wings to his body and soars to heights into which even the eagle dare not go. For work in this unnatural environment only the man who is in every way physically fit should be selected.

When our Air Medical Service was established it was fortunate to have at hand a series of reports of the Air Medical Services of our Allies by medical officers who have attained distinction in the field of scientific research. Birley, Dreyer, Haldane, Flack, Douglas, and Priestly among the British; Nepper, Josue, Lombaert, Guilbert, Garsaux among the French; Gradenigo and Herlitzka among the Italians, had been studying for years the physical deteriorations peculiar to flying which, even early in the war, so emphasized the military importance of this particular problem of the Air Service.

The keynote of the American Air Medical Service is the handling of the flier as an INDIVIDUAL.

During the early part of the war the German method of air fighting was patterned after that of their infantry; the pilot of the machine received his commands and carried them out regardless of changing conditions. The observer in a two-seater machine gave the pilot his orders, just as an infantry officer gave orders to his subordinate. There were only a few picked flying officers, usually of high social position, who were what might be called "sportsmen." The efficiency of the German Air Service was greatly increased in the year 1917 by their allowing a certain freedom of action to their pilots in order to cope with the more speedy allied air-men who had proven individually far superior in action, spirit and initiative. Infantry and cavalry which strike in large numbers must be handled as a single force; they must have coordination and absolute oneness of action or half their effectiveness is lost. The efficiency of such troops is measured by the successful handling of a large striking force as a single unit. The aviator is the rank and file and commanding officer, all in one. The outcome of a reconnaissance flight may determine the fate of thousands on the ground; but it is the flier's individual decision, initiative and action, that spell victory or defeat for him.

The Air Medical Service, devoted as it is entirely to the study of the flier as an individual, naturally falls into three main lines of activity—the Selection of the Flier, the Classification of the Flier, and the Maintenance of the physical efficiency of the Flier. These three branches of the Air Medical Service are presented in concise form in Part I of this book. In Part II is given a fuller discussion of these same subdivisions.

Underlying " Selection " is a full realization that it is possible for a man to fly in spite of one or many handicaps; the object to be attained, however—the defeat of the enemy—demands that only such fliers be sent against him as are the very best air-fighting material—not merely men who are able to fly.

" Classification " is the second step. The flying service is now highly specialized. Men are called upon to perform widely diversified classes of work, such as pursuit, reconnaissance, photography, bomb-dropping and night-flying. Not every aviator, regardless of perfect training and physical fitness, is necessarily fitted for all types of air activities. There is a marked difference in the individual ability to withstand a diminished oxygen supply; this has made it necessary to classify the fliers on an altitude basis. By means of tests applied at the Medical Research Laboratory at Mineola, Long Island, and at the branch laboratories in the various flying schools throughout this country and overseas, fliers are being classified as fitted for low, moderate, and high altitudes, night-flying, and other special types of work.

The " Maintenance " of physical efficiency of the fighting force is the supreme function of the Air Medical Service. There is a sharp contrast between the work of selection and the work of maintenance. In selection the sole object is that all questionable material be *kept out* of the service. In maintenance the great object is that every aviator be *kept in* the service.

When an airplane begins to show signs of trouble, it is taken off the field and put in condition. This is the only way to keep a plane in commission. When the flier shows the first signs of staleness, of nervous exhaustion, or of digestive disturbance he must be " overhauled " by a medical expert. That distinctly American product—the Flight Surgeon—bears the same relation to the flier that the mechanical expert bears to the airplane.

The airplane is in need of frequent overhauling; the flier even more. The secret of prolonged usefulness of any aviator is that he be kept constantly fit. The Flight Surgeon, by both old and new diagnostic methods, supplemented by his knowledge of the peculiarities of the individual flier, is able to detect very early, the signs of deterioration. The corrective measures to be applied will belong to one of three classes. They are medical, physical, and what we may term nutritional. The medical needs constitute especially the problem of the Flight Surgeon. In order to supplement his work and take care of the physical needs of the flier, there have been secured for the Aviation Service the services of experienced college trainers. These men have been given a course of instruction covering the special aspects of physical training as it applies to the care of the flier, and have then—as Physical Directors—been sent out to each flying field to assist the

Flight Surgeon. These Physical Directors fill a special need in the work of " maintenance " in that they bring to this service the practical experience already derived from the handling of athletes in colleges or athletic clubs.

In order to handle most successfully the third class, namely, nutritional problems, the services of the Nutrition Officer are required. The Nutrition Officer must be a man well trained in the knowledge of food values in relation to the body and he, under direction of the Flight Surgeon, is charged with not only the problem of the proper feeding of the normal flier, but especially of the flier suffering transitory digestive disturbance—a type of defect that affects greatly the efficiency of the flier when in the air.

The work of the Air Medical Service reached its culmination with the placing of a Flight Surgeon in each flying school in the United States where his work in the " care of the flier " has been but a preparation for the larger service to the aviator who is actually on the fighting front overseas. It is only through the complete Flight Surgeon Service, including those features supplied by the Physical Director and the Nutrition Officer, that the flier may be maintained at his full efficiency in active service.

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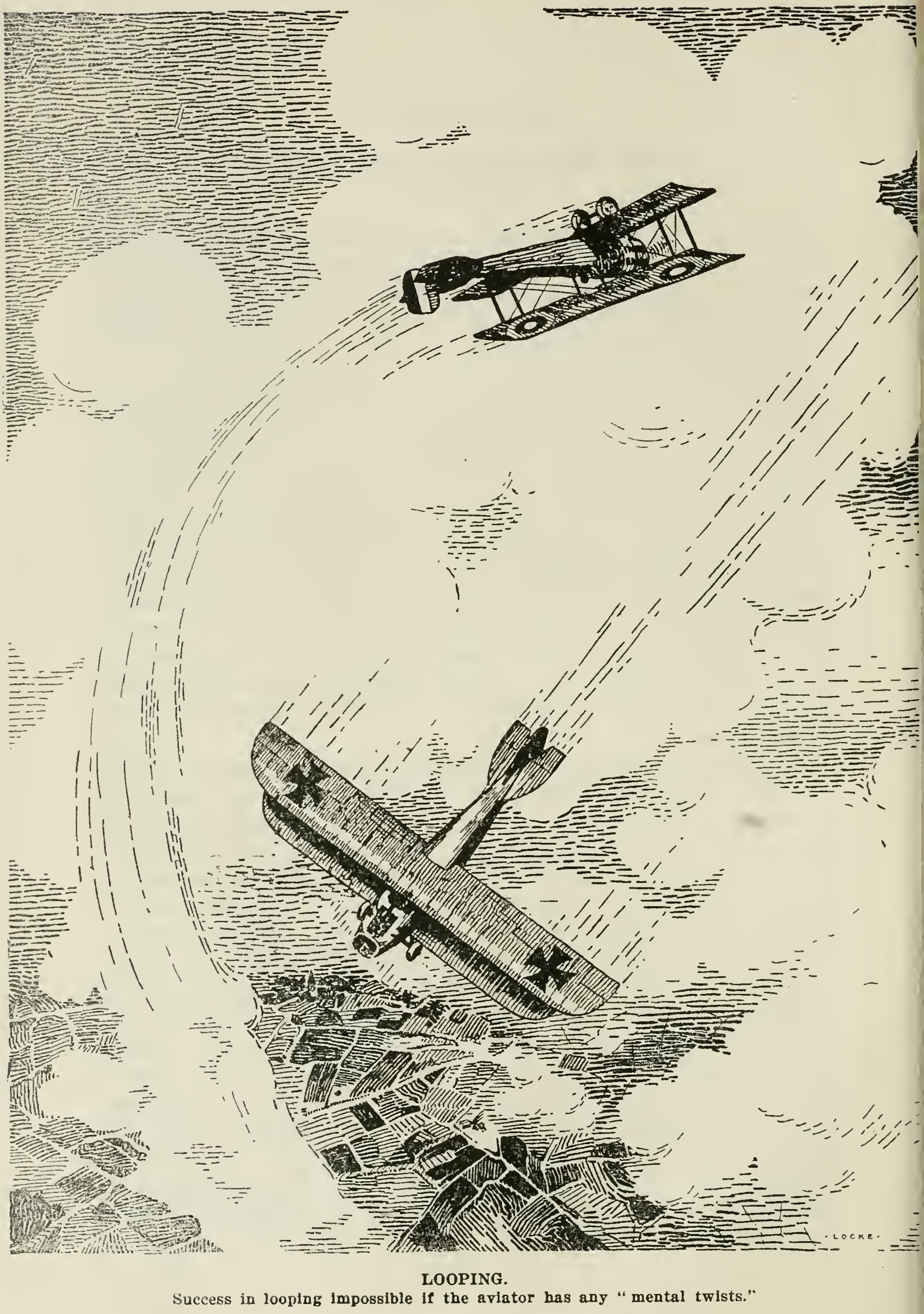
CHAPTER II.

THE SELECTION OF THE FLIER.

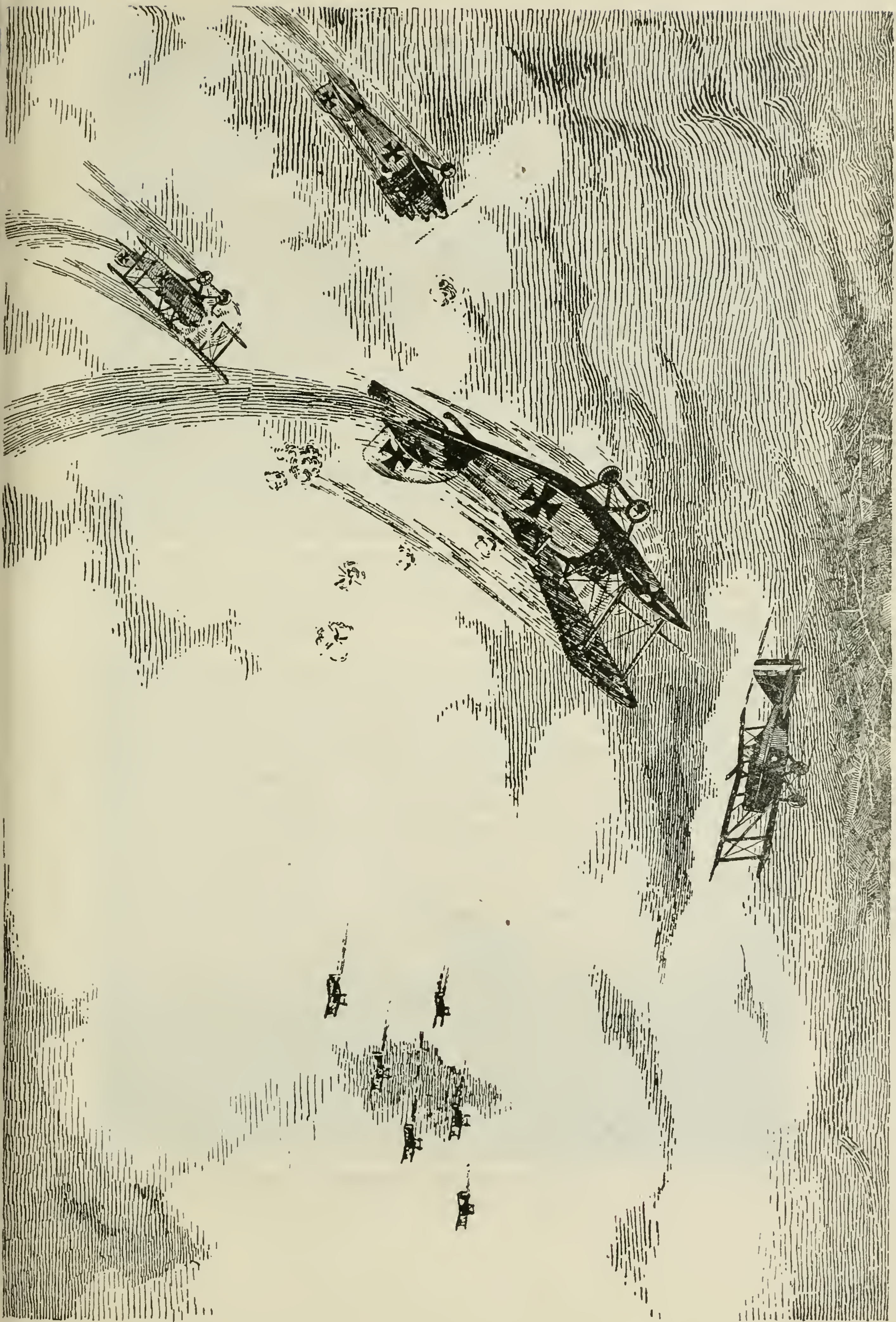
When it was announced that a state of war existed between the United States and Germany, it at once became apparent that a tremendous number of aviators must be secured for the military service within the shortest possible space of time. The medical problem consisted of selecting thousands of physically acceptable men for aviation and placing them in training for war service immediately.

It was found necessary to decide upon new methods of physical examination and to adopt new standards of physical qualifications for this branch of the service. Before our entrance into the war considerable thought had been given to the problem of what should constitute the physical requirements for admission into the aviation service, and medical officers had been in conference with other members of the medical profession who were interested in this question. Due consideration also had been given to the study of the requirements formulated by England, France, and Italy, and also Germany. The examination according to amended blank 609, A. G. O., was put into operation in May, 1917, and it is worthy of note that this same series of tests remains unaltered, even to the minutest detail, up to the present time.

The judgment applied to the original selection of those to constitute the Air Fighting Force of the United States was not based upon an attempt to decide whether or not the individual selected would be able to fly. It was known that men had been able to fly in spite of one or more physical handicaps, such as having only one leg, having one eye, having tuberculosis, or being cross-eyed, or having one collapsed lung, or being well over 50 years of age. Instances were at hand of those so handicapped who had been able to learn to fly and to fly well. Ultimate economy as well as immediate efficiency indicated unquestionably the wisdom of admitting to training only the very best material. The enormous number of applicants at hand made it possible to maintain the highest standards in selecting men for this service. It had been demonstrated by the experience of our Allies that careful selection would avoid the expense, in time and money, of training large numbers of those who would not make good in the service. Furthermore, our measuring stick was chosen in anticipation of peak-load requirements. It was realized that each man entering the flying service might be called upon to negotiate



LOOPING.
Success in looping impossible if the aviator has any " mental twists."



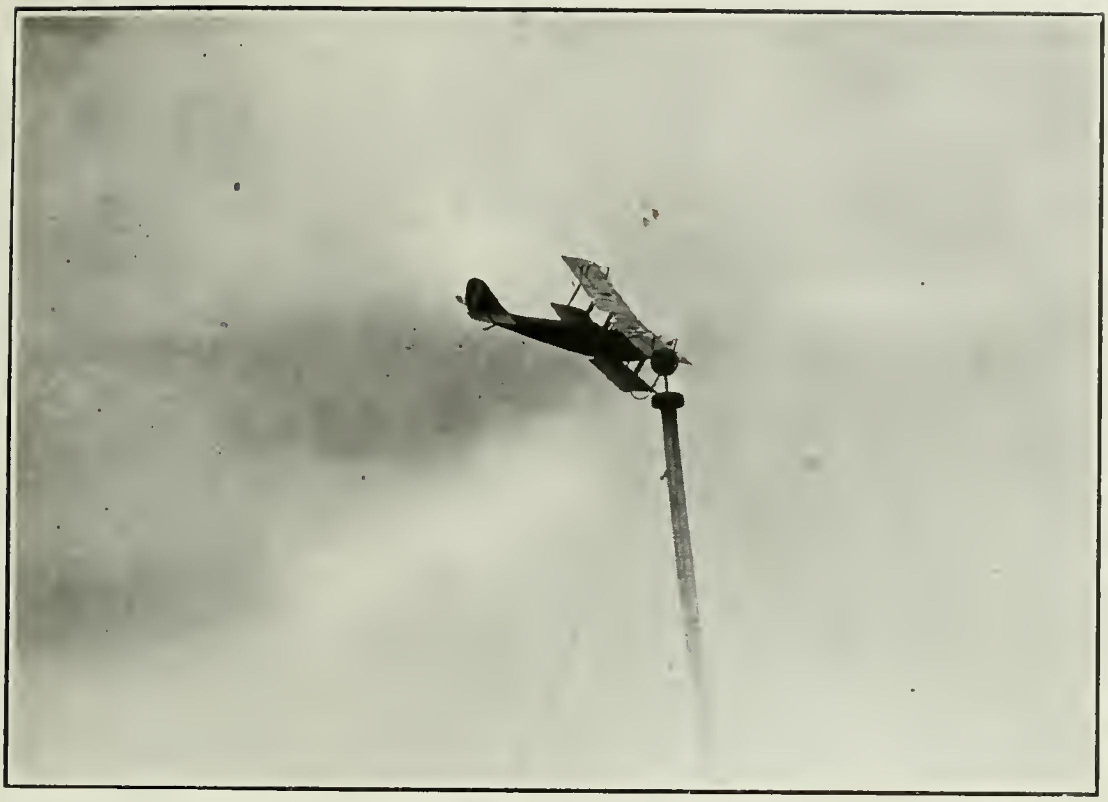
THE JACKALS.
To keep the formation the aviator has to keep both his nerve and his head.

critical emergencies in the air; that insufficient oxygenation coupled with prolonged nervous tension under high altitude combat conditions, actual injury, sudden changes in circumstances demanding instant decision and action, would require of him the utmost mental and physical capabilities.

It is only right that we should supply for our air fighters as good if not better planes than those used by the enemy. In the same spirit, it is our duty to bear in mind that when an American aviator meets a German aviator the outcome of the encounter may easily depend upon which of the two possesses the better vision and other special senses, the better nervous system, and the better mental and physical equipment in general. The flier starting for the enemy's lines carries with him a certain potential disaster for the Hun. The one-eyed man may succeed; the possession of two eyes, however, would render success more certain. The responsibility of the Air Medical Service in the selection of the flier is that no aviator shall fail in his mission against the Hun because of discoverable physical defect.

In order to make the examination of standard character, it was necessary to make the tests practicable of application in all parts of the United States without at the same time in any way lowering the requisite rigid standards or lessening the completeness of the examination. This could be attained only by (1) the standardization of the tests and (2) the standardization of the examiners. To accomplish this, a medical officer was sent to each of 35 cities throughout the United States, with the result that in each one of these cities there was established a medical unit for the examination of applicants for the Aviation Service. The requirements of the examination were fully explained to each unit, so that not only the same equipment was used, but also exactly the same technique. This made it impossible for any applicant to say, "I wish I had been examined in a certain city where the tests are easy, rather than in a certain other city where the tests are exacting." Those specialists were selected who were most expert in the practice of their chosen work; where a new type of examination was essential, such as the turning-chair tests, those otologists were selected who were familiar with these tests, and, in addition, they were given intensive training by medical officers sent for the purpose of establishing a uniform technique. Thus in a few months the examination was put on a uniform basis in all Physical Examining Units.

In order to save time, already existing institutions, such as large hospitals or State universities, with their equipments, were utilized as these examining centers. Volunteer staffs of civilian consultants were locally organized and the work of the Physical Training Units systematized to a point of highest efficiency, with the result that



JUST MISSING A FLAGSTAFF.

Prompt action, intelligently executed, saved this flyer and his machine from a crash. Fighting in the air makes continual demands on such ability.

MAKING A PERFECT LANDING.

This requires perfect stereoscopic vision.

FIGHTING IN THE AIR MAKES THE MOST SEVERE DEMANDS ON PILOTS.
Only the most fit are chosen for this work.

CADET AMONG THE CLOUDS.
A situation in which vision is of little use. The "motion-sensing" portion of the interval ear must be normal, or the pilot can not detect movement normally.

within a few days after the arrival of the medical officer the units were ready for work. By this method of decentralization the examination of thousands of applicants in a minimum time was made possible. Once it was assured that those charged with the responsibility of conducting the examination were fully equipped and capable of making the tests, full authority was vested in the medical officer in charge. Thirty-two military units, later established in the divisional camps of the United States, attended to the examinations of the enlisted applicants for air training. By far the majority of applicants were civilians, however, and the 35 original units in the cities, each examining from 10 to 60 applicants a day, soon provided the thousands of men required.

Attention should be drawn to the contribution to the Government war work represented by the vast amount of professional service rendered without pay by the civilian members of these units. These civilian consultants included many of the foremost specialists of the United States; were the services rendered by them to be represented in terms of Liberty bonds, the sum total would constitute a very respectable loan without interest. It is worthy of special mention that in addition to the routine examining work of the units, the members performed many hundreds of surgical operations enabling the applicants to qualify physically for this service, without cost either to the applicant or to the Government.

A public meeting was held in each city under the auspices of the medical profession of that city. The mere establishment of the units was by no means all that was accomplished by the work of the Medical Department. Throughout the United States there was no lack of interest on the part of the young men of the country to enter the flying service. There was, however, a striking need for authoritative information regarding the Aviation Service and how to go about getting into it. A by-product of the establishment of the units was the stimulation in each city of large public interest in this branch of the service. In one city after the meeting 95 men expressed their desire to enter this service.

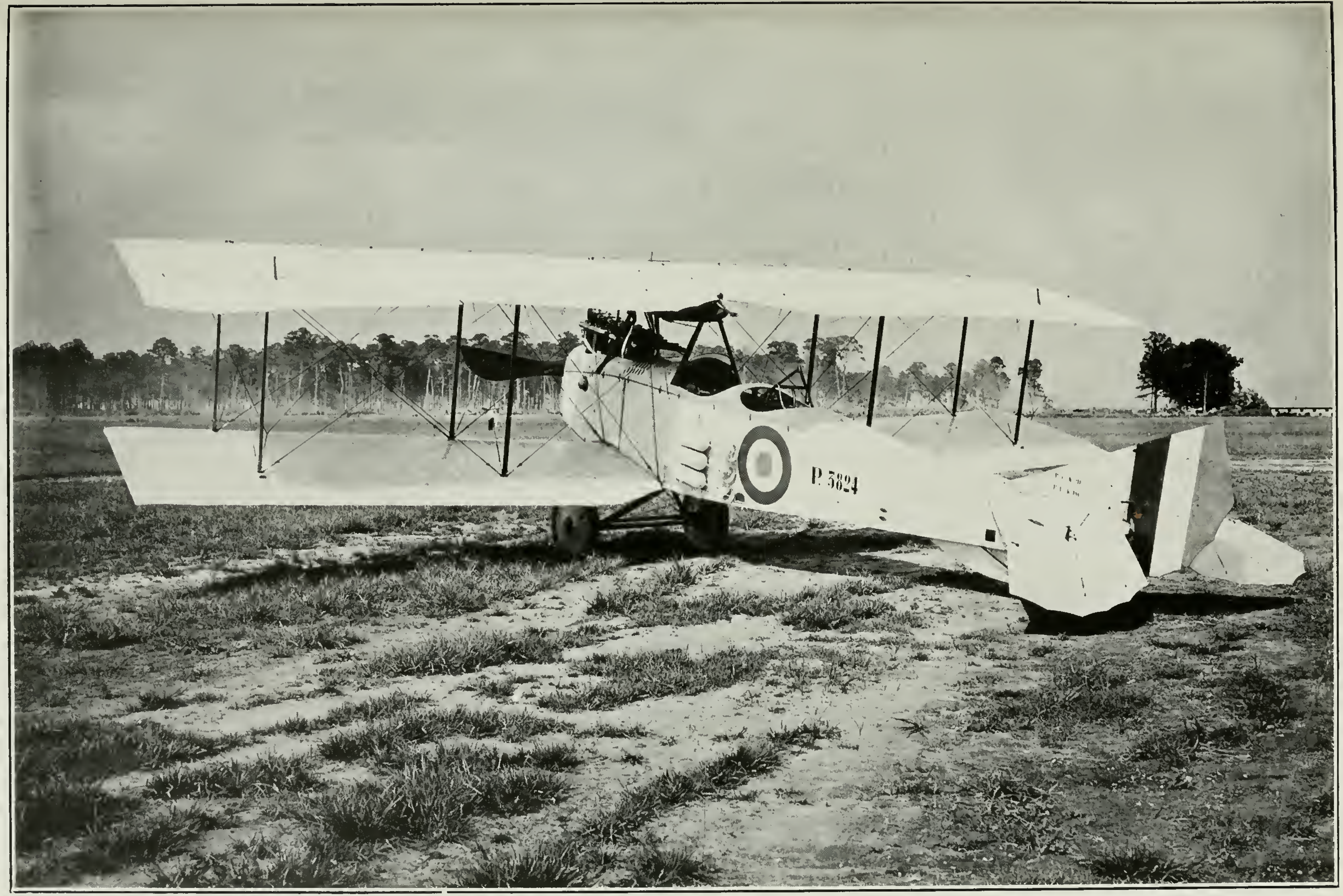
In the rush of events after our entrance into the war not only was there a lack of information regarding Air Service, but there was a considerable amount of misinformation, most probably attributable to German propaganda. Throughout the country was spread the information that the average life of an aviator was only a few hours of actual service. Parents were given to believe that their sons were being taken for an almost immediate and inevitable sacrifice. Furthermore, there was not a city in the United States in which it was not firmly believed by the public that the much-discussed medical examination of an aviator was a form of refined torture. One story was that of the "needle test." This mythical examination was supposed to consist of placing a needle between the candidate's forefinger and thumb, blindfolding him, then shooting off a pistol behind his ear. The examiner would then note whether, due to his supposed lack of nerve, the applicant had pushed the needle through his finger. Another much-rumored test was described as follows: When the applicant least expected it he would be hit over the head with a mallet, and if he regained consciousness within 15 seconds he was qualified as being of the stuff of which aviators are made. It was the medical officer who could supply the needed information and also demonstrate the utter nonsense of this prevailing misinformation. In this way parents were assured by the Surgeon General that their sons were put through only an ordinary physical examination to insure their fitness for the service, and that for their own protection they would not be accepted unless physically sound. The mystery of the examination was removed by actual demonstration, aided by moving pictures.

At these public meetings were gathered those of the medical profession and general public who were interested in aviation. The interest aroused within the medical profession by the work of the Physical Examining Units also resulted in bringing into the Air Medical Service a large number of specialists whose training in the examination of aviators fitted them later for a larger sphere of usefulness in the care of the flier.

STANDARD SCOUT.

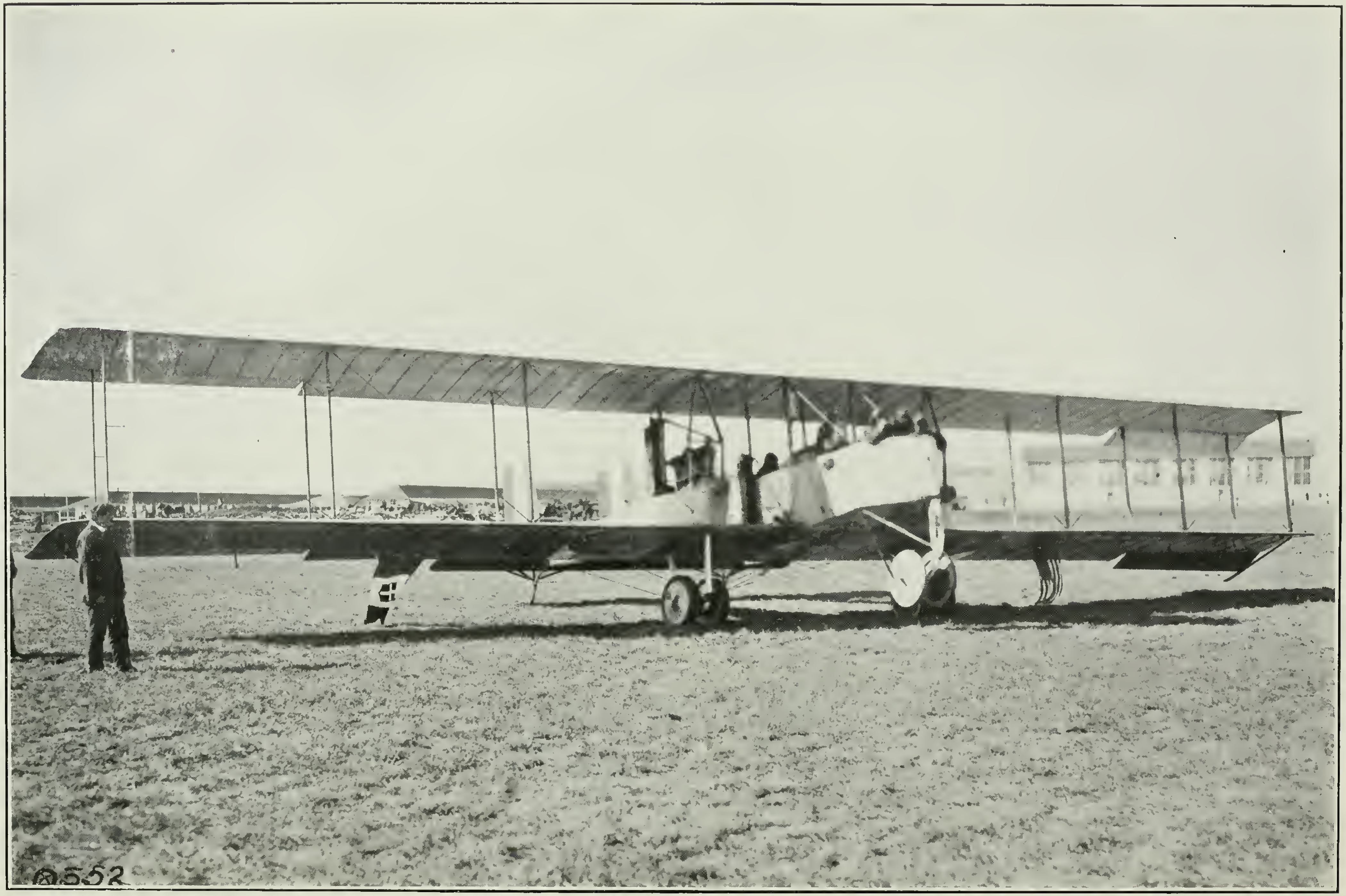
"NIEUPORT."

"LOENING MONOPLANE. HISPANO SUISA MOTOR."



BOMBING MACHINE.

A type of bombing machine. Pilots shown by medical research to be unfit for high-altitude work may be used in these machines, which fly at a comparatively low altitude.



CAPRONI BIPLANE.

CHAPTER III.

CLASSIFICATION.

The flier, who through good training has become perfect in his technique and who through proper care is physically fit, is not necessarily fitted for all types of air activities. When the present war first began, there were but few airplanes and what airplanes existed were used for all kinds of work. If an airplane and a man could stay in the air, they were used for any service which an emergency might call for. On one day the pilot might be asked to go across the lines on a reconnaissance mission and with the same machine, which was very limited in climbing ability and speed, he would be called upon the following day to go into the air to fight.

With the coming of improved designs and the more skillful managing of airplanes by fliers, different types of machines have become classified into special groups for special work. The flying service is now highly specialized. Men are called upon to perform widely diversified classes of work, such as pursuit or scout work, reconnaissance, photography, day or night bombing, artillery observation, and for each of these special missions the pilot is provided with a certain type of plane adapted to the work in hand.

Both the enemy and ourselves divide the machines used for service into two distinct classes; we have both the fighting machines which are a fast, quick-climbing type, easily and quickly maneuvered, and heavier machines which are slower in action and capable of carrying almost any weight.

It is easy to see that a fast-climbing machine is bound to carry the pilot to greater heights than the slow, weight-carrying machines. Whereas in 1915, flying rarely exceeded 8,000 or 10,000 feet, through improved designs scouts of to-day climb to altitudes even as high as 25,000 feet, and this height is attained in a very short space of time. The nature of the work of a scout, which is simply hunting out the enemy and attacking him, also necessitates descents from high altitudes at tremendous speed.

Night bombing has been carried out at altitudes as low as 300 feet. Day bombing, in order not to reveal the objective of the flight and to guard against concentrated anti-aircraft fire, may call for flights at very high altitudes. The possible necessity of attaining such altitudes presents a nice problem when we consider the weight of bombs which must be carried, together with the protective equipment with which the plane must be loaded. Reconnaissance machines rarely get to high altitudes owing to the necessity for more or less close observation of the ground, and machines doing this work must accomplish very low flying even in the face of highly concentrated anti-aircraft fire and enemy activity in order to fulfill their mission. Machines cooperating with the artillery which have to make range corrections for batteries do not often work above 6,000 or 8,000 feet. From this we can see that the machines doing the types of work just mentioned, except day bombing, fly very much lower than the pursuit or scout planes. With their capacity for carrying a larger amount of fuel, they can remain in the air for very long periods. When a long trip is to be made, such as a bombing raid far into the enemy country, at least four or five hours must elapse and the pilot is apt to be fatigued to the limit of his endurance. Especially is this the case in cold weather and under the long strain of an extended flight encountering anti-aircraft fire and enemy planes.

Pilots of scout machines, on the contrary, owing to the speed and climbing ability possessed by planes built for this type of work, never stay in the air much over two and one-half or three hours on account of being unable to load up their machines with more than a moderate weight of fuel. But they have to go to tremendous heights, they have to change those heights very quickly and very often, and they are subject to quick changes of temperature as well as sudden variations in oxygen content of the air.

In view of these facts the Air Medical Service realized the importance from a purely military standpoint of careful classification of fliers. The work of the Medical Research Laboratory has demonstrated that of each 100 carefully selected fliers only 61 are physically and mentally capable of attaining an altitude of over 20,000 feet with safety; 25 out of each 100 are physically and mentally unsafe at altitudes above 15,000 feet; and 14 out of each 100 are physically and mentally unsafe at altitudes above 8,000 feet. Or that 61 of the 100 are fit for any type of air work; that 25 may do bombing; that 14 should be limited to reconnaissance or night bombing. Such classification of pilots for specific duties constitutes a new factor of conservation and safety to our forces.

The feature of knowing the limitations of a valuable man spell increased efficiency.

Just as the pilot is provided with a certain type of plane adapted to the work in hand, so the plane must be provided with a pilot adapted to the work in hand.

It is true that in the absence of a pilot physically and mentally adapted for high-altitude work it is possible to use one who is adapted only for low-altitude work by equipping him with an apparatus to supply oxygen according to his needs. Supplying oxygen to fliers has been a subject of much experiment and study during the past two years both by the enemy and by the allies. The British have used an oxygen apparatus of satisfactory type for two years—the Dreyer apparatus; this type of apparatus is being produced in the United States in increasingly large numbers, and at the same time modifications and improvements are being constantly made. In the very nature of things, however, it is impossible to count upon adequate and ready-to-serve oxygen supply for each aviator in each machine which emergency may send into high altitude. Until the final absolute perfection of oxygen apparatus for the flier and the equipping of each high-altitude plane has been accomplished, cognizance must be taken of altitude rating of the flier in "selecting the man for the job."

Physiologic studies on men undertaking to live at high altitude, such as Pike's Peak, have proven that a very complex series of changes occur before their bodies become able to live normally with less oxygen. This is acclimatization, and this occurs in the man living on Pike's Peak, but not in the aviator who alternates constantly between high and low altitudes.

The flier must undergo abrupt changes in atmospheric pressure and oxygen supply. Atmospheric pressure plays a very unimportant rôle; the whole problem resolves itself into a deprivation of the normal oxygen supply. The fact that there is "oxygen-want" at high altitudes suggested that any piece of apparatus that would permit the breathing of a reduced amount of oxygen could be used to test the ability of men to withstand high altitudes. The Flack bag was the prototype of the rebreathing apparatus which has been developed in the Medical Research Laboratory and perfected for such tests. By means of this apparatus the aviator rebreathes air confined in a tank, from which he gradually consumes the oxygen. As the percentage of oxygen decreases the aviator, in effect, is slowly ascending to higher altitudes. In the course of 25 to 30 minutes he lowers the oxygen content of the air in this tank to 8 or 7 per cent, which is equivalent to attaining altitudes of 25,000 to 28,000 feet.

Another method of attaining the same result is by means of the diluting apparatus, which supplies directly to a mask over the face whatever proportions are desired for a mixture of air and nitrogen. All of these tests have been standardized and confirmed by the low-pressure tank, in which the air is rarefied to correspond to any given altitude.

By a comparison of the percentage of oxygen to which the aviator succumbs when on the low-oxygen tests it is possible to determine precisely the altitude at which the aviator would fail were he in the air. This determination is made on the ground, without danger either to the aviator or to his machine, and has been taken as the basis for the classification of aviators now in use by the Medical Research Laboratories.

It may be noted that these tests of the ability of an aviator to withstand oxygen reduction could not be made safely in the air, as the effects of oxygen-want are insidious and often the aviator succumbs very suddenly and completely when his limit is reached.

The effect of low oxygen upon the mental processes of the aviator varies greatly in the individual. The aviator usually becomes mentally inefficient at an altitude at which there is as yet no serious failure of his vital bodily functions. If he were sent to an altitude which his heart could safely stand, his efficiency would nevertheless suffer because his brain is not acting properly. By simple tests of mental alertness during rebreathing it is easy to determine that one flier becomes mentally inefficient at 15,000 feet, in sharp contrast to another aviator who has his full mental powers up to and beyond an altitude of 25,000 feet.

Low oxygen has a marked effect upon vision. Oxygen-want exaggerates to a marked degree any existing defect of the eyes. In many young healthy men the rebreathing tests made manifest eye defects which may have eluded detection by the most expert examination. Crash reports have demonstrated that a large proportion is due to such eye defects. Again, in night flying it is most important that the flier shall be able "to see well in the dark." Many aviators are able to fly well without any difficulty in the daytime, but not at night. Laboratory tests determine definitely which individuals possess the ability to see well at night.

"Stunting" is essentially an internal-ear problem. During and after rapid turnings the flier's brain is receiving impulses from his semicircular canals. Nothing can control or alter the sending or receiving of these impulses. These impulses produce sensations of motion. Fliers vary greatly in their ability to interpret correctly the significance of these impulses. Experience alone enables the aviator to familiarize himself with the meaning of these impulses; those who develop the greatest ability in this respect naturally fall into the scout-pursuit class. Those who, in spite of training, are still disturbed or bewildered by stunting should be reserved exclusively for straight flying, such as bombing and photography. Again, the peculiar demands of night flying, reducing, as it does, at times to the vanishing point, information coming from the eyes, require a type of flier who possesses the keenest ear sense for the detection of movement.

The rebreathing test is also very valuable in determining staleness in aviators. As staleness is caused by frequent exposure to high

RE-BREATHER.

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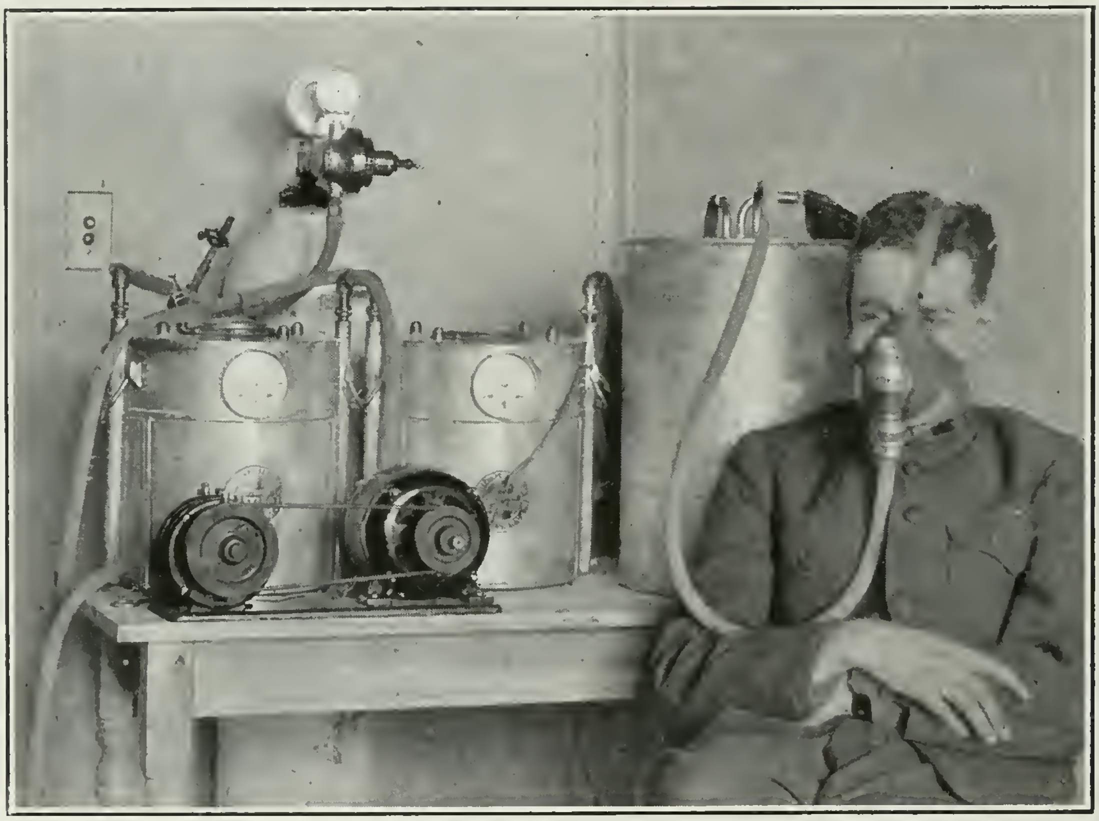

DREYER DILUTING APPARATUS.

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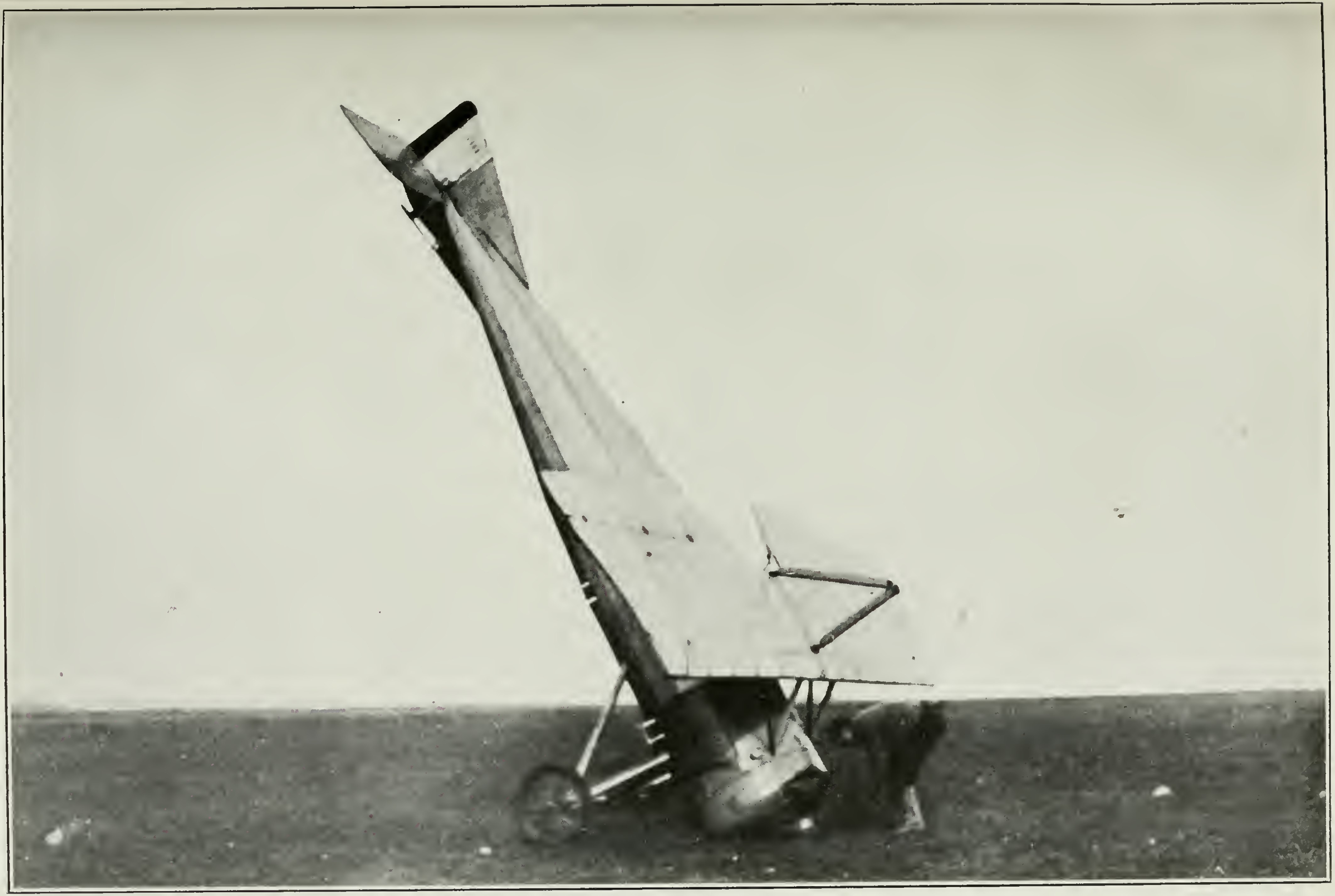
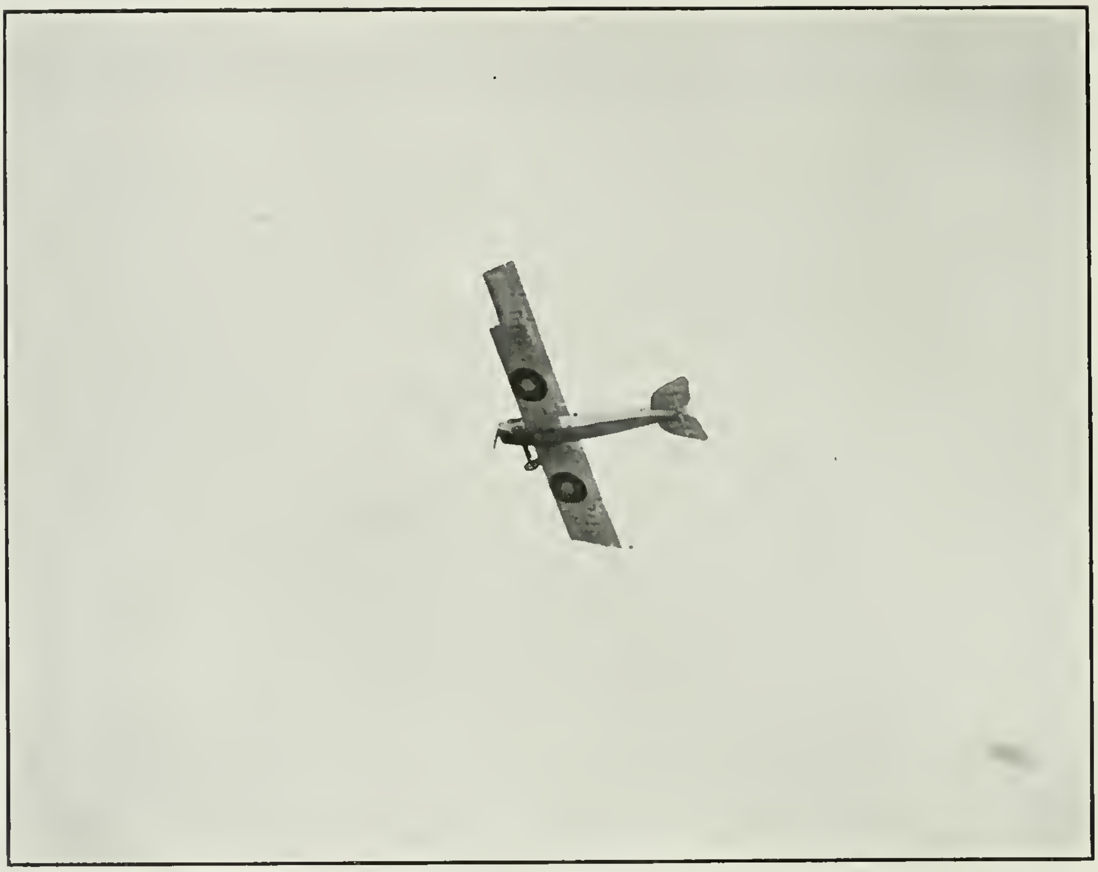


A GRASS CUTTER COME TO GRIEF.

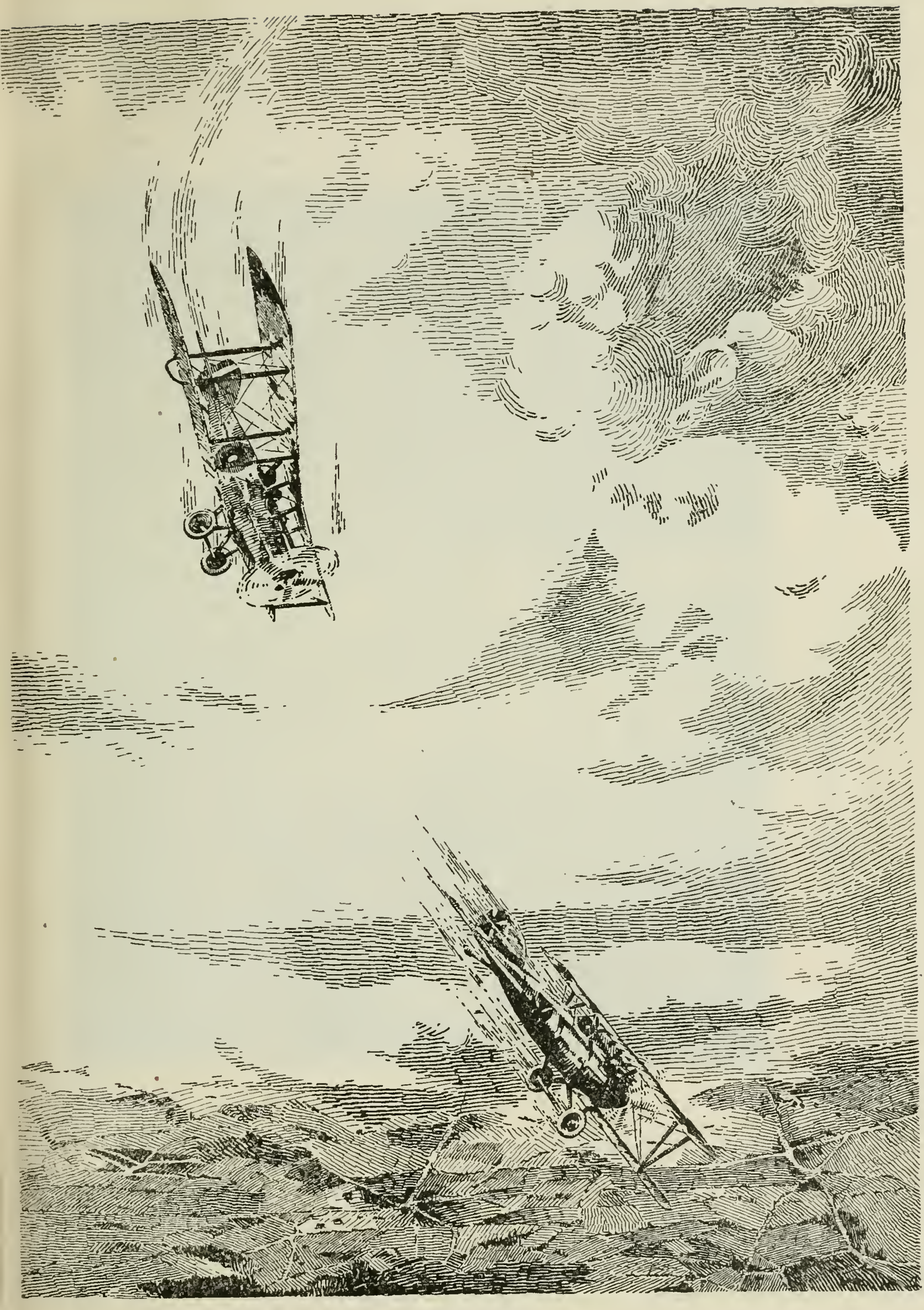
Deficiency in vision is responsible for poor judgment in landing. Accidents such as this can be diminished in number by eliminating defects and deficiencies in pilots through most careful and continuous medical supervision.



VERTICAL BANK. SIDE SLIPPING—2,000 FEET IN THE AIR.

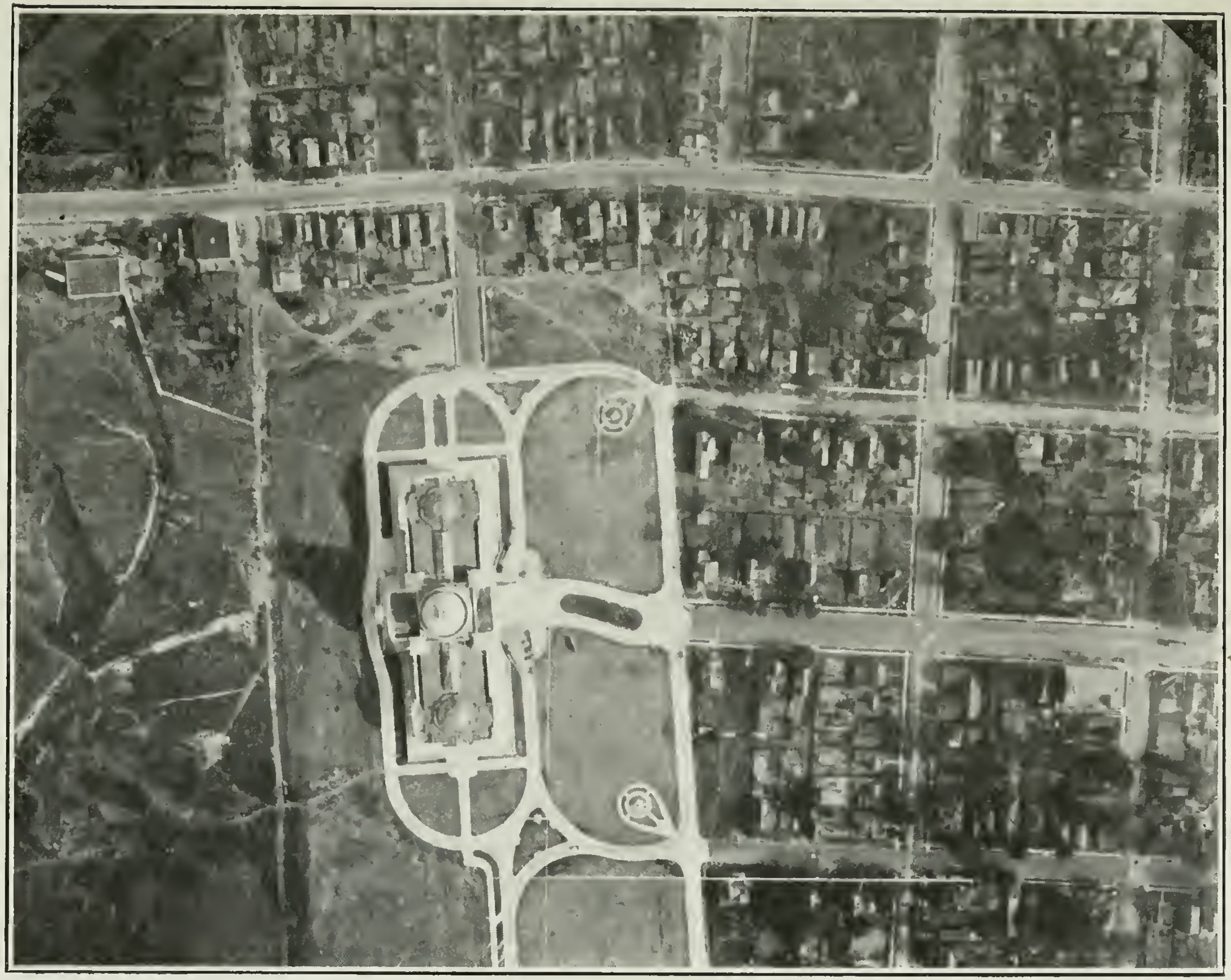
Poor balancing ability can thus endanger pilot and machine.

26a-4



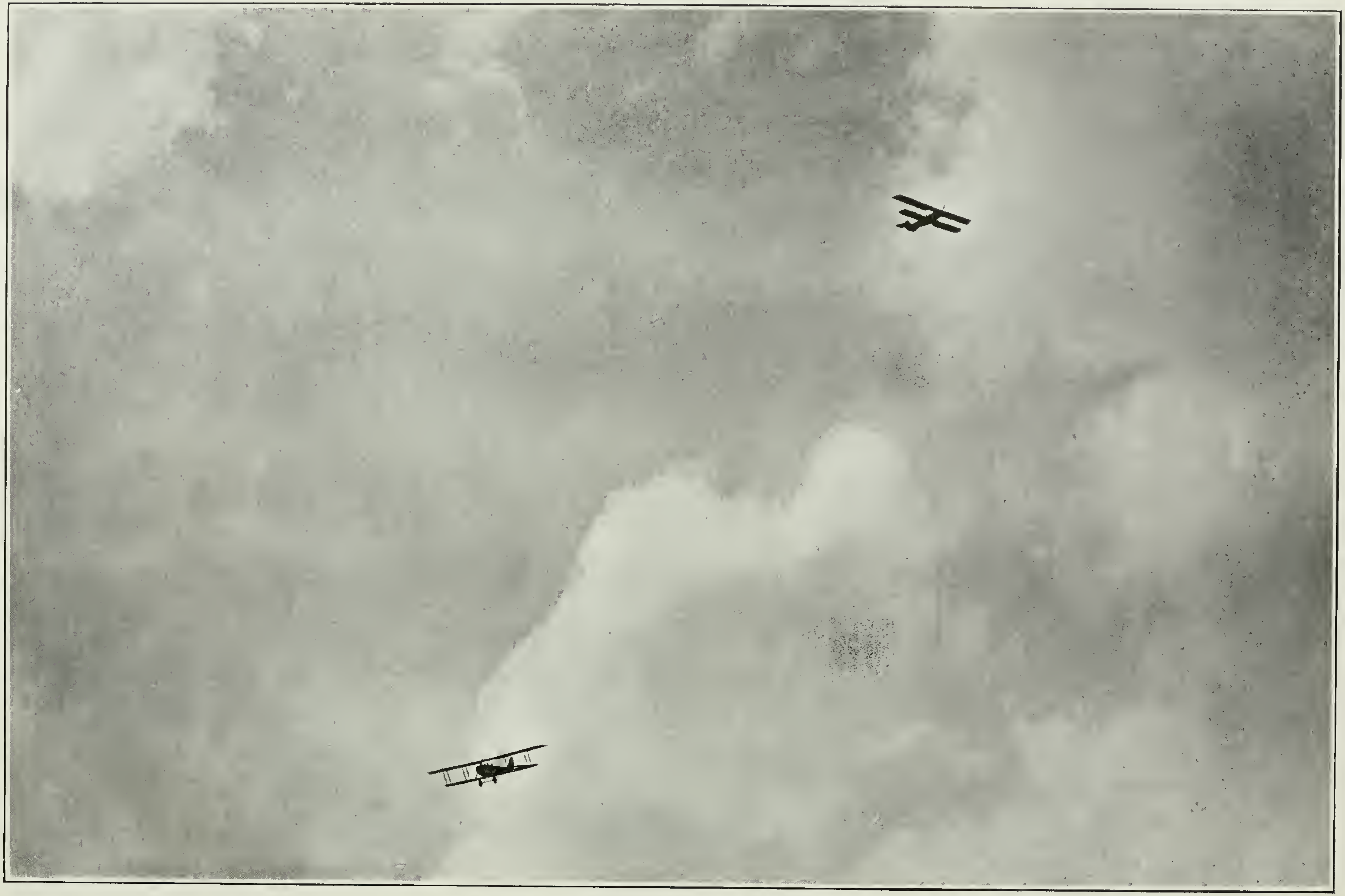
THE CHASE.
A critical moment when the nervous system should be in good order.

altitudes, evidence of this is easily obtained by means of the rebreathing machine. Where originally a flier was able to tolerate an altitude of 20,000 feet or more before showing certain symptoms of staleness, after flying for 100 hours or more, it is frequently found in reexamination by means of the rebreather that he is stale and is unable to tolerate the oxygen reduction equivalent to 10,000 feet. Incipient cases of staleness are thus easily detected. The detection of the early cases of staleness is of greatest importance in that it makes it possible to ground a man for a certain period and thus enable him to recover entirely, whereas if this condition is not diagnosed early it will progress until a point is reached where it is impossible for the aviator to " come back " and his services as a flier are thus lost to the country. When the staleness becomes marked the aviator is very liable to faint in the air, thus losing his life and wrecking his machine. By periodically examining aviators the first signs of staleness will be detected early and measures can be taken to conserve the efficiency of those who would otherwise be inevitably lost to the service.



VIEW FROM AN AIRPLANE.

A portion of Little Rock, Ark., showing State Capitol, 4,000 feet altitude.



PLANES FLYING HIGH UP AMONG THE CLOUDS

RESNATI CRASH AT MINEOLA.

This great flier was sick, and he had been urged not to fly by one of our Flight Surgeons.

GINO CRASH AT MINEOLA.

CHAPTER IV.

THE FLIGHT SURGEON.

The Flight Surgeon constitutes the ultimate "answer" to the maintenance problem of the Air Medical Service.

In the foregoing chapters has been presented the work of the selection of the aviator and of the classification of the aviator. The Air Medical Service, however, does not end here. It is all very well to have chosen with great care those hand-picked men who constitute our Air Force and, thanks to the enormous number of applicants, to have adhered to the highest standards in their selection. It is all very well to have medical specialists classifying fliers and determining their peculiar fitness for special branches of aerial activity. This, however, by no means marks the limit of usefulness of the Air Medical Service. The one immediate need of the military aviator in all the services of the world is an organization for his upkeep and care in actual service. After two and one-half years of bitter experience it was gradually borne in upon the allies that at the end of a certain amount of continuous service the flier begins to show unmistakable signs of deterioration, and the economical thing to do is to relieve him temporarily from active flying. This was a new thought in aviation. Up to that time it had been the practice to keep the flier at it until he broke. His breaking was signalized sometimes by simple failure to return from behind the enemy lines; sometimes by becoming mentally and nervously so exhausted as to be of absolutely no use; at other times becoming so physically worn out that even the casual observer would recognize his unfitness for service.

The old method was to get as much out of a flier as possible, then discard him as useless for further air service. The alumni of this old school, although not all present, because of the graduation of so many behind the enemy lines, are now represented by the hundreds of "washed out" fliers from the Italian, French, and British services that one meets in various ground activities in the flying schools of America and Europe.

Many of these are unnecessarily wasted. Their loss to active service could have been materially reduced by means of competent medical officers who, recognizing the early beginnings of deterioration, could have taken them off in time to permit full recuperation and restoration to active flying.

It is easy to sum up the various means by which a flier's usefulness may be terminated. They are exactly three:

(1) The Hun.

(2) Failure of the engine or plane.

(3) Failure of the flier himself.

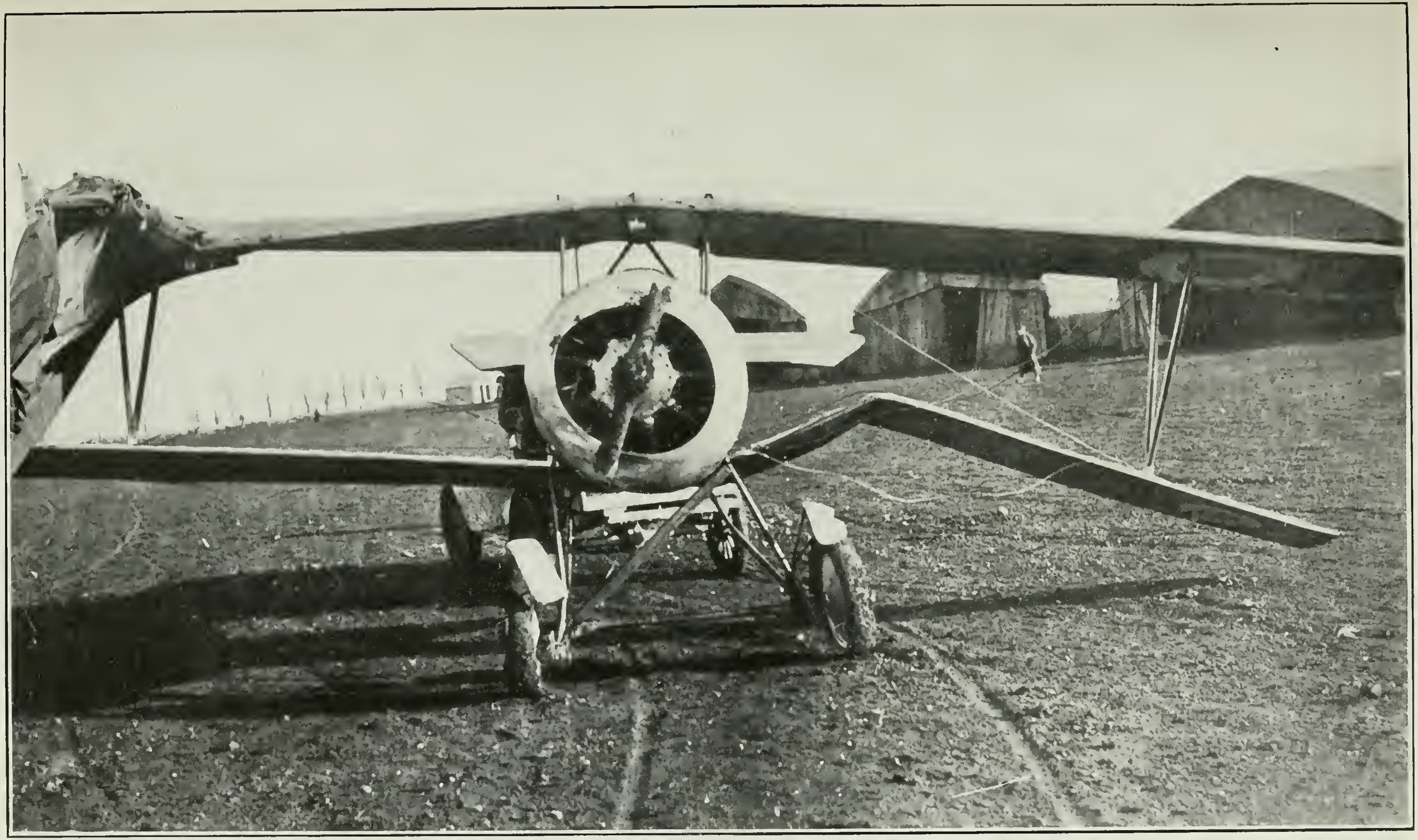
While it is not possible to arrive at exact percentages, estimates based upon information from every source in Italy, France, and Great Britain, interviews with commanding officers and medical experts in all the flying centers and at the various fronts, indicate that not 2 per cent of the fliers lost to active service are put out by the Hun. Failures of the airship are, at the present time, responsible for very limited losses to the service, thanks to the inspections to which they are constantly subjected. Two years ago this statement would not have been true; the mechanical genius of the world has been applied to make the airplane safer and with such effect that it happens only rarely that the flier becomes useless through the fault of the ship. Statements from all sources agree that of the total number of fliers permanently out of flying service, not over 8 per cent have been rendered unserviceable because of mechanical shortcomings of plane or engine. When it has been stated that 2 per cent of the total number of fliers incapacitated for further air service are put out by the Hun, and 8 per cent because of mechanical shortcomings of the airplane, the remaining 90 per cent looms large, when it is realized that this proportion represents troubles in the flier himself.

After assembling all possible information, subjecting it to careful study by competent experts and reaching definite conclusions, the material so obtained has been put into shape for further training of a corps of medical officers who have had opportunity to become familiar with the Air Medical Service by actual experience in the examination of applicants, the post-surgeon work in flying fields, and the reexamination of fliers. This is the epitome of the development of the flight surgeon idea. Through such a corps of officers, established in the various flying fields, practical application can be made of means and methods devised for the better maintenance of the physical efficiency of the flier. Just as the Medical Department of the Army has been able to wipe out typhoid fever, and made it possible to construct the Panama Canal by the elimination of yellow fever, so the Air Medical Service is destined to serve by prevention of the crash rather than by "picking up the pieces" afterwards.

Medical officers of the various air services had observed that more than half of the injuries sustained in crashes were caused by the aviator striking his head against the cowl. It was suggested that the cowl be cut out so as to give 8 inches more room in front. A

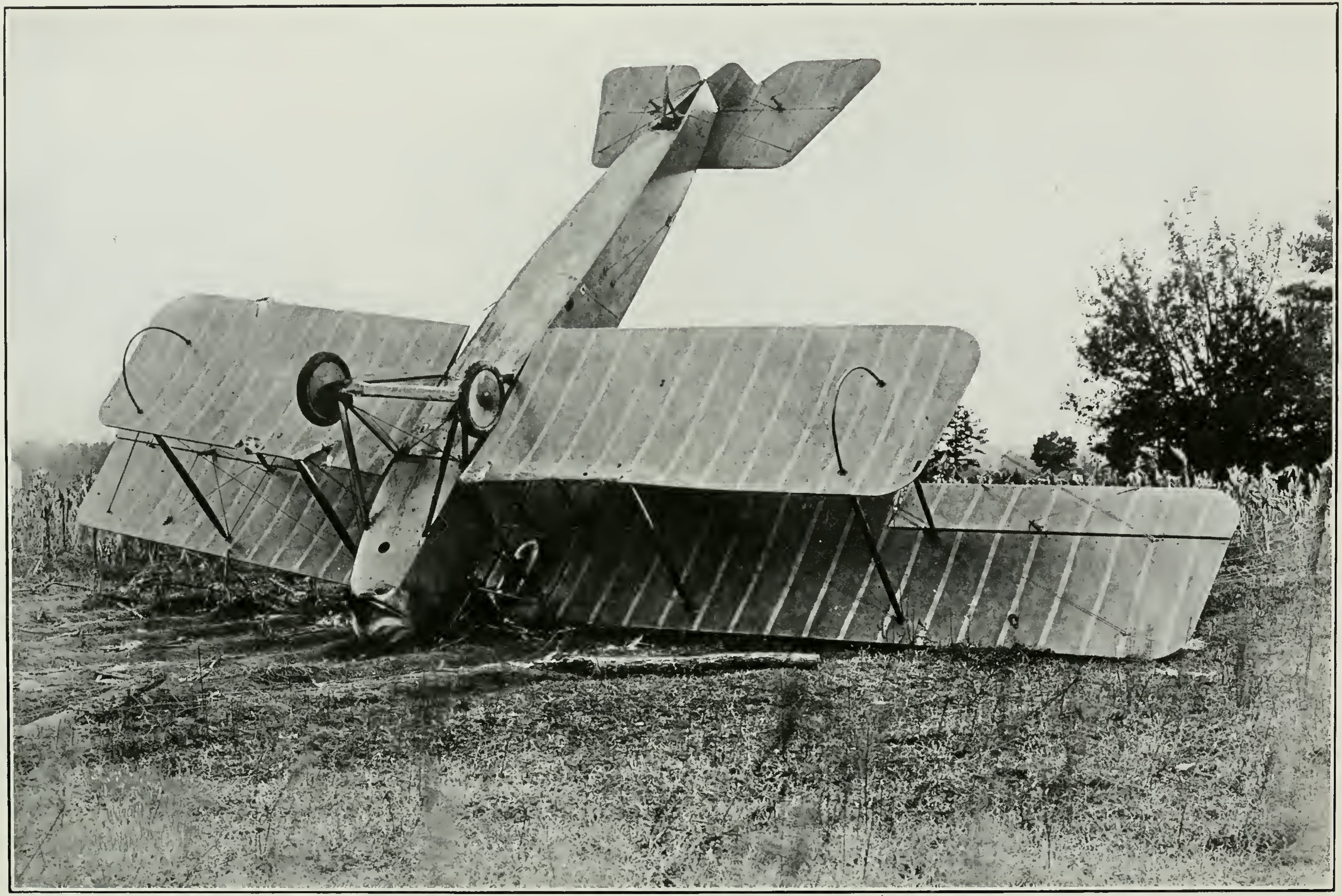
RESULT OF COLLISION IN AIR.

COLLISION ON GROUND (TAXIED TOGETHER), AIR-SERVICE FLYING SCHOOL, RICH FIELD, WACO, TEX.

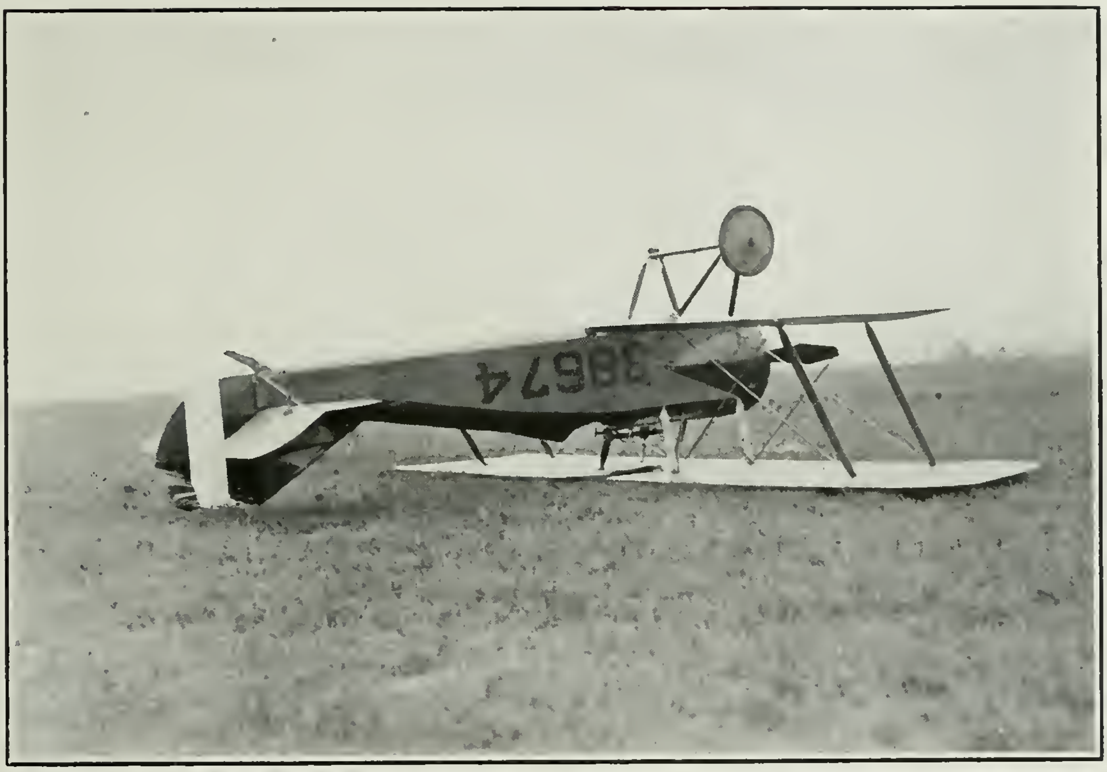


VIEW OF PLANE AFTER HAVING DROPPED 500 FEET.

Only 8 per cent of these accidents are due to defective machines; 90 per cent are due to imperfections in pilots. We must decrease the number of accidents.



AIRPLANE AFTER TURNING TURTLE.



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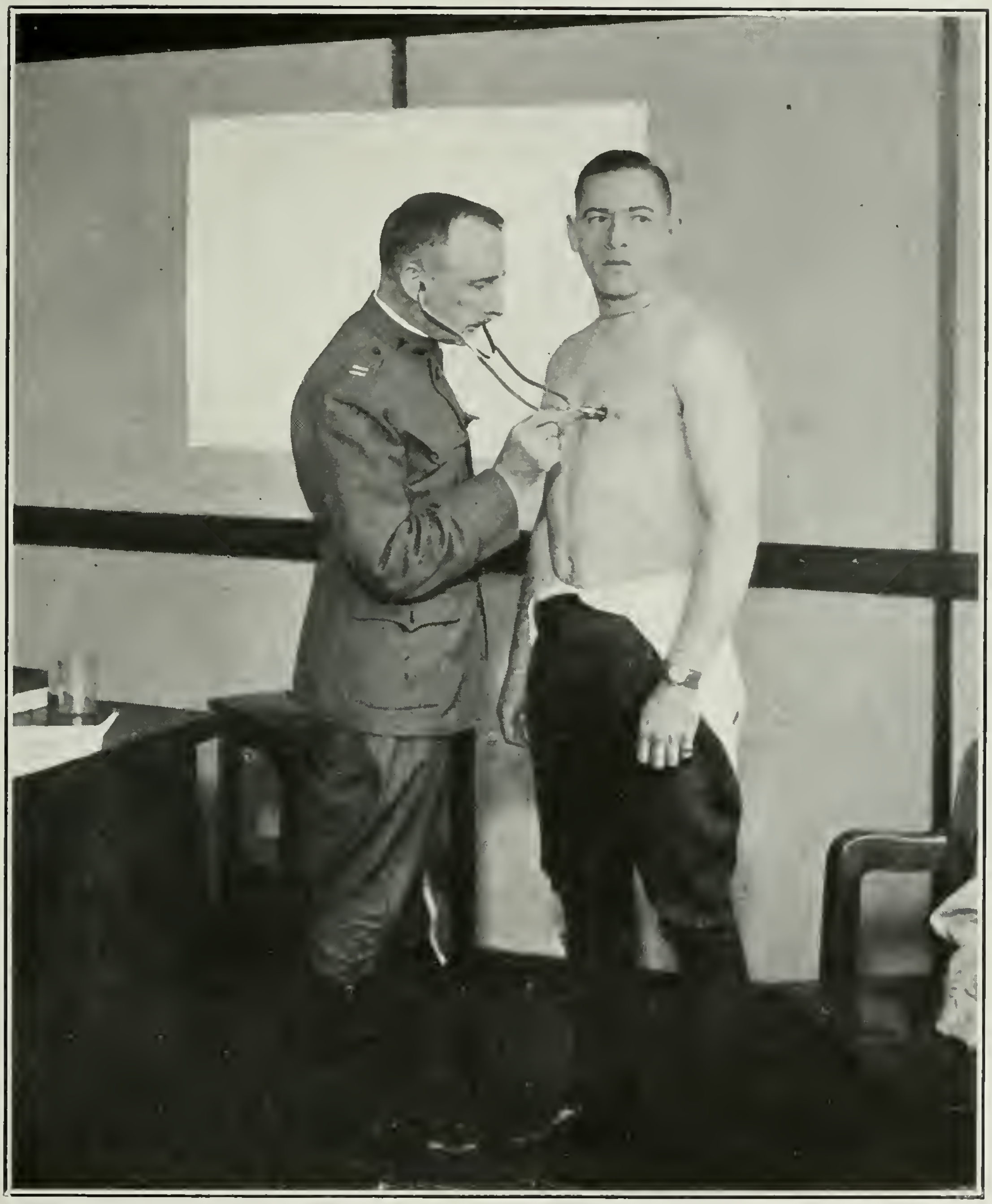
STAFF OF MEDICAL RESEARCH LABORATORY AT MINEOLA.



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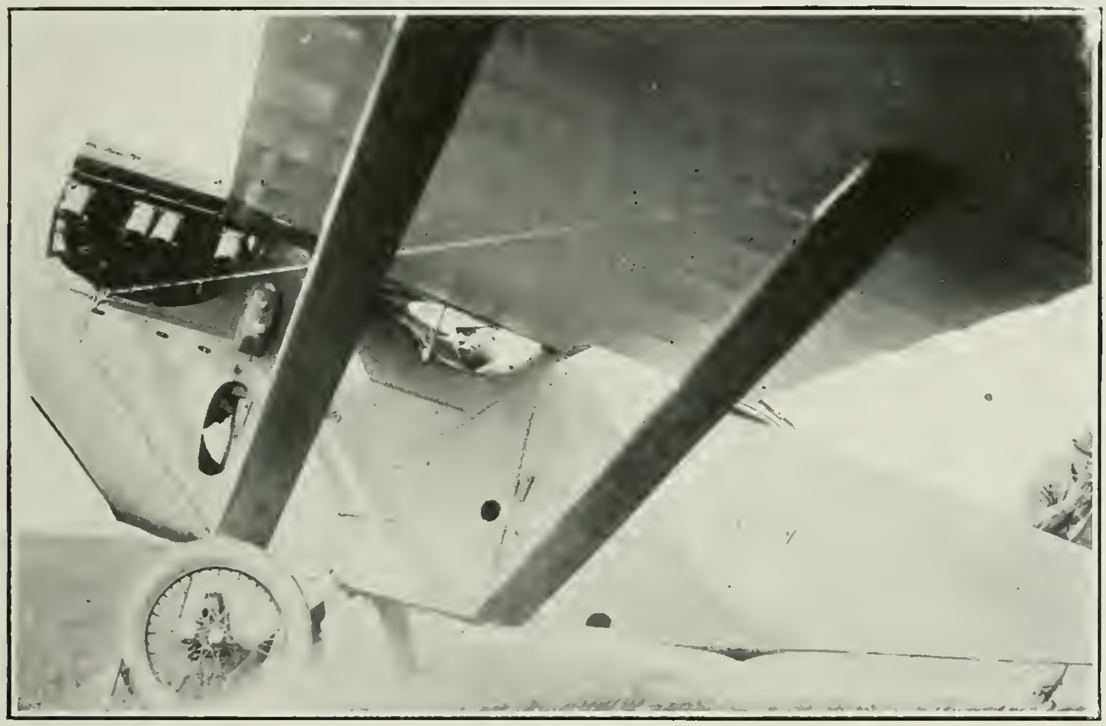
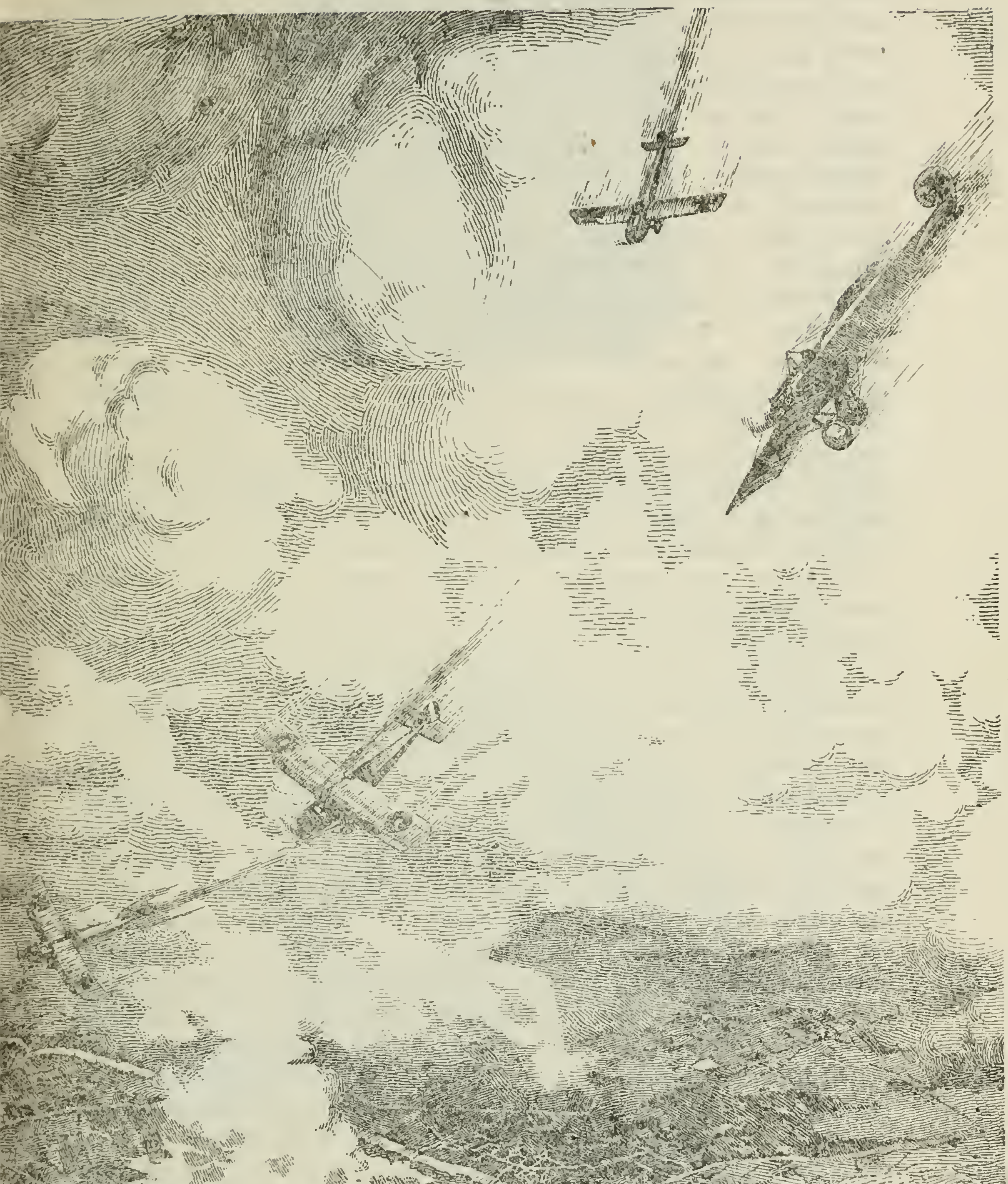
EXAMINATION OF FLIER.

COLLISION—300 FEET ALTITUDE

30a-8



MAJ. HITCHCOCK IN PILOT'S SEAT.

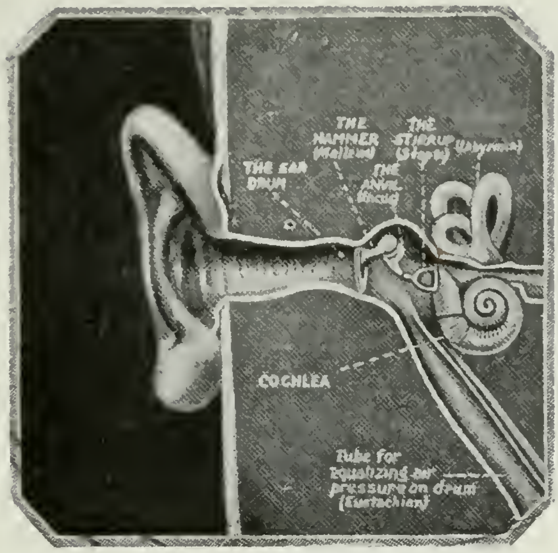


DECOYED.

report just received from the Royal Air Force, Canada, states that since this change in the cowl has been made these head injuries have been practically eliminated. Another suggestion was to lash the safety belt to the machine by a simple rubber shock absorber; the same report states that since this has been done, the number and extent of injuries to the upper abdomen and ribs have been decidedly reduced. The problem of protecting the flier against the extreme cold of high altitudes in winter was solved by designing electrically warmed clothing, thereby enabling him to continue his flying under conditions, which, up to that time, had rendered it impossible. The problem of enabling a flier to withstand the glare of reflected sunlight above cloud banks and to enable him to pierce camouflage was solved by furnishing him with the "Noviol" type of goggles. During the first two and one-half years of the war no attempt was made to compensate the flier for his lack of sufficient oxygen in high-altitude work. There is one British squadron which has used the Dreyer oxygen apparatus since January, 1917; a recent report from the British front states that this squadron has been performing six times the amount of work of any other similar squadron which is not supplied with oxygen.

The above are examples of what has already been accomplished towards reducing this "90 per cent;" many other methods are now being developed. Within the past few months has been perfected an apparatus whereby cadets may acquire flying experience and training without leaving the ground.* This machine is a modification of the old-fashioned universal joint, composed of three concentric rings so pivoted together as to permit the fuselage, which is pivoted within the innermost ring, to be put through every possible evolution to be experienced in actual flying. This apparatus is practically an airplane in every respect. The cadet sits in the fuselage and by means of the joystick and rudder puts himself through practically all the evolutions which he is later to experience in the air. An analysis of the "crash reports" has shown that a remarkably large number are solely due to a failure to come out of the spinning nose dive or tight spiral. The only reason that the cadet has failed to come out of these maneuvers is that he had not yet become accustomed to these unusual movements. These evolutions stimulate the internal ears which send nerve-impulses to the brain. The individual has no control over these impulses; the only thing he can do is to learn the significance of these impulses by experience. The problem is extremely simple. All that is needed is that every cadet shall "fly" the apparatus day after day until he is entirely familiar with these new sensations. Any mistake that he makes causes him no harm, because he never leaves the ground. He is then prepared to

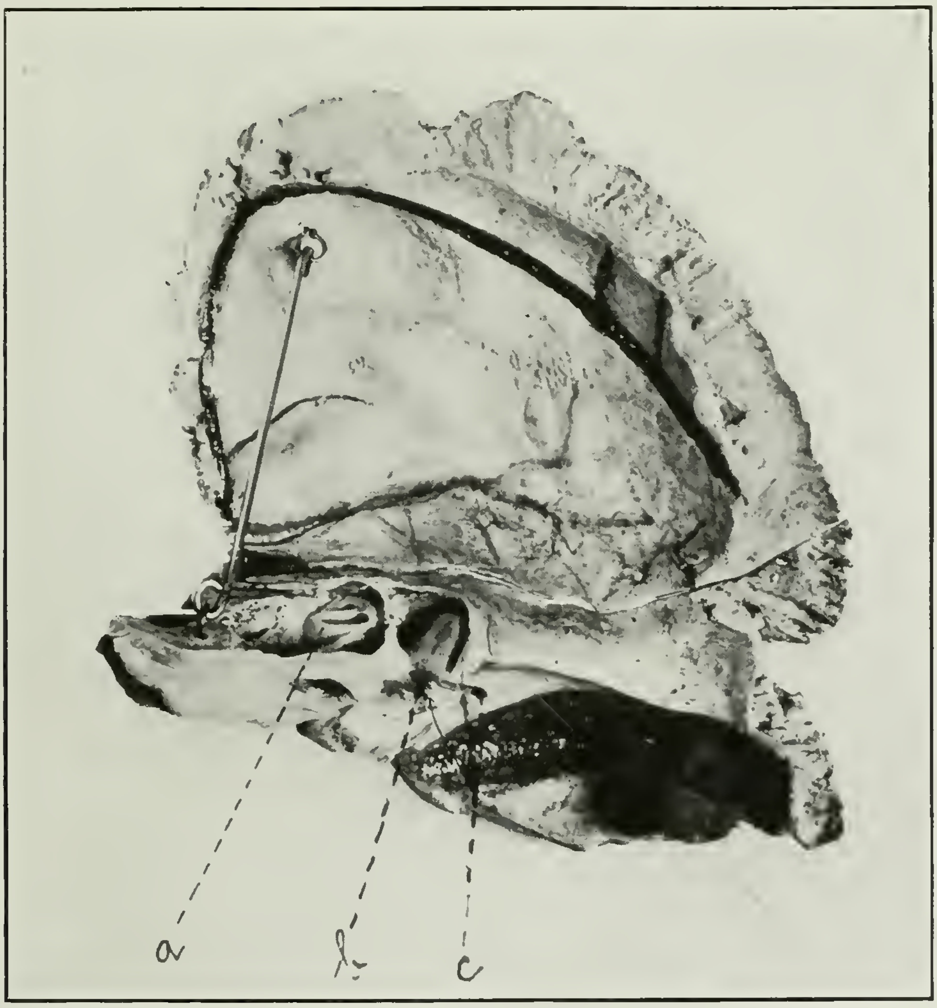
*The Ruggles Orientator.



(Diagrammatic.)

THE SIXTH SENSE. THE THREE SEMICIRCULAR TUBES CONSTITUTE THE "MOTION-SENSING" ORGAN.

The internal ear or labyrinth consists of a bony and a membraneous part, the latter contained in the former. The bony labyrinth is composed of the vestibule, the semicircular canals, and the cochlea. These three canals constitute what is known as the static labyrinth. The bony canals contain the membranous canal, and the membranous canal, in turn, contains the endolymph, which is a fluid that fills the membraneous canal. This posterior part of the internal ear is constructed solely for the detection of movement, and constitutes the special sense organ of "motion-sensing". Man is acquainted with movement through this organ by the flowing of the endolymph within the canals.



HUMAN TEMPORAL BONE, NATURAL SIZE, INTERNAL OR BRAIN SURFACE; SHOWING INTERNAL EAR CONSISTING OF COCHLEA (a), THE SUPERIOR AND POSTERIOR SEMICIRCULAR CANALS (b and c) WHICH HAVE BEEN EXPOSED BY REMOVING PORTION OF THE BONE.

(Actual photograph.)

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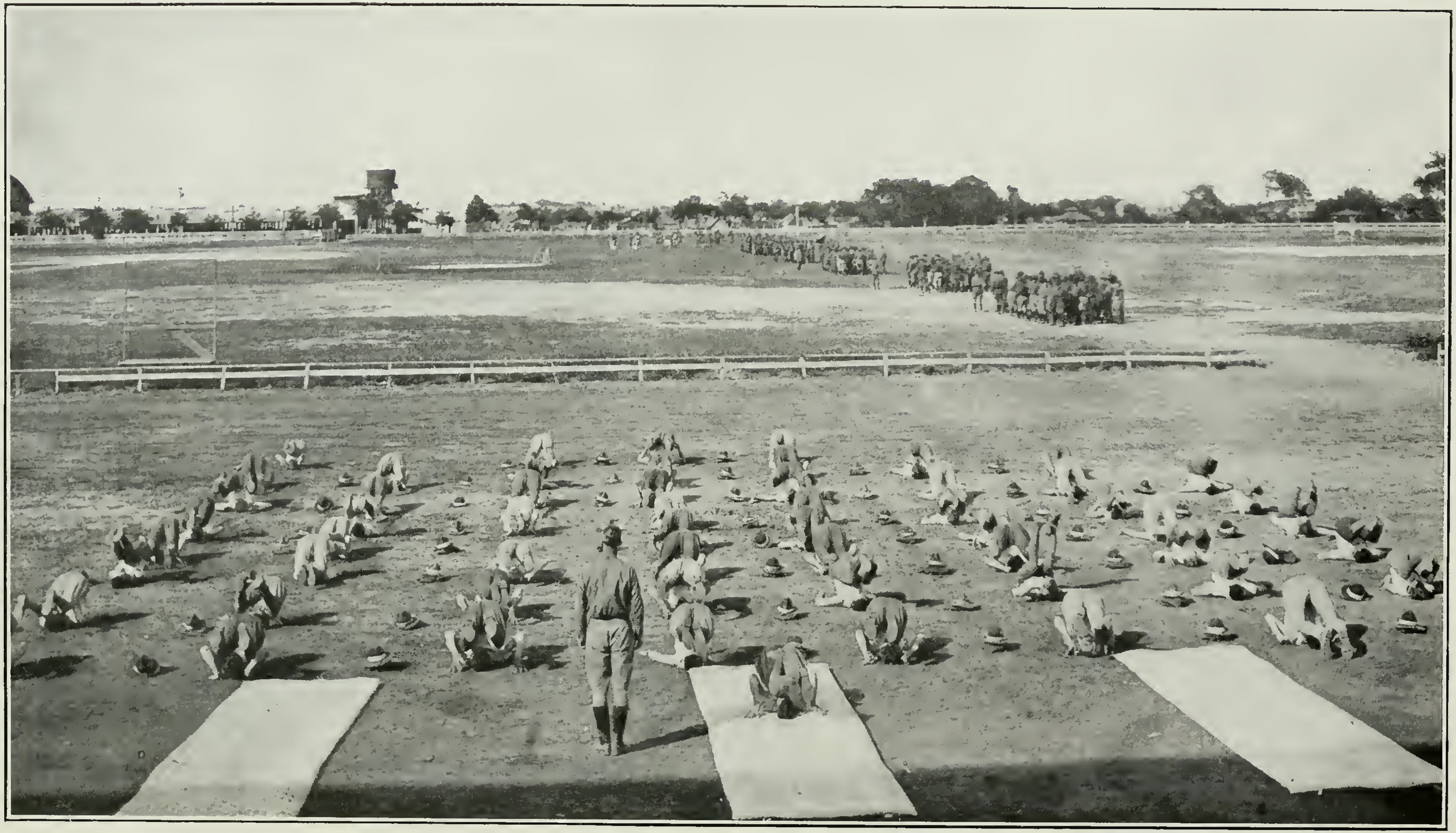


AVIATION CALISTHENICS.

undertake "stunting" in the air. Flying training by this "ground training flying apparatus" should be under the combined supervision of the officer in charge of flying and the flight surgeon.

Another method of educating the cadet is by means of flying calisthenics. By daily turning and tumbling exercises the cadet, who at first is awkward and bewildered, soon becomes accustomed to positions and movements to which he had previously been unaccustomed.

When we remember that each aviator overseas means an expenditure of upwards of $40,000—as represented by his training in the ground school and in the flying school, by the employment of airplanes and the necessary mechanicians for their upkeep, as well as his personal expense to the Government for pay and transportation—we realize that, apart from the humanitarian standpoint, there is a purely military aspect which demands proper care of this tremendous financial investment. This saving of invaluable human material and money can be accomplished only by providing a specially trained medical officer who, as medical advisor to the Commanding Officer, is charged with the duty of maintaining the mental and physical fitness of the individual fliers of the command. This officer is the Flight Surgeon.

To meet this problem, the general staff authorized this new grade in the tables of organization, the "Flight Surgeon." Authorization was also made for the grade of "Physical Director." The original authorization provided for 50 flight surgeons and 50 physical directors; one flight surgeon, with a physical director as his assistant, was to be provided for each flying school in the United States, and the others for overseas service as needed.

Specifically, "the duty of the Flight Surgeon is to act as advisor to the Commanding Officer of flying schools and squadron groups. Although under the Post Surgeon, he has freedom of independent initiative in all questions of flying fitness of aviators or cadets. Subject to the approval of the Commanding Officer, he is expected to institute such measures as periods of rest, recreation, and temporary excuse from duty, as may seem to him advisable. He takes sick call for aviators and cadets and recommends the disposition of cases excused from duty. He will visit such cases as may be in the hospital at the post and consult with the attending surgeon or physician regarding them. From time to time he will make routine reexaminations of aviators and cadets; also such special examinations as he may deem advisable, being assisted therein by data furnished by the Branch Medical Research Laboratory. He will live in as close touch with the fliers and cadets at his station as is consistent with the conditions."

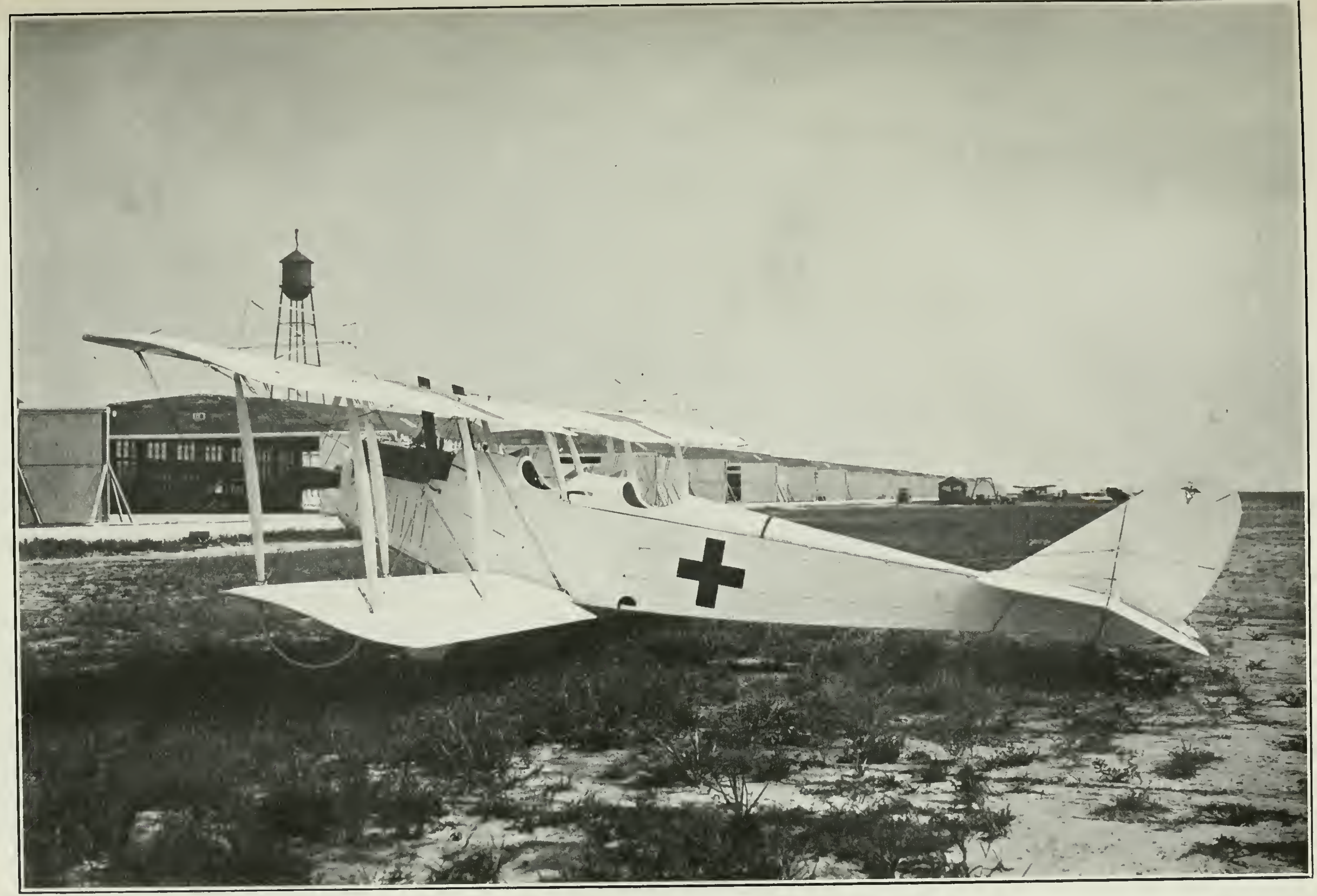
"Each Flight Surgeon will have as an assistant a Physical Director, whose duty is to supervise such recreation and physical training of aviators and cadets as is considered necessary. He will live and mess with the cadets, keep as closely in touch with them as possible, study their habits, temperaments, and physical fitness, and advise the Flight Surgeon in all matters regarding these points."

So much for the official routine; it needs but a glance at the many activities suggested to realize that back of this order was a great need—the daily care and watchfulness over the aviator.

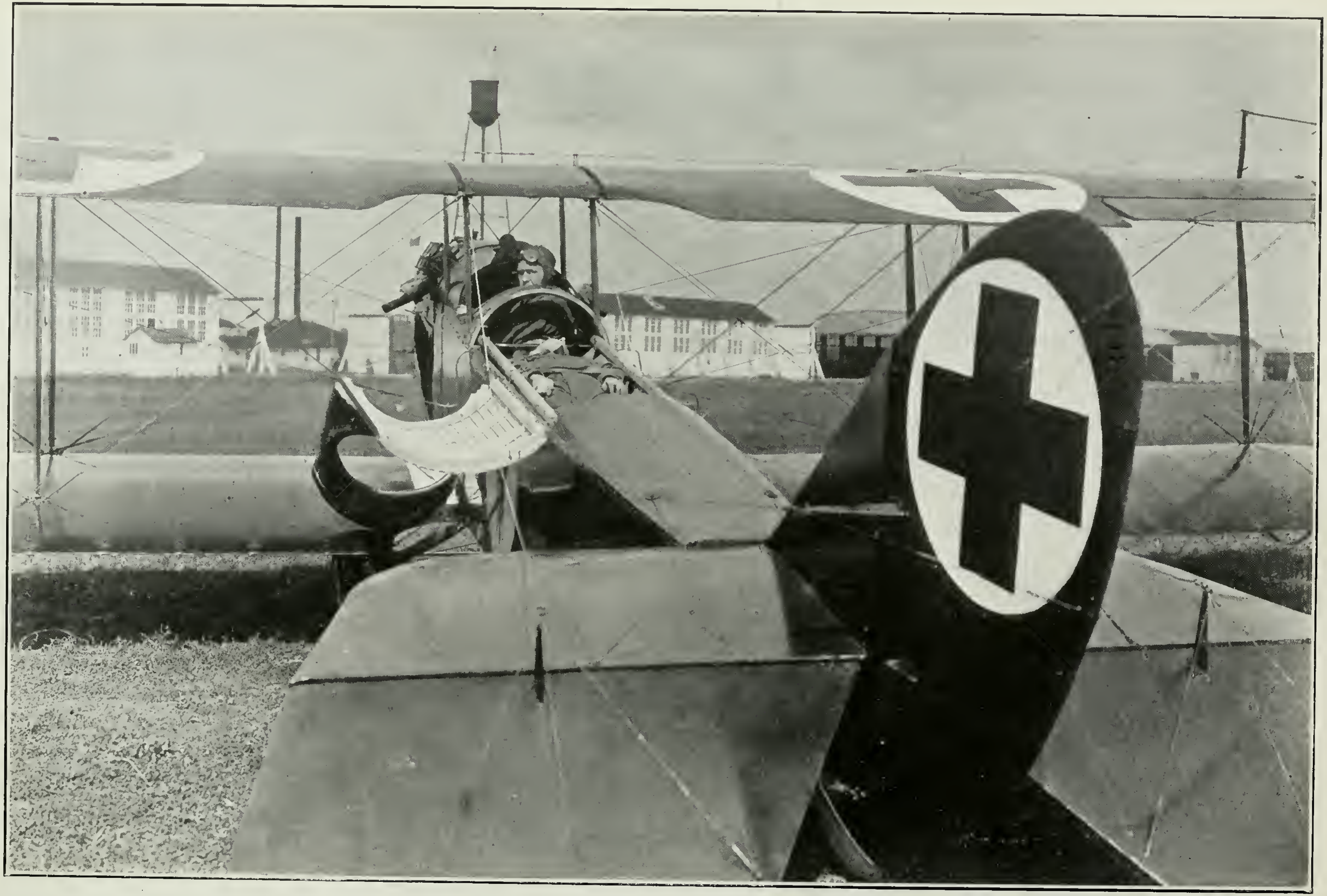
The medical study of aviation is so new that unless a medical officer has been specially trained for the aviation service he can have no idea whatever of the methods of making diagnosis of the ills peculiar to flying. For this highly specialized phase of medical work the Flight Surgeon must have certain special qualifications. For this reason the greatest care has been exercised in the selection of each Flight Surgeon, as it was recognized that the entire success of the work depended upon the personality, experience, and diagnostic skill of the medical officers selected for this special duty.

Ideal material for Flight Surgeons became available when a large number of Physical Examining Units completed their work. Those medical officers were chosen who had had large experience in examining hundreds or thousands of applicants for the service. From this group were selected those whose personality was such that they could not only command the respect but the confidence of the individual aviator. This is essential. The efficient Flight Surgeon is one whose personality is such that the cadet, flying officer, or aviator at the front, feels that he has, in his Flight Surgeon, one to whom he can go without restriction—in the same spirit with which, in civilian life, he was accustomed to consult his family physician. When a prospective Flight Surgeon had been selected for his exceptional ability and knowledge of the special diagnostic tests, and for his personality, he was then sent to the Medical Research Laboratory at Mineola, Long Island, where he received intensive training in those special tests with which he had not yet become familiar in his original examining work.

The Flight Surgeon was also given adequate opportunity to acquire actual flying experience both at Mineola and at the flying fields. This enabled him to supplement his other special preparations for his own peculiar work with the much needed first-hand "knowledge of the air." Permission has been granted by the Director of Military Aeronautics for these officers, among others, to take regular ground and air courses of instruction in flying, and many of the Flight Surgeons have already qualified for R. M. A. Actual flying is of great value as an additional aid in rendering the Flight Surgeon better able



HOSPITAL SHIP.



AMBULANCE SHIP.

This ship is painted red with white circles in which is a red cross, thus easily seen in the air, all other ships giving it right of way. Enables patient to be taken to hospital quickly and with no jarring.

34a-3

BOXING.

TUG OF WAR.

NET BALL.

POOL.

BOWLING.

MAJ. WM. R. REAM, THE FIRST FLIGHT SURGEON
TO BE PUT ON FLYING STATUS.

MAJ. REAM IN HIS PLANE.

to realize and cope with the peculiar conditions and ills incidental to aviation.

At the Medical Research Laboratory he was enabled to secure all the up-to-the-minute information regarding the eye, ear, nose and throat, cardio-vascular, physiologic, psychiatric, and psychologic work. Of the new problems taken up at the Medical Research Laboratory, studies in psychiatry were of peculiar importance. No Flight Surgeon can adequately diagnose an aviator's condition who has not the ability to determine the mental condition of the individual. If an aviator is having sleepless nights, worrying over financial problems, anxieties regarding the wife at home who is about to become a mother, or other anxieties of everyday occurrence in human life, it is not surprising if we find that he is not in fit condition to fly. It has been repeatedly proven that if the aviator who has been flying badly under such a mental handicap, tells his troubles to an intelligent and sympathetic listener, he is almost invariably able to "get hold of himself," after which he goes out again and flies well. The Medical Research Laboratory provides instruction in all these essential branches; after a course of four or five weeks of such intensive instructions the Flight Surgeon is then sent to work among the aviators, under actual service conditions.

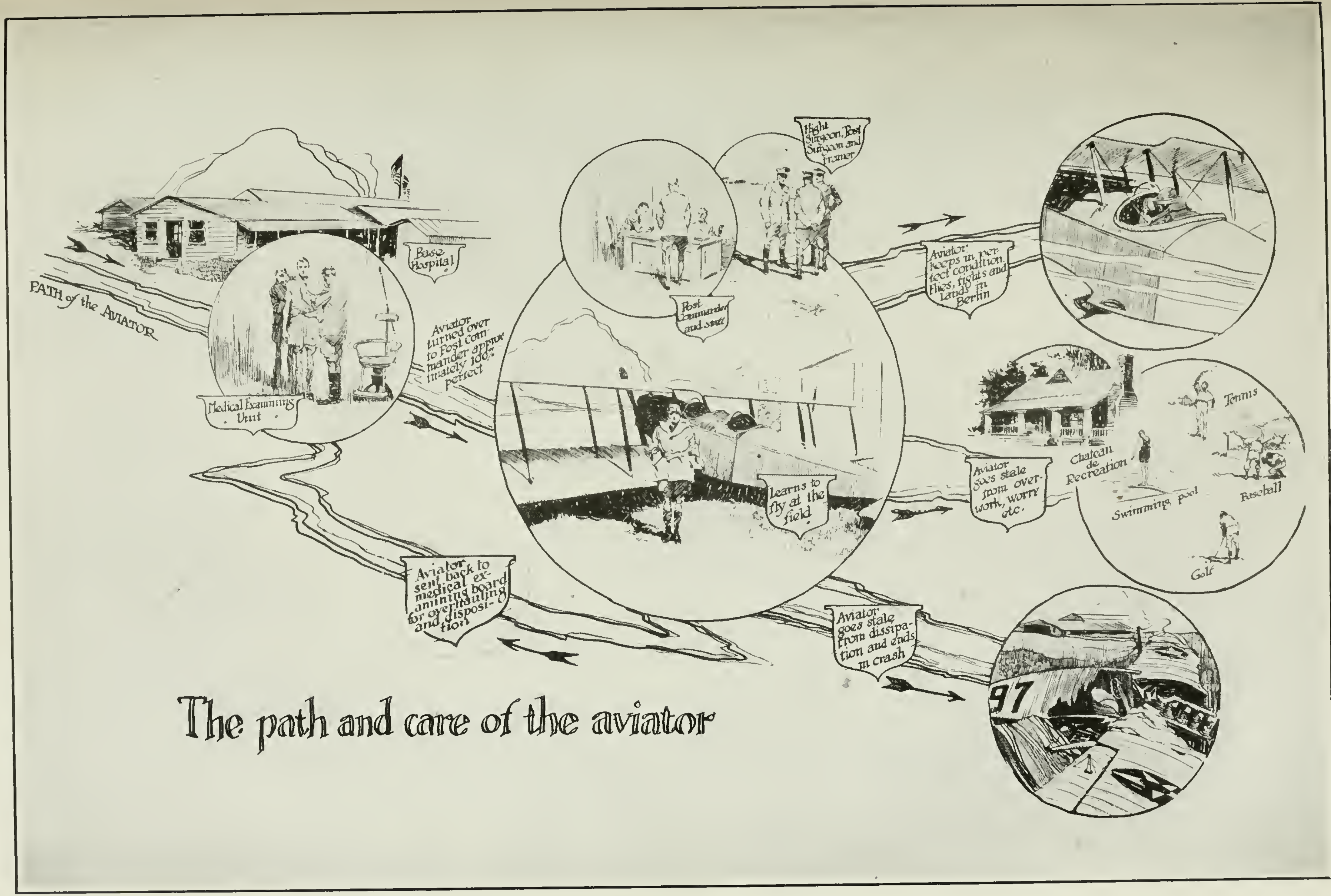
It has become evident during the past nine months through activities of nutritional survey parties of the Food Division, Surgeon General's Office, that there is great need in each aviation camp for a Nutrition Officer. Stated in the briefest terms the needs for his services are these:

The strain on the flier—especially the mental strain—is great. He is very susceptible while on flying duty to influences that would ordinarily not affect him at all. To reach and maintain his maximum efficiency requires his being in the best physical and mental condition. In peace times, under conditions where neither life and death nor great ideals are at stake, a "training table" is maintained for club or college athletes. This is done because it is recognized that improper feeding may reduce a man's efficiency, or even put him "out of the running" in a contest in which his best is required to win. In the case of the flier we are concerned, when he goes up, not only with questions of life and death and ideals, but with the fact that he, more than the average athlete, depends for success upon clearness of mind, quickness of thought, keenness of judgment. All these are mental faculties, not muscular. The nervous system is more highly differentiated than the muscular system, and by reason of that fact more easily upset by improper food.

For the highest efficiency of the flier there is required some form of training table. At times when he is slightly unfit, with headache, constipation, etc., this is doubly needed. A Nutrition Officer with special training in knowledge of food values should supervise the messes of all students and officer fliers in order to keep up the efficiency of the fliers and prevent as far as possible the development of digestive ailments of even minor character. But in addition to this, every flier who develops a digestive disorder should constitute a special problem for the Nutrition Officer so that he may become "fit" again at the earliest possible moment. With such food supervision the general efficiency of the fliers can be raised definitely, the number of hours per month that these men are fit for flying duty increased, and finally the danger to both life and equipment of the flier greatly reduced.

With expert supervision of the flier's nutrition and exercise, supplementing his own professional knowledge concerning flying and the aviator, the Flight Surgeon neglects nothing of a practical value which can be used in maintaining in the highest degree the physical efficiency of the Air Fighting Force.

Without exception the Commanding Officers of the aviation fields have welcomed the advent of the Flight Surgeon. They realize the tremendous responsibility of sending a man into the air who may, at the time, be mentally or physically unfit for flying. No Commanding Officer has, for the sake of a large record, ever shown a tendency to force his men into the air. From a military standpoint they realize that an attempt to escape duty on the part of an aviator is an altogether different matter from such an attempt of men enlisted in other branches of the service. The Commanding Officer, or officers in charge of flying, who are constantly observing their men in flight, sense certain transitory changes in a man's condition which impair his air efficiency. They are often called upon to ground such a man or relieve him from duty. It is not to be wondered at, therefore, that they welcome the support of the Flight Surgeon who adds a medical knowledge to their own, which after all is based upon experience alone. The Flight Surgeon, in addition to maintaining at the highest point the physical efficiency of the flying force of a command, is prepared at any time to furnish to the Commanding Officer a reliable expert opinion as to each individual's mental and physical fitness for flying duty.


PATH of the AVIATOR
Base Hospital
Medical Examining Unit
Aviator turned over to Post commander approximately 100% perfect
Post Commander and staff
Flight Surgeon, Post Surgeon and Trainer
Learns to fly at the field
Aviator sent back to medical examining board for overhauling and disposition
Aviator keeps in perfect condition, flies, fights and lands in Berlin
Aviator goes stale from overwork, worry etc.
Chateau de Recreation
Tennis
Swimming pool
Baseball
Golf
Aviator goes stale from dissipation and ends in crash
97
The path and care of the aviator

PART II.

CHAPTER I.

THE ORGANIZATION FOR EXAMINATION OF APPLICANTS.

Owing to the enormous number of applicants for the Air Service to be examined in a relatively short period it became apparent that a radical departure from precedent would have to be made in order to handle this number effectively. During the early part of 1917 the Aviation Examining Board in Washington, D. C., passed on approximately all applicants for commissions in the Aviation Section, Signal Corps; but as it became apparent that the commissioned personnel would be greatly augmented, the number of these boards was increased, until in January, 1918, there were 35 Examining Boards established in the principal cities of the United States, which, with the 32 additional boards established at National Army and National Guard divisional cantonments, made a total of 67 Aviation Examining Boards.

Although the type of Examining Board officially prescribed was adhered to, the details of the constitution of the board were altered in order to facilitate the handling of such large numbers of applicants. Each board had a president, a representative of the Air Service, and a medical officer.

These representatives of the Air Service were responsible for determining the mental, educational, professional, and moral desirability of the applicants selected. As this work was of a highly specialized nature, these men were called upon to undergo intensive special training as expert examiners for this particular service. It was also necessary that the medical member of the board should be thoroughly qualified to make examinations in ophthalmology, otolaryngology, the cardio-vascular system, the respiratory system, and neurology.

To meet the demands for examination in various localities, and because it is manifestly impossible to find highly developed special training in any one individual along all of the above-mentioned lines, the medical member of the board was elaborated into the Physical Examining Unit, the size of the unit depending on the amount of applicant material assembled at any one place. In some cases as many as four or five board examiners were working; at the same time the number of physicians working together as a Physical Examining Unit varied at different points from 7 to 28.

The necessity for a special system of keeping the records was met by devising certain standardized paper-work blanks which enabled the Examining Unit to file complete records of its findings in every case, together with a file of cross-index records completing the mental, moral and professional findings. In this way the Examining Boards and Physical Examining Units attained a proficiency which permitted the examination of a large number of applicants per day at each place. As a matter of fact, a greater number of individuals consulted the Board than eventually applied, for it became apparent very early that one of the important functions which the Examining Board could subserve was the dissuasion from applying of all those who were manifestly the wrong kind of material. The use of mature judgment on the part of the Examining Board in culling from applicant material that which was unsatisfactory at a preliminary consultation resulted in a great saving of time on the part of the Physical Examining Units.

In the course of a few months the men who were conducting the work of the Examining Boards had acquired a technique in the conduct of the examinations which, while individually developed, was surprisingly similar in general character. Most examiners were able to complete between four and five examinations per hour, but this came to be regarded as the maximum of speed. Whereas it was obviously impossible to establish in the 67 boards, which were operating at the same time, anything like an absolute model for basing judgment as to the qualifications of an applicant, the standard maintained was sufficiently high to supply the ground schools with satisfactory material.

The professional or mental examination requires the utmost judgment and knowledge of men. Not every man is at his best when confronted with the immediate necessity of displaying his mental ability. Extreme sensitiveness or modesty may put him at a disadvantage, his alertness being temporarily obscured; and it is here that the examiner can display the tact that will bring into notice any desirable qualities which the applicant may have.

It became apparent in the conduct of these board examinations that it was quite important to take into consideration the existence of qualifications in applicants whose early educational training had been neglected by cause of circumstances. This is well illustrated by the following instance: A first glance over the blanks of two applicants showed one of them to be a plumber, the other to be a graduate of a well-known university. The Board President called attention to the probability that the first would evidently prove unsuitable for officer material, whereas the second undoubtedly would prove to be a man of culture and education, with a reasonable amount of sports and athletic experience. The applicants were then called upon to enter and be examined. The first appeared, and apparently was a very unusual type of plumber. As the examination proceeded the questions of the President of the Board elicited the facts that while the applicant followed plumbing as a breadwinning occupation, he had diligently pursued a course of self-education and had attained an unusually high familiarity with radio work. In fact, he had established a radio laboratory in connection with his plumbing shop, in which he devoted a great deal of his unoccupied time to the development of this particular hobby, and his proficiency in this had reached a point which earned the recognition of the faculty of a near-by college. Some of the students at this college applying for a course in radio work had been organized into a special class by the faculty and had been turned over to the plumber for instruction. This proved so successful that further classes in radio work were organized among students of this institution of learning. In addition, the plumber turned out to be a man of broad views and capabilities, and was unanimously adjudged as extremely desirable material for officer training in the Air Service. The university graduate was then called in for examination, and it was immediately evident that he was the type of perfunctory student who had done just enough work in the required course to enable him to qualify for his degree. He had taken no part in athletics of any kind, and his record of achievement both in college and afterwards was only a drab blank. In this case it was again the unanimous opinion of the Board that he was distinctly not desirable for officer material for the Air Service.

In testing the general fitness of an applicant, the questions asked are of broad scope, aimed to suit the individual case, but obviously they would defeat their own purpose if designed to trip a man, make him ill at ease, or in any way put him at a disadvantage.

Final decision of the Examining Board as to the acceptability of the individual applicant was made after receiving the complete medical report from the Physical Examining Unit.

CHAPTER II.

THE ESTABLISHING OF 67 PHYSICAL EXAMINING UNITS.

Through our entrance into the world war, it was found necessary to devise at once a practical means of enlarging the Air Service commensurately with the rôle it was destined to play in our military operations. There was an immediate demand for thousands of men who would measure up to the physical and mental requirements for aviation.

The Surgeon General of the United States Army, faced with this problem, decided to place the supervision of the work in the hands of one medical officer, giving him full power, under the Chief Signal Officer, to determine the physical fitness of these applicants.

The order which created this work of such far-reaching importance should be here quoted:

Special Orders, No. 207.

War Department, *Washington, September 6, 1917.*

Lieut. Col. Theodore C. Lyster, Medical Corps, now on duty in the office of the Surgeon General, in addition to his other duties, is designated as Chief Surgeon, Aviation Section, Signal Corps, United States Army.

Lieut. Col. George H. Crabtree, United States Army, retired, now on duty in the office of the Surgeon General, will report in person to the Chief Signal Officer of the Army for duty as assistant to the Chief Surgeon and Sanitary Inspector, Aviation Section, Signal Corps, United States Army.

By order of the Secretary of War:

Tasker H. Bliss,
Major General, Chief of Staff.

Official:
H. P. McCain,
The Adjutant General.

The physical examinations required new methods; the physical qualifications new standards. These, also, had to be designed not merely for one place or one examining group.

For this purpose a medical officer was sent to each of 35 cities throughout the United States to assist in establishing at these centers medical units for the examination of applicants for aviation; also, by public meetings not only to explain the true nature of this new branch of the service, but to correct any erroneous impression regarding the rigidity of the tests.

These public meetings were attended by the medical profession and general public, who were instructed in the great need for large numbers of fliers, in the desirability of this service, and in the detailed requirements for admission.

On the day following the general public meeting there was held a special meeting of certain physicians of the city. It was at this meeting that the Physical Examining Unit was established. One of the physicians was selected to be commissioned in the Medical Reserve Corps and placed in charge of the unit. The personnel of the civilian consultants was carefully selected and organized into groups representing their respective specialties.

Every minute detail of the physical examination blank (Form 609 A. G. O.) was then explained and discussed. It was emphasized that the service required that each unit should conform to certain definite standards. The identical instruments of precision, such as the phorometer, Jennings color test, and the American modification of the Barany chair, were required in each unit.

Acknowledgment is made here of the spirit and enthusiasm with which these groups of physicians entered into the attempts to accomplish a work of a standard character.

Hospitals and other already existing institutions with their equipment were used for these examining centers. The consultants chosen were well-recognized eye, ear, nose and throat specialists, internists, surgeons, and neurologists. Their work was divided into three groups, (1) the eye, (2) the ear, nose and throat, and (3) the general physical examination.

Each Physical Examining Unit was authorized to select a man to act as clerk, sending his name to the Office of the Chief Surgeon, which then authorized this man's enlistment in the grade of a private, Medical Department, and assigned him for duty with the unit. This being accomplished, recommendation was at once made for his promotion to the grade of sergeant, if such promotion seemed advisable. In many places where large numbers were examined volunteer assistants were obtained, with the sergeant supervising their work.

These units determined the physical condition of the men ordered by the Examining Board to appear for such examination. When the examination had been completed, the papers were signed by the officer in charge of the unit and returned to the Board, which body then considered the man's mental and moral make-up, decided as to his fitness, and announced to him the result. If he was accepted he was immediately enlisted in the Reserve Corps and placed on the inactive list.

The first unit was established in Philadelphia, at the hospital of the University of Pennsylvania, where the aviation examinations were begun on May 15, 1917. After this, units were established with great rapidity in New York, Boston, Ithaca, Washington, and Chicago, all of these being in active operation by the end of June of that year.

On July 6, 1917 (Special Order No. 155, paragraph 35), a medical officer was detailed to visit the following places to establish Physical Examining Units and to standardize the examinations: Champaign, Ill.; Indianapolis, Ind.; St. Louis, Mo.; Kansas City, Mo.; Denver, Colo.; Memphis, Tenn.; Cincinnati, Ohio; Cleveland, Ohio; Buffalo, N. Y.; Pittsburgh, Pa. This entire tour was concluded in six weeks.

More units were established in the fall of 1917. The following itinerary, showing as it does the rapidity with which ground was covered, emphasized the enthusiastic cooperation of the medical profession in each city, which made it possible to establish so many units in such a short time:

	1917.
Leave Washington	Sept. 6.
Arrive Richmond, Va	Sept. 6.
General public meeting under auspices medical societies,	Friday evening. Sept. 7.
Leave Richmond	Sept. 8.
Arrive Charleston, S. C	Sept. 9.
General public meeting	Monday evening, Sept. 10.
Leave Charleston	Sept. 11.
Arrive Savannah, Ga	Sept. 11.
General public meeting	Wednesday evening, Sept. 12.
Leave Savannah	Sept. 13.
Arrive Atlanta, Ga	Sept. 14.
General public meeting	Friday evening, Sept. 14.
Leave Atlanta	Sept. 15.
Arrive Birmingham, Ala	Sept. 16.
General public meeting	Monday evening, Sept. 17.
Leave Birmingham	Sept. 18.
Arrive New Orleans, La	Sept. 18.
General public meeting	Wednesday evening, Sept. 19.
Leave New Orleans	Sept. 20.
Arrive San Antonio, Tex	Sept. 24.
General public meeting	Wednesday evening, Sept. 26.
Leave San Antonio	Sept. 27.
Arrive Los Angeles, Cal	Sept. 30.
General public meeting	Monday evening, Oct. 1.
Leave Los Angeles	Oct. 4.
Arrive San Francisco, Cal	Oct. 6.
General public meeting	Saturday evening, Oct. 7.

These urban units were supplemented by the addition of 32 units at divisional cantonments, and so successful was this method of handling this great bulk of work that by the fall of 1917, 67 units were actively conducting the examinations. The following list of Physical Examining Units and Examining Boards includes the names of the officers in charge, civilian consultants and volunteer clerks, representing the complete personnel of the units. This list gives some idea of the work involved in the service of "The selection of the aviator."

PHYSICAL EXAMINING UNITS WITH EXAMINING BOARDS ATTACHED.

ALEXANDRIA, LA.—*Base Hospital, Camp Beauregard.*

Officer in charge, Capt. H. H. Forcheimer, M. R. C. Capt. James C. Harkinns, M. R. C.; Capt. Robert Lockhart, M. R. C.

Examining board: President, Division Signal Officer; Lieut. James H. Phillips, M. R. C.

AMERICAN LAKE, WASH.—*Base Hospital, Camp Lewis.*

Officer in charge, Maj. J. J. Kyle, M. R. C.; Capt. R. K. Hutchins, M. R. C.; Capt. David C. Twitchell, M. R. C.; Lieut. William J. Kerr, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Timothy T. Gibson, M. R. C.

ANNAPOLIS JUNCTION, MD.—*Base Hospital, Camp Meade.*

Officer in charge, Maj. E. C. Ellett, M. R. C. Maj. George B. Wood, M. R. C.; Capt. Gordon Wilson, M. R. C.; Lieut. A. E. Strauss, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Lee A. Hadley, M. R. C.

ANNISTON, ALA.—*Base Hospital, Camp McClellan.*

Officer in charge, Capt. A. L. Bishop, M. R. C.; Capt. Harold D. Brewster, M. R. C.; Capt. W. W. Osgood, M. R. C; Lieut. Ernest P. Boas, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Adlai E. Callahan, M. R. C.

ATLANTA, GA.—*Base Hospital, Camp Gordon.*

Officer in charge, Capt. Cabot Lull, M. R. C.; Capt. L. H. Prince, M. R. C.; Lieut. G. A. Bulson, M. R. C.; Lieut. C. D. Giddings, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Otto J. Schott, M. R. C.

ATLANTA, GA.—*Emory University.*

Officer in charge, Capt. Dunbar Roy, M. R. C.; Capt. Louis Levy, M. R. C.; Lieut. Ernest S. Colvin, M. R. C.

Examining board: President, Capt. I. H. Saunders, S. C. First Lieut. John H. Hall, M. R. C.

Eye, ear, nose and throat: Dr. G. D. Ayer.

General physical: Dr. C. C. Aven, Dr. W. L. Funkhouser, Dr. L. G. Baggett, Dr. W. W. Young, Dr. R. A. Bartholomew, Dr. John H. Vermilye.

AUGUSTA, GA.—*Base Hospital, Camp Hancock.*

Officer in charge, Maj. J. F. Culp, M. R. C.; Capt. Charles H Erway, M. R. C.; Capt. W. J. Olds, M. R. C.; Lieut. S. Calvin Smith, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Alex. A. Drill, M. R. C.

AUSTIN, TEX.

Officer in charge, Capt. John H. Timberman, M. R. C.

Eye, ear, nose and throat: Dr. S. N. Key, Dr. S. J. Clarke, Dr. J. R. Nicholls, Dr. H. L. Hilgartner, Dr. W. A. Harper.

General physical: Dr. T. J. Bennett, Dr. S. E. Hudson.

AYER, MASS.—*Base Hospital, Camp Devens.*

Officer in charge, Maj. W. F. Knowles, M. R. C.; Maj. W. B. Lancaster, M. R. C.; Capt. H. W. Stevens, M. R. C.; C. S. Harry I. Barnes, U. S. A.

Examining board: President, Division Signal Officer; Lieut. Richard J. R. Caines, M. R. C.

BATTLE CREEK, MICH.—*Base Hospital, Camp Custer.*

Officer in charge, Maj. R. B. Canfield, M. R. C.; Maj. G. F. Suker, M. R. C.; Lieut. M. K. Fromm, M. R. C.; Lieut. A. F. Jennings, M. R. C.

Examining board: President, Division Signal Officer; Capt. William J. Uppendahl, M. R. C.

BIRMINGHAM, ALA.—*University Free Dispensary.*

Officer in charge, Capt. Kosciusko W. Constantine, M. R. C.

Examining board: Lieut. Gaston W. Rogers, M. R. C.

Eye: Dr. S. L. Ledbetter, sr.; Dr. A. B. Harris.

Ear: Dr. W. B. Smith, Dr G. W. Harrison.

General Physical: Dr. H. S. Ward, Dr. U. J. W. Peters, Dr. E. M. Mason.

BOSTON, MASS.—*Massachusetts Charitable Eye and Ear Infirmary.*

Officer in charge, Capt. Harry P. Cahill, M. R. C.; Lieut. John G. Jennings, M. R. C.

Examining board No. 1: President, Capt. F. L. Wells, C. S. Capt. Wm. W. Laing, M. R. C.; Lieut. Wm. J. Harkins, M. R. C.

Examining board No. 2: President, Capt. Abraham L. Lavine, S. C. Capt. Chas. S. Butler, M. R. C.; Capt. Robt. F. Souther, M. R. C.

Eye, ear, nose, and throat: Dr. William J. Harkins, Dr. Wm. I. Wiggin, Dr. Geo. H. Poirier, Dr. Harold L. Babcock.

General physical: Dr. Martin J. English, Dr. John O'Donnell, Dr. Francis T. Jansen, Dr. Joseph M. Lynch.

BUFFALO, N. Y.—*Buffalo General Hospital.*

Officer in charge, Capt. George F. Scott, M. R. C.

Examining board: President, Capt. Lester F. Gilbert, S. C. Capt. George F. Cott, M. R. C.

Eye: Dr. Alfred F. Luhr, Dr. Ray A. Edson, Dr. A. G. Bennett, Dr. H. H. Glosser, Dr. F. Park Lewis, Dr. H. W. Cowper, Dr. Lucien Howe.

Ear, nose, and throat: Dr. Chester C. Cott, Dr. Walter J. Wurtz.

General physical: Dr. F. J. Parmenter, Dr. Chas. A. Wall, Dr. Jas. B. Gross, Dr. H. C. Buswell, Dr. Henry R. Hopkins, Dr. Chas. G. Stockton.

Volunteer clerks: Miss Anna B. O'Day.

CANAL ZONE.—*Ancon Hospital.*

Officer in charge: Capt. George C. Marshall, M. R. C.

CHARLOTTE, N. C.—*Base Hospital, Camp Greene.*

Officer in charge: Capt. George A. Renn, M. R. C.; Lieut. Herman Elwyn, M. R. C.; Lieut. T. E. McConnell, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Curtis R. Senter, M. R. C.

CHARLESTON, S. C.—*Roper Hospital.*

Officer in charge: Capt. Chas. W. Kollock, M. R. C.

Examining board: Capt. Chas. W. Kollock, M. R. C.

Eye, ear, nose, and throat: Dr. Charles W. Kollock.

General physical: Dr. J. A. Finger, Dr. J. C. Guess, Dr. W. H. Frampton, Dr. Edward Rutledge, Dr. J. C. Mitchell, Dr. E. L. Jager, Dr. F. B. Johnson, Dr. C. F. Bullock.

CHICAGO, ILL.—*Illinois Charitable Eye and Ear Infirmary.*

Officers in charge, Maj. Casey A. Wood, M. R. C.; Maj. Norval H. Pierce, M. R. C.; Capt. Francis Lane, M. R. C.; Lieut. Eugene Cary, M. R. C.; Lieut. Charles P. Small, M. R. C.

Examining board: President, Capt. Charles E. Morrison, S. C.; Lieut. Forrest H. Sholts, S. C.; Capt. George W. Woodnick, M. R. C.

Eye: Dr. E. W. Reagan.

Ear, nose and throat: Dr. Austin A. Hayden, Dr. E. E. Birmingham, Dr. F. H. Henderson, Dr. Alfred Lewy, Dr. E. La Mothe, Dr. F. S. Wilson, Dr. R. J. Atwood, Dr. W. K. Spiece.

General physical: Dr. Frank Leslie, Dr. H. Smith.

Volunteer clerks: Miss Helen Adams, Miss Margaret Monroe, Miss Judith Cattell.

CHILLICOTHE, OHIO.—*Base Hospital, Camp Sherman.*

Officer in charge, Maj. C. R. Holmes, M. R. C.; Maj. Casey Wood, M. R. C.; Capt. S. Rinehart, M. R. C.; Lieut. W. L. Freyhof, M. R. C.

Examining board: President, Division Signal Officer; First Lieut. Brose S. Horne, M. R. C.

CINCINNATI, OHIO.—*Cincinnati General Hospital.*

Officer in charge, Capt. Arthur C. Bachmeyer, M. R. C.

Examning board: President, Capt. Dudley B. Lawrence, S. C.; Capt. Arthur C. Bachmeyer, M. R. C.

Eye: Dr. Victor Ray, Dr. Fred Lamb, Dr. Jesse Wyler, Dr. Wylle Ayres, Dr. Clarence King, Dr. John Ranley, Dr. Walter Forchheimer.

Ear, nose, and throat: Dr. Samuel Iglauer, Dr. Horace Tangeman, Dr. Walter E. Murphy, Dr. Robert Stevenson, Dr. William Mithoefer, Dr. William C. Harris, Dr. Charles C. Jones.

General physical: Dr. Mark A. Brown, Dr. Oscar Berghausen, Dr. Arthur E. Osmond, Dr. William J. Graf, Dr. Edward A. Wagner, Dr. E. C. Steinharter.

CLEVELAND, OHIO.—*Lakeside Hospital.*

Officer in charge, Capt. John M. Ingersoll, M. R. C.

Examining board: President, Capt. Madison Bentley, S. C. Capt. F. E. Cutler, M. R. C.

Eye: Dr. W. E. Bruner, Dr. W. C. Tuckerman, Dr. R. B. Metz, Dr. S. H. Monson, Dr. W. P. Chamberlin, Dr. P. G. Moore.

Ear, nose and throat: Dr. C. E. Pitkin, Dr. E. W. Garrett, Dr. W. S. Chamberlin, Dr. W. G. Mussun, Dr. W. J. Abbott, Dr. A. E. Fried, Dr. W. A. Medlin, Dr. F. W. Linn.

General physical: Dr. C. E. Hoover, Dr. R. S. Dinsmore, Dr. L. H. Stewart, Dr. L. W. Ladd, Dr. P. M. Spurney, Dr. C. T. Bahler, Dr. E. H. Cox, Dr. K. H. Martzloff, Dr. A. B. Denison, Dr. R. E. Mosiman, Dr. D. V. Rosenberg.

COLUMBUS, OHIO.

Officer in charge, Capt. Franklin E. Cutler, M. R. C.; Lieut. A. H. Seeds, M. R. C.

Examining board: President, Capt. C. C. Jones, S. C.

Eye: Drs. Ivor G. Clark, J. B. Alcorn, A. W. Prout.

Ear, nose and throat: Drs. John E. Brown, A. C. Wolfe, C. H. Hoffhine, H. G. Beatty.

General physical: Drs. J. W. Leist, F. M. Stanton, C. T. Okey, R. L. Barnes, J. H. J. Upham, H. R. Burbacher, W. H. Hodges.

Volunteer clerk: John E. Brown, jr.

COLUMBIA, S. C.—*Base Hospital, Camp Jackson.*

Officer in charge, Capt. Burton Chance, M. R. C.; Capt. J. W. McConnell, M. R. C.; Lieut. Berton Lattin, M. R. C.; Lieut. Wilson Pendleton, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Bernard Barrow, M. R. C.

DEMING, N. MEX.—*Base Hospital, Camp Cody.*

Officer in charge, Capt. H. R. Carter, M. R. C.; Capt. L. C. Covington; Lieut. Ernest A. Duncan, M. R. C.; Lieut. E. E. Johnson, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Samuel Roth, M. R. C.

DENVER, COLO.—*406 Metropolitan Building.*

Officer in charge, Capt. Robert Levey, M. R. C.

Examining board: President, Capt. Alfred W. Tozzer, S. C. Capt. Robert Levey, M. R. C.

Eye: Dr. Edward Jackson, Dr. D. G. Monaghan, Dr. D. H. Coover, Dr. J. A. McCaw, Dr. H. H. Stilwill, Dr. William H. Crisp.

Ear, nose and throat: Dr. C. E. Cooper, Dr. Harry Baum, Dr. E. W. Collins.

General physical: Dr. C. B. Van Zant, Dr. Stanley B. Eichberg, Dr. E. H. Mugrage, Dr. Philip Hillkowitz, Dr. George A. Moleen.

DES MOINES, IOWA.—*Base Hospital, Camp Dodge.*

Officer in charge, Maj. C. F. Todd, M. R. C.; Capt. John. H. Peck, M. R. C.; Lieut. Frank D. Lusk, M. R. C.; Lieut. L. Shields, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Ralph W. Faus, M. R. C.

DETROIT, MICH.—*Harper Hospital.*

Officer in charge, Capt. George E. Frothingham, M. R. C.

Examining board: President, Capt. Paul Magoffin, S. C. Capt. G. E. Frothingham, M. R. C.; Lieut. Frank L. Ryerson, M. R. C.

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Ear, nose and throat: Dr. William A. Defnet, Dr. Howard W. Peirce, Dr. Jacob S. Wendel, Dr. H. L. Simpson.

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Examining board: President, Division Signal Officer; Lieut. Vctor E. Bellinger, M. R. C.

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Officer in charge, Maj. G. M. Coates, M. R. C.; Capt. H. D. Pierce, M. R. C.; Lieut. Geo. McLean, M. R. C.; Lieut. T. G. Schnabel, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Arthur W. Carley, M. R. C.

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Officer in charge, Capt. O. L. Smith, M. R. C.; Lieut. Malcolm R. Brewer, M. R. C.; Lieut. Chas. S. Kibler, M. R. C.

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Officer in charge, Capt. Ernest Dew. W. Wales, M. R. C.

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Examining board—Continued.
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LITTLE ROCK, ARK.—*Base Hospital, Camp Pike.*
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Examining board—Continued.

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Examining board: President, Capt. Harold S. Arnold, M. R. C. Lieut. James A. Honeij, M. R. C.

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General physical: Dr. Wilder Tileston, Dr. Isao Hirata, Dr. Israel Kleiner, Dr. Edgar N. Johnson.

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Eye—Continued.
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Ear, nose and throat: Dr. Hampton P. Howell, Dr. Phillip D. Kerrison, Dr. Edgar H. Farr, Dr. Warren C. McFarland, Dr. W. L. Culbert, Dr. Frank H. Bartlett, Dr. John R. Page, Dr. Walter F. Babb, Dr. John E. Welsh, Dr. John D. Richards, Dr. Stephen W. Roof, Dr. James J. King, Dr. Louis Hubert, Dr. George E. Steel, Dr. John B. Rae.
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General physical: Dr. Rodney W. Bliss, Dr. LeRoy Crummer, Dr. Adolph Sachs, Dr. Edson L. Bridges, Dr. Arthur J. Dunn, Dr. C. C. Tomlinson, Dr. Frank M. Conlin, Dr. J. Clyde Moore, Dr. Warren Y. Thompson.

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General physical: Dr. Geo. M. Ferguson, Dr. Francis Ashley Faught, Dr. J. V. C. Roberts.

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Ear, nose and throat: Dr. Frank Kistner, Dr. Wilson Johnston, Dr. Ralph F. Davis, Dr. Robert B. Karkeet.
General physical: Dr. Murray M. Levy, Dr. C. Stuart Menzies, Dr. I. C. Brill, Dr. T. Homer Coffen, Dr. C. F. Bloom.
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Eye, ear, nose and throat: Dr. Joseph A. White, Dr. W. L. Mason, Dr. John Dunn, Dr. Karl Blackwell, Dr. Clifton Miller, Dr. D. A. Kuyk, Dr. W. B. Hopkins.
General physical: Dr. Manfred Call, Dr. M. P. Rucker, Dr. M. O. Burke, Dr. Douglas Vanderhoof, Dr. H. W. Randolph, Dr. T. N. Barnett, Dr. J. M. Hucheson, Dr. E. B. Talbot, Dr. Herbert Mann, Dr. F. P. Righter, Dr. W. S. Bordon, Dr. Robt. S. Bosher, Dr. William H. Higgins.

ROCKFORD, ILL.—*Base Hospital, Camp Grant.*
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Examining board: President, Division Signal Officer; Lieut. Edwin G. Schwartz, M. R. C.

ST. LOUIS, MO.—*Washington University.*
Officer in charge. Capt. Harry W. Lyman. M. R. C.; First Lieut. Joseph J. Reilly, M. R. C.
Examining board: President, Capt. Chas. H. Hammond, S. C.; Capt. Frederick C. Simon, M. R. C.
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St. Louis, Mo.—*Washington University*—Continued.

Examining board—Continued.

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General physical: Dr. George Dock, Dr. R. K. Andrews, Dr. H. S. O'Connell, Dr. H. C. Peacock, Dr. W. K. Brown, Dr. W. H. Omsted, Dr. Ellsworth Smith, Dr. S. Moore, Dr. F. H. Eberhard, Dr. C. E. Gilliland, Dr. A. R. Tormey, Dr. Frank N. Wilson, Dr. A. McClory, Dr. S. T. Lipsitz, Dr. G. Canby Robinson, Miss W. McNitt, Dr. L. H. Hempelmann, Dr. A. R. Schreffler, Dr. T. C. Lyter, Dr. E. P. Buddy, Dr. J. L. Tierney, Dr. Warren Elmer, Dr. Chas. H. Neilson, Dr. J. J. Singer.

Volunteer clerks: Miss Anita Brinkmeyer, Miss Edith Foster. Mr. G. W. Tucker.

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Ear, nose and throat: Dr. Fred Stauffer, Dr. A. J. Ridges, Dr. F. H. Raley.

General physical: Dr. C. L. Shields, Dr. J. C. Landenberger, Dr. W. R. Tyndale, Dr. H. B. Felts, Dr. H. P. Kirtley, Dr. W. T. Ward, Dr. Ray Groesbeck.

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Officer in charge, Capt. Robert J. Hunter, M. R. C.; Lieut. Douglas Edwards, M. R. C.

Examining board: President, Capt. Rufus Scott, jr., S. C.; Lieut. Russell MacDonald, S. C.; Lieut. Edward E. Collins, M. R. C.; Lieut. Wilson M. Basset, M. R. C.

Eye: Dr. Applewhite.

Ear, nose and throat: Dr. Moss, Dr. Sykes.

General physical: Dr. Hicks.

Volunteer clerk: Miss Lathrop.

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Examining board: President, Capt. George M. Stratton, S. C.; Capt. Elbridge J. Best, M. R. C.

Eye: Dr. Walter S. Franklin, Dr. Edmund Glaser.

General physical: Dr. Franklin Cookingham.

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General physical: Dr. F. H. Houston, Dr. C. A. Rutherford, Dr. W. T. Woolley, Dr. C. F. Davidson, Dr. D. A. Dowling, Dr. N. A. Johanson, Dr. H. J. Davidson, Dr. O. F. Lamson, Dr. Welden E. Young, Dr. E. G. Newlands, Dr. Albert Raymond, Dr. James Shannon, Dr. Montgomery Russell, Dr. O. J. West.

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Examining board: President, Capt. V. A. C. Henmon, S. C.; Lieut. Fedor L. Senger, M. R. C.

Eye: Dr. Frank W. Marlow, Dr. Julius H. Kevand, Dr. Norman W. Foster, Dr. Herbert L. Stebbins, Dr. G. Griffin Lewis, Dr. David F. Gillette.

Eye, nose and throat: Dr. Thomas H. Halstead, Dr. Harold G. Kline, Dr. Samuel R. Fowler, Dr. George H. Rockwell, Dr. Mortimer G. Brown, Dr. Sargent F. Snow, Dr. H. Leland Fifield.

General physical: Dr. I. Harris Levy, Dr. Charles D. Post, Dr. Joseph R. Wiseman, Dr. A. E. Larkin, Dr. James Sheehan, Dr. Herbert C. Yeckel, Dr. Earl V. Sweet, Dr. Arthur D. Meyers.

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Examining board: President, Division Signal Officer; Lieut. Leonard Champion, M. R. C.

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Ear, nose and throat: Dr. O. A. M. McKimmie, Dr. G. S. Saffold, Dr. R. R. Walker, Dr. W. T. Parsons, Dr. W. C. Sparks, Dr. E. A. Taylor, Dr. D. B. Moffett, Dr. C. L. Billard.

General physical: Dr. A. W. Boswell, Dr. J. L. Thompson, Dr. M. F. Cuthbert, Dr. J. B. Nichols, Dr. Frank Leech, Dr. P. S. Roy, Dr. E. Y. Davidson, Dr. W. I. Mallory, Dr T. Miller, jr., Dr. D. G. Lewis.

Volunteer clerks: Miss Eleanor Martin, Mrs. F. W. Smith, Miss Dorothy Woodworth, Mrs. Ward Brown, Miss B. Gower, Miss Stella Devine, Miss M. Harrington, Miss Alida Haines, Miss E. C. Taylor.

WRIGHTSTOWN, N J.—*Base Hospital, Camp Dix.*

Officer in charge, Maj. Wells P. Eagleton, M. R. C.; Capt. Wm. J. Hammed, M. R. C.; Capt. P. H. Moore, M. R. C.; Lieut. T. A. Smith, M. R. C.

Examining board: President, Division Signal Officer; Lieut. Samuel J. Ellison, M. R. C.

YAPHANK, N. Y.—*Base Hospital, Camp Upton.*

Officer in charge, Maj. E. B. Dench, M. R. C.; Capt T C. Richie, M. R. C.; Capt. Jas. L. Wheaton, M. R. C.; Lieut. Edward J. Riley, M. R. C.

Examining board: President, Division Signal Officer; Lieut, Walter C. Liebmann, M. R. C.

APPLICANTS HANDING IN IDENTIFICATION SLIPS AUTHORIZING A PHYSICAL EXAMINATION FOR ENTRANCE INTO THE AVIATION SECTION, SIGNAL CORPS.

CHAPTER III.

WORKING METHODS OF PHYSICAL EXAMINING UNITS.

Blank 609 A. G. O. shown in figure 1 is the only form specified for the examination of applicants for the Aviation Service. While this blank is comprehensive in all-important details, it was not required that the examination should follow the order of items. The organization of the work of the unit was systematized with a view to saving time and energy in the carrying out of these examinations. Such a system was especially necessary in a large unit where from 20 to 75 men had to be examined every day.

In the actual working of an Examining Unit where the number of examiners is necessarily limited, it is convenient to map out and subdivide various types of examinations in such a way that the different examiners comprising the unit may all be busy at the same time. For purposes of description it might be well for the reader to put himself in the position of an observer and watch the method of procedure with a given group of applicants from the moment they enter this unit to the time they leave. Various units in different parts of the country have adopted proceedings suitable to local conditions. If a small number of applicants are to be examined, the following method of procedure has been found satisfactory:

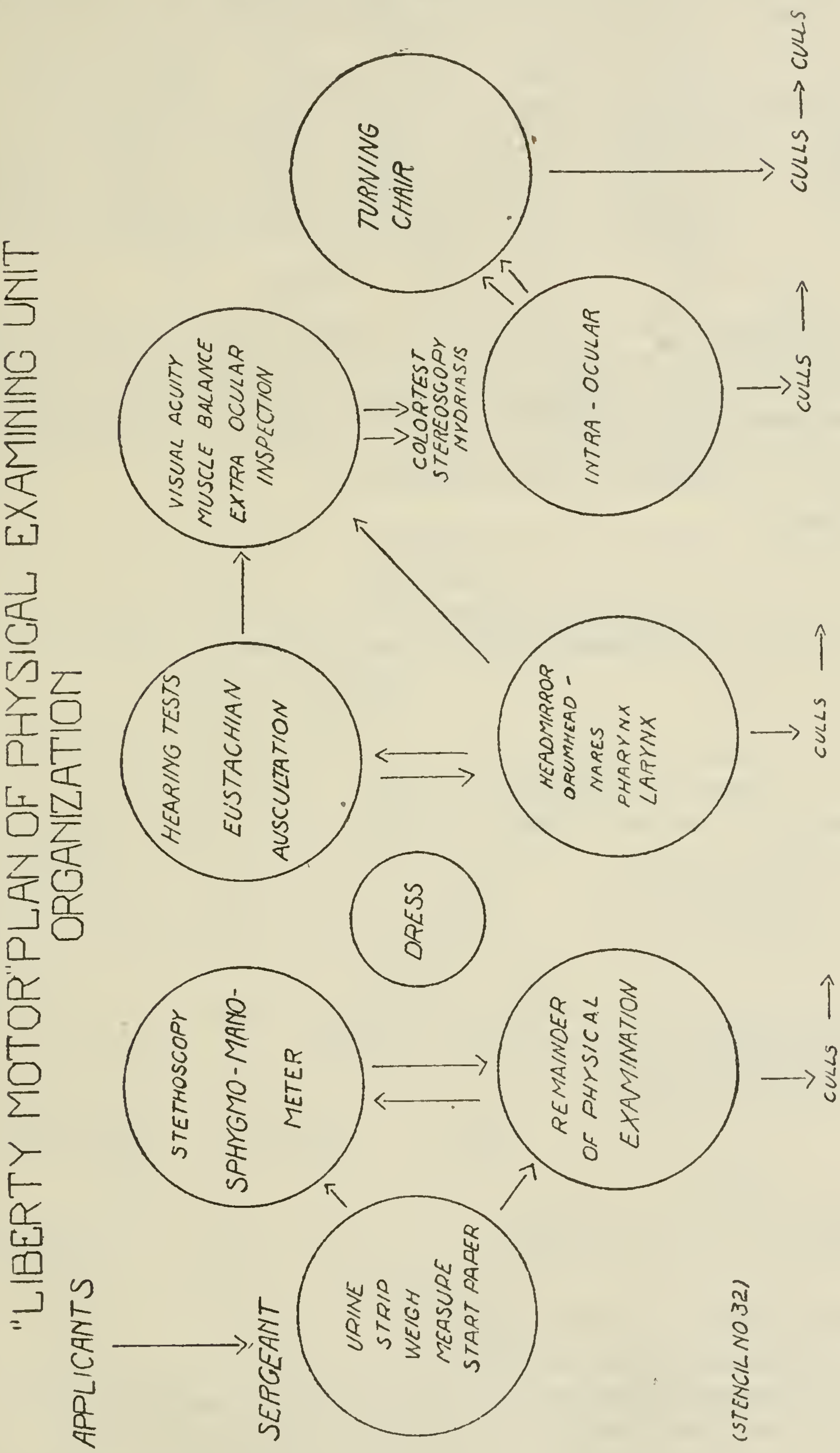
The receiving sergeant gives each applicant a number as he enters the room; this number is retained by him throughout the entire examination. Specimens of urine are then secured and the total number of applicants for the day is divided into three groups, one group being sent to the eye examiner, one group for general physical examination, and one group for the turning-chair tests, and the ear, nose and throat examinations. In this manner the ophthalmologist, the otologist and the internist are all working simultaneously. It usually takes about the same length of time for these three types of examinations, so that when the ophthalmologist is finished with his group, the otologist has similarly completed his work and is ready for the next group. In this manner these three groups alternate so that all of the examinations are completed at about the same time.

In large cities where it was necessary to examine from 25 to 50 applicants, the following so-called "Liberty motor plan" was devised and found very satisfactory. (A quotation from Stencil No. 32 gives in detail the workings of this method of examining the applicants.)

For the guidance of the various Physical Examining Units the following standard "Liberty motor" scheme of organization of units was submitted. This was deduced from the experience of a large number of units covering from six to eight months' continuous work and is definitely established to be adequate to the examination of 20 applicants per day at an average cost in time to each individual composing the unit of not more than 55 to 75 minutes per day.

Reference to the schematic representation of this organization will make it plain that, beginning at 7 a. m., for example, the applicants appear before the sergeant, who takes the urine, strips, weighs, measures, and starts the records of physical examination; at 7.20 the general physical examiners appear and find that the sergeant has, already stripped and awaiting them, at least two applicants, one of whom goes to the examiner who is to conduct the stethoscopic and sphygmomanometer examinations, and the other of whom goes to the other examiner, who is to conduct the remainder of the general physical examination; the two applicants then change about, and upon completion of the general physical examination they dress. By that time, 7.40, the two ear, nose and throat specialists appear and at once proceed to examine those applicants, as indicated in the scheme; one man conducting hearing tests and auscultation of the Eustachian tubes only, the other man with the head mirror inspecting drumheads, nares, pharynx, and larynx. The applicants then change about and are completed as to ear, nose and throat examinations, whereupon they both go to the eye specialists, who appear at 8 a. m. Here a change in the order occurs in that both applicants go to the visual acuity and muscle balance tests at once, and during the examination of one the second eye specialist conducts the color and stereoscopic tests of the second applicant. The first applicant's visual acuity, muscle balance, and extra-ocular examination being completed, he in turn is subjected to the color and stereoscopic tests, after which they are both ready for mydriatic, and as soon as the mydriasis occurs their intra-ocular examination is completed, and they then go to the turning-chair examiner, who appears at 8.20. As is indicated on the diagram, at each stage of the examination "culls"—that is, border-line cases or those who will need special follow-up examinations—are set aside so as not to interrupt the current of regular examination of the day's material, and after completion of examination of all other applicants these "culls" are then subjected to whatever additional examination or examinations may be considered necessary.

The "Liberty motor" scheme for conducting the work of Examining Units has been worked out with just one object in view, namely, to save all possible time and work for the examiners, and at the same time to insure to the service the highest type of professional services in examining applicants for the Aviation Service. The usual type of organization for Physical Examining Units includes two teams, one working Mondays, Wednesdays, and Fridays; the other Tuesdays, Thursdays, and Saturdays. If the "Liberty motor" organization scheme and schedule is adhered to, it makes possible the careful examination of as many as 20 applicants per day by the unit, at an



average cost not greater than 55 to 75 minutes per day, three days a week, to any one member of the unit.

Sample schedule according to "Liberty motor" organization, two teams, each working three days per week.

O'clock.	Monday.	Tuesday.	Wednesday.	Thursday.	Friday.	Saturday.
7.00	Sergeant.	Sergeant.	Sergeant.	Sergeant.	Sergeant.	Sergeant.
7.20, general physical	Dr. Jones. Dr. Allen.	Dr. Nash. Dr. Dodge.	Dr. Jones. Dr. Allen.	Dr. Nash. Dr. Dodge.	Dr. Jones. Dr. Allen.	Dr. Nash. Dr. Dodge.
7.40, ear, nose, throat	Dr. Smith. Dr. Bowen.	Dr. Watts. Dr. Atkins.	Dr. Smith. Dr. Bowen.	Dr. Watts. Dr. Atkins.	Dr. Smith. Dr. Bowen.	Dr. Watts. Dr. Atkins.
8.00, eye	Dr. Hughes. Dr. Brown.	Dr. Wilson. Dr. Gordon.	Dr. Hughes. Dr. Brown.	Dr. Wilson. Dr. Gordon.	Dr. Hughes. Dr. Brown.	Dr. Wilson. Dr. Gordon.
8.20	Chair.	Chair.	Chair.	Chair.	Chair.	Chair.

Strict adherence to the "Liberty motor" scheme of Physical Examining Units results in the greatest possible saving of time and labor on the part of those constituting the unit. With properly developed team and individual technique, a seven-man team can complete careful examination of 20 applicants at a cost of not to exceed 55 to 75 minutes for any individual on the team. Punctuality is the keystone of such an organization.

Blank 609.]

FIGURE 1.

[First page.]

PHYSICAL EXAMINATION OF APPLICANTS FOR DETAIL IN THE AVIATION SECTION, SIGNAL CORPS.

Place ______________________

Date ______________________

Name____

Rank and organization or status______________________

1. History of previous or present eye trouble______________________________
____
____
____
____
____

2. Stereoscopic vision, if stereoscope is available ______________________
3. Ocular movements ____
4. Pupillary reactions ____

	Direct.	Consensual.	Accommodation.
Right eye ______	__________	____________	______________
Left eye________	__________	____________	______________

5. Intraocular tension__ {Right ________________________________ Left ________________________________

6. Any visible lesion of eyes?__ {Right________________________________ Left________________________________

7. (*a*) Is ocular nystagmus present?________________________________
   (*b*) Does ocular nystagmus occur when eyes are turned easily to one side?__
   (*c*) Does ocular nystagmus occur when eyes are turned to the extreme side?

8. Field of vision__ {Right________________________________ Left________________________________

9. Color vision ____

____

10. Muscle balance, at 20 feet (use phorometer or maddox rod):

Hyperphoria ____

Esophoria ____

Exophoria ____

[Second page.]

11. Visual acuity:

(*a*) Distance, at 20 feet__ Right________________ Left________________

(*b*) Near point_ Right ________________ cm. = Left________________ cm. =

12. Ophthalmoscopic findings (5 per cent euphthalmine dilatation) Right ______ ___________ Left ______ ___________

EAR.

13. History of ear trouble:

(*a*) Ever have ringing or buzzing in either ear, earache, discharge, or mastoiditis? ________________________________

(*b*) Ever have attacks of dizziness from any cause? ______________

(*c*) Ever been seasick? ________ If so, how often? ____________ and how long does it last? ______________________________

(*d*) Ever had a severe injury to head? __________________________

14. (*a*) Appearance of external auditory canal__ Right ____________________ Left ____________________

(*b*) Appearance of membrani tympani__ Right ____________________ Left ____________________

(*c*) Hearing (watch, No. inches; whisper, No. of feet)________ Right, /40 (40/40 normal)____feet. Left, /40 (40/40 normal)____feet.

NASO-PHARYNX.

15. Condition of nares (if obstructed, state degree, character, and cause):

Right ____

Left ____

16. Condition of tonsils and history of attacks of tonsillitis:

Right ____

Left ____

17. Presence of adenoids ____

18. Condition of eustachian tubes (if obstructed state character and degree) after politzeration or per catheter______________________________

____

19. Static tests, horizontal plane (shoes removed). Applicant to stand with knees pressed back, arms loose by side of body, eyes closed, inner margins of feet touching each other________________________________

____

____

[Third page.]

20. Equilibrium (vestibular) Head tilted forward 30 degrees. Eyes closed. Rotation nystagmus normal 26 seconds, a variation of 10 seconds allowable.
    (*a*) Right: Applicant to be turned toward his right, 10 turns in exactly 20 seconds, horizontal nystagmus to left for ---------- seconds.
    Left: Applicant to be turned toward his left, 10 times in exactly 20 seconds, horizontal nystagmus to right for ---------- seconds.
    (*b*) Pointing tests:
        (1) Before turning—Right arm ----------, left arm ----------
        (2) After turning 10 times in 10 seconds to right—Right arm ----------, left arm ----------
        (3) After turning 10 times in 10 seconds to left—Right arm ------------, left arm ------------
    (*c*) Falling tests:
        (1) Turn to right, 5 turns in 10 seconds—Falls to ------------
        (2) Turn to left, 5 turns in 10 seconds—Falls to ------------

----

----

21. Dynamic tests, horizontal plane (eyes closed and shoes removed). Applicant to walk on feet flat to floor straight forward 20 feet and back to point of starting. Repeat if necessary. Slight variation allowable if not constant --

----

----

22. Height ------------ inches. Weight ------------ pounds.
23. Chest measurement: Expiration ----------- inches; inspiration----------- inches.
24. Respiratory system --
25. Bones and joints ---
26. Skin --
27. Nervous system ---
28. Vascular system --
    (*a*) Pulse: Rate ---------- per minute; quality --------------------
    (*b*) Condition of arteries --
    (*c*) Blood pressure; Systolic --------------; diastolic --------------
    (*d*) Heart ---
    (*e*) Veins ---
    (*f*) Hemorrhoids --
29. Digestive system ---------------------------------- ------------------
30. Hernia --
31. Genito-urinary system ---
32. Urinalysis:
    Specific gravity--------------
    Reaction ------------------
    Casts ----------------------
    Sugar ---------------------
    Albumen ------------------
33. Is the candidate physically qualified for aeronautical duty? --------------
----

[Back of form.]

INSTRUCTIONS.

The following instructions will govern the Medical Officers making the examination:

EYE DETERMINATION.

1. *Question* the candidate carefully regarding *previous* or *present eye trouble,* use of glasses, headaches, lacrymation, scotoma, and photophobia; also diplopia (muscæ volitantes panorama symptoms), glaucomatous symptoms, night blindness or asthenopia when not wearing correcting lenses. Any one of the latter group disqualifies and also of the former group if marked. Note findings.

2. *Stereoscopic vision* is the ability to appreciate depth and distances by means of binocular single vision. Objects printed on the test cards furnished for use with the stereoscope are drawn to scale, the distance between corresponding points of similar objects are *equal;* between dissimilar objects, unequal. They are seen at different apparent depths, the result of superposition of each two similar images in space; the less the distance between the objects, the nearer they appear to the observer's eyes, the greater the distance between, the farther away they appear. A normal eye can appreciate an apparent difference in distance between stereoscoped objects of 0.01 mm. Adjust the oculars of the stereoscope at their focal distance (15 cm.) from the glass stage and rotate by means of the milled edge on either ocular cup so that the interpupillary distance will be as great or greater than the distance between any two similar points of objects to be stereoscoped. With good illumination, have the candidate name the sequence of objects from front to rear as he sees them through the stereoscope. This should be done readily and without error, otherwise it is a cause for rejection.

3. *Ocular movements* are tested roughly by requiring both eyes of the candidate to be fixed on the examiner's finger, which is carried from directly in front to the right, to the left, up, and down. The movements of each eye must be regular and identical.

4. *Pupillary reactions* should be regular and equal in each eye when responding to (1) direct and (2) indirect light stimulation and (3) to accommodation. Face the candidate and place a card as a screen before both eyes. Uncover one eye after a short interval and allow light to shine in this eye. The resulting contraction of the iris of this eye is called *direct.* Repeat, but now observe the shaded eye. This reaction is indirect or *consensual* of the shaded eye. Repeat for the other eye.

With both the candidate's eyes open and uncovered, have him *fix* on a pencil held a few inches directly in front of him. Bring the pencil toward him until it nearly touches his nose. Both irides will contract, which is called the *reaction to accommodation.*

5. *Intraocular tension* is tested roughly by palpation. The candidate looking downward, palpate the eye through the upper lid with the index finger of each hand, and compare the tension with the other eye and with an eye believed to be normal. If not normal it is a cause for rejection.

6. *Any visible lesion* of the eye is determined by having the candidate near to and facing a well-illuminated window and assisted by the use of a hand lens. The eyes should be free from disease, congenital or acquired, such as lesions of the cornea, iris, or lens, including affections of surrounding structures such as pathological conditions of the lachrymal apparatus, conjunctival deformities, or any other affection which would tend to cause blurring of vision if the eyes, unprotected by glasses, were exposed to wind or other unfavorable atmospheric conditions.

7. *Ocular nystagmus* is determined, and if it is rhythmical and occurs—(*a*) and (*b*)—on looking straight ahead or laterally, 40 degrees or less, it is a cause for rejection.

(*c*) *Spontaneous ocular nystagmus* produced by extreme lateral sight, 50 degrees or more, is not a cause for rejection, as it is found in the normal individual. It is usually manifested by a few oscillating lateral movements, never rotary, which appear when the eyes are first fixed in extreme lateral positions. Select a scleral vessel near the corneal margin as a point for observation.

8. *Field of vision* is tested separately for each eye. Place the candidate with his back to the source of light and have him fix the eye under examination (the other being covered) upon the examiner's, which is directly opposite at a distance of 2 feet. The examiner then moves his fingers in various directions in a plane midway between himself and the candidate, until the limits of indirect vision are reached. The examiner thus compares the candidate's field of vision with his own and can thus roughly estimate whether normal or not. A restricted field of vision should be confirmed by the use of a perimeter, as it would then be a cause for rejection.

9. *Color vision* should be normal for red and green. A Jenning's test set is preferred. If not available, then select a skein of any shade of red or green worsted and have the candidate select, in separate piles, all skeins containing red or green. If confusion, colored lights at 20 feet should be used as a test before rejecting.

10. *Muscle balance at 20 feet.*—A phorometer, with spirit level, maddox rod, and rotary prism attached, should be used to determine the presence or absence of a muscular imbalance. Adjust the phorometer close to and in front of the candidate's eyes, at 20 feet distance from a point of light 10 mm. in diameter on the same level with eyes. Darken the room and arrange the prisms so that their bases are situated inward; two images of the light will then be seen displaced laterally. If on a level, there is a normal balance of the vertically acting extrinsic eye muscles or orthophoria; if not on the same level, there is vertical imbalance or hyperphoria; left if the left image is below, right hyperphoria if the right image is below. Read off on the scale the amount necessary to bring the images on the same level.

Repeat the tests with the prisms, one up and one down. If the images now are directly above each other there is no lateral imbalance, but if laterally displaced and on the same side with the eye seeing each image, there is homonymous diplopia due to a lateral imbalance called *esophoria*. If the images are crossed there is *exophoria*. Read off on the scale the amount necessary (prism diopters) to bring them in the same vertical meridian. If not more than one (1) degree of hyperphoria and more than two (2) degrees of esophoria or exophoria, the test is satisfactory.

11. *Visual acuity.*—(*a*) Acuity for distance tested at 20 feet from a well illuminated Snellen test card, if less than 20/20 in either eye, tested separately, disqualifies.

(*b*) Near point, or acuity for near vision, is determined separately for each eye by requiring the candidate to read in a good light the Jaeger No. 1 test type, first gradually bringing the card toward the uncovered eye until the nearest point to the eye, at which the test type still remains distinct, is reached. The distance of this point from the anterior surface of the cornea, measured in centimeters, is the near point. Greater than 11 cm. at 20 years of age, greater than 13 cm. at 25 years of age, or greater than 15 cm. at 30 years of age, disqualifies.

12. *Ophthalmoscopic findings.*—Drop one drop of a 5 per cent solution of euphthalmine in each eye. Have the candidate keep his eyes closed. After 15 minutes repeat the drops, then examine 15 minutes later. A pathological condition of the fundus, active or quiescent, is cause for rejection.

EAR DETERMINATION.

13. Abnormalities are cause for rejection.

14. *Hearing* should be normal for each ear. To determine this both the whisper and watch tests are used. After examining both external auditory canals and membrani tympani by means of a speculum and a good light (first removing any wax if present) for abnormalities such as small and tortuous opening, presence of pus, perforation, scars, retraction, or other evidence of past or present inflammation, which are causes for rejection, the candidate is required to stand at 20 feet from the examiner and facing away from him. An assistant closes the ear not under examination with his moistened index finger pressed firmly into the external auditory meatus. The examiner facing the back of the candidate exhales and then, with his residual air, *whispers* numbers, words, or sentences which the candidate should repeat. The other ear will then be tested in a similar manner. If unable to hear, the examiner will approach until the candidate does hear, the distance being recorded in feet. If less than 20 feet it is a cause for rejection. A quiet room is essential.

The watch test is preferably made with a loud-ticking watch such as the ordinary Ingersoll which, while variable, should be heard at about 40 inches. Any watch used should have been previously tried out on at least five normal persons and the distance heard made a matter of record. The number of inches in distance heard by the candidate, eyes closed and opposite ear occluded, is taken as the numerator and the distance the watch should be heard as the denominator. This should be the equivalent of 40/40, otherwise disqualifies.

NASO-PHARYNX.

15 to 18. This region should be carefully examined. If defects can be removed by operation, this should be required prior to completing the examination. If nonoperable or operation refused, it is a cause for rejection.

STATIC TESTS.

19. The position should be maintained for one minute without marked swaying. Eyes closed.

EQUILIBRIUM (VESTIBULAR TESTS).

20. The nystagmus, past-pointing and falling, after turning, are tested. The turning chair must have a head-rest which will hold the head 30 degrees forward, a foot-rest, and a stop-pedal.

(*a*) *Nystagmus.*—Head 30 degrees forward; turn candidate to the right, eyes closed, 10 times in exactly 20 seconds. The instant the chair is stopped, click the stop-watch; candidate opens his eyes and looks straight ahead at some distant point. There should occur a horizontal nystagmus to the left of 26 seconds duration. Candidate then closes his eyes and is turned to the left; there should occur a horizontal nystagmus to the right of 26 seconds duration. The variation of 8 seconds is allowable.

(*b*) *Pointing.*—(1) Candidate closes eyes. sitting in chair facing examiner, touches the examiner's finger held in front of him, raises his arm to perpendicular position, lowers the arm, and attempts to find the examiner's finger. First the right arm; then the left arm. The normal is always able to find the finger. (2) The pointing test is again repeated after turning to the right, 10 turns in 10 seconds. During the last turn the stop-pedal is released and as the chair comes into position, it becomes locked. The right arm is tested, then the left, then the right, then to the left until he ceases to past-point. The normal will past-point to the right 3 times with each arm. (3) Repeat pointing test after turning to the left.

(*c*) *Falling.*—Candidate's head is inclined 90 degrees forward. Turn to the right, 5 turns in 10 seconds. On stopping, candidate raises his head and should fall to the right. This tests the vertical semicircular canals. Turn to the left, head forward 90 degrees; on stopping, the candidate raises his head and should fall to the left. Unless each test is normal, it is a cause for rejection.

Special Regulations No. 50 Aviation Section, Signal Corps, 1917, War Department, and Circular No. 2, War Department, November 1, 1916, and the physical requirements of recruits will govern 22 to 32 inclusive.

STEREOSCOPIC VISION.

Stereoscopic vision is an essential in the proper estimation of distance. Lacking this function an aviator could not tell the arrangement of an enemy plane formation or its distance from him. It is necessary, sometimes to land with terrific speed, and he must be able to judge his distance from the ground.

CHAPTER IV.

SIGNIFICANCE OF THE TESTS COMPRISING THE PHYSICAL EXAMINATION.

Although it has been found that the details of the examination given on the back of Form 609 are ample for the purposes of examiners who have long been accustomed to work in Physical Examining Units, experience has shown that a more detailed description of these tests is of value to those who are not so familiar with the work.

EYE.

HISTORY OF PRESENT OR PREVIOUS EYE TROUBLES.

In the early days of the work of the Examining Units, when history of the asthenopic symptoms was presented, the question of refraction was considered a most important one. Indeed on the first examination chart one of the requisites was an accurate determination of the refractive error of the eyes under a cycloplegic. This was done because it had been found on many occasions during active flying that men with latent hyperopia lost their power of accommodation and the hyperopia became manifest. This condition naturally caused an impairment of the visual acuity.

After a short time, however, it was decided that if a careful analysis was made by the examiner of the relations between age, vision at infinity, the near-point of accommodation, and the muscle balance, this, together with the estimate of the refraction with the ophthalmoscope, would be sufficiently accurate for all purposes and the complete refraction was omitted.

The applicant is also questioned as to the occurrence of headache, whether they were ever migranous in character, and if so whether they were accompanied by hemianopsia or scotomata. If either of the latter were likely to appear it was considered advisable that the applicant be disqualified. A history of photophobia is important. Diplopia and night-blindness are two conditions which are so obviously disqualifying that they need no further comment.

STEREOSCOPIC VISION.

Three cards similar in appearance, but with differing arrangements of numbers are used. The transferring of information from applicant to applicant concerning the order of numbers on these cards is impossible.

It has happened that applicants have been rejected who possessed good stereoscopic vision, the fault being in the way the test was applied. In some cases time and patience are needed to teach the applicant what he is expected to do.

Since stereoscopic vision is essentially a binocular act it is important to make sure that the applicant is actually seeing the pictures with both eyes simultaneously. It is possible to have simultaneous binocular vision without stereoscopic vision but it is not possible to have stereoscopic vision without both eyes fixing the object practically simultaneously. There are two ways of telling whether he is using both eyes, subjective and objective.

The subjective usually suffices. While the applicant is holding the instrument in the proper position with the headrest touching or nearly touching the forehead and is trying to see the pictures, the card being at about the middle of the slide, you cover first one lens and then the other with a card and ask him if he sees the particular picture he is looking at about equally well with each eye. If so, then when the card is removed he should either fuse or see double or suppress one image. If he fuses he will detect the stereoscopic separation in space of the objects depicted on the card. Show him how to improve the focus by sliding the card forward and back but advise him to keep it as far away as is consistent with clearness. If you suspect that he is suppressing try the objective test. Have him hold the instrument a few inches away from the face so that you can watch his eyes and by covering first one, then the other, in the same way that is done when applying the Duane cover test, you can see whether there is a movement of redress showing that one eye was not fixing while the other was. You must start with both his eyes uncovered and then interpose a card before the eye that you think is correctly fixing, while you watch the uncovered eye. If it was properly fixing it will not move but will continue to fix as before. It is essential that each eye be looking at the same object; select one, say the middle one of the bottom row and by covering first one eye and then the other assure yourself that the instrument is being held so that each eye can see the required picture.

Having determined that both eyes are fixing the same object move the instrument gradually nearer and see if he can not fuse them.

It may be necessary to move the stereoscope forward and back several times before he succeeds.

OCULAR MOVEMENTS.

Ocular movements are tested roughly by requiring both eyes of the candidate to be fixed on the examiner's finger, which is carried from directly in front to the right, to the left, up, and down. The movements of each eye must be regular and identical.

UNIV. OF CALIFORNIA

CONSENSUAL PUPILLARY REACTION.

By shading one eye from the light and then covering and uncovering the other eye, the pupil of the eye that is shaded will be seen to dilate and then contract in a degree approximating the dilatation and contraction of the uncovered eye. This is called the consensual reflex and indicates normal connection between the fibers of the two optic nerves.

67b–1

TAKING THE INTRAOCULAR TENSION OF THE EYE.

Intraocular tension is tested roughly by palpation. The candidate looking downward, palpate the eye through the upper lid with the index finger of each hand, and compare the tension with the other eye and with an eye believed to be normal. If not normal it is a cause for rejection.

67b–2

EXAMINED FOR EXTERNAL DISEASES OF THE EYE.

67b—3

TAKING THE FIELD OF VISION WITH PERIMETER.

This is taken one eye at a time, the other eye being closed. He fixes the uncovered eye on a white spot in the center and without removing his gaze from this spot, indicates when he sees the white spot in the picture approaching from the sides. This is recorded on the chart. The field of vision of an aviator must be good, else objects approaching him from above, below or on the sides might not be noticed.

PUPILLARY REACTIONS.

Pupillary reactions should be regular and equal in each eye when responding to (1) direct and (2) indirect light stimulation and (3) to accommodation. Face the candidate and place a card as a screen before both eyes. Uncover one eye after a short interval and allow light to shine in this eye. The resulting contraction of the iris of this eye is called "direct." Repeat, but now observe the shaded eye. This reaction is indirect or consensual of the shaded eye. Repeat for the other eye.

With both the candidate's eyes open and uncovered, have him fix on a pencil held a few inches directly in front of him. Bring the pencil toward him until it nearly touches his nose. Both irides will contract, which is called the reaction to accommodation.

EXTERNAL OCULAR EXAMINATION.

Intraocular tension is tested roughly by palpation. The candidate looking downward, palpate the eye through the upper lid with the index finger of each hand, and compare the tension with the other eye and with an eye believed to be normal. If not normal it is a cause for rejection.

Any visible lesion of the eye is determined by having the candidate near to and facing a well-illuminated window and assisted by the use of a hand lens. The eyes should be free from disease, congenital or acquired, such as lesions of the cornea, iris, or lens, including affections of surrounding structures such as pathological conditions of the lachrymal apparatus, conjunctival deformities, or any other affection which would tend to cause blurring of vision if the eyes, unprotected by glasses, were exposed to wind or other unfavorable atmospheric conditions.

OCULAR NYSTAGMUS.

Ocular nystagmus is determined, and if it is rythmical and occurs (*a*) and (*b*)—on looking straight ahead or laterally 40° or less, it is cause for rejection.

FIELD OF VISION.

Field of vision is tested separately for each eye. Place the candidate with his back to the source of light and have him fix the eye under examination (the other being covered) upon the examiner's which is directly opposite at a distance of 2 feet. The examiner then moves his fingers in various directions in a plane midway between himself and the candidate, until the limits of indirect vision are reached. The examiner thus compares the candidate's field of vision with his own and can thus roughly estimate whether normal or not. A restricted field of vision should be confirmed by the use of a perimeter, as it would then be a cause for rejection.

COLOR VISION.

The color perception test is one which may be very widely misapplied to the detriment of the service. If a man has definitely correct perception of red and green he is suitable for this service. There are marginal colors represented on the Jennings test which are the source of some confusion and have been not infrequently the basis of disqualification of a good applicant. It should be definitely ascertained that a man's red and green perceptions are normal by the use of the Jennings' test, but the disqualifying of otherwise desirable applicants because they have punched some lavenders or lilacs for rose, for instance, should not occur.

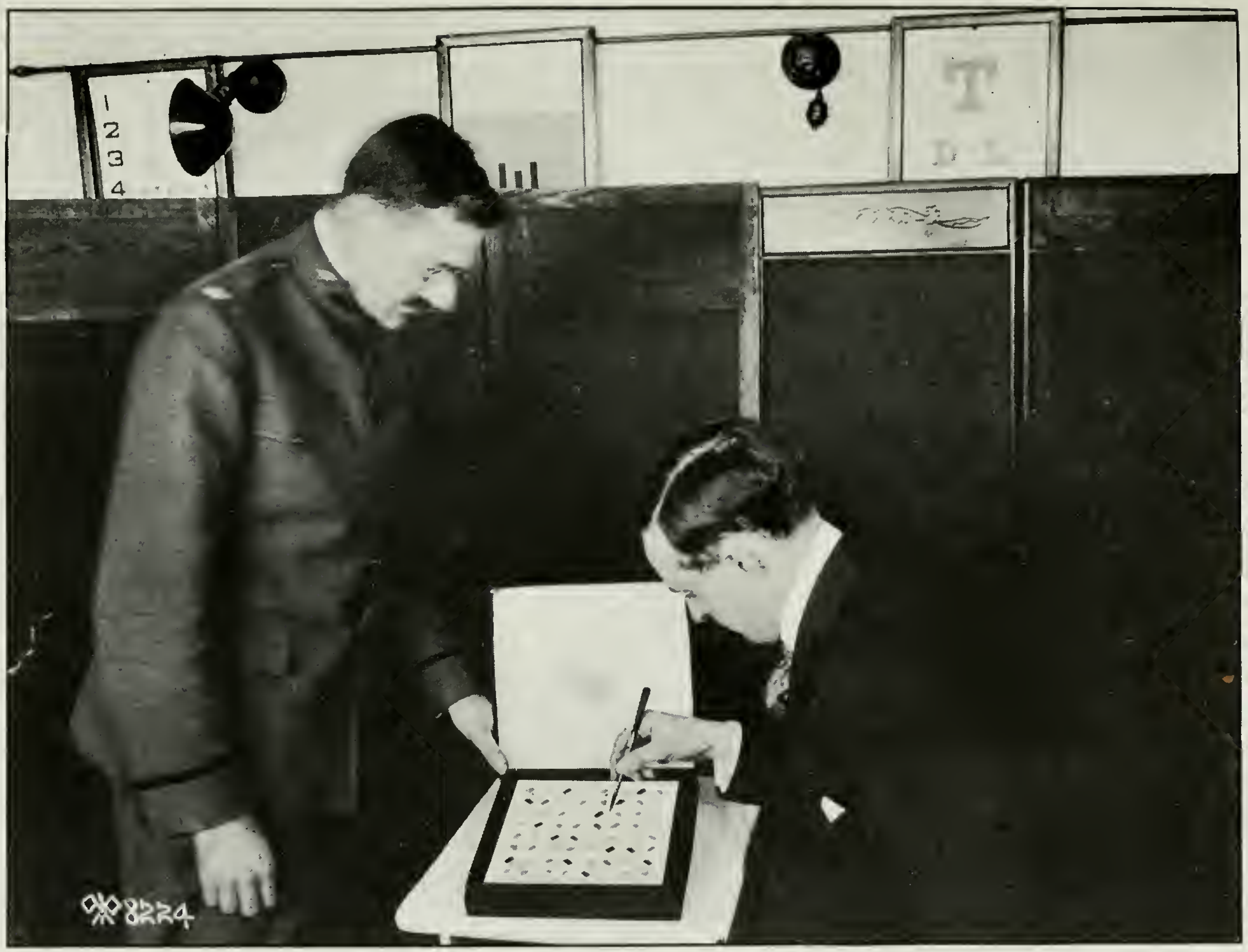
A high standard of color vision has been demanded of prospective fliers; but its importance is demonstrated when it is realized that normal color vision is required not only for the recognition of signals but of the insignia on the planes. The detection of the color of the ground where freshly turned earth may be the only evidence of new entrenchments and landing places, may be simply a differentiation of tints of brown and green and is all that the pilot has to suggest to him the type of ground over which he is observing.

MUSCLE BALANCE.

The first detail which should be noted is the age of the applicant; the next is the distance visual acuity, which should be 20/20 in each eye (and by 20/20 it is safe to mean that a man has full normal vision, not necessarily that he read without one mistake every letter in the ordinary 20-foot line; a man who misreads one or two letters in the 20-foot line and compensates for such misreading by reading correctly one or two letters in the next smaller line can be considered to have full normal vision; in such a case full normal vision should be expressed by the term "20/20").

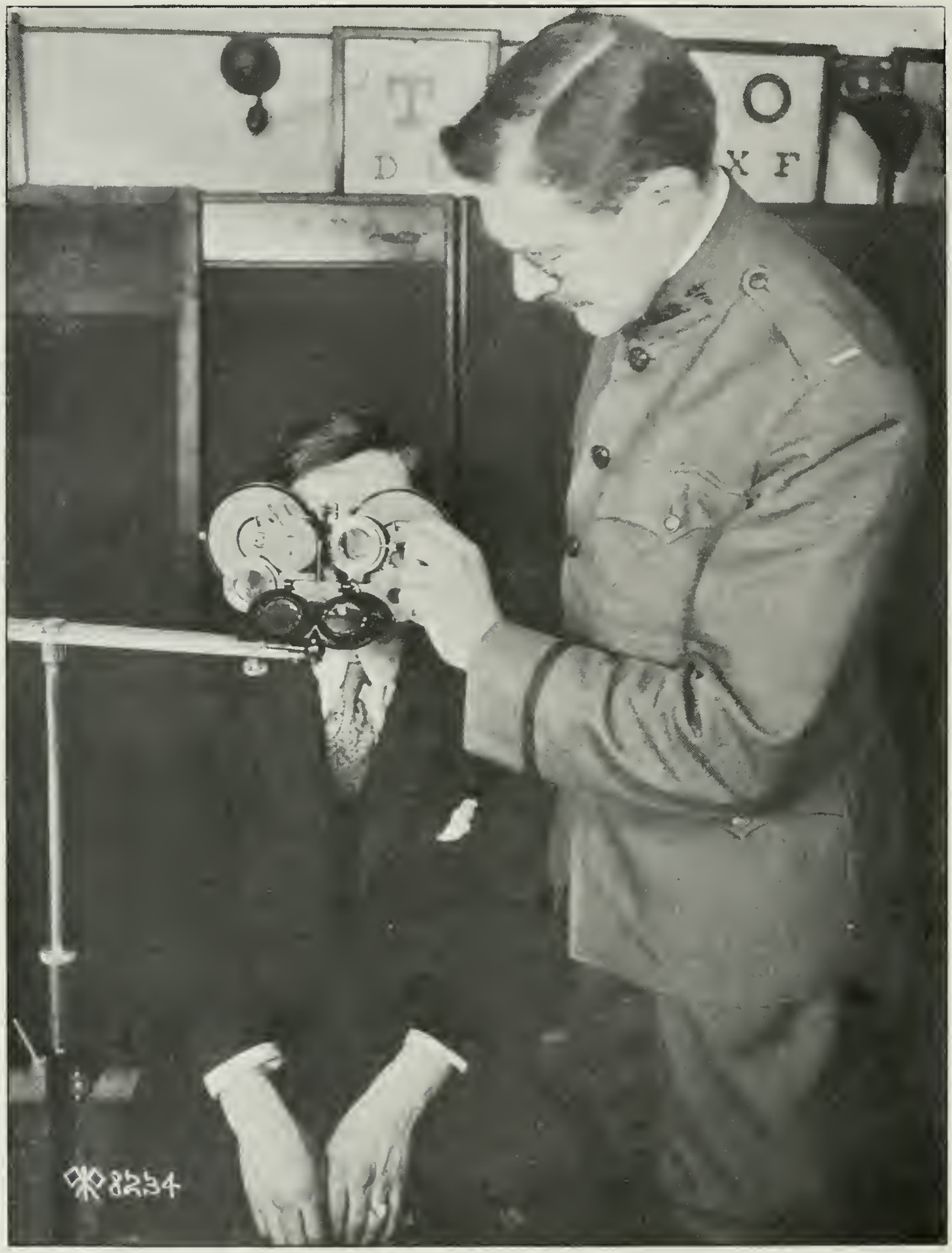
The third point in this chain of evidence as to the ocular desirability of the applicant is the near-point of accommodation, and the fourth point is the muscle balance test. Muscle balance constitutes one of the greatest sources of exclusion from the service of any of the "609" qualifications. The attitude of the examiner concerning muscle balance should be as follows: As long as the applicant has a muscle balance which is commensurate with his refraction, and his refraction is not of a nature to endanger the service, he should not be disqualified. For example, an applicant, age 22, vision 20/20—20/20, near-point of right eye 12 cm., left eye 13 cm., has manifestly some degree of latent hyperopia, either simple or compound. This entails

68b–1



JENNINGS' SELF-RECORDING COLOR TEST.

A perforated cardboard exhibiting confusion colors is placed before the applicant, one perforation corresponding with each color and shade. Some shade of red or green is placed in front of the applicant and he is asked to name it and to select by punching through the perforations anything in the chart which contains red or green, as the case may be. These punches are recorded on a blank beneath the chart so arranged as to show whether or not they were punched correctly.



TESTING THE MUSCLE BALANCE OF THE EYE.

The muscle balance of the eye must be in perfect alignment. In other words, there must be no latent tendency for the eye to turn up or down or in or out. If there is, the aviator may see double and thus endanger his life at a critical moment.

68b—2

the using up of a certain amount of his total available accommodation in the act of seeing with 20/20 acuity at the distance. If he has applied a certain amount of accommodative effort in seeing 20/20—20/20, he has at the same time applied a commensurate amount of convergence, inasmuch as accommodation and convergence are functions indissolubly linked together. Therefore, if such a man shows 4½° to 5½° of esophoria he is not necessarily an unsafe individual for our service.

The fourth point is the test of convergence and divergence. Convergence is tested by measuring the near point of convergence. A less valuable subsidiary test is the prism convergence tested at 20 feet. The divergence is found by measuring prism divergence at 20 feet. Lastly, test the power of overcoming prisms up and down.

In interpreting your findings the muscle balance should always be considered in the light of both the refraction and the convergence, divergence, and sursumvergence tests.

Thus, an applicant whose near point is farther away than normal for his age—say 14 cm. at 21 years of age when it should be about 11 cm.—is probably hypermetropic though it might be that his accommodation is subnormal. If hypermetropia is suspected, the question may be settled by direct ophthalmoscopy, if you have acquired facility in measuring the refraction say to 1 or 1½ D in that way, or by the fogging test. This is applied by placing +2 sph. over both eyes. If his vision is not greatly reduced, it is because he is hypermetropic.

Now, if he is hypermetropic some esophoria is to be expected and even as much as 5° should not cause concern provided that he has good divergence as tested with prisms, say 5° or more. Esophoria due to convergence excess is not disqualifying if there is good power of divergence. Esophoria due to divergence weakness is decidedly disqualifying. Such a case would probably not have hypermetropia.

Following up this line of thought it is but a step to visualizing what might happen to such an individual under stress of fatigue such as he may reasonably expect to encounter in active service. When a sufficient degree of fatigue shall have been reached by the applicant during a flight and combat, his ability to maintain the amount of accommodative contraction necessary to keep his visual acuity up to 20/20 in each eye will come to an end. He will then find his distance visual acuity dropping perhaps to 20/30, 20/40, or even 20/50 in relatively high cases of latent hyperopia. What happens to his muscle balance at such a time? Will he find himself also tending to become diplopic? In all probability not, as with the relaxation of his accommodation there can be expected a commensurate diminution in his convergence, and at that time, instead of showing five and one-half degrees of esophoria, he would show less. On the other hand, let us suppose that such an individual had shown two degrees of exophoria; with the onset of his fatigue relaxation of accommodation he would probably experience a commensurate amount of decrease in his convergence, resulting in an increase in his already existent exophoria, and he would find with his decreased visual acuity an amount of exophoria which would almost certainly determine the onset of diplopia, as man is very much less able to maintain fusion in the presence of a sudden increase in divergence than he is in the presence of an increase in convergence. It, therefore, seems important to standardize the method of attaining a decision as to the ocular desirability of the applicant in each case along the lines indicated, namely: take into consideration (1) age, (2) distance acuity, (3) near point of accommodation and convergence, (4) muscle balance, and (5) duction tests, beginning with prism divergence, minimum five degrees. In certain cases of fatigue, spasm of accommodation and consequent increase in convergence must be expected. The toxins of fatigue have been determined to be responsible for this type of ciliary spasm. Their presence in the circulation gives evidence of a more extreme stage of fatigue than that in which is found fatigue-relaxation, and should such a degree of fatigue be reached it is quite true that crossed diplopia may constitute the chief symptom. Nevertheless, of the two conditions it is safe to assume that ciliary spasm with crossed diplopia will occur with much less frequency, and inasmuch as it is impossible to take steps which will insure against both, it is the part of wisdom to follow a plan which promises to prevent the one which is apt to occur most easily and frequently. As some young hyperopes of high degree are able to maintain 20/20 acuity in the absence of fatigue, an additional procedure of great value in arriving at a determination of disqualifying degrees of hyperopia is the fogging test with a + 2.00 sphere. If an applicant is able to read 20/20 through a + 2.00 sphere it is absolutely certain that his refraction is between + 2.50 and + 5.00 or greater. Such applicants should be absolutely disqualified.

VISUAL ACUITY.

The applicant is seated at a distance of 20 feet from a well illuminated test card, a trial frame or phorometer is properly adjusted to the face, the left eye is covered, and he is asked to read the lowest line possible on the card. The standard was 20/20ths uncorrected vision in each eye and the great majority of the men accepted had 20/15ths or better. To many it has seemed that the standard for visual acuity is too high; that the applicant might quite safely be accepted with 20/30ths, or even 20/40ths, in one eye; but it has been deemed advisable that the visual requirements should not be markedly lowered as long as a sufficient number of applicants were secured

VISUAL ACUITY FOR DISTANCE TESTED BY MEANS OF SNELLEN'S CHARTS AT A DISTANCE OF 20 FEET.

The applicant is required to have at least 20/20 vision, which is indicated by line 7 of this picture.

TAKING NEAR-POINT WITH JAEGER'S TEST TYPE.

One eye being covered, it is the nearest point to the eye at which the applicant, by forcing his vision, can read the finest type distinctly. It shows whether or not he is exceedingly far-sighted and also determines the tone of the ciliary muscle within the eye.

71b–1

OPTHALMOSCOPIC EXAMINATION.

The fundus of the eye is carefully examined for evidences of past or present disease which may disqualify him even though his direct vision be normal.

71b–2

so conforming to the present requirement, which is 20/20 in one eye and 20/20–3 in the other.

In measuring the near-point of accommodation, be sure to make it clear to the applicant what he is to decide for you. It is the point where the test object (type or Duane line) begins to blur. The reason for this is that as long as it is sharp and clear-cut it is in focus, but as soon as it comes nearer than focus, which is the near-point, it ceases to be clear-cut and begins to be blurry. However, it is still easily distinguished. If you wait until it is so blurry as to be indistinguishable, you will be far inside the true near-point. Every examiner should have a fairly exact knowledge of the near-point, which is the normal average for any given age, at least for 18 to 45. If, then, his findings in a given case depart from the average, some explanation should be sought.

The most frequent explanation perhaps will be an error of observation, next will be a moderately nearer near-point due to extra good (supernormal) accommodation. Next a moderately more remote near-point due to hypermetropia, which uses part of the accommodation for its correction, or due to subnormal accommodation, most frequent under low oxygen, not common in healthy young men in good physical condition.

OPHTHALMOSCOPIC FINDINGS.

The number of men who have been disqualified on the ophthalmoscopic examination is also unfortunately large. During late childhood and adolescence it is not uncommon for the individual to encounter a transitory acute chorioditis incidental to some systemic infection or dissemination of a focal infection the evidence of which remains during life in the form of atrophic spots and clumped pigment, but which causes very little, if any, visual incapacitation to the individual. It really constitutes not more than the scar following recovery from such a disease as smallpox; it does not indicate a condition which tends to recur; and, providing it has not been detected in question No. 8 or No. 11, it actually is no physical incapacitation to the individual. Therefore, it is safe to rule upon such findings that "scars do not disqualify." On the other hand certain applicants show acute and subacute recrudescing chorio-retinitis in the presence of full normal vision, which condition is indubitable evidence of the existence somewhere in the body of an active focus of infection. In such cases, if the focus of infection is definitely located and eliminated, and the evidence is clear that as a result of such elimination the chorio-retinitis is on the wane—in all probability permanently—such a case should be not disqualified after the lapse of an adequate period of time in which to ascertain that the chorio-retinitis is waning. Such ocular manifestations of focal infection as

TEST TYPES.

V = .50 D.

The fourteenth of August was the day fixed upon for the sailing of the brig Pilgrim, on her voyage from Boston round Cape Horn, to the western coast of North America. As she was to get under way early in the afternoon I made my appearance on board at twelve o'clock in full sea-rig, and with my chest, containing an outfit for a two or three years voyage, which I had undertaken from a determination to cure, if possible, by an entire change of life, and by a long absence from books and study, a weakness of the eyes which had obliged me to give up my pursuits, and which no medical aid seemed likely to cure. The change from the tight dress coat, silk cap and kid gloves of an undergraduate at Cambridge, to the

V = .75 D.

loose duck trousers, checked shirt and tarpaulin hat of a sailor, though somewhat of a transformation, was soon made, and I supposed that I should pass very well for a Jack tar. But it is impossible to deceive the practiced eye in these matters; and while I supposed myself to be looking as salt as Neptune himself, I was, no doubt, known for a landsman by every one on board, as soon as I hove in sight. A sailor has a peculiar cut to his clothes, and a way of wear-

V = 1. D.

ing them which a green hand can never get. The trousers, tight around the hips, and thence hanging long and loose around the feet, a superabundance of checked shirt, a low-crowned, well-varnished black hat, worn on the back of the head, with half a fathom of black ribbon hanging over the left eye, and a peculiar tie to the black silk neckerchief, with sundry other *details*, are signs the want of which betray the beginner at once.

V = 1.25 D.

Beside the points in my dress which were out of the way, doubtless my complexion and hands would distinguish me from the regular *salt*, who, with a sun-browned cheek, wide step and rolling gait, swings his bronzed and toughened hands athwart-ships half open, as though just ready to grasp a rope. "With all my imperfections

V = 1.50 D.

on my head," I joined the crew, and we hauled out into the stream and came to anchor for the night. The next day we were employed in preparation for sea, reeving and studding-sail gear, crossing royal yards, putting on chafing gear, and taking on board our powder. On the

V = 1.75 D.

following night I stood my first watch. I remained awake nearly all the first part of the night, from fear that I might not hear when I was called; and when I went on deck, so great were my ideas of the importance of my trust, that I

V = 2. D.

walked regularly fore and aft the whole length of the vessel, looking out over the bows and taffrail at each turn, and was not a little surprised at the unconcerned manner in which the billows turned up their

73b–1

EXTERNAL AUDITORY CANAL IS CAREFULLY INSPECTED, AND EAR DRUMS EXAMINED FOR EVIDENCE OF PAST OR PRESENT DISEASE OF THE INTERNAL EAR.

APPLICANT MUST HEAR THE WHISPERED VOICE AT A DISTANCE OF 20 FEET, EACH EAR BEING EXAMINED SEPARATELY.

73b–3

THE NOSE IS EXAMINED FOR DEVIATED SEPTUMS, ENLARGED TURBINATES, POLYPS, OR OTHER EVIDENCE OF SINUS DISEASE.

It is essential that the nose be normal for the proper ventilation of the middle ear through the Eustachian tubes and the free passage of properly warmed and moistened air to the lungs.

anterior uveitis or so-called serous iritis should not be overlooked and should be regarded as disqualifying, unless strong evidence can be brought to bear to indicate that the source has been permanently removed.

EAR.

HISTORY OF EAR TROUBLE.

The answers to these questions are designed in a general way to arrive at an indication of any previous ear trouble. It is to be taken into consideration that very few applicants are willing to admit the history of ear discharge or dizziness, and conclusions will have to be drawn from the examination of the drumhead and subsequent hearing and rotation tests.

It is the universal experience that most applicants deny that they have ever been seasick, thinking thereby to prove that they would be unaffected by the motion of an aeroplane. Answers to this question for that reason must be taken with considerable allowance. It is to be emphasized that it would be improbable for a person with perfectly normal ears not to become seasick upon his first exposure to a rough sea.

APPEARANCE OF MEMBRANA TYMPANI.

A perforation of the drumhead, unless transitory, is to be regarded as a cause for rejection. If the drumhead is excessively thin and scarred, even if the hearing is normal, it should receive special consideration, including catheter and pneumatic otoscope. Experience has shown that even in the low-pressure chamber of the laboratory, perforations can easily occur in such drums by a rapid descent.

Pathological conditions of the internal ear disqualify. Acute and chronic disease of the middle ear disqualifies, except that reexamination after full recovery may be made the basis of subsequent acceptance. Moderately retracted drumhead, loss of light reflexes, thickened drum membrane, and chalk deposits do not disqualify, provided the hearing is normal. The pathology of the drumhead is not an index of the hearing ability. No conclusions can be drawn without hearing tests.

NASO-PHARYNX.

CONDITION OF THE NARES.

This region must be carefully examined. If defect can be removed by operation, this should be required prior to acceptance. If nonoperable or operation is refused, it is a cause for rejection.

The question as to what degree of deviation of the septum demands an operation is a difficult one to answer and must be left to the experience of the examiner. One thing must always be clearly borne in mind: Aside from the straightening of an occlusive deviation for the purpose of giving the applicant better air, resecting the septum is not infrequently of great value as a prophylactic measure. The majority of individuals who have trouble with their ears are troubled because of a post-nasal and Eustachian tube catarrh. Septal deviation far back, impinging on the inferior turbinate and acting as a continual irritant to the naso-pharynx, should be corrected. Cases of marked deviation associated with moderately atrophic condition of the mucus membranes do not necessarily require operations. The prime object is to prevent acute post-nasal trouble which might come on as a result of exposure, rather than to attempt to obviate an insidious middle ear catarrh which might have come on in later life.

The nares should be most carefully examined for any signs of accessory sinus disease. Even a suspicion of this condition should lead to a most careful and painstaking examination and reexaminations, including properly taken X-ray stereoscopic photographs.

CONDITIONS OF TONSILS.

The diagnosis of diseased tonsils is a difficult one and must be left largely to the experience of the individual examiner. Applicants are disinclined to admit a history of sore throats. It must not be forgotten that probably 80 per cent of the sick call on the other side is made up of sore throats. Soldiers who never complain of throat trouble in this country, when they are subjected to the exposure incidental to field service, rapidly develop inflammatory throat conditions which render them temporarily unfit for duty. One should be cautious in declaring a tonsil healthy. All throats should be examined under good illumination; attempt to express contents of crypts should be made and if questionable matter can be squeezed out the tonsils should be removed. Buried tonsils should be removed, as should the true hypertrophic type. The experience of this service has been that in spite of the fact that all applicants were originally examined by throat specialists, many when reexamined showed chronically diseased tonsils. In general it is better to err slightly on the side of radicalism in regard to operation on the tonsils for those about to enter active military service.

PRESENCE OF ADENOIDS.

Adenoid tissue is very common in children and increases in size from birth to the age of six years and then normally subsides about the age of puberty. One does not expect to find much adenoid tissue in adults. Adenoids do their harm early in life, and this, as far as it concerns this examination, is evidenced by deformed jaws, misshapen noses, and poor hearing. Adenoid tissue in the adult is easily

THE PHARYNX, THE LARYNX, AND POSTERIOR NASAL SPACE ARE EXAMINED; SPECIAL ATTENTION IS GIVEN TO DISEASED TONSILS AND PRESENCE OF ADENOIDS; IF PRESENT, MUST BE REMOVED.

APPLICANT IS REQUESTED TO SAY "K, K," WHICH CLOSES THE POSTERIOR PHARYNX.

With a Politzer bag air is forced into one nostril, the other being occluded. If the Eustachian tubes are patulous he feels air enter the middle ear.

seen with a post-nasal mirror, the digital examination being unnecessary.

CONDITION OF EUSTACHIAN TUBES.

The condition of the Eustachian tubes is one of vital importance to the aviator. Generally speaking, it can be said that if the applicant's drumhead and hearing is normal, the Eustachian tube is probably in good condtion. In addition, regulations require that the patulence of the tube should be demonstrated by the auscultation tube during inflation by means of Politzerization or catheretization. The former procedure is ample for all practical purposes. If tubal troubles are of such a nature as to demand it, an examination should be made with some good pharyngoscope.

STATIC AND DYNAMIC TESTS.

In the static test the applicant is required to stand in the position specified with his eyes closed for one minute. Too much importance must not be attached to the fact that the applicant is slightly unsteady. They expect that this and the dynamic test is some sort of a trick examination and become very nervous. Some sway markedly and are unable to walk in a straight line. Disqualification on these tests should only be made with the greatest reservation and when confirmed by other tests, showing that the applicant has marked instability of his coordinating mechanism. In the thousands of applicants so far examined none were rejected for these causes alone. In the dynamic test if the applicant swerves more than three feet from the straight line, he must be asked to repeat the test until the examiner is convinced that his deviation from the line is so abnormal as to be a cause for rejection.

TURNING-CHAIR (EAR MOTION-SENSING) TESTS.

The motion-perceiving apparatus of the internal ear is subjected to stimulation by motion of certain standard quantity and quality, and the results are observed according to uniform standard methods. Two results are noted—a sensory result, the subjective sensation of motion, and a motor result, involuntary movement of the eyes. When the subjective sensation of motion is in accord with fact, we call it normal sensing of motion; when it is not in accord with fact, we call it "vertigo." The only difference between normal perception and vertigo lies in the sensing of motion being in accord with, or contrary to, fact. The most practical means of applying motion stimulus is by the rotating chair, inasmuch as the application of motion in a linear direction, for the period of time and in the intensity necessary to elicit certain standard responses to that stimulus, would necessitate apparatus entirely too bulky to be susceptible of practical application under ordinary conditions of office examination. By making use of a rotational-motion stimulus instead of a linear-motion stimulus, it was possible to work out a standard means of applying motion stimulus in certain definite quality and quantity in a manner, and by means of an apparatus easily handled in an office. For this reason only, the subject of the tests of the vestibular apparatus is made to experience rotational vertigo. An additional advantage in using the rotating chair is that it applies motion stimulus of a character to produce a more enduring stimulation of the end-organs of the semicircular canals.

Motion in a linear direction applied to a fluid contained in a semicircular canal is physically incapable of setting up a flow of that fluid, just as rotational motion applied to a fluid contained in a straight canal can not set up a flow.

Ewald's experiment long ago determined that involuntary pulling of the eyes in a certain definite direction and plane occurs during the time the fluid in a normal semicircular canal is made to flow in one direction; and during the time this fluid is made to flow in the opposite direction involuntary pulling of the eyes in the opposite direction occurs. By applying rotational motion, it is possible to reproduce Ewald's experiment in effect, as a test of eye reactions to vestibular stimulation; and when the character and intensity of rotational stimulus is standardized, comparisons of the results can be made and a normal eye reaction determined. This motor expression of motion stimulation is nystagmus.

The normal man experiences a sensation of vertigo for between 15 and 40 seconds after being turned, according to standard technique. Evidence of this subjective sensation may be had by voluntary or involuntary testimony; voluntary testimony such as "I'm turning to the right," "I'm still turning to the right," etc., during the persistence of the subjective sensation; involuntary testimony, such as the pointing test and the falling test. Standard tests make use of involuntary testimony in all cases; occasionally this is amplified by voluntary testimony with advantage. In observing the pointing before turning, a very important element in the test can be injected by implanting in the mind of the applicant the definite idea that he is to attempt to determine the location in space of the observer's finger, solely by registering in his memory the location of it according to his tactile sense. This can be augmented by having him touch the observer's finger, in more than one position; as, for instance, directly in front of the right hand, come back and touch; then locate again 30 degrees outward and come back and touch; the same procedure in front of the left hand. This implants in his mind the fundamental idea of being able to orientate himself solely by means of information coming from his tactile sense. After standard rota-

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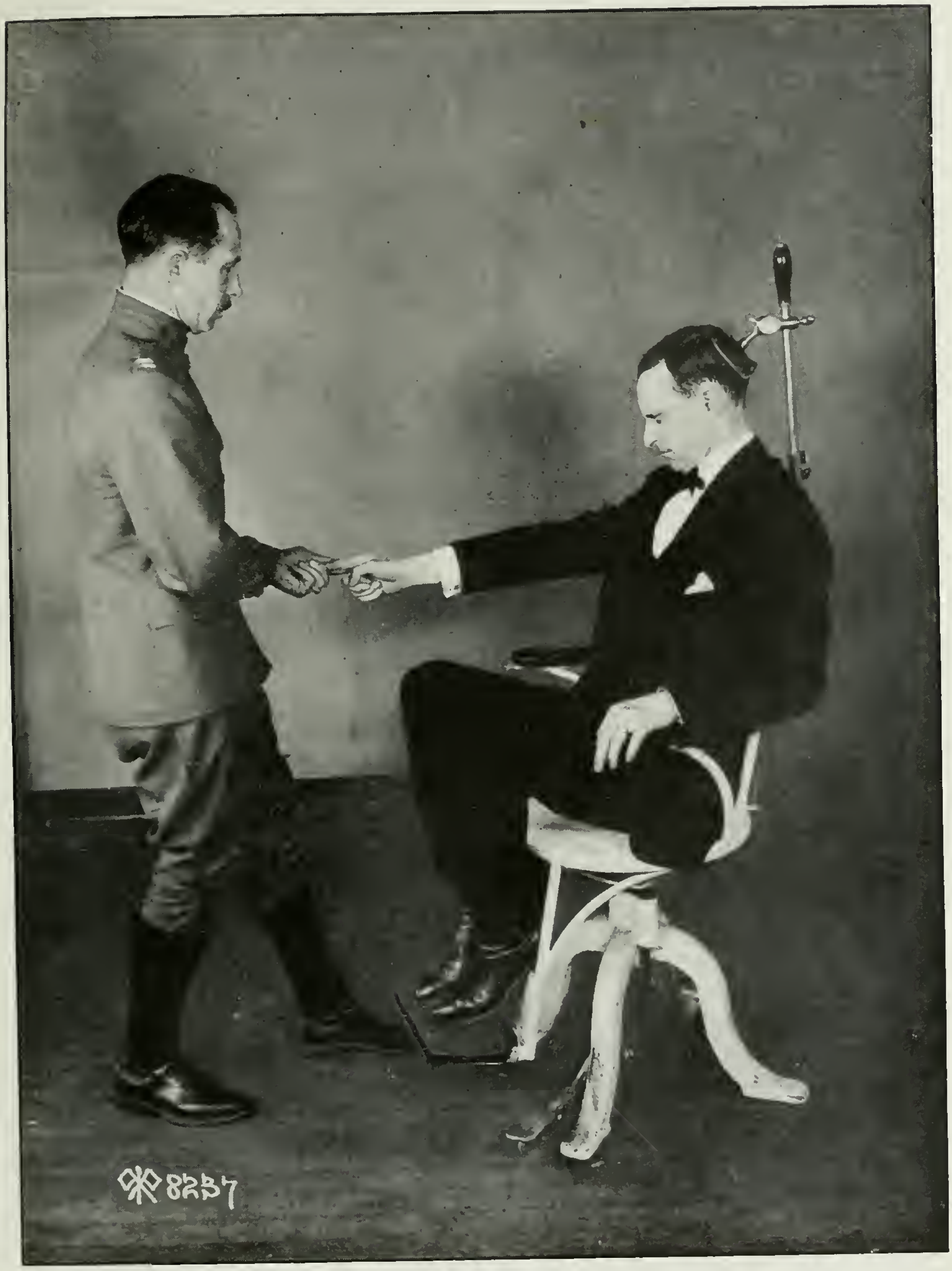
TESTING FOR SPONTANEOUS NYSTAGMUS BEFORE TURNING.

Popalar Science Monthly .

CAN HE PILOT A BATTLEPLANE.

To find out if his ear motion-sense is good he is whirled around in a special chair. The object of the whirling is to displace the fluid in the inner ear, the fluid that controls the ear motion-sense and tells whether he is moving or not. The examiners then note how long it takes him to recover poise.

76b–2



THE APPLICANT EXTENDS HIS RIGHT ARM AND TOUCHES THE EXAMINER'S HAND. THEN HE RAISES HIS ARM VERTICALLY AND IS TOLD TO BRING HIS FINGER BACK AND TOUCH THE EXAMINER'S HAND AGAIN.

This is done with the eyes closed. See fig. 8245 for result after turning.

AFTER TURNING APPLICANT RAISES THE FINGER IN AIR AND ATTEMPTS TO TOUCH EXAMINER'S FINGER.

HAVING BEEN TURNED TEN TIMES IN TEN SECONDS TO THE RIGHT AND BEEN STOPPED, THE ENDOLYMPH CONTINUES TO FLOW TO THE RIGHT WHICH MAKES IT APPEAR THAT HE IS TURNING TO THE LEFT.

This gives him false orientation which causes him to past-point to the right, which he continues to do so long as the endolymph flows.

76b—5

PUTTING HIM THROUGH THE FALLING TEST.

The applicant is placed in a chair with his head forward approximately ninety degrees to bring the vertical canals of the inner ear in the horizontal plane. After having been turned five times in ten seconds to the left, for example, he feels that he is falling to the right when he sits up with his eyes closed.

77b–1

PUTTING HIM THROUGH THE FALLING TEST.

After having beeen turned five times in ten seconds to the left, with the eyes closed, which causes the flowing of the endolymph in the direction of the turning, the applicant, upon sitting up, feels that he is falling to the right, because of this endolymph movement. He tries to overcome this and actually falls to the left.

77b–2

tion of the right, for example, normal man experiences certain very definite vertigo—a subjective sensation of turning to the left in the same plane as the rotation, for a normal period of time. If the pointing test is carried out during this period of vertigo, instead of succeeding in pointing accurately to the testing finger, he executes the pointing in accordance with his subjective sensation of motion. Feeling that he is turning definitely away from the testing finger, to the left, he reaches for it to the right. This is normal past-pointing. The insulation of the applicant during this test should be as perfect as possible. A black domino mask should be used, absolute quiet should be maintained, olfactory impressions should be shunted out, and he should be left as solely as possible dependent upon the information brought to him along the vestibular tract alone. The applicant should be definitely instructed before turning that he should not expect a verbal order to touch the observer's finger, raise his hand and come back, and attempt to find it after the turning; he should be practiced before turning, in executing his touch, raising his hand, and coming back to find the finger upon receipt of the signal from the observer's finger as it comes into the position which it maintains during the test—the observer bringing up his finger into position so as to tap the applicant's finger as a signal for him to execute his pointing, without verbal command. It is very important for the applicant's finger to find a finger of the observer when he comes down in search of the finger which is testing him. Otherwise, there is injected into his mind a disconcerting element of dissatisfaction in having failed to find the finger for which he was searching. For this purpose the index finger of the observer's left hand can be held in readiness to furnish the touch necessary to shunt out this sense of failure. In observing the past-pointing after rotation, the observer's right index finger should be definitely fixed against the observer's hip, so that visual attention to it on the part of the observer can be dispensed with, the hip-rest insuring its remaining definitely where it was when the applicant first touched it in making the pointing test. The observer's eyes can be free to watch the applicant's finger at the top of the swing. Past-pointing at the top of the swing is just as definitely normal past-pointing as at the completion of return to touch. Many cases compensate after evincing a normal tendency, let us say, to past-point outward with the right hand when they should do so, and subsequently execute a compensatory touch or inward pointing at the bottom of the return. In such cases the pointing should be registered as that executed at the top of the swing, which is the primary and clean response before it has been altered by the subconscious or conscious compensation effected by other mental processes. Visual attention on the part of the observer to the applicant's hand at the beginning of his downward pointing is of enormous importance and it should be very carefully observed as part of the standard technique.

The falling test is similar. A normal man, on attempting to sit upright after leaning forward during right rotation, feels that he is turning to the left, for instance, and so gives involuntary expression to this sensation by falling to the right on attempting to assume an erect sitting posture.

These tests can be completed in less than five minutes. Incidentally, these tests are in no sense severe and are in fact seldom regarded even as unpleasant. Occasionally nausea occurs after these turnings; it is then merely necessary to stop the examination for the time being and complete the remainder of the tests after an interval of half an hour. There is no need whatever to make these tests in any way distressing to the applicant.

With respect to the internal ear motion-sensing apparatus, its nerve-paths and brain connections, these turning-tests quickly separate the obviously fit from the unfit. The majority of the applicants show normal responses; no further testing is required and they therefore qualify and are accepted. Some applicants show such markedly subnormal responses that they are immediately disqualified and rejected. A limited number give what might be termed "border-line" responses; the question then arises, Has this particular applicant sufficient ear motion-perceiving sense to become an aviator? It is here that the caloric test is useful. The turning has tested both the right and left ears simultaneously. The caloric method enables us to test each ear separately. Water at 68° F. is allowed to run into the external auditory canal from a height of about 3 feet through a stop-nozzle, with the head tilted 30° forward, until the eyes are seen to jerk or the individual becomes dizzy. The length of time from the beginning of the douching until the jerking of the eyes becomes apparent, or until the applicant says he is dizzy, is accurately measured by a stop-watch. The type of nystagmus is then noted. With head in upright position, it should be rotary and the direction of the jerk should be to the side opposite the ear douched. The length of the douching shown by the stop-watch in the normal is 40 seconds. The eyes are then closed and the past-pointing is taken. The head is then immediately inclined backward 60° from the perpendicular (or 90° from the original position). There should then appear a horizontal nystagmus to the side opposite to the ear douched. The eyes are then closed and the past-pointing is taken with the head in this position. The left ear is then douched and the same procedure carried out. If the caloric test applied to one of these "border-line" cases shows only a slight impairment of the responses from each ear, the applicant is qualified. If instead of 40 seconds of douching there was required not more than 90 seconds of douching to elicit

TURNING-CHAIR EXAMINATION BEING UNSATISFACTORY, APPLICANT'S EARS ARE DOUCHED WITH COLD WATER, 68°

79b–1

PAST-POINTING TO THE LEFT AFTER HAVING DOUCHED LEFT EAR WITH COLD WATER.

79b–2

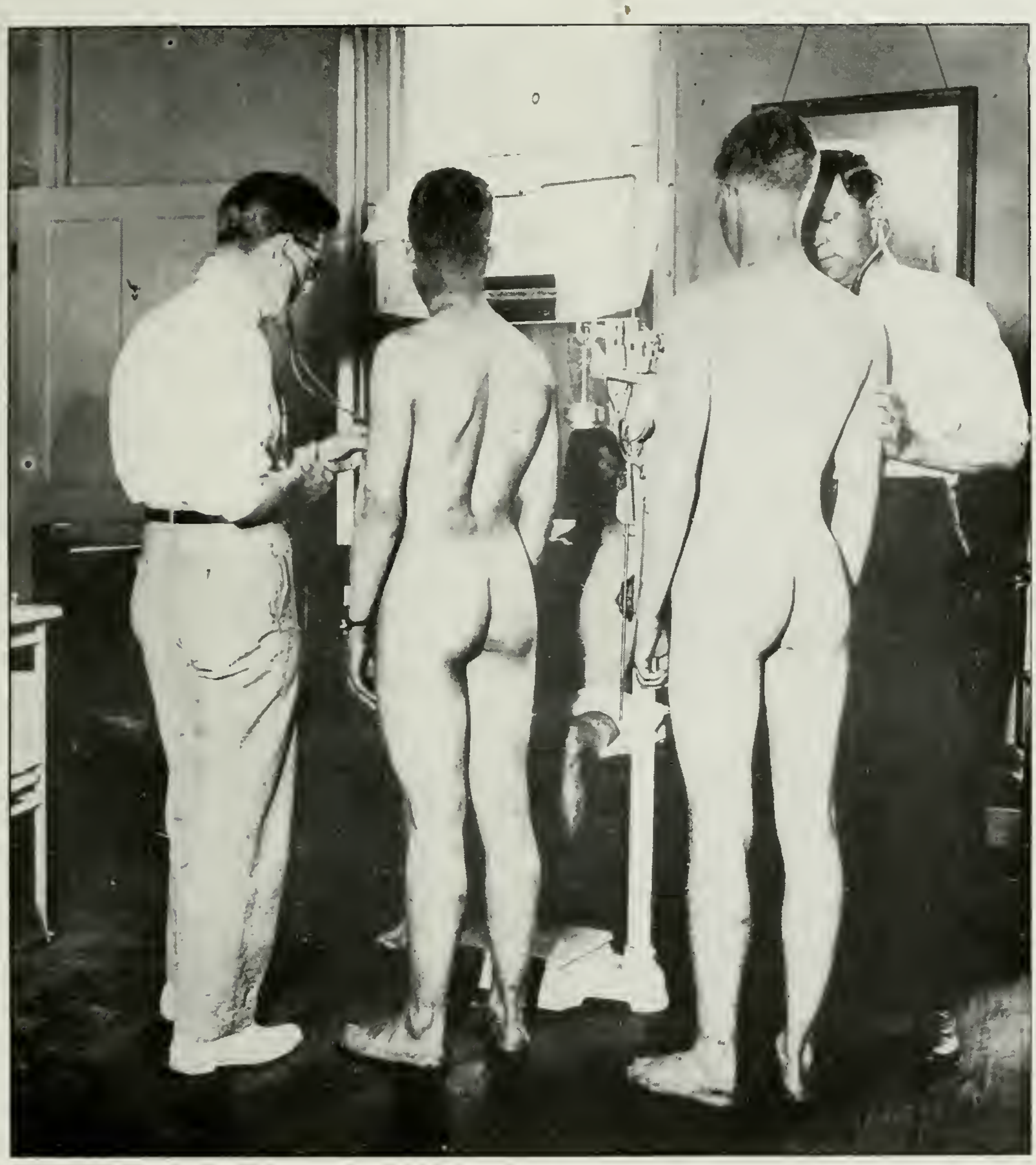
HEIGHT AND WEIGHT ARE CAREFULLY TAKEN.

79b–3

UNIV. OF CALIFORNIA

SHOWING TYPE OF YOUNG PHYSICAL MANHOOD WHO CAME UP FOR EXAMINATION

79b—4



SHOWING PART OF THE PHYSICAL EXAMINATION OF HEART AND LUNGS.

79b–5

EXAMINATION OF THE RESPIRATORY SYSTEM.

79b–6

normal responses, the applicant is not rejected. Care should be taken to be certain that the cold water is reaching the drumhead during this caloric test, as wax or other obstruction in the external canal would interfere with the responses in a perfectly normal individual.

After carefully considering the foregoing, the neurologist and the general diagnostician can not fail to be struck with the comprehensive character of these vestibular tests. Frequently they are looked upon as *Ear* tests only. Six months ago one of the greatest otologists of Europe, in discussing these tests, raised the question as to the necessity or advisability of including in aviation examinations the past-pointing and falling tests, his contention being that, in testing nystagmus only, one secures definite evidence of the functional state of the semicircular canal end-organs of the internal ear. When his attention was drawn to the fact that, in testing the past-pointing and falling in addition to the nystagmus, one establishes definitely the functional intactness (1) of the various afferent paths and the intracranial structures through which they pass, (2) of the cerebral cortical centers and their transcortical association tracts, (3) the afferent cerebral paths and the nuclei through which they pass, (4) the cerebellar nuclei and correlation paths to and from cerebellar cortical centers, (5) various portions of the Pons and Medulla Oblongata, his attitude was completely changed and he became a firm advocate of the complete testing of nystagmus, past-pointing and falling as a routine procedure.

It can not be emphasized too strongly that the vestibular tests are not merely tests of the internal ears. To be sure, these tests do determine the functional integrity of the internal ear; but in addition they determine the functional integrity of a large portion of the Central Nervous System.

HEIGHT AND WEIGHT.

The standard limits of height and weight are: Minimum height, 60 inches; maximum height, no limit. Minimum weight, 110 pounds; maximum weight, 180 pounds, with 10 pounds leeway.

CHEST MEASUREMENT.

It has transpired that a low vital capacity (by which is meant the amount of air that can be expelled from the lungs after full inspiration) is undesirable in aviators. This may be roughly estimated by an expansion of not less than 3 inches in an individual of average size. The judgment of the examiner should be applied in seeing that the expiration and inspiration measurements are commensurate with the size of the applicant.

89118—19——6

RESPIRATORY SYSTEM.

In examining the chest, attention must be paid, in connection with other signs, to any indications of an incipient tuberculosis. It is always safer if such a condition is suspected to order an X-ray examination. On account of various disputes which have arisen over this point, many units have found it extremely valuable to retain these plates for their permanent record.

BONE AND JOINTS.

In making this examination it is well to put the applicant through several of the Army setting-up exercises. The applicant is first instructed to touch his fingers to the floor without bending his knees. He must next tread water, that is, he is instructed to bring each knee alternately up to his chest and back again. He is next instructed to spring into the air, striking his buttocks with his heels; he is made to squat, keeping his knees apart. Flexion extension and rotation of upper extremities complete the necessary information as to bones and joints. It is safe to pass as nondisqualifying, second degree of flat foot of rather extreme proportions, providing there is absence of symptoms of incapacitation.

SKIN.

Such skin diseases as general acne vulgaris and psoriasis of extensive distribution should be regarded as disqualifying. Some cases may be cleared up by treatment, and, as in all similar disqualifications, the elimination of the condition should permit the applicant qualifying for service. The underlying reason for disqualification of this character is that barrack-mates and tent-mates of the victims of such skin diseases are prone to regard them as of a contagious and dangerous nature, and the admission of such into the service is bound to engender widespread disquiet and discontent on the part of others.

NERVOUS SYSTEM.

The nervous system has been subjected to a rather extensive scrutiny by the examinations entailed by questions Nos. 2, 3, 4, 8, 9, 10, 11, 12, 14 (*c*), 19 and above all, 20. Additional observations should be made concerning tremor (which may be the cue to more extensive examinations of the thyroid and its associated endocrine system), various motor coordinations with closed eyes, such as bringing the tips of the index fingers together with arms outspread, bringing the tips of the index fingers into delicate touch with the tip of the nose, etc.; cutaneous sensibilities and deep reflexes.

EXAMINING THE BONES AND JOINTS AND GENERAL MUSCULATURE.

80b–1

FEET ARE EXAMINED VERY CAREFULLY FOR FLAT FOOT OR FALLEN ARCHES.

VASCULAR SYSTEM.

Concerning the vascular system, the dissertation contained in the general instructions is very full and constitutes an almost classical guide to such examinations. The systolic blood pressure taken by the mercury column, or by an aneroid instrument carefully corrected as to reliability, should not exceed 145 mm.; the diastolic should show commensurate pulse pressure; the remainder when diastolic is subtracted from systolic should be, roughly, one-half the diastolic figure. For instance; systolic 120, diastolic, 80; remainder, 40, which is one-half of 80. Systolic murmurs in the presence of definitely (1) good muscle sound, (2) good valve closure sound, (3) absence of stenotic sounds, (4) apex beat in mid-clavicular line, (5) normal percussion outlines, (6) absence of history of an etiologic character, (7) absence of history of cardiac character, may be safely construed as nondisqualifying; especially may this be so construed if marked alteration in the character of the murmur ensues upon change of posture or exercise. Moderate varicosities without any symtoms should not be regarded as disqualifying.

DIGESTIVE SYSTEM.

Examination of the teeth must not be neglected. It must never be forgotten that crowned teeth, pyorrhea, and alveolar infections may be the sources of much toxemia. Special attention should be given to this matter and if there is any doubt in the mind of the examiner as to the condition of the candidate's teeth, his mouth should be put in good shape before final acceptance. In addition to the findings concerning the digestive system, see that the imprint indicating missing teeth appears at the right side of line 29.

HERNIA.

No hernia or any dangerous condition of weak scars should be accepted. Successful operation for hernia permits applicant qualifying, however.

GENITO-URINARY SYSTEM.

No focal infection or chronic disease of the genito-urinary tract and no venereal disease should be accepted.

URINALYSIS.

A great many applicants show transitory albuminuria of a nondisqualifying character, so-called orthostatic or postural albuminuria. It is necessary to determine that an albuminuria is transitory and that it is definitely not renal in origin, as would be shown by the absence of casts, cylindroids, renal epithelium or other renal elements. In this connection it is interesting to note that at one of the examining units for a period of nine days every applicant showed albuminuria. The cause of this was found by the members of the unit to be the taking of urine specimen at the end of the examination. It is absolutely necessary to adhere to the routine, taking the urine samples at the beginning of all examinations. If albumin has been found in the urine, which may be of a temporary nature, the examination blank must not be turned in until the three additional examinations are made on three successive days. The results of such examinations should be typed in the lower left-hand corner of the last page just under the numerals " 33 " and if at the end of the third day the urine is found free from albumin, the applicant is marked as physically qualified and the examination blank turned in.

FINAL QUESTION—IS THE APPLICANT PHYSICALLY QUALIFIED?

After the examinations have all been made the officer in charge of the unit must answer " Yes " or " No " to the final question. If the applicant's examination has been satisfactory in all respects, the word " Yes " is placed on the first line followed by his signature. If one or more actual disqualifications have been found, the word " No " is placed, followed by the numbers indicating the examination on which the applicant was disqualified.

IN EXAMINATION OF THE NERVOUS SYSTEM ALL REFLEXES ARE TAKEN.

The above is an examination of the patella reflex.

EXAMINATION OF TEETH.

Applicant must have at least two opposing molars.

CHAPTER V.

STATISTICAL REPORT OF RESULTS OF THE EXAMINATIONS MADE BY THE 67 PHYSICAL EXAMINING UNITS.

STATISTICAL REPORT OF THE PHYSICAL EXAMINATION OF APPLICANTS FOR COMMISSION IN THE AIR SERVICE.

A careful tabulation has been made of the results of the physical examination of all men who applied for detail as cadet fliers. Individual units, in many cases, sent in comprehensive reports, but the methods employed and the results obtained were so varied that it was found inexpedient to consolidate their findings. The following tables were obtained through access to the original examination papers after they had been forwarded from the 67 units to their final haven in Washington. From these papers the required data was obtained. That in turn was punched on cards which were assembled and tabulated according to the method employed at present for getting statistical returns involving large numbers.

The accuracy of the findings of many individual units has been established by their close resemblance to the returns of the work when done as a whole.

The outstanding point of interest is the fact that of those who came up for physical examination, 70.7 per cent qualified, and 29.3 per cent were rejected.

Separating the causes of disqualification into nine groups, the following rates, based on the total number examined, are obtained:

	Per cent.
1. Eye	5.9
2. Ear	1.2
3. Nose and throat	.8
4. Equilibrium	2.0
5. Vascular system	1.5
6. Urinalysis	.4
7. Other and general subnormalities	1.9
8. Disqualified on two tests	7.0
9. Disqualified on three or more tests	8.6
Total	29.3

It is interesting to note that for any one cause of rejection the failure to meet the eye requirements easily leads, being 5.9 per cent; 7 per cent were rejected for failure to meet two tests and 8.6 per cent for inability to meet three. Although the present compilation does not show it, from conclusions drawn from the statistics of certain units, it can easily be taken for granted that visual defects were present in at least half of the cases where men failed on two or more counts. In other words, it is safe to assume that practically 50 per cent of those rejected failed to meet the eye requirements.

In giving the results of the eye tests, it will be noticed that the highest rate of failure is accorded to visual acuity—3.3 per cent, or more than one-half of the total number rejected on this particular count.

Next in order of importance come color vision, muscle balance, and stereoscopic vision, their combined rates, 2.2 per cent, accounting in a large degree for the balance of those who failed in the eye tests. It will be observed that the percentages of failure through other visual defects are very small, indeed, averaging about four out of every thousand examined.

The following table gives the rates of failure in the eye tests classified according to causes:

	Per cent.
History of eye trouble	0.03
Stereoscopic vision	.5
Ocular movements	.04
Pupillary reactions	.01
Intraocular tension	.003
Visible lesion of eyes	.03
Ocular nystagmus	.02
Field of vision	.003
Color vision	1.
Muscle balance	.7
Visual acuity	3.3
Ophthalmoscopic findings	.3
Total	5.936

The greater part of the rejections of those who failed in the ear tests was due to defects of the external auditory canal and hearing, being 1 per cent out of a total of 1.2 per cent, or, one out of every 100 examined.

The specific causes of disqualification with rates are as follows:

	Per cent.
History of ear trouble	0.1
Appearance of external auditory canal and hearing	1.
Appearance of membrani tympani	.1
Total	1.2

Eight-tenths per cent or 8 men out of every 1,000 men examined were disqualified on account of naso-pharynx defects, 0.4 per cent of which was due to condition of the nares, 0.4 per cent due to condition of tonsils, other naso-pharynx causes being entirely negligible.

The equilibrium tests proper, exclusive of the static and dynamic tests, are cause for practically all of the rejections in this particular field, being 2 per cent out of a total of 2.04 per cent, or 2 out of every 100 men examined. The average duration of nystagmus of the entire number of men examined was, after turning to the right, 23.5 seconds; after turning to the left, 23.2 seconds. In those who qualified, the nystagmus after turning to the right was 23 seconds, after turning to the left, 23.1 seconds.

It will be observed that these findings are almost identical with the average duration of nystagmus of the total number examined. In getting an average on nystagmus duration the result is neutralized by a combination of hypersensitives and subnormalities; in other words, some cases revealed a high degree of nystagmus, while others fell far below normal. It was accordingly found expedient to separate the duration of nystagmus into two groups, that which was less than 16 seconds and that which was over 36 seconds.

The average duration of nystagmus of those who showed less than 16 seconds after turning to the right was 12.4 seconds, after turning to the left, 12.5 seconds.

The average duration of nystagmus of those who showed more than 36 seconds after turning to the right was 50.2 seconds, and after turning to the left, 48 seconds.

The average number of past-pointings for the total number examined is as follows:

	Times.
After turning to right with right arm	3.8
After turning to right with left arm	3.7
After turning to left with right arm	3.8
After turning to left with left arm	3.7

The average number of past-pointings for those who qualified was:

	Times.
After turning to right with right arm	3.9
After turning to right with left arm	3.8
After turning to left with right arm	3.9
After turning to left with left arm	3.8

In failure to qualify in the vascular system requirements, heart defects lead, being seven times as great as respiratory causes. This in itself signifies but little, for all vascular system defects amount to but 1.5 per cent, or 15 out of every 1,000 men examined. The following table gives the rates:

	Per cent.
Blood pressure	0.2
Heart	.8
Respiratory system	.1
Other subnormalities	.4
Total	1.5

In the general physical requirements, the percentage of those who were rejected is 0.7 per cent, or 7 out of every 1,000 men examined. This rate is included in the nine main classifications under, " Other and general subnormalities." Separating the general physical causes into groups, the following rates are obtained:

	Per cent.
Over or under age	0.04
Bones and joints	.2
Condition of skin	.04
Condition of nervous system	.08
Digestive system	.07
Hernia	.1
Genito-urinary	.2
Total	.73

Of those who qualified, the following were the percentages at each age:

	Per cent.		Per cent.		Per cent.
19	0.3	30	2.2	41	0.01
20	3	31	1.3	42	.01
21	5	32	.7	43	.01
22	7.8	33	.3	44	.02
23	8.5	34	.2	45	.0
24	8	35	.1	46	.003
25	7.2	36	.1	47	.01
26	6.2	37	.04	48	.01
27	4.3	38	.1	No age given	8.8
28	3.7	39	.02		
29	2.8	40	.01	Total	70.7

From a combination of the rates from the ages of 21 to 26, it will be observed that 43 per cent, or nearly one-half of the number of men accepted, qualified at these ages, the rate gradually lessening until there are isolated cases of men being admitted for some special qualification at an age beyond the limit prescribed by law. The highest rate at any given age is 8.5 per cent for 23 years, or in other words, over 8 out of every 100 men who qualified were of this age; the ages of 22 and 24 furnishing practically the same quota.

Of those disqualified on one test, the percentages for each age are as follows:

	Per cent.		Per cent.		Per cent.
18	0	33	0.1	48	0
19	.08	34	.04	49	0
20	.7	35	.03	50	0
21	1	36	.01	51	0
22	1.6	37	.003	52	0
23	1.7	38	.02	53	0
24	1.5	39	.01	54	0
25	1.4	40	0	55	0
26	1.3	41	.01	56	0
27	1	42	.003	57	0
28	.8	43	.003	58	0
29	.7	44	.01	No age given	.7
30	.6	45	.003		
31	.3	46	0	Total	13.8
32	.2	47	.003		

Of those disqualified on two or more tests the rates for each age are as follows:

Age	Per cent.	Age	Per cent.	Age	Per cent.
18	0.003	33	.07	48	0
19	.1	34	.06	49	0
20	.8	35	.04	50	0
21	1.2	36	.02	51	0
22	1.9	37	.01	52	0
23	2	38	.02	53	0
24	1.8	39	.01	54	0
25	1.7	40	.01	55	.003
26	1.4	41	.003	56	0
27	1.1	42	.003	57	0
28	1	43	.003	58	.003
29	.6	44	.003	No age given	.5
30	.6	45	0		
31	.3	46	.003	Total	15.5
32	.2	47	0		

Reports of the Physical Examining Units at San Antonio, Tex., and Washington, D. C., are attached.

Striking similarity in statistical findings of the entire series is evident on careful perusal of the details. It is not necessary to append further detailed reports from other Examining Units, as these two furnish sufficient data to constitute typical examples.

REPORT OF THE PHYSICAL EXAMINING UNIT AT SAN ANTONIO, TEX.

1. From August 17, 1917, to March 12, 1918, inclusive:

Total number of applicants examined		3,326
Total number of applicants failed	894	
Total number of applications on file	68	
	less	962
Total number of applicants accepted		2,364

NOTE.—Do not try to strike a percentage balance with these figures. Many of those on file have passed, but we have not forwarded the papers on account of orders to stop examining after February 9, 1918.

2. For purposes of statistics our records are available from October 1, 1917, to March 12, 1918, as follows:

Accepted:	
Aviators	1,162
Aerial observers	63
Balloonists	77
Nonfliers	587
Rejected:	
Aviators	650
Aerial observers	38
Balloonists	26
Nonfliers	66

Percentage:

	Per cent.
Aviators failed to pass	36
Aerial observers failed to pass	38
Balloonists failed to pass	25
Nonfliers failed to pass	10

3. Equilibrium record:

Total number of men turned in chair	2,537
Total number of men given caloric only	10

Average duration of nystagmus for above 2,537 cases was:

Right turn — Nystagmus to left duration 22.7 plus seconds.
Left turn — Nystagmus to right duration 23 seconds.

Comparison of results before and after the use of mydriatic.

Average duration of Nystagmus taken before drops were used in eyes (2,123 men):

Right turn — 22.7 plus seconds.
Left turn — 23.3 plus seconds.

Average duration of Nystagmus taken after a mydriatic was used in eyes (414 men):

Right turn — 21.7 plus seconds.
Left turn — 22.1 plus seconds.

The above shows practically no change after the use of a mydriatic.

Comparison of the findings by different examiners.

Average duration first 100 cases:

Right turn — 21.7 plus seconds.
Left turn — 23.3 seconds.

Average duration of last 100 cases before we began to use a mydriatic first:

Right turn — 21.8 plus seconds.
Left turn — 23.1 plus seconds.

Average duration of last 100 cases examined (mydriatic used):

Right turn — 21.8 plus seconds.
Left turn — 22.9 plus seconds.

4. Of the total of 2,547 men examined by balance test 151 failed to pass for aviators, which makes a percentage of failures 5.9 per cent.

Quite a few of those included as not passed for aviation in the above paragraph were accepted as balloonists.

REPORT OF THE PHYSICAL EXAMINING UNIT AT WASHINGTON, D. C.

The Washington unit has examined to date (July 5, 1918) approximately 3,000 applicants for the Aviation Section, Signal Corps. Careful statistics have been compiled of the results of these physical examinations. We submit herewith a consecutive 1,000 of this number. The findings should prove a reliable base for estimates on greater numbers. Seven hundred and sixty-five, or 76.5 per cent, were qualified, and 235, or 23.5 per cent, were disqualified.

Table 2 gives in detail the results of the physical examinations of the 1,000 men consecutively examined.

An applicant is often disqualified on more than one count, but for the purposes of classification the causes of rejection have been separated into three groups: (1) The eye, (2) ear and equilibrium, and (3) physical, the rejections being classified according to the main causes of rejection, with various subdivisions, which are combined often with counts of lesser importance.

TABLE II.—*Showing the results of the physical examination for aviation of a consecutive 1,000 men at the examination unit, Washington, D. C.*

ACCEPTED.

Causes.	Number.			Rate.		
	Total.	Normal.	Defective.	Total.	Normal.	Defective.
Total	765			76.5		
Age	18,356			24		
Stereoscopic	765	757	8	100	99.0	1.0
Color vision	765	762	[1] 3	100	99.6	.4
Muscle balance:						
Hyperphoria	765	765		100	100	
Exophoria	765	764	1	100	99.9	.1
Esophoria	765	754	11	100	98.6	1.4
Adduction	368			.5		
Abduction	195			.3		
Visual acuity:						
Right				20/18		
Left				20/18		
Near point:						
Right	8,329.5			10.9		
Left	8,273			10.8		
Ophthalmoscopic:						
Right	765	762	3	100	99.6	.4
Left	765	763	2	100	99.7	.3
History of ear trouble:						
a	765	763	2	100	99.7	.3
b	765	764	1	100	99.9	.1
c	765	764	1	100	99.9	.1
d	765	764	1	100	99.9	.1
Appearance of membrani tympani:						
Right	765	764	1	100	99.9	.1
Left	765	764	1	100	99.9	.1
Watch:						
Right /30	22,669			29.6		
Left /30	22,642			29.6		
Voice:						
Right	15,282			20		
Left	15,278			20		
Condition of nares:						
Right	765	744	21	100	97.3	2.7
Left	765	745	20	100	97.4	2.6
Tonsils:						
Right	765	601	164	100	78.6	21.4
Left	765	598	167	100	78.2	21.8
Presence of adenoids	765	720	45	100	94.1	5.9
Condition of Eustachian tubes	765	765		100	100	
Equilibrium:						
a—						
Right	20,049			26.2		
Left	19,741			25.8		
b, 1—						
Right	765	765		100	100	
Left	765	765		100	100	
b, 2—						
Right	2,095			2.7		
Left	2,081			2.7		
b, 3—						
Right	2,128			2.8		
Left	2,071			2.7		
c—						
Right	765	765		100	100	
Left	765	765		100	100	
Height	50,824			66.4		
Weight	107,557			140.6		
Chest measurement:						
Expiration	24,324½			31.8		
Inspiration	27,516½			36		
Respiratory system	765	765		100		
Bones and joints	765	762	3	100	99.6	.4
Pulse rate	64,417			84.2		
Systolic	97,356			127.3		
Diastolic	63,987			83.6		
Heart	765	764	1	100	99.9	.1
Veins	765	765		100		
Hemorrhoids	765	764	1	100	99.9	.1
Digestive system	765	764	1	100	99.9	.1
Hernia	765	764	1	100	99.9	.1
Genito-urinary system	765	760	5	100	99.3	.7
Urinalysis, specific gravity	778,043			1,017		

[1] But slightly defective. Waived because of previous experience and exceptional ability.

TABLE II.—*Showing the results of the physical examination for aviation of a consecutive 1,000 men at the examination unit, Washington, D. C.*—Continued.

REJECTED.

Causes.	Number.			Rate.		
	Total.	Normal.	Defective.	Total.	Normal.	Defective.
Total	235			23.5		
Age	5,636			24		
Stereoscopic	235	189	46	100	80.4	19.6
Color vision	235	218	17	100	92.8	7.2
Muscle balance:						
Hyperphoria	235	232	3	100	98.7	1.3
Exophoria	235	219	16	100	93.2	6.8
Esophoria	235	223	12	100	94.9	5.1
Adduction	3 86			1.6		
Abduction	209			.9		
Visual acuity:						
Right				20/26		
Left				20/24		
Near point:						
Right	2,671.5			11.4		
Left	2,627.5			11.2		
Ophthalmoscopic:						
Right	235	223	12	100	94.9	5.1
Left	235	223	12	100	94.9	5.1
History of ear trouble:						
a	235	231	4	100	98.3	1.7
b	235	233	2	100	99.1	.9
c	235	233	2	100	99.1	.9
d	235	232	3	100	98.7	1.3
Appearance of membrani tympani:						
Right	235	231	4	100	98.3	1.7
Left	235	230	5	100	97.9	2.1
Watch:						
Right /30	6,714			28.6		
Left /30	6,591			28		
Voice:						
Right	4,551			19.4		
Left	4,373			18.6		
Condition of nares:						
Right	235	231	4	100	98.3	1.7
Left	235	231	4	100	98.3	1.7
Tonsils:						
Right	235	205	30	100	87.2	12.8
Left	235	205	30	100	87.2	12.8
Presence of adenoids	235	226	9	100	96.2	3.8
Condition of Eustachia tubes	235	235		100	100	
Equilibrium:						
a—						
Right	6,245			26.6		
Left	6,253			26.6		
b, 1—						
Right	235	233	2	100	99.1	.9
Left	235	233	2	100	99.1	.9
b, 2—						
Right	634			2.7		
Left	570			2.4		
b, 3—						
Right	627			2.7		
Left	595			2.5		
c—						
Right	235	232	3	100	98.7	1.3
Left	235	229	6	100	97.4	2.6
Height	15,920			67.7		
Weight	32,629			138.8		
Chest measurement:						
Expiration	7,446			31.7		
Inspiration	8,348½			35.5		
Respiratory system	235	232	3	100	98.7	1.3
Bones and joints	235	230	5	100	97.9	2.1
Pulse rate	19,990			85.1		
Systolic	30,152			128.3		
Diastolic	16,334			69.5		
Heart	235	228	7	100	97	3.0
Veins	235	234	1	100	99.6	.4
Hemorrhoids	235	235		100	100	
Digestive system	235	229	6	100	97.4	2.6
Hernia	235	233	2	100	99.1	.9
Genito-urinary system	235	232	3	100	98.7	1.3
Urinalysis, specific gravity	239,277			1,018		

Of the 235 rejections, 149 were defective in vision, 51 in the ear and equilibrium tests, and 35 failed to come up to the physical requirements.

Table 3 gives the three main groups and their subdivisions, with rate per 1,000; showing that 15 per cent of the 1,000 examined (over one-half of the total number rejected) were disqualified on vision; 5.1 per cent on ear and equilibrium tests, and 3.5 per cent on physical counts. Equilibrium alone was the cause of rejection of 3.3 per cent, and equilibrium in combination with other counts, 4.8 per cent.

TABLE III.—*Showing the three main groups, and their subdivisions with rates.*

Causes of rejection.	Number.	Rate.
Total	235	23.5
Eye	149	15.0
Stereoscopic	8	0.8
Color vision	15	1.5
Muscle balance (one of which had double vision)	13	1.3
Field of vision	2	0.2
Visual acuity (seven of which had defective near point)	63	6.3
Near point	4	0.4
Lesions of the fundus	7	0.7
Stereoscopic and muscle balance	6	0.6
Visual acuity and stereoscopic	5	0.5
Visual acuity and muscle balance	5	0.5
Visual acuity and fundus	3	0.3
Visual acuity and color blindness	2	0.2
Visual acuity and hearing	3	0.3
Visual acuity and equilibrium	10	1.0
Visual acuity, muscle balance, and fundus	1	0.1
Visual acuity, muscle balance, and stereoscopic	2	0.2
Ear and equilibrium	51	5.1
Ear	10	
Ear and hernia	1	1.3
Ear and chronic purulent otitis media	2	
Ear and equilibrium	5	0.5
Equilibrium	31	
Equilibrium, hay fever, and defective static sense	1	3.3
Equilibrium, result of injury to head in motor accident	1	
Physical	35	3.5
Heart	8	0.8
Lungs	3	0.4
Lungs and hay fever	1	
Weight	11	1.1
Bones and joints	2	0.2
Hernia	2	0.2
Teeth	2	0.2
Urinalysis	4	0.4
Varicose veins	1	0.1
Stammering	1	0.1

Number of applicant.			
1001	Extra ventricular systolic every 7th or 8th beat. Nondisabling	(28d)	Passed. (*Waived.*)
1002	Vision with +2.00 sp. L. on =20/20 each eye	(11a)	Passed. *Balloon service.* (*Waived.*)
1003			Passed.
1004	*Has not four opposing molars*	*(29)*	*Rejected.*
1005	*Touches with both hands; both positions of head, 30° forward; 60° back*	*(20)*	*Rejected. Recommended for balloon service.*
1006			Passed.
1007	Operation for tonsils	(16)	Passed.
1008			Passed.
1009	Operation for tonsils		Passed.
1010	*Visual acuity, R. 20/20—1; L. 20/50; #29 has not four opposing molars*	*11 and 29*	*Rejected.*
1011			Passed.
1012			Passed.
1013			Passed.
1014			Passed.
1015	Tonsils		Passed.
1016			Passed.
1017	Operation for tonsils	(16)	Passed.
1018	Operation for tonsils	(16)	Passed.
1019	Operation for synechia	(15)	Passed.
1020			Passed.
1021	Operation for tonsils and adenoids	20–17–16	Passed.
1022	Urinalysis, marked trace albumin	32	Passed.
1023	Operation for tonsils	16	Passed.
1024	*Stereoscopic vision very poor; (#2) surgical varicocele (31), visual acuity (11)*		*Rejected.*
1025			Passed.
1026	*Systolic murmur, transmitted to arilla*	*28d*	*Rejected.*
1027	Operation for tonsils	16	Passed.
1028	Operation for tonsils	16	Passed.
1029	*Comp. fracture left forearm. Muscular devl. poor; frail appearance*	*25*	*Rejected.*
1030		*2*	Passed.
1031	Reexamined on stereoscopic test	2	Passed. (*Waived.*)
1032	Left varicocele, surgical	31	Passed, if operated upon for 31.
1033			Passed.
1034			Passed.
1035	Operation for tonsils; after operation, vision 20/20	16	Passed.
1036	Operation for tonsils	16	Passed.
1037			Passed.
1038		*11a*	*Rejected.*
1039	*#2 unable to stereoscope; #10 Eso. 5°. Add. 20°. Abd. 3/4° 11b. Unable to get any point*	*2–10–11*	*Rejected.*
1040	Muscular development good	22	Passed. (*Waived.*)
1041	Operation for tonsils	16	Passed.
1042		*11*	*Rejected.*
1043			Passed.
1044	*Has not required number of opposing molars*		*Rejected.*

1045			Passed.	
1046			Passed.	
1047			Passed.	
1048			Passed.	
1049	Surgical varicocele		*Rejected.*	*Recommended for balloon service.*
1050			Passed.	

TABLE I.—*Giving on example of the methods used in posting the results of the examination, and containing the numbers of the first 50 men of the 1,000 consecutively examined.*

Number of applicant.	Age.	2 Stereo.	9 Color vision.	10 Muscle balance. Hyper.	Exo.	Eso.	Add.	Ab.	11 Visual acuity. R.	L.	Near point. R.	L.	12 Ophthalmoscopic. R.	L.	13 History of ear trouble. (a)	(b)	(c)	(d)	14 (b) Appearance of membrani tympani. R.	L.	(c) Watch. R.	L.	Voice. R.	L.	15 Condition of nares. R.	L.	16 Tonsils. R.	L.	17 Presence of adenoids.	18 Condition of Eustachian tubes.	20 Equilibrium. A. R.	L.	b. 1 R.	L.	b. 2 R.	L.	b. 3 R.	L.	c. 1	2	22 Height.	Weight.	23 Chest measurement. Expiration.	Inspiration.	24 Respiratory system.	25 Bones and joints.	28 (a) Pulse rate.	(c) Systolic.	Diastolic.	(d) Heart.	(e) Veins.	(f) Hemorrholds.	29 Digestive system.	30 Hernia.	31 Genito-urinary system.	32 Urinalysis, specific gravity.	*Causes of rejection or waiver. See other page.	Number of applicant.
01..	20	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	9	9	N.	N.	No.	No.	No.	No	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	27	27	T.	T.	2	2	2	2	R.	L.	69	133	33	37½	N.	N.	84	142	90	N.	N.	N.	N.	No.	N.	1.018	See #28d	1001
02..	20	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	15	15	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	28	25	T.	T.	2	2	2	3	R.	L.	65	118	32	37½	N.	N.	96	120	82	N.	N.	No.	N.	No.	N.	1.018	11a	1002
03..	21	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	9	9	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	27	25	T.	T.	2	2	3	3	R.	L.	65	126	32	35½	N.	N.	82	136	86	N.	N.	No.	N.	No.	N.	1.018	.....	1003
04..	30	N.	N.	N.	N.	N.	.....	.....	20/20-1	20/20	10	10	N.	N.	No.	No.	No.	No.	N.	N	30/30	25/30	20	20	N	N.	N.	N	No.	P.	26	22	T.	T.	2	2	3	2	R.	L.	66	110	28½	33	N.	N.	82	120	80	N.	N.	No.	*	No.	N	1.019	29	1004
05..	22	N.	N.	N.	N.	N.	.....	.....	20/20-1	20/20	10	10	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N	N.	N.	N	No.	P.	24	30	T.	T.	1	T.	1	PPR.	R.	L.	69	170	35	38	N.	N.	78	116	70	N.	N.	No.	N.	No.	N.	1.020	20	1005
06..	23	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	9	9	N.	N.	No	No.	No.	No.	N	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	25	23	T.	T.	3	2	2	2	R.	L.	65	136	30	35½	N.	N.	72	132	84	N.	N.	No.	N.	No.	N.	1.016	.....	1006
07..	22	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	10	10	N.	N.	No.	No.	No.	No.	N	N.	30/30	30/30	20	20	N.	N.	*	*	No.	P.	29	32	T.	T.	3	2	3	2	R.	L.	68	148	32	35½	N.	N.	68	130	86	N.	N.	No.	N.	No.	N.	1.019	16	1007
08..	25	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	10	10	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	28	25	T.	T.	2	2	3	3	R.	L.	68	132	32	37½	N.	N.	84	120	80	N.	N.	No.	N.	No.	N.	1.017	.....	1008
09..	28	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	9	9	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	*	*	No.	P.	35	29	T.	T.	3	3	3	3	R.	L.	68	138	31½	36	N.	N.	76	130	82	N.	N.	No.	N.	No.	N.	1.018	16	1009
10..	27	N.	N.	N.	N.	N.	.....	.....	20/20-1	20/50	9	9	N.	N.	No.	No.	No.	No.	N	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	30	29	T.	T.	3	2	2	3	R.	L.	67	157	33	36½	N.	N.	72	120	80	N.	N.	No.	*	No.	N.	1.022	11 29	1010
11..	25	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	9½	9½	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	20	20	T.	T.	2	2	3	2	R.	L.	70	140	31	36	N.	N.	78	140	90	N.	N.	No.	N.	No.	N.	1.017	.....	1011
12..	24	N.	N.	N.	N.	N.	.....	.....	20/15	20/15-1	12	12	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	18	17	T.	T.	2	2	3	3	R.	L.	65	121	28½	33½	N.	N.	96	130	84	N.	N.	No.	N.	No.	N.	1.018	.....	1012
13..	27	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-1	13	13	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	26	27	T.	T.	3	3	3	3	R.	L.	68	152	33	36½	N.	N.	88	148	90	N.	N.	No.	N.	No.	N.	1.017	.....	1013
14..	22	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/20+3	8	8	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	25	25	T.	T.	2	2	2	2	R.	L.	67	128	30½	35	N.	N.	84	124	70	N.	N.	No.	N.	No.	N.	1.017	.....	1014
15..	25	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-2	12	11	N.	N	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	*	*	No.	P.	21	23	T.	T.	3	3	3	3	R.	L.	65	163	34	37½	N.	N.	84	120	80	N.	N.	No.	N.	No.	N.	1.017	.....	1015
16..	29	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-1	12	12	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	28	26	T.	T.	2	2	3	3	R.	L.	66	136	31½	35	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.020	16	1016
17..	25	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-1	11	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	*	*	No.	P.	21	22	T.	T.	2	3	2	2	R.	L.	65	115	27	30¾	N.	N.	96	120	70	N.	N.	No.	N.	No.	N.	1.019	16	1017
18..	21	N.	N.	N.	N.	N.	.....	.....	20/15-2	20/15-4	11	12	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	*	*	No.	P.	26	25	T.	T.	3	3	3	3	R.	L.	66	136	30	41	N.	N.	75	120	80	N.	N.	No.	N.	No.	N.	1.019	16	1018
19..	22	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-2	11	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	*	*	N.	N.	No.	P.	29	28	T.	T.	3	3	3	3	R.	L.	67	126	30	33½	N.	N.	90	125	90	N.	N.	No.	N.	No.	N.	1.019	15	1019
20..	22	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-1	10½	9	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	16	16	T.	T.	2	2	2	2	R.	L.	69	140	32	36	N.	N.	84	136	78	N.	N.	No.	N.	No.	N.	1.016	.....	1020
21..	24	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-3	11	10	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	*	*	*	P.	35	30	T.	T.	4	3	1	4	R.	L.	72	148	30½	35	N.	N.	78	118	78	N.	N.	No.	N.	No.	N.	1.020	20 17-16	1021
22..	22	N.	N.	N.	N.	N.	.....	.....	20/15	20/15-2	11	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	20	25	T.	T.	3	3	3	4	R.	L.	68	112	29½	32½	N.	N.	80	126	78	N.	N.	No.	N.	No.	N.	[1] 1.009	32	1022
23..	20	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	11	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	*	*	No.	P.	24	21	T.	T.	3	3	3	4	R.	L.	64	130	33½	36	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.018	16	1023
24..	24	N.	N.	N.	N.	N.	.....	.....	20/30-2	20/20-1	10	10	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	18	16	T.	T.	3	3	2	3	R.	L.	65	121	29½	34	N.	N.	84	130	74	N.	N.	No.	N.	No.	*	1.016	2-11-31	1024
25..	21	N.	N.	N.	N.	N.	.....	.....	20/15	20/15	11	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	19	17	T.	T.	2	3	4	2	R.	L.	68	129	30½	34½	N.	N.	84	128	82	N.	N.	No.	N.	No.	N.	1.019	.....	1025
26..	21	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-1	10	10	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	34	34	T.	T.	2	2	2	4	R.	L.	64	137	31½	34½	N.	N.	96	150	90	N.	N.	No.	N.	No.	N.	1.018	28d	1026
27..	23	N.	N.	N.	N.	N.	.....	.....	20/15	20/15	11	11	N.	N	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	*	*	No.	P.	20	21	T.	T.	2	2	3	3	R.	L.	65	148	31	35½	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.020	16	1027
28..	22	N.	N.	N.	N.	N.	.....	.....	20/15	20/15	11	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N	*	*	No.	P.	17	17	T.	T.	2	3	3	3	R.	L.	68	155	31½	30¾	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.016	16	1028
29..	22	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-5	12	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	23	20	T.	T.	3	3	3	3	R.	L.	69	119	30	34	N.	*	100	115	90	N.	N.	No.	N.	No.	N.	1.020	25	1029
30..	25	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	11	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	18	18	T.	T.	3	3	3	3	R.	L.	72	157	34	39	N.	N.	80	120	75	N.	N.	No.	N.	No.	N.	1.020	.....	1030
31..	21	*	N.	N.	N.	N.	.....	.....	20/10-5	20/10-3	10	10	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N	N.	N.	No.	P.	21	22	T.	T.	3	3	2	2	R.	L.	67	123	31	35	N.	N.	82	122	80	N.	N.	No.	N.	No.	N.	1.016	2	1031
32..	20	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	11	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N	N.	N.	No.	P.	21	27	T.	T.	3	3	4	4	R.	L.	69	139	30	34½	N.	N.	76	125	75	N.	N.	No.	N.	No.	*	1.020	31	1032
33..	23	N.	N.	N.	N.	N.	.....	.....	20/15	20/15	12	12	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	32	21	T.	T.	3	3	3	3	R.	L.	68	133	29¾	33½	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.020	.....	1033
34..	27	N.	N.	N.	N.	N.	.....	.....	20/15	20/15	11	11	N	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	25	21	T.	T.	4	4	3	3	R.	L.	71	178	34½	38	N.	N.	80	138	82	N.	N.	No.	N.	No.	N.	1.013	.....	1034
35..	23	N.	N.	N.	N.	N.	.....	.....	20/30+4	20/30+4	10	10	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N	*	*	No.	P.	21	18	T.	T.	2	3	3	2	R.	L.	68	122	30½	34	N.	N.	78	120	78	N.	N.	No.	N.	No.	N.	1.017	16	1035
36..	27	N.	N	N.	N.	N.	.....	.....	20/20	20/20	9½	9½	N.	N.	No.	No.	No.	No.	N.	N	30/30	30/30	20	20	N.	N.	*	*	No.	P.	28	25	T.	T.	3	3	3	3	R.	L.	66	132	30¾	34½	N.	N.	84	126	82	N.	N.	No.	N.	No.	N.	1.019	16	1036
37..	23	N.	N.	N.	N.	N.	.....	.....	20/20+3	20/20+3	11½	10	N.	N	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	32	33	T.	T.	4	3	3	3	R.	L.	66	130	31½	36¾	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.017	.....	1037
38..	27	N	N.	N.	N	N.	.....	.....	20/30-2	20/15-3	13	13	N.	N.	No.	No.	No.	No.	N.	N	30/30	30/30	20	20	N.	N.	N.	N	No.	P.	25	28	T.	T.	2	2	2	2	R.	L.	70	142	30	34¼	N.	N.	84	126	80	N.	N.	No.	N.	No.	N.	1.018	11a	1038
39..	21	*	N.	N.	N	5°.	.....	.....	10/200	20/15	*	12	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	27	27	T.	T	2	2	2	2	R.	L.	65	136	33	36	N.	N.	75	132	90	N.	N.	No.	N.	No.	N.	1.018	#2-10-11	1039
40..	22	N.	N.	N.	N.	N.	.....	.....	20/20+3	20/15-1	12½	12	N.	N.	No.	No.	No.	No.	N.	N	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	32	28	T.	T.	3	3	3	3	R.	L.	66	108	29½	32½	N.	N.	88	130	80	N.	N.	No.	N.	No.	N.	1.018	22	1040
41..	21	N.	N.	N.	N.	N.	.....	.....	20/20+4	20/20+4	12	10½	N.	N.	No.	No.	No.	No.	N.	N.	25/30	30/30	20	20	N	N.	*	*	No.	P.	28	26	T.	T.	2	2	2	2	R.	L.	65	130	31	34½	N.	N.	81	125	80	N.	N.	No.	N.	No.	N.	1.021	16	1041
42..	28	N.	N.	N.	N.	N.	.....	.....	20/30+1	20/15-2	13	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N	No.	P.	31	24	T.	T.	2	2	2	2	R.	L.	71	152	30¾	35½	N.	N.	72	126	80	N.	N.	No.	N.	No.	N.	1.016	11	1042
43..	24	N.	N.	N.	N.	N.	.....	.....	20/20-2	20/20	10	10	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	29	28	T.	T.	2	2	2	2	R.	L.	67	142	31½	34¼	N.	N	88	121	80	N.	N.	No.	N.	No.	N.	1.017	.....	1043
44..	27	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	10	10	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	24	26	T.	T.	2	2	2	2	R.	L.	67	146	31	34¾	N.	N.	90	124	82	N.	N.	No.	*	No.	N.	1.023	29	1044
45..	21	N.	N.	N.	N.	N.	.....	.....	20/20	20/20	9	9	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	34	28	T.	T.	2	2	2	2	R.	L.	66	133	30	33½	N.	N.	81	120	80	N.	N.	No.	N.	No.	N.	1.021	.....	1045
46..	27	N.	N.	N.	N.	N.	.....	.....	20/15	20/15-1	14	12	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N	N.	N.	No.	P.	22	22	T.	T.	2	2	3	3	R.	L.	68	130	30½	34	N.	N.	72	130	90	N.	N.	No.	N.	No.	N.	1.020	.....	1046
47..	25	N.	N.	N.	N.	N.	.....	.....	20/15-1	20/15-2	12½	12	N.	N	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	30	35	T.	T.	2	2	3	3	R.	L.	69	128	29¾	34	N.	N.	84	128	80	N.	N.	No.	N.	No.	N.	1.018	.....	1047
48..	22	N.	N.	N.	N.	N.	.....	.....	20/15	20/15	10	11	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	33	32	T	T.	3	3	3	3	R.	L.	69	144	31	35½	N.	N.	84	128	76	N.	N.	No.	N.	No.	N.	1.010	.....	1048
49..	25	N.	N.	N.	N.	N.	.....	.....	20/20+4	20/20-2	25	25	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	17	13	R.	L.	2	1	T.	1	R.	L.	68	136	32½	35½	N.	N.	78	120	80	N.	N.	No.	N.	No.	*	1.017	11-20-31	1049
50..	26	N.	N.	N.	N.	N.	.....	.....	20/20+3	20/20-3	12	12	N.	N.	No.	No.	No.	No.	N.	N.	30/30	30/30	20	20	N.	N.	N.	N.	No.	P.	23	24	T.	T.	3	3	3	3	R.	L.	67	141	32	36	N.	N.	80	122	72	N.	N.	No.	N.	No.	N.	1.017	.....	1050

[1] Marked trace of albumin.

NOTE (a).—For key to Table I, refer to examination blank used by units.
NOTE (b).—Hyperphoria not over 1° entered as normal; esophoria and exophoria not over 2° entered as normal

ecutively examined.

23		24	25	28						29	30	31	32		
Chest measurement.				(a)	(c)		(d)	(e)	(f)						
Expiration.	Inspiration.	Respiratory system.	Bones and joints.	Pulse rate.	Systolic.	Diastolic.	Heart.	Veins.	Hemorrhoids.	Digestive system.	Hernia.	Genito-urinary system.*	Urinalysis, specific gravity.	*Causes of rejection or waiver. See other page.	Number of applicant.
33	37½	N.	N.	84	142	90	N.	N.	N.	N.	No.	N.	1.018	*See #28d*	1001
32	37½	N.	N.	96	120	82	N.	N.	No.	N.	No.	N.	1.018	*11a*	1002
32	35½	N.	N.	82	136	86	N.	N.	No.	N.	No.	N.	1.018	....	1003
28½	*33*	*N.*	*N.*	*82*	*120*	*80*	*N.*	*N.*	*No.*	*	*No.*	*N.*	*1.019*	*29*	*1004*
35	*38*	*N.*	*N.*	*72*	*116*	*70*	*N.*	*N.*	*No.*	*N.*	*No.*	*N.*	*1.020*	*20*	*1005*
30	35½	N.	N.	72	132	*84*	*N.*	*N.*	No.	*N.*	*No.*	*N.*	1.016	....	1006
32	35½	N.	N.	68	130	86	N.	N.	No.	N.	No.	N.	1.019	16	1007
32	37½	N.	N.	84	120	80	N.	N.	No.	N.	No.	N.	1.017	....	1008
31½	36	N.	N.	76	130	82	N.	N.	No.	N.	No.	N.	1.018	16	1009
33	*36½*	*N.*	*N.*	*72*	*120*	*80*	*N.*	*N.*	*No.*	*	*No.*	*N.*	*1.022*	*11–29*	*1010*
31	36	N.	N.	78	140	90	N.	N.	No.	N.	No.	N.	1.017	....	1011
28¾	33¼	N.	N.	96	130	84	N.	N.	No.	N.	No.	N.	1.018	....	1012
33	36½	N.	N.	88	148	90	N.	N.	No.	N.	No.	N.	1.017	....	1013
30¾	35	N.	N.	84	124	70	N.	N.	No.	N.	No.	N.	1.017	....	1014
34	37¼	N.	N.	84	120	80	N.	N.	No.	N.	No.	N.	1.017	....	1015
31½	35	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.020	16	1016
27	30¾	N.	N.	96	120	70	N.	N.	No.	N.	No.	N.	1.019	15	1017
36	41	N.	N.	75	120	80	N.	N.	No.	N.	No.	N.	1.019	16	1018
30	33½	N.	N.	90	125	90	N.	N.	No.	N.	No.	N.	1.019	15	1019
32	36	N.	N.	84	136	78	N.	N.	No.	N.	No.	N.	1.016	....	1020
30½	35	N.	N.	78	118	78	N.	N.	No.	N.	No.	N.	1.020	20–17–16	1021
29½	32¾	N.	N.	80	126	78	N.	N.	No.	N.	No.	N.	[1] 1.009	32	1022
33¾	36	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.018	16	1023
29½	*34*	*N.*	*N.*	*84*	*130*	*74*	*N.*	*N.*	*No.*	*N.*	*No.*	*	*1.016*	*2–11–31*	*1024*
30¼	34¼	N.	N.	84	128	82	N.	N.	No.	N.	No.	N.	1.019	....	1025
31½	*34¾*	*N.*	*N.*	*96*	*150*	*90*	*N.*	*N.*	*No.*	*N.*	*No.*	*N.*	*1.018*	*28d*	*1026*
31	35½	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.020	16	1027
31½	36¼	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.016	16	1028
30	*34*	*N.*	*	*100*	*115*	*90*	*N.*	*N.*	*No.*	*N.*	*No.*	*N.*	*1.020*	*25*	*1029*
34	39	N.	N.	80	120	75	N.	N.	No.	N.	No.	N.	1.020	....	1030
31	35	N.	N.	82	122	80	N.	N.	No.	N.	No.	N.	1.016	2	1031
30	34½	N.	N.	76	125	75	N.	N.	No.	N.	No.	*	1.020	31	1032
29¼	33½	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.020	....	1033
34½	38	N.	N.	80	138	82	N.	N.	No.	N.	No.	N.	1.013	....	1034
30½	34	N.	N.	78	120	78	N.	N.	No.	N.	No.	N.	1.017	16	1035
30¾	34½	N.	N.	84	126	82	N.	N.	No.	N.	No.	N.	1.019	16	1036
31¼	36¾	N.	N.	72	120	80	N.	N.	No.	N.	No.	N.	1.017	....	1037
30	*34¾*	*N.*	*N.*	*84*	*126*	*80*	*N.*	*N.*	*No.*	*N.*	*No.*	*N.*	*1.018*	*11a*	*1038*
33	*36*	*N.*	*N.*	*75*	*132*	*90*	*N.*	*N.*	*No.*	*N.*	*No.*	*N.*	*1.018*	*#2–10–11*	*1039*
29¼	32½	N.	N.	88	130	80	N.	N.	No.	N.	No.	N.	1.018	22	1040
31	34½	N.	N.	81	125	80	N.	N.	No.	N.	No.	N.	1.021	16	1041
30¾	*35½*	*N.*	*N.*	*72*	*126*	*80*	*N.*	*N.*	*No.*	*N.*	*No.*	*N.*	*1.016*	*11*	*1042*
31½	34¾	N.	N	88	124	80	N.	N.	No.	N.	No.	N.	1.017	....	1043
31	*34¾*	*N.*	*N.*	*90*	*124*	*82*	*N.*	*N.*	*No.*	*	*No.*	*N.*	*1.023*	*29*	*1044*
30	33½	N.	N.	81	120	80	N.	N.	No.	N.	No.	N.	1.021	....	1045
30½	34	N.	N.	72	130	90	N.	N.	No.	N.	No.	N.	1.020	....	1046
29¾	34	N.	N.	84	128	80	N.	N.	No.	N.	No.	N.	1.018	....	1047
31	35¼	N.	N.	84	128	76	N.	N.	No.	N.	No.	N.	1.016	....	1048
32½	*35½*	*N.*	*N.*	*72*	*120*	*80*	*N.*	*N.*	*No.*	*N.*	*No.*	*	*1.017*	*11–20–31*	*1049*
32	36	N.	N.	80	122	72	N.	N.	No.	N.	No.	N.	1.017	....	1050

CHAPTER VI.

REPORT OF MEDICAL OFFICERS JUST RETURNED FROM ENGLAND, FRANCE, AND ITALY—JANUARY 28, 1918.

PREFACE.

Whether or not "Aviation will win the war," as so many authorities state, we at least know one fact positively, and this fact makes clear the function and purpose of the Medical Department of our Aviation Service—we should and must keep the fighting force of our Aviation Service at its highest degree of efficiency.

The British, at the end of the first year of the war, found to their astonishment that of the total number of accidents to their fliers, 65 per cent were due to physical defects of their pilots. They at once realized the need of expert medical study of their fliers. The next year the rate was 20 per cent and the next year 12 per cent.

The medical problem of aviation consists of:

(1) The selection of the flier.

(2) The care of the flier. This includes (*a*) classification of the pilot, and (*b*) maintenance of efficiency in actual service.

The selection of the flier in the United States was accomplished by the work of 67 physical examining units, which, in the course of little over seven months, have examined thousands of applicants.

In order to study the conditions abroad and to learn the methods of the Aviation Service of the Allies, medical officers concerned in the development of our service were sent to England, France, and Italy. Our methods of examining candidates in the United States and our plans for the care of the flier, both at home and abroad, were submitted to all the experts of the British, French, and Italian forces, and have met with unreserved approval. It was surprising to hear the same statement reiterated by the British, French, and Italians—"It is very fortunate that the Air Forces of the United States are profiting by the mistakes of our flying service in recognizing at the beginning that the medical problem of Aviation is a very special problem and can not possibly be conducted except by an organized body of experts."

The most essential feature of the present plan for the CARE of the Aviator is the selection of medical officers who will act as ADVISORS to the commanding officers of flying schools and squadron groups. Such medical advisors are to be selected from those who have been most familiar with the examination of the applicants for the Aviation Service, and before undertaking these duties they should, in addition, have undergone a special course of training under the direction of the Research Board of this department. This training will equip them to furnish the commanding officers with reliable daily information as to the physical fitness of the individual fliers in their commands.

Research work can also be carried out in certain large flying schools in France, and it is here that the preliminary work done in the United States can find its practical application in field service.

Interviews with British, French, and Italian fliers made clear that they considered it a most excellent plan to have a medical advisor attached to squadron groups; they frankly stated that if such supervision had been possible in the early days of their service, many hundreds of fliers would have been saved. We believe, and this belief is confirmed by the unanimous opinion of those in charge of the British, French, and Italian services, that such supervision of the physical welfare of the flier will reduce to a minimum fatalities and accidents in our Air Service.

GENERAL STATEMENT.

It is only in the last two years that serious consideration has been given to the importance of medical supervision of all that pertains to aviators. As early as 1910, Germany had made some study and published a definite form of examination for those wishing to qualify as pilots in the aeronautical services of their country. As far as is known, no serious study was being made on any large scale in any other country. In 1914, a board of medical officers drew up a form for the physical examination of officers of the Regular Army who wished to transfer to the Aviation Section of the Signal Corps. As the applicants were confined entirely to regular officers who had previously been physically examined, the type of the examination was made largely one of selecting men with special qualifications for flying. Special stress was laid upon visual, aural, and cardiac conditions.

In 1916, after two years of war, it was seen by the various countries engaged, as well as the United States, that physical defects were of great importance in the causation of air accidents. The British services at this time were not laying special stress upon rejecting candidates for flying positions because of physical defects. In 1916, however, they realized that it was necessary to make a careful selection of candidates in order to have efficient flying forces. Gradually they have elevated their standards, guided by practical experience in the flying and air fighting, especially in Flanders.

Both the French and Italian air services have expert examiners, whose sole duty it is to select from the applicants men physically fit for service in the air. In fact, in all the armies of the Allies (except the Russian, about which we have no definite information) there have been established research boards consisting of medical experts who have devoted all their time to the special problems of Aviation.

As stated in the preface, the medical problem in Aviation is divided into two parts: (1) The SELECTION of the flier, and (2) the CARE of the flier.

THE SELECTION OF THE FLIER.

This is accomplished in the United States by the work of 67 examining units with a personnel of over 500 physicians. In charge of each unit there are one or more commissioned officers who have, for many months, spent all their time in studying this subject. In establishing these units, it has been impressed on these officers that they are not only to examine candidates, but are to take this opportunity to prepare themselves for the care of the flier with the Expeditionary Forces at the front and at the flying schools in Europe.

THE GERMAN SERVICE.

For obvious reasons full details are not available, but we do know the essential points, having learned them from German prisoners. The Germans have a specially organized medical service for the study of the flier. Every individual aviator goes through his original examination all over again once a month. In this way the Germans are able to keep their air flying force at its highest efficiency by keeping in continual touch with the mental and physical condition of each aviator. This REEXAMINATION OF THE FLIER is an essential part of our proposed plan. Those medical officers in the United States who are most fitted for this work (and they include a large number of the highest-grade physicians and specialists in the United States) can be selected and sent abroad in increasing numbers according to the requirements of our service in Europe; they are fully trained and equipped by months of previous study in the EXAMINATION of the flier to apply the same standards and the same methods in the study and care of the flier.

For example, medical advisors serving with the British forces at the front realized that there was much more demanded of the medical service than the physical selection of pilots, or the sanitary and medical control such as would be furnished to other branches of their army. They realized that the very nature of the services of the flying officer was such as to demand special supervision at all times. They found as follows:

Aviation presents new physiological and pathological problems which require special study, and which can only be dealt with satisfactorily by a specially trained body of medical men. Medical officers who are only familiar with the ailments of nonflying men can not, without previous and special study of the matter, properly deal with or understand the conditions which may arise in aviators. For example, greatly rarified air at high altitudes, with the consequent difficulty of getting a sufficient supply of oxygen for the needs of the body, produces a number of conditions of importance and gravity which are being studied actively at the present time. Flying at high altitudes or for a long period without proper precautions has, on account of the great strain involved, serious effects not only on the cardio-vascular system, but also on the muscular and nervous systems. So far our knowledge of these matters and of the best methods of dealing with them is still in quite an early stage. Nevertheless, in certain directions, some points have already been made out which have proved of great practical importance in the selection of flying officers, in obviating some of the special risks referred to above, and in watching and treating these officers. For example, as regards the admission of cadets, the tests suitable for a flying officer differ in some respects from those necessary for officers who do not fly. Thus, accuracy of sight is most essential to the flying officer, particularly for fighting, observing, and landing, whilst a certain amount of disability of the lower limbs may not necessarily debar a man from being an efficient aviator, though it would probably completely incapacitate him for the other services. These points could, no doubt, be quickly grasped by any medical man, but, in addition to them, the cadet must be specially examined as to the heights to which he can ascend, with or without an artificial supply of oxygen. Perhaps the point in which the special education of the medical officer is most necessary is in the daily care and watchfulness over the aviator. The flying officer is a most valuable man, and as the result of the effects of high altitudes and variations in the amount of oxygen, and of the severe nervous and muscular strain to which he is constantly subjected, he is more easily incapacitated than officers in any of the other services. Hence he needs very special and constant attention as to his diet, exercise, and habits, which should be carefully regulated. He should be, from time to time, examined both immediately after a flight and also after he has had a rest from flying. Note must be made of the condition of his heart and of his nervous and muscular systems, especially in connection with the altitude which he has attained and the length of time he has been in the air.

This examination is necessary so that the medical officer may be able to order rest and treatment in cases where a flying officer shows signs of becoming stale or of breakdown. If, on the one hand, this is not properly attended to, it is certain that a large number of officers will go on flying long after they ought to have been resting, and may thus become permanently incapacitated for flight. If, on the other hand, these officers are carefully watched, as stated above, and placed under treatment as soon as there is any sign that they are suffering from stress of flying, they may go on for a long time without becoming permanently unfit, and in this way the great wastage of flying personnel which now occurs may be largely prevented. The skill necessary for the medical examination and treatment of flying officers and men, as described above, can only be obtained by special training and constant practical experience of the effects of flying.

To mention one more example, it is found that in certain individuals who may have apparent perfect acuity of vision, there exists a lack of ability to make use of both eyes, which interferes with judgment of distance; this disability tends to increase under the strain of aviation, and to result in bad landings, "crashes," and consequent loss of personnel and material. There is, however, some evidence that this condition can be, and has been, cured by specially skilled and practiced medical officers.

In the spring of 1916 it was seen that the physical examination required of the United States Army for the Aviation Section, Signal Corps, needed revision. While the character of the examination was, in general, satisfactory, there was a lack of definite standards which made its practical application on a large scale impossible. It was realized at this time that the examination had to be shortened and that only trained men, proficiently qualified, should make these examinations. In May, 1917, the revision of this examination form was completed and put into operation and officially authorized. Hospitals with well-equipped medical staffs were selected in each of the largest cities of the United States, and designated as examining units to carry out these examinations. Within a month, some 20 of these units had been established, each unit capable of examining on an average of 30 candidates a day. The succeeding month, the number of these units was increased till, at the present time, there are some 67 examining units in the United States with the capacity of examining a large number daily. It is believed advisable to examine a large number of candidates, place them on a waiting list until such time as the Air Service shall need them. As the number rejected is very great, the total number examined therefore has to be largely in excess of the actual needs.

The Surgeon General of the United States Army and the Chief Signal Officer both realized that the medical service attached to the air forces in the United States needed more independence of action than would be necessary for medical services attached to other arms of the service. As soon as the Aviation Section, Signal Corps, was made a separate service under the general supervision of the Chief Signal Officer, a medical division was authorized for the Aviation Section, Signal Corps. A Chief Surgeon was designated and all personnel, supplies, and equipment attached to the Medical Division of the Aviation Section, Signal Corps, was placed directly under the Commanding General of this service.

Paragraph 191, Army Regulations, 1913, states: "That in the United States the commander of a territorial department commands all the military forces of the Government within its limits, whether of the line or staff, except in so far as exempted from his control by the Secretary of War. Among the exempted institutions are general depots of supply and all schools of instruction for every branch of the service, including Signal Corps aviation schools and the United States Army Balloon School." The transfer of this personnel was duly made, and the relation of the Chief Surgeon, Aviation Section, Signal Corps, to the Surgeon General was placed on a similar basis to that of the relation of the Chief Surgeon of the territorial department to the Surgeon General. All medical problems, whether sanitary or the study of fliers, come under the direct supervision of the Chief Surgeon, Aviation Section, Signal Corps.

In order to carry further the work of the Medical Department of the Aviation Section, Signal Corps, a Research Board was authorized for duty in the office of the Chief Surgeon, to study all phases of flying which bore direct relation to the mental or physical equipment of the flier; such a board has now been in operation since October, 1917.

RELATION TO FORCES ABROAD.

Because of the impossibility of visualizing in the United States military conditions existing in France, and as the whole object of the development of the air forces in the United States was obviously for the purpose of eventually having them serve abroad, it was deemed urgent that medical officers, responsible for the development of the medical service, Aviation Section, Signal Corps, in the United States, should have an opportunity to see what was actually taking place at the front. When it was decided to send the present Commanding General Air Service in France abroad, two medical officers were selected to go with him for temporary duty. The purpose of their visit was to obtain all available information relative to the medical services of the Allied Countries to find out what policy was to be adopted by the Commanding General American Expeditionary Forces, and then to assist in every possible way toward the organization of medical services under the air forces for American Expeditionary Forces, should such be authorized; and to take back the information in order to build up the medical services, Aviation Section, Signal Corps, in the United States, on lines suitable to the needs abroad. At the present time in the United States medical officers are being trained in large numbers in the various special duties which they will be required to perform when it is realized how essential are their services to the success of the Air Forces.

ENGLISH.

The lack of oxygen at high altitudes, the cause of so many symptoms complained of by the flier, is responsible for the disability of a large percentage of pilots. In order to study the oxygen question, we were sent to Advance Headquarters, Royal Flying Corps, British

Expeditionary Forces, immediately on arrival in France. The following report was made:

1. As per instructions, I have made a study of the above subject from November 28 to the present date.

2. The Siebe-Gorman, Dreyer, and Garsaux oxygen apparatuses have been studied during this period.

3. A visit of two weeks and a half to Advance Headquarters, Royal Flying Corps, British Expeditionary Forces, gave opportunity to interview practically all the surgeons, experts, squadron commanders, supply officers, and others acquainted with the "oxygen situation." From a practical standpoint, it is now definitely determined that oxygen must be supplied to those flying above 15,000 feet.

4. The great heights now attained make it essential that some type of oxygen apparatus be produced at once for our Service.

5. From my observations, it appears that the Dreyer apparatus is the best of those now in use. This apparatus has been used in active service at the British front for over eight months and found satisfactory. On the date of December 1, 1917, there were from 40 to 50 in actual daily use. The Commanding General stated that the only reason these apparatuses were not used in larger numbers was they could not be supplied fast enough.

6. I recommend that the Dreyer apparatus be adopted by the Air Service, United States Army, and that they be manufactured in large quantities at once in the United States. Also recommend that this apparatus be manufactured in the United States to supply the Royal Flying Corps; this would be appreciated by them.

7. Further refinements, alterations or improvements that may be possible can be undertaken by our Research Board in the States, in connection with Lieut. Col. Dreyer, who will shortly work with them in an advisory capacity in Washington, D. C. It seems best, at present, however, to rush through the production of the present Dreyer apparatus for immediate use.

The Air Service, American Expeditionary Forces, by cable to the United States, ordered the production of approximately $700,000 worth of Dreyer oxygen apparatus. (On arrival in the United States we find that this is in production.)

Visits to squadrons at the British front brought out the following information:

INTERVIEWS WITH COMMANDING OFFICERS, FLIERS, AND OBSERVERS AT THE BRITISH FRONT.

REGARDING VALUE OF THE USE OF OXYGEN FOR FLIERS.

Maj. D——, commanding officer, —— Squadron, Royal Flying Corps:

We advise our men to fix the mask in position before leaving the ground. When using the Dreyer apparatus at an altitude of over 10,000 feet it is best for the pilot to adjust the mask and wear it from the time he starts until he comes back and gets out of the plane. There is no question that these men in my command who have used the oxygen apparatus are not by any means as tired as they used to be before they used this apparatus. The symptoms complained of occurred usually after a flight of an altitude of over 15,000 or 16,000 feet. Following are the main symptoms:

Headache.—This is usually the first symptom noted.

Fatigue.—As a rule this is so marked that the flier on returning to his squadron is almost too tired to appear before me and make a report of his flight.

Vertigo.—One man first noticed that he was dizzy, and then at an altitude of 18,000 feet he fainted. This occurred at a position 20 miles over the fighting line, within the enemy territory. After the plane had dropped for a considerable distance this man regained consciousness and came back safely to his squadron, a distance of over 30 miles. He made a good landing, but then immediately fainted. Vertigo has been complained of frequently.

Since the use of the oxygen the men have not complained of any headache, fatigue (except what you might call ordinary fatigue), or vertigo.

Maj. D——— commands a squadron of high fliers exclusively, and they have been using the Dreyer oxygen apparatus for several months.

Capt. P———, pilot, who has been flying at an average height of 20,000 feet:

Before the oxygen apparatus was used I used to suffer a great deal from flying at high altitude. I would notice a palpitation of my heart not only in the air at this high altitude, but also on the ground for a period of 24 hours after a flight. I would have a bad headache, not only in the air, but also after coming down. This would last from 5 to 6 hours. I used to get this palpitation of the heart and headache when I would fly over 16,000 feet; I would also feel "rotten and done up," and as time went on it became so bad, I was so tired I could not sleep for 30 hours; if I would fly on Monday I would be unable to sleep Monday afternoon, Monday night, or all day Tuesday, and I would have my first sleep on Tuesday night. I do not know how to explain why I could not sleep; it was apparently not in any way due to "nervousness."

Since I have used the oxygen apparatus I have had no palpitation, no headache, no fatigue at all, and I sleep normally.

An observer. This man says that he has been flying at an average height of 20,000 feet for several weeks, and that he is very active in the use of the machine gun and he has not had any symptoms at all. He does not feel that he would have any need of oxygen whatever; he states also that it would be a great nuisance for an observer to have to wear a mask, because it would interfere with his movements in the rear compartment.

An observer. This man had seen active service at high altitudes, and, as in the previous report, he did not notice any discomfort, or any impairment of his mental or physical efficiency. However, after seeing active service of six months he states he has "vertigo and fatigue," and after he has come down from a great height he now feels "done up."

COMMENT.

From a medical standpoint it is definitely determined that no human being can fly at altitudes such as 20,000 feet for any considerable length of time without doing himself a definite injury. This effect of "OXYGEN WANT" is most marked on the central nervous system. The writer was present for one week at the examinations made upon fliers, all of whom were suffering from the effects of high flying. In the Twenty-fourth General Hospital, British Expeditionary Forces, one ward is devoted to the care of fliers suffering from "OXYGEN WANT," and during the week mentioned there were observed 22 such cases. The entire group of men, from all appearances, looked perfectly healthy. Here was a ward full of young active men suffering in no way, and they could have been used in any other service, but not one of these men was able to continue with his duties as a flier.

These men were examined by Capt. Dudley Corbett, Royal Army Medical Corps, who made a special point of the following tests:

THE "FLACK" OXYGEN TEST.

The Flack apparatus consists of a bag containing 5 liters of air taken from the room in which the examination was made; attached to this bag is a tin cylinder which contains chemicals which would take up any carbon dioxide that passed through the can; there is a mouthpiece at the other end of the can. First of all, the air from the room would be forced in the 5-liter bag, then the man to be examined would take the mouthpiece into his mouth and close his lips firmly upon it; he would then breathe in and out through his mouth, holding his nose all the time. The only air which he was obtaining came from the 5-liter bag; the carbon dioxide which he would exhale was absorbed by the chemicals in the tin box, so that he was able to keep on breathing this air until the amount of oxygen in the bag became so small that he was not able to stand it any longer. The length of time that the man was able to keep this up was noted; then a sample of the air in the bag was taken and immediately examined, and the percentage of the oxygen in the bag was determined by careful analysis; and in this way it was very simple to determine what altitude this man would be able to attain.

THE CONDITION OF THE NERVOUS MECHANISM OF THE HEART.

The pulse was taken, counting each quarter of the minute for one minute with the man seated at rest. This was repeated with the man standing up, and again repeated after the man had stepped up and down upon a chair five times; he placed his right foot on the chair and stepped up on the chair, bringing his left foot up to the chair, and repeating this exercise five times. This simple test was very helpful in determining whether slight exercise would cause a marked increase of the pulse rate.

It is definitely determined that the aviator who flies above 10,000 feet MUST HAVE OXYGEN. Its routine use would prove very valuable, not only in keeping up the efficiency of the aviator, but in prolonging the period of time of his service before it would be necessary to send him away for a rest.

Nothing could better illustrate that the medical problem of aviation is a special problem than a study of these pilots at the Twenty-fourth General Hospital. Not a single man was injured in body or limb, and according to usual medical standards and usual methods of examination each one of these men would be considered as perfectly fit for service. As a matter of fact, not a single man was fit for service. They were unable to fly. Their chief complaints on attempting to fly were headache, vertigo, and "lack of confidence." It seems to me that there are two possible causes for this undermining of the stability of the central nervous system:

1. The cumulative effect on the nervous system of an insufficient supply of OXYGEN.
2. The unquestioned factor of the "MENTAL STRAIN" of long-continued service.

Maj. James L. Birley and Capt. Dudley Corbett, in charge of the British work at the front, have asked for our American turning-chair in order to have another method of testing the stability or instability of the central nervous system. Just as the heart shows marked rapidity because of lack of tone of its nerve mechanism, so stimulation of the ear would produce hyperactive responses; no flier, for example, should be returned to active service who is quickly nauseated after a few turns in the chair. They therefore plan the following tests in routine study of this type of cases:

1. The Flack oxygen test.
    - A. Noting the length of time that the individual is able to continue his rebreathing before becoming faint or dizzy.
    - B. An analysis of the percentage of oxygen in the 5-liter bag.
    - C. A careful estimate of the quality and rapidity of the pulse during the time that the individual is breathing in and out of the Flack bag.
2. The examination of the pulse before and after graded exercises.
3. The turning test, in the turning-chair, to determine the stability of the ear mechanism, including the internal ears and the intracranial pathways from the ears.

By means of these tests, the examiner is able to give an intelligent opinion as to the disposition of the pilot; he thus can recommend that he should be sent to his home in England on a vacation, or be sent to England to one of the training schools to act as instructor to cadets, or kept in the hospital for a short time for observation, or be sent at once to the front.

Maj. James L. Birley, Royal Army Medical Corps, Maj. G. Dreyer, Royal Army Medical Corps, and Capt. Dudley Corbett, Royal Army Medical Corps, are responsible for the development of all this work at the British Front. The idea originated with Maj. Birley, and he has by his own personal initiative created this special service. The fliers who are incapacitated for one reason or another are sent to Maj. Birley and Capt. Corbett for study. After such study they make recommendations as to the disposition of each individual pilot or observer.

The following was written by Maj. James L. Birley, Royal Army Medical Corps, for our information:

GENERAL ADMINISTRATION MEDICAL SERVICES ATTACHED TO ROYAL FLYING CORPS.

All medical officers attached to the Royal Flying Corps hold commissions in the Royal Army Medical Corps and come under the general administration of the Army Medical Service, both at home and in the field.

All medical officers attached to the flying services act in an advisory capacity only. For example, there is a Medical Research Committee sitting in London which advises the heads of department of the flying services direct, and does not act through the administrative head of the Medical Department of the Air Service, as with us no such administrative head exists in the field. I really correspond to the Medical Research Committee at home, and give my advice to the General Officer Commanding in the Field direct.

As regards administrative authority I act through the Director General Medical Service in France, but I am allowed considerable freedom in this respect as a matter of courtesy.

The Flying Corps in the Field is organized as follows:

Brigades.

Corps (Artillery) Wing, 3 to 6 squadrons.	Army Wing, 3 to 12 squadrons.	Balloon Wing, 4 to 14 balloon sections.

Each squadron consists of 18 to 21 machines. There is one Brigade to each Army, and in addition there are two Wings not attached to Armies, which come under the direct orders as regards operations of the General Officer Commanding, Royal Flying Corps.

One medical officer is attached to each Brigade and in a few cases to each Wing, excluding the Balloon Wing.

He is responsible to the Director Medical Services of his Army for sanitation, etc. His special duty is to study the flying man, and in this respect he is guided by me. Acting under the authority of the Director General Medical Services, I give orders to the Brigade and Wing medical officers for the disposal of all flying officers who are suffering from any of the special disorders of flying, such as to render them unfit for active service flying. Within limits no flying officer is allowed to go sick to hospital without first being seen by his Brigade or Wing medical officers.

The Brigade medical officers are supplied with a little special equipment (sphygmomanometer, aural specula, eustachian catheter, etc.).

He is responsible for seeing that the medical orderly attached to each squadron is capable of dealing with any ordinary emergency.

The morning sick of squadrons and balloons are dealt with by neighboring medical units.

Ordinary medical equipment is supplied through the Director Medical Service of the Army concerned, such as drugs, dressings, splints, etc.

I am trying to get one medical officer per Wing recognized as the proper establishment, but at present suitable medical officers are scarce. With only one medical officer per Brigade, it is quite impossible for him to get to know personally all the flying officers in his Brigade, and this constitutes a serious disadvantage.

Since the beginning of October a ward at Twenty-fourth General Hospital, at ———, has been put at the disposal of the Royal Flying Corps for the reception of cases suffering from the special disorders of flying. Officers are sent down there with a Field Medical Card, filled in by the Brigade medical officers, and the beds are very ably looked after by Capt. Dudley Corbett, M. D.

MAIN PRINCIPLES GOVERNING THE MEDICAL SERVICE ATTACHED TO THE ROYAL FLYING CORPS, AND METHODS BY WHICH WE TRY TO CARRY THEM OUT.

1. Systematic medical examination of all candidates for flying officers.
2. Medical history of every flying officer from the day he joins, compiled by medical officers attached to the Royal Flying Corps.
3. Selection of candidates for particular types of work.
4. The care of flying officers in the air and on the ground.
5. Scientific research.

Of these (1) is being systematically carried out at home.

(2) This is being partially done by sending all flying officers suffering from the special disorders of flying to the special ward at Twenty-fourth General Hospital. From here, if they are temporarily unfit for service flying, they are evacuated to the Central Royal Flying Corps Hospital, in England. A record in duplicate is kept of every officer admitted to the Twenty-fourth General Hospital, and one copy goes with him to England.

Every candidate's medical state is filed at home and can be referred to by me when occasion arises.

Ordinary sick and wounded are sent to the nearest miltary hospital. Those who have to be evacuated to England are sent to the Central Royal Flying Corps Hospital, and are never seen by me. If not sent to England, they are either returned (slight cases) direct from the field hosp'tal to their squadrons; otherwise they are treated at the base and then returned to one of our two base depots. Here they report to the medical officer in charge of the depot, and if marked "Fit" are posted to squadrons. If temporarily unfit, I am informed, it is arranged to have them sent to Twenty-fourth General Hospital for overhaul.

The arrangement of having flying men sent to our special ward at Twenty-fourth General Hospital, who are suffering from conditions the direct result of, or of particular importance as regards flying, and having ordinary sick and wounded on the other hand dealt with by the ordinary field and base hospitals, answers well, provided that cases returned from hospital in France are passed fit for flying before being posted, by a medical officer attached to the Royal Flying Corps; and (b) those who have to be sent to England are treated at the Central Hospital, where flying is specially understood. Both these provisos are in course of fulfillment. In the case of (a), if there is any doubt as to a man's fitness, he is sent to the special ward at Twenty-fourth General Hospital for investigation. From there we can send a man to England on three weeks' sick leave when occasion seems to demand it.

(3) This is being done at home, but to what extent I do not know.

(4) In France, I act as advisor in respect to clothing, protection against frostbite, oxygen, the periods of service and rest, etc.

Royal Flying Corps squadrons have a special allotment of leave which gives them 14 days in England about every three months. Pilots and observers generally go home (to rest, to act as instructors in the air, on the ground, etc.) after five or six months in fighting, long reconaissances and bombing squadrons, and after seven to nine months in artillery squadrons. It is impossible, and I think it would be very unwise to try, to lay down a law for everyone, not only because individuals vary, but also on account of the varying number of hours flown per month according to the state of the weather, activity on the front, etc. A good artillery pilot will get through, in rough figures, 350 to 450 hours, before he goes home; a good scout pilot 150 to 250 or 300 hours. As a general rule, not more than two "shows" over the lines are done by any one flying man per day. This in an artillery squadron would mean seven hours flying, in a single-seater fighter four hours, and in a two-seater fighter five hours, per day. Pilots doing long reconnaissance work, or long bomb raids, are very rarely called upon to do more than one flight a day, i. e., three to four hours; but with oxygen two flights can be and have been done, without ill effects.

It will thus be seen that our flying personnel is kept at it pretty hard. Casualties are always replaced within a few hours, and each squadron has an excess of two pilots over the number of machines.

It is one of the prime duties of a squadron commander to look out for tired pilots, and in this he is helped by the Brigade medical officer. The latter can always refer any case direct to the officer commanding the Brigade.

No medical officer can order a pilot to go home for a rest, but merely advises his brigadier, and things being as they are, I should be very sorry to have this practice changed. Such cases are frequently referred to me for decision, and I always make a point of consulting the squadron commander of the officer under discussion.

A Brigade medical officer can order any flying officer to hospital, and if he is suffering from fatigue, etc., he automatically goes to Twenty-fourth General Hospital, at once, where all such cases are seen by me. Until comparatively recently, it has been the practice to send tired pilots to England to the Home establishment without any medical supervision. I do not think this is sound, and we are now having increasing numbers of tired men sent to Twenty-fourth General Hospital, where we can give them a preliminary rest and overhaul, and form some idea of their fitness for the future.

As regards the health of flying officers in aerodromes, exercise is insisted on in the winter but not in the summer. No rules exist about tobacco or alcohol. There is no serious abuse of the latter, but the majority of pilots undoubtedly smoke far too much.

I am arranging lectures during the winter on "health," and shall talk about venereal disease. There is too much of this in the Flying Corps, but the trouble is that 90 per cent of it is caught on leave in England or in base ports when coming out to France. The General Officer Commanding has empowered us to do what I think best in this matter.

POOLS.

At each of our base depots is a pool of flying officers, where new pilots from England, and others discharged from hospital, await their turn to be posted, to fill up casualties.

These pools are not satisfactory, as it is impossible to provide suitable employment on the ground for any group of people whose prime duty is in the air, and whose numbers vary from day to day (e. g. from over 100 to 15). A new and inexperienced pilot from England who has to wait 10 days or a fortnight at the pool before being posted, and has probably absorbed in that time a good deal of morbid "shop," arrives at his new squadron with his tail down. The whole question has been taken up, and the practicability of turning the pools into schools of gunnery instruction on the ground is being considered as a satisfactory solution.

INEFFICIENT PILOTS AND OBSERVERS.

Our general policy as regards these is as follows:

Officers found permanently unfit for further flying on medical grounds, but fit for general service in the infantry or artillery, etc., are disposed of by the Personnel Branch at Headquarters, Royal Flying Corps. If an officer has done well as a flying officer, every effort is made to retain him in the Flying Corps on a ground job. If he has only been flying a short time and seems likely never to make an aviator, he is transferred to some other branch of the service.

An officer who is "technically" inefficient is not dealt with by the Medical Service. Those who are "temperamentally" unfit are generally referred by the Personnel Branch to me in order that they may have my views before making a decision.

Experience has taught me to group cases of loss of nerve in the air as follows:

(*a*) Loss of nerve for flying any machine—as far as my experience goes, this condition is nearly always permanent.

(*b*) Loss of nerve for "stunting"—this is usually temporary, and associated very often with symptoms of vertigo, etc.; of recent origin. In some cases, however, it has been present from the start and has been thoroughly suppressed. I intend recommending such cases as pilots on heavy and stable bombing machines; for example, the Handley-Page.

(*c*) Loss of nerve for fighting in the air—this may be temporary or permanent, according to the degree of fatigue.

(*d*) Loss of nerve for anti-aircraft shells—this seems to be more generally permanent than otherwise. An officer who has been blown up by a shell or bomb on the ground and has had physical or mental manifestations as an immediate result (so-called "shell shock"), is in my opinion almost invariably mentally incapable of facing anti-aircraft fire.

(*e*) Loss of nerve due to crashes—in a very large majority there is a history of concussion at the time of the crash, and I never commit myself to an optimistic prognosis in these cases. The presence of fatigue is very often associated in the case of a good pilot with some change in his behavior in the air, etc.

The most frequent symptom is stunting near the ground. Pilots have often told me that they do this to try and convince themselves that they are as confident as ever.

I do not think it is necessary for me to refer to symptoms, such as unsociability, loss of weight, lack of physical and mental energy, bad dreams, insomnia, low blood pressure with an increase above the normal of the pulse pressure, as you have seen all these cases at Twenty-fourth General Hospital.

WORK AT TWENTY-FOURTH GENERAL HOSPITAL.

In addition to the lines of investigation which you saw, we hope in the near future to get written records of pulse, respiration, and blood pressure during the test with Flack's bag. This will give a clearer indication of how a man reacts to lack of oxygen, and can be obtained, by merely recording the percentage of oxygen at which symptoms of syncope supervene.

Capt. Corbett has already begun to make systematic Hæmoglobin estimations, both at rest and during the bag test. I hope shortly to obtain the assistance of Capt. H. C. Basett at Twenty-fourth General Hospital, as the work is rapidly becoming too heavy for one man. This officer is well known to Dr. Coile, as he visited the station when holding the Oxford Radcliffe Traveling Research Fellowship, and has for some months been conducting researches on shock in cases of gun-shot wounds.

I also hope to see Mr. Sydney Scott installed there shortly to undertake the otological work on a comprehensive scale. I feel very strongly that we should be possessed at -------------- of the proper methods of investigation to enable us to state whether a man is fit for service flying or not; and, if unfit, whether temporarily or permanently. I do not consider that we are justified in embarking on any elaborate or theoretical methods of research, as it seems to me that this is better done in England and, I am glad to be able to add, America.

THE USE OF OXYGEN IN THE AIR.

The report written by me on the effects of high flying at high altitudes, dated March 27, 1917, still holds good in the main, and there is no doubt that flying above 10,000 feet is more tiring than flying below that height.

Three D. H. 4 squadrons are now completely equipped with oxygen apparatus, and use it as a routine in spite of the extra weight entailed and various drawbacks with regard to the present type of mask.

I do not propose "pushing" oxygen until the improved masks and light cylinders are in this country in large quantities, as an unnecessary weight and uncomfortable mask only prejudice pilots against oxygen. In fact, the whole question of popularizing oxygen depends on the recognition of the necessity of providing the individual with an apparatus which he prefers to use than to do without. And in this connection too much stress can not be laid on the mask, because here we are right up against the individual, and the wide use of oxygen resolves itself in the end into the provision of a comfortable mask which pilots will use.

It has been found that it is essential for the observer to be able to disconnect himself from his regulator, otherwise the tubing between mask and regulator interferes with his movements, the mask is pulled off, and probably never replaced.

We, therefore, intend in future to have a standard length (3 or 4 feet) of tubing attached to the mask, both for pilot and observer. By means of a bayonet screw joint this is connected with the tubing from the oxygen outlet of the regulator. When the aviator wishes to disconnect, he has only to take hold of the joint, give it a half turn and pull; he will then be left with a small length of tubing attached to his mask, not long enough to get in his way, and the distal end of the other length of tubing will be fixed to the side of the machine handy for reconnection when required. In this way the mask is retained on the face, a point of practical importance. For individuals who particularly dislike any form of mask, the Flack rigid mask will be provided, hung up in any convenient position, and when oxygen is needed the observer merely holds it over his face.

Our aim is to provide pilots, who do not move about, with a continuous supply from the automatic Dreyer regulator, and observers with an intermittent supply, either from the same regulator or from the Siebe-Gorman Mark II, giving them the mask which they individually prefer.

We shall shortly have three masks available:

1. The improved Dreyer.
2. The rigid Flack.
3. The combined helmet and mask in which can be incorporated, where necessary, the wireless microphone.

Pilots and observers are advised to put on the mask before starting.

The following weights may be useful:

		Type of regulator.	Cylinder with valve.	Duration of supply at 2 liters per minute per person.
1. Scout	Pilot	Dreyer (5 lbs.)	(300 L) 5 lbs.	2½ hours.
2. Two-seater fighter	Pilot Observer	Dreyer (5 lbs.)	(500 L) 7 lbs.	2½ hours. 1¼ hours.
3. D. H.-4	Pilot Observer	Dreyer (5 lbs.)	(500 L) 7 lbs.	1 hours. 1 hours.
4. Long bomber	Pilot Observer	S. G. Mark II (4 lbs.). S. G. Mark II (4 lbs.).	2 (500 L each) 14 lbs. 2 (500 L each) 14 lbs.	8 hours. 4 hours each.

England is being asked to send the following samples, addressed to general secretary, United States Army Aviation, 119 D Street, N. E., Washington, D. C.:

Light oxygen cylinder with valve containing 500 liters filled at 150 atmospheres.

Combined oxygen and telephone mask and helmet.

Improved Dreyer mask.

Black mask.

Set of connections for using one Dreyer regulator, two cylinders and two persons.

Mark I goggles.

Mark II Siebe-Gorman regulator with connections, including mask.

I am also writing to Capts. C. P. Heald and Martin Flack reference your proposed visit to England.

JAMES L. BIRLEY,
Major, R. A. M. C. Headquarters, Royal Flying Corps.

DECEMBER 20, 1917.

For your information, we are also including the following article written at the Front by Maj. James L. Birley on March 27, 1917:

MEMORANDUM ON THE EFFECTS OF HIGH FLYING UNDER ACTIVE SERVICE CONDITIONS.

PRELIMINARY.

This report is based on my own observations, as well as on the reports which have been furnished by medical officers attached to Brigades.

It should be clearly understood that in the period covered by this report there has been only a limited number of squadrons in which routine work is carried out at heights as great as 13,000 to 14,000 feet, and a still smaller number at heights greater than these. In no case is work done above 18,000 feet, and no squadron which works systematically at or above 15,000 feet has been out longer than three months.

The effects of high altitude vary enormously in different individuals, and no symptoms or group of symptoms are universal. A minority of flying officers profess a total ignorance of any symptoms whatever, while others experience them only after they have carried out several flights at high altitudes. In this connection, it must be remembered that the necessity of attention to the technical and other duties of a flight may in itself suffice to divert an officer's notice from physical symptoms, unless the latter became imperative.

Other factors which make for a lack of uniformity in the effects observed are (1) meteorological conditions, (2) different types of machines, and (3) varying states of physical fitness. These will be referred to more fully in subsequent sections.

SYMPTOMS OF HIGH FLYING.

1. *Relatively constant.*—(1) During the flight (in order of frequency):

(*a*) Shortage of breath (dyspnoes): This is extremely common, but it varies in degree. Very few pilots breathe through the nose above 12,000 feet. When dyspnoes is experienced, its intensity varies directly with the altitude. It is usually noticed at about 15,000 feet, and the character of the breathing is generally described as "gasping" or "panting." It is exaggerated by muscular exertion, such as using the pressure pump, and is more noticeable in cold weather and cold machines than in warm. Pilots look upon this shortness of breath as something very ordinary, and are not in the least alarmed by it.

N. B.—It is interesting to note that the Sopwith scout, which is an admittedly warm machine, has done more high flying in France than any other one type. The officer in command of a Sopwith Squadron, which has been working at 15,000 to 16,000 feet for three months, categorically denies that his pilots suffer any inconvenience from high flying (vide infra, however).

(*b*) Aural symptoms—tinnitus, deafness, giddiness: These occur with any rapid change of altitude, but they are exaggerated among high-flying pilots. Slow descent ameliorates but does not entirely abolish the condition.

(*c*) Paraesthesis—chiefly of the extremities; e. g., the hands, feel "like cotton wool and all numb." Sometimes there is a sensation "as if the whole body were swelling."

(2) After landing:

Fatigue: This is the commonest of all symptoms. It should be noted that a long flight at any altitude is apt to be associated with after-fatigue, and that machines which fly high are, generally speaking, longer in the air than those which fly low. Nevertheless, it is quite certainly the case that flying at heights over 11,000 to 12,000 feet accentuates the condition, and that the greater the height the more lasting is the sense of tiredness. Less often it is felt in the air, as a general feeling of loss of energy and strength. On landing there is a sense of lassitude and sleepiness, and some pilots make a point of lying down and going to sleep. The opinion is generally held amongst flying officers that this fatigue is temporary and has no bad after effects.

2. *Relatively inconstant.*—

N. B.—It is difficult to group these symptoms in order of frequency, but an attempt has been made.

(1) During the flight:

(*a*) Faintness and dizziness: It is not always possible to attribute these conditions to altitude. A feeling of faintness has occurred in a few cases at and above 17,000 feet; several pilots at lower altitudes have "queer" feelings and dizziness.

The following cases are of interest:

An N. C. O. pilot had been flying at home up to 8,000 feet without experiencing any symptoms whatever. One day, in France, he reached 12,000 feet and at once felt faint, sick, and breathless. He managed to descend, and at 5,000 feet recovered completely. On landing, he suffered from pains in the head which lasted an hour or two. On examination, the apex beat was internal to the nipple line, and the area of cardiac dullness not increased. The pulse rate was 100, and was easily raised by slight exertion, and there was a faint spical systolic murmur, not conducted.

An officer extremely fond of flying, during the cold weather, suddenly felt faint and giddy one day at 10,000 feet. The machine was landed by the observer. The pilot had to be assisted out of the machine and then slept for a long time, to wake up with a splitting headache. Physical examination revealed nothing, and his physique was well above the average. Not long after this, in warmer weather, he fainted at 12,000 feet. He had never noticed shortness of breath in the air. This officer is now doing well in a Corps Squadron.

Two other pilots, both of poor physique and slight build, feel faint and dizzy, one at 9,000 feet; the other at 12,000 feet. The former has cardiac irritability, and has already been sent home to be boarded.

(*b*) Nausea and vomiting: This is rare below 15,000 feet, but has occurred in several officers above this height. Most R. N. A. S. pilots think that the exhaust fumes are largely responsible.

(*c*) Pains in one or both ears: This persists for a few hours. In one case this was associated with labyrinthine deafness; in the other there was no evidence of ear disease, and the condition was improved by regular Politzeration or catheterization of the Eustachian tube.

(*d*) Frontal headache: Often sudden in onset and lasting for a short time after landing. One pilot has it at 12,000 feet; another at 15,000 feet.

(*e*) Intense desire to micturate and parched mouth: These usually go together and occur in spite of the bladder being emptied just before leaving the ground. On landing after a high flight a large quantity of urine is sometimes passed.

(*f*) Physical fatigue: During a high flight "one requires to be pulling oneself together continually."

(*g*) Diminished sense of stability: Several pilots do not care to bank near the ground on descending from above 10,000 feet, as they are not so certain of that sense of balance which is an essential attribute of flying; there is some evidence which points to a greater frequency of bad landings after high flyings than low ones.

(2) After landing:

(*a*) Frontal headache.

(*b*) Pain in ears.

(*c*) Palpitations of brief duration.

(*d*) Trembling of hands.

SIGNIFICANCE OF SYMPTOMS.

The symptoms are divisible into two groups:

(1) Those depending on the fall of oxygen pressure.

This group comprises probably all the above with the exception of ear symptoms, paræsthesis, and in some cases headache.

Severe cold undoubtedly intensifies the dyspnea, a fact which perhaps may be partly explained by a constriction of the alveolar vessels. Fatigue is also increased by cold.

Tremors, altered sense of stability, muscular and mental fatigue must be ascribed to deficient oxygenation, resulting in relative cerebral anemia.

The dryness of mucuous membranes and rapid filling of the bladder are interesting, in view of the supposition that oligaemia, or diminution of the blood volume at the expense of the plasma, plays a prominent rôle in the reaction of the organism to sudden and gross changes in altitude.

(2) Those depending on the fall of atmospheric pressure.

The diminution of pressure on the body surface has, so far as I am aware, received but scant attention. The subjective sensations in the lines may be reasonably ascribed to this factor.

Both headache and aural symptoms are exaggerated by catarrhal conditions of the nose and throat. In some cases the former have been very severe. Unilateral earache is not uncommon; the origin and prevention awaits discovery.

REMOTE EFFECTS OF CONTINUED HIGH FLYING.

1. *Physical.*—(*a*) Blood: Five pilots who had flown at or above 15,000 feet for some months and had occasionally reached 18,000 feet, also five pilots who had averaged 11,000 feet for five months and had repeatedly been up to 15,000 feet, together with controls (Maj. Dreyer and myself), were examined in January.

All 12 individuals showed a normal number of red cells, hemoglobi percentage, and color index, except 2 pilots, who were slightly anemic.

(*b*) Emphysema: A great many high-flying pilots present evidence of this condition, as shown by the percussion note, together with diminution or even obliteration of the normal area of cardiac dullness.

(*c*) Cardio-vascular system: In several pilots the apex beat has been found to be in the left nipple line, and in one case one-half inch external.

Several officers, including two very experienced pilots, have premature beats at regular intervals. They are wholly unaware of this peculiarity, and I regard the condition with equanimity.

Cardiac irritability constitutes an absolute bar to, and is certainly aggravated by, high flying. As to whether this condition is caused de novo by high flying, it is yet too early to make a positive statement, but there is evidence that such is the case.

2. *General.*—Vide under "General conclusions."

ACCLIMATION.

Three pilots have definitely stated that this has occurred in their own cases, so that shortness of breath was postponed until greater altitudes were reached, e. g., 15,000 feet instead of 12,000; in two cases, 18,000 feet instead of 15,000 feet in the other. All these pilots were definitely emphysematous; one has been missing for two months, and there is reasonable ground for supposing that he fainted in the air and never recovered control.

In my opinion, acclimation in the air does not occur to a sufficient extent or with sufficient rapidity as to render it of any practical utility, and I hold the same view, though more strongly, with regard to artificial acclimatization on the ground.

GENERAL CONCLUSIONS.

Several commanding officers in the field do not anticipate any widespread physical disturbances as a result of high flying, such as scientific knowledge would lead us to expect. Others, on the other hand, fully realize the difficulties ahead. Moreover, in one squadron in which ill effects were stoutly denied, two officers have already been seen whose condition is clearly attributable to altitude.

It should also be noted that at present no squadron flying at the greater altitudes is working at full pressure; i. e., there are many "off" days, and never more than one flight in any day. Further, the newer types of machines are likely to be faster climbers, and as far as evidence is at present available, rate of climb and physical effects are directly related.

That an individual who is tired or in a poor state of health is more susceptible than one who is fresh and fit, is a fact which can be corroborated almost daily.

No exact data are available for estimating the effects of tobacco, alcohol, or lack of exercise, and I feel this aspect of the question is so complex and so intimately bound up with the personal equation, that its treatment calls for the greatest care and prudence.

Finally, I believe one is justified in concluding that flying at high altitudes (over 15,000 feet) entails additional strain, which will eventually result in a shorter average term of efficiency per pilot; that routine flying above 18,000 feet without artificial aid in a large majority of individuals is not a practical proposition; and that wide benefits are likely to accrue from the adoption of a suitable oxygen apparatus.

James L. Birley,
Major, R. A. M. C., M. O. i/c Headquarters, R. F. C.

In the field, *March 27, 1918.*

We are also including the following article written by Capt. Dudley Corbett, Royal Army Medical Corps, on August 3, 1917:

FLYING FATIGUE AND EFFICIENCY.

[By Capt. Dudley Corbett, Royal Army Medical Corps, attached to Royal Flying Corps.]

It need hardly be re-stated that the essential aim of the medical service of any branch of the Army is the maintenance of fighting efficiency. These notes, the result of eight months experience with the Royal Flying Corps in the Field, have been written solely with this aim in view. The various factors leading to what is here termed Flying Fatigue are by no means generally understood by those to whom such information would be valuable, so that an attempt is here made to explain the whole question in non-medical language. At the same time certain suggestions are put forward as ideals to be aimed at without going into details as to whether they are immediately practicable.

THE SELECTION OF PERSONNEL.

Much has already been done toward the more efficient and economic use of personnel, but it is suggested that even now there is a considerable waste of time and money in training pilots who prove either entirely unsuitable for the Royal Flying Corps in any capacity, or at least unsuited for the work to which they have been posted.

It seems that this is to a certain extent due to an insufficient appreciation of the value of close cooperation between the medical service and those in charge of personnel, or, in other words, that full use is not at present being made of scientific medicine when selecting pilots.

Given general physical fitness, it is impossible to lay down any rules by which one may detect the type of individual who will make a first-class pilot under service conditions, unless one makes use of special methods of examination. One finds first-class fighting pilots among all sorts and conditions of men, in the thin weedy nervous type as well as in the sturdy and robust, so that it may be safely said that physical appearance is a fallacious guide.

Instead of one Royal Army Medical Corps officer, the candidate should be examined by a standing Medical Board, one of whom should possess previous experience with the Royal Flying Corps in the Field. In order to cope with the work there could be a number of such boards at given centers throughout the country, such as one for each command.

If the candidate is found generally fit, this body should arrange for him to undergo certain physiological tests to determine whether he is likely to suffer from dizziness or sickness, and, further, to what height he should be able to fly without experiencing symptoms of oxygen starvation. His reaction time to visual, auditory tactile impressions could be taken in order to test the general alertness of mind and body. Such tests have been devised and are being perfected, and their employment, though not a necessity, would be of great value. The results of all these investigations could be tabulated, so that in the end the authorities would possess information enabling them to make the best possible use of the material at their command.

Records of the examination could be kept, so that when at some future date the officer had to go before the Board again by reason of fatigue or other disability comparisons could be made and much useful knowledge and experience gained.

It might be asked, Is all this trouble worth while? The medical view is that greater efficiency would be secured if some such scheme could be made practicable, and that in making these suggestions one is considering the future and the inevitable expansion of the flying services.

It is true that the research branch of the Medical Service to the Royal Flying Corps is still in its infancy and that we have a great deal to learn, but that is only an argument for its expansion and greater appreciation.

At present one occasionally finds pilots posted at a squadron who from some physical defects are quite unfitted for the Royal Flying Corps under active service conditions, others who feel sick and dizzy when banking, and others who are persistently sick after an hour or so in the air.

Their tuition and training does not disclose these failings beforehand. Again, a pilot is sent to a Scout Squadron who fly regularly at 12,000 feet to 15,000 feet or more, and it is found that he faints at 15,000 feet. On inquiring into his history one discovers that he has never previously been above 7,000 feet when training at home. His life and the value of the machine have beeen risked unnecessarily. It should be possible on medical grounds alone to eliminate or so distribute such cases that services are utilized to the best advantage. The sickness and dizziness could perhaps only be discovered during the training period, but tests for determining the candidate's capacity to endure high altitudes should be carried out during the preliminary medical examination.

FLYING FATIGUE.

Fatigue as ordinarily understood is the result of continued hard work without adequate rest. Considered from this point of view alone it might well be understood that active service flying would eventually lead to some fatigue. The strain of flying during the summer months when operations are in progress is intense, although the total number of hours worked may not be great, yet there is the strain and the excitement of fighting, the tension of standing by, and the short and irregular hours of sleep. There are no fixed days or periods of rest, no days when a fellow can say to himself " to-day I am free," no matter what the weather is. Nevertheless, these circumstances alone are not sufficient to account for the symptoms found when a pilot gets tired after three or four months' service. In respect to hard work, discomfort, and lack of rest, the infantryman is more highly tried than the airman, who has a comfortable camp and mess to return to when the day's work is done. The explanation of flying fatigue must be sought in the fact that flying takes a man into an element for which he was not specially designed by nature. His sense of equilibration and the mechanism by which he appreciates his position in space are severely tried, with the result that those who are less adaptable to their environment than others suffer from giddiness and sickness. He is rapidly subjected to varying changes of atmospheric pressure and temperature. Further, he spends a certain number of hours each day in breathing air deprived of its proper proportion of oxygen. It will be shown later that this fact is probably one of the most important causes of flying fatigue.

FATIGUE AND NERVES.

A tired pilot is commonly supposed to have "nerves." As a general statement of fact this is quite erroneous, and it is consequently extremely unfortunate that the word "nerves" should ever have crept into popular talk in connection with flying. It is frequently, but by no means always true, that he is nervous in the sense of being afraid of things which previously did not affect him in the least. Still his nervousness is only a symptom of fatigue, he is suffering no more from "nerves" than a patient with pneumonia is suffering from cough. This use of the word "nerves" leads to a confusion between nervousness due to fatigue and that due to temperament, a state of affairs that is most undesirable. Also there should be a distinction between both these forms of nervousness and that which may follow a crash where the pilot or observer has been badly shaken or slightly concussed. In short, a man may suffer from fatigue with no symptoms of nervousness, or he may suffer from nervousness without being fatigued. It is true that in all cases where nervousness is a symptom the result is the same, namely, the exhaustion of whatever store of nervous energy was originally possessed by the individual; still it is desirable that there should be no confusion as to the cause of the nervousness in any given instance.

We are dealing here with nervousness only as it is a symptom of fatigue, and as one symptom out of many. Still, before we leave the subject, it is desirable to emphasize the importance of the effect of slight concussion upon the production of the train of symptoms known popularly as "nerves." A man may have had a bad crash and be much shaken, yet he will be fit to fly in a day or two provided there have been no symptoms of concussion. If, as the result of the crash, he has lost consciousness even for a few seconds, if his memory is subsequently a blank as to events just before or after the crash, if his manner has been strange directly afterwards, then it may safely be said that he has had concussion. If, in addition to any or all of these symptoms, there is evidence of a blow on the head, the diagnosis is complete.

Unless he gets adequate rest at once, he will lose all confidence in flying and become nervous, shaky, and apprehensive.

A man who has once suffered from concussion and temporarily rendered fit by a short period of rest, will be liable at any time during his flying career to a nervous breakdown. Flying fatigue has no connection with this form of nervousness except so far as the strain of flying unmasks an already existing instability or sensitiveness of the nervous system, due to previous concussion.

SIGNS OF FLYING FATIGUE.

(1) *Subjective.*—A man first notices that he is beginning to feel generally tired, and that he has lost some of his original keenness. His sleep does not refresh him. He gets occasional headaches. Later he does not get off to sleep quite so well as he did, or he may get off fairly soon, and yet wake up early in the morning. He may lose his appetite. His digestion may trouble him, and constipation is common in such cases. His sleep may be troubled with dreams of flying and fighting, and nightmares of all kinds. He may notice

that he is getting irritable and that he can not stand the society of his friends "en masse," but prefers to go off by himself and read. He probably feels quite fit and keen when in the air, but has to force himself to go up. After landing he may be shaky and feel utterly exhausted. He may be conscious of his heart beating, may awake at night with palpitation, and if he does he will find that he gets very short of breath on exertion. He may get sick in the air for the first time in his life.

Although he feels tired, yet fits of restlessness overcome him; he can not sit down quietly to read and write, but must need to be pottering about the aerodrome. He may reach that stage where he can not bear to see a machine or listen to ordinary flying talk.

Sooner or later he must give in. The more stout-hearted he is the longer he disregards nature's danger signals. He is not inclined to talk about his sensations. Any such thing is suggestive of " wind up," a state which he quite abhors. To keep himself going he may rely on alcohol, although this tendency is rare, but he nearly always smokes too much for which no one can blame him. He may cease to take trouble about his flying and fighting tactics. Tired pilots have confessed to me that they have got into a frame of mind when, if they meet any enemy machine, they feel that they must either turn tail or go for it recklessly; they can not trouble to think about maneuvering.

I am not sure that many good pilots have not met their end from sheer carelessness. They become too tired to think. All these symptoms may come on gradually, or the complete state of fatigue may be precipitated by a bad crash.

(2) *Objective signs.*—What then is found on examination in such cases? To the experienced medical officer the signs are unmistakable, but they are varied, depending on which main system of the body has suffered most under the strain. One group may predominate or all may be present in a varying degree.

(*a*) In almost every case of fatigue there is an accentuation of the normal heart beat. In a really healthy person at rest this should be 70 to 80 beats a minute, and there should be little difference between the rate when he is sitting down and that when he is standing up. On the other hand, with the tired pilot, the pulse rate at rest is frequently 100 a minute, which rises to 120 a minute when he stands up. In severe cases the ratio may be 110 to 130 or more. The exercise of touching the toes six times produces an even greater rise of rate in all such cases.

As to the cause and meaning of this condition we are at present uncertain. It is similar to that which is found among the infantry and is described as " soldier's heart," which is one of the symptoms of prolonged strain, but we do not know at present whether it is due to the same cause. At any rate, it is fairly certain that the heart itself is not diseased in any way, and that no permanent damage will ensue.

It must, however, be obvious to anyone, that if the slight exercise of standing up from a sitting position produces a marked rise in pulse rate, the strain and excitement of active service flying must, when the pilot is in the air, produce a similar if not greater rise of rate, leading to faintness and giddiness.

A pilot in this state not only can not possibly be as alert and efficient as one who is fresh, but also, there is the danger of his killing himself or his observer by bad landings.

This abnormal and sensitive pulse rate is, in my experience, the most common sign of fatigue. There are, however, others which frequently accompany it, but it may exist alone.

(*b*) Sometimes the digestive system suffers, and one finds a dirty furred tongue, which does not clean with ordinary remedies, and the patient complains of indigestion and abdominal pain.

(*c*) Occasionally the eyesight fails, the vision becomes hazy, and the pilot complains that he can not see the ground clearly to land, and has difficulty in picking out enemy machines. There may be no direct defect of vision at all, but more frequently there is some slight error which he was previously able to correct by the unconscious muscular power of the eye. The muscle gets tired with the strain, and the defect shows itself. A few days' rest has been sufficient, in the few cases I have seen, to restore normal vision once more.

(*d*) Finally, what evidence does the medical officer find of "nerves?" The subjective sensations, the nervousness, the iritability, and so forth, have already been described. Some patients talk freely on the subject, while from others the information can be obtained by judicious questioning. The objective signs are simple, a tremor of the hands and of the tongue when protruded, and what is known in medical language as "an exaggeration of the deep reflexes." Normally, when the tendon of a muscle is smartly tapped, the muscle will respond by contracting. If there is any interference with the nerve supply to the muscle, it will not contract at all, while, if the nervous system generally is in an irritable state, the contraction will be much quicker and fuller than normal.

One does not, by any means, always find these signs in pilots who are suffering only from fatigue. If they have had some severe nervous shock, such as a bad crash, or have been shot about, then all or any of them may be expected. If there has been no severe nervous shock, nervousness is one of the late symptoms of fatigue, and it should be our object to see that the tired pilot never reaches the stage of "nerves" because he will probably take the longer to recover.

OXYGEN STARVATION.

What evidence have we at present that "oxygen starvation" plays any part in fatigue? Two facts can be briefly mentioned here. It is now well recognized that pilots and observers of long distance high-flying machines, such as the D. H. 4, feel extremely tired and exhausted, not only after landing, but also during the following day in some cases, unless they have been provided with oxygen.

Secondly, experiments have been carried out to test the effect of altitude on mental concentration. An individual used to the air is tested on the ground with an apparatus for measuring his reaction time, a kind of scientific game of "snap." He is then taken up to 5,000 feet only and brought down again. On landing, he is again tested, and it is found that his reaction time is distinctly slowed down, and his mind is not so alert as it was before.

Those who have ascended to great heights in balloons have recorded how their senses have become almost paralyzed, and they have had to make the most intense effort to take the necessary steps to come down.

It is probable then that further research will definitely prove oxygen starvation plays a considerable part in the causation of flying fatigue.

Those who live permanently at high altitudes gradually get used to the rarified air, their blood undergoing certain compensatory changes. It has been proved that no such change takes place in the blood of a high-flying pilot.

It is worth noting, however, that there are some people who are very little affected by heights which will render the average person quite uncomfortable. They can go to 15,000 or even to 18,000 feet and do not experience any of the usual sensations, nor do they feel anything like so tired afterwards.

The reason for this is still obscure. but it has something to do with the efficiency of the lungs. There is a simple means of testing this efficiency, namely, to see how one can hold one's breath. Two or three deep breaths are taken in and out; the lungs are then filled to their utmost capacity and the breath is held for as long as possible. Forty-five seconds is a minimum time; anything less than this means that the individual will not be able to stand hard work in the air, even at moderate altitudes; the longer he can hold his breath the better will he be able to stand high altitudes without fatigue and distress.

There are more accurate methods than this rough test, but it is nevertheless a reliable guide.

FATIGUE AND EFFICIENCY.

Before putting forward suggestions as to the remedy for these troubles, a brief allusion to the relations between work, fatigue, and efficiency may be made. Reasons will be given as to why it would be true economy to take all possible steps to prevent fatigue, and why this would result in greater efficiency.

It has been proved over and over again in industrial life that continuous hard work without adequate rest tends in the long run to lower the quality of the work turned out. This was seen in the earlier days of the war when the munition factories worked overtime and on Sundays. In a fuse factory, for instance, the gross output was increased with overtime and Sunday work, but so much had to be scrapped owing to bad workmanship that the net output of perfect fuses diminished after a week or two but rose again as soon as Sunday work was abolished.

It must be remembered that the general level of efficiency of any group of workers depends not on a few brilliant and tireless performers, but upon the average individuals of the group. So also must be the case in a Flying Corps Squadron. The pace must be set by the capacities of the average member. This will not prevent extra work being put in by those of stouter metal, but on medical grounds the average and inferior members should not be screwed up to the level of those who are specially gifted to stand strain and fatigue. If this is done it means that there is a constant wastage from fatigue, thereby preventing in many cases the average man from reaching that stage of experience attained by the tougher members of the squadron.

An illustration of the value of experience is provided by the monthly casualty lists of the Brigade. In the first six months of this year, the battle casualties among pilots and observers during the first two months of service were 53 per cent, the lowest ratio being 43 per cent and the highest 81 per cent.

It should, therefore, be the object of those concerned with personnel that the experienced individual is not wasted by the premature onset of fatigue, premature in the sense of its being preventable. The conditions at present tend to cause overwork among the more experienced members of the squadron. First because there is insufficient care in the medical selection of new pilots. A new pilot is posted who is really unfit for the work, several days may elapse before the fact is obvious, and several more are wasted before he is replaced owing to the necessary inquiries and formalities. Again, a similar result is effected by the falling out from fatigue of those who can not keep up with the pace set. Finally, in his turn, the tough and experienced man gives in.

It is not denied that whatever is done, something of the kind is bound to happen eventually, but it is suggested that the onset of fatigue could be postponed by appropriate measures and that a squadron would thereby gain a greater accumulation of experience, and a greater output of good work would result.

THE REMEDY.

In order to delay the onset of fatigue, there should be either more rest or less work, and oxygen should be in general use for all.

My own opinion is that there would be no necessity to cut down the work if everyone could be certain of a complete day of rest at stated intervals, no matter what the weather was. Then, particularly if any such scheme is impracticable, there should be a Flying Corps rest station similar to the existing corps rest stations. It should be situated well back some 10 miles or so from the aerodromes in some quiet and pleasant spot. Here could be sent those who could reasonably be expected to return to duty within 10 days, no matter from what they were suffering. It would receive those who are suffering from a slight shock as the result of a crash, those with some minor ailment, as well as those who are beginning to feel the effects of fatigue early in their period of service, owing to some particularly strenuous time of overwork.

The recuperative powers of the young are remarkable, so long as the period of strain and exhaustion has not been too long. A child will recover from a short acute illness far better than from a long period of ill health; so also a young pilot subjected to a short period of severe strain may be apparently exhausted, but will rapidly recover with a few days' rest on the ground.

Whatever he is suffering from, it is better for him to be sent right away from the life and noise of the aerodrome; he will return the fresher and the more fit for work. It is true that in slack time he can go to a clearing station and rest, but in busy times he can not be kept there and must be evacuated to make room for others.

SUMMARY AND CONCLUSIONS.

Flying fatigue is a special form of fatigue which is due to the strain of service upon an individual whose powers of endurance are weakened by his having to spend so many hours each day in an atmosphere lacking in oxygen and by the severe strain of fighting or observing. This means that at the time when his nervous system and his muscles are required to work most efficiently they are in reality working at a disadvantage because the blood which nourished them is deficient in oxygen. The result is fatigue which eventually shows itself by the various signs which have been described.

A crash, a severe shock, or slight concussion, may unmask existing fatigue and cause the nervous symptoms and signs to predominate. Otherwise it is not usual for the tired pilot to show any objective signs of "nerves" until he becomes tired indeed.

It is desirable that he should be given a rest before he reaches this stage, and it is suggested that in the early stage of fatigue a few days' complete rest away from the squadron might save an early breakdown.

The remedies for fatigue are more opportunities for rest and the more general use of oxygen.

It is proposed that the medical examination of candidates should be more strict, that no pilot should be posted to work for which he is unfitted by some physical defect or individual peculiarity, it being possible to tell whether anyone can stand high altitudes without ill effect. In this way greater economy and efficiency of personnel could be effected.

It is expected that the more general use of oxygen will do away with a great deal of the trouble experienced from early fatigue, and enable many to become efficient pilots and observers who would otherwise be unable to stand the strain.

Research and the opportunities for research, are both urgently needed for the investigation of this, and many other medical questions connected with flying.

DUDLEY CORBETT,
Lieut. R. A. M. C., Medical Officer i/c 5th Brigade,
Royal Flying Corps.

AUGUST 3, 1917.

A good deal of this is now quite crude; it is written only in the light of rough clinical observation, for the information of the lay and military mind.

DUDLEY CORBETT,
Capt., R. A. M. C.,
24th General Hospital.

DECEMBER 12, 1917.

The following letter was written by Maj. Birley on January 14, 1918:

We are trying to improve the Flack experiment. At present it is chiefly useful for discovering those very rare cases of men with apparently healthy hearts and lungs, who are nevertheless so sensitive to reduced oxygen pressure that they can not fly above 7,000 to 8,000 feet. It is quite clear that a study of the pulse during the experiment is going to give results of more importance than can be obtained be merely determining the percentage of oxygen at which a man begins to lose consciousness. In other words, we are trying to find out how a man reacts to diminished percentages of oxygen. The short period covered by the test in its present form, together with the fact that the amount of oxygen available is not under control, has led us to attempt something better. Dreyer is getting on to it, but the rough idea is to have an air space into which the subject breathes which can be filled with varying proportions of nitrogen or oxygen at the will of the experimenter. In this way we can prolong the experiment to any extent, vary the composition of the air, and in fact, have all the advantages of the exhaustation chamber minus the expense and unpleasantness of exposing one's self to low pressures. I am expecting Sydney Scott at the end of the month. Can you lend, give, or sell us one of your turning-chairs?"

Yours, sincerely,

JAMES L. BIRLEY,
Major, R. A. M. C.

The following report is from one of our officers:

I visited different squadron groups at the British Front and had the opportunity to talk intimately with many pilots and observers. The following incidents serve as an illustration of the life and activities of these young aviators:

I was sitting at mess with Major D. when a pilot entered and reported that he had just dropped bombs on the German trenches from the height of 500 feet. He had maneuvered the machine in such a way that there had occurred only a few shots through the aeroplane, and some queer missile had ripped through the back of the overcoat and coat of the observer, but had merely taken the skin off of the back of his neck. A few minutes later this observer appeared with a bandage about his neck. Both the pilot and observer then sat down for their lunch, and the incident was apparently forgotten as being merely a part of the day's work. It would be highly profitable to other officers of the Air Service as well as medical officers to become familiar with the actual life of the fliers at the front.

One can learn most in sitting round the fire at night in intimate conversation with these young men. Their extreme youth is striking; one observer, age about 18, had the face of a baby, and yet was known to be a courageous and efficient man, especially clever in manipulating a machine gun. These men were interested to hear about the ear as the organ of balance, and also enthusiastically approved the idea of our plan for the CARE OF THE FLIERS. They feel it would be a "wonderful thing" to have a high-grade, specially trained physician living among them, to whom they could go with the same freedom in which they were accustomed to go to their family physician at home. They volunteered the thought that many times when they were not feeling well they would never think of going to the commanding officer with their troubles for fear that he would think they were "swinging the load" (British slang for "malingering"). On the other hand, if they were with a medical officer whom they trusted and looked to for advice, they would not hesitate to tell their woes to him freely. These shrewd youngsters were able even among themselves to detect the beginning of a nervous breakdown in one of their fellow pilots. One aviator said "Do you see that chap over there; he is laboring under his present work; he has no idea himself that there is anything the matter with him or that he is working under special strain. He has been at it for three months, but I can tell that what used to be a spontaneous and enthusiastic work on his part has now become a downright labor which he has to force himself to carry out." It impressed me that if these medically untrained boys could analyze the physical state of their comrades how much better could this be done by an older "comrade," a medical adviser who was not only specially trained in the care of the flier, but, and very important, one who was selected for his personality and ability to "get under the skin" of these pilots and observers. Such a medical officer attached to squadron groups should fulfill the function of a friend to the flier as well as giving him scientific observation and care. It can be stated without reservation that such a person would become a powerful factor in lifting and maintaining the morale of these flying officers. This was heartily approved by them, and they said they were sorry that such a plan could not be carried out for them. It is probable that a sufficient number of British Medical Officers can not be spared for such a service, and it seems to me that it is perfectly possible and highly desirable that we should offer a dozen or more of our trained specialists to be attached in this capacity as Medical Advisers to the commanding officers of the British squadron groups. Director Gen. T. H. Goodwin, of the Royal Army Medical Corps, would appreciate such help from us, and on our part such a contribution could be very easily arranged, as we have not only such a large number of physicians in our service, but such a large number of those specially trained in the States for the care of the flier. These American officers could work under the direction of Maj. James L. Birley.

The trip back from the British front was made by auto with Capt. T———, who is in charge of British squadrons devoted exclusively to night flying. (Capt. T——— has had 600 hours in the air day flying and 200 hours of night flying.) He asked me if there was any medical explanation for the following: Many experienced aviators have been sent to him who had no difficulty whatever in flying in the daytime, and yet he found them to be unfit for night flying. I suggested that an examination of their ear mechanism, either by the turning-chair or the caloric test, would be highly desirable, and that very possibly the uncertainty of these individuals flying at night might be attributed to a poor sense of balance which had not been in evidence in their day flying, because they had been able to maintain their balance by the sense of sight. Capt. T—— then said that he wished all such men could have such an ear examination before they were sent to him for night flying work.

A visit to England, including London and flying camps in England, enables us to become familiar with the British technique of examination of the applicants for the flying corps, and also to study their methods for the medical care of the aviator in the flying schools. The experts of the British forces, both at the front and also in England, emphasized their approval of our plans for the physical care of the flier.

FRENCH.

The French have placed the examination of candidates for the Aviation Service in the hands of specialists who have carried out much experimental work of value in this study, especially in the problem of OXYGEN INSUFFICIENCY. Prof. Josue has been in charge of the cardio-vascular work, and Prof. Lombard in charge of the examinations of the internal ears and the balance mechanism. Dr. Garsaux has conducted the experimental work in regard to the oxygen problem at the Aero-Technique Institute. The institute contains an excellent vacuum chamber in which experimental work has been carried out for many months. As one result of this work there has been produced the Garsaux oxygen apparatus, so constructed as to give, automatically, an increasing amount of oxygen with each increase in altitude. A complete description of the Garsaux oxygen apparatus and a description of the vacuum chamber are in our possession, also an article written by Dr. Garsaux, " Sur le Mal des Aviateurs et les Moyens a employer pour l'Eviter."

At this writing, toward the end of January, 1918, there is planned a complete reorganization of the French Medical Aviation Service, and it is contemplated that Prof. Nepper will be put in charge of this work. We have in our possession the standards and requirements of the French Aviation Service, both of the Army and of the Navy. It is striking to note that the French, like their allies, were not able to bring about during the early part of the war a special study of the medical problem of the flier. It was not recognized that such a study was at all necessary for the efficiency of the Air Service. Now, however, those in authority have come to recognize the need for such special medical work.

The French medical officers said that they would gladly meet with us and with the medical officers who were working along similar lines in the British and Italian service in order that through an informal exchange of ideas we might all obtain the benefit of each others' experiences in this study. Such an informal meeting would be highly desirable and should perhaps most suitably be arranged to take place in Paris.

The following article by Dr. Guilbert, attached to the French Aviation Service, is included, particularly as it is written for the instruction of the aviator himself and shows that the French have a similar viewpoint to ours in regard, not only to the examination, but also to the CARE of the flier.

PHYSIOLOGY, PHYSICAL INAPTITUDE, AND HYGIENE OF THE AVIATOR.

[Lecture by Dr. Guilbert, attached to French Air Service. Translated from the French by Maj. Ralph Goldthwaite, M. C.]

I. PHYSIOLOGY.

At a time when aviators are multiplying and astonishing us by their prowess, it is useful to recall some ideas on physiology which may interest us, and some principles of hygiene which you should observe.

The aviator is often, with good reason, compared to the bird. The bird does not fly by any marvelous or extraordinary process. He rests on the air; and the aviator does the same thing. But between them there exists a marked difference, in that the bird, when he flies, is in his own element; man, on the contrary, intended for life on the earth, has need, when he undertakes this extraordinary sport, not only of all his physical energy, but in addition all his moral force and his intelligence, and he can not leave anything to chance. That is to say, in aviation, physiology plays a large part.

The aviator first of all should keep a calm and cool attitude of mind, and not exaggerate his reflexes, but should know how to utilize them rapidly. He must be the master of his impressions and be ready to make a prompt decision and have knowledge of the smallest of his movements.

On the subject of proper equilibrium, it is especially custom which will give these qualities. Violent reactions and poor equilibration at the start will often disappear with training, for one becomes accustomed to sensations of being in the air, as to all others.

These sensations are quite different than the general public imagines. It is generally believed that the rise and descent of an aeroplane are accompanied by uncomfortable feelings similar to those produced by riding in an elevator. It is often thought that the movements of the apparatus would give the pilot or passenger vertigo, or a sort of seasickness, and in fact it is quite astonishing that this is not the case. The absence of vertigo in the healthy individual results from the isolated independence of the apparatus. On the ground, when one happens to be in a place which is high and dangerous, and where one sees the wide expanse around him, one has a feeling of being insufficiently sustained, one fears that the support will give way, hence the impression of fear and vertigo.

In an apparatus in flight there is nothing of this sort. There is complete separation from the earth, which appears then as an absolutely strange element. The apparatus as a whole, its area, its speed, all contribute to suppress the causes of attraction, and especially of vertigo. All this is so true, that one often sees individuals, who can not lean out of a window without feeling dizzy, who have no such sensation in the course of an ascent in an aeroplane. It is a fact that there are few places where one can obtain such an impression of calmness and immobility as in an aeroplane. It very often seems as if one did not move, and it is only by observing the ground that one becomes certain of his progress. In full flight, a feeling of security comes upon you; one sees the objects of the earth grow smaller and then disappear. Little attention is given to the successive crossings of zones of air more and more cold, and less and less dense. One does not realize that the conditions of existence must change, and that the organs must adjust themselves to these conditions. Consequently, as long as they are intact and resistant they should be capable of repeating these efforts indefinitely.

In a general way, flights are made at a great altitude, the ascent is more or less rapid, and from the highest point the aeroplane redescends toward the ground often too rapidly; the great speed of the ascent and dizzy descent are the two principal factors which produce aviators' sickness of which so much has been said the last few years, especially at the Academy of Medicine.

Doctors and professional aviators have noticed that during the ascent, respiration becomes shorter, the heart beats faster, up to a height of 1,500 meters. At this altitude the pilot may be taken with nausea and a sensation of dilation of the stomach, vision may become less clear, although at 2,000 meters, in general, the visual acuity increases by a third by reason of the congestion of all the organs of the head, and in particular of the choroid and of the retina. The throat may give the impression of a feeling of dryness, the ears may ring and have a sensation of obstruction. The nose is insufficient, and the pilot must open his mouth to assist him in breathing. He may also be taken with a desire to sleep, he may become apathetic, and movements become painful, nervous or jerky, and of an unusual amplitude.

In the descent, the heart beats stronger, but without acceleration; the heart beats increase in volume and in proportion to the rapidity of the descent. It is difficult to give an account of what happens as regards respiration, by reason of the rapidity of the fall, which causes a sort of physical anguish. As for the ringing of the ears, that tends to increase toward the end of the descent, accompanied perhaps by small hemorrhages. At the moment of reaching the earth, buzzing of the ears may be of such intensity that the pilot is deaf and can not even hear his motor by osseous transmission. He feels a sensation of disagreeable tension in the ears, due to the difference of pressure which occurs on the two sides of the drum, on the one side the exterior atmospheric pressure, and on the other side the intratympanic pressure, and perhaps the intravascular.

This sensation, very common as it is on the bimotors, may at times persist for a long time but ends usually after some movements of swallowing, which open up the orifices of the Eustachian tubes.

When one decides to come to earth, by making a blowing effort with nose and mouth closed, at two or three hundred meters from the ground, one can inflate the ears and thereby avoid the heavy feeling in the head and the painful sensations on the throat.

But there is still another series of phenomena which increases clearly in proportion as one approaches the ground. It is, first, the sensation of smarting in the face, with reddening and very high color. The eyes sting, and are injected; the nostrils are moist, then comes headache, or more exactly a sort of heavy feeling in the head with a sensation of obstruction, a swelling up in the pharynx at the level of the larynx. Finally there is a strong tendency to sleep.

To explain these different difficulties one may admit that an organism which falls to the earth in four or five minutes, or less, after having attained three or four thousand meters of elevation in twenty minutes, has not had the time to adapt its circulatory system to the different barometric pressures, which are changing rapidly. For example, a change from 591 mm. of mercury pressure, at 2,000 meters, to 760 mm. mercury on the ground. All these uncomfortable sensations experienced by certain aviators in their ascents and descents, which seem to have been the cause occasionally of fatal accidents, prove the necessity for all aviators of having absolutely normal sensory organs: respiratory, circulatory, urinary, and locomotor, as well as a perfect play of the nervous functions.

This leads me to open up a new question which is important for you, and often delicate to me—I wish to speak of the physical inaptitude of being a pilot, and also causes which may, at times, modify a previous aptitude. It generally costs a good many candidates to find out those who are inapt, whether it be medical examination or from the opinion of the monitors. They should understand perfectly that their personal interest is at stake as well as the interest of the country. Aviation, already perilous for those who have a particular aptitude for it, will be certainly fatal to one who has not this aptitude. There are abundant examples of this point. But certain men see, in the fact of their inaptitude, a reflection on their pride, which has, however, nothing to do with the question. No one can pretend to be fit for everything. How many among you are there who would have no disposition, for example, for music, painting, fencing, equitation, and yet you do not feel yourselves humiliated? There is no more reason to desire to be necessarily suited for aviation, which is, in a way, a kind of art. After this digression, let us return to the main subject—physical inaptitude.

II. PHYSICAL INAPTITUDE.

As for that, I'm going especially to bring myself down to observations that I have gathered together concerning scholars who have not been able to succeed in obtaining their brevet, since my arrival at the school. Each one may obtain information which is useful in filling certain gaps in his physical make-up. He will also be able to modify his conceptions of the proper care of an aeroplane, and render his make-up and the apparatus in accord. I will tell you nothing of the deaths which come to my mind, but I leave to you the care of inquiring for yourselves as to witnesses and details of a fall, and the probable causes which have led up to it.

As far as one has been able to judge, certain types of aeroplane are better suited to certain individuals. I will refer only to those who have been discharged from the service for their professional or physical inaptitude. Setting aside the question of intelligence, the human machine should respond to certain physical conditions. Pilots should be young men, capable of rapid reaction, though it is difficult to fix the limit of age in a definite way. One may say, however, that as time goes on, before giving intensive service at the front, a student pilot should not have passed 30 years of age. There are, however, exceptions. Certain subjects have the faculty of saving their organs in their youthful condition, particularly those adept in sports; these make usually the best aviators, even if their age is relatively advanced. Young pilots have rapid and exact reactions, and are less sensitive to cold. It is necessary to note that in growing old the sensitiveness to cold is much greater; which seems to explain, in my opinion, the fatigue of the arteries and kidneys in particular. It is known that the oxygen diminishes proportionately as one goes up in the air. Respiratory exchanges become more difficult, the blood gets rid of its toxins with greater difficulty, and there is greater necessity for elimination by the kidneys, which are the other eliminative organs for poisons. And in the same measure the skin must furnish assistance, or otherwise an excess of toxins will occur in the blood, causing pains in the head, visual troubles, nervous troubles, due to poisoning of the small capillaries of the brain. You will find, equally independent of the age, a cause of diminution of resistance of the kidneys in individuals, due to the cerebral activity being dulled by the use of pseudo-stimulants, such as morphine, cocaine, opium, and ether.

The same applies also to those who are affected by gonorrhea, syphilis, or other conditions which are conveniently called venereal, which are, all the more for their victims, factors of moral depression.

You will then understand the necessity for you to have a renal apparatus in good condition. Imagine to yourselves what would be the condition of a pilot who had weak kidneys and who had albuminuria, when you know that cold is a serious danger for this sickness. The very nature of the affection exposes him to vertigo, muscular cramps, nose-bleed, apathy, etc. Any one of those ills, insignificant on the ground, becomes important at 3,000 meters in affecting the maneuvers of this pilot.

I know very well that with good luck he would be able to right himself in time. But one can see how, at times, pilots handicapped by these affections, or by others, may compensate for these divers inferiorities by qualities of accomplished sportsmen or moral qualities of the first order. These cases are the exceptions, of which we can not take account before we see what is necessary for pilots in general.

Let us look now to the respiratory apparatus. It is necessary to have good lungs to be an aviator. It is evident that this increases very much the capacity of resistance of the organism. Nevertheless one knows aviators of the greatest merit who are very poorly equipped in this way. That does not prevent them from fighting very well even at 4,000 meters. But it is far better not to count on that, and it is well to suspect all who have a predisposition for hemoptysis from chronic pulmonary congestion or tuberculosis or by arterial hypertension.

As for the heart, the question is once more categorically defined. It is necessary that the blood be regularly brought to the different parts of the body in order to nourish it, and to maintain it constantly at the same temperature, if one wishes that the individual should not suffer too much from difference in pressure in mounting or descending.

Auscultation of the heart, in very careful manner, is of the utmost importance. The blood pressure, systolic and diastolic, should be taken, and the pulse pressure—the normal relation between these three—established.

In a general way, the practice of aviation tends to produce a lowering of the blood pressure, particularly of the maximum pressure, the minimum pressure remaining normal. This lowering is especially appreciated in subjects who are slightly or partially trained. Continued driving, even in one very well accustomed, may produce a marked lowering of arterial pressure. As this hypotension affects at the same time both the maximum and the minimum, and in that it tends to persist, there is indicated, further clinical investigation as to the origin of these manifestations. Without wishing to draw hasty and questionable conclusions, I will say that among scholars who have been discharged, the greater part owe their professional inaptitude to modifications of arterial pressure.

Note, in passing, that all the causes of raising from lower to higher blood pressure, such as excessive eating, alcoholism, tobacco, women, which lead to organic loss of equilibrium, show themselves by lack of adjustment to external conditions. In Paris, in one of the halls of the Grand Palais, there is a collection of interesting experiences on the inaptitude of candidates who are piloting aeroplanes, experiences some of which you certainly have heard.

This bureau is under the direction of Dr. Nepper, a distinguished physiologist. He has studied with the aid of the graphic method the influence of emotions on the circulatory and respiratory rhythm rates.

In my opinion, it is not necessary to draw from this examination too definite conclusions, when it is a question of measuring the intensity of emotional reactions of the subject. On the other hand, there is another series of experiences which to my mind is extremely important. It consists of calculating by the use of a very exact electrical chronometer (d'Arsonval) the reaction time of the individual to visual, auditory, and tactile impressions.

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With a normal individual this time is about .14 of a second for tactile and auditory impressions, .19 of a second for visual impressions. (I will remark in passing that the time necessary to produce a voluntary movement of adaptation of defense is too slow for visual impressions.)

It has been observed thus that the nervous, inattentive, or ill-balanced individual reacts in a variable fashion, and it is exactly on this proper means of reaction time that one judges the aptitude of the aviator, in accordance with how this mark approaches or varies from unity.

This fashion of judging candidates by two methods is excellent; it is particularly valuable for controlling other methods of examination, and of fixing for us doubtful cases.

Let us now take the question of sight, which is still under dispute at the present time. It is better in principle not to have a vision corrected by glasses. The aviator needs perfect vision, and a perfect ability to distinguish colors, and a rapid appreciation of distances, and the faculty of accommodating rapidly. I have been informed of many accidents that are due to hyperopia, myopia, astigmatism; in other words, to anomalies in vision. The same thing holds for hearing. Both the middle and the internal ear should be intact. The changes of increased pressure and diminished pressure in the air and blood make themselves very strongly felt in sclerotic ears, because their tissues have lost their elasticity, which renders these effects transitory.

In other words, how can the pilot get information of the changes of the rhythm of his motor, or of the whizzing of the air on the piano wires of the machine, if his hearing misinforms him? How can he have perfect equilibrium in the air if he has an alteration of the semicircular canals in the internal ear, which are in such intimate relation with the cerebellum, the nerve center of equilibrium? The slightest affection of these predisposes to vertigo of a pathological character.

One portion of the examination which has been too much neglected up to very recent times is that of the nasal passages. It is important that they be in a perfect condition, not only to allow to the pilot easy respiration, but, even more, to give him a clear perception of smells. Outside of vision and hearing and smell there should exist also in the aviator a special sense which I might call the sense of flight, which may be developed, but which can not be created all at once. The proof of it is that there are very intelligent subjects, men to whose physical fitness absolutely no objection could be made, who could never make more than passable aviators. A good pilot should feel entirely at ease in space. He should be able to recognize at once the slightest difficulties with his machine in any one of the three dimensions. He should possess fundamentally the skill of command to reestablish equilibrium at any instant, just as a cyclist on his bicycle, but with this difference, that there exists a slight space of time between the moment of the movement of control and that of the effect produced. It is necessary then to correct the movement made, and at that point is the delicate matter of making the movement with too much intensity, or, on the other hand, insufficient intensity.

In a word, it is the instantaneous transformation of a passing sensation to precise muscular contractions, but of infinite variability, with the purpose of constantly reacting to the invisible movements of the atmosphere and with all the other difficulties which may occur. This capacity, as it seems to me, is, above all, the result of training. Repetition of the same movement results in the formation of a nervous center which commands all the muscles involved in the execution of those movements, and then of centers in the medulla, which become substituted for the brain, in a transformation of a sensation to a movement. This is the theory of reflexes.

The formation of these reflexes varies with the temperament of each person. The rapidity of acquiring them constitutes what is called aptitude. But in so far as the pilot does not acquire this automatic feature of his movements, he will have to furnish in his work a sustaining effort of attention, a great effort of will, which may go so far as producing nervous fatigue.

It remains for me still to mention, amid the causes which may modify the degree of aptitude, impressionability. Scholars have been seen who were victims of slight falls, who could not continue their apprenticeship as they were haunted by apprehensions of other accidents. They are accused of moral weakness. Very often there is a correlation between this moral and physical state in such a way that the subjects of whom I speak have been victims of a nervous disturbance when taking a flight.

On the other hand, pilots who have been able to continue their training after slight or severe accidents have developed a coolness and benefited from their experiences. They have learned what it cost not to take sufficient account of the council of their teachers, and they think better of what they are doing and are more prudent. I do not mean to say that all have falls, but rather they have drawn conclusions from those that they have seen. They generally owe their improvement to the spirit of observation. They have noticed all the causes of failures, and they know how they should carry themselves, not only in their apparatus but also in the interval between flights. And it is men of that type who are best able to accept the advice on physical and moral hygiene.

III. HYGIENE.

Without having had their practical experiences, I will attempt nevertheless to indicate to you certain precautions which will be necessary for you to take to maintain your aptitude for aviation, and to get the most possible out of your faculties. You know that in all the training for sports there is necessitated a definite type of life. Athletes, runners, horsemen, even submit to it, and with the very best of reasons; therefore you, who give yourselves to a new sport, more delicate and more difficult than the others, must also do so.

This necessity of being careful about oneself is imposed upon all without exception, but it is quite evident that scholars, students recruited among the wounded or sick of the war, should submit to it even more rigorously than others, for they ought not to lose sight of the fact that they are more exposed than healthy individuals to the dangers of aviation, whether it be cold, dampness, or diminution of the proportion of oxygen which occurs when one gets to a certain height or when the respiration is embarrassed by fatigue.

Let us speak first of the hygiene of the aviator on the ground. The first thing that would be necessary to him is great liberty of spirit. He should avoid family attachments and other liasons too absorbing. He should accustom himself to react against anxieties and unpleasant conditions of all sorts. How can the pilot be a complete master of his apparatus if he is distracted in his mind, and his thought is elsewhere?

A second question, none the less important, is that of fatigue. The act of flying demands a great expenditure of energy, as much physical as moral. It is a question then of not wasting this energy in between times. Consequently he should avoid all ordinary causes of fatigue, such as excessive alcoholism, tobacco, cards, or love. How many fatal accidents have originated from forgetting these prescriptions?

In the matter of eating, there is nothing special to say. Naturally one needs carefully prepared food, which will permit of proper recuperation of the expended energy of the organism. But it is also necessary to avoid excess at the table, for loaded stomachs disturb clearness of thought, precision of sensation, and perfect execution of movement.

To sum up, the aviator, whether he be at school or at a squadron, needs a certain amount of comfort, sufficient hours of sleep, and a well-regulated life. The day that he suffers from any illness whatever, if he has slept poorly, or has bad digestion, and does not feel himself in good form, it is preferable for him to remain on the ground when he can.

At the front, it is not always possible to do this. But at such a time one may always have recourse to stimulation with such tonics as quinine, arsenic, kola, etc. But so long as you are an apprentice, only fly when you are in good health and in perfect possession of your senses. Thus you will always do well to have a certain interval between your repast and the hour of flight, in order that digestion may have time to be completed.

I also call to your attention how foolish it is to go up in an aeroplane not only in a condition of drunkenness, but even in a state of excitation, which may falsify your sensations and predispose you to foolish action.

Finally, I would recommend to you a very ordinary thing, but one which nevertheless has its importance. It is never good to go up in an aeroplane without first having moved one's bowels and voided the urine, so as to avoid, in case of a serious fall, the rupture which may result in the intestines or bladder. The old adage of our fathers: "Head fresh, abdomen free, feet warm," should be observed in aviation more particularly than elsewhere.

Once in his apparatus, the pilot should take account of the cold and of the moisture of the air. The action of cold on the organism increases by stages. It is at first a sensation of chilling indicated by a pallor of the skin, diminution of the excretion of the skin, and by goose pimples on the flesh. When the pilot is sufficiently protected the phenomena stops here. Otherwise the chilling becomes more accentuated, and one notices a painful sensation, the extremities become stiff, a numbness comes on, with a tendency to sleep.

How to contend against this lowering of temperature? At the very beginning, the organism provides itself at the first with a peripheral vaso-constriction, then with an increased production of heat. But if the cold becomes more intense, or if its action is prolonged, external protection becomes necessary.

From the first, a shelter is necessary, and the aeroplane constructors have provided it, at the same time satisfying the laws of aerodynamics, the fuselage of the apparatus being covered in such a way that only the head of the pilot emerges from the hood.

Finally, there is need of appropriate clothing. Best is certainly woolen clothing, for it is proved that wool counteracts most advantageously the loss of heat which, as on the earth, moves by conductivity, radiation, and evaporation, and especially by convection. The chilling by convection is due to the circulation of external air, which rapidly passes even through the thickest clothing, chills the skin, and escapes after having been warmed. Let us say in passing that paper lining in the form of thin layers gives greatest amount of protection. Flannel applied directly over the skin is highly recommended, for it regulates evaporation. A woolen sweater is added to this, then a combination suit, fur-lined, and fur-lined boots, sufficiently large to avoid any pressure on the feet or limbs.

One should not put tampons of cotton in the ears because they are useless and even dangerous to the security of the aviator. You will remember that in ascending the aviator is relieved in breathing largely by making use of the mouth and by practicing the valsalva maneuver, which consists in making a blowing effort with the mouth and nose closed; and that in descending he will relieve himself by practicing the experiment of Toynbee, which consists in making a movement of swallowing after having closed the nose and mouth. The eyes will be protected from the effect of the wind and dust by glasses similar to those used by automobilists. The hands should be covered by large gloves, thickly fur-lined with rabbit skin or cat fur, for example.

As for the head covering, it will consist of a woolen helmet or one of skin surmounted by a helmet of leather furnished with iron strips to lessen the shock in case of fall. In passing, I will recall to your attention that the helmet alone suffices in warm weather to protect the pilot from sunstroke.

In résumé, the costume of the aviator should be warm and sufficiently ample, of a type to permit ventilation of the body and a complete liberty of movement. As for the rest, this amplitude will only result in increasing the heat by the insulated layer which the inclosed air produces.

In the winter time one may add to this clothing by utilizing skins of animals, waxed, such as the "parapluies du chauffeur," which will have at the same time the advantage of protecting him from the moisture. This last is important, for it has the natural consequence of chilling the body very rapidly, if allowed to penetrate.

At times it happens, on the other hand, that the air is very dry at great elevations. Then the loss of water, which takes place through the skin and mucous membrane, may not be compensated for sufficiently quickly by the production of water from the body. As a result of this, sensations of parching of the skin, chapping, cracking of the lips, and the arrest of the salivary secretion, dryness of the throat, develop, produced all the more quickly when the hygrometric conditions have changed very rapidly.

All these phenomena increase with elevation. It is well for you when you make a high flight to apply to your face, and especially to the nostrils and the lips a light coating of ointment such as cold cream, glycerine, petrolatum, etc.

Along the same line it would be well to induce a little vaseline in the nostrils in order to preserve the mucus in the nose and pharynx. This last precaution will have the advantage of being also helpful against humidity and dryness.

Finally, I will make one last recommendation, that of taking a light rest after each flight. It is the best way to preserve strength, and to reinvigorate oneself in proportion. That will permit you when you are at the front, to remain there much longer and to do much better work while there.

DOCTOR GUILBERT.

ITALIAN.

The best medical experts of Italy are in charge of the examination and care of the flier. This work is fully organized and is much appreciated by their Air Service. The Italians have two centers at which this work is done. They have the most complete equipment and every encouragement and opportunity to do the highest type of work.

PSYCHO-PHYSIOLOGIC INSTITUTE, ———, ITALY, DECEMBER 28, 1917.

This institute is in charge of specialists and is under the direction of Prof. Gradenigo. At present he is in ——— opening up another examining center. This is done so that it will not be necessary for all applicants to go to ———. The first thing that strikes us on seeing the Italian medical situation is that ALL candidates came from some other branch of military service, for the obvious reason that ALL fit men are already in the service. It is a case of request for TRANSFER into the Aviation Service.

CANDIDATES.

All candidates are examined here at this institute. The present average is 35 per diem. They expect soon to get up to 80. This is probably due to the anticipated work of the unit at ——. There are some of the military surgeons working here, although these seem to be made up mostly of those who were specialists in civil life, before the war. Then there are also "civilian consultants." I do not know whether they are appointed by the Government or by Dr. Gradenigo. They seem, however, to be the very best type of physicians, and are of the average age of about 48. They are of the dignified "professor" sort.

REEXAMINATION OF FLIERS.

None are examined again so long as they seem to get along all right. But I just saw a man who had had a spill, which had broken two ribs. This man feels all right and probably wonders what it is all about—but they have sent him back to ——— to be examined all over again. They reexamine all those who have been injured before allowing them to fly again. As ——— is not "very far away"—this is not such an enormously large country—it probably does not take a very long time for the aviator to get here and then get back to the front. It would seem, however, that if they could have experts also at the front that they could solve this matter in a much simpler way, by providing a final opinion on the spot, even if they had only one more unit located at headquarters at the front.

SPECIAL FEATURES OF THE ITALIAN EXAMINATION.

They put great emphasis on the REACTION TIME. Their tests are very simple and admirable. I was put through the tests as a "candidate." I held my finger pressed down on a sort of telegraph key, and all I had to think about was that the instant a light flashed in front of me I was to lift my hand instantly off the key. This was repeated quickly 30 times and recorded on a watchlike instrument. The whole thing was electrical and there was very little opportunity for error apparently; anyhow there is no doubt that frequent experiments have demonstrated an average "normal" time for this response to come through, and so when any man falls well below this average it is safe to say that he does not respond as quickly as he ought. The point is that the Italians lay stress on the importance of an alert response, motor, to external stimuli. They disqualify about 2 per cent of the men by their failure in this test alone. If a man is perfectly normal in his entire mechanism and yet does not show that he is "quick on the trigger," he is considered unfit to be a flier.

OBSERVATIONS MADE DECEMBER 29, 1917.

A full day spent in going through all the Italian tests in detail.

ESSENTIAL POINTS.

They record many of their tests on revolving drums. The test of the emotions is particularly striking. Rubber tubes are adjusted, one to a double pad over the region of the common carotids, another over the chest, another over the right hand, and another to a glass tube in which the left forearm is inserted, and then the tube filled with water. The drum starts to revolve. The needles record the pulse of the carotids, the respiration, whether there is any tremor of the right hand, and the level of the vasomotor tone in the left forearm. Suddenly a bomb is exploded directly behind the man, by throwing it on the floor under him. All the needles take a sudden jump. The man I saw showed, however, an immediate return of all the needles to their original amplitude and level of the line—that is to say, the tracings after the explosion were just the same as before. This showed that he had a normal involuntary "start" when the bomb went off, but that it did not disturb him because his heart-beat, his respirations, steadiness of the right hand, and vasomotor tension in the left forearm showed immediate recovery. Other tracings of others examined showed that these functions did not recover, but were "all shot to pieces"; the pulse would be very rapid, also respirations, the right hand would tremble and the vasomotor tension line dropped—showing that the peripheral tension had diminished—evidence of shock. This latter type is disqualified.

The Italians even go so far as to take a tracing of the degree of nasal stenosis. A catheter is put in the right naris all the way back. Man breathes, then cotton is put in the left naris. If the tracing shows no increase, it is evidence that the left naris is stenosed. They hitch up the tube to a sort of barometric tube and measure the degree of stenosis. To me, this seems very "fancy" and entirely unnecessary, as it is a very simple matter to see what is the condition of a man's nares. However, it must be noted that the Italians do not put all the candidates through the tests. It depends on how much time they have. Also on special cases they have all these data to help them.

They have a VACUUM CHAMBER. Many experiments have been made in it during the past dozen years or more. (We have in our possession reprints which they gave me, written in French.) They feel that: 1. Oxygen is not necessary for fliers. 2. If given, it should not be pure oxygen, but oxygen 90 per cent, carbon dioxide 10 per cent.

This enabled them to take their famous ourang-outang much higher than he could go with pure oxygen alone. They also have made tests on human beings with the same results and conclusions. They did not feel that the present heights attained in flying required OXYGEN, and were very definite in their statement that no professors had done as much work on this subject as they had done here in Italy, and that there was no room for argument. (So I did not open any argument.)

The Carlinga is the pièce de résistance. It is a regular aeroplane seat and body.

TESTS.

1. *Man blindfolded.*—They move the outfit, man and all, to a certain inclination. Then he indicates with a pointer what he considers to be the exact perpendicular. This error is read off on a scale.

2. *Eyes open.*—He takes hold of the joy stick. They move the outfit and he moves the stick to compensate. There is a system of electric lights connected with this test, to determine if he is accurate. They have electrical connections with the under end of the joy stick, and when he presses it in a certain direction those particular lights flash. There are three sets of lights, one set for lateral movement, one for sagittal—both controlled by the joy stick—and one set for horizontal movement controlled, as in a plane, by the foot rudder.

This test is obviously along entirely original lines. It constitutes the test for the reaction time to the detection of movement. Just as the reaction time has been tested for the sense of sight, the sense of hearing, and the sense of touch, so by means of the Carlinga it is possible to determine the reaction time to a stimulation of the vestibular mechanism and deep sensibility.

They place a prime importance on the mechanism vestibulaire. They would not think of accepting a man whose ear mechanism was not good. And yet all they do in the turning-chair is to turn, with EYES OPEN, and see if he has a good nystagmus. Say that between 25 and 35 is normal. This exactly agrees with our figures as we test, eyes straight ahead, and they with eyes in the extreme position opposite endolymph movement. This would normally increase the length somewhat. They were much interested in our methods, and had a copy of it in Italian. They asked me to demonstrate our method. They had no suitable head-rest and let the head go in any position; also they had no stop-pedal and were a little uncertain of meaning of past-pointing. They knew what I meant, but did not seem to see that it had anything especially to do with the aviator. They made no mention of the use of the caloric test.

Their general physicals are well done, but nothing of interest.

Eye work beautifully done, and the instruments very fine. Every man has the test for vision "at night." This is done in a dark room and estimation made in two ways: (1) A light is moved further and further away from the card; (2) cards are of varying backgrounds, becoming darker and darker.

VISIT TO PROF. (LIEUT. COL.) GRADENIGO, ITALY, JANUARY 5, 1918.

The professor says that the great need is that the doctors concerned in the matters of aviation should get together and learn from each other. He volunteered the idea that all the tests of all the countries should, as far as possible, be the same. The objections to this are that the number and type of candidates in these different countries vary so greatly. He is, however, in complete accord with the value of knowing each other's ideas. He will, in the immediate future, cooperate in any plan that is presented to bring about an interchange of ideas. He urged that we send our men from ——— to be examined by them here. He put it rather in this way:

> We, the Italians, are at your service to examine any of your men for you at any time. Also that a comparison of the findings of the examination might be helpful. This new unit at ——— will be in good working order in a few weeks, although it will be a couple of months before it is equal to ———.

We have in our possession the examination blanks used by the Italian service. Each special department has its own blank. After these are all filled, another blank is used by the medical officer in charge, who makes a brief summary of the results of the detailed examinations given in the various blanks. The Italians also furnished us with many photographs of their apparatus and methods of examination, also data bearing especially upon the elaborate studies which have been conducted by the University at ——— for many years, upon the effects of high altitudes upon human beings and ourang-outangs.

We explained that our standards were very simple and definite because of our 67 units and the need of standardizing the work at all these places. The main suggestion that we have learned from the Italians is that we might do well to make a routine test of the REACTION TIME. They consider it very important. It would, however, be very difficult to apply it in any standard way for so many units.

The Italians are eager to join us in any effort to help "the cause": namely, the "SPECIAL MEDICAL CARE OF THE AVIATOR."

CHAPTER VII.

MANUAL OF THE MEDICAL RESEARCH LABORATORY.

I.—ALTITUDE PHYSIOLOGY.

In recent years our knowledge of the conditions pertaining to life at high altitudes has been enriched by careful scientific investigations. The majority of these have been carried out on Monte Rosa in Europe and on Pike's Peak in the United States. Further contributions come from studies made in pneumatic cabinets in which the atmospheric pressure can be reduced to any degree corresponding to known heights.

The physiologic effects of altitude on man and other animals have a threefold interest. The purely scientific aspects of the life under conditions of low barometric pressure are themselves deserving of careful investigation. The fact that altitude plays a part in therapeutics and forms a feature of climatology, as applied by medicine, furnishes another reason why the subject should be placed on a rational basis. While the coming into prominence of aviation which requires a man to ascend into the air as the bird, frequently to moderate and sometimes to great altitudes, furnishes a third reason why we should know what constitutes fitness for life in rarefied air. As soon as an attempt is made to interpret the physiologic phenomena of altitude in terms of their causes difficulties arise. The reason for contradictory theories is to be found in the complexity of the factors which enter into the environment at high altitudes. Among the climatic variables are the low atmospheric pressure with its low partial pressure of oxygen, the peculiarities of the sunshine, low temperature and humidity, the high wind, the electric conditions of the atmosphere, and ionization. It has been found difficult to study these factors one at a time, but with the use of the pneumatic cabinet it is possible to eliminate all factors except lowered barometric pressure and also to study the added influence of other altitude factors. The consensus of opinion held is that the physiologic effects noted at high altitudes are due to the lack of oxygen resulting from the lowered partial pressure of oxygen.

It is clearly established to-day that high altitudes or low barometric pressure when first encountered may interfere with the normal workings of the human machine. A sudden disturbance of any sort of the bodily functions is usually manifest by symptons of illness.

Those disturbances brought on by change of altitude cause the so-called mountain sickness, or, better, altitude sickness, the symptoms of which are generally so mild that they may be entirely overlooked by the unobservant. Mankind differs greatly in the power of adjustment to changes of environment. Hence, it is found that mountain sickness befalls some individuals at a lower, others at a higher altitude, but it is also certain that no one who proceeds beyond a certain elevation—the critical line for him—escapes the malady. An elevation of 10,000 feet or even less might provoke it in some, others may escape the symptoms up to 14,000 feet, while only a very few, possessed of unusual resisting power, can without much distress venture upward to 19,000 feet. The symptoms of mountain sickness depend not only on the nature of the individual and his physical condition, but also on various intricate contingencies, especially on the amount of physical exertion made in ascending; that is, on whether the ascent is performed by climbing or by passive carriage on horse, on railway train, or in an aeroplane.

There are two forms of mountain sickness; the acute and the slow. The acute, due to going too far beyond the individual critical line, breaks out suddenly on entrance into the rarefied air; the slow manifests itself later and other debilitating causes besides the barometric depression often contribute to produce it.

The acute form is characterized by a rapid pulse, nausea, vomiting, physical prostration which may even incapacitate one for movement, livid color of the skin, buzzing in the ears, dimmed sight, and fainting fits.

In the slow form of mountain sickness, which may be called the normal type, the newcomer at first complains of no symptoms. In fact, when questioned he says he feels fine. Occasionally he may report that on stooping over and raising himself up again, he feels dizzy and has a visual sensation of blackness. Even at this time on examination there is found blueness of the lips, edges of the eyelids, gums, and under the finger nails. Some hours later he begins to feel "good for nothing" and disinclined for exertion; to express it differently, he finds that he feels somewhat weak and exhausted. He goes to bed and has a restless and troubled night and wakes up next morning with a severe frontal headache. Many find that the headache begins to develop toward evening or during the night of the first day. Following it there may be vomiting and frequently a sense of depression in the chest. The patient may feel slightly giddy on arising from bed and any attempt at exertion increases the headache which is nearly always confined to the frontal region. On examination the face may be slightly cyanosed, the eyes look dull and heavy and there may be a tendency for them to water. The tongue is furred, the pulse is nearly always high, being generally in the neighborhood of 100 or over. The temperature is normal or slightly under. The patient often feels cold and shivery. All appetite is lost, some have diarrhœa and abdominal pain. A tendency to periodic breathing is observed in many and physical exertion is accompanied by great hyperpnoea.

There are wide divergencies from this slow or normal type of mountain sickness. Dr. Ravenhill has grouped these into two classes, (1) those in which cardiac symptoms, and (2) those in which nervous symptoms predominate. Neither is common. The cardiac type is well illustrated by one of Dr. Ravenhill's cases. An English gentleman in the Andes Mountains ascended from sea level to 15,400 feet in 42 hours. Three years before he had lived at the same altitude for a period of three months and had been in good health the whole time. He seemed in good health upon arrival; he kept quiet, ate sparingly, and went to bed early, but awoke the next morning feeling ill with symptoms of the normal type. Later in the day he began to feel very ill. In the afternoon his pulse rate was 144, respirations 40. Later in the evening he became very cyanosed, had acute dyspnœa and evident air hunger, all the extraordinary muscles of respiration being called into play. His heart sounds were very faint; the pulse irregular and of small tension, thus presenting a typical picture of a failing heart. The condition persisted during the night: he coughed up with difficulty and vomited at intervals. He was sent down on an early train the next morning. At 12,000 feet he was considerably better and at 7,000 feet he was nearly well. Dr. Ravenhill thought that he would have died had he remained another day.

The nervous type of mountain sickness in its simplest form consists of the feeling of a nervous excitation and buoyancy. Some feel as though they are being lifted into the air as by a balloon. There may be a tendency to twitching of the lips and trembling of the limbs. In severe cases these may lead on to violent spasmodic movements of the limbs and even convulsions. Vertigo may be a prominent symptom, though it is very rarely pronounced.

The symptoms of mountain sickness persist for one, two, and three days and then gradually disappear as the adaptive reactions to high altitude occur. The action of gradually developing want of oxygen at very high altitudes is very insidious as dangerous effects may develop with a dramatic suddenness. Two now historic experiences illustrate this. In 1862 the well known meteorologist, Glaisher, and his assistant, Coxwell, ascended in a balloon. Glaisher first noticed at an altitude of about 26,000 feet that he could not read his instrument properly. Shortly after this his legs were paralyzed and then his arms, though he could still move his head. Then his sight failed entirely and afterwards his hearing and he became unconscious. His companion meanwhile found that his arms were paralyzed, but that he was still able to seize and pull the rope of a valve with his teeth—this permitted gas to escape—so that the balloon descended. As Glaisher recovered consciousness, he first heard his companion's voice and then was able to see him, after which he quickly recovered. The balloon, during the ascent, reached an altitude of about 30,000 feet. The second of these historic experiences is found in a graphic account given by Tissandier, the sole survivor of a party of three in a fatal balloon ascent in 1875.

"I now come to the fateful moments when we were overcome by the terrible action of reduced pressure. At 22,900 feet (320 mm.) we were all below in the car—torpor had seized me. My hands were cold and I wished to put on my fur gloves; but, without my being aware of it, the action of taking them from my pocket required an effort which I was unable to make. At this height I wrote, nevertheless, in my notebook almost mechanically and reproduce literally the following words though I have no very clear recollection of writing them. They are written very illegibly by a hand rendered very shaky by the cold: "My hands are frozen. I am well. We are well. Haze on the horizon, with small round cirrus. We are rising. Crocé is panting. We breathe oxygen. Sivel shuts his eyes. Crocé also shuts his eyes. I empty aspirator, 1.20 p. m., —7 to —11 degrees, barometer 320. Sivel is dozing, 1.25, —11 degrees, barometer 300. Sivel throws ballast (last word scarcely legible)." I had taken care to keep absolutely still without suspecting that I had already perhaps lost the use of my limbs. At 24,600 feet the condition of torpor which overcomes one is extraordinary. Body and mind become feebler little by little, gradually and insensibly. There is no suffering. On the contrary one feels an inward joy. There is no thought of the dangerous position; one rises and is glad to be rising. The vertigo of high altitude is not an empty word; but so far as I can judge from my own impressions this vertigo appears at the last moment, and immediately precedes extinction, sudden, unexpected, and irresistible. I soon felt myself so weak that I could not even turn my head to look at my companions. I wished to take hold of the oxygen tube but found that I could not move my arms. My mind was still clear, however, and I watched my aneroid with my eyes fixed on the needles which soon pointed to 290 mm. and then to 280. I wished to call that we are now at 26,000 feet, but my tongue was paralyzed. All at once I shut my eyes and fell down powerless and lost all further memory. It was about 1.30."

The balloon ascended 28,820 feet and then descended. Tissandier recovered but his companions lost their lives in the ascent. These extreme cases are cited here in order to bring to the attention of aviators the risk in going to extremely high altitudes without oxygen.

THE CAUSE OF THE SYMPTOMS OF MOUNTAIN SICKNESS.

The essential cause of altitude sickness is lack of oxygen. The probability of this explanation was first clearly pointed out by Jourdanet, but it was Paul Bert, in 1878, who first furnished clear experimental proof that the abnormal symptoms and dangers depend on the imperfect aeration of the arterial blood with oxygen. He concluded that all the symptoms are simply those of want of oxygen. Later observers, however, questioned this conclusion and attributed the symptoms in whole or in part to other causes. Mosso attributed many of the symptoms to the lack of carbon dioxide, while Kronecker has invoked mechanical factors as a cause. The evidence accumulated by more recent workers, both on mountains and in pneumatic chambers, have definitely confirmed Paul Bert's conclusion.

The call for oxygen in the body comes from the active cells of the tissues. It has been evident for sometime that the place of oxidation is in the cells and not in the blood as was formerly maintained. Complete deprivation of oxygen results in asphyxiation and death. The question that naturally arises is; Is the quantity of oxygen taken up by the cell, conditioned primarily by the needs of the cell or by the supply of oxygen? This has been answered clearly; the cell takes what it needs and leaves the rest. Therefore, it is important that sufficient oxygen be available in the blood when the demand is made by the tissues. The rate of flow and the amount of oxygen passing from the blood to the tissues depends on the difference between the pressure of oxygen in the blood and in the tissue. The higher the oxygen pressure in the blood the greater will be the amount of oxygen passing from the blood of the capillaries into the tissues in a given unit of time. Oxygen diffuses from the place of higher pressure to the place of no pressure or low pressure. In the active tissues the oxygen tension is always low and it is usually supposed there is then no oxygen pressure at all inside the cells. The dissociation of oxygen from the hemoglobin of the blood occurs with great rapidity, but it is greatest where the differences in pressure are greatest. It follows, therefore, that the oxygen pressure in the blood must be sufficiently high to supply the needs of the cell in the brief interval of time that the blood is passing through the capillaries.

There are many ways in which the oxygen supply of the body may be reduced. Whatever the method used there will occur compensatory adaptive reactions in the blood, the breathing, and the circulation for the purpose of furnishing the oxygen needed by the cell. Reduction of oxygen available to the tissues might be brought about by blood letting and anemia; by the administration of carbon monoxide or sodium cyanide; by life on high mountains, in a balloon, in an aeroplane at high altitudes, or in pneumatic cabinets at reduced pressure; by the artificial restriction of the free influx of atmospheric air into the lungs; and by artificial pneumothorax. Any of these methods, if carried beyond a certain point, is known to produce death. If, on the other hand, they are only carried far enough to give a mild oxygen hunger, the body will, as a rule, react so as to compensate for the reduction in the oxygen supply.

In blood letting, which produces an artificial anemia, the percentage of oxygen in the venous blood may be reduced from the normal 12 volumes per cent to 4 or even 3 per cent. In animals thus treated both the circulation and the breathing will show compensatory activity. In cases of anemia with a 20 per cent reduction in hemoglobin an increased pulse rate and an increased respiration will be observed. In cases of poisoning with carbon monoxide and sodium cyanide there will likewise be modifications in the blood flow and respiration. Kholer compressed the trachea of rabbits by tying a lead wire around it. The animals recovered from the operation and lived four weeks. Apparently, to compensate for the interference in breathing, there was an increased rate of respiration and heart activity which made good the oxygen needs of the organism. In case of artificial pneumothorax the hemoglobin of the blood has been shown to increase, the pulse rate to accelerate, and the respiration to deepen. We shall discuss later the adaptive changes which fit the human mechanism for high altitudes. These adaptive reactions are also seen in the blood, in the breathing, and in the circulation.

While all of the tissues of the body are sensitive, the nervous tissues are the most sensitive to oxygen want. The adaptive responses to a lack of oxygen are undoubtedly initiated in the central nervous system. Gaser and Loevenhart find that all of the medullary centers in the brain respond in the same way; first, by stimulation, and then by depression.

The more definite adaptive altitude changes disclosed by experiments are: (1) An increase in the percentage and the total amount of hemoglobin in the blood of the body and also associated with this a redistribution of the red corpuscles whereby a reserve supply is thrown into the general circulation; (2) a fall in the lung alveolar carbon dioxide pressure and a rise in the alveolar oxygen pressure, the result of increased ventilation of the lungs due to deeper breathing; (3) a rise in the arterial blood oxygen pressure which provides a partial pressure of oxygen in the blood much above the alveolar oxygen pressure in the lungs; (4) an increase in the rate of blood flow. Each of these adaptive changes clearly assures a more adequate supply of oxygen for the tissues. The blood changes provide for more oxygen in a given unit volume of blood. The greater ventilation of the lungs permits a more thorough saturation of the hemoglobin with oxygen than would be possible if the oxygen pressure in the lungs decreased proportionately with the fall in barometric pressure. The rise in arterial blood oxygen pressure also means a greater saturation of the hemoglobin. The more rapid rate of blood flow raises to a limited extent the oxygen pressure in the blood passing through the tissues. A discussion of these adaptive changes follows:

THE CHANGES IN THE BLOOD OF MAN AT HIGH ALTITUDE.

It has long been known that the effect of life at high altitudes is to cause an increase in the number of red corpuscles per cubic millimeter of blood and an increase in the hemoglobin percentage of the blood. In 1878 Paul Bert predicted that the blood of man and animals living at high altitudes would be found to have a greater oxygen capacity than that of corresponding individuals living at lower levels. He surmised that the cause of this increase in the oxygen carrying power of the blood would be found to be the decrease in the partial pressure of the oxygen in the atmosphere respired. In 1882 he gave an account of some experiments in which the blood obtained from animals living at a high altitude in Bolivia was found to contain a larger percentage of oxygen than did blood taken from animals at sea level. A little later, in 1890, Viault observed the increase in the number of red corpuscles per cubic millimeter of blood in himself and his companions during a three weeks' visit in Peru at an altitude of 14,400 feet. Numerous subsequent observations which have dealt with these phenomena have confirmed beyond question the earlier data. The following figures illustrate the differences observed in mankind living at different altitudes:

(1) The red corpuscles vary at sea level between 4.5 and 5.4 millions per cubic millimeter; at Colorado Springs, altitude 6,000 feet, between 5.5 and 6.3 millions; and on Pike's Peak, altitude 14,110 feet, between 6 and 8.2 millions.

(2) The percentage of hemoglobin at sea level varies between 94 and 106, average 100; in Colorado Springs, 105 to 118, average 110; and on Pike's Peak, 120 to 154, average 144.

(3) The percentage of oxygen capacity in the blood at sea level varies between 17 and 18.7; in Colorado Springs, 20 and 21.7; and on Pike's Peak, approximately 27.4.

Miss Fitzgerald has found that for every 100 mm. fall in atmospheric pressure there is an average rise of about 10 per cent in hemoglobin and that this rise is approximately the same for women and men. There are greater individual variations in the total increase. It is possible that under a pressure greater than atmospheric the hemoglobin would fall below 100 per cent. The observations of Madame Bornstein on animals have apparently shown a decrease in the percentage of hemoglobin when they were exposed to a pressure greater than atmospheric.

Incidentally it is interesting to note that the blood of the people living at high altitudes fails to show an increase in leucocytes, but does show an increase in the lymphocyte index. Thus at sea level this index averages 37; at Colorado Springs (6,000 feet) 42.5; and

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on Pike's Peak (14,110 feet) 50. An increase in the number of blood platelets as well as in the specific gravity of the blood has been observed. The following illustrates the increase in specific gravity: At Colorado Springs, 1.067; after six months residence on Pike's Peak, 1.073.

THE SEQUENCE IN THE BLOOD CHANGES DURING A PERIOD OF RESIDENCE AT HIGH ALTITUDE.

The facts so far given are those obtained from the study of people who are acclimatized to the altitude in which they are living. On passing from a low to a high altitude some time is required to react to the low oxygen of the new altitude. On ascending passively to such an altitude as 14,000 feet it has been found that immediately after arriving no change can be detected in the number of red corpuscles and the percentage of hemoglobin. Just when the changes begin has not been determined, but usually within 24 hours a marked increase in both will be present. A rapid increase in the number of red corpuscles and percentage of hemoglobin occurs during the first two or four days of residence; then follows a more gradual increase extending over three to five or more weeks. These changes are illustrated in the following table:

Date.	Havens.		Schneider.		Sisco.	
	Hemoglobin.	Corpuscles.	Hemoglobin.	Corpuscles.	Hemoglobin.	Corpuscles.
Average, Colorado Springs	109	6,024,000	109	5,992,000	113	6,372,000
June 17, Pike's Peak	123	6,872,000	116	6,472,000	120	6,732,000
June 18, Pike's Peak	126	7,024,000	115	6,400,000	125	6,880,000
June 19, Pike's Peak	129	7,160,000	122	6,800,000	126	6,720,000
June 20, Pike's Peak	130	7,292,000	121	6,848,000	122	6,624,000
June 21, Pike's Peak	132	7,200,000	123	6,736,000	130	6,928,000
June 22, Pike's Peak	135	7,296,000	121	6,472,000	133	7,032,000
June 24, Pike's Peak	135	7,248,000	126	6,616,000	134	7,104,000
June 26, Pike's Peak	134	7,000,000	127	6,656,000	131	6,856,000
June 28, Pike's Peak	129	6,840,000	129	6,896,000	135	7,120,000
June 29, Pike's Peak	132	6,976,000	129	6,960 000	....	....

Views differ as to the mechanism by which the changes in hemoglobin and red corpuscles are brought about. These views may be conveniently divided into three main classes: (1) Those theories which insist that the increase in hemoglobin and red corpuscles is real and not merely relative; two explanations of the increase have been proposed: (*a*) that the increase is due to increased activity of the blood-forming organs, resulting in an increase in the hemoglobin and red corpuscles; (*b*) that the increase is due to a lengthening of the life of the corpuscles. (2) The concentration theories, according to which the increase in hemoglobin and red corpuscles per unit volume is due to increased concentration of the blood. According to this view, the increase in both is only apparent, and there is no increase in the total number of red corpuscles and the amount of hemoglobin in the body. (3) It has been held that the increase in hemoglobin and corpuscles is due to unequal distribution of the red corpuscles. They are supposed to be more numerous in the blood of the capillaries and smaller vessels and less numerous in the large vessels. This view has not been supported experimentally and may be considered untenable. It has further been supposed that there exists in the body a reserve or dormant supply of red corpuscles which is drawn upon at high altitudes. The discussion at issue seems to permit the following conclusion: The initial rapid increase in hemoglobin and red corpuscles is brought about in part by the passing into the systemic circulation of a large number of red corpuscles that under ordinary circumstances at low altitudes are sidetracked and inactive, and in part by a concentration resulting from a loss of fluid from the blood. The more gradual increase in red corpuscles and hemoglobin extending over several weeks is brought about by an increased activity of the blood-forming centers, so that there results an actual increase in the total number of corpuscles and the amount of hemoglobin. The evidence for the above statement can be briefly summarized. Schneider and Havens have shown that abdominal massage and physical exertion at low altitudes cause an increase in the number of red corpuscles and hemoglobin in the peripheral capillaries; while in men partially or wholly acclimatized to a high altitude abdominal massage either does not change or lowers the content of hemoglobin and red corpuscles, and physical exertion fails to cause an increase. This failure to obtain an increase at high altitude may be accounted for on the assumption that the need for oxygen has called into permanent circulation the reserve supply of corpuscles that is present at low altitude. That an actual concentration of the blood occurs during the first few days of residence at high altitude was proven for three subjects by Douglas, Haldane, Henderson, and Schneider during an investigation made on Pike's Peak. One of their subjects had, after a few days of residence, about a 15 per cent increase in hemoglobin and a total blood volume 10.8 per cent less than at Colorado Springs (altitude 6,000 feet). Dreyer and Walker, reviewing Abderhalden's data, found that a little less than half of a 25 per cent increase of the hemoglobin in rabbits, that Abderhalden concluded was due to concentration, was actually a result of concentration, while the balance of it was to be explained by a new formation of hemoglobin. That there is also an active new formation of hemoglobin and red corpuscles is indicated by several researches. Thus, Zuntz and co-workers found, on comparing stained sections of bone marrow taken from dogs, one group of which had been kept at sea level and the second at a high altitude, that the latter show a decrease in fat cells and an increase in the blood elements. This, they concluded, indicated increased activity of the corpuscle-producing centers at the high altitude. Douglas, Haldane, Henderson, and Schneider, by the carbon-monoxide method of Haldane and Lorraine Smith, found that during a residence of five weeks on Pike's Peak (altitude 14,110 feet) four men had a large increase in the total amount of hemoglobin and also an increase in the total volume of blood. Laquer found that dogs deprived of hemoglobin of half of their blood supply regenerated it in about 16 days on Monte Rosa, while at a low altitude 27 days were required for the restoration after a similar hemorrhage.

It has been shown in studies on Pike's Peak that the increase in hemoglobin and red corpuscles for an individual is not the same during several trips and sojourns at that altitude. The increase occurs most rapidly when the subject is in excellent physical condition. If prior to the ascent his life has been sedentary and he is known to be physically unfit the changes will be slow in beginning, and the increase when followed day by day will be moderate or slight. If, on the other hand, the subject has taken regular physical exercise and is in excellent condition or physically fit there will be a decided rise in both hemoglobin and red corpuscles in the first 24 hours spent at the high altitude. It has also been shown that fatigue, induced by walking up a mountain, delays the increase in hemoglobin and red corpuscles. The lesson to be gained from these observations is that physical fitness qualifies the subject to react quickly when under the influence of the low oxygen at high altitudes.

CIRCULATION AT HIGH ALTITUDES.

There has been a great interest in the problem of circulation at high altitudes. Many persons, especially those with weak hearts, have an unwarranted fear of high altitudes because they have been informed that they injure the heart. The early studies have been of a fragmentary nature, the observations being confined wholly to a study of pulse rate and the systolic blood pressure. It has recently been shown that there is an increased rate of blood flow at very high altitudes. This is a compensatory reaction which will insure to the tissues a more adequate blood supply. A more rapid rate of blood flow will raise to a limited extent the oxygen pressure in the blood passing through the capillaries, and so insure better oxidation within the tissues. The recent investigations have included observations on the pulse rate, arterial pressures, capillary pressure, and venous blood pressure. Indirect methods have also been employed with the hope of determining the output of the heart per beat as well as the rate of blood flow through the lungs and other tissues.

THE PULSE RATE.

Of all the circulatory changes due to diminished barometric pressure the acceleration of the heart rate is the most noticeable. The majority of the earlier records are from studies made of men who had undergone considerable physical exertion in climbing a mountain. The fatigue thus induced has obscured the early influence of altitude. Therefore, in order to understand the reaction of the heart it is necessary to eliminate all extraneous modifying influences such as fatigue and cold. Pike's Peak offers an excellent opportunity for such Alpine physiological studies, because men may be carried up passively by railway or in an automobile.

It is generally recognized that at moderately high altitudes, 6,000 to 8,000 feet, or even 9,000 feet, the inhabitants do not show an augmentation in heart rate. There is considerable variation in pulse rate of different healthy individuals at sea level. Thus it was found that athletes in Oxford had rates which may be considered normal that range between 44 and 80. In a study of medical students at Cambridge the range was between 47 and 90. The same limits will be found in men acclimated to the moderate altitudes.

On ascending passively to a high altitude, such as 14,000 feet, there is at first no noticeable increase in the rate of heart beat. What happens after the ascent depends on the condition of the subject. If he has ascended much beyond what has been spoken of as the critical altitude line for the individual an attack of mountain sickness is to be expected. If he has not passed his critical line, or only reached it, his pulse rate will continue for some hours at the tempo common to it at the lower altitude. Any exertion will obscure the altitude reaction; if, however, he remains quiet, by the next morning, even while still in bed, the pulse rate will be slightly accelerated. Each successive morning for three to five days the rate will be found to be somewhat greater than on the previous morning. The following example illustrates the amount of change: Thus one subject who had in Colorado Springs (altitude 6,000 feet) an average early morning rate of 53, had on Pike's Peak the first morning a rate of 58; the second 60; the third 63; and the fourth 66. In those who are influenced by altitude sickness the story is different. The heart accelerates as the attack of mountain sickness comes on, and the early morning pulse rate may have reached its maximum by the first morning. As the attack passes off the heart will slow. An example of this reaction is found in the following subject, who had in Colorado Springs an average early morning pulse rate of 61. He became mountain sick six hours after arriving at the summit of Pike's Peak. His pulse rate the next morning was 89, slowing to 80 the second; to

78 the third; and to 72 on the fifth morning. In men who undergo the exertion of climbing a mountain the pulse rate reaction is quite like that observed in those who become mountain sick. The increase in the heart rate has been found to range from 30 to 74 per cent. The amount of acceleration at high altitudes is determined to some extent by physical fitness. There will be less acceleration in the man who is in the pink of condition, while the augmentation is great in those who had been leading a sedentary life and are physically below par. The daily mean pulse rate for men at high altitudes shows approximately the same proportionate increase as the early morning pulse rate does when compared with rates experienced at lower altitudes. The influence of posture upon pulse rate has been investigated, and it has been established that the heart is not necessarily more irritable to changes in body position at high than at low altitudes. In general it may be said that the heart works at an increased rate in all postures at the high altitude. The amount of increase in the pulse rate differs with individuals. Some men will show at the high altitude, such as 14,000 feet, an acceleration of only a few beats over the low altitude rate, while others show an increase of 10 or more beats per minute.

During a sojourn at a high altitude the pulse rate may show a gradual daily increase for a period of one or two weeks, ordinarily not more than one week. With longer residence there is a tendency to return toward the low altitude rate. It appears that the slowing of the heart takes place as other adaptive changes reach their maximum efficiency. Rarely does the pulse rate return completely to the normal rate of the low altitude.

ARTERIAL PRESSURES.

In recent years stress has been laid on blood pressure findings at high altitudes, the value of which has undoubtedly been overestimated. Just what normal blood pressures are at sea level is a matter concerning which there is the widest diversity of opinion. Janeway states that " in the great majority of young males, 100 to 130 mm. will be found ", and names the normal diastolic pressure as from 65 to 110. Faught states that 120 may be taken as the normal systolic pressure in the male at the age of 20 and adds 1 millimeter for every additional 2 years of life. He believes that the question as to what variations from this are normal can not be definitely answered, but suggests 17 mm. above or below, or a total variation of 34. The most satisfactory data on blood pressures, as far as the interpretation of altitude effect is concerned, is that obtained from observations made upon the same men at both a low and a high altitude. Such comparisons have been made on Pike's Peak. Data, accumulated during a period of more than 5 years in the laboratory at Colorado College in Colorado Springs, show that at an altitude of 6,000 feet the systolic pressure is in the majority of young men less than 120 mm. and falls within the range given by Janeway. The diastolic pressure likewise corresponds to that observed in young men at sea level. We may conclude then that at moderate altitude, normal healthy young men show the same range and distribution of pressures as do young men at sea level.

Many physicians still believe that at high altitudes, such as 14,000 feet, the blood pressure increases simultaneously with the decrease in atmospheric pressure, and they conclude that this increase means injury, especially to the weakened heart. The investigations of more recent years show that this opinion is untenable. The observations on Pike's Peak which extend over a number of years and which were made upon men who ascended the mountain passively show that in those who react well to the altitude the changes were surprisingly slight, in fact, they were so slight that they fall for the most part within the errors of observations. Schneider and Sisco concluded that for many, and very likely the vast majority of healthy men, an altitude of 14,000 feet does not influence the arterial blood pressures. In a certain but as yet undetermined percentage of men this altitude will cause a demonstrable fall, and in exceptional men, particularly those who do not react well to the high altitude, will bring about a rise in the arterial pressures.

During an attack of mountain sickness there will be manifested a disturbance in circulation, as shown by the definite rise in the arterial pressures. Thus in one subject the following changes in pressure were noted during and after an attack of mountain sickness: In Colorado Springs, 6,000 feet, he averaged in systolic pressure 118, and in diastolic 85. On going to the summit of Pike's Peak he was ill with mountain sickness the first three days, during which time his systolic pressure averaged 129, and the diastolic pressure 91. However, by the morning of the fourth day he was decidedly better, in fact, had recovered, and during the next three days his systolic pressure averaged 116, and the diastolic 84. The fear of high altitudes undoubtedly is a result of over-emphasis of the circulatory conditions observed during the early days spent at a high altitude when the organism has not as yet accommodated itself to the new conditions of environment. Certainly after adjustment the blood pressures do not show an important change.

VENOUS BLOOD PRESSURE.

Venous pressures have not received the same amount of attention at either high or low altitudes as have the arterial pressures. It is only in recent years that satisfactory methods of observing venous pressure have been available. Hooker in Baltimore finds that in healthy men the venous pressure varies or ranges between 2 and 16 centimeters of water. Schneider and Sisco found the same pressures may be considered as normal on healthy young men at an altitude of 6,000 feet. On Pike's Peak they find a marked fall of between 20 and 87 per cent in the venous pressure of healthy young men. The changes in venous pressure occurred slowly, in fact, in some of their subjects the pressure was somewhat higher during the first half day spent at the higher altitude. While the venous pressure was shown to fall, they found the venous supply of blood and the venous pressure remained sufficient at the altitude to give a maximum efficiency of heartbeat.

CAPILLARY BLOOD PRESSURE.

Lombard has shown for low altitudes that the most compressible capillaries disappear at a pressure between 15 and 25 millimeters of mercury. The average capillary between 35 and 45 millimeters, and the most resisting capillaries between 60 and 70 millimeters. On Pike's Peak the capillary pressures were in some men slightly lower than when at an altitude of 6,000 feet, while in others the capillary pressures were unaffected by altitude.

It has been frequently claimed that bleeding from the nose, lips, gums, lungs, and stomach is a common experience at high altitudes and this has been attributed to increased capillary pressure. The above observations show this conclusion to be incorrect. Among the thousands of people that ascend Pike's Peak every summer there occur only a few cases of hemorrhage and these are of the nose only. Such cases are so rare that doubt would be thrown on the usual explanation, even in the absence of positive proof that capillary pressure is not increased with altitude.

THE OUTPUT OF THE HEART AND THE RATE OF BLOOD FLOW.

Attempts made to determine the output of blood per beat from the heart have not been very successful. By use of the recoil method of Yandell Henderson the mass movement of the blood has been studied on Pike's Peak. The observations indicate that the output of the heart is either the same as at low altitude or may be slightly less. It is assumed that the pulse pressure is an index of the heart output per beat. Since it has been shown that the pulse pressure is the same at the high and low altitudes for particular subjects under observation we may be permitted to conclude that the output of the heart is unchanged with altitude. If the pulse rate be multiplied by the pulse pressure and the product be taken as a relative measure of the volume of the blood stream per minute, a marked increase in the circulation rate is indicated for high altitudes.

That the rate of blood flow is increased with altitude has been shown by two researches. Schneider and Sisco used Stewart's calorimeters to determine the rate of the blood flow through the hands. The method determines the amount of heat given off by the resting hand in a given time and indirectly the temperatures of the arterial and venous blood. With these data it is possible to calculate how much blood has passed through the hand in order that it might give off a determined amount of heat. By this method the blood flow through 100 c. c. of hand volume was shown to be from 30 to 70 per cent greater, in six men studied, on the summit of Pike's Peak than in Colorado Springs. Kuhn, on Monte Rosa, also has demonstrated, by calculations made from determinations of the oxygen capacity of the blood, the total oxygen consumption and the pulse rate, that the per minute output of the heart is increased at that high altitude.

WHAT CAUSES THE CIRCULATORY CHANGES REPORTED AND THE INCREASED RATE IN FLOW?

All adaptive changes occurring at high altitudes seem to be for the purpose of supplying a more adequate supply of oxygen for the tissues. If, therefore, oxygen want is the cause of the observed increase in the flow of the blood, it is to be expected that the inhalation of pure oxygen while at the high altitude may so benefit the body as to retard the heart and diminish the rate of the blood flow. Schneider and Sisco found that the breathing of an oxygen-rich mixture while on Pike's Peak slowed the heart appreciably and diminished the rate of the blood flow through the hands; from which we may conclude that lack of oxygen calls forth certain definite circulatory responses in men for the purpose of increasing the rate of blood flow, in order that the oxygen pressure may be sufficient to furnish the tissues with the oxygen needed as the blood passes through the capillaries.

THE EFFECTS OF PHYSICAL EXERTION ON THE PULSE RATE AND THE BLOOD PRESSURES AT HIGH ALTITUDE.

The normal circulatory conditions for the majority of men at high altitudes are an increased rate of heart beat and an unchanged, or slightly lowered, arterial pressure, and a lowered venous pressure. All investigators have found that a more marked increase in the pulse rate occurs during work at a high than results with the same exertion at a low altitude. Just what height must be reached before altitude accelerates the exercise pulse rate has not been definitely determined, but the inhabitants at 6,000 feet show no noticeable exercise altitude effect. Observations on the after-effects of walking for 15 minutes at the rate of 3 and 4 miles per hour. show clearly that physical exertion accelerates the heart more at a high than at a low altitude and that the influence is disproportionately increased as the amount of work is increased. The effect of the lowered barometric pressure is manifest not only in the greater acceleration of the heart, but in the great extention in the time required for the rate to return to the normal after work has ceased. Furthermore, these altitude reactions are greatest during the first days and become less as the individual becomes acclimated. The arterial pressures will be higher after a given rate of walking at a high altitude than after the same amount of work at a lower altitude. Here likewise the greater the exertion the more pronounced is the influence of lowered barometric pressure. In physically fit men the effect of altitude is much less. The facts show that the heart and the blood vessels undergo a greater strain under exertion at the high than is experienced for the same form of exercise at low altitudes. The excessive response of the circulatory mechanism during and immediately following physical work is greatest during the first days; and descreases, particularly for moderate exertion, as the bodily changes of the acclimatization progress. For persons in excellent physical condition and who have reacted well to the altitude the changes of the acclimatization will permit of moderate exertion without a lowered barometric pressure manifesting itself by the more pronounced acceleration of heart rate and increased blood pressure. The evidence at hand makes it probable that in vigorous work, even in those who are best adapted to the high altitudes, one will continue to get a more pronounced reaction than would occur at a low altitude. In order that the effects of acclimatization may be better understood the following examples of the circulatory effects of altitude are given: Walking for 15 minutes at the rate of 3 miles an hour in Colorado Springs one subject had the following changes: An increase of 11 beats in pulse rate and no change in systolic and diastolic pressures. During the first day spent on Pike's Peak a similar walk accelerated the pulse 34 beats, caused a rise in the systolic pressure of 28 mm., and in the diastolic 4 mm. On the fourth day of residence this amount of work accelerated the pulse only 24 beats, increased the systolic pressure 8 mm., and did not affect the diastolic pressure. This same subject, walking at the rate of 4 miles per hour for 15 minutes in Colorado Springs had the following reactions: Average increase in pulse, 24 beats; systolic pressure, 6 mm.; and diastolic pressure, 1 mm. The first day spent on Pike's Peak, this amount of exercise accelerated to pulse 61 beats, systolic pressure 44 mm., and diastolic pressure 7 mm. On the fourth day the pulse increased 54 beats, systolic 23 mm., and diastolic 4 mm. These observations suggest that it would be best to avoid physical work during the first days spent at very high altitudes.

It is to be expected that living at a high altitude, especially when much physical work is done, will increase the weight of the heart, for all muscular exertion tends to increase the weight of the heart, and the result of the work at high altitudes would accentuate the tendency. Strohl compared the heart of Alpine snow birds living at altitudes ranging from 6,700 to 10,000 with the Moor snow bird, which is not found above 2,000 feet, and found that the average weight of the heart of the Alpine snow bird was about 46 per cent heavier than that of the Moor bird. The hypertrophy of the right was greater than that of the left ventricle. He made one observation of considerable interest, in which he found that the heart of a young Alpine snow bird one and a half months old had the same proportions in weight as that of the Moor snow bird, which suggests that the differences ordinarily observed at the two altitudes are due to the greater circulatory reactions called forth during muscular work at the high altitude.

RESPIRATION AT HIGH ALTITUDE.

It has been known since the researches by Haldane and pupils that the volume of fresh air taken into the lungs per minute during rest is so regulated as to keep the partial pressure of carbon dioxide in the alveolar air practically constant for the individual. Therefore the carbon dioxide content of the alveolar air is taken as an index of lung ventilation. The breathing, however, is dependent on the integrity of a very small area, the respiratory center, of the brain in the medulla oblongata. The reaction of this center is regarded as automatic, and any interference with its supply of properly aerated blood causes greatly increased activity and thereby increased breathing. Carbon dioxide in the blood is the stimulant which excites this nervous center of our respiratory mechanism and maintains its regular action. There is no doubt that slight changes in carbon dioxide in the blood affect the respiratory center. The effects of these changes are rapid and marked when in laboratory experiments with animals all the nervous connections between the lungs and the respiratory center are severed. A decrease in the amount of oxygen in the blood will also affect the respiratory center. It is generally held that the amount of oxygen must be markedly lowered before the respiratory center begins to be stimulated by the decrease in oxygen. For our present purposes, the explanation of the breathing changes at high altitudes, attention may be centered on the carbon dioxide content of the blood and in the alveoli of the lungs. Both the percentage of oxygen and that of carbon dioxide are very constant in the alveolar air in spite of great changes in the amount of oxygen consumed and carbon dioxide given off by the body. Since the volume of fresh air taken into the lungs per minute is so regulated as to keep the partial pressure of carbon dioxide in the alveolar air practically constant for each individual (at about 40 mm. for adult men at sea level), the alveolar ventilation must vary according to the mass of carbon dioxide given off. Even during muscular work this rule holds approximately true under ordinary conditions. A diminution in the alveolar carbon dioxide pressure has been found to indicate an increase in the lung ventilation, while an increase in carbon dioxide means lessened ventilation and a reduction in alveolar oxygen.

The ventilation of the lungs for people dwelling at high altitudes is greater than that of mankind living at sea level. On going from sea level to an altitude of 6,000 feet, with a fall of about 145 mm. from normal in barometric pressure, the alveolar carbon dioxide pressure is lowered about 4 mm.; and on further ascending to the summit of Pike's Peak (14,110 feet) with an added decrease of about 160 mm. in barometric pressure, the alveolar carbon dioxide pressure falls on an average about 10 mm. more. This is a little more than a 30 per cent decrease and indicates a corresponding increase in the breathing. The full extent of the fall takes about two weeks to develop, and thereafter the carbon dioxide pressure will remain practically steady.

If the same alveolar carbon dioxide pressure were to be maintained on Pike's Peak with a barometric pressure of about 457 mm. that is normal at sea level, there would be a marked shortage of oxygen. This would be true, because a deficiency of oxygen in the alveolar air always runs parallel to the excess in carbon dioxide. If the carbon dioxide pressure remained at 40 mm. while the atmospheric pressure had fallen from 760 to 457 mm., it would amount to a relative increase of about 27 per cent in the carbon dioxide and a similar decrease in oxygen. The partial pressure of oxygen in the alveolar air would therefore be about 50 mm. lower than in the inspired air. Allowing for the pressure of aqueous vapor at body temperature, it is found that the pressure of oxygen in the lungs at the altitude of Pike's Peak would be 36 mm. This is an oxygen pressure which would be found if dry alveolar air contained only 5 per cent of oxygen at normal atmospheric pressure, and it is known that marked symptoms of want of oxygen are ordinarily produced under such conditions. Parallel with the fall of about 13 mm. in the alveolar carbon dioxide pressure on Pike's Peak there occurs a rise in the alveolar oxygen pressure of a little more than 16 mm. so that the alveolar oxygen pressure at that altitude is about 52 mm. This rise in the oxygen above what might be expected when carbon dioxide remains unchanged is due to increased breathing.

On going to a very high altitude the breathing is increased at once and the alveolar carbon dioxide pressure falls correspondingly, but if the altitude is only very moderate there is at first no effect on the breathing. After some days, however, it will be found that the alveolar carbon dioxide pressure has fallen, indicating that the breathing is deeper. The fall reaches a certain amount and the breathing a certain depth, depending on the altitude, and then ceases. Studies on persons residing permanently at different altitudes show that there is a progressive decrease in the alveolar carbon dioxide pressure corresponding to increase in altitude. For every fall of 100 mm. of barometric pressure there is approximately a fall of 4.2 mm. in the pressure in the alveolar carbon dioxide. There is likewise a progressive fall in the oxygen pressure, but this does not follow exactly the same ratio as the carbon dioxide changes. The following illustrates alveolar air altitude changes:

	Barometer.	Carbon dioxide pressure.	Oxygen pressure.
		Mm.	*Mm.*
Sea-level	760	40	100
6,000 feet	615	36	78
14,100 feet	458	27	53
24,600 feet	312	21	33

That the diminution in carbon dioxide is a response to the diminished oxygen pressure there can be no doubt. If the barometric pressure is kept steady and the oxygen pressure is diminished by lowering the percentage of oxygen, the results are precisely the same as those obtained with changes in altitude.

Since the content of carbon dioxide and oxygen in the lung alveoli give an index of the total ventilation of the lungs in breathing, frequent chemical analyses of the alveolar air during and after an ascent will indicate how much the breathing is increasing. As stated above, the breathing responds at once as an ascent is made, but the changes are not completed for several weeks. The following data will illustrate the rate of change:

	Percentage of gases in alveolar air.		Partial pressure of gases in alveolar air.	
	CO_2.	O_2.	CO_2.	O_2.
Sea-level	5.55	14.08	39.6	100.4
Colorado Springs	6.54	12.94	37.3	73.8
Pike's Peak (14,110 feet)	7.8	....	32.2	....
40 minutes after arrival	7.52	11.38	31.1	47.1
Second day	7.41	11.26	30.7	46.6
Fourth day	7.21	....	....	....
Seventh day	7.21	11.98	29.6	49.0
Twenty-eighth day	6.63	13.08	27.4	54.0

In physiology it is found that the action of gases within the body is determined by the pressure and not by the percentage of gas. The above table shows that the percentage of alveolar carbon dioxide rises with the altitude, but as its partial pressure is determined by the barometric pressure we find that there is a fall in the alveolar carbon dioxide partial pressure as altitude increases. As the partial pressure of carbon dioxide in the alveolar air is about a third less (about 27 mm. as compared with 40 mm.) on Pike's Peak than at sea level, it is evident that the alveolar ventilation during rest for an equal production of carbon dioxide is about 30 per cent greater than on Pike's Peak. Actual measurements show that the volume of air breathed by a subject on Pike's Peak is 27 per cent greater during rest in bed, about 31 per cent greater when standing at rest, about 50 per cent greater when walking at the rate of 4½ miles per hour, and 100 per cent greater during more severe exertion than for similar experiences at sea level. An increase of 30 to 50 per cent in the air breathed when the subject is at rest is not noticeable subjectively. During hard work, on the other hand, an increase of 50 per cent in alveolar ventilation is very noticeable since panting becomes excessive with a good deal of muscular work. During hard work, even at sea level, the depth of breathing is about maximal. Hence the increased alveolar ventilation at a high altitude during exertion implies a corresponding increase in the frequency of breath, with a corresponding increased sense of effort. It is clear, therefore, that at the high altitudes, such as 14,000 feet, there is excessive hyperpnea on exertion. The hyperpnea is probably about three times greater than would be the case with a corresponding exertion at sea level. Walking at the rate of 4 miles an hour at sea level would cause no respiratory inconvenience, but the same work at 14,000 feet causes extreme and urgent hyperpnea. Excessive hyperpnea on exertion persists at 14,000 feet during the entire sojourn, but it becomes less marked after the first day or two.

During inaction the breathing at high altitude is ordinarily modified only in depth. The rate of breathing at sea level varies normally between 14 and 18 breaths per minute. In many men this rate also continues at an altitude of 41,000 feet. During exertion the rate must increase since at sea level for a given exercise the breathing is often maximal. It follows, therefore, that the same exertion at the high altitude, if it increases the total ventilation of the lungs, can only do so by increasing the rate of breathing. The following observations made on Pike's Peak clearly prove the above statement: The subject had breathed when in bed at sea level at the rate of 16.8 breaths per minute, when on Pike's Peak 17.3; on standing at sea level 17 breaths per minute, on Pike's Peak 20; walking at the rate of 4 miles per hour at sea level 17.2 breaths per minute, on Pike's Peak

29; and at the rate of 5 miles per hour at sea level 20 breaths per minute, on Pike's Peak 36.

To explain the fall in alveolar carbon dioxide pressure and the increased ventilation of the lungs at high altitudes it is necessary to consider the changes that occur in the blood. Greater stress was laid by Mosso upon the diminished carbon dioxide in the breath, not because its diminution is of any importance in the breathing, but because this is the reflection of a lowered carbon dioxide pressure in the body generally. Want of carbon dioxide would, other things being equal, affect the affinity of the blood for oxygen. Decreased carbon dioxide alone in the blood would increase the affinity of the blood for oxygen. However, with the increase in altitude it is found that the affinity of the blood for oxygen remains approximately unaltered in spite of the lower carbon dioxide tension. This suggests that as one ascends the carbon dioxide in the blood is replaced by something else which produces an equal effect on the affinity of the hemoglobin for oxygen. A study of the dissociation curve of the blood made by Barcroft at various altitudes indicates that there is an increase in the acid radicals, or a decrease in the bases of the blood. The higher the altitude reached the more marked is the acidosis, but at any given altitude the acidosis and the diminution of carbon dioxide so nearly balance each other that the reaction of the blood remains practically constant. Only a very careful study has been able to show that the increase of acidity is slightly in excess of the loss of carbon dioxide. This would lower the affinity of the blood for oxygen very slightly; but at the same time the change would be sufficient to give the increased stimulation to the respiratory center, which would account for the increased ventilation of the lungs. What acid is responsible for the acidosis in the blood at high altitudes has not yet been ascertained. It was once thought that lactic acid appeared in the blood with the acclimatization to high altitude, but this is not maintained at present. It may be that there is no increase of acid at all, but, rather, a diminution in the amount of alkali present. The fact that the alkalinity of the blood is diminished at high altitudes was first demonstrated by Galeoti in 1903. At that time it was already known that lactic acid is produced by an excessive muscular exertion, as a consequence, no doubt, of a lack of oxygen in the active muscles, and this suggested that lactic acid is formed when the organism experiences the oxygen want at high altitudes. But the excess of lactic acid formed during muscular exertion disappears again within an hour, together with its effect on the alveolar carbon dioxide pressure. If the diminished alkali of blood at high altitudes were simply due to lactic acid formed in excess, we should similarly expect this diminished alkalinity to disappear and appear rapidly, and would expect similar marked variation in the alveolar carbon dioxide pressure. The increase in acid in the blood and the lowering of the alveolar carbon dioxide, however, require days to develop. Vezar has shown that oxygen want increases the activity of the kidneys, which suggests that oxygen want so affects the kidney that it excretes alkali more freely. It certainly looks as if the blood and the breathing changes were due to some adaptive alteration in the regulation of blood alkalinity. "The fixed alkalinity of the body as a whole, including the blood, is evidently regulated normally by the action of the kidneys, although the liver, by varying the amount of ammonia in the blood, may also contribute to the regulation. A slight and gradual adaptive alteration in what one may call the exciting threshold of alkalinity for the kidneys would explain the reduced fixed alkalinity of the blood in acclimatized persons." The above observations, if correct, indicate that there is a loss of reserve alkalinity among the inhabitants of high altitudes which may place the body at a disadvantage in certain pathological conditions.

OTHER ALTITUDE RESPIRATORY OBSERVATIONS.

Periodic breathing is frequently observed among newcomers at very high altitudes—the type varying in different persons. It may occur in groups of three or four breaths, each succeeding breath being deeper than the preceding one and each group then followed by a pause in breathing; or there may be no pause, the breaths occurring in groups of 6 to 10 in which there is a gradual increase in depth to the mid-point and then a gradual decrease. The periodic breathing often is initiated by muscular exertion and may be started at any time by a few forced breaths or by holding the breath a few seconds. No doubt the spontaneous periodic breathing met with at the high altitudes depends upon want of oxygen in that it has been shown that it may be abolished by the administration of pure oxygen. Periodic breathing disappears in the majority of men as they become acclimated to the altitude.

The ability to hold the breath is decreased at high altitudes. It has been found that when first arriving at 14,000 feet men may be able to hold the breath almost as long as at a low altitude. Day after day, for some time, it will be found that the voluntary effort of holding the breath becomes greater and that the period of holding grows shorter. No doubt the ability to hold the breath decreases as the acidosis of the blood increases.

It is a popular belief that high altitudes increase the size of the chest and the vital capacity. Humboldt, in 1799, claimed to have observed this increase in people of the Andes; and Williams noted the same result after residence in a high mountain resort. With these exceptions all observers agree that for the majority of persons the low atmospheric pressure alone does not increase the vital capacity. It has been shown that the enlargement of the heart at high altitudes is the result of the greater demands made upon that organ during physical exertion. If the chest should be found larger among the inhabitants of high altitudes it likewise may be explained by the increased demand made upon the breathing during muscular effort. The immediate effect of altitude is to cause a slight decrease in the vital capacity. A comparison made of men, at a low and high altitude, indulging in outdoor sports, would show that the vital capacity and the chest measurements are similar. Use makes the organ, and the size of the chest depends upon the demands made in breathing by physical exertion during the period of growth.

THE OXYGEN PRESSURE OF THE ARTERIAL BLOOD AT HIGH ALTITUDES.

The problem which concerns us here is to determine the forces by which oxygen is transported from the alveolar air of the lungs into the blood. With increasing altitudes the air is reduced and oxygen tension becomes lower and lower. At a height of about 15,000 feet the barometric is little over half that of atmospheric pressure and the oxygen tension, therefore, only about 11 per cent of an atmosphere. As has been pointed out, the presence of man at any considerable altitude necessitates adjustment on his part so that the persistent undiminished oxygen requirement of the body can be satisfied under the enforced changes of atmospheric conditions. Three of the possible means of providing the necessary oxygen have already been discussed. The fourth possibility is still under debate among physiologists. All the symptoms of altitude sickness, due to the diminished barometric pressure, depend directly or indirectly upon the diminution of arterial oxygen pressure and the consequent imperfect aeration of the arterial blood and deficient saturation of its hemoglobin with oxygen.

The passing of oxygen from the alveolar air into the blood of the lung capillaries may be wholly the result of diffusion of oxygen, in which case it would pass from a place of high to one of low pressure. If oxygen passes from the alveoli only by diffusion, the pressure of oxygen in the blood will always be less than, or at the best equal to the alveolar oxygen tension. If the pressure of oxygen in the blood is under certain circumstances, higher than that of the alveolar air there can be no doubt that forces other than diffusion must come into play. This would necessitate an active secretion by the epithelial cells of the lungs. At sea level, during rest, the arterial oxygen pressure is practically identical with the alveolar oxygen pressure. The Anglo-American Pike's Peak Expedition in 1911 made a careful study of the arterial oxygen pressure and found in every case that the arterial oxygen pressure in men on Pike's Peak was much above the alveolar oxygen pressure. The average excess of oxygen pressure in the arterial blood was 35.8 mm.; the mean normal resting alveolar oxygen pressure 52.5 mm.; the arterial oxygen pressure, therefore, 88.3 mm. The alveolar oxygen pressure at sea level is about 100 mm. and that of the blood about the same. At sea level the arterial blood is 96 per cent saturated with oxygen, while on Pike's Peak, if the changes of acclimatization are well established, it is 95 per cent saturated. One subject was examined within an hour after reaching the summit of Pike's Peak by railway. His face had a distinctly bluish color and he suffered somewhat severely from mountain sickness during the ensuing 24 hours. At this time—the time of the experiment—his arterial oxygen pressure was 52.7 millimeters, or only 7 millimeters above the alveolar oxygen pressure. Three days later, when he had become acclimated, feeling perfectly well and with normal color, the arterial oxygen pressure was 81.4 millimeters, or 40.7 millimeters above the alveolar oxygen pressure. These results are very striking and point consistently to the conclusion that in acclimatization to high altitudes the lungs acquire the power of raising the arterial oxygen pressure by actively secreting oxygen.

Certain indirect evidences support this theory of oxygen secretion. It was found on Pike's Peak, on saturating the blood with alveolar air in a saturator, that the blood was noticeably dark in color as compared with the blood when drawn. It is well known that men can live and work at higher altitudes than that of Pike's Peak. In the explorations of the Duke of the Abruzzi in the Himalayas he and his companions climbed to an altitude of 24,580 feet; the atmospheric oxygen pressure saturated in inspiration would be 55.4 millimeters and the alveolar oxygen pressure only 21 millimeters. Blood saturated with alveolar air at this pressure would be less than half saturated with oxygen, which is the percentage found in the arterial blood of animals at the point of death from asphyxia. Nevertheless, at this altitude the members of the expedition felt well and were able to do the climbing necessary in attaining the altitude. The recent advances in knowledge as to the blood gases and the physiology of respiration make it difficult to explain by the simple diffusion theory the reactions above quoted. Haldane and his colaborators have found that at sea level muscular work may furnish a powerful stimulus to secretory absorption of oxygen by the lung epithelia tissue. Therefore one advantage in indulging in heavy muscular work would be to train the lungs in oxygen secretion.

THE VALUE OF THE FACTORS OF ACCLIMATIZATION.

The acclimatization to oxygen want in mountaineers or persons living at high altitudes is evidently attributable to four factors:

The increased breathing, the increased percentage of hemoglobin, the increased rate of blood flow, and the increased oxygen tension in the blood, the result of increased activity of the lung epithelium.

There are varying degrees of susceptibility to want of oxygen among any group of men exposed to low barometric pressure. With a rapidly falling oxygen pressure some persons simply become blue and lose consciousness without the adaptive mechanisms of the body making any evident response. Men who are fortunate enough to possess brain centers sensitive to oxygen want will respond quickly to the stimulus of a lack of oxygen and either escape or have only a mild attack of mountain sickness. On the other hand, those with an insensitive nervous mechanism will fail to respond, or be so slow in doing so that a period of altitude sickness must be expected. This sickness will begin to wane when the adaptive changes begin to be manifest. There are marked individual differences which are no doubt associated in some way with the freedom of the blood supply to the brain. Ordinarily on ascending a mountain the respiratory adjustment occurs first, beginning almost at once; it requires, however, several weeks to become complete. After some delay the blood changes, the increase in the rate of blood flow, and the so-called oxygen secretion manifest themselves. The order of their onset and the rapidity of development will depend on the physical condition of the individual and the sensitiveness of the brain centers to low oxygen.

There is at the start a rapid increase in each of the factors involved, followed by a more gradual continuation of the effect extending over some weeks. The increase in the rate of blood flow and the oxygen secretion by the lungs are developments of the first two or three days spent at the high altitude. The blood changes, while rapid during the first few days, require more than five weeks to reach their maximum value. The changes in the breathing, the blood, and in oxygen secretion are of a permanent character and will not diminish with a prolonged residence at the high altitude. The changes in the rate of blood flow are of a less permanent character; with the acclimatization the pulse rate returns somewhat toward the sea-level values. Undoubtedly the heart is under a greater strain during the early days spent at a high altitude than later, when the adaptive changes have been completed. Physical fitness usually assures an early and rapid response to the stimulating effects of low oxygen at the high altitude. Fatigue and other debilitating causes delay the response and make the individual more liable to an attack of altitude sickness.

The longer the period of sojourn at a high altitude the more permanently fixed become the altitude adaptive changes. This fact has been proven by studies on the after effects of high altitudes in those who return toward sea level. If the sojourn at the high altitude were of a short duration, only a few days, on returning the blood is restored almost immediately to its normal composition. The breathing likewise at once takes on the normal depth and rate. After a sojourn of five weeks on Pike's Peak the after effects on descending were shown to be present for a period of at least two weeks. At the end of a six months stay at the same altitude the percentage of hemoglobin, number of red corpuscles, total volume of blood, and total oxygen capacity did not alter at once and were at least 10 weeks in being restored to the low-altitude values. The breathing for 24 hours was as great as when at 14,110 feet and then slowly, throughout a period of 10 weeks, decreased to the normal for the lower altitude. The first days after descending, the pulse rate was about 10 beats below the normal for the low altitude, but later accelerated to the normal for the particular altitude.

The study of the after effects indicates that the aviator remains at the high altitudes too short a period of time to secure permanent adaptive reactions which increase toleration of high altitudes. Repeated experiments in pneumatic chambers and with carbon monoxide occasionally have increased in some men the ability to tolerate low oxygen. The experience in aviation indicates that the changes in altitude during flying are made so rapidly that the compensating mechanisms for low oxygen are overworked to a greater or less degree, and as a consequence instead of securing acclimatization to low oxygen a weakening of the adjusting mechanisms occurs, which renders the flier more liable to an attack of altitude sickness.

PHYSICAL FITNESS AND THE ABILITY TO WITHSTAND HIGH ALTITUDES.

The ability to endure comfortably and well high altitudes is dependent upon the ease and the quickness with which the adaptive responses in the breathing, the blood, and the circulation take place. An explanation of the difference in reaction observed among the members of a group of men when at a high altitude is to be found in the degree of individual physical fitness. In persons damaged by disease, overwork, unhygienic living, or weakened by inactivity and by loss of sleep, the power of adjustment is as a rule below par. The normal equilibrium of the body is so nicely adjusted that under usual conditions the physiological balance is largely maintained by adjustments that are made with little or no expenditure of energy. There is a certain range of greater or less breadth through which the external factors of the environment may be varied and yet be met by an automatic adjustment of the physiological processes in the body which will preserve the vital balance of the mechanism. But beyond a certain point, specific for each organism, changes in the external conditions will necessitate more radical alterations which will tax the compensating mechanisms to the utmost capacity in order to prevent disaster. Theoretically the organism which has been called upon repeatedly to make a certain kind of adjustment will be the one most capable of responding when an extraordinary demand is made. The unusual demand made upon the organism at a high altitude is that of supplying the requisite amount of oxygen to the tissues from an atmosphere that provides oxygen at a greatly reduced pressure. An organism that has always been able to supply its oxygen needs without profound or costly changes because the demands for oxygen have never been excessive or the oxygen supply has never been reduced will most likely not readily respond when it meets a shortage of oxygen. In the everyday experiences of life there arises a marked increase in the demand for oxygen during physical exertion. Excessive exertion may, of course, call for so much oxygen that the adjustments of the body may fail to provide sufficient quantity for complete combustion in the muscles. That this is often the case is proven by the great production of lactic acid during physical work. Since physical exertion does increase the demand for oxygen it is to be expected that the organism which has been called upon to do physical work frequently will have acquired marked powers for compensating for oxygen want.

Comparisons made of animals leading a muscularly inactive life with those of a closely related species whose mode of living calls for much running and great physical endurance show certain well-defined differences attributable to muscular action and the call for oxygen. It has been found that the active animal has a heart which relatively is three or four times heavier than that of the inactive animal. Also the rate of the heart beat is much slower—only about a third—the rate of respiration less, the depth of breathing greater, and the percentage of hemoglobin greater in the active than in the inactive animal. Furthermore, the flesh of the active animal is darker in color, due to the presence of a larger amount of myohematin—the substance with marked affinity for oxygen. These differences are undoubtedly adaptive and fit the organism to supply the tissues with the extra amount of oxygen required during exertion.

The adaptive characters found in physically active animals are very like those that appear in the body of man when he follows a regular and consistent course of physical training, and they likewise are characteristics which will permit the individual to tolerate well high altitudes. Comparisons made of athletic and nonathletic individuals show that the athletic, or better, the physically fit persons possess certain physiological conditions of advantage at high altitudes.

In the physically fit the daily indulgence in physical exercise will be found to have increased the percentage and the total amount of hemoglobin in the blood. With this advantage, if he goes to a high altitude, he quickly responds to the stimulating influence of oxygen shortage by throwing into the circulation the reserve supply of corpuscles and by further concentration of the blood. Consequently the tissues are supplied with blood which per unit of volume is richer in oxygen than it would be if the hemoglobin were less concentrated. In the untrained man there is less hemoglobin, and the changes induced by altitude occur so slowly that he will most likely suffer with altitude sickness because of oxygen want.

In the physically well trained the breathing is slow and deep, while in the untrained it is shallow and rapid. Deep breathing, which can be cultivated by exercise, but not satisfactorily by voluntary attention, ventilates the lungs more effectively than shallow breathing; therefore at a high altitude there is advantage in being a deep breather. It also can be shown that the breathing of the physically fit man responds quickly and well to the high altitude demand for more oxygen, while in the untrained it will be slower in doing so.

At sea level moderate muscular work does not create a great demand for oxygen, but strenuous and prolonged exertion may tax the oxygen-providing mechanisms to their utmost capacity. In order to meet this increased demand for oxygen the lungs may respond by secreting oxygen into the blood. Repeated demands for oxygen secretion would, so to speak, train the lung epithelium for the unusual work. It is suggested that such a reaction by the lungs would be valuable when one ascends to high altitudes, in that the lungs would then immediately begin to secrete oxygen. Oxygen secretion is in the nonathletic type of individual acquired only after several days of residence at a high altitude, but in the vigorous well-trained man it probably begins almost immediately.

As a result of physical training the heart reduces its rate of beating and is less sensitive to changes in posture and to moderate exertion. In the physically fit the heart rate does not increase much on standing, but in the wearied or physically stale subject it increases as much as 44 beats per minute. The vasomotor control of the splanchnic area in man experiences a change of adjustment when the body is moved from the horizontal to the upright standing position. In a robust subject the splanchnic vasotone increases and the blood pressure is raised about 10 millimeters of mercury. In an individual weakened by dissipation, overwork, lack of sleep, etc., the blood pressure tends not to rise, but to fall. Weakness is sometimes shown by a decrease in blood pressure and at other times by an excessive increase in the heart rate.

At a high altitude, especially during the first days of residence, any physical exertion makes a greater demand on the heart than the same amount of work at sea level. In the nonathletic individual the heart reacts excessively as a result of work, while in men in excellent physical condition the reaction at a high altitude is less and the strain on the heart will, therefore, be much less. A trained heart, like a trained muscle, works more smoothly and easily than the untrained, and therefore endures fatiguing work better than the untrained heart.

Medical experience with the "stale pilot" and the "stale athlete" has shown that as a man becomes stale his pysiological condition reverts to that of the nonathletic type of individual. Staleness is recognized by an increased frequency of pulse, which is also poor in volume and low in tension. There will be distress on slight exertion, accompanied by a rapid rise in the pulse rate, which returns only after a long interval to its former rate. The breathing also frequently becomes shallow and rapid, and the extremities become poor in color and cold because of poor circulation.

Most of the symptoms reported as common among aviators while flying are those that are characteristic of mountain sickness. It has been shown that mountain sickness is not so common among robust as among individuals of sedentary habits of living. We may venture to conclude, therefore, that the man who is in the "pink of condition" as a result of consistent and common-sense physical training will be more resistent to the action of altitude than the untrained or the physically stale man.

Medical experience with "stale" aviators shows a type known as the nervous in which there is poor muscular control over balance movements, fine tremors of the hands and eyelids, greatly increased reflexes, loss of sleep, nightmares, and apprehensive starts with slight noise. The influence of high altitudes on the nervous system has not been carefully studied, but there are those who believe that in persons with poor compensation and an unstable nervous system there is increased irritability or hyperexcitability which may manifest itself in motor, sensory, or psychic spheres, or in a combination of them. Associated with the increased excitability there is increased rapidity of fatigue which finds expression in muscular weakness and diminished physical endurance, as well as failure in adaptability and power of concentration mentally. Such persons complain of a mental unrest, approaching anxiety, and find difficulty in carrying on the usual mental requirements of their occupations. Such a condition may be the forerunner of a simple neurasthenia or a more profound neurosis.

The nervous system is exceedingly sensitive to oxygen want. It is significant, therefore, that in the nervous system arrangements are provided for a free supply of oxygen. The lack of oxygen at high altitudes is felt by all body tissues, but especially by the nervous tissues. It seems to be established that there is an irritability of the nervous system that may be attributed to diminished oxygen supply by reason of a failure on the part of certain individuals to compensate adequately to lack of oxygen when at the high altitude.

Relation of altitude, pressure, and oxygen.

mm. HG.	Elevation.	O_2.	mm. HG.	Elevation.	O_2.
	Feet.	*Per cent.*		*Feet.*	*Per cent.*
760	0	20.96	412	16,000	11.39
732	1,000	20.15	397	17,000	10.97
704	2,000	19.38	382	18,000	10.56
677	3,000	18.64	368	19,000	10.16
651	4,000	17.93	354	20,000	9.78
626	5,000	17.25	341	21,000	9.41
602	6,000	16.60	328	22,000	9.05
579	7,000	15.97	315	23,000	8.70
557	8,000	15.37	303	24,000	8.35
536	9,000	14.80	290	25,000	8.01
516	10,000	14.25	278	26,000	7.68
497	11,000	13.73	266	27,000	7.35
478	12,000	13.23	254	28,000	7.03
461	13,000	12.75	242	29,000	6.71
444	14,000	12.28	230	30,000	6.40
428	15,000	11.83			

In order that the reasoning which led to the development of the rebreathing apparatus and the study of man under rebreathing may be understood, it will be necessary to insert here a brief statement concerning our knowledge of the effects of high altitudes. It has been known for a long time that man living at extremely high altitudes may develop what is popularly known as "mountain sickness," during which he exhibits certain definite symptoms. After a shorter or longer period of sojourn at the high altitude, these symptoms pass away and acclimatization takes place. During the last 40 years, but more particularly the last 18 years, physiologists have been carefully investigating "mountain sickness" and the adaptive changes that occur in the body of man and animals living at great altitudes. There has come from this study almost complete agreement of the investigators. There is, in fact, no room now for doubt that the essential cause of all the symptoms of altitude sickness and the adaptive changes within the body is the lack of oxygen, which is the result of the rarefaction of the air that occurs as altitude increases. The fact that there is oxygen want at high altitudes suggested the fact that any mechanism that would permit the breathing of a reduced amount of oxygen could be used to test the ability of men to withstand the effects of low oxygen. The rebreathing apparatus was designed not only to expose man to low oxygen but to a constantly decreasing amount of oxygen. A description of the apparatus and the method of use will be found elsewhere in this report.

In order that oxygen percentages may be translated into altitudes, the relation of altitude and oxygen, as well as altitude and pressure, are shown in chart 1. On referring to the 12 per cent oxygen line, it will be observed that when the subject of experimentation is breathing 12 per cent oxygen, he is physiologically at an altitude of 14,400 feet, and when breathing 10 per cent oxygen the equivalent altitude is 19,400 feet.

One purpose in the method of examining aviators by rebreathing is to reproduce the gradually decreasing oxygen tension that they will experience as they ascend in the air. A sudden disturbance of bodily functions usually is manifested by symptoms of illness. The disturbance brought about by changes of altitude and by low oxygen cause the so-called "altitude sickness." Individuals differ greatly in the power of resistance. Hence, we find that altitude sickness

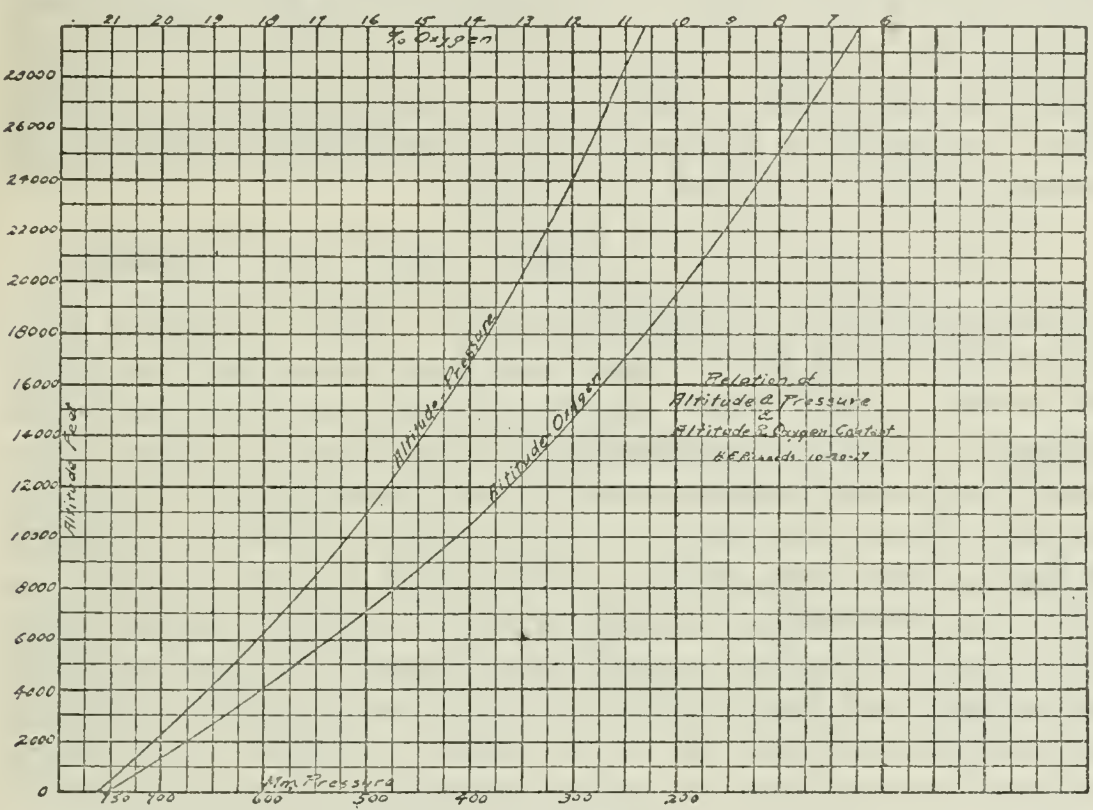


CHART 1.

attacks some at a lower, others at a higher altitude, but it is also certain that no one who proceeds beyond the elevation—that is, the critical line for him—escapes the malady. An elevation of 10,000 feet, or even less, may provoke it in some; others may escape up to 14,000 feet or even 17,000 feet; while only a few possessed of unusual resisting power can, without pronounced symptoms, venture upward to 18,000 feet. The flier himself may not be conscious of the symptoms when they first appear. The degree of illness will be determined by the length of time the subject is exposed to oxygen want. In the rebreathing experiments we produce artificially a mild attack of altitude sickness. The percentage of oxygen at which the symptoms appear will indicate the altitude at which similar symptoms may be expected to occur, provided the length of time given to the rebreathing experiment has not been too short. Throughout rebreathing experiments attention has been directed to a study of the pulse rate, the arterial blood pressure changes, the character and the volume of the breathing, and to the color changes in the skin and mucous membranes. It is well to recall here that in an attack of " mountain sickness " the pulse rate is always accelerated and the systolic and diastolic pressures are higher than in normal life. The patient may feel slightly giddy and there may be buzzing in the ears, dimmed sight, and fainting attacks. The face may be cyanosed and the eyes look dull and heavy. In some degree all of these conditions may occur as the subject undergoes the exposure to low oxygen tension during a rebreathing experiment. Many of the reactions here called " symptoms," which occur under low oxygen tension at high altitudes and during a rebreathing experiment, are simply compensatory changes by which nature endeavors to keep the tissues abundantly supplied with oxygen.

II.—THE PHYSIOLOGY OF REBREATHING AND AVIATION.

The physiological observations made on men and animals living at high altitudes or under reduced atmospheric pressures show clearly that a very marked process of adaptations occurs which renders the mechanism capable of meeting the call of the tissues for oxygen. The aviator must also be able to adapt himself physiologically to altitude changes. The aviator does not remain at high altitudes long enough to benefit from slow adaptive physiological changes, therefore his body must be capable of making rapid compensatory changes which will provide the oxygen needed by the tissues. He must be able to bear abrupt and great changes in atmospheric pressure. Without the occurrence of some one or more definite adaptive physiological responses to provide for his oxygen needs as he ascends, his life and aeroplane become more and more jeopardized as he continues to ascend.

That the body can and does respond to the demands for oxygen during rapid ascents has been proven by laboratory experiments and the experience of aviators and balloonists. The physiological responses that are definite, like those experienced by the mountaineer, are an increased ventilation of the lungs and a more rapid blood flow. In a few men a concentration of the blood may also occur.

It has been clearly established that the essential cause of the adaptive changes within the body when at high altitudes is the lack of oxygen, which is due to the rarefaction of the air that occurs as altitude increases. The fact that there is this oxygen want, suggested that any mechanism that would permit the breathing of a reduced amount of oxygen could be used to test the ability of men to withstand high altitudes. The rebreathing apparatus has been perfected for such tests. During the tests the subject breathes the air in the tank. He sits with a clip placed on the nose and with a comfortably adjusted mouthpiece in the mouth, which is suitably connected by means of inch tubing with light automatic valves. He inhales the air through the respiratory valve direct from the tank and exhales through the expiratory valve into a cartridge containing an absorbent for carbon dioxide. The exhaled air is thus freed from carbon dioxide as it is returned to the tank. A spirometer compensates for changes in volume and writes a record of the respiration upon the revolving drum of a kymograph. By this arrangement the subject continues to rebreathe the air in the tank from which he gradually absorbs oxygen. As the percentage of oxygen decreases, the subject, in effect physiologically, is slowly ascending to higher altitudes. The volume of air rebreathing is sufficient to require between 25 and 30 minutes to lower the amount of oxygen to 8 or 7 per cent, which is equivalent to altitudes of 25,000 to 28,000 feet.

A COMPARISON OF THE REBREATHING TEST AND THE DILUTION TEST.

Comparisons to date of the rebreathing and dilution tests upon the same individuals show a marked similarity in the reactions which occur and demonstrate conclusively that the adaptive changes occurring in both cases are due to low oxygen.

The dilution apparatus[1] used in our laboratory is an arrangement whereby it is possible to let pure atmospheric air or a mixture of atmospheric air and nitrogen pass into a breathing chamber and accordingly, at will, change the relative proportions between atmospheric air and nitrogen. This permits of changing the partial pressure of oxygen at any desired rate, thus producing the same effect as if the partial pressure of oxygen were reduced by mounting in the air.

The rebreathing machine is an apparatus whereby the subject rebreathes a specified amount of air from a tank, thereby causing a gradual and progressive decrease of the oxygen. The CO_2 of the expired air is removed by an absorbent and therefore is not a factor in the test.

Both tests are essentially low oxygen tests, as the nitrogen and CO_2 play no part in producing any of the adaptive changes.

The similarity and parallelism of the reactions in both tests upon the same individuals are marked.

A comparison of many charts showed the average point of acceleration of the pulse to be the same in both the Dilution Test and the Rebreathing Test. Also the limits of compensation for the systolic and diastolic were the same in both. A fall in the systolic at a cer-

[1] See Reports of the Air Medical Investigation Committee, No. 2, England.

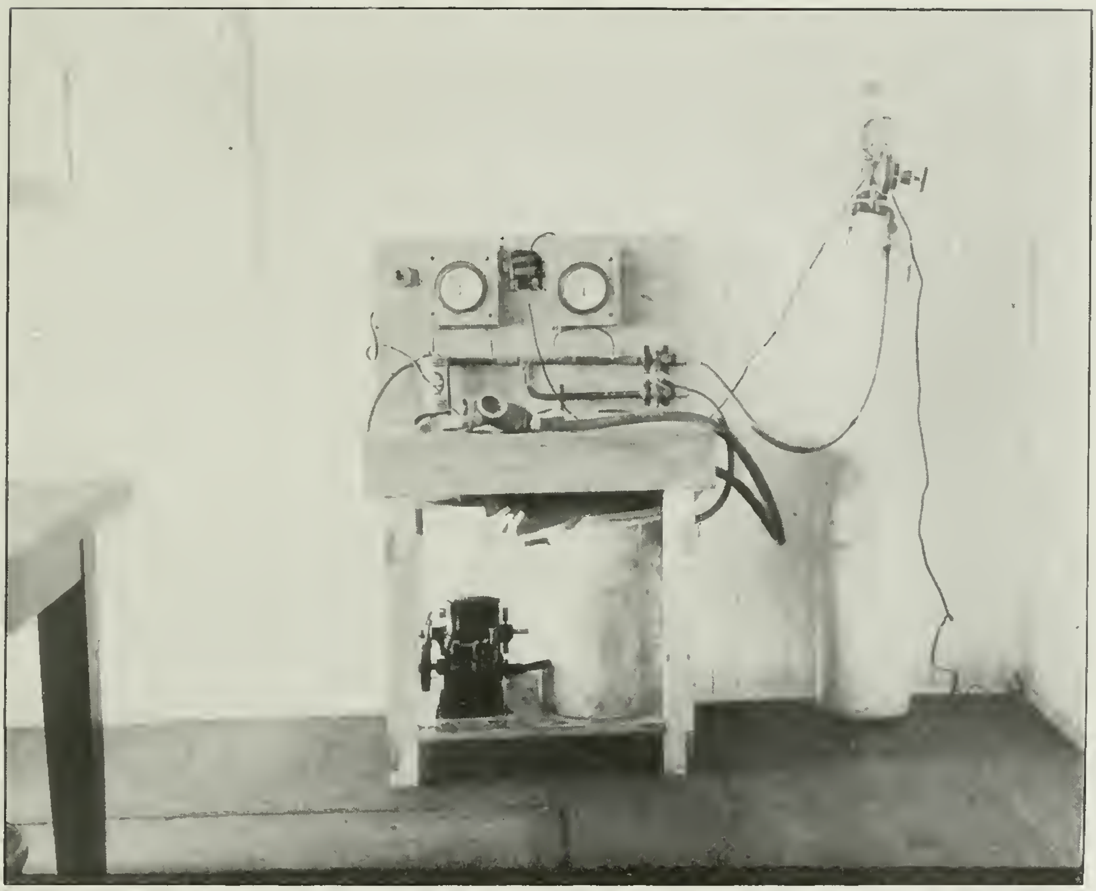
tain percentage of oxygen in the Rebreathing Test was almost invariably accompanied by a fall in the systolic at the same percentage of oxygen in the Dilution Test. The same was true of the pulse rate and diastolic pressure.

Throughout rebreathing experiments physiological, psychological. and other observations are made on the subject of the test. By the physiologist, the rate and per minute volume of respiration, pulse frequency, systolic and diastolic arterial pressures are studied for each candidate tested and have been found to give valuable evidence as to when he first responds to the reduction in oxygen and as to the efficacy of his compensatory reaction. Some men are sensitive to oxygen want and compensate in their breathing and circulation of the blood so that they endure as low as 6 per cent of oxygen. Others fail to compensate in one or both of these mechanisms or compensate inadequately and, therefore, can not endure so low an oxygen per cent. All gradations between failure to compensate and adequate compensation down to 6 per cent of oxygen have been found among the men examined under the low oxygen of the rebreathing tests. From the data obtained during the rebreathing test it becomes possible to determine approximately the maximum altitude to which the aviator may safely ascend.

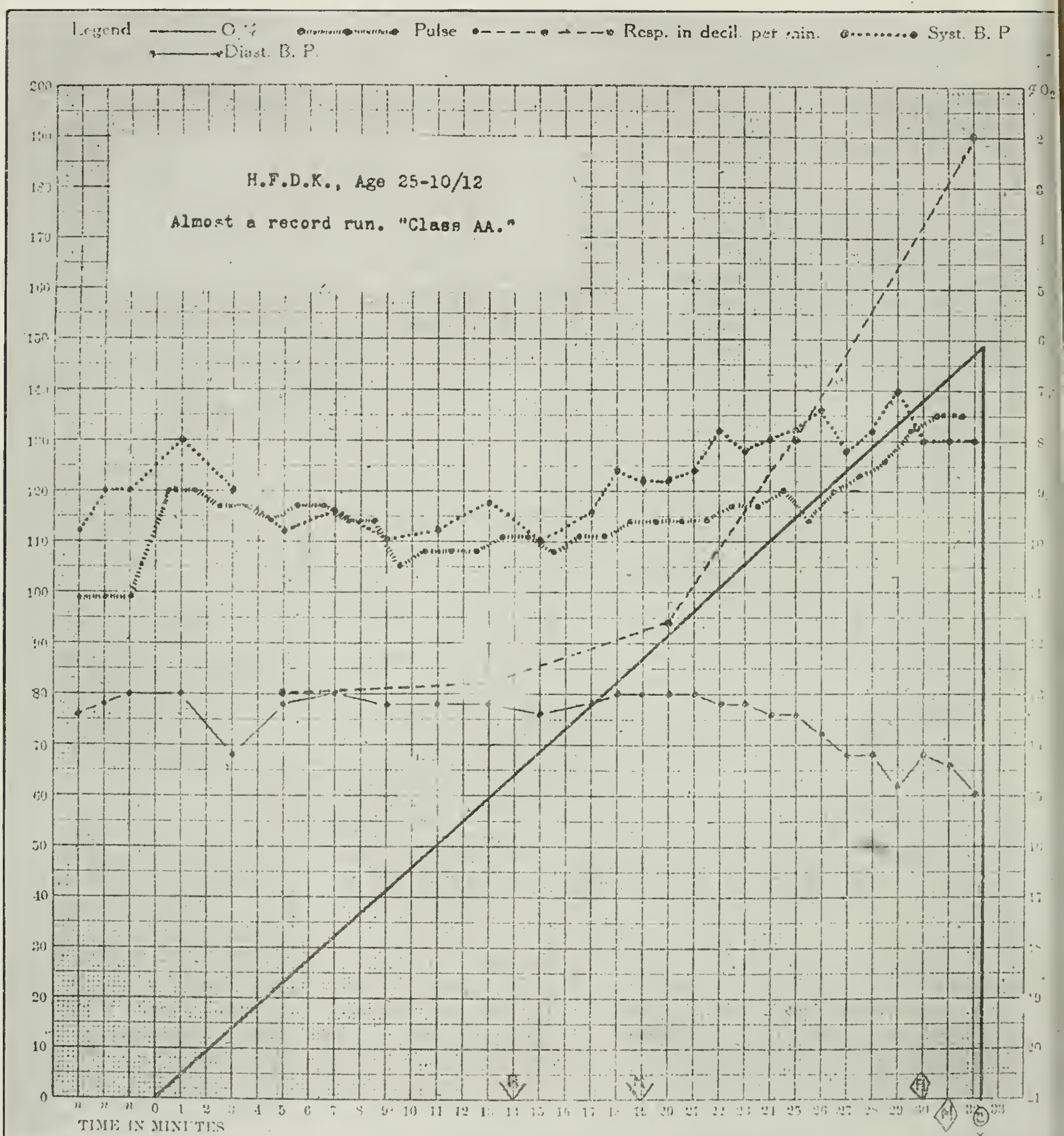
THE BREATHING WHEN UNDER THE ACTION OF PROGRESSIVE DECREASE IN THE OXYGEN SUPPLY.

The character of the breathing undoubtedly has an important bearing on the ability of men to endure at high altitudes. The shallow breather is at a greater disadvantage than the man who breathes deeply when under the influence of low oxygen. In breathing a part of the fresh air remains in the nose, pharynx, larynx, trachea, and bronchial tubes and is emptied out again at the beginning of the next expiration in an almost unchanged condition, without having actually mingled with the air in the alveoli of the lungs. In shallow breathing, therefore, only a comparatively small amount of the fresh air gets past this so-called dead space to mingle with the air in contact with the blood vessels of the lungs. The deeper the breathing the greater will be the amount of fresh air that reaches the aveoli of the lungs and hence the greater will be the supply of oxygen for the body tissues.

The men examined have shown rates of breathing when sitting that ranged between 14 and 25 breaths per minute. Between 40 and 50 per cent breathed at the rate of 18 and 19 breaths per minute. The per minute volume of breathing ranged between 7 and 12.5 liters, with the majority between 8.5 and 9 liters. The average tidal volume of air breathed was 500 cubic centimeters for the group, while the extremes were 360 and 630 cubic centimeters, respectively.



DREYER LOW OXYGEN APPARATUS.


Legend O % Pulse Resp. in decil. per min. Syst. B. P
Diast. B. P.
H.F.D.K., Age 25-10/12
Almost a record run. "Class AA."
TIME IN MINUTES

The smaller volumes of tidal air were found among subjects who breathed most frequently. Thus one man who breathed 24 times per minute had a tidal air volume of 375 cubic centimeters, while another whose rate was 14 per minute had a tidal air volume of 620 cubic centimeters. A slow, deep breathing will, as a rule, introduce more fresh air into the alveoli of the lungs than the shallow, rapid type of breathing.

As the percentage of oxygen gradually decreases during a rebreathing test there occurs a marked respiratory response to the lessening oxygen tension which increases the amount of air breathed per minute. This increase in the lung ventilation in a few men begins with the first decrease in the oxygen percentage of the air breathed and is a gradual proportional increase in inverse ratio with the reduction in oxygen. Over 50 per cent of the men examined gave the first respiratory response between 16 and 14 per cent of oxygen. Twenty-five per cent responded first at a lower oxygen tension, while a small number of men gave no respiratory response to the decrease in available oxygen. The increase in lung ventilation is for the higher percentage of oxygen only slight, but usually becomes more pronounced when the available oxygen has been decreased to between 12.5 and 9 per cent. (See charts 1–6.)

The rate of breathing for many men remain unchanged throughout the rebreathing test. The majority, however, show an increase of from two to four breaths per minute at between 8 and 6 per cent of oxygen. A few of the men examined, shown by other tests to be somewhat physically stale, increased the frequency of breathing enormously. Thus one subject, with a frequency of 22 when sitting quietly breathing atmospheric air, breathed 43 times per minute at 8.5 per cent of oxygen.

The amount per minute volume increase in the breathing during a rebreathing test differs with individuals. The majority of men examined show at per centages of oxygen between 8 and 6 per cent an increase of 5.5 liters over the volume breathed at the beginning of the experiment. This increase gives for the average man a total volume of breathing per minute of approximately 14 liters at oxygen tensions corresponding to an altitude of 25,000 feet. The total per minute volume of air breathed has, in exceptional cases, been as great as 26 and 37 liters of air at oxygen tensions corresponding to from 25,000 to 28,000 feet.

It is the depth of breathing which ordinarily is increased by low oxygen. The vast majority of subjects show an increase in depth of breathing of from 20 to 128 per cent when under 8.5 to 6 per cent oxygen. The volume of each breath in these men if found to range between 600 and 1,260 cubic centimeters, while for the same subjects when sitting quietly breathing atmospheric air the tidal volume is found to range between 360 and 630 cubic centimeters.

A good respiratory reaction to the gradual decrease in the oxygen of a rebreathing test will be manifest in a slight increase in the depth of breathing which begins at 16 or 15 per cent oxygen and continues to progressively increase slightly and gradually until 12.5 to 9 per cent of oxygen. From these percentages down to 8.5 and 6 per cent of oxygen the total per minute volume of breathing increases much more rapidly and the frequency of breathing may also then increase to from two to five breaths per minute. A total per minute increase of at least 5.5 liters should occur at the lower percentages of oxygen. The increase in the depth of breathing which occurs under low oxygen more effectively ventilates the alveoli of the lungs and, therefore, raises the alveolar oxygen tension above that which would be present if the breathing remained unchanged. Such an increase in alveolar oxygen permits the blood to be more thoroughly saturated with oxygen, and consequently the subject can endure a lower oxygen, which is equivalent to a higher altitude.

Some men have repeatedly been under observation, and most of those reacted very much the same each time when subjected to low oxygen. Thus one man who endured low oxygen unusually well in a series of seven tests averaged an increase of 6.5 liters in his breathing when breathing 7 per cent of oxygen. Another subject, who invariably suffered when under the influence of low oxygen, in a series of five tests during a period of eight days had an average increase of only 3.3 liters in lung ventilation.

When the per minute volume of breathing fails to increase as the amount of oxygen inhaled decreases, or when it increases only slightly—1 or 2 liters—the lung ventilation is sufficient and the subject will be found unable to tolerate as low a tension of oxygen as the man whose breathing gradually deepens as the available oxygen decreases. Only a few men have failed to show a respiratory response to low oxygen, and none of these have tolerated well such low oxygen as 10 to 9 per cent. Men whose respiratory center is insensitive to oxygen want either fail to show an increase in the breathing or are slow in doing so, and in either case there would be poor toleration of high altitudes.

An occasional subject has been examined whose breathing responded well at first, but later, when the percentage of oxygen was low, suddenly began to breathe less. When this happened fainting or unconsciousness quickly followed. One subject in three tests separated by intervals of several days suddenly showed a decrease in his breathing when at 10 per cent of oxygen. He fainted the first time and was only saved from doing so the others by being returned at once to atmospheric air.

THE CIRCULATION WHEN UNDER A DECREASING OXYGEN SUPPLY.

The rate of flow and the amount of oxygen passing from the blood to the tissues depends on the difference between the pressure of oxygen in the blood and in the tissue. The higher the oxygen pressure in the blood the greater will be the amount of oxygen passing from the blood of the capillaries into the tissues. In active tissues the oxygen tension is always low. It is usually supposed that there is no oxygen pressure at all inside the cells. The dissociation of oxygen from the hemoglobin occurs with great rapidity and is greatest where the differences in pressure are greatest. It follows, therefore, that when the blood flows more rapidly through the capillaries of a tissue more oxygen will be made available than if it flows slowly. At high altitudes, or under low oxygen, the blood is, at first at least, less saturated with oxygen than at low altitudes. Therefore, if the blood contains less oxygen an increase in the rate of blood flow through the capillaries would be a means of providing the tissues with the oxygen demanded for their activity. An increased rate of blood flow has been demonstrated in men living at high altitudes and is undoubtedly one of the first of the adaptive or compensatory changes observed in the rapid ascents made by the aviator.

Circulatory observations made on Pike's Peak (14,110 feet) indicated that the increase in the rate of blood flow was the result of a greater frequency of heart beat and a dilatation of the arterioles.

A study of the pulse rate during exposure to low oxygen should, therefore, give a definite indication of the sensitiveness of the organism to low oxygen. We have found the pulse rate to be a trustworthy indicator of oxygen want provided care is taken at the beginning of a low oxygen or rebreathing experiment to have the subject calm and quiet. Excitement or anxiety may give a higher initial pulse rate, which will obscure the beginning of the oxygen wan response.

Throughout the rebreathing test the candidate's pulse is counted for a period of 20 seconds each minute. The systolic and diastolic blood pressures are determined every other minute during the first part of the test and every minute after the oxygen has been reduced to approximately 11 per cent. The rate of heart beat has been found to accelerate in a few men at 17.5 per cent oxygen (5 00 feet). In one group of 70 men the accelerations began as follows

1 per cent began to react between 7,000 and 8,000 feet	16. 0–15. 5 per cent oxygen.
12 per cent began to react between 8,000 and 9,000 feet	15. 5–14. 9 per cent oxygen.
20 per cent began to react between 9,000 and 10,000 feet	14. 9–14. 2 per cent oxygen.
14 per cent began to react between 10,000 and 11,000 feet	14. 2–13. 7 per cent oxygen.
23 per cent began to react between 11,000 and 12,000 feet	13. 7–13. 2 per cent oxygen.
20 per cent began to react between 12,000 and 13,000 feet	13. 2–12. 7 per cent oxygen.
6 per cent began to react between 13,000 and 14,000 feet	12. 7–12. 2 per cent oxygen.

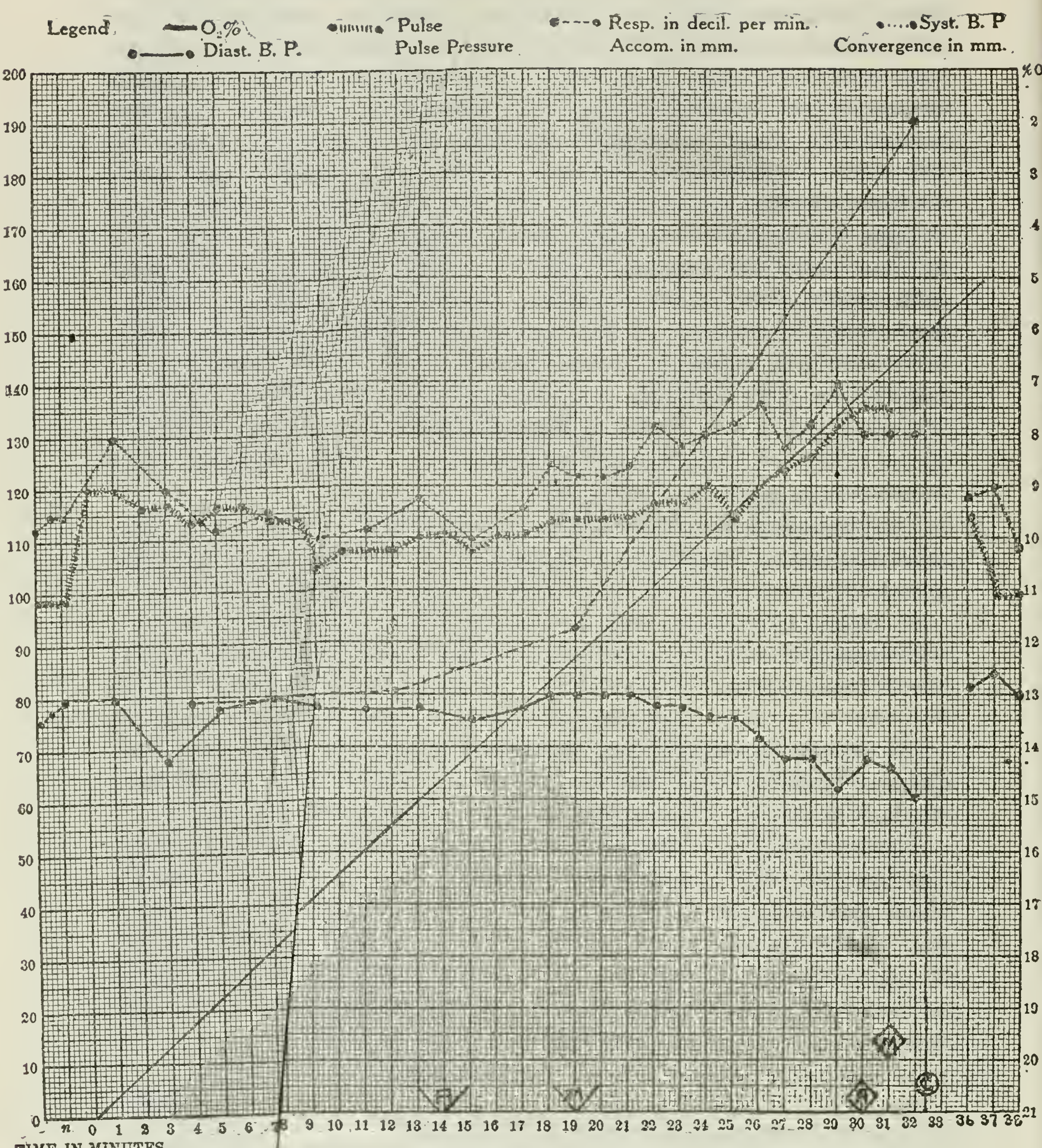


CHART 2.

No. 155.—H. F. K. CADET. Age 25 years, 10 months.

This is almost a record run for low percentage reached, and preservation of efficiency practically unimpaired until the very last. Pulse rather high from the start, as is often the case in subjects who compensate particularly well, and both pulse and blood pressure show some psychic influence at the start. During the course of the test there is a typical moderate rise in pulse and systolic pressure and a gradual tendency downward of the diastolic pressure. No suggestion of circulatory exhaustion. Rated AA, a particularly good subject.

The increase in heart-beat frequency is at first slight, only from one to three beats, but as the oxygen percentage decreases a greater increase in rate is likely to occur with each decrement in oxygen. A very marked acceleration usually occurs when the oxygen has fallen to between 13 and 9 per cent. In some men after the beginning of the more rapid increase in acceleration a steady increase in rate occurs down to even 6.5 or 6 per cent oxygen, while in others after a period of rapid acceleration the amount of accel8ration becomes less with each decrease of 1 per cent in oxygen. The last condition suggests that the power to compensate has about reached its maximum. Some men at first react with a good acceleration in rate but soon reach a rate beyond which there will be no further response, even though the oxygen percentage continues to be lowered. In such cases after holding at a fixed rate for a while the heart suddenly begins to slow, a sure indication that the limit of endurance has been reached.

A total increase of from 15 to 40 beats in the heart rate during a rebreathing test in which the oxygen is lowered to between 7.5 and 6.5 per cent constitutes a good reaction to oxygen want. A failure to respond by an acceleration in heart beat to lowered oxygen either means inability to react to the low oxygen of high altitudes and early failure or it may mean that sufficient compensation is secured by increased breathing or blood concentration, or both. Our experience indicates that the failure to respond is associated with poor toleration of low oxygen. An acceleration in heart rate of more than 40 beats—50 to 70 have been observed—throws too great a burden on the circulatory mechanism and occurs only in men who do not tolerate well low percentages of oxygen. In such men other compensatory reactions may fail to occur. So far as the response in pulse rate to decreasing oxygen is concerned it therefore becomes possible to rate the reactions as poor, good, and excessive. A poor or an excessive heart response should disqualify the candidate for very high altitudes; he should only ascend to moderate heights.

A delay in the first appearance of acceleration of the heart rate may be due to an insensitive cardiac brain center and an early response may indicate a mechanism very sensitive and responsive to any decrease in available oxygen. It should be borne in mind, however, that while ordinarily there is an early acceleration in the heart rate, a delay may be due to the efficiency of other methods of compensating to the stimulus of oxygen want.

The determination of systolic and diastolic arterial blood pressures show whether the vasomotor mechanism responds to the stimulus of oxygen want in an adequate manner for maintaining the increase in the rate of blood flow and at the same time whether the heart is compelled to work against an increased resistance. They further give an index, the pulse pressure, of the volume of ventricular output.

COLOR CHANGES DURING REBREATHING.

The skin-color changes also give a satisfactory means of judging the reaction of the subject to low oxygen. The normal condition is a gradual development of cyanosis. In a healthy reaction this is delayed in its onset; in a poor case it appears early and becomes much more pronounced as rebreathing continues. Some men do not show a well-defined cyanosis but become pale and deathlike in color. This is not a good reaction and may be found associated with other symptoms—heart and circulatory—which disqualify for high altitudes.

THE DURATION OF THE REBREATHING TEST.

The length of time taken to reach a low oxygen in the rebreathing test will profoundly alter the ability to endure extremely low percentages. If the oxygen is lowered rapidly the candidate compensates to a lower percentage than is possible where the rate of decrease in the oxygen is slower. Three rebreathing experiments made on the same subject illustrate the condition. The volume of air was so small for the first test that in 23½ minutes the oxygen was lowered to 6.3 per cent, at which the subject's power of compensation failed. The next day rebreathing a larger volume of air for 38 minutes he compensated to 7 per cent only. On the following day in a test of 85 minutes' duration, compensation failed at 8.7 per cent of oxygen. Individual differences will be found; in some men time has a more profound influence than in others. Thus another subject compensated in a test of 36 minutes down to 7.5 per cent and in one of 90 minutes to 8 per cent of oxygen. Therefore, when testing ability to endure low oxygen, some allowance must be made for the time taken to reach a given percentage. If each of two men tolerate down to 7 per cent oxygen but one is carried down in 20 and the other in 40 minutes, the one who endures for 40 minutes will have the better power of compensation.

Control tests have been conducted in the pneumatic or low-pressure chamber to determine the reliability of the rebreathing test. A subject was first under observation in a rebreathing test and again on the following day taken into the low-pressure chamber for similar observations, while the pressure was lowered at the same rate that the oxygen had been absorbed in the rebreathing test. The breathing, pulse rate, and blood pressures reacted about the same in each experiment. In order that a comparison might be made of the breathing under the two conditions, the alveolar air was analyzed from time to time during each kind of test. A fall in the alveolar carbon dioxide and oxygen pressure occurred in both experiences. The average amount of fall for eight men at the per cent of oxygen or pressure corresponding to 20,000 feet was for carbon dioxide during rebreathing 8.5 millimeters and low pressure 9.3 millimeters; for the oxygen in rebreathing 66.2 millimeters and low pressure 68.8 millimeters. These figures show that the increase in the breathing and lung ventilation was about the same under the two different low-oxygen experiences. The pulse rate also was found to begin to accelerate at about the same time in each kind of test and to accelerate in equal degree. These and other physiological observations made on men undergoing the rebreathing test or under decreasing atmospheric pressure prove that the same compensations are used by the body in each, and these we know are the adjustments made to the influence of oxygen want.

In the optimum type of response to the low oxygen of the rebreathing test the systolic pressure remains unchanged; that is, it holds on a level, until the oxygen has been lowered to between 14 and 9 per cent after which, as the oxygen is further lowered, it gradually rises, or there may occasionally occur a gradual rise in the systolic pressure beginning with the first increase in heart rate (see chart 3). This rise in pressure is ordinarily to from 15 to 20 mm. Hg. Other subjects who appear to have tolerated low oxygen well, even to as low as 6.5 per cent of oxygen, have had a systolic pressure which held at the normal (see chart 2).

A rise in the systolic pressure of more than 30 mm. Hg.—40 to 60 mm. have been observed—is very likely due to a vasomotor failure to respond with a dilatation of the arterioles. Such conditions will lead to overwork by the heart and may result in early circulatory failure.

There are other conditions of systolic pressure that are occasionally found in men undergoing the rebreathing test. A small percentage of subjects examined had a fall in the systolic pressure which began about the time the pulse rate started to accelerate and continued to decline throughout the test. Such men have not tolerated the extremely low percentages of oxygen that men of the optimum type of response have endured.

A large percentage of subjects have shown a sharp and sudden fall in the systolic pressure at low percentages of oxygen. This fall if allowed to continue will lead to fainting. The subject recovers his normal pressure at once if he is returned to atmospheric air.

The best condition in the response of the diastolic pressure to a decreasing oxygen supply consists in an unchanged or slightly increased pressure throughout the test. Many men show a gradual well-controlled fall in the diastolic pressure (see charts 5 and 6) during the terminal period when the systolic pressure is rising. Such a fall in the diastolic pressure if it occurs slowly and is not great constitutes a fairly good reaction to extreme oxygen want and can be explained as a vasomotor dilatation which occurs in order to protect the heart against the rising systolic pressure. In the optimum type of response to low oxygen the terminal fall in the diastolic pressure may not

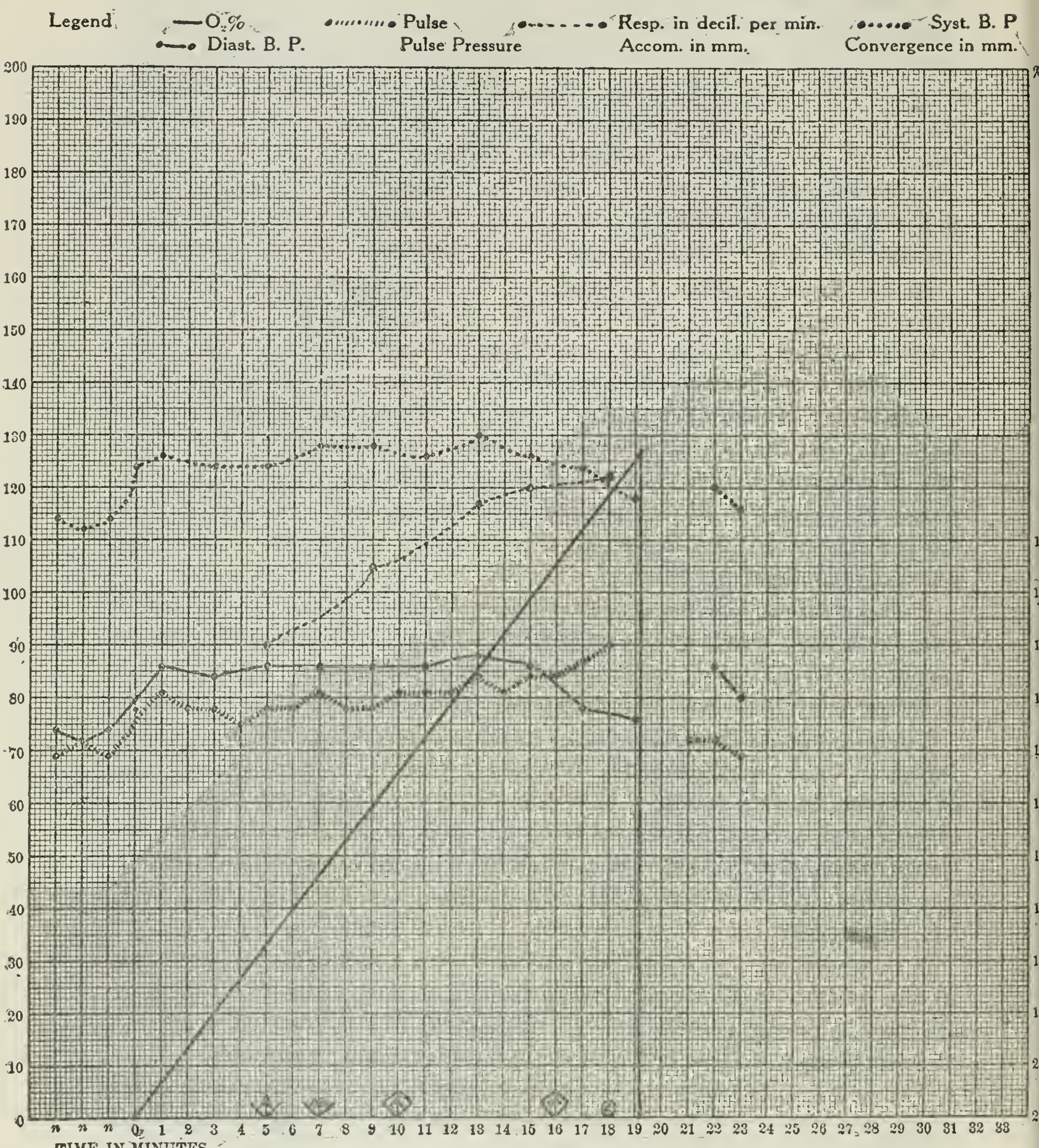


CHART 3.

No. 50.—E. O. T., 2d Lieut. PILOT. Age 31 years 8 months.

In good health, but "out of training" and 20 pounds overweight.

This chart shows almost total failure to compensate. There is very little change in pulse or blood pressure, and the respiratory reaction is deficient. For this reason there is early appearance of inefficiency as shown by the psychological characters, and he is "completely inefficient" above 9 per cent. Since there is no circulatory reaction, there is no evidence of strain. Class C. "Becomes inefficient at a relatively low altitude."

occur, and if present is never very pronounced and does not occur before the oxygen is reduced to 9.5 per cent or less.

About 66 per cent of all men examined have had a fall in the diastolic pressure. At least half of these have been sudden and great. The rapid fall is always associated with fainting, and usually precedes a systolic fall. If the two occur together, in the order just indicated, the experiment must be terminated at once if fainting is to be prevented. The pronounced and sudden fall in diastolic pressure may occur at a high oxygen percentage. It has been found to occur as early as 14 and 13 per cent of oxygen (10,400 and 12,200 feet). Such sudden falls in the diastolic pressure appear to be due to an overcoming of the vasomotor center by oxygen shortage. A decided fall in the diastolic pressure even if more or less definitely controlled is an indication that the subject will not tolerate well the altitude corresponding to the oxygen percentage at which it appears.

Three types of circulatory reaction to oxygen want have been observed. The first, the optimum, in which the pulse rate accelerates moderately as the oxygen decreases, the systolic pressure is unchanged or shows a terminal rise of not more than 20 to 30 mm. Hg., and the diastolic pressure remains unchanged or rises slightly (see chart 2). The second, the controlled diastolic fall, in which the pulse rate accelerated moderately and the systolic pressure rises as the diastolic pressure gradually falls (see charts 3 and 6). The third, the fainting type (see charts 1 and 4), in which after a period of fair, good, or excessive response in the rate of heart beats to low oxygen the diastolic pressure suddenly falls and soon thereafter the systolic pressure falls and the pulse rate slows. The optimum type may tolerate as low an oxygen as 6 per cent and may lose consciousness without fainting. He recovers quickly when restored to air, while the heart rate and blood pressures are soon back to their normals. The fainting type rarely endures as low an oxygen and if allowed to run his course faints completely, and as he revives he requires a considerable time, sometimes an hour or two, to regain his normal pulse rate and blood pressures. There are, of course, gradations between the types here described.

The pulse pressure during a rebreathing test remains fairly constant in most men until the oxygen has fallen to between 12 and 9 per cent (14,500—22,000 feet), after which it increases in amount during the further reduction in oxygen. The rise in pulse pressure occurs when the systolic pressure is rising and the diastolic either remaining constant or slowly falling. This is also the period when the heart beat is accelerating most rapidly. The amplitude of the heart output, it is claimed, is shown by the pulse pressure; if the

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pulse pressure be multiplied by the pulse rate and the product be taken as a relative measure of the volume of the blood stream and increase in the circulation rate will be indicated, beginning between 16 and 14 per cent of oxygen and progressively increasing as the oxygen further decreases. The period of most rapid flow of blood would, therefore, be that when the pulse pressure is also increasing, that is, from between 12 and 9 per cent of oxygen to the end of the test. Therefore a marked increase in the rate of the circulation of the blood during exposure to a low and decreasing oxygen is indicated. This increase in blood flow is, as shown earlier, an important and necessary compensatory reaction to low oxygen.

Incidentally a few venous blood pressure determinations made during exposure to a decreasing oxygen supply have shown a drop in venous pressure, which becomes very pronounced when the oxygen is 10 per cent or less. The following are typical examples:

1. Normal venous blood pressure was 10.8 centimeters of blood. After 25 minutes, during which time the oxygen was gradually decreased to 8 per cent, it had fallen to 3.5 centimeters of blood. Returned to normal within five minutes after being returned to air.

2. Normal venous pressures 9 centimeters; 20 minutes later at 10 per cent oxygen, 3.5 centimeters. Return to normal after experiment required 15 minutes.

3. Normal, 6.6 centimeters; fell to 5 centimeters in 30 minutes when the oxygen had reached 7.5 per cent.

This fall in venous pressure calls to mind a similar fall reported by Schneider and Sisco in men on Pike's Peak, and it indicates that the reactions observed in the rebreathing tests are the result of the same cause—low oxygen.

VENOUS PRESSURE.

For the determination we used a tilting table, which made it easy to study the subject in the horizontal position. The subjects of our studies were officers and enlisted men of the laboratory, presumably normal men.

Venous pressure was determined by noting the height to which the arm could be lifted before some prominent bit of vein in or near the hollow of the elbow collapsed, and comparing this with the height of the point of reference between these two levels, read in centimeters, gives the venous pressure directly in centimeters of blood.

The point of reference was taken as 5 centimeters below the level of the nipple, and this level was carried away from the breast by means of a simple spirit level. Measurements were read on a centimeter rule suspended from the ceiling.

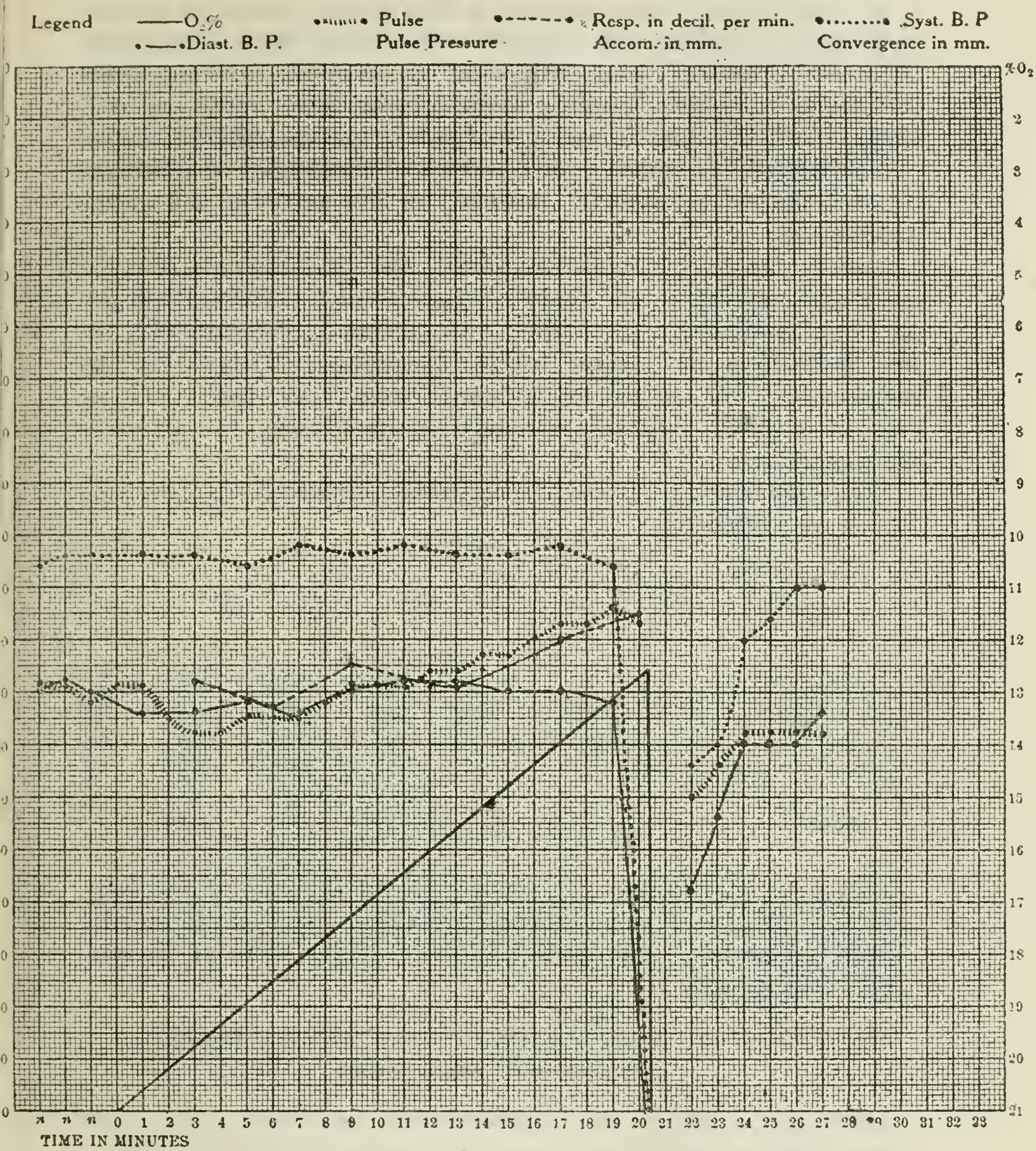

CHART 4.

No. 144.—L. R. S. CADET. Age 20 years, 2 months.

Is decidedly "stale," hates to go up in the air at all. Feels tired and depressed, and is discontented in the service at present. Certain complications at home are on his mind a good deal.

This chart is typical of a man in poor physical and mental condition. He fainted rather suddenly at about 13 per cent. Previous to this he had shown little compensatory response; blood pressure too low from the start, pulse rising slightly and respiration hardly at all affected. This man might be expected to faint at any time during a flight, irrespective of elevation.

No rating given, but for the time being is unfit to fly at all. Withdrawn from flying and recommendation made for furlough.

The data on the venous pressure study, though meager as yet, are sufficient to show that with an increase of altitude there is a decrease in venous pressure. This change in venous pressure shows great individual variations, ranging from 4.1 per cent to 104 per cent drops. Only one case showed a final rise in venous pressure. After a drop from 8.3 centimeters of blood to 5.3 centimeters of blood the pressure started to rise and continued to rise until the end of the experiment.

Out of nine cases, the one mentioned above was the only one that did not show a lowered venous pressure under decreased oxygen. In many cases the pressure showed a tendency to decrease with the first indications of lowered oxygen percentage. Others did not respond until the oxygen had reached about 13 per cent to 14 per cent, after which the pressure dropped quite abruptly to the end of the experiment.

From eight cases studied with the Dreyer apparatus, the following data were compiled:

	Normal V. P.	Fall in V. P.	Per cent fall.	O_2.
	Cm. blood.	*Cm. blood.*	*Per cent.*	*Per cent.*
1	8.75	9.05	104.0	10.2
2	6.45	2.40	37.2	7.5
3	4.48	.98	21.8	8.5
4	9.70	6.25	64.5	6.6
5	2.40	1.10	45.8	10.0
6	4.03	2.58	64.0	7.3
7	6.30	3.50	55.5	8.7
8	6.88	.28	4.1	8.63
Average	6.12	3.27	49.6	8.43

The above studies bear out rather well the findings of Schneider and Sisco in their Pike's Peak investigations, and indicate that the reactions observed in the rebreathing tests are the result of the same cause—low oxygen.

THE RELATION OF VITAL CAPACITY, POWER TO HOLD THE BREATH AND ENDURANCE OF LOW OXYGEN.

The English suggest the rejection of all candidates with a vital capacity below 3,000 cc. and view with suspicion all below 3,400 cc. The candidate also should be able to hold the breath a minimum, in three times, of 45 seconds. They find that good pilots manage 60 seconds or more. If dizziness, blurred vision, etc., occur under 40 seconds, they reject the candidate, no matter what the vital capacity may be. A further test often applied is to have the candidate hold the breath after the moderate exercise of stooping and touching the floor four times. After the exercise the candidate should be able to hold the breath 30 seconds. Good pilots hold at least 40 seconds, generally between 50 and 60 seconds. None of the men examined by us had a vital capacity less than 3,400 cc. Four who were unable to endure a low percentage of oxygen in the rebreathing experiments had vital capacities ranging between 4,400 and 5,000 cc. In view of our observations it appears that the vital capacity does not serve as an index for the approximation of the limits of endurance of low oxygen (see following table prepared from observation on 50 men).

Subject.	Vital capacity.	Holding of breath.		Lowest per cent of oxygen endured.	Danger percentage.
		Before exercise.	After exercise.		
		Seconds.	*Seconds.*	*Per cent.*	
An	4,200	40	24	6.8	Not reached.
Br	5,000	75	50	8.4	10.
Be	4,600	80	58	9.2	9.2.
Cl	3,800	47	38	6.6	8.3.
Fin	4,500	107	34	9.8	11.3.
Fer	4,350	72	57	7.2	11.3.
Gin	4,400	60	54	6.8	Not reached.
Kr	3,800	76	40	8.8	10.
Par	5,200	56	57	6.3	6.3.
Roc	4,500	62	30	7.3	10.3.
Sch	4,750	75	74	6.3	7.7.
Sny	4,700	60	24	6.7	8.
Tr	3,650	62	32	8.2	8.2.
W	4,200	29	20	7.3	Not reached.

An., with a vital capacity less than that of Br., Be., and Fin., had not completely reached the limit of endurance at 6.8 per cent (28,400 feet), while Br. failed at 8.4 per cent (24,000 feet), Be. fainted at 9.2 per cent (21,800 feet), and Fin. at 9.8 (20,000 feet). Compare the last three with Cl., whose vital capacity was only 3,800 cc., and who endured low oxygen down to 6.6 per cent.

The length of time the breath was held did not give an indication of how low in oxygen the subject would go on the rebreathing apparatus. Fin. and Be., who fainted at 9.8 per cent (20,000 feet) and 9.2 per cent (21,800 feet), respectively, held the breath longer than the average. An., who managed only 40 seconds, withstood 6.8 per cent oxygen (28,400 feet), and W., who held only 29 seconds, endured low oxygen down to 7.5 per cent (26,000 feet).

VITAL CAPACITY AND INTESTINAL GASES AT HIGH ALTITUDES.

That vital capacity of the lungs decreases with lowering atmospheric pressure has long been established by investigations carried on in this country and abroad. The cause of the decreased vital capacity at high altitudes has not, however, been wholly determined. That oxygen want plays a part in this as well as in other physiologic low-pressure symptoms seems, from our investigations, to be practically certain. That oxygen want alone is not wholly responsible seems equally certain.

For our investigations we used a simple water spirometer with a capacity of about 7 liters. The work was done in the low-pressure chamber under conditions simulating those encountered at altitudes ranging between sea level and 22,000 feet.

First a series of observations was made in which the subjects were taken to 20,000 feet, without oxygen, to determine the amount of decrease in vital capacity. In 17 cases the average decrease was 0.48 liter (approximately 10 per cent), the maximum 1.08 liters (25 per cent), and the minimum 0.15 liter (3 per cent). A well-defined decrease does not occur below 10,000 feet; the majority of men seem to hold on well to 12,000 to 14,000 feet. In this connection it is interesting to note that three men who have lived most of their lives at altitudes above 5,000 feet retained their normal vital capacity to greater altitudes than did the men who had always lived at low altitudes. In one the first break came at 14,000 feet, the second held to 16,000 feet, and the third was still normal at 18,000 feet. On the other hand, several whose homes had been at less than 1,000 feet showed a decreased capacity at 10,000 feet.

A second series was run in which the subjects took oxygen throughout the experiment, and in this series there also occurred a decrease in vital capacity. In six cases, going from sea level to 20,000 feet, the average decrease in vital capacity was 0.20 liter, or 4.5 per cent below normal.

A number of men were taken to 20,000 feet without oxygen. At that altitude they were given oxygen and held a sufficient length of time for the oxygen to effect the system. The usual decrease to 20,000 without oxygen was observed. When oxygen was administered a definite and unmistakable return toward the normal was noted, but in no case did the readings at 20,000 feet equal the normal readings at sea level. In a study of six cases the following data were obtained:

Average V. C. at sea level	4.45
Average V. C. at 20,000 feet without O_2	3.94
Average V. C. at 20,000 feet after taking O_2	4.23

That the aviator may be distressed by an abdominal bloating due to expansion of gases in the intestine during an ascent has been suggested. The gases accumulated in the digestive organs expand as the external pressure falls so that at 18,000 feet—that is, half an atmosphere of pressure—the gases in the digestive organs will expand to double their volume. This may lead to an unpleasant pressure on the abdominal wall and diaphragm and this, it has been suggested, might cause difficulty in breathing by forcing up the diaphragm and thus decreasing the space of the thoracic cavity. When gas forms continually in the digestive organs in consequence of a diet rich in carbohydrate foods, such as sugars, green vegetables, and others that are easily fermented, the decrease in vital capacity might be expected

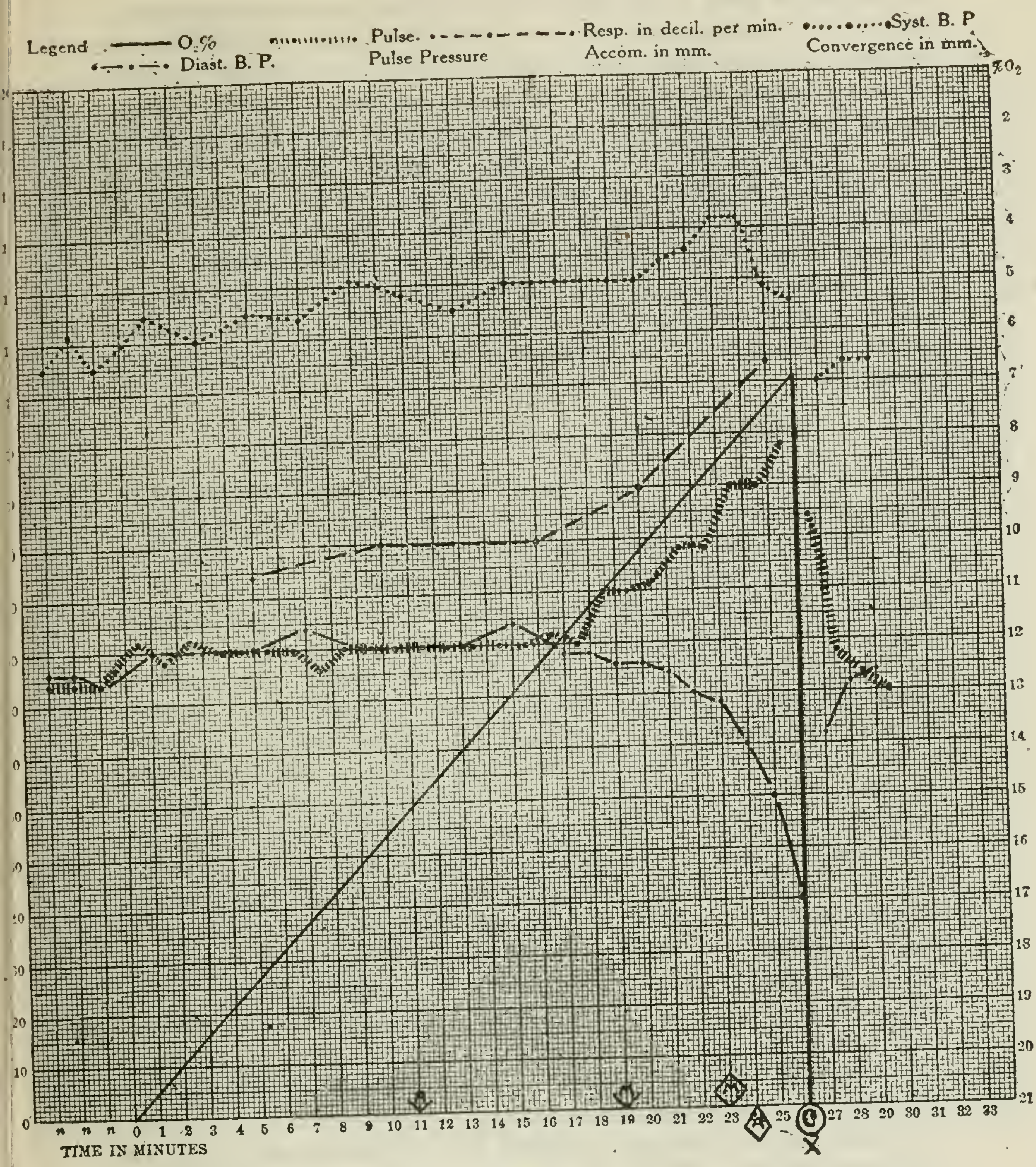

CHART 5.

No. 352.—R. P. E. CADET. Age 22 years, 7 months.

Preliminary blood pressures: Reclining, 134; standing, 142; after exercise, 160; two minutes later, 134.

During the test has a high and gradually increasing systolic pressure. Diastolic comes down rather steeply after 20 minutes (10 per cent), though never out of control. Pulse and respiration normal. Marked psychic effects soon after diastolic pressure begins to fall. High blood pressure, with signs of fatigue, but candidate in class C in spite of his reaching a fairly low percentage before the actual break.

to be greater than in the man in whom little or no fermentation is occurring. Careful study of this condition failed to establish any relation between abdominal bloating and the decrease in vital capacity during experiments in the low-pressure chamber. It was found that the abdominal measurements may vary greatly at any single pressure while the vital capacity remains constant. Belching or otherwise releasing the digestive gases reduced the abdominal measurements and materially relieved the distress of the subject without causing any noticeable change in the vital capacity.

The decrease in vital capacity of the lungs appears, therefore, to be largely due to the oxygen want of high altitudes and not to be caused by the pushing up of the diaphragm by the expanding gases of the intestines.

VASOMOTOR TONE AND ENDURANCE OF LOW OXYGEN.

Since physical fitness has been found to influence profoundly the ability of men to endure low oxygen it was thought that Crampton's "blood ptosis test" might be used to approximate the altitude the aviator could tolerate. The vasomotor mechanism is easily wearied and damaged by unhygienic influences. The fact that the vasomotor control of the splanchnic area in man experiences a change of adjustment when the body is moved from the horizontal to the upright-standing position has been used by Crampton to devise a percentage scale of vasomotor tone for rating. In vigorous subjects the heart rate does not increase on standing but in wearied subjects it increases as much as 44 beats per minute. In a perfectly strong subject the splanchnic vasotone will increase on standing and raise the systolic blood pressure about 10 millimeters of Hg. while in an individual weakened by dissipation, overwork, or lack of sleep the pressure will tend not to rise but to fall. To estimate the vasomotor tone the pulse rate and the systolic pressure are determined on a subject after reclining five minutes and again after he is required to stand. A subject sometimes may show weakness by a decrease in blood pressure and at other times by an increase in heart rate, and vice versa. It was determined that a decrease of one millimeter of mercury was equivalent to an increase in heart rate of approximately two beats.

A study of 130 aviators in which the vasomotor tone index was compared with the physiological compensatory reactions during exposure to the influence of the low oxygen of the rebreathing test has shown that Crampton's vasomotor tone index does not give a reliable indication of the subject's ability to withstand low oxygen tensions. When the candidates are arranged in the four groups of our scheme for classifying aviators the AA group has an average vasomotor tone of 88.75, the A's 68.25, the B's 57, and the C's 68.13. Collectively, therefore, the vasomotor tone index appears to furnish information

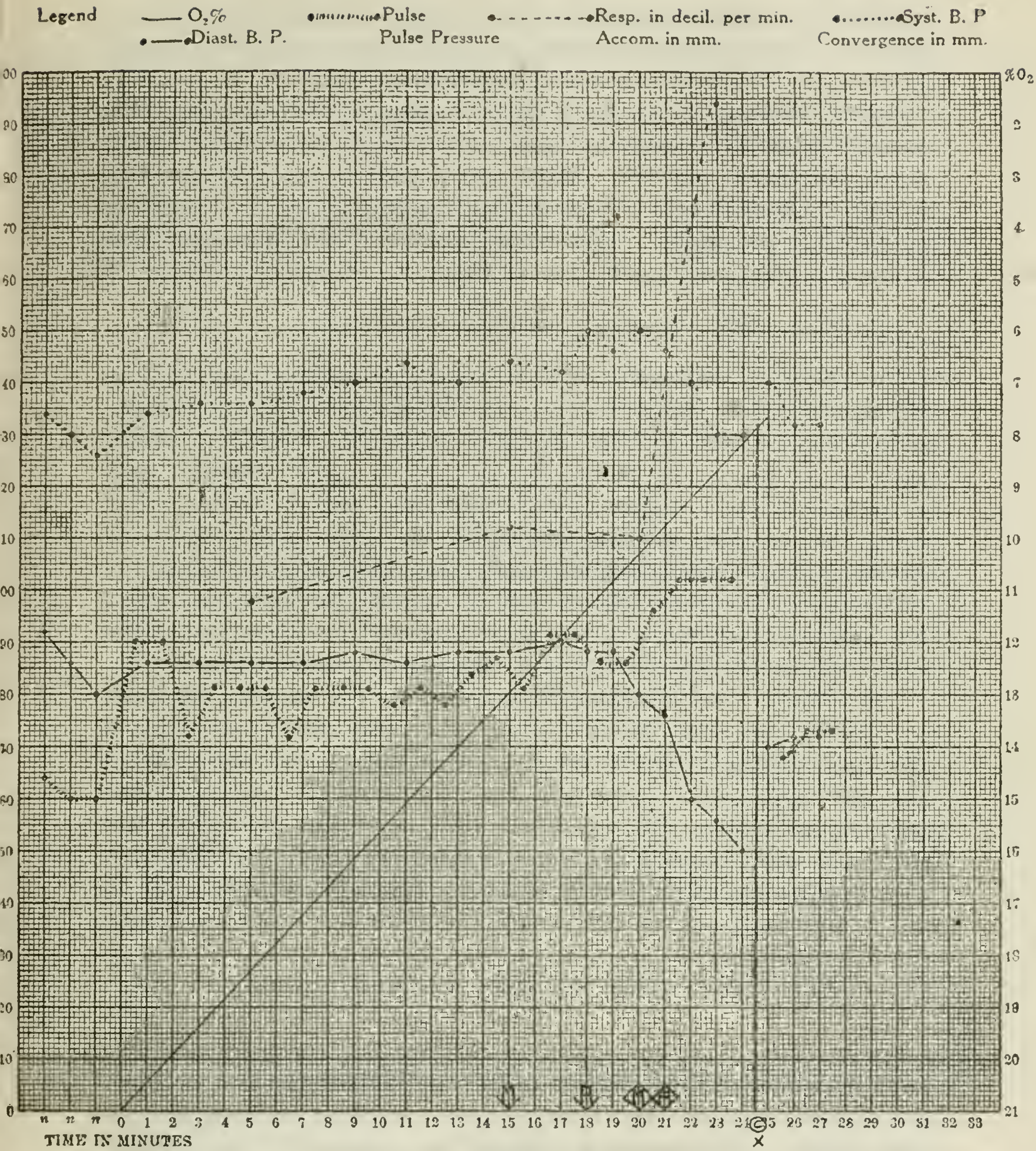

CHART 6.

No. 351.—W. S.

Age 20 years 4 months.

Preliminary blood pressures: Reclining, 122; standing, 138; after exercise, 156, and two minutes later, 138.

During the test the pressure is a little high and trends upward. The diastolic pressure begins to fall rather rapidly after the nineteenth minute (10.5 per cent), but is never out of control. At the same time systolic pressure falls somewhat and the pulse fails to advance. This is the picture of circulatory fatigue, and if pushed much longer collapse would follow. Note that marked psychological effects (diamonds) appear just as the circulatory fatigue becomes manifest. Complete inefficiency at a rather high percentage (8 per cent). Class B.

that might be useful except for the C group. The number of men in class C is rather small, 5 in all, so that the chance for error is greater. An examination of the individual cases in the four groups shows clearly that the Crampton vasomotor tone index can not be depended upon as a test for ability to react to low oxygen. Thus among the A's are vasomotor tones as low as 30 and as high as 110, among the B's 15 and 105. With such a wide range of variation it becomes evident that the vasomotor tone index can not be substituted for the rebreathing test. Low vasomotor tone is no doubt present in physically stale men, but it also occurs in men temporarily fatigued.

THE PULSE RATE AND BLOOD PRESSURES AFTER PHYSICAL EXERTION.

It is generally assumed that in vigorous physically fit men the rate of heart beat does not accelerate as much during a given exercise as in men out of training and therefore physically "soft." Furthermore, in the physically fit the rate returns to normal quickly, while in the less strong a higher rate is maintained some time after exercising. After short periods of exertion the pulse rate usually goes subnormal, but after fatiguing and exhausting exercise returns to normal more slowly and only rarely passes into the subnormal stage. The amount of increase in the heart rate and the time required to return to normal may be used as a measure of physical fitness.

All aviators and candidates examined in the Medical Research Laboratories undergo the following test: The candidate stands at ease while his pulse rate is counted; when two successive counts are the same the rate is recorded, and the arterial blood pressures immediately taken. The candidate then places his right foot on a chair and raises himself five times to the erect position on the chair. This exercise requires about 15 seconds. Immediately thereafter the pulse rate is counted for 20 seconds, and next, as quickly as possible, the arterial pressures are determined. He then stands at ease for two minutes, after which the pulse rate and pressures are again taken.

An analysis of 170 cases taken at random has been made and comparisons made with the reaction of the candidate to the low oxygen of the rebreathing test. Also a comparison with the vasomotor tone has been made. The following changes in pulse rate were obtained immediately after the exercise: Decrease in 7.1 per cent, no change in 7.6 per cent, an increase of from 1 to 10 beats in 38.2 per cent, an increase of from 11 to 20 in 34.1 per cent, and 21 to 30 in 13 per cent. Just what increase in the rate of heart beat is excessive is yet to be determined. Maj. Flack and Capt. Bowdler conclude for the same exercise that an increased rate of over 25 and a return period of over 30 seconds are points calling for careful consideration. Only 6.5

per cent of our subjects had an increase of over 25 beats. On comparing the above data with the showing the men made in ability to compensate to the low oxygen of the rebreathing test, we find no definite relationship indicated between the amount of acceleration after exercise and endurance of low oxygen. Neither do we find a relationship between the exertion pulse rate acceleration and Crampton's vasomotor tone index.

We did not follow the return of the pulse rate to normal after exercise but noted the rate two minutes after. The rate at the end of the second minute was above normal in 33 per cent, normal in 16.8 per cent, and subnormal in 50.2 per cent of the men. None of the subjects had a rate of over 10 above normal at the end of two minutes. The number above normal is certainly excessive according to the standards of Flack and Bowdler. In this study no relationship could be established with the ability to compensate to low oxygen nor with the vasomotor tone.

The changes in the systolic pressure immediately after the exercise show nothing definite as to physical condition and as to ability to endure low oxygen. The systolic pressure two minutes after exercise, when compared with the pulse rate changes, show collectively interesting differences. The group with the pulse rate above normal had systolic pressures above normal in 22.8 per cent and below normal in 66 per cent of the men; those whose pulse rate had returned to normal showed 68 per cent above and 18 per cent below the normal systolic pressure: while in those in which the pulse rate was subnormal 82.1 per cent were above and only 7.1 per cent below their normal systolic pressure. It appears, therefore, that when the heart rate remains up after exercise the systolic pressure more frequently becomes subnormal. This observation has not been found to bear upon the ability of men to react to low oxygen. It does, however, indicate that the vasomotor tone index is a more reliable method of judging fatigue and possibly staleness than either a study of the pulse rate or systolic pressure alone.

Flack and Bowdler believe the ideal pulse rate for a flying officer has a small range between systolic and diastolic pressures (20–30) with a rest rate increased 20–25 by exercise and returning to the rest rate in 10–15 seconds. They further state that a pulse of 60 to 72 little raised by exercise (10 beats per minute) and returning to normal in 10 seconds is a good sign, generally associated with excellent physique and good stability of the nervous system. We have no reason to doubt their conclusion but believe the values given may be increased by a good margin and still retain the physical perfection desired. About 37 per cent of our subjects had when standing upright pulse rates above 85 and the pulse pressures of the great ma-

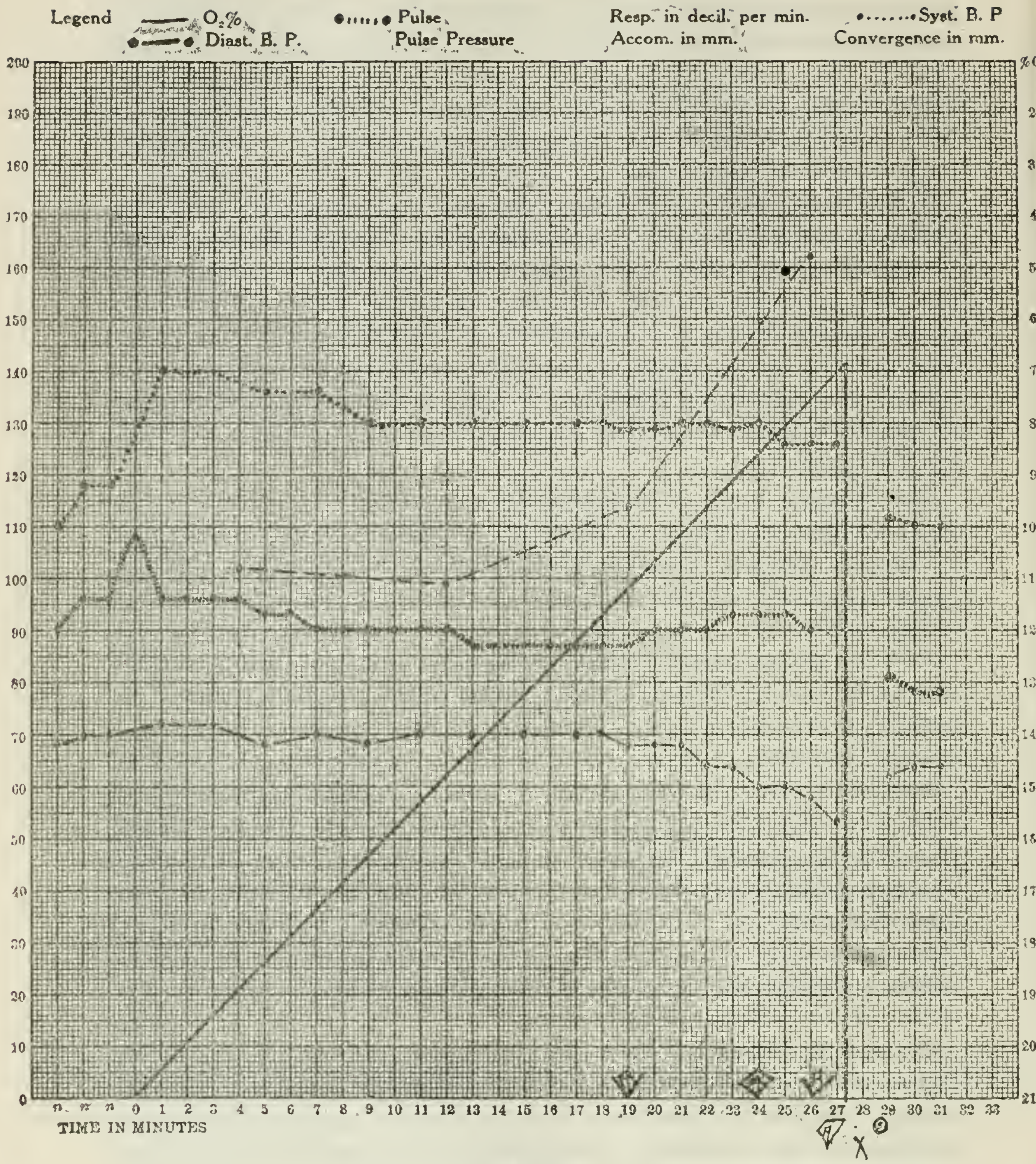

CHART 7.

No. 154.—S. A. C. CADET. Age 23 years 5 months.

Good condition.

This chart is rather a curiosity. It shows (aside from a psychic rise at the start) practically no low oxygen effect on pulse or blood pressure. There is fair response in respiration. In spite of this, the subject preserves his efficiency by the psychological tests to a very low percentage, viz, 6.8 per cent. This is a most unusual case, which should be investigated further. There is no doubt that he compensates in some way, since his efficiency holds out so well, but he does not do it in the usual way. Most cases showing such lack of response in pulse would show early inefficiency. Rated AA.

jority ranged between 30 and 60 mm. Hg. They believe that a diastolic pressure below 70 with a pulse pressure greater than 50, is strong evidence that the cardiovascular system is unsuited for air work. About 30 per cent of our fliers have had when standing a pulse pressure greater than 50. The method of taking the arterial pressures may account for the differences noted. We have used the Tycos sphygmomanometer and taken the pressures with the arm at the side by the auscultatory method, the systolic pressure being read at the point of reappearance of the pulse and the diastolic pressure at the point of disappearance of the sound.

In comparing our data with the conclusions of Flack and Bowdler we find 33 per cent of our men had a pulse rate above normal at the end of two minutes. Without taking into consideration the interplay between pulse rate and systolic pressure, it apparently would not be just to rule against the subject because of a slow return.

OBSERVATIONS ON THE EFFECTS OF FLYING UPON THE PULSE RATE AND THE ARTERIAL PRESSURES.

The experiments were carried out on the flying plateau immediately before and after a flight. The aviator reclined for five minutes, after which the pulse rate was counted and the pressures then taken. He next was required to stand while each was again determined. The same method of examination was followed before and after flight. Such observations are still being continued. None of the flights have exceeded a height of more than 6,000 feet, while the average altitude attained varied between 2,500 and 4,000 feet. The duration of the flight rarely exceeded an hour. The pulse rate in both postures was found to be more rapid after than before the flight in about 60 per cent of the men, was unchanged in 20 per cent, and was decreased in 20 per cent. The increase was in several as high as 28 beats per minute. The excitement attending the anticipation of the flight was evidenced in a more rapid pulse rate only in men who had but little experience in solo flying or had some trouble in previous flying.

The systolic pressure in both postures, reclining and standing, was higher after than before the flight in approximately 75 per cent of the men studied, 20 per cent had a lower systolic pressure on the return, while about 5 per cent showed no change. The amount of rise above normal ranged from 2 to 34 millimeters of mercury. The greatest fall was 10 millimeters of mercury.

The diastolic pressure was in approximately 56 per cent of the men lower after flying than before. In no case was the fall excessive.

By balancing the systolic pressure and the heart rate for reclining and standing postures to determine the efficiency of the vasomotor system and rating the reaction, according to Crampton's scale of vasomotor tone, we find that the majority of the aviators studied show

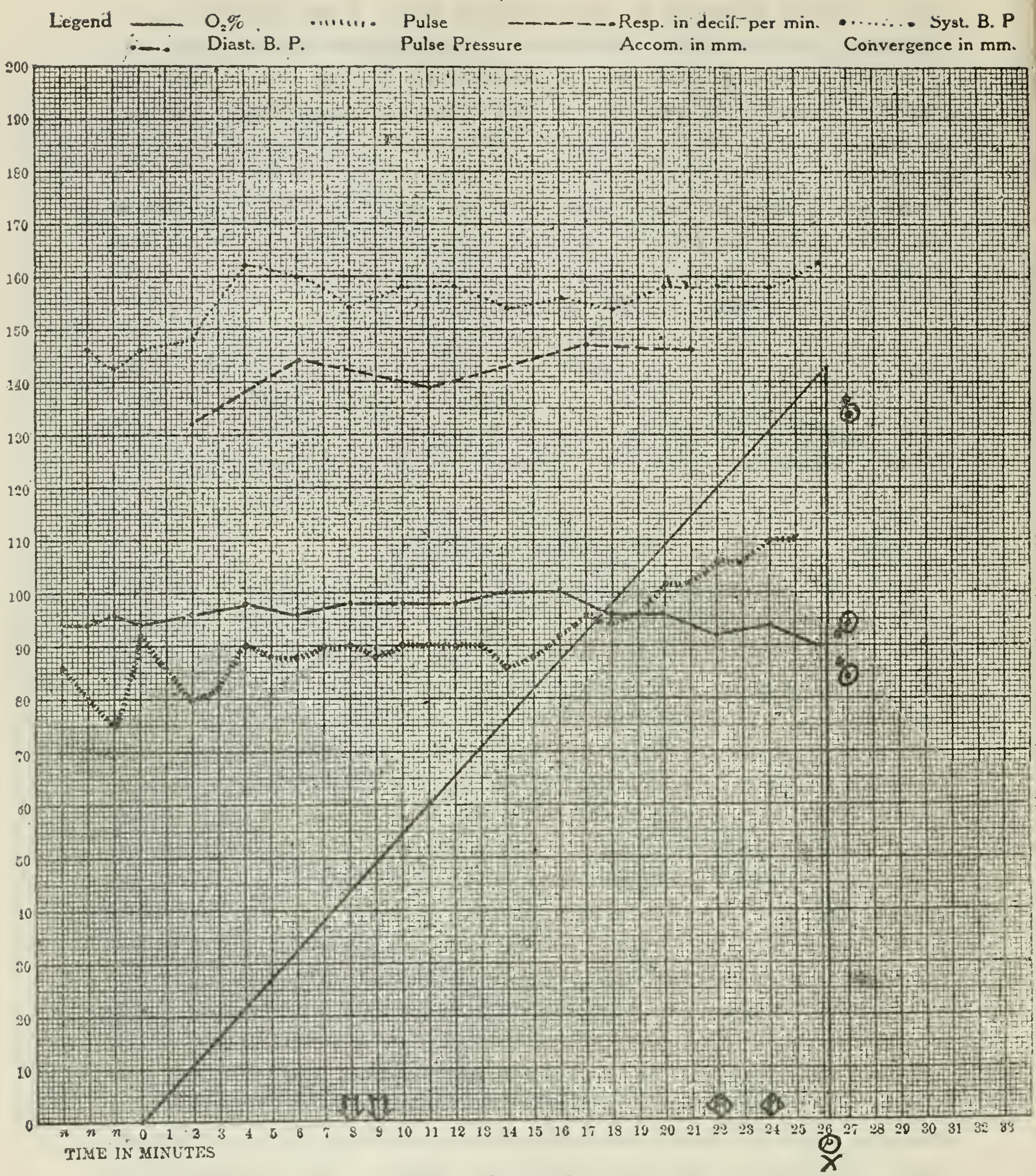

CHART 8.

No. 110.—R. S. CADET. Age 35 years 11 months.

This chart is of a type which is not uncommon among older subjects, and must be interpreted either as decreased flexibility of the arteries or less effective vasomotor control. It emphasizes the fact shown by experience that the best age for flying is the early twenties—a man of 36 has already begun to grow old.

Preliminary blood pressures: Reclining, 124; standing, 132; after exercise, 142; and two minutes later, 124.

During the test the systolic pressure rises at the start and remains at about 160. As often happens when systolic is high, there is not a very marked rise in pulse. There is no evidence of circulatory fatigue, and he reaches a low oxygen percentage with excellent command of his faculties. His present performance is first class, but it is unlikely that he would remain in condition long if he runs such a blood pressure when he flies. Class B.

evidence of circulatory fatigue after the flight. The vasomotor tone fell in at least 65 per cent of the men; in some the fall was slight, but in several instances it exceeded 30 per cent. In view of the limited amount of field study of the aviator and the fact that the flying has been at comparatively low altitudes, final conclusions can not yet be made. From the data available it appears that low flying fatigues the circulatory mechanism, but not, however, as much as the same time spent in physical work.

THE HEMOGLOBIN WHEN UNDER A DECREASING OXYGEN SUPPLY.

Since an increase in the percentage of hemoglobin in the blood is one of the most important of the low oxygen compensations found to occur in men and animals living at high altitudes on mountains, it is interesting to find that it may also occur during short exposure to low oxygen. The rebreathing test of not more than 30 minutes duration is too short a period of time to permit a concentration of hemoglobin in the majority of men. Only an occasional subject may show a definite concentration. In order to test out the part that the blood changes may play as a compensatory factor for oxygen want in such a short period as the aviator spends in the air, a series of experiments are now being made in the pneumatic or low pressure chamber and also under low oxygen. In these the subject is held at a chosen pressure or a given percentage of oxygen for from 40 to 90 minutes, the entire experiment lasting as much as two or two and a half hours. The hemoglobin has been determined by two methods, the Gower-Haldane hemoglobinometer and the Du Bousque colorimeter, on blood taken from a finger or an ear, and also from a vein in the arm.

At least 25 per cent of all men examined have shown a well-defined increase in the percentage of hemoglobin, and the majority some evidence of concentration. We have found that the blood from the finger or ear and from the vein showed it equally well by the two methods used in the determinations. The following illustrates the amount of concentration: Normal per cent of hemoglobin with the Gower-Haldane hemoglobinometer, from a finger 100, from a vein 90. After 80 minutes under low oxygen, 60 of which were spent at 10 per cent oxygen, finger 105, vein 102. The amount of concentration has been as great as 9.5 per cent. It has been most clearly induced at pressures, and percentages of oxygen, corresponding to between 18,000 and 20,000 feet. Almost all of the men have had to be held at the high altitudes 20 or more minutes before concentration began to be evident.

Since the blood changes do not always occur, and are slow in appearing when they do, the determination of hemoglobin during a rebreathing test has not been made a part of the routine examination.

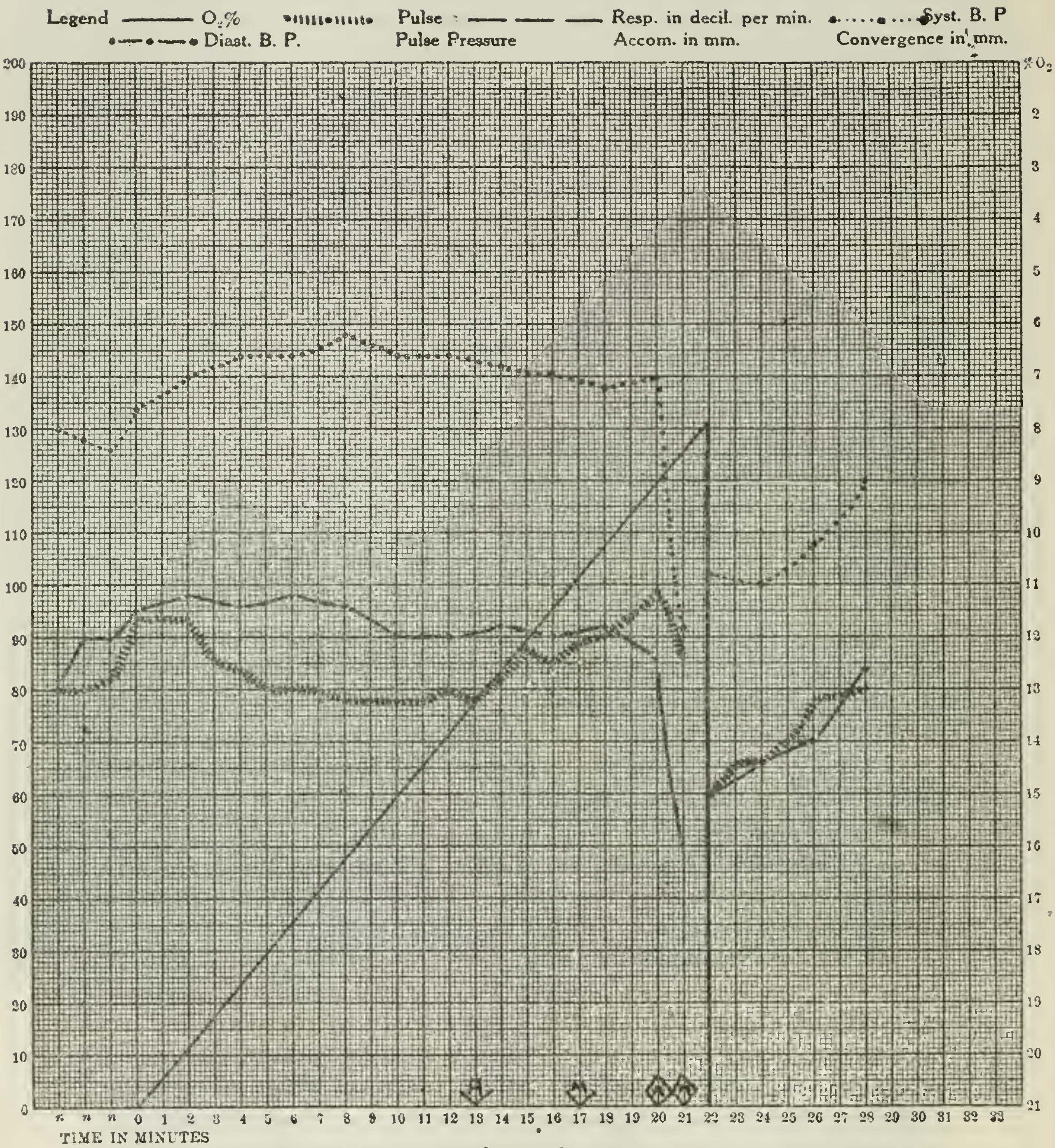
Legend —— O_2% Pulse Resp. in decil. per min. Syst. B. P
Diast. B. P. Pulse Pressure Accom. in mm. Convergence in mm.
% O_2
TIME IN MINUTES

CHART 9.

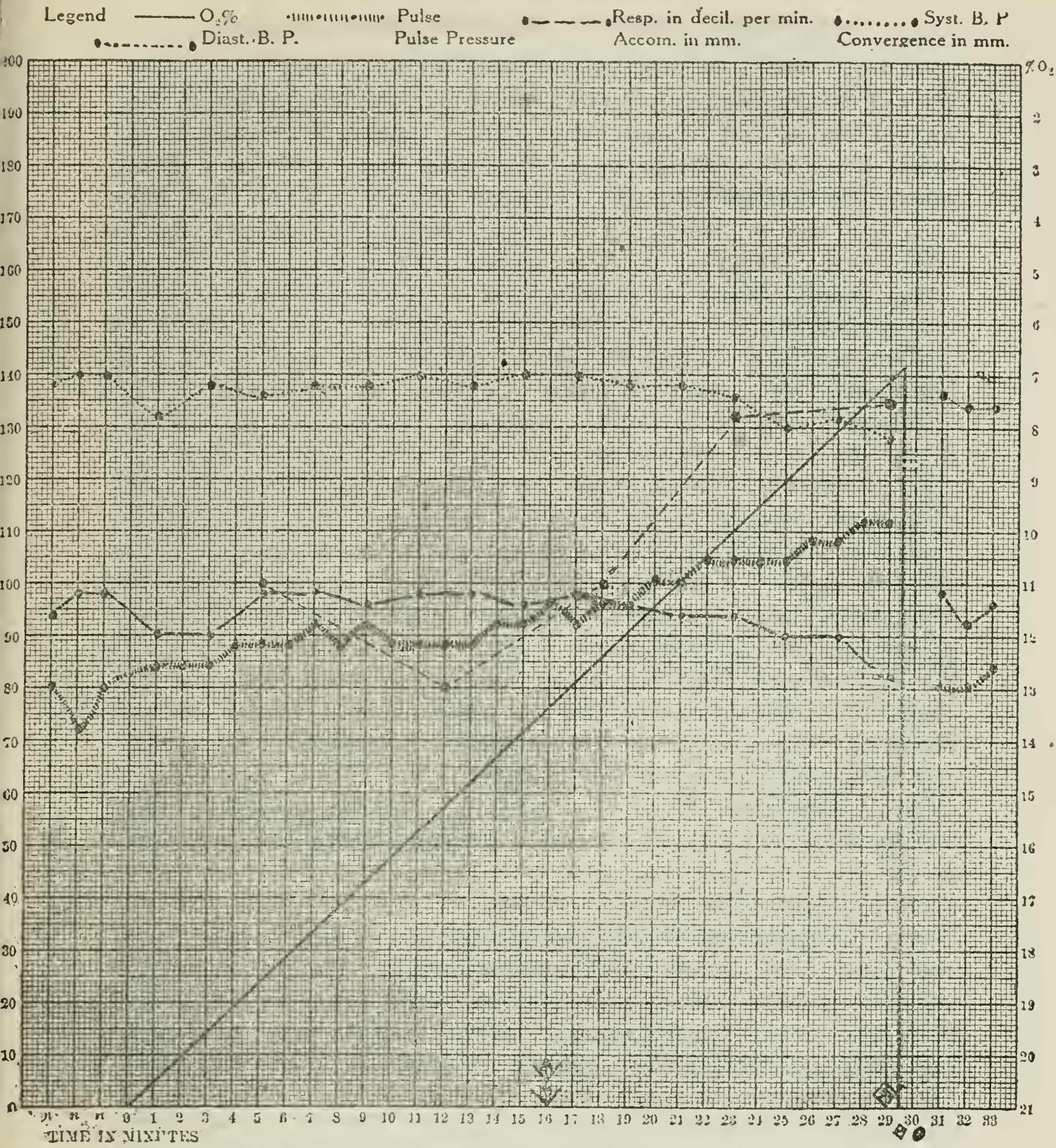

CHART 10.

No. 63.—J. E. S. CADET. Age 21 years 1 month.

Left hospital three days ago, where he was laid up for a week with influenza. Feeling fairly well to-day, though not up to his usual form.

The first chart is typical of a man out of condition, rather high systolic pressure, psychic rise in both pulse and pressure, followed by a sudden faint at about 8 per cent. In this the diastolic pressure fell practically to zero; the systolic pressure and pulse also broke sharply, as may be seen by the slow recovery after the experiment was terminated.

He was tested again two weeks later (chart not given), and made a very good run, with the exception of a rather high blood pressure (148). In this test he was not completely inefficient when taken off at 5.5 per cent. After two weeks he was given a third test (second chart), which entitles him to an AA rating. The systolic pressure stays below 140, there is no break in diastolic, and there is a moderate, healthy rise in pulse.

This case illustrates the very serious effects of temporary indisposition.

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THE RELATIVE VALUE OF THE COMPENSATORY FACTORS.

In order that a better understanding might be had of the interplay of the compensatory factors, when man ascends quickly to very high altitudes and remains only a short time, a few hours at the most, a number of experiments have been made with men in the pneumatic chamber and also under low oxygen in which they have been held for an hour or two under conditions corresponding to altitudes of 15.000 to 20,000 feet. In all of these, two of the compensatory changes, those in breathing and in circulation, have appeared almost simultaneously and increased steadily with the gradually increasing altitude. When the desired altitude was reached and then maintained the breathing either continued at the depth it had acquired during the period of progressive change or it became still deeper for a time. The pulse rate, which gives an index of the increase in the rate of blood flow, accelerated during the period corresponding to ascent; and, then, when the altitude was held, usually remained constant, or, in some of the men, retarded somewhat after the hold began. A slowing of the pulse rate, when an altitude was maintained for a time, was so frequently observed that we sought for an explanation of the decrease in rate. In a number of men it was found that the heart was being relieved by other compensatory factors. In such cases one or the other or both of two changes occurred. There occurred either a further deepening of the breathing, or a concentration of the hemoglobin, or both of these changes took place together. Often the breathing, after increasing in amount during the ascent, held at a constant increased depth during the stay at the given altitude; but in such the hemoglobin was found to be concentrating as the pulse rate slowed.

An unusual but interesting case was found in a man whose breathing failed to respond to the changes in altitude. He did not tolerate the low pressure well at first, but felt better after some time had been spent at the chosen pressure. In this man the heart accelerated decidedly and later his hemoglobin concentrated about 8 per cent. His improvement occurred when the hemoglobin showed concentration.

As yet no attempt has been made to study oxygen secretion during our rebreathing experiments or in the pneumatic chamber.

Our studies show that during short exposures to high altitudes, or low oxygen, such as the aviator experiences, the compensatory reactions of the body to a decreased oxygen are made almost entirely by the circulation and by the breathing. A few men may, after the lapse of an hour or more, secure some benefit from a slowly developing concentration of the hemoglobin of the blood. The order of response by the adaptive mechanisms is not that of the good reaction seen among mountaineers, in whom the breathing first responds while the other compensatory changes take place more slowly. The reaction resembles more nearly that seen during an attack of mountain sickness among mountaineers. In such men the heart beat is greatly accelerated during the attack. The aviator, it appears, must depend largely upon his heart and his breathing for compensation to the fall in oxygen which he encounters as he ascends.

The length of time taken to reach a low oxygen in the rebreathing test will profoundly alter the ability to endure extremely low percentages. If the oxygen is lowered rapidly, the candidate compensates to a lower percentage than is possible where the rate of decrease in the oxygen is slower. Three rebreathing experiments made on the same subject illustrate the condition. The volume of air was so small for the first test that in 23½ minutes the oxygen was lowered to 6.3 per cent, at which the subject's power of compensation failed. The next day, rebreathing a larger volume of air for 38 minutes, he compensated to 7 per cent only. On the following day, in a test of 85 minutes' duration, compensation failed at 8.7 per cent of oxygen. Individual differences will be found; in some men time has a more profound influence than in others. Thus, another subject compensated in a test of 36 minutes down to 7.5 per cent and in one of 90 minutes to 8 per cent of oxygen. Therefore, when testing ability to endure low oxygen, some allowance must be made for the time taken to reach a given percentage. If each of two men tolerate down to 7 per cent oxygen but one is carried down in 20 and the other in 40 minutes, the one who endures for 40 minutes will have the better power of compensation.

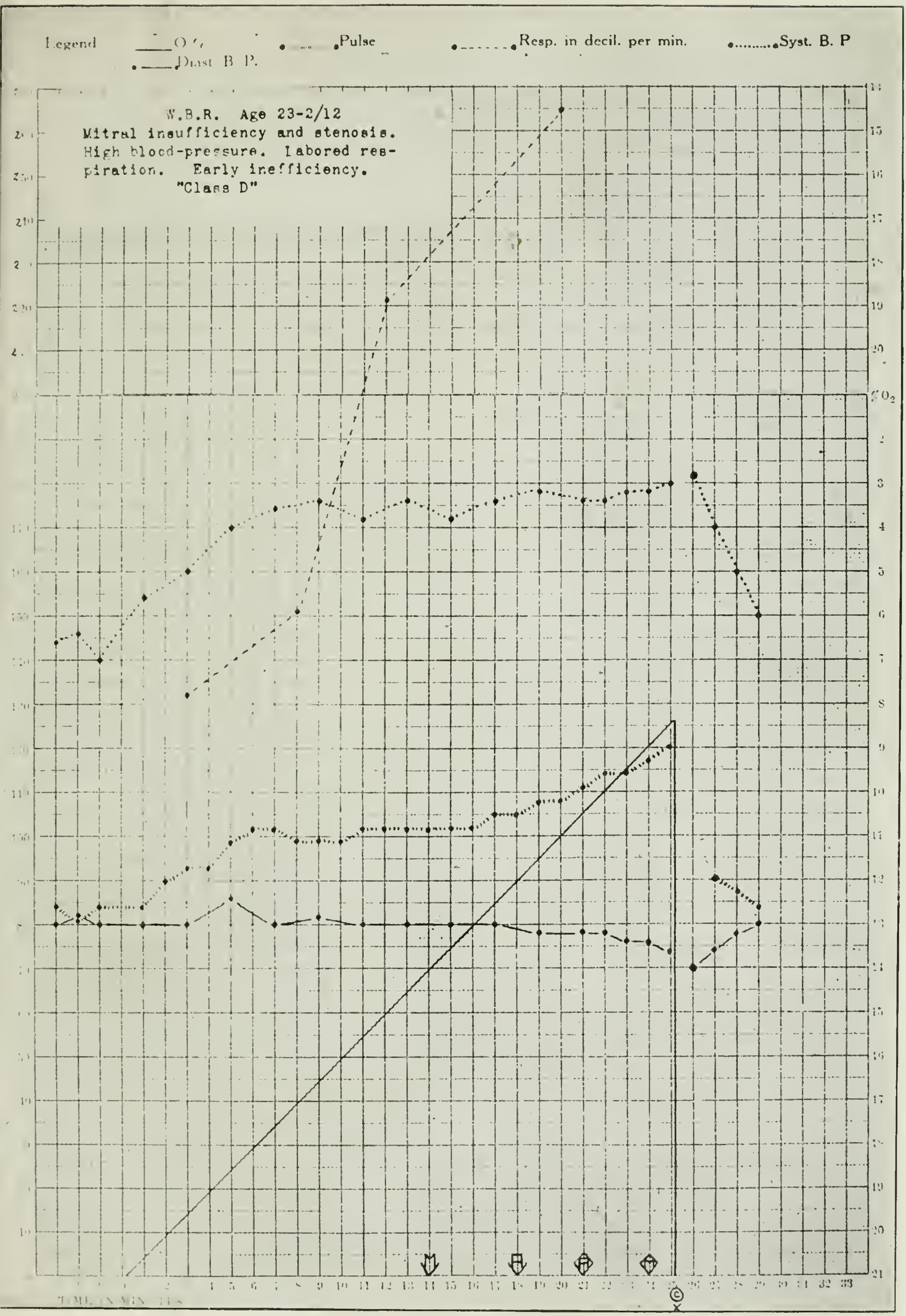
Control tests have been conducted in the pneumatic or low-pressure chamber to determine the reliability of the rebreathing test. A subject was first under observation in a rebreathing test, and on the following day taken into the low-pressure chamber for similar observations, while the pressure was lowered at the same rate that the oxygen had been absorbed in the rebreathing test. The breathing, pulse rate, and blood pressures reacted about the same in each experiment. In order that a comparison might be made of the breathing under the two conditions the alveolar air was analyzed from time to time during each kind of test. A fall in the alveolar carbon dioxide and oxygen pressure occurred in both experiences. The average amount of fall for eight men at the per cent of oxygen or pressure corresponding to 20,000 feet was for carbon dioxide during rebreathing 8.5 millimeters and low pressure 9.3 millimeters; for the oxygen in rebreathing 66.2 millimeters and low pressure 68.8 millimeters. These figures show that the increase in the breathing and lung ventilation was about the same under the two different low-oxygen experiences. The pulse rate also was found to begin to accelerate at about the same time in each kind of test and to accelerate in equal degree. Those and other physiological observations made on men undergoing the rebreathing test or under decreasing atmospheric pressure prove that the same compensations are used by the body in each, and those we know are the adjustments made to the influence of oxygen want.

ALVEOLAR AIR PRESSURES IN THE LOW PRESSURE CHAMBER AND ON THE REBREATHING APPARATUS.

Whether the individual is in the low-pressure chamber or on the rebreathing apparatus he can equally well be subjected to gradually decreasing oxygen pressure. The rebreathing machine has been shown to be equivalent to the low-pressure chamber for testing the ability of an individual to adapt himself to low oxygen pressure so far as circulatory and psychological reactions are concerned. A consideration of the respiratory factors in each was necessary in order to complete the comparison. The respiratory factors to be considered are: First, the alveolar air pressures; second, the volume per minute and rate; third, the blood gases.

A series of experiments were carried out to show the changes in the alveolar air pressures during an ordinary rebreathing test lasting about 30 minutes, in which the subject was exposed to a fall of oxygen per cent from 20.96 to 9.8, or corresponding barometric pressures of 760 mm. to 350 mm. (20,000 feet). The subject was put on the rebreather and samples of the alveolar air were taken every 4 or 5 minutes until the end of the run. The time and the oxygen per cent of the rebreathed air were noted and the corresponding barometric pressure for each oxygen per cent determined. The same subject was taken into the low-pressure chamber a few days later and the barometric pressure was lowered according to the rebreathing schedule previously made. Alveolar air samples were taken at corresponding minutes and altitudes. Both series of alveolar air samples were analyzed with the Henderson-Orsat gas analyzer and the partial pressure calculated allowing 40 mm. Hg. for the tension of water vapor. The curves of each subject were plotted on the same chart.

The curves of the alveolar air pressures plotted (see chart 9A) from the data obtained in the low-pressure chamber and with the rebreathing apparatus are striking in their similarity. In many cases they practically coincide. The oxygen tension in the alveolar air of eight subjects on the rebreathing machine fell from 102.5 mm. Hg. to 36.3 mm. during runs from 760 mm. to 350 mm., or 20.96 per cent oxygen to 9.8 per cent. This is an average fall of 62.2 mm. for 20,000 feet (see Table 1). In 10 corresponding experiments in the low-pressure chamber the alveolar oxygen tension fell from 104.6 mm. to 35.8 mm. during the ascent to 20,000 feet. The average fall was 68.8 mm. (see Table 2).



Legend
O%
Pulse
Resp. in decil. per min.
Syst. B. P
Diast B. P.
W.B.R. Age 23-2/12
Mitral insufficiency and stenosis.
High blood-pressure. Labored respiration. Early inefficiency.
"Class D"
CO_2
TIME IN MINUTES

In the previous eight cases, in which the alveolar oxygen pressure was determined on the rebreathing apparatus, the alveolar carbon dioxide pressure fell from 42.6 mm. to 34.1 mm., an average fall of 8.5 mm. (see Table 3). In the 10 corresponding cases in the low-

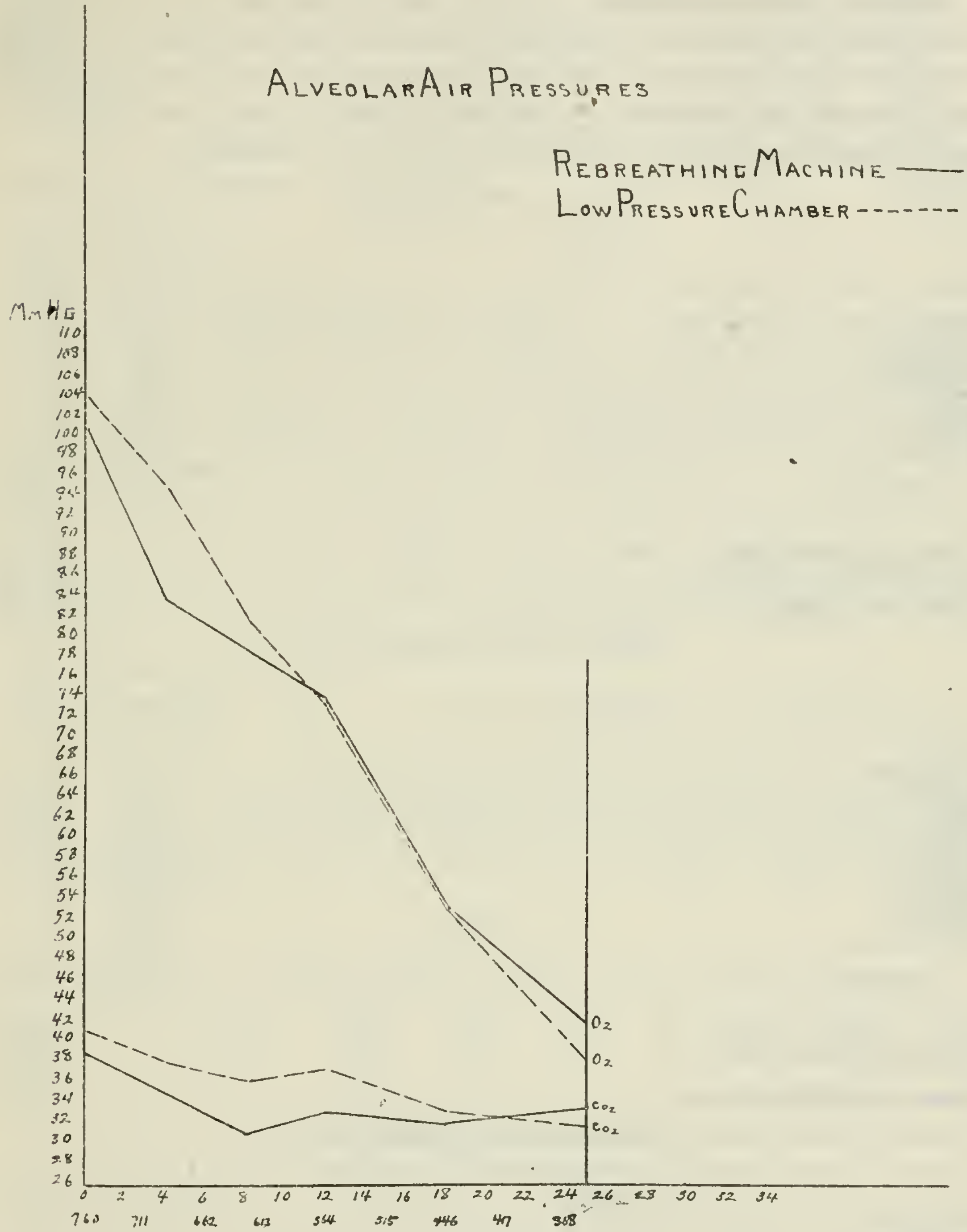


CHART 9A.

pressure chamber the alveolar carbon dioxide tension fell from 40.1 to 30.8 mm., an average fall of 9.3 mm (see Table 4).

The curve of the alveolar oxygen tension obtained in the low-pressure chamber or on the rebreather is essentially a straight line. That of the alveolar carbon dioxide tension is not so regular. Certain irregularities in the curve were found which could be correlated with changes in lung ventilation as indicated by the volume of air breathed per minute. In seven cases there was a gradual fall of alveolar carbon dioxide pressure as the barometric pressure was lowered from 760 mm. to 350 mm. (20,000 feet). In two cases it remained nearly constant until about 550 mm. and then fell fairly rapidly.

An examination of tables 1, 2, 3, 4, and of the plotted curves shows very definitely that the changes of the alveolar air pressure during exposure to progressively diminished oxygen pressure are quite similar and that the respiratory factors as well as the circulatory and psychological reactions are the same in the two methods.

TABLE 1.—*Rebreathing* O_2.

Subject.	760 mm.	350 mm.
Griest	106.5	39.9
Browning	106.0	33.8
Pierce	103.0	39.0
Burlingame	109.0	38.0
Jenkins	97.5	24.0
Smart	99.0	38.0
Kuempel	97.5	36.0
McKinnie	101.2	42.0
Average	102.5	36.3=66.2

Average O_2 tension, 760 mm	102.5 mm.
Average O_2 tension, 350 mm	36.3 mm.
Average fall for 20,000 feet rise	66.2 mm.

TABLE 2.—*Low pressure* O_2.

Subject.	760 mm.	350 mm.
Neuswanger	116.7	33.4
McKinnie	104.2	38.0
Dorsey	94.5	34.4
Smart	92.0	36.0
Merrill	104.5	43.0
Kuempel	105.5	31.2
Jenkins	108.0	34.4
Burlingame	106.2	33.4
Leinbach	106.2	36.1
Pierce	108.7	38.7
Average	104.6	35.8=68.8

Average O_2 tension, 760 mm	104.6 mm.
Average O_2 tension, 350 mm	35.8 mm.
Average fall for 20,000 feet rise	68.8 mm.

TABLE 3.—*Rebreathing* CO_2.

Subject.	760 mm.	350 mm.
Burlingame	43.5	39.9
Browning	40.9	35.4
Greist	42.4	39.3
Pierce	43.1	32.6
Jenkins	45.6	18.0
Kuempel	43.8	34.8
McKinnie	39.2	33.0
Smart	42.5	39.8
Average	42.6	34.1= 8.5

Average CO_2 tension, 760 mm	42.6 mm.
Average CO_2 tension, 350 mm	34.1 mm.
Average fall for 20,000 feet rise	8.5 mm.

TABLE 4.—*Low pressure* CO_2.

Subject.	760 mm.	350 mm.
Smart	39.8	37.2
Burlingame	41.2	34.7
Pierce	39.0	30.4
Jenkins	38.7	27.3
Kuempel	39.8	24.4
McKinnie	40.4	31.6
Leinbach	37.8	27.6
Merrill	40.0	29.7
Dorsey	44.4	30.8
Neuswanger	40.4	34.7
Average	40.1	30.8= 9.3

Average CO_2 tension, 760 mm .... 40.1 mm.
Average CO_2 tension, 350 mm .... 30.8 mm.

Average fall for 20,000 feet rise .... 9.3 mm.

From these preliminary experiments we should infer that in the ordinary short experiments in which the barometric pressure is lowered to about 350 mm. in 20 minutes, similar to the conditions during a rebreathing test, the alveolar carbon dioxide pressure starts to fall with the barometer. The law of Haldane and Preistly, which states that during rest under ordinary conditions the alveolar carbon dioxide pressure remains constant, holds good only when the barometric pressure remains constant also. These experiments point to the view that the alveolar carbon dioxide pressure does not remain constant under progressively diminished barometric pressure to the extent formerly believed.

A few men were taken to 15,000 feet at the rate of 1,000 feet per minute, held there for five minutes and then dropped at the same rate to 2,000 feet. This procedure was repeated three times in succession. The alveolar gas pressures were remarkably constant for the same altitude in each of these cases. Table 5 gives the result in two such cases.

TABLE 5.

Barometer.		760 mm.	425 mm.	700 mm.	425 mm.	700 mm.	425 mm.	760 mm.
1	O_2	104	40	91	40	92	39	98
	Co_2	41	39	43	39	41	39	42
2	O_2	106	51	96	47	95	48	95
	CO_2	41	29	34	32	36	30	41

In a number of experiments the subjects were exposed to low oxygen tension for longer periods. When the individual is held for an hour or more at a low barometric pressure, 380 mm. for example (18,000 feet), the alveolar air pressures tend to remain remarkably constant. In 10 cases the average alveolar carbon dioxide pressure at the end of 96 minutes was only about 1 mm. lower than when the low barometric pressure was first reached. The fact that there was no striking change in alveolar carbon dioxide pressure during prolonged exposure to a given low barometric pressure led us to examine the volume of air breathed per minute during these exposures and the carbon dioxide capacity of the blood at the beginning and at the end.

Eight experiments were carried out to determine the volume of air breathed per minute. The subject wore an American Tissot mask and inspired through a gas meter. The resistance of the meter was not great enough to cause any change in the rate or volume of respiration, as shown by control runs for periods of one to two hours. The average volume breathed per minute at 760 mm. was 7 liters. With the ascent to 380 mm. an increase in ventilation took place, attaining its maximum about 10 minutes after the low barometric pressure had been reached. In six cases of these eight the lung ventilation decreased more than a liter while the low barometric pressure was being held. In several cases the breathing decreased to its original volume before the ascent. During these exposures the type of breathing frequently changed from shallow rapid to slow and deep respiration. In one case the rate fell from 14 per minute to 9 within 20 minutes after reaching 380 mm.

During short exposures to progressively diminishing oxygen pressure with either the rebreather or in the low-pressure chamber the lung ventilation increases. In the rebreathing experiments the first respiratory response has been found to be between 16 and 14 per cent of oxygen. In the low-pressure chamber in a few experiments the response in breathing occurred at about 8,000 feet, or at approximately 15 per cent of oxygen. In several instances, however, the response began immediately.

CARBON DIOXIDE CAPACITY OF THE BLOOD.

Both on the rebreathing apparatus and in the low-pressure chamber the carbon dioxide capacity of the blood was determined before the experiment and at the end, while the subject was still under the influence of low oxygen. On the rebreathing apparatus 12 cases were examined, some of which reached 6.2 per cent of oxygen and showed a marked respiratory reaction. There was, however, no noticeable lowering of the carbon dioxide capacity of the whole blood as determined by the Henderson method. Even in the low-pressure chamber, where the subject was exposed to a pressure of 380 mm. for periods of over an hour, no decreased alkalinity of the blood could be detected. This is not surprising in view of the fact that the volume per minute breathed was lowered at the end of these experiments.

HEMOGLOBIN CHANGES.

One of the factors which compensate for prolonged exposure to low atmospheric pressure has been shown to be the hemoglobin. On Pike's Peak a relative increase in the per cent of hemoglobin takes place, which is later superseded by an actual increase in the number of red cells. The ordinary rebreathing test is too short to permit of a concentration of hemoglobin, but in experiments in the low-pressure chamber, where the subject is held for periods of an hour or two, a well-defined increase has been found with the Gower-Haldane hemoglobinometer in blood taken from the finger and from the vein in more than 25 per cent of the cases examined. In several cases the amount of increase was more than 6 per cent and in one case as high as 9 per cent. In a few instances the number of erythrocytes was determined and an increase found, which in one case was 9.6 per cent and in another case 14 per cent.

CHANGES IN PULSE RATE DURING EXPOSURE TO LOW OXYGEN PRESSURE.

In a series of experiments in the low-pressure chamber, in which the barometric pressure was lowered to 380 mm. (18,000 feet) at the rate of 1,000 feet per minute and held at that altitude for periods varying from 60 to 104 minutes, the pulse rate was taken every minute during the procedure. The curve of the pulse changes plotted against the variation in the barometer, and time shows that the rate increases as the barometric pressure decreases, but does not maintain its maximum during the hold at the high altitude.

In 18 cases out of 20 there was a slowing of the pulse rate while the low pressure was being maintained. The average pulse rate at 760 mm. was 73 per minute. During the ascent to 380 mm. the average increase in the pulse rate was 19 beats, or about 1 beat per 1,000 feet. This increase in the pulse rate began between 2,000 and 3,000 feet in an average of 34 cases. In only 4 cases did it appear as late as 8,000 feet. In no other case was it above 4,000 feet.

The maximum pulse rate was reached in 24 minutes after the beginning of the ascent, or 6 minutes after the barometric pressure of 380 mm. have been attained. During the hold of this altitude, averaging 86 minutes, the average pulse slowed to 84 beats per minute, an average drop of 8 beats. The individual decrease in pulse rate varied from 5 to 14 beats and in 7 of the 20 cases it was 10 beats or more. (See Table 6.)

TABLE 6.—*Change in pulse rate during exposure to low oxygen tension.*

Experiment.	Normal.	Maximum.	Time reached.	Maximum.	Time reached.	Fall.	Total time.
1	64	91	23	81	62	10	81
2	70	94	31	86	76	8	82
3	65	102	26	102	49	1	64
4	88	99	25	93	81	6	104
5	75	89	30	83	72	6	86
6	72	87	22	82	82	5	92
7	71	86	20	78	75	8	91
8	73	93	22	81	75	12	77
9	78	94	22	80	35	14	61
10	74	120	24	106	56	14	68
11	69	87	27	78	85	9	96
12	80	100	22	90	54	10	65
13	59	80	22	70	72	10	78
14	60	82	24	74	77	8	79
15	81	88	22	82	64	6	78
16	95	99	25	99	80	....	85
17	67		28	84	72	6	78
18	76	88	26	81	81	7	100
19	72	94	24	89	68	5	71
20	76	82	22	71	68	11	91
Average	73.25	91.80	24.35	84.0	69.2	7.8	85.75

THE RELATIVE VALUE OF THE COMPENSATORY FACTORS.

The factors which are involved in the compensation during very long exposures to low-oxygen pressures, as on Pike's Peak, have been shown to be, first, the circulation, as indicated by the pulse rate and the blood pressure; second, the respiration, as shown by the rate, volume per minute, carbon dioxide and oxygen pressures in the alveolar air, and the carbon dioxide capacity of the blood; third, the hemoglobin; fourth, secretion of oxygen by the lung epithelium. Evidence bearing on the nature of the first three factors has been secured in these experiments. There is undoubtedly a considerable amount of coordination and interplay of the various factors. In the rebreathing tests the circulation responds first, later the respiration. In these tests the subject is pushed until he shows signs of failing in compensation. The situation is different when the individual is kept at a given low pressure in the pneumatic chamber. Both the pulse and the respiration accelerate during the ascent, but in a great many cases the pulse rate falls while the chosen pressure is being maintained. We should look for compensation by other factors in these cases, either by means of increased lung ventilation, concentration of hemoglobin, or possibly secretion of oxygen through the lung epithelium. In a number of men the heart was relieved by further deepening of the breathing or a concentration of the hemoglobin, or both changes occurred. A number of cases have been observed in which a concentration of hemoglobin took place while the heart rate slowed (see chart 10A), and the lung ventilation either maintained its own or became less.

An unusual but interesting case was found in a man whose breathing failed to respond to the change in altitude. He did not tolerate the low pressure well at first, but later his condition improved while the given low pressure was being maintained. The heart rate accelerated markedly and later his hemoglobin concentrated above 8 per cent. His improvement occurred when his heart was relieved by the concentration in hemoglobin.

Our studies show that during short exposures to high altitudes or low oxygen, such as the aviator experiences, the compensatory reactions of the body are made almost entirely by the circulation and the breathing. Some men may secure some benefit after an hour or more from a slowly developing concentration of the hemoglobin of the blood. The order of response by the adaptive mechanisms is not that of the good response seen among mountaineers, in whom the breathing first responds while the other compensatory changes more slowly occur. The reaction resembles more nearly that seen during an attack of mountain sickness among mountaineers. In such men the heart beat is greatly accelerated during the attack. The aviator must depend largely on his heart and his breathing for compensation to the fall in oxygen pressure which he encounters during an ascent.

III.—THE EFFECTS OF LOW ATMOSPHERIC PRESSURE ON THE CIRCULATORY SYSTEM.

It has long been recognized in an unscientific way that high altitudes are "bad for a weak heart." At such elevations as those of Denver, Phoenix, or Mexico City, patients with any degree of cardiac incompetence noticed undue shortness of breath, palpitation, general weakness, and occasionally there have been cases of sudden decompensation and acute pulmonary congestion. Even much lower eleva-

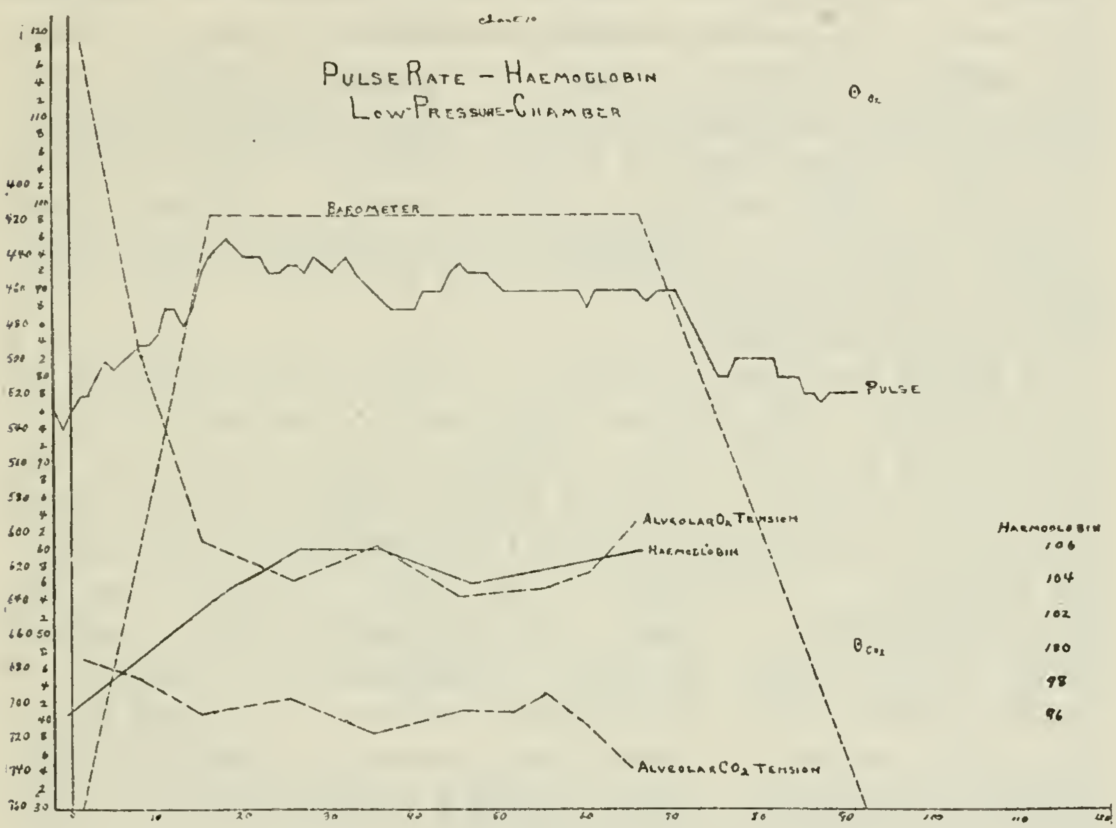


CHART 10A.

tions have been suspected by the laity of causing distinct heart symptoms. The reason for this has not been understood, because very little research work from this point of view has been carried on. The physiological results on Monte Rosa, Pike's Peak, etc., have had as participants and subjects almost entirely healthy men of the mountaineering type, and in these there has been so little evidence of circulatory strain, to say nothing of actual incompetence, that it was generally assumed that the supposed dangers from the heart were mythical or at least much exaggerated.

As a part of the research now being carried on at the Medical Research Laboratory of the Air Service at Mineola the behavior of the heart and circulation has received much attention. We have had almost ideal conditions for this study, having at our disposal two methods of producing physiological effects comparable to those of aviation. In these effects the determining factor is, of course, low-oxygen tension in the air.

In the rebreathing apparatus the percentage of oxygen is gradually lowered, while in the low-pressure chamber the percentage remains the same, but the barometric pressure may be reduced to any desired point. In either case accurate observations of heart and circulation are conveniently made. The two methods give strictly parallel results, which tally very accurately with actual conditions in the air as far as it has been possible to investigate the latter directly or to judge from what is told by aviators of their own experience. The material studied has consisted largely of healthy and youthful individuals, though even among supposedly normal men not a few pathological hearts have been discovered, and from the neighboring post hospitals we have obtained a few subjects who were known to have definitely abnormal hearts. In the near future we hope to extend very considerably our observations on the grosser forms of valvular and myocardial disease and on cases with various degrees of decompensation.

The results have been exceedingly interesting and important and have so fitted in with the experiences and the problems of aviators that they can not but be of the greatest practical value. They have shown that the ability to exist at altitudes higher than the normal depends to a very marked degree on the competence of the circulatory apparatus. The demand on the latter is so great that even slight abnormalities in heart or blood vessels result at moderate heights in clear signs of cardiac insufficiency and distress. So searching indeed is this test for cardiac disease of any kind that we have come to regard the rebreathing apparatus and the low-pressure chamber as the one sure way of making a positive diagnosis in cases where there is doubt, and believe that they may later prove to be of great value for routine clinical work.

At the same time the effects upon the normal heart have been equally striking and more unexpected. While the hardiest type of subject shows almost no demonstrable effect on the circulation, others are evidently laboring under heavy strain, and it appears that dilatation of the heart followed by collapse is an extremely common occurrence even at moderate altitudes. This accords with the known frequency of aviators fainting in the air, almost always with fatal results, of course. We have been able to throw much light on the reasons for this disastrous occurrence, and to show not only that evident disturbances of heart function, such as cardiac lesions, are predisposing causes, but that temporary indispositions which are too frequently considered trivial have a very marked influence. For example, a recent infection, a bad cold, nervous factors, etc., may so impair a man's resistance that his heart will give out and he will faint during the test. We believe that this has actually occurred in numerous cases during actual flight.

It has been estimated in the British Service that of all fliers lost to active flying service less than 2 per cent are put out by German bullets, only 8 per cent as the result of a defect in the plane, the remaining 90 per cent because of the physical condition of the pilot. Our work leads us to believe that a considerable proportion of the physical defects leading to accident are the immediate or late effects of strain on the circulation under the influence of low oxygen tension in the air.

PHYSIOLOGY OF CIRCULATION.

The purpose of the heart and blood vessels is to transport oxygen and food to the tissues and to remove their waste. The work of the circulatory system must be governed by the changing needs of the tissues in these respects. If a given group of muscles, for example, are doing more than their usual work they must have an increase of blood supply. This regulation comes mainly from the vital centers in the medulla, and consists for the most part in variations in the size of blood vessels (vasomotor tone), in the rate of the heart, and in the amount of lung ventilation. The medullary centers are in turn activated by certain chemical factors in the blood, and probably also more directly by their own metabolism and need for oxygen.

The work done by the heart is very large even when the body is at rest. It has been calculated that this amounts in ordinary conditions to the work involved in lifting 20 kilogram one meter each minute or about 140 pounds 1 foot. During exercise this work is, of course, much increased.

Apart from the strain thrown upon the heart by extraordinary demands it is evident that even its ordinary work requires the best of conditions to be carried successfully. Heart failure may be the result, therefore, not only of extra work asked of the heart, but of any condition which interferes with its success in doing its ordinary work.

The efficiency of the heart depends, first, on the quality of the heart muscle; second, on an abundant coronary circulation, capable not only of supplying ordinary needs, but of meeting the demand for considerable increase; third, on the quality of the blood which nourishes the heart muscle, especially its content in oxygen; and fourth, on an economical regulation of the work of the heart and of all of the elements in circulation and respiration, so that these functions may be carried out successfully, but without unnecessary strain. The last factor depends partly on the accuracy and economy with which the need for blood flow to each part of the body is met, and partly to the regulation of general vascular tone, so that the blood flow can take place to the maximum of efficiency without undue resistance (increased blood pressure).

EFFECT OF LOW OXYGEN TENSION ON CIRCULATORY PHYSIOLOGY.

The behavior of the organism under low pressure illustrates two physiological principles:

First, that the animal body being very accurately fitted for one set of environmental conditions, finds itself in an abnormal situation if these conditions are changed ever so slightly. We know that the body feels the change in its oxygen supply within the first few thousand feet, perhaps even the first few hundred feet after ascent begins from the surface of the earth. In consequence of this certain readjustments and compensations are necessary to keep the oxygen tension in the air.

The second principle is that however accurately the body is adjusted to its usual surroundings, its powers of accommodation to new conditions are very great, even when those conditions represent something quite out of the ordinary experience of the body. Thus when adjustments are demanded to make good oxygen deficiency in the atmosphere, such adjustments almost infallibly will be made and in sufficient abundance to keep bodily functions normal until the change from usual conditions has become so great that the powers of compensation are exhausted.

In other words, the aviator making an ascent to great heights gives the picture not of a man suffering more and more severely from the noxious effects of low oxygen but of a man who by exercising his powers of compensation is keeping his functions normal just as long as these powers remain equal to their task.

It was in fact a good deal of a surprise to us to find this unexpected normality of our subjects in the early experiments, for not only were the physical and psychic powers being kept intact until an extreme degree of oxygen want was reached, but the adjustment was so smoothly and economically made that our examination of heart and blood vessels and the respiratory phenomena would have led us to suppose that nothing out of the ordinary was going on at all.

This statement applies, however, only to what we may refer to as the "optimum" type of subject, and it was only by observing the behavior of less good subjects that we arrived at an understanding not only of the nature of the compensation which was making this normality possible, but of the very great strain which is often involved in maintaining it. For while our optimum subjects remained in good condition and efficient to very great heights and at the same time exhibited no signs of strain in the circulatory reactions other subjects either failed to make the compensation and so became inefficient at low altitudes or made the compensation only at the cost of very evident strain, such as led in many cases to cardiac dilatation, circulatory collapse, and fainting.

COMPENSATION FOR OXYGEN DEFICIENCY.

We must first discuss the nature of the compensating process and later consider how different types of organisms respond to this demand.

When the tissues feel a deficiency in the oxygen supply, demand is immediately registered for more. Just how this deficiency is felt and what the nature of the demand is we need not discuss at this point. (As a matter of fact, we have very little knowledge on the subject.) It is sufficient that such demand is made and that it is promptly complied with.

When there is deficiency in the oxygen carried by the blood there are two obvious methods of remedy open—either (*a*) more oxygen must be carried by the same amount of blood or (*b*) more blood must flow to the tissues carrying less oxygen per unit but in sum bringing the required amount.

INCREASED RESPIRATION.

To meet the demand of (*a*), if the blood carries less oxygen per unit because of lowered tension in the alveolar air, this tension may be raised by increased ventilation of the lungs. Normally the percentage of oxygen in the alveolar air (that which comes in contact with the blood) is from 13 to 15 per cent, giving a tension of 100 or more mm. Hg. Increased respiration will raise this percentage to 17, 18, or even 19, thus increasing the oxygen tension in the blood to a like degree. In fact, we know that increase in respiration begins to occur almost as soon as the sea-level pressure is left behind.

The limit of compensatory mechanism is soon reached however. Since the atmosphere contains only 21 per cent oxygen, the alveolar air can only with difficulty be brought up to 19 per cent, and an increase from 15 to 19 per cent will certainly not compensate for a drop in atmospheric pressure of one-half, such as occurs when a height of 18,000 feet has been reached.

INCREASED BLOOD FLOW.

The second method will be more productive of results. Instead of providing the normal amount of blood with the usual burden of oxygen an increased blood flow with a lessened amount of oxygen per unit will answer as well.

Increased blood flow is accomplished in two ways. There must be peripheral relaxation of the arteries to allow more blood to pass, and there must be increase in the amount of blood coming from the heart. The latter is accomplished either by increase in pulse rate (more beats per minute delivering the normal volume) or by increase in volume output per beat. Increase in heart output by either method would, of course, tend to raise the blood pressure.

It may be emphasized that a very considerable increase, possibly a doubling, of the blood flow may be accomplished with very little evidence that this is taking place, since the various mechanisms for accomplishing it interplay in such a fashion as to hide each others' traces. Thus increase of pulse may be made unnecessary by increase of volume per beat (it is, however, still a controversial question how much the latter can vary). Again, increase of heart output must, of course, raise the blood pressure, while decrease in peripheral resistance (vasodilatation) lowers it again. We have reason to believe that for a given organism a certain blood pressure is optimum, combining efficiency with economy, and that the body tries to keep to this pressure as closely as possible. For this reason the best type of subject will show almost no change in either systolic or diastolic pressure until late in the experiment, when the powers of compensation are being pushed to the limit.

RELATION OF VASOMOTOR CONTROL OF THE HEART.

A thorough understanding of the interplay between heart and blood vessels is necessary in order to comprehend the adjustment and failures of adjustment occurring on exposure to low oxygen. In everyday life this interplay is constantly going on; the better the condition of the heart muscle and of the arteries and the better the nervous control the more successful will the organism be in keeping up its efficiency. Every effort, such as rising from a chair or running for a street car, even every emotion, calls for increase of blood flow and would inevitably give rise to increase of blood pressure and extra work for the heart if vasodilatation did not ease the strain and at the same time allow the increased flow. A young man with good arteries can exert fairly violent muscular efforts with moderate and transitory rise in pulse and blood pressure. An older man, however, whose arteries are less flexible, can not do this. In his case the blood pressure may increase to a dangerous point because of failure of the peripheral tone to relax. The result of this failure will be either that the heart is put upon a dangerous strain or that the demands are simply not met. In the latter case the organism will for the time being have to run with a deficit; hence loss of efficiency and symptoms of deficient circulation (dyspnea, cyanosis, weakness, etc.).

NERVOUS FACTORS IN VASOMOTOR CONTROL.

The nervous element in the control of the vasomotors is of great importance. It is well known that the vasomotor system is the most sensitive part of the body. The slightest emotion will cause flushing or pallor, or even an anemia of the brain, which leads to fainting. The nervous regulation is especially under the influence of lack of "condition" from various causes, such as infections, indigestion, lack of sleep, etc. If a man is out of condition a slight effort will cause twice the rise in pulse and blood pressure that it normally should, and this rise will last much longer.

There are observations to show that purely nervous factors, such for instance as great mental concentration, will cause a higher and more lasting rise than severe muscular exertion. This is presumably because in physical exertion vasodilatation will provide for the extra blood flow needed with very little necessity for increasing the blood pressure. Where nervous tension is at a high pitch, however, the vasomotors are certain to share in this tension. Peripheral resistance will be high and the blood pressure will be high and sustained. Pressures of 200 have been observed in young men as a result of mental work or excitement, and such a pressure may last for an hour or more, often until peripheral relaxation has been brought about by such means as vigorous muscular exercise, a hot bath, etc. We shall see later that this psychic reaction of peripheral vascular tension (and of increased heart rate as well) has a marked influence on the ability to withstand low oxygen.

In the normal organism the amount of blood flow will not only be regulated as to total amount, but there will be accurate division according to the needs of the various parts of the body.

The aviator is not using his muscles to a great extent, so does not need a great increase in blood flow here, though the deficiency in oxygen is probably felt to some extent in all the tissues and the blood flow to all parts of the body may need to be increased somewhat. Two parts of the body however, must be especially taken care of—the brain centers which feel the want of oxygen and are regulating its supply and the heart muscle which is doing more than its ordinary work. It is probable that one important difference between the "optimum" type and the type who overcompensates and strains his circulation is that the former keeps brain and heart well supplied with blood but does not flood the rest of his body, while the latter has a marked increase of flow to all parts and so throws this unnecessary extra work upon the heart.

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FAILURE TO COMPENSATE.

It has already been suggested that when circumstances arise calling for a compensation involving heart strain certain hearts will respond with the necessary effort even to their own detriment, while certain others will give up the task at once and allow physical inefficiency to result. The difference is partly one of condition of the heart muscle and general physical tone, and partly of the quickness and efficiency of the nervous reactions which govern the vital functions. The same principle applies to the whole body, even to the personality, as well as to the heart alone. One individual will drive at business, athletics, etc., with an intensity which brings success, but often at the cost of health; another will save his health but lose the game or the business deal.

This conception is necessary in understanding the reaction to low oxygen. One subject will compensate fully with strain if it is necessary; the other will very early give up the effort and his efficiency will be correspondingly early impaired. Inasmuch as the strain is most vitally felt in the circulatory apparatus it follows that the subjects who are most vigorous in adjusting themselves to the new condition will show cardiac exhaustion, while those who show early inefficiency will not. Furthermore, a man who shows early inefficiency can still go on with the experiment, becoming more and more inefficient, but not straining his heart. The man who compensates, in other words, frequently gives out from heart or vasomotor exhaustion (faints) while the man who does not so compensate may remain more or less in possession of his faculties to a much higher altitude. This result seems paradoxical since the former class are individuals who are physically far superior to the latter.

INSUFFICIENT COMPENSATION.

It is to be assumed, of course, that no organism will fail to make any efforts to adjust itself to altered conditions. We have, however, encountered a few individuals whose reactions have been almost nil. Such men show no demonstrable rise in pulse, no change in blood pressures, and none in respiration. From this one could predict that the psychological tests (the best criterion we have as to the sufficiency of the compensation) will show early deterioration. We have observed "complete inefficiency" in a few cases as low as 6,000 feet (or at the corresponding oxygen percentage). Such men are usually constitutionally inferior, often undersize, with poor chests, poor color, clammy, mottled hands, poor complexion, etc.

In addition to these types of constitutional inferiority similar lack of reaction will be shown by many men, especially those toward middle age, who have led a sedenetary life, are overweight and flabby, perhaps with fatty hearts. In these cases it might be expected that a good course of physical training would much improve their reactions. It has long been recognized on Pike's Peak that the visitors of athletic type and in good training are much less likely than others to be mountain sick.

It is not to be expected that either of these types will commonly be found among a class so carefully selected as aviators. Less degrees of inability to compensate, however, are not uncommonly found. All these cases, of course, follow the rule that the less vigorous the compensation the less likely the subject is to show heart strain.

THE "OPTIMUM" TYPE.

At the other extreme is the "optimum" type for aviation, those who compensate fully to very great altitudes, retaining their efficiency and yet doing this in so accurate and economical a fashion from the point of view of the circulation that there is little or no evidence of strain. When the break comes (above 25,000 feet in the low-pressure tank, at from 5.5 to 7 per cent on the rebreathing apparatus) it comes with great suddenness; from almost full efficiency there is a quick lapse into unconsciousness, but still with no circulatory collapse. There is no loss of general muscular tone; the subject remains sitting with eyes open, stylus held firmly in hand, color full, though of course cyanotic, pulse full and regular, systolic and diastolic pressures maintained. Recovery is almost instantaneous on return to normal oxygen pressure and is complete. The subject usually refuses to believe that he has not been conscious and efficient throughout. We must attribute this unconsciousness to direct action of low oxygen on the cortical centers while the circulation is still in order.

CIRCULATORY COLLAPSE.

Quite different is the picture when circulatory failure has occurred; cardiac dilatation, sudden collapse of vascular tone, ashy pallor, cold sweat, complete loss of muscular tone, so that the subject always falls from his chair. Recovery is slow and unsatisfactory; it is often an hour before the man is himself again. Circulatory collapse may be seen at any stage of the experiment, depending on the amount of strain preceding it, and occasionally comes on most unexpectedly.

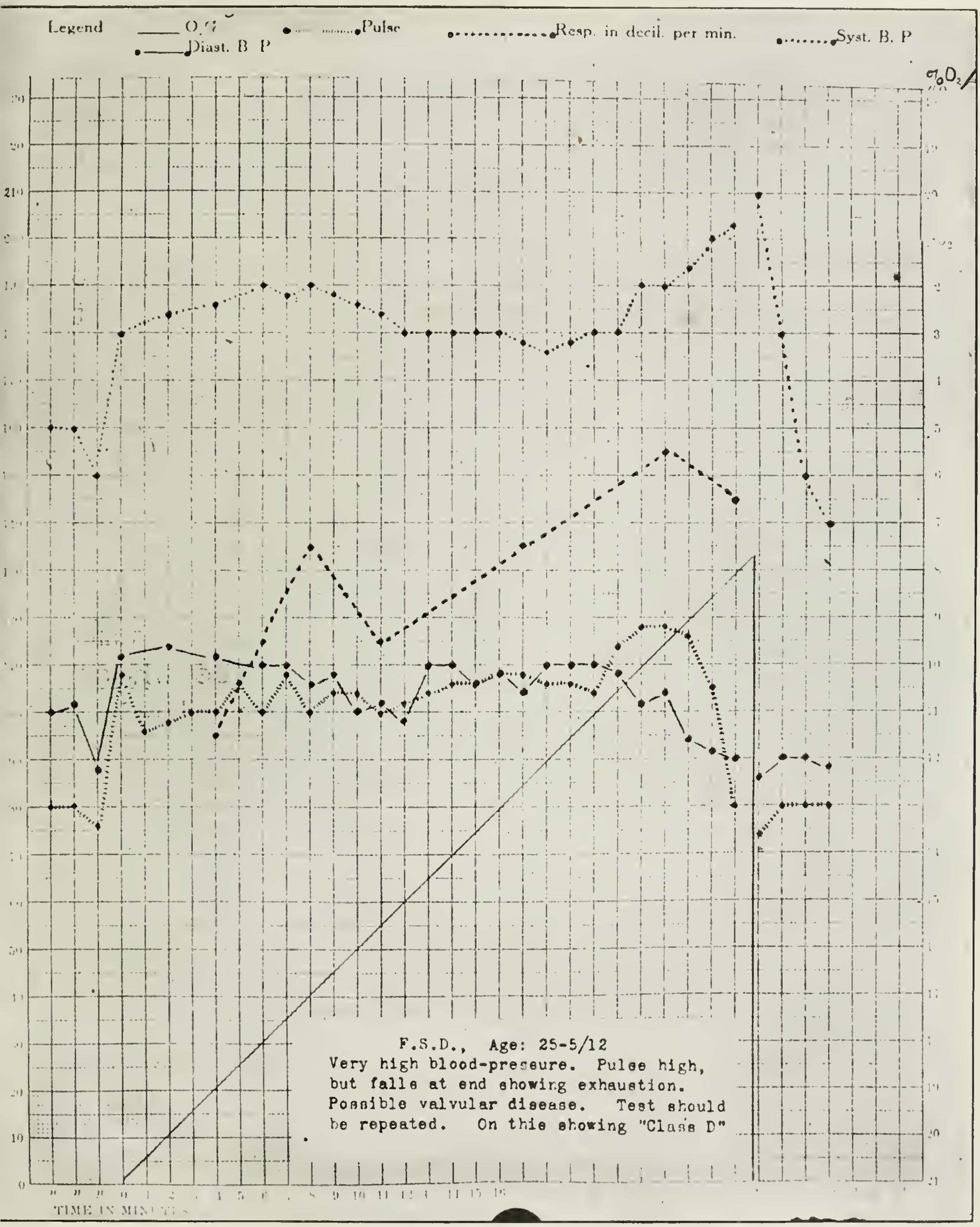
HEART STRAIN.

The syndrome of heart strain, followed by dilatation and fainting, is of very great importance in aviation. We know that fainting in the air is common and that such an occurrence is practically always fatal. We know also that aviators almost invariably develop in time a disabling "staleness," which we strongly suspect is the result of this recurring heart strain, and that fliers who have "gone stale" are particularly sensitive to low oxygen and particularly liable to dilatation and fainting.

That heart strain is common was shown during a recent demonstration of the low-pressure chamber to a group of medical officers, men certainly of average health, though not in the best of training. Five men were taken into the tank and of these two had acute heart symptoms and had to take oxygen before 20,000 feet was reached. The following day five more men underwent the test; one had a dilatation at 14,000 feet, another at 16,000 feet, and a third at 18,000 feet. In other words, just half of a group of ordinary subjects showed this very striking effect. It was interesting that in each case the dilatation was demonstrated by percussion while the subject still felt perfectly well, according to his statement, but in each case he began to feel ill before a minute had passed and would have fainted if oxygen had not been given promptly.

Let us summarize what has already been said as the incidence of heart strain; the "optimum" subjects do not show it, either because they have a strong heart muscle or because their compensation is made so economically as to throw a minimum of work on the heart. The poor types of reactors (those whose compensation is of low grade) do not show it, because their hearts are not being asked to overwork. Subjects with defective heart muscle do not show it, because their hearts refuse to overwork. Those who do show it are young men of quick reaction, usually of excellent constitution, though often "out of condition." Such subjects often have a marked psychic reaction from the start, with rise in pulse and blood pressure, indicating undue tension of the nervous system. When one listens to the heart it is evident almost from the start that this organ is working too hard; at first, perhaps, with plenty of reserve, but later the limit is passed and there is a sudden break.

What is the essential difference between the "optimum" type and what might be called the "next to the optimum type," by which the one shows no circulatory exhaustion up to the point of unconsciousness while the other breaks? It is partly strength and quality of heart muscle and ability to stand strain; it is partly a smooth working of the nervous regulation of heart and blood vessels, including freedom from high nervous tension; it is partly the ability to furnish an abundant circulation through the coronary vessels when need arises. It can be expressed in one word familiar to physical trainers, "condition." If we knew just what "condition" means we should have the answer to the question above.


Legend
O.%
Pulse
Resp. in decil. per min.
Syst. B. P
Diast. B. P
%O₂
TIME IN MINUTES
F.S.D., Age: 25-5/12
Very high blood-pressure. Pulse high,
but falls at end showing exhaustion.
Possible valvular disease. Test should
be repeated. On this showing "Class D"

CONDITION.

We imagine the chief elements in athletic condition are a strong heart muscle, a highly efficient coronary circulation, and good peripheral vasomotor control. We may guess that there may be even deeper factors, such as a difference in the chemistry of the tissues allowing rapid metabolism, and the ability to generate energy rapidly without the accumulation of harmful end products. At any rate, our work strongly emphasizes the necessity for keeping aviators as nearly as possible in perfect physical condition and preventing them from flying when they are not so. We believe they should daily be made to exercise in such a way that the heart will have to work harder, the coronary vessels deliver a full volume of blood, the vasomotors be practiced in their work, the respiration deepened, and metabolism kept going at an increased rate.

TEMPORARY INDISPOSITIONS.

By "lack of condition" we mean not only "softness" due to lack of exercise, but many temporary indispositions, such as may follow a bad cold, recent illness, lack of sleep, overwork, alcoholic excess, etc. The influence of such factors on ability to withstand low oxygen was well illustrated by a subject who had been tested many times and found to be one of the hardiest we had met with. One day he was carried in the low-pressure chamber to an altitude of 22,000 feet and kept there about 15 minutes with almost no effect on his general efficiency or on his heart. That evening he dined with friends, drank a moderate amount of alcohol, and went to bed late. The following morning he felt rather giddy and had a slight headache. He was taken to 18,000 feet in the low-pressure chamber. At this point he had reached complete inefficiency by the psychological tests, was rather cyanotic, and examination of his heart showed the left border out 3 or 4 cm. If he had not been given oxygen at once or brought down quickly he would have fainted. It was fortunate for him that this occurrence took place in the laboratory and not while in an aeroplane thousands of feet above ground.

We can only speculate as to whether such differences in condition are due to variations in nervous control or whether they have a basis in the chemistry of the tissues. At any rate, such temporary lack of condition is a much more serious matter than we are tempted to believe. Athletic trainers recognize it clearly enough and would not allow such a man to participate in a game, not because he would injure himself, but because he would not hold up to the strain and might lose the game. In flying, where the aviator's life is at stake, equal care should be observed, to say the least.

PHYSIOLOGY OF EXERCISE COMPARED WITH AVIATION.

It must be borne in mind that the demand made upon the heart in aviation is widely different from that of physical exercise. The most obvious difference is that one call is familiar, and we are used to meeting it; the other is unfamiliar and requires delicate and accurate reflexes to sense it and to meet it properly.

In the body at sea level the regulation of the vital functions is largely activated by carbon dioxide or, more broadly speaking, by the chemical constitution of the blood. During exercise a large amount of CO_2 is produced, and at the same time other metabolic products find their way into the blood, so that respiration and circulation are stimulated to great activity. There is a great margin of safety in this method; long before CO_2 and other substances in the blood have risen to a toxic level the feeling of exhaustion is so insistent that further physical effort becomes almost impossible. For this reason circulatory collapse rarely occurs as the result of physical exertion.

In the case of aviation, on the other hand, no extra CO_2 is being found, and the low atmospheric pressure so reduces the partial pressure of the CO_2 in the blood that it exerts little, if any, regulatory action. The probability is that the activation of the vital centers in this case ceases to be a function directly of the constitution of the blood, but depends on the oxygen metabolism of the nerve-tissue itself. At any rate the margin of safety between the stimulating and the paralyzing effect of oxygen-want is very narrow, and since there is no dyspnea and distress preceding the final collapse, the latter comes on with no warning; hence its terrible danger to the aviator.

In exercise, again, there is a natural check against excess which is lacking in exposure to rarefied air. When exhaustion comes one is forced to rest, thus terminating the extra work for the heart and giving a chance for recovery. In the case of the aviator, however, exhaustion brings exactly the opposite result. If the heart falters for a moment, not only do the nerve centers run the risk of exposure to a paralyzing anoxemia, but the coronary circulation becomes insufficient, and on the fullness of the coronary blood supply depends the ability of the heart to do this work. Thus a vicious circle is started, and, once the heart has begun to fail, nothing can avert collapse. In exercise faltering of the heart means the opportunity to recover, in aviation it means a break in competence and dilatation, and probably death if the exposure were continued.

FAINTING.

Before leaving the subject of fainting it should be remarked that this occurrence is common at all altitudes, even the lowest. It occurs, of course, in ordinary life on the surface of the earth, not as a sequel of heart dilatation, but as a vasomotor neurosis pure and simple. Evidently, however, since it occurs so very frequently in flying we can not consider it purely a neurosis or dismiss it as a psychic effect. We must say rather that it represents a demoralization of the vasomotor system in its effort to make the fine (even though not laborious) adjustments necessary to compensate for oxygen deficiency.

An interesting analogy may be drawn to writer's cramp and other occupational neuroses, which suggests an explanation for the occurrence of vasomotor phenomena, such as fainting during exposure to low oxygen. These neuroses are never found on the long continuance of fine muscular movements involving accurate coordination, as in writing, use of the typewriter, sewing, playing a musical instrument, etc. On this analogy it is easy to understand how the constant delicate adjustments demanded of the whole circulatory system during repeated flights at ever-varying altitudes may lead to demoralization of the vasomotor system even when the actual strain is not great.

For this reason we are inclined to class fainting as a low-oxygen effect even when it occurs near the earth. It is probable that the routine use of oxygen at the lowest altitudes would prevent a great deal of the fainting in the air. As our work has progressed we have become more and more impressed with the perfectly definite effects following exposure to altitudes below 5,000 feet. These results are usually not observed at once, but are cumulative, and are ordinarily seen only in aviators who have begun to "go stale." It is not sufficient, therefore, to bar a stale aviator from high flights; he should not fly at all.

EFFECTS ON PATHOLOGICAL CASES.

We shall now consider rapidly the behavior on low-oxygen tests of subjects with definite circulatory lesions of various types.

ARTERIOSCLEROSIS.

Individuals with stiff arteries give a very characteristic reaction. They illustrate very clearly that the physiological response to low oxygen has to begin at a very low altitude in order to preserve the normality of the body. Such subjects will show effects very early, both by their inefficiency and by the abnormality of their heart sounds. We have seen several who were "completely inefficient" at 8,000 feet, while at the same time the heart rhythm was hurried, the first interval shortened, and the first sound weak and valvular.

The essential difficulty with stiff arteries is that they will not play their part smoothly in bringing about increased blood flow and at the same time sparing the heart. For this reason, even in ordinary life, arteriosclerotics must continually be having sudden marked rises in blood pressure, the result of every exertion and every emotion.

The extra strain thus thrown on the heart must lead either to overwork of that organ or else to inefficiency.

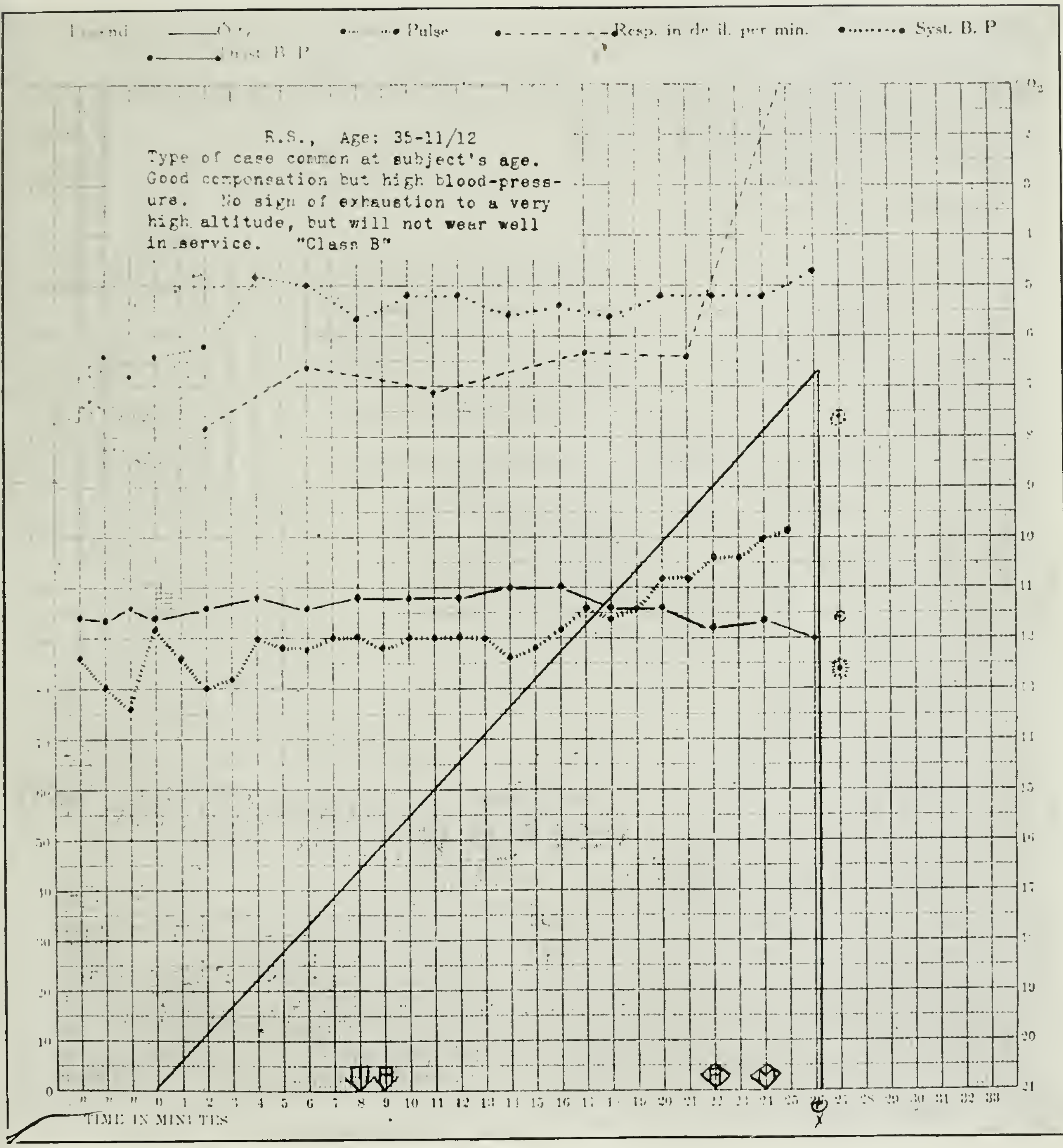
Nothing illustrates so well this lack of adaptability of old arteries as aviation. Almost immediately the blood pressure rises sharply. (We have observed a pressure of 180 in several perfectly healthy and vigorous older men.) At the same time the pulse accelerates. This strain has to be carried by the heart at a time when the coronary vessels, themselves sclerosed, are not furnishing the heart muscle the extra blood supply called for, and the blood that does come carries progressively less and less oxygen. Of course the heart can not meet the demand for more blood supply, and the work is simply not done. Such hearts do not dilate, in our experience, because they give up the task rather than overstrain themselves; at any rate, we have never dared to carry such a subject to a point where there was likelihood of cardiac dilatation.

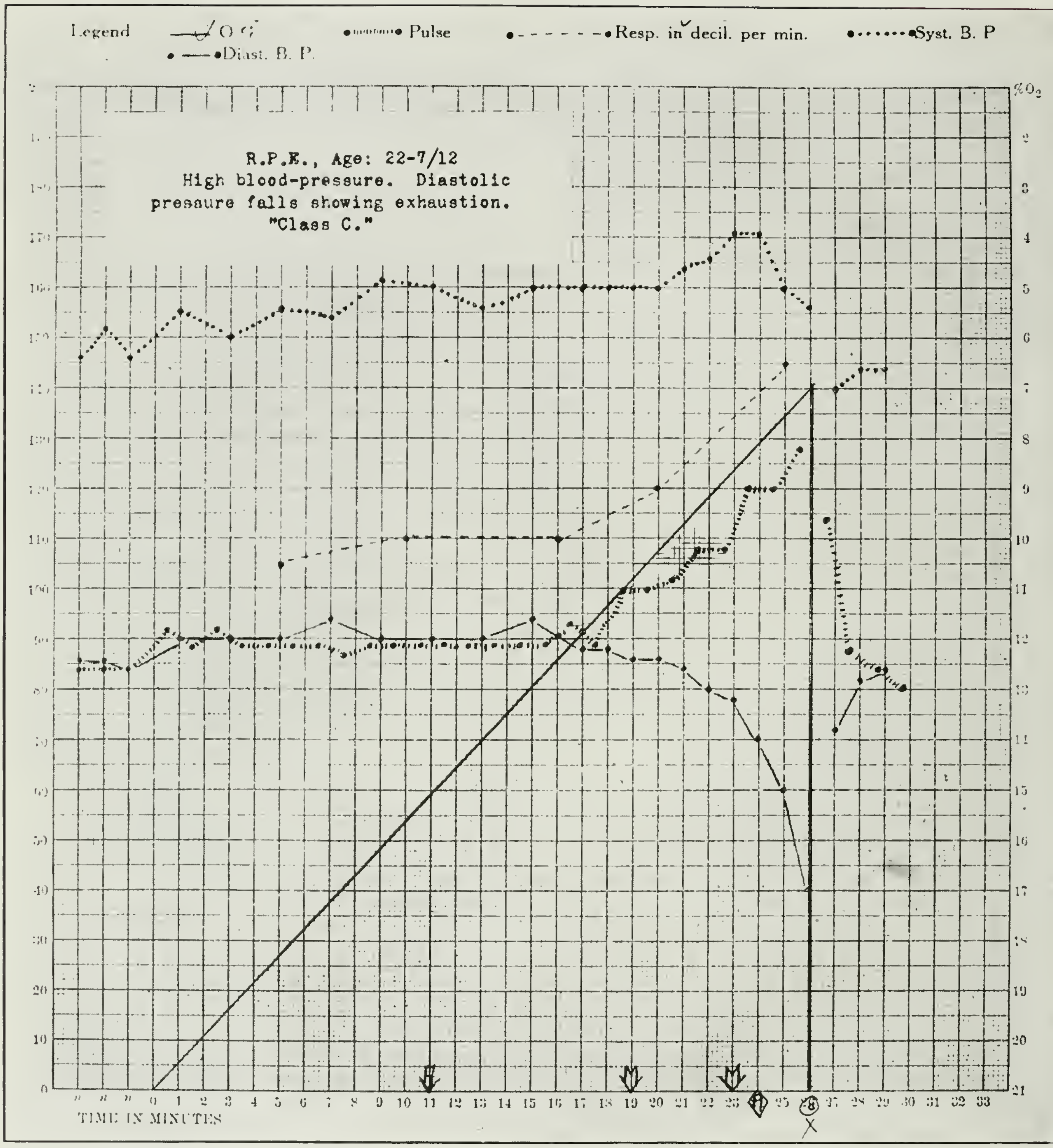
It is an old aphorism that age means only the condition of the arteries. It is well recognized abroad that the best age for the aviator is in the early twenties, and that the older he is beyond this point the less efficient he is likely to be in service. Our observations with the low-oxygen tests bear out this strongly and suggest that the explanation may lie in slight changes in the arterial walls and musculature at a much earlier age than it has been supposed that such changes can occur.

This statement does not imply that there are no men above 30 or even in their forties who belong to the "optimum" class, but the older a man is beyond 20 the more likely he is to show the arterial type of reaction to low oxygen. Thus, many men of about 35 will show a certain hypertension from the start, with a constant rise as the test goes on, e. g., 135, rising to 150 to 160. In these cases the heart muscle will carry the burden much longer than in the manifest arteriosclerotics, and there will be normal psychological reactions achieved by heart strain, followed eventually, in many cases, by dilatation of the heart.

ARRHYTHMIA.

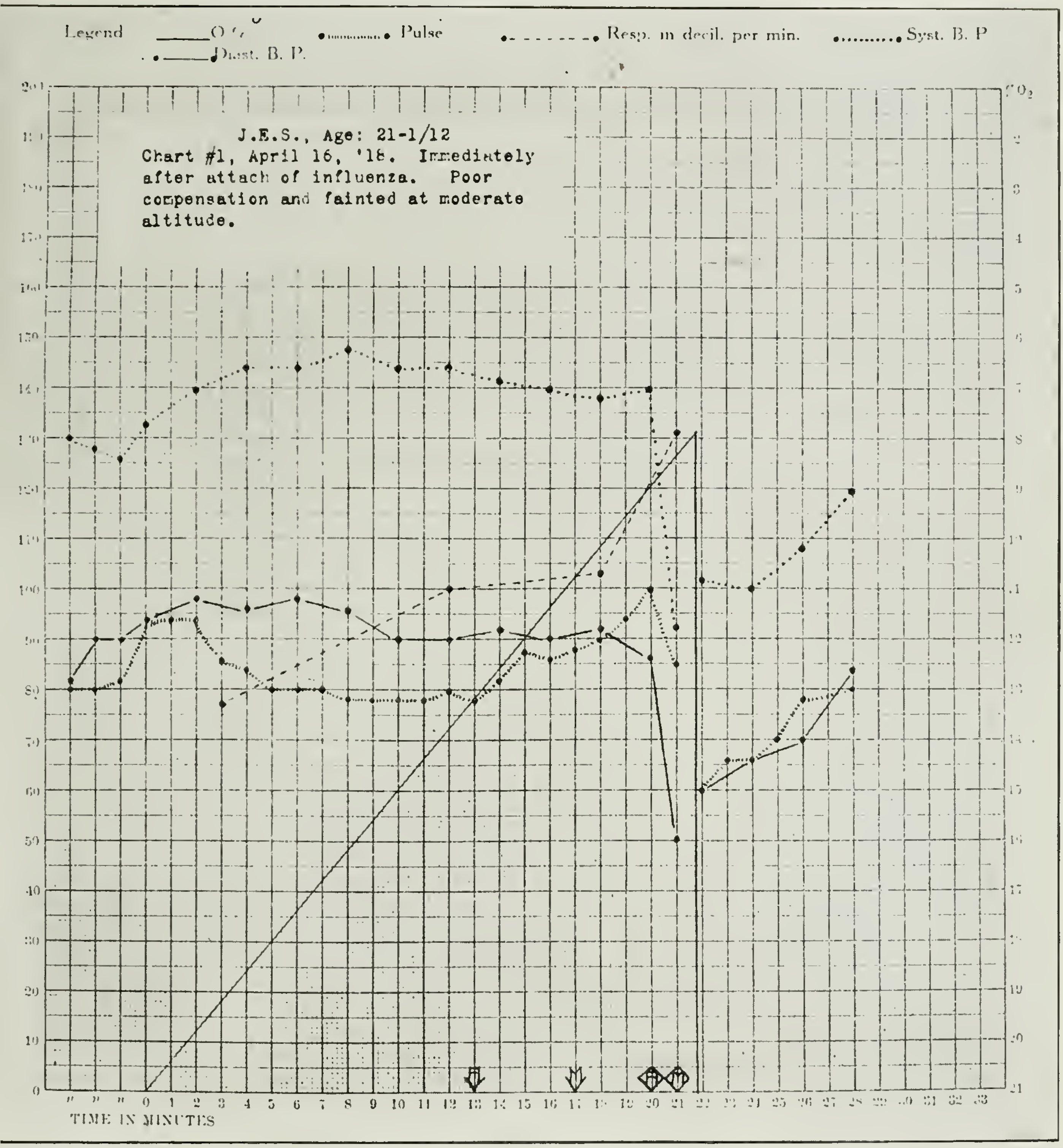
The effect of low oxygen on subjects who have any tendency to arrhythmia is very striking. Abnormalities of the heart-beat mechanism invariably become exaggerated to an alarming degree. An occasional extrasystole, for example, will occur more and more frequently as the test progresses, until the majority of the contractions are of ectopic origin or until there are considerable periods of abnormal beats in series like those of paroxysmal tachycardia. This, of course, interferes with the efficiency of the circulation, so that these subjects become very cyanotic, very uncomfortable, and fail early to perform well on the psychological tests.

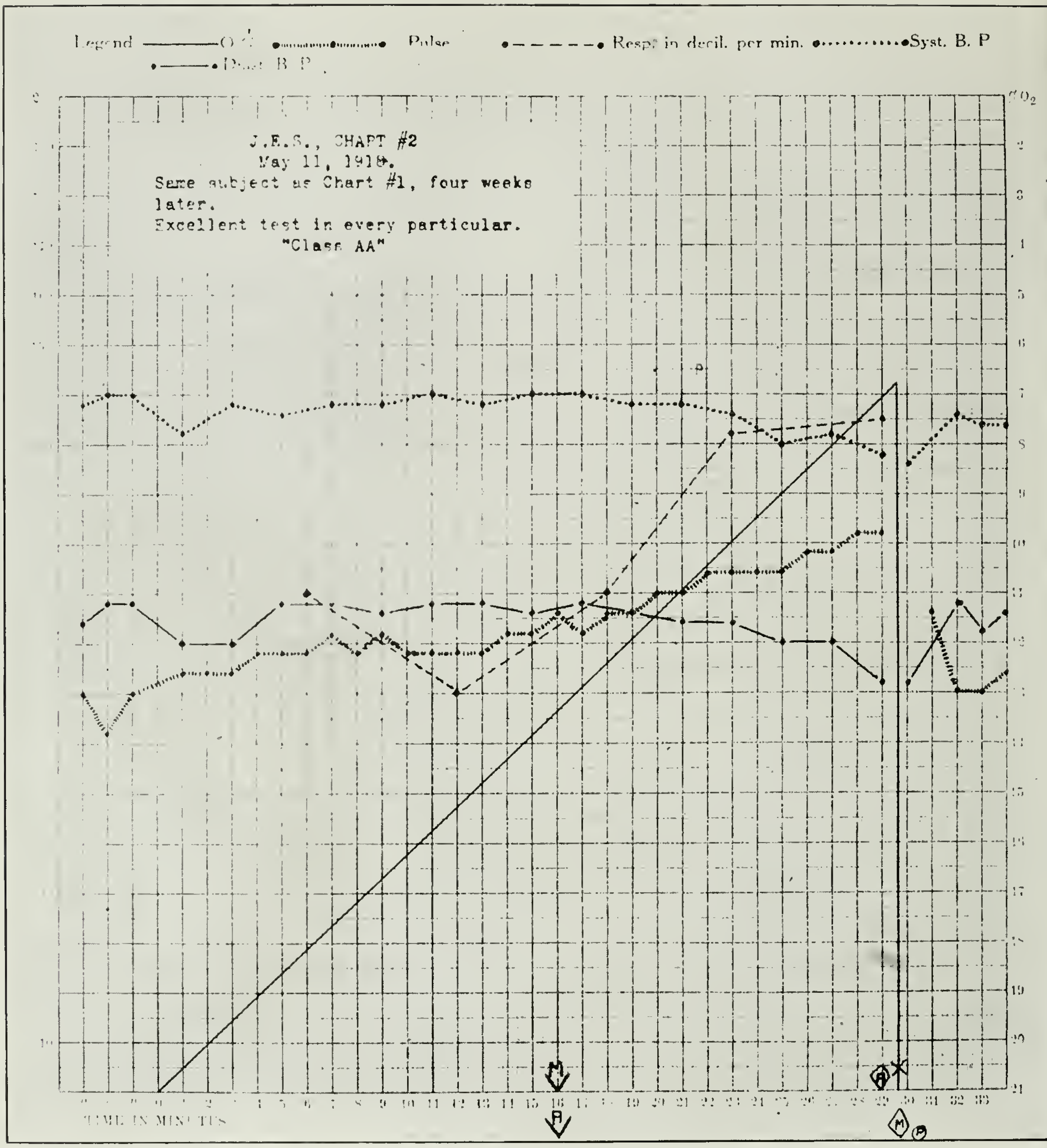

Pulse
Resp. in de il. per min.
Syst. B. P
R.S., Age: 35-11/12
Type of case common at subject's age.
Good compensation but high blood-pressure. No sign of exhaustion to a very high altitude, but will not wear well in service. "Class B"
TIME IN MINUTES



No. 325. CADET. Age 22 years, 7 months.

This chart shows compensation. There is a fair response in respiration. There is a typical rise in pulse and systolic pressure and a controlled but rather rapid terminal fall of the diastolic pressure. The systolic pressure is too high for an A rating.


Legend
Pulse
Resp. in decil. per min.
Syst. B. P
Diast. B. P.
J.E.S., Age: 21-1/12
Chart #1, April 16, '18. Immediately after attach of influenza. Poor compensation and fainted at moderate altitude.
TIME IN MINUTES



No. 63. CADET. Age 21 years, 1 month.

Left the hospital three days ago where he was laid up for a week with influenza. Feeling fairly well to-day, though not up to his usual form.

The first chart (chart 1) is typical of a man out of condition, rather high systolic pressure, psychic rise in both pulse and pressure, followed by sudden faint at about 8 per cent. In this the diastolic pressure fell practically to zero; the systolic pressure and pulse also broke sharply as may be seen by the slow recovery after the experiment was terminated.

He was tested again two weeks later (chart not given) and made a very good run with the exception of a rather high blood pressure (148). In this test he was not completely inefficient when taken off at 5.5 per cent. After two weeks he was given a third test (chart 2), which entitles him to an AA rating. The systolic pressure stays below 140, there is no break in diastolic, and there is a moderate healthy rise in pulse.

This case illustrated the very serious effects of temporary indisposition.

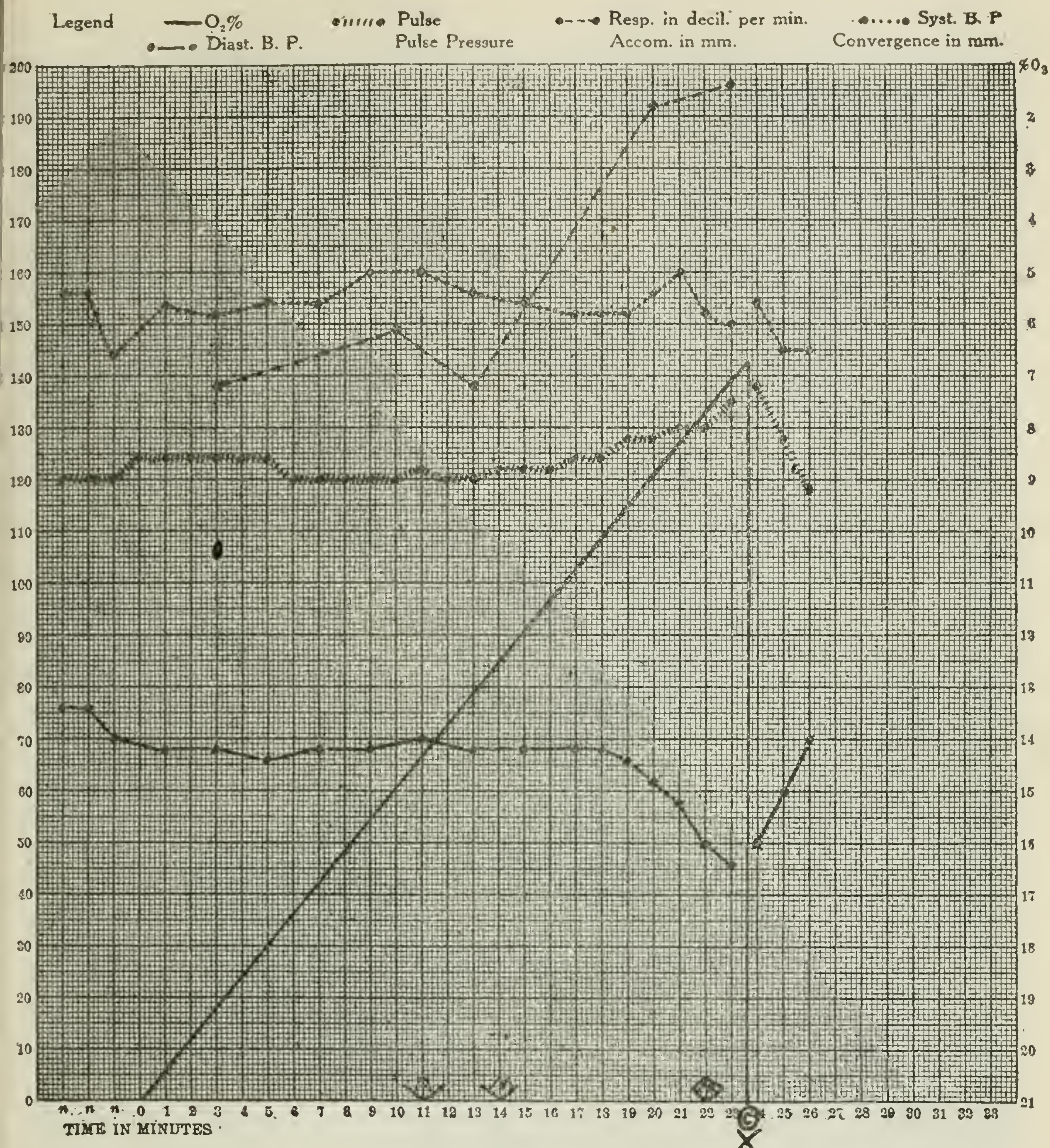


CHART 11.

No. 217.—D. R. CADET. Age 20 years, 6 months.

There was a roughening of the first heart sound heard before the test. No demonstrable enlargement, second sounds equal. During the test a definite systolic murmur developed and the pulmonic second sound was accentuated. There is no doubt of the diagnosis of mitral insufficiency well compensated.

The chart is typical of most cases of valvular lesions. The pulse is high throughout the test. The systolic pressure is high and uniform. Diastolic pressure begins to fall between 9 and 10 per cent, but is in control at all times. Respiration shows rather a marked response. Efficiency is well preserved, the psychological rate being A. This is accomplished at the expense of marked overwork of the heart. Although this is well borne at the present time, the presumption is that the subject would soon show the effects of wear, and permanent damage to the heart might easily result. Class D.

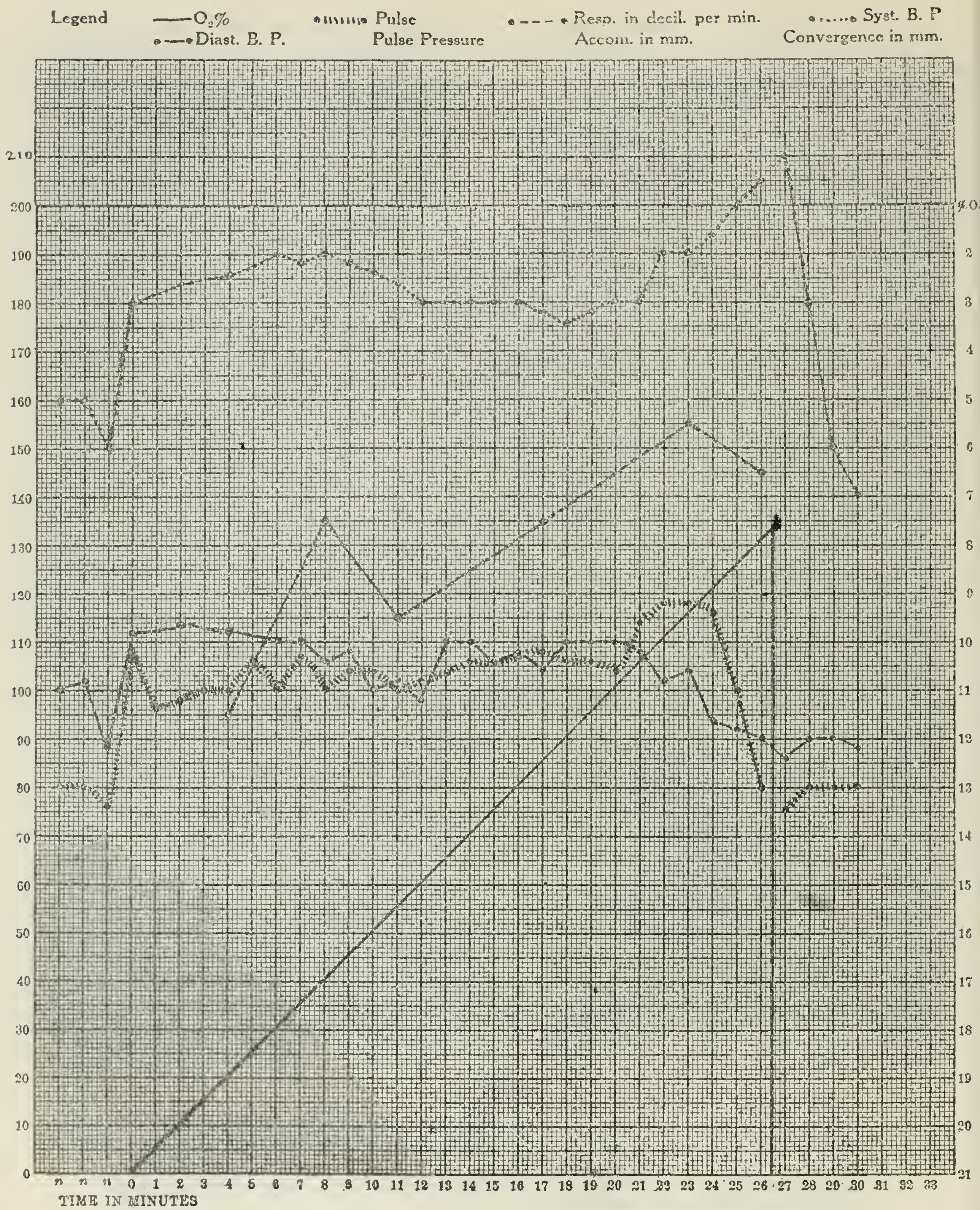


CHART 12.

No.—.—F.S.D. CADET. Age, 25 years 5 months.

An unusually bad record. Systolic pressure very high and at the end rises to 210. Diastolic shows marked fatigue though the oxygen percentage reached is not very low. Pulse rather high at the start shows very little acceleration later and at about 9 per cent begins to fall rapidly.

The heart sounds became roughened, suggesting a valvular lesion, which seems extremely likely from the blood pressure. Should be studied further; test should be repeated. On the showing of the chart given the rating should not be better than D.

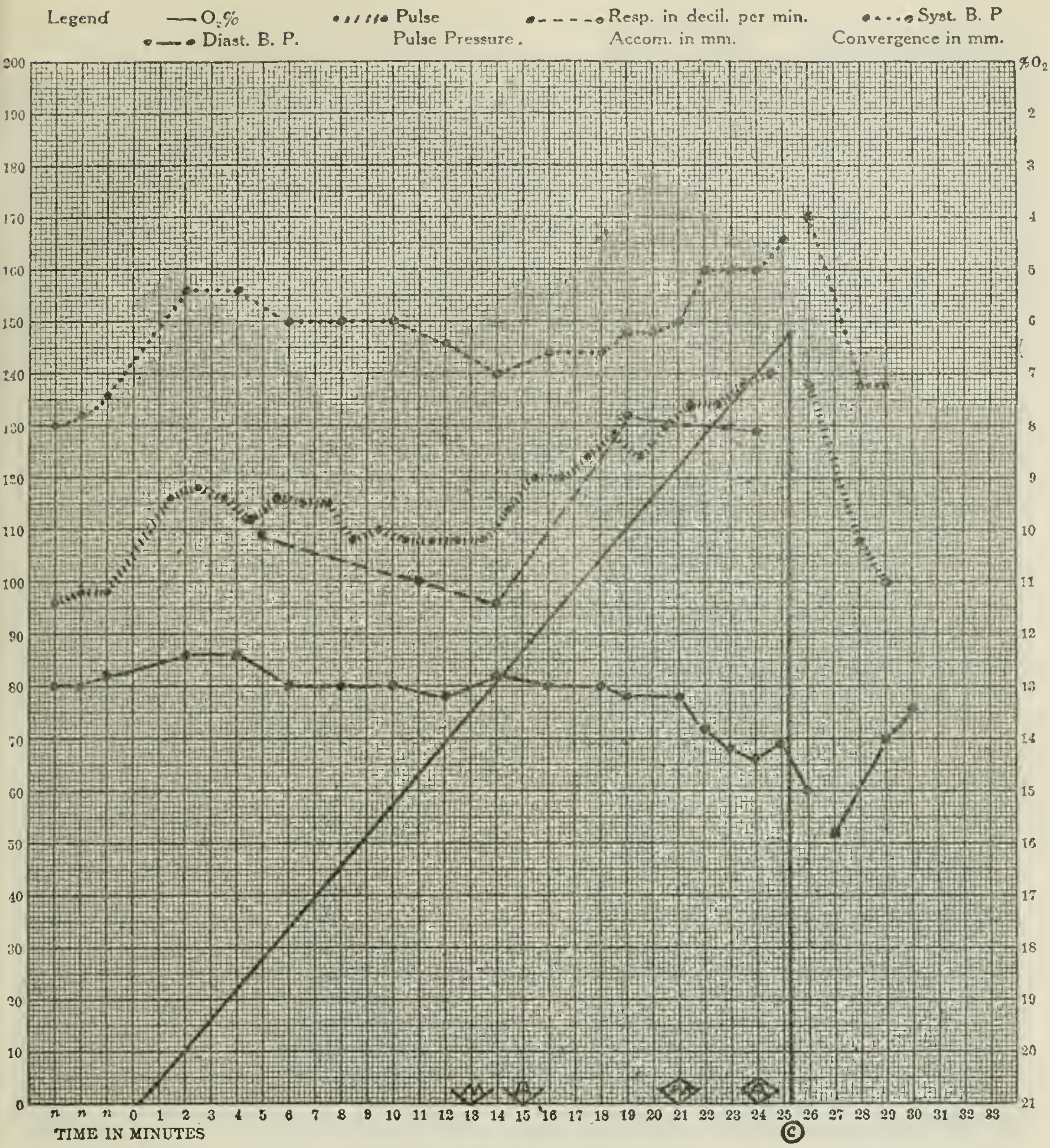


CHART 13.

No. 163.—H. B. R. CADET. Age, 23 years 5 months.

An example of compensation held to a very low percentage with heavy circulatory strain. There is a marked psychic reaction in both pressure and pulse at the start, but this subsides somewhat in the first 15 minutes and should not count too much against the subject. What is against him is the marked rise in pressure toward the end (166) together with a high pulse and falling diastolic, which may be interpreted as showing fatigue though no actual collapse occurred. Class C. Holds his efficiency well but at the expense of severe heart strain; high blood pressure and pulse. Nervous type. Would wear out rapidly if used for high work.

At the same time it may be remarked that these very qualities might make him a very valuable pursuit flier as long as he lasted.

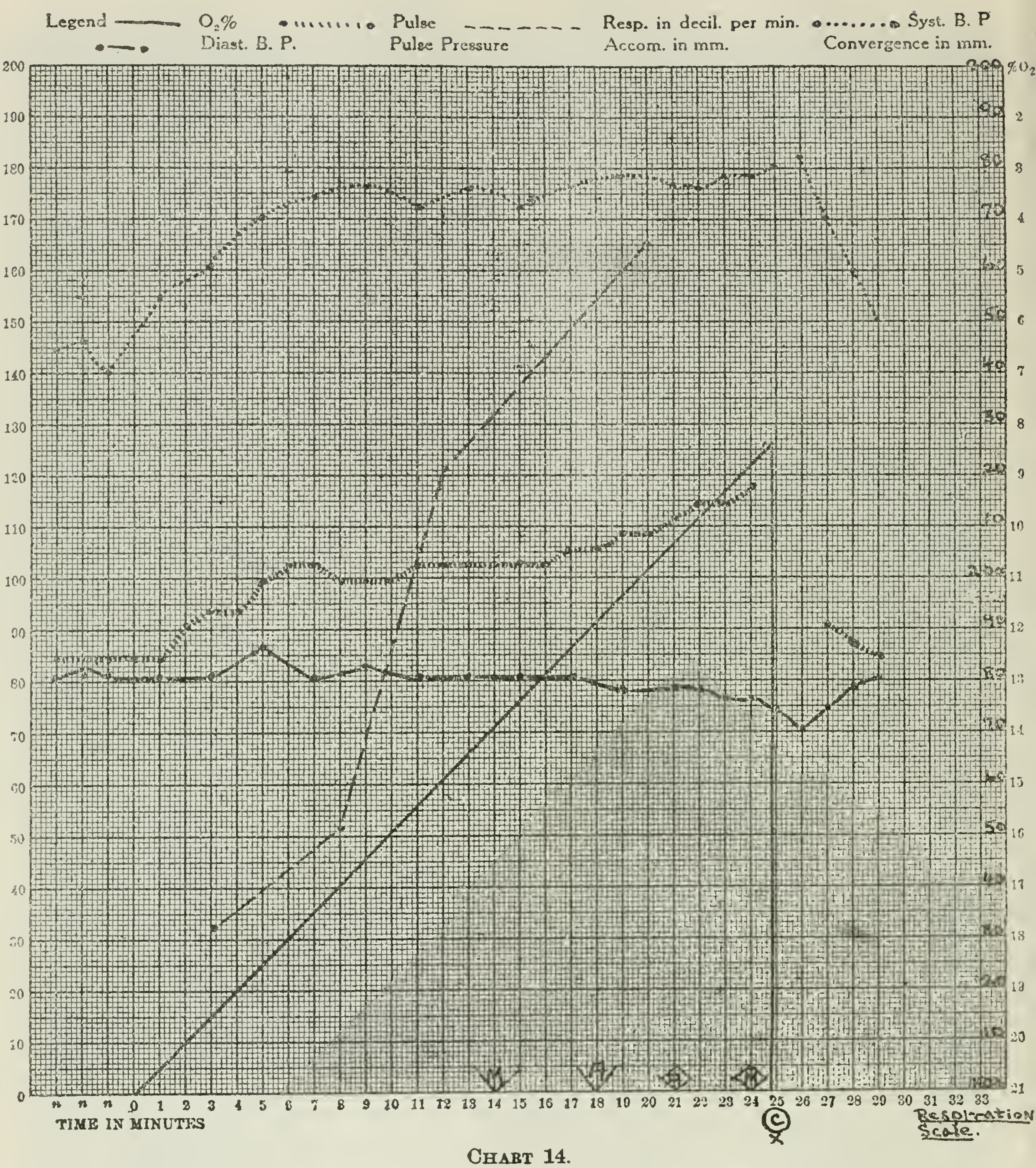


CHART 14.

No. 123.—W. B. R. CANDIDATE. Age, 23 years 2 months.

Suggestion of presystolic thrill and murmur at apex found before the test.

During test these became much more marked and a systolic murmur developed. Systolic pressure high from the start and steadily increased. Diastolic remained low. Note the very marked early increase in respiration indicating great discomfort in breathing. Became inefficient at a rather high oxygen percentage. This chart is characteristic of the way many valvular heart cases respond to the test. He was not carried far enough to get the circulatory collapse that would almost certainly have come as a result of the high pressure and pulse. Class B.

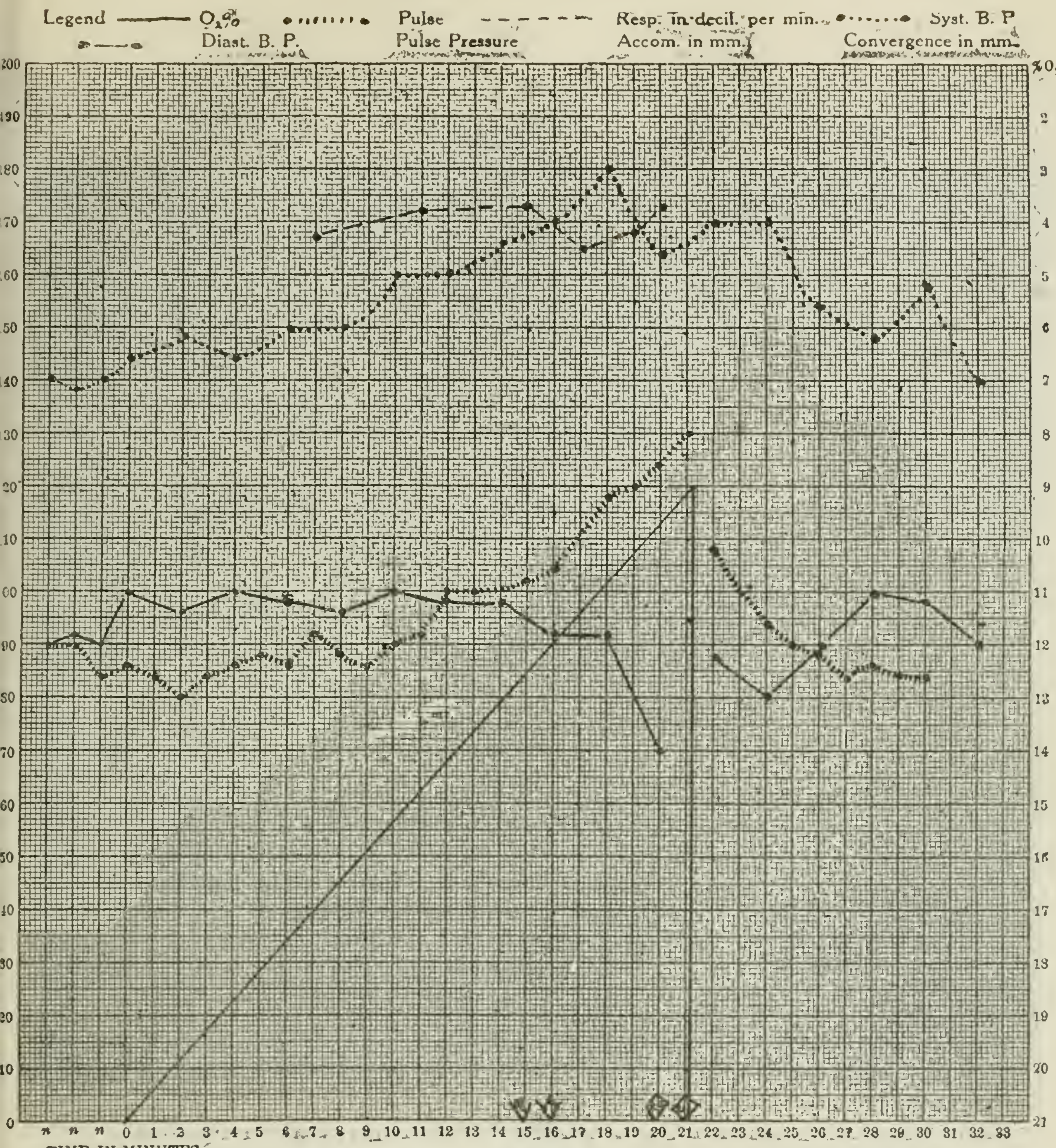


CHART 15.

No. 82.—D. H. O. CADET. Age, 24 years 7 months.

Only significant finding in history or physical examination was a rather red throat. Blood pressure reclining 120, standing 132, after exercise 146 and two minutes later 138. Was rather nervous on test.

Pulse reacts normally but rather excessively considering the percentage reached. Respiration somewhat full from the start, but shows no increase. Systolic pressure high and steadily increases to 180. At this point (above 10 per cent) the combination of high pressure and pulse seems to be more than the heart can stand. There was probably a dilatation; at any rate the subject almost fainted as indicated by the fall in both systolic and diastolic pressures. A very bad run, hardly sufficient to rate C. The test was repeated a week later. At this time the percentage reached was much lower before inefficiency. The blood pressure was still a little too high; 134 rising to 156. On the second run alone he would be entitled to B, but since he had shown high blood pressure twice, very high once, it was considered safer to rate him C.

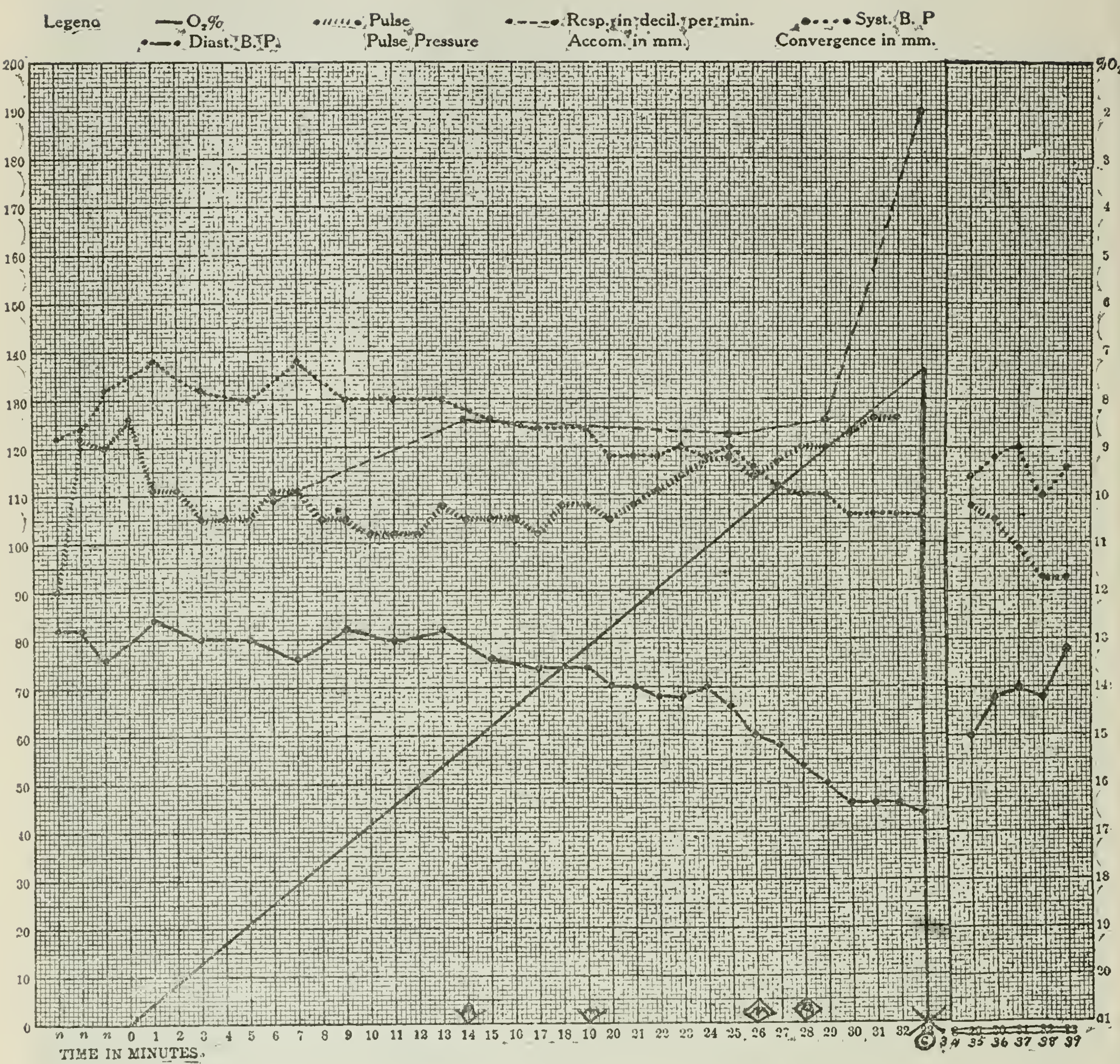


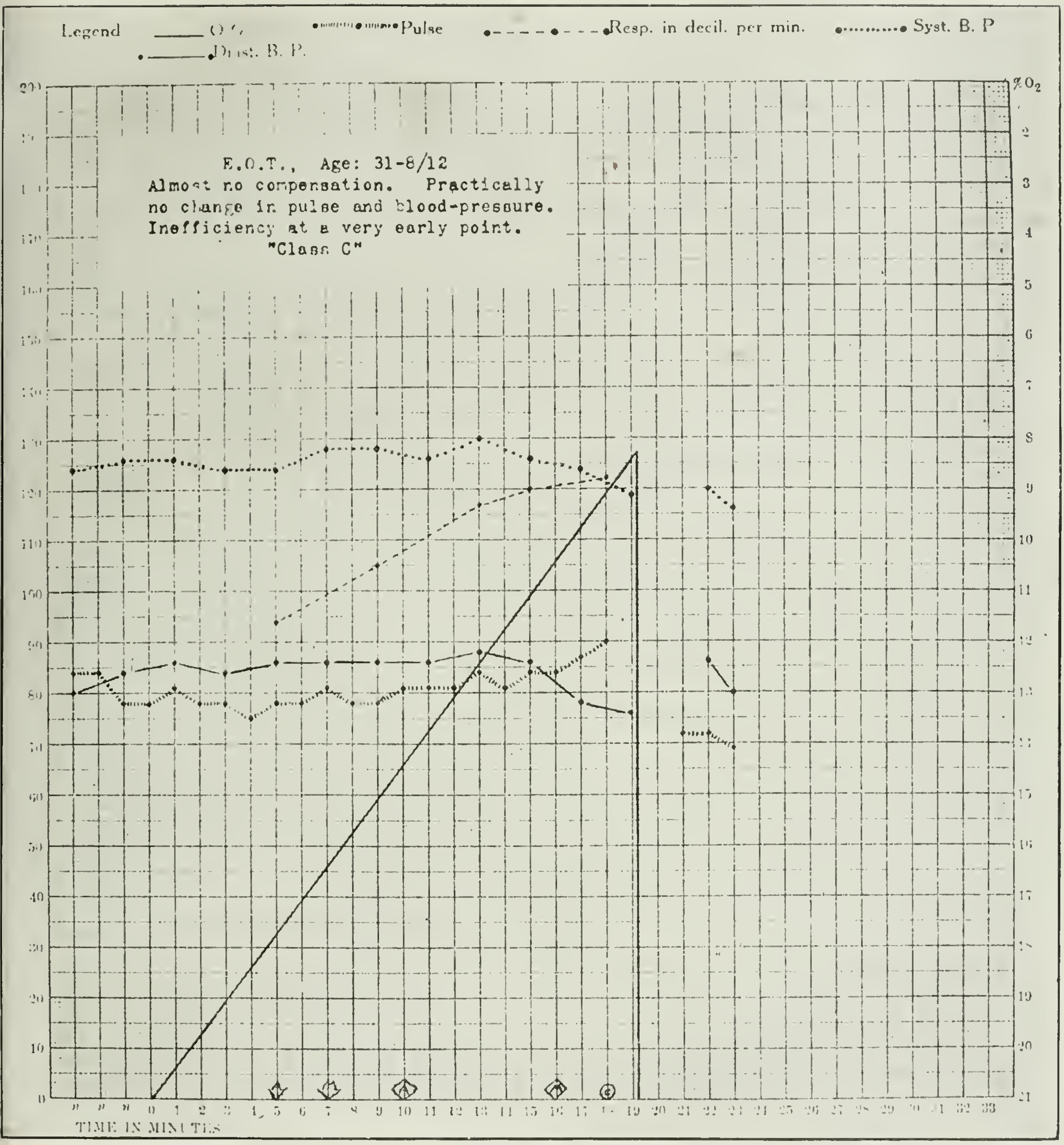
CHART 16.

No. 382.—A. M. G. PILOT. Age 25 years, 2 months.

This man is an instructor in flying and has had 200 hours of aviation. He feels decidedly stale and has asked to be relieved of flying for the present. Is afraid to go up because he has such poor judgment in his present condition.

Preliminary pulse: Reclining 69, standing 105; after exercise 120, two minutes later 102.

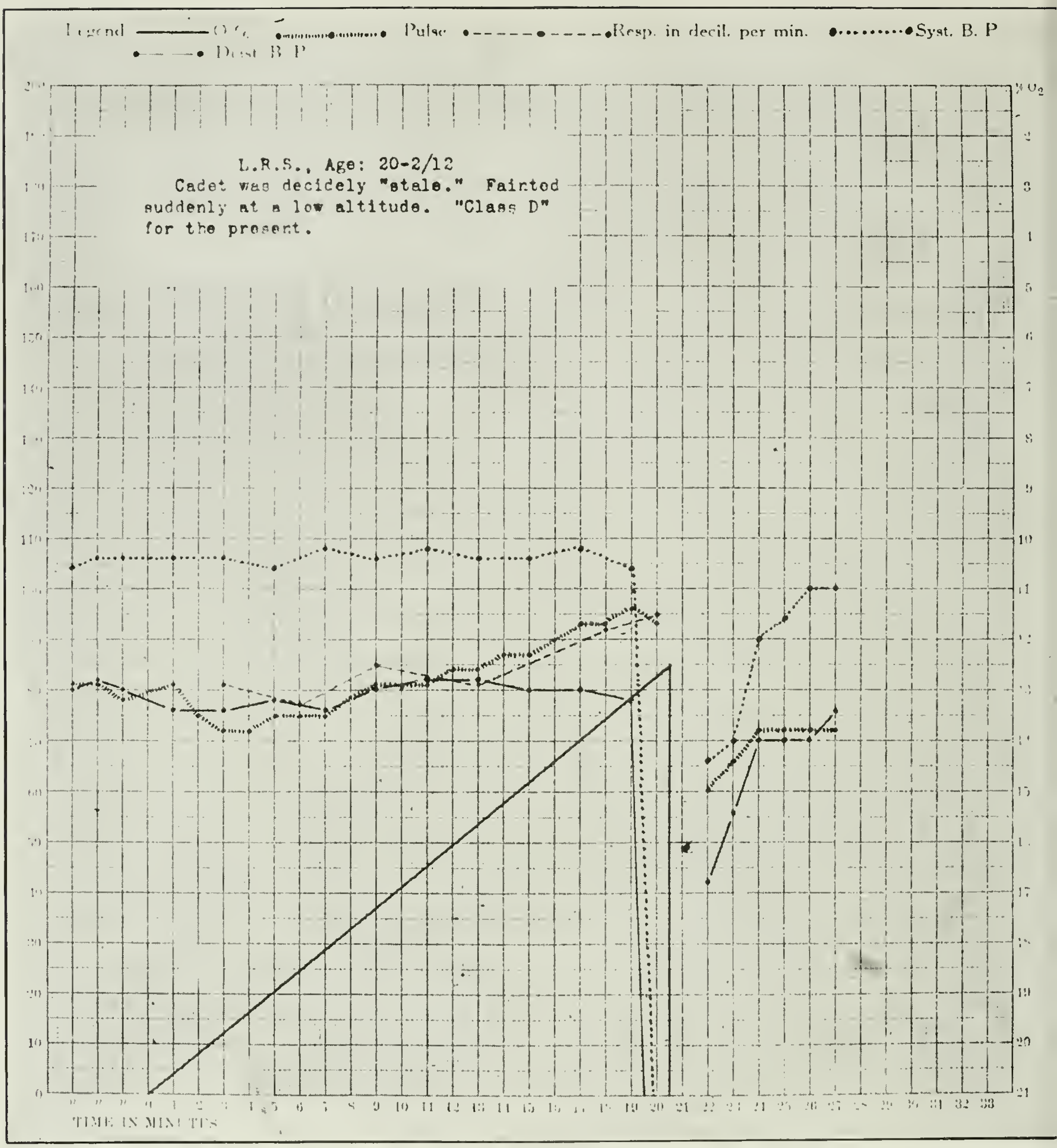
The only abnormal feature of his test was the slow but steady decrease in both systolic and diastolic pressures. He reached a fairly low oxygen percentage before becoming inefficient. The proof of staleness here is not full, but the preliminary pulse reactions and the blood pressures during the test are suggestive.



No. 50. PILOT. Age 31 years, 8 months.

In good health, but "out of training," and 20 pounds overweight.

This chart shows almost total failure to compensate. There is very little change in pulse or blood pressure, and the respiratory reaction is deficient. For this reason there is early appearance of inefficiency as shown by the psychological characters, and he is "completely inefficient" above 9 per cent. Since there is no circulatory reaction there is no evidence of strain. Class C. Because inefficient at a relatively low altitude.



No. 144. CADET. Age 20 years, 2 months.

Is decidedly "stale," hates to go up in the air at all. Feels tired and depressed and is discontented in the service at present. Certain complications at home are on his mind a good deal.

This chart is typical of a man in poor physical and mental condition. He fainted rather suddenly at about 13 per cent. Previous to this he had shown little compensatory response, blood pressure too low from the start, pulse rising slightly and respiration hardly at all affected. This man might be expected to faint at any time during a flight irrespective of elevation.

No rating given but for the time being is unfit to fly at all. Withdrawn from flying and recommendation made for furlough.

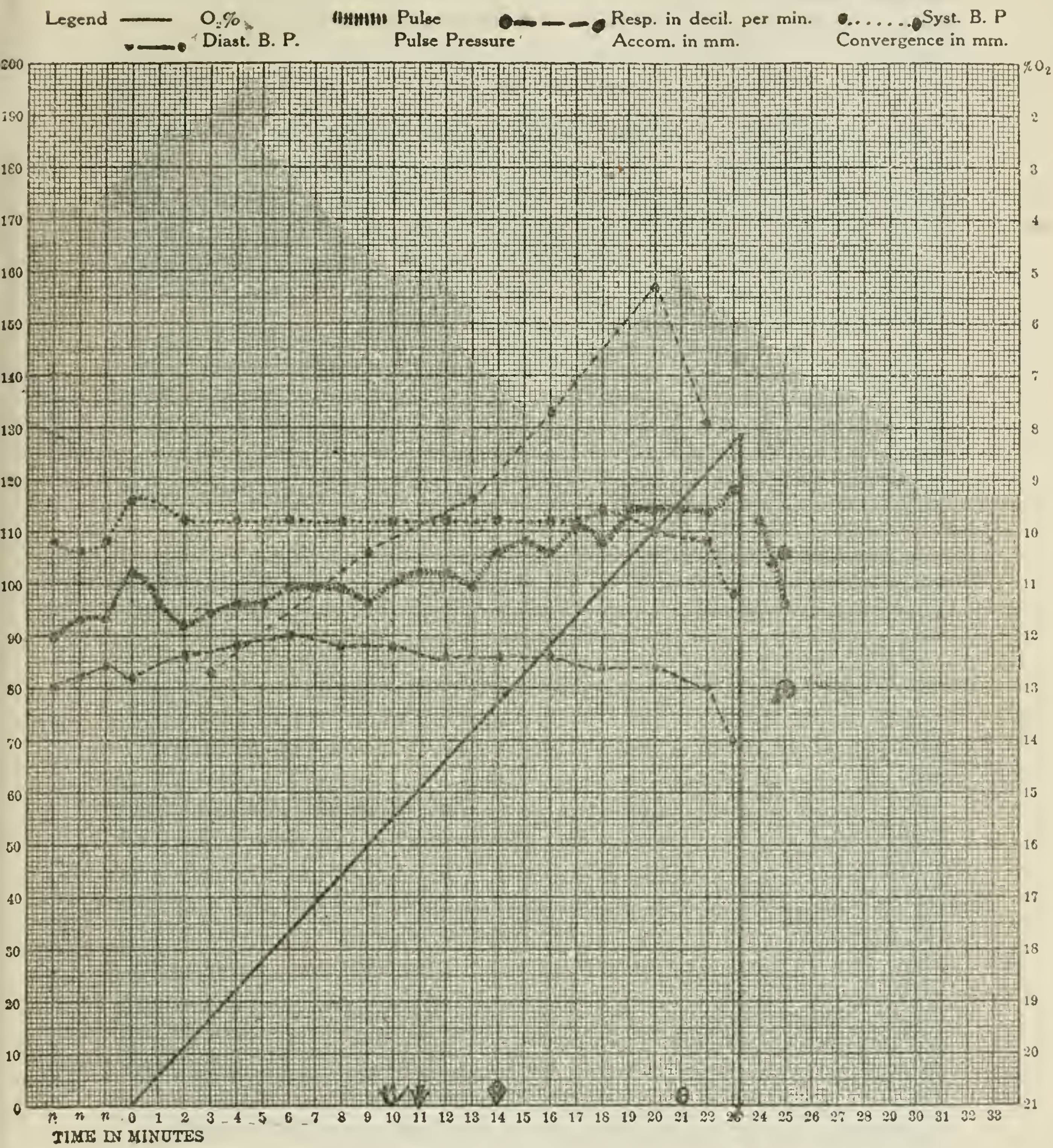


CHART 17.

No. 51.—R. N. H. PILOT. Age 23 years, 6 months.

This is another example of poor compensation. Very little response in pulse, none in systolic pressure, very low pulse pressure. Respiration increased but later feel off. At the end there is a fall in systolic and diastolic pressures indicating failure of the circulatory apparatus to continue even the limited effort it is making. Psychological effects early. Class C. Becomes inefficient at a relatively low altitude.

Sinus arrhythmia always becomes more marked during the test, but is to be regarded rather as a sign of youth and vigorous reactions than as an abnormality. It has no clinical importance as far as we know.

VALVULAR DISEASE.

The diagnosis of valvular lesions is easy during the low-oxygen test. We have been able to identify a considerable number of cases in men who had passed rigorous Army examinations. Murmurs and thrills develop in a surprising fashion when due to organic disease. On the other hand, we have observed a certain number of presumably functional murmurs which did not alter during the test while the heart continued to be perfectly normal in action.

The behavior of hearts with valvular lesions depends on their degree of compensation. If this is poor and the heart muscle weak they will give up the fight early, allowing inefficiency to develop; at the same time there will be marked cyanosis and great discomfort in breathing, with palpitation. Cases with poorly compensated mitral stenosis do especially badly and are very uncomfortable.

A well-compensated mitral inefficiency, however, behaves like an overworking normal heart. Such hearts must have a good quality of heart muscle and good coronary circulation to remain compensated in ordinary life, and are well used to overworking at times to meet the demands of every day. They react vigorously to low oxygen, as a rule, run a rather high blood pressure, an increased pulse, give evidence of overwork from the start, and eventually dilate and give out.

We believe that no man with a valvular lesion should be allowed to fly, no matter how perfect the compensation, not only because of the likelihood of immediate heart strain, with dilatation and fainting, but because in the course of time the cumulation of repeated strains will bring on a disastrous condition of the heart. Cases have been observed in the service where a heart originally well compensated has eventually broken down, and the subject in these cases is not only unfit for further flying but the heart injury may be irremediable and he may have to look forward to a life of invalidism and early death. We have seen two cases of mitral disease in aviators where distress was found to be pretty marked when the plane rises to 2,500 feet.

ATHLETIC HEARTS.

"Athletic hearts" behave particularly badly under low oxygen. There is still no general agreement as to just what this term signifies, whether it represents merely a great hypertrophy of the heart which has not receded or whether there has been definite injury to the heart muscle by strain. The latter supposition is the more probable, because we know that the normal body not only possesses great powers of increasing its various functions to meet special calls, but that the recession from such unusual increase in tissue and function is normally accomplished easily and safely. We must, therefore, assume on general principles that the so-called "athletic heart" means an injured heart muscle, not a subinvolution. Clinically the diagnosis is usually easy: A history of excessive athletics, especially rowing and distance running, a heart somewhat enlarged to percussion, an abnormally heaving apex beat, and sounds which are either notably loud and booming, or in a later stage are of poor and valvular quality. There is usually an absence of murmurs, though the dilatation can easily lead to a relative mitral leak.

The reactions of the athletic heart to low oxygen are always excessive, marked increase in blood pressure and pulse, but there is likely to be a rather early loss of compensation, since the damaged heart muscle is unable to carry the strain; it will either give up the task (cyanosis, inefficiency, etc.) or will dilate and cause fainting.

IV.—MANUAL OF OTOLOGIC DEPARTMENT, MEDICAL RESEARCH LABORATORY.

1. Introductory.

MEDICAL PROBLEMS—OTOLOGIC RESEARCH PREVIOUS TO THE WAR.

Certain unique features concerning the study of the ear in aviation are worthy of special attention. Since our entrance into the war the Medical Department of the Aviation Service has encountered certain problems of ophthalmologic, cardio-vascular, respiratory, psychiatric, and other character. The work of research into the relation between the motion-perceiving function of the internal ear and flying, however, had been undertaken long before the entrance of the United States into the war. A group of otologists had conducted experiments and carried on investigations involving the end-organs, nerve paths, and brain connections of the vestibular portion of the internal ear for a period covering the preceding decade. Many months before the United States entered into the conflict several of this group of otologists had been in correspondence with the Medical Department of the United States Army upon the subject of the physical requirements of applicants for the air fighting forces, and the total available work done upon both sides of the Atlantic was made the basis of the standards adopted for these physical requirements of prospective Army fliers.

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ARBITRARY REQUIREMENTS FIXED BY CHIEF SURGEON, AIR MEDICAL SERVICE.

Immediately after our entrance into the war the present Air Medical Service was organized. The Chief Surgeon of the Air Medical Service, when he was confronted with the problem of formulating a plan for selecting men for training as fliers for the Army, decided to attempt to limit the admissions into this service to men who were definitely known, as far as was possible to determine by skilled medical examinations, to be possessed of normal physical equipment.

ONLY PHYSICAL ITEMS COVERED BY MEDICAL EXAMINATION.

The determination of their possession of all attributes other than physical fell to another division of the Air Service, the Mental Examining Board, and at no time constituted a part of the work of the Medical Service. The sole duty of the Chief Surgeon with respect to the examination of applicants for flying training was to demonstrate in each man the presence of normal physical equipment.

FORMATION OF STANDARD BLANK FOR PHYSICAL EXAMINATION.

For the purpose of furnishing a standard plan on which these physical examinations could be conducted upon a uniform basis, blank 609, A. G. O., was formulated, after consultation with the highest medical authorities in the various special fields of medical work covering the complete physical examination of man. The ophthalmologist, the otologist, the rhinolaryngologist, the neurologist, the respiratory and cardiovascular specialist, the gastroenterologist, the orthopaedist, the general surgeon, the dermatologist, the genitourinary specialist, are all represented in the constitution of this examination blank, and the general field of complete physical examination covered to the satisfaction of each.

PHYSICAL EXAMINING UNITS.

Special care was exercised to pick the highest grade medical examiners available at each point where it was deemed necessary to establish a Physical Examining Unit, and the work of each unit was departmentalized in the best manner possible to render each examiner capable of serving in his most efficient capacity.

No difficulty was encountered in securing the services of men well trained in all special medical work represented in this blank, with the notable exception of the examination of the internal ear. This was relatively so new that the limited number of those capable of doing this portion of the work rendered it necessary in establishing each Physical Examining Unit, to pay special attention to the selection of the otologist. In many instances it was necessary to develop the man capable of handling this portion of the work by a special intensive course of training and instruction.

DETAILED INSTRUCTIONS.

Carefully detailed instructions were prepared by high authorities upon the individual medical branches involved in this special examination, and these were sent to each Physical Examining Unit for its guidance; from time to time additional instructions were issued by the Chief Surgeon for the purpose of further improving the examining service; special visits to Physical Examining Units were made from time to time with a view to maintaining this service at its highest efficiency, and frequent consultation of the best-informed medical authorities on the subjects involved were held, in attempts to omit nothing which might improve the quality of this work. Full reference was made to the accumulated experience of the Allies; and confidential and other reports from medical officers in England and France were thoroughly digested and used to shape up the service of the Chief Surgeon's examiners.

IMPORTANT SENSORY EQUIPMENT.

Among the applicant's sensory equipments which were deemed important to demonstrate as normal were visual perception, sound perception, deep sensibility (or muscle-joint-splanchnic or kinæsthetic sense), tactile sense, and motion perception; special examination of olfactory, taste, and certain other special senses, such as cold, heat, pain, pleasure, sexual, tickle, hunger, thirst, nausea, and others were not deemed of sufficient military importance to warrant special scrutiny.

COMPARISON OF GROUND AND AIR SERVICE CONDITIONS.—MOTOR COORDINATIONS.—BODILY ADJUSTMENTS.—IMPORTANCE OF SENSES TO MOTOR ACTS.

The difference between the man on the ground and the man in the air lies in the fact that the former can stand still, the latter can not. When the flier walks across the field to his plane, all his motor coordinations are concerned with maintaining the proper relation between his body and the element which is supporting its weight, the earth. When he straps himself in the seat before flight he practically straps wings to his body; thenceforth, until the end of his flight, every motor coordination is concerned with maintaining a proper relation with the new element which is supporting his weight, the air. The only means he possesses of adjusting his relation with the new weight-supporting element is the plane; while flying, all motor coordinations, whether carefully calculated or instinctively performed, are concerned exclusively with controlling the plane. The promptness and efficiency with which motor coordinations are performed depend directly upon the acuteness of sensory perceptions.

MOTION INDISPENSABLE TO FLYING.—SPECIAL IMPORTANCE OF MOTION SENSING.—INTEGRAL ELEMENTS IN MOTION SENSING.

Rising in the air in an aeroplane is made possible only by rapid motion. Acuity of motion perception assumes much greater importance to the flier than to the pedestrian, and in order to appreciate the full importance of this, one must have a clear conception of the component senses going to make up motion perception. Muscle-and-joint sense, splanchnic, visceral sense, kinæsthetic sense—all grouped for convenience under the term "deep sensibility," vestibular sense, vision and tactile sense, each participate in the composite of general motion perception.

DEEP SENSIBILITY ON THE GROUND COMPARED WITH IN AIRPLANE.

The motion sensing of deep sensibility on the ground is practically exclusively concerned with sensing the effect of the pull of gravity upon the body; in the air it is also concerned with sensing the effect upon the body of two other pulls, that of the plane's propeller and that of centrifugal force on curves. Impulses generated by these three pulls coming in via the deep sensibility tract must undergo accurate analysis in the brain and be properly estimated and labeled, if confusion and misinterpretation are to be avoided. While such analysis is accomplished by normal individuals, it is only at the expense of a certain amount of the more accurate sensing of the pull of gravity. Whereas on the ground practically 100 per cent of this incoming information expresses gravity pull, a less percentage of gravity pull is expressed by it in the air.

VISION ON THE GROUND COMPARED WITH IN THE AIR.

Vision, possibly the most important of all motion-perceiving senses on the ground, suffers some impairment of its usefulness in the air by reason of the reduction in the number of visible elements in the new environment, such as the usual objects making up the landscape. When darkness or cloud further reduces the utility of vision, this sense becomes almost eliminated as a source of guiding information to the flier.

TACTILE SENSE RELATIVELY UNIMPORTANT.

Tactile sense contributes less than any of the other three senses to motion perception on the ground; to the flier, although insulated by warm clothing, goggles, gauntlets, and helmet, it is still of value as a source of guiding information.

VESTIBULAR SENSE, ITS MOTION SENSING UTILITY AS GREAT IN THE AIR AS ON THE GROUND.

Vestibular sense suffers no depreciation in utility in the air as compared with on the ground. Its sole function has always been, and continues unaltered in any way to be, pure sensing of motion. In flying, therefore, its function assumes a relatively greater importance than that of the other special senses cooperating with it to furnish the individual with his composite of knowledge concerning motion.

In view of the foregoing, it is apparent that, in flying, motion takes on a much greater importance as regards potential safety or disaster for the individual than it possesses on the ground and that motion perception is commensurately of greater importance in the air than on the ground.

Regardless of the actual percentages which would express the shares of vision, deep sensibility, vestibular and tactile sense in the total of motion-sensing on the ground, it is established that three of these four are reduced in efficiency by conditions incidental to flying, and the fourth, vestibular sense, is not so reduced, and is therefore of relatively increased importance. It follows that it is of prime importance to determine that men to be trained as fliers possess normal vestibular apparatus. So important is it for the flier to possess normal vestibular acuity of motion-perception that no man should be permitted to begin training as a pilot who has not definitely shown normal reactions to vestibular tests.

VESTIBULAR FUNCTION STANDARD REQUIREMENTS.

The entire vestibular apparatus was tested as carefully and as accurately as the state of our knowledge concerning it permitted. It was decided to reject applicants whose vestibular apparatus gave evidence of motion-sensing acuity below a certain degree, albeit it was fully realized, in establishing this limit, that it in no way represented a line of demarkation between acuities of this perception compatible with and incompatible with flying.

POSSIBILITIES OF GREATER LATITUDE REALIZED.

It was fully realized by the Chief Surgeon and his staff that it is possible for a man to fly with a vision of 20/40 or 20/60, or with a talipes, or with a hearing of 5/40. The decision was arbitrarily made, however, that no man would be accepted for flying training by the Army except those with 20/20 vision, absence of gross malformations, 40/40 hearing, and acuity of vestibular motion-perception as represented by a minimum of 16 seconds' nystagmus and normal past-pointing and falling responses to standard stimulation.

DIFFICULTIES IN DECIDING UPON ARBITRARY STANDARDS—CONFIRMATION OF WISDOM OF ADOPTED STANDARDS.

At the time of the establishment of these standards it was recognized as a very difficult matter to state dogmatically what constituted the average length of nystagmus and past-pointing. All that could be relied upon were deductions from clinical experiments with a series of healthy individuals examined by various observers over a period covering over 10 years as contrasted with the impaired responses observed in over a thousand pathologic cases. It was realized that it was a great responsibility to establish what should be regarded as normal responses. It is therefore with a great deal of satisfaction that we publish at this point the composite results of the turning-chair test performed by skilled standardized otologists in the examining units on many tens of thousands of applicants for the Aviation Service. A compilation of statistics has been made, the digest of which, with respect to responses in nystagmus, past-pointing and falling, entirely confirms the judgment upon which the original standards were based.

The turning-chair tests proper, exclusive of the static and dynamic tests, are cause for practically all of the rejections in this particular field, being 2 per cent out of a total of 2.04 per cent, or 2 out of every 100 men examined. The average duration of nystagmus of the entire number of men examined was, after turning to the right. 23.5 seconds; after turning to the left, 23.2 seconds. In those who qualified, the nystagmus, after turning to the right was 23 seconds, after turning to the left, 23.1 seconds.

The average number of past-pointings for the total number examined is as follows:

After turning to right with right arm	3. 8 times
After turning to right with left arm	3. 7 times
After turning to left with right arm	3. 8 times
After turning to left with left arm	3. 7 times

POSSIBILITY OF ALTERATION IN ADOPTED STANDARDS.

The Chief Surgeon held himself in readiness to alter the adopted physical standards at any time evidence indicating the wisdom of so doing was adduced; realizing the wealth of available material for Army fliers at the start of the formation of the United States Flying Corps, it was deemed best to maintain the highest standards until it became apparent that a change was for the best interests of the service.

FALLIBILITY OF ENTRANCE EXAMINING SERVICE.

The physical examinations of applicants were carried out at 67 Physical Examining Units, 32 of which were constituted by Army medical men in various camps. As was to be expected, a certain amount of evidence of the fallibility of these examinations has come to light. Certain men have been encountered in the Air Service who were physically unfit, and certain others have been rejected who were physically fit. Considering the magnitude of the task, however, a review of the results of the examinations of a hundred thousand applicants in nine months reveals a performance on the part of these examining units which is satisfactory to the Chief Surgeon.

2. Ear, Nose and Throat Requirements.

DETAILS REGARDING EXAMINATION OF QUESTIONS OF BLANK 609, A. G. O., FROM 13 TO 21, NOT INCLUDING 20, WHICH HAS ALREADY BEEN TOUCHED UPON.

13. *History of ear trouble*—
   (*a*) Ever have ringing or buzzing in either ear, earache, discharge, or mastoiditis?
   (*b*) Ever have attacks of dizziness from any cause?
   (*c*) Ever been seasick? If so, how often and how long does it last?
   (*d*) Ever had a severe injury to head?

The answers to question 13 are merely designed in a general way to arrive at an indication of any previous ear trouble. It is to be taken into consideration that very few candidates are willing to admit the history of ear discharge or dizziness, and conclusions will have to be drawn from the examination of the drumhead and subsequent hearing and rotation tests.

It is the universal experience that all candidates deny that they have ever been seasick, thinking thereby to prove that they would be unaffected by the motion of an aeroplane. Answers to this question for that reason must be taken with considerable allowance. It is to be emphasized that it would be improbable for a person with perfectly normal ears not to become seasick upon his first exposure to a rough sea.

14b. *Appearance of membrana tympani.*—A perforation of the drumhead, unless transitory, is to be regarded as a cause for rejection. If the drumhead is excessively thin and scarred, even if the hearing is normal, the applicant should be rejected. Experience has shown that even in the low-pressure chamber of the laboratory perforations can easily occur in such drums by a rapid descent.

Pathological conditions of the internal ear disqualify. Acute or chronic disease of the middle ear disqualifies, except that reexamination after full recovery may be made the basis of subsequent acceptance. Moderately retracted drumhead, loss of light reflexes, thickened drum membrane, and chalk deposits do not disqualify provided the hearing is normal. The pathology of the drumhead is not an index of the hearing ability. No conclusions can be drawn without hearing tests.

15 to 18. *Nasopharynx.*—This region must be carefully examined. If defect can be removed by operation, this should be required prior to acceptance. If nonoperable or operation is refused, it is a cause for rejection.

The question as to what degree of deviation of the septum demands an operation is a difficult one to answer and must be left to the experience of the examiner. One thing must always be clearly borne in mind; aside from the straightening of an occlusive deviation for the purpose of giving the candidate better air, resecting the septum is not infrequently of great value as a prophylactic measure. The majority of individuals who have trouble with their ears are troubled because of a postnasal and Eustachian tube catarrh. Septal deviation far back, impinging on the inferior turbinate and acting as a continual irritant to the nasopharynx, should be corrected. Cases of marked deviation which have led to atrophic condition of the mucus membranes do not necessarily require operations. The prime object is to prevent acute postnasal trouble which might come on as a result of exposure, rather than to attempt to obviate an insidious middle-ear catarrh which might have come on in later life.

The nares should be most carefully examined for any signs of accessory sinus diseases. Even a suspicion of this condition should lead to a most careful and painstaking examination, including properly taken X-ray stereoscopic photographs.

16. *Condition of tonsils and history of attacks of tonsillitis.*—The diagnosis of diseased tonsils is a difficult one and must be left largely to the experience of the individual examiner. Candidates are disinclined to admit a history of sore throats. It must not be forgotten that probably 80 per cent of the sick calls on the other side is made up of sore throats. Soldiers who never complain of throat trouble in this country when they are subjected to the exposures incidental to field service rapidly develop inflammatory throat conditions, which disqualify temporarily for duty. One should be cautious in declaring a tonsil healthy. All throats should be examined under good illumination; attempt to express contents of crypts should be made, and if questionable matter can be squeezed out the tonsils should be removed. Buried tonsils in which the anterior pillar is affected should be removed, as should the hypertrophic type. The experience in this laboratory has been that in spite of the fact that all candidates were originally examined by throat specialists, many when reexamined in this institution showed diseased tonsils. Our general impression is that it is better to err slightly on the side of radicalism in regard to operation on the tonsils for those about to enter active military service.

Examination of the teeth must not be neglected. It must never be forgotten that crowned teeth, pyorrhea, and alveolar infections may be the sources of much toxemia. Special attention should be given to this matter, and if there is any doubt in the mind of the examiner as to the condition of the candidate's teeth he should be instructed to have his mouth put in good shape before finally passing him.

17. Adenoid tissue is very common in children and increases in size from birth to the age of 6 years and then normally subsides about the age of puberty. One does not expect to find much adenoid tissue in adults. Adenoids do their harm early in life, and this, as far as it concerns this examination, is evidenced by deformed jaws, misshapen noses, and poor hearing. Adenoid tissue in the adult is easily seen with a post-nasal mirror, the digital examination being unnecessary.

18. The condition of the Eustachian tubes is one of vital importance. Generally speaking, it can be said that if the candidate's drumhead and hearing are normal the Eustachian tube is probably in good condition. In addition, regulations require that the patulence of the tube should be demonstrated by the auscultation tube during inflation by means of Politzerization or catheterization. The former procedure is ample for all practical purposes. If tubal troubles are of such a nature as to demand it, an examination should be made with some good pharyngoscope.

STIMULATION OF END-ORGANS.—RESULTS SENSORY, MOTOR.—VERTIGO.—KIND OF MOTION USED AS STIMULUS.

20. *Vestibular tests.*—The motion-perceiving apparatus of the internal ear is subjected to stimulation by motion of certain standard quantity and quality, and the results are observed according to uniform standard methods. Two results are noted—a sensory result, the subjective sensation of motion, and a motor result, involuntary movement of the eyes. When the subjective sensation of motion is in accord with fact, we call it normal sensing of motion; when it is not in accord with fact, we call it "vertigo." The only difference between normal perception and vertigo lies in the sensing of motion being in accord with or contrary to fact. The most practical means of applying motion stimulus is by the rotating chair, inasmuch as the application of motion in a linear direction, for the period of time, and in the intensity necessary to elicit certain standard responses to that stimulus would necessitate apparatus entirely too bulky to be susceptible of practical application under ordinary conditions of office examination. By making use of a rotational-motion stimulus instead of a linear-motion stimulus it was possible to work out a standard means of applying motion stimulus in certain definite quality and quantity in a manner and by means of an apparatus easily handled in an office. For this reason only the subject of the tests of

the vestibular apparatus is made to experience rotational vertigo. An additional advantage in using the rotating chair is that it applies motion stimulus of a character to produce a more enduring stimulation of the end-organs of the semicircular canals.

Motion in a linear direction applied to a fluid contained in a closed semicircular canal is physically incapable of setting up a flow of that fluid, just as rotational motion applied to a fluid contained in a straight canal can not set up a flow.

NYSTAGMUS.

Ewald's experiment long ago determined that involuntary pulling of the eyes in a certain definite direction and plane occurs during the time the fluid in a normal semicircular canal is made to flow in one direction; and during the time this fluid is made to flow in the opposite direction involuntary pulling of the eyes in the opposite direction occurs. By applying rotational motion it is possible to reproduce Ewald's experiment in effect, as a test of eye reactions to vestibular stimulation; and when the character and intensity of rotational stimulus is standardized, comparisons of the results can be made and a normal eye reaction determined. This motor expression of motion stimulation is nystagmus.

MEASURING VERTIGO—VOLUNTARY TESTIMONY—INVOLUNTARY TESTIMONY—TECHNIQUE—POINTING TEST—STANDARD TECHNIQUE OF POINTING TESTS.

The normal man experiences a sensation of vertigo for between 15 and 40 seconds after being turned according to standard technique. Evidence of this subjective sensation may be had by voluntary or involuntary testimony; voluntary testimony, such as "I'm turning to the right," "I'm still turning to the right," etc., during the persistence of the subjective sensation; involuntary testimony, such as pointing test and falling. Standard tests make use of involuntary testimony in all cases; occasionally this is amplified by voluntary testimony with advantage. In observing the pointing before turning, a very important element in the test can be injected by implanting in the mind of the applicant the definite idea that he is to attempt to determine the location in space of the observer's finger solely by registering in his memory the location of it according to his tactile sense. This can be augmented by having him touch the observer's finger in more than one position, as, for instance, directly in front of the right hand, come back and touch; then locate again 30 degrees outward and come back and touch; the same procedure in front of the left hand. This implants in his mind the fundamental idea of being able to orientate himself solely by means of information coming from his tactile end-organs. After standard rotation to the right, for example, normal man experiences a certain very definite vertigo, a subjective sensation of turning to the left in the same plane as the rotation for a normal period of time. If the pointing test is carried out during this period of vertigo, instead of succeeding in pointing accurately to the testing finger he executes the pointing in accordance with his subjective sensation of motion. Feeling that he is turning definitely away from the testing finger to the left, for example, he reaches for it to the right. This is normal past-pointing.

INSULATION OF SUBJECT.

The insulation of the applicant during this test should be as perfect as possible. A black domino mask should be used, absolute quiet should be maintained, olfactory impressions should be shunted out, and he should be left as solely as possible dependent upon the information brought to him along the vestibular tract alone.

SIGNALING SUBJECT—OBVIATING SEARCH MOVEMENTS—OBSERVING PAST-POINTING—HOW TO CONSTRUE COMPENSATORY POINTING.

The applicant should be definitely instructed before turning that he should not expect a verbal order to touch the observer's finger, raise his hand and come back, and attempt to find it after the turning; he should be practiced before turning in executing his touch. raising his hand, and coming back to find the finger upon receipt of the signal from the observer's finger as it comes into the position which it maintains during the test—the observer bringing up his finger into position so as to tap the applicant's finger as a signal for him to execute his pointing without verbal command. It is very important for the applicant's finger to find a finger of the observer when he comes down in search of the finger which is testing him. Otherwise, there is injected into his mind a disconcerting element of dissatisfaction in having failed to find the finger for which he was searching. For this purpose the index finger of the observer's left hand can be held in readiness to furnish the touch necessary to shunt out this sense of failure. In observing the past-pointing after rotation, the observer's right index finger should be definitely fixed against the observer's hip, so that visual attention to it on the part of the observer can be dispensed with, the hip rest insuring its remaining definitely where it was when the applicant first touched it in making the pointing test. The observer's eyes can be free to watch the applicant's finger at the top of the swing. Past-pointing at the top of the swing is just as definitely normal past-pointing as at the completion of return to touch. Many cases compensate after evincing a normal tendency, let us say, to past-point outward with the right hand when they should do so, and subsequently execute a compensatory touch or inward pointing at the bottom of the return. In such cases the pointing should be registered as that executed at the top of the swing, which is the primary and clean response before it has been altered by the subconscious or conscious compensation effected by other mental processes. Visual attention on the part of the observer to the applicant's hand at the beginning of his downward pointing is of enormous importance and it should be very carefully observed as part of the standard technique.

FALL TEST.

The fall test is similar. A normal man, on attempting to sit upright after leaning forward during right rotation, feels that he is turning to the left, for instance, and so gives involuntary expression to this sensation by falling to the right on attempting to assume an erect sitting posture.

These tests can be completed in less than five minutes. Incidentally, these tests are in no sense severe and are in fact seldom regarded even as unpleasant.

Occasionally nausea occurs after these turnings; it is then merely necessary to stop the examination for the time being and to complete the remainder of the tests after an interval of half hour. There is no need whatever to make these tests in any way distressing to the candidate.

OBVIOUSLY UNFIT CASES—BORDER-LINE CASES—CALORIC TEST—DETAILS—ALLOWABLE LATITUDE—DRUMHEAD INSPECTION.

With respect to the internal ear motion-sensing apparatus, its nerve paths and brain connections, these turning tests quickly separate the obviously fit from the unfit. The majority of the candidates show normal responses; no further testing is required, and they therefore qualify and are accepted. Some candidates show such markedly subnormal responses that they are immediately disqualified and rejected. A limited number give what might be termed "border-line" responses; the question then arises, Has this particular applicant sufficient motion-sense to become an aviator? It is here that the caloric test is useful. The turning has tested both the right and left ears simultaneously. The caloric method enables us to test each ear separately. Water at 68° F. is allowed to run into the external auditory canal from a height of about 3 feet through a stop nozzle, with the head tilted 30° forward, until the eyes are seen to jerk and the individual becomes dizzy. The length of time from the beginning of the douching until the jerking of the eyes becomes apparent, or until the applicant says he is dizzy, is accurately measured by a stop-watch. The type of nystagmus is then noted. With head in upright position, it should be rotary and the direction of the jerk should be to the side opposite the ear douched. The length of the douching shown by the stop-watch in the normal is 40 seconds. The eyes are then closed and the past-pointing is taken. The head is then immediately inclined backward 60° from the perpendicular (or 90° from the original position). There should then appear a horizontal nystagmus to the side opposite to the ear douched. The eyes are then closed and the past-pointing is taken with the head in this position. The left ear is then douched and the same procedure carried out. If the caloric test applied to one of these "border-line" cases shows only a slight impairment of the responses from each ear, the candidate is qualified. If instead of 40 seconds of douching, there was required not more than 90 seconds of douching to elicit normal responses, the applicant is not rejected. Care should be taken to be certain that the cold water is reaching the drumhead during this caloric test, as wax or other obstruction in the external canal would interfere with the responses in a perfectly normal individual.

After carefully considering the foregoing the neurologist and the general diagnostician can not fail to be struck with the comprehensive character of these vestibular tests, for frequently they are looked upon as ear tests only. Six months ago one of the greatest otologists of Europe in discussing these tests raised the question as to the necessity or advisability of including in aviation examinations the past-pointing and falling tests, his contention being that in testing nystagmus only, one secures definite evidence of the functional state of the semicircular canal end-organs of the internal ear. When his attention was drawn to the fact that in testing the past-pointing and falling in addition to the nystagmus one establishes definitely the functional intactness, (1) of the various afferent paths and the intracranial structures through which they pass, (2) of the cerebral cortical centers and their transcortical association tracts, (3) the efferent cerebral paths and the nuclei through which they pass, (4) the cerebellar nuclei and correlation paths to and from cerebellar cortical centers, (5) various portions of Pons and Medulla Oblongata, his attitude was completely changed and he became a firm advocate of the complete testing of nystagmus, past-pointing and falling as a routine procedure.

It can not be emphasized too strongly that the vestibular tests are not only ear tests; in addition they actually test very extensively a large portion of the central nervous system.

Certain infectious diseases are known to manifest a predilection to attack the vestibular apparatus. Acute toxic end-organ disease and neuritis of the VIII nerve are well recognized complications of mumps, typhoid, and some of the commoner epidemic infections; syphilis is particularly prone to attack the VIII nerve. Permanent impairment of function of the vestibular apparatus in varying degrees ensues upon any such attack. It therefore becomes necessary to reexamine fliers at regular intervals in order to make certain that no functional deterioration of the vestibular apparatus has taken place. Regular examinations should be made at intervals of about eight weeks. Special examination should be made at once of any flier who manifests unusual failure to negotiate air maneuvers with ordinary skill.

3. Otologic Problems Under Consideration at the Medical Research Laboratory.

The first otologic problem attacked in the Medical Research Laboratory was the effect of low oxygen on the phenomena of nystagmus and past-pointing. It has been demonstrated by the cardiovascular and physiological departments that deleterious effects of low oxygen are noted in connection with the cardiovascular and respiratory systems. As was to be expected, before low-oxygen effects on the internal ear motion-sensing apparatus could be demonstrated, cardiovascular and respiratory effects became manifest. Therefore, it has thus far been difficult to carry these ear tests to a satisfactory conclusion. In these examinations the rotating chair was placed in the low-presure tank with the subject and observers. After having attained a height of 5,000 feet, the candidate was exposed to the effects of this altitude for 5 minutes, when the routine nystagmus and past-pointing experiments were carried out. The same procedure was repeated at varying altitudes up to 18,000 feet. These findings, reported in detail in another article, showed no consistent variations from the responses obtained at sea level. We may, therefore, with a fair degree of safety assume that at altitudes up to 18,000 feet no marked changes in this function of the internal ear occur as the result of low oxygen. The cochlear portion was similarly unaffected at these altitudes.

During these experiments abundant opportunity was afforded to examine a large number of drumheads—both of the candidates and of the observers. Experimental work in the laboratory has confirmed the practical observations of fliers—that middle-ear difficulties occur during descent rather than ascent. One point has been established without question, that the amount of injection of the drumhead is directly proportionate to the degree of patulence of the Eustachian tube. Intense pain in the middle ear and down the neck was experienced by many subjects, who showed on examination, to have moderate or severe congestion of the naso-pharynx. One case was extremely illuminating and shows that we must not conclude that because atrophic rhinitis is present, the tubes must necessarily be patulous. One of the examining medical officers had extremely atrophic and badly retracted drumheads with scars from repeated suppurative attacks. A rapid descent produced a double bilateral perforation, the perforations evidently occurring on the sites of former perforations. A sharp stabbing pain was felt as the observer dropped rapidly from 14,000 to 1,000 feet, and an examination showed a bright red circle of tiny blood vessels surrounding the pin-point perforations. The subsequent healing was uneventful.

One of the observers, who had a history of repeated attacks of suppurative otitis media in early childhood, developed a typical acute purulent otitis media after several ascents in the low-pressure chamber on three consecutive days.

One of the foremost otologic problems constantly before the chief of the Air Medical Service has been how much leeway can be safely allowed in standard tests of vestibular functions and acuity of perception. As has been mentioned before, all motor coordinations made by the flier during flight, whether carefully planned and consciously performed or instinctively and subconsciously executed, have only one ultimate expression, namely, the determining of his relations with respect to his environment and with respect to the new element which is supporting his weight, the air. Either instinctive action or carefully considered intentional action upon the part of the flier is determined entirely by information which is coming into his possession concerning his relations with his environment. This information can be had by him only through the activities of his special senses. But possession of normal perceptive end-organs, nerve paths, and brain connections does not constitute definite assurance that the individual will accomplish satisfactorily balance or orientation. Further, he may accomplish balance satisfactorily and still be completely disorientated; or he may be properly orientated and fail to accomplish balance properly. The two are independent functions of the mind, closely associated, but in no way functionally interdependent. On the other hand, lack of normal perceptive apparatus does constitute definite assurance that the individual will be physically less able to accomplish balance or orientation, or both, under certain circumstances under which these would be possible for the man in full possession of normal perceptive apparatus. There are certain circumstances under which balancing can be performed adequately even by the man who is possessed of less than full normal equipment. There is no doubt that man can accomplish a certain kind of flying blindfolded, or without functionating vestibular apparatus, or without normal deep sensibility. Hence this important air medical problem is to study the "peak load" requirements, the conditions of emergency and confusion which may be encountered unexpectedly in the air, and to attempt to estimate carefully the minimum perceptive equipment which would be adequate under these conditions to enable the flier to negotiate such difficult and unusual phases of flying. There are certain temperaments, certain types of minds, certain intangibly different mental composites, which determine the inability of the individual to negotiate these critical points in flying, even though he be in full possession of his sensory perceptive facilities. "Self possession," "coolness," "bravery," "sand," "nerve," "presence of mind," "judgment," on the other hand, added to a perceptive equipment of less than normal may determine the success of an individual in emerging safely from a critical air situation. While this is unquestionably the fact, these mental qualities are so intangible, so indeterminable, and, above all, so distinctly not in the category of things physically to be examined and measured by the medical examiner that it is not deemed justifiable for the physical examiner to admit into the Air Service or to allow to remain in the Air Service anyone who is discovered to be lacking in acuity prescribed for the several special senses known to be prime requisites of the flier.

MOTION-SENSING EXPERIMENTS IN LINEAR UPWARD AND DOWNWARD DIRECTION.—GROUPS TESTED.—CONDITION OF TESTS.

One of the methods of approaching the problem of determining what is the relative value of the various sensory contributions to the individual's total knowledge concerning motion, was a series of experiments performed in a bank of elevators capable of performing vertically upright trips 40 stories in extent, a height of over 400 feet, at a maximum speed of 1,000 feet per minute. For this purpose four groups of individuals were selected, namely, (1) normals, (2) deaf-mutes totally lacking vestibular perception, (3) deaf-mutes possessing vestibular perceptions in various degrees below the normal, and (4) tabetics whose deep sensibility was impaired to various degrees. These experiments were carried out during a period of six weeks, with a view to determining the average ability of each group to sense the various vertically up and down movements to which they were subjected. The elevator shafts were entirely dark, and the lights on the cars were shut off during the experiments, so that no information reached the individual via the visual tract. Each individual of the normal group was first determined to be possessed of normal vestibular and deep sensibility.

The following is a digest of the findings:

GROUP 1.

FINDINGS IN NORMALS.

ACCELERATION.

1. During acceleration upward all were able to sense accurately the character of the motion to which they were subjected.

SUSTAINED SPEED.

2. A slower sustained rate of speed immediately ensuing upon acceleration upward was uniformly misinterpreted as arrest of motion, or as very slow motion.

RETARDATION.

3. Retardation to the slowest possible, continued speed upward, ensuing upon sustained speed upward, was universally sensed as motion vertically downward.

GROUP 2.

FINDINGS IN DEAD VESTIBULE DEAF-MUTES.

4. The deaf mutes in whom the vestibular function was totally abrogated sensed acceleration upward correctly.

5. These individuals were uniformly inconsistent in describing the character of slow motion vertically upward at a constant rate of speed, sometimes guessing " upward " and sometimes guessing " downward," but always acutely sensitive to the fact that they were undergoing motion of some kind.

6. Retardation, ensuing upon motion vertically upward at a sustained rate of speed, was uniformly correctly sensed by these individuals.

7. Arrest of motion ensuing upon retardation or motion at a sustained rate of speed was uniformly correctly sensed by these individuals.

8. In these individuals it was impossible to produce the illusion of reversal of motion by alteration in the speed of the car. It was apparent that absence of hearing and vestibular sense had keyed up to a high degree of attention and sensitiveness the deep sensibility tract, though it is not believed that this observation justifies a statement that the sensing of the deep sensibility impulses was keener than that of the normal individual. It seems certain, however, that the attentions of these individuals to motion perceptions coming in via the deep-sensibility tract were more intense than that of the ordinary normal individual.

GROUP 3.

FINDINGS IN LIVE VESTIBULE DEAF-MUTES.

9. Deaf-mutes in possession of intact vestibular apparatus and normal acuity of perception absolutely duplicated the findings of the first group of full normal individuals tested, as shown in items 1, 2, and 3 of this digest of results.

89118—19——17

10. Deaf-mutes in whom acuity of vestibular perception was reduced to an index represented by two or three seconds duration of nystagmus and no past-pointing and almost absent falling were able to sense acceleration vertically upward correctly and failed to identify slower motion at a sustained rate of speed upward, but sensed the motion very positively, though labeling it at times "motion downward" and at other times "motion upward"; they were able to detect retardation and arrest keenly, but did not experience the illusion of reversal of motion either following acceleration, retardation, or arrest of motion.

Group 4.

FINDINGS IN TABETICS.

11. Tabetics in whom vestibular tests had demonstrated the presence of normal vestibular functions were roughly of two classes—the lower or dorso-lumbo-sacral type and the higher or the cervico-dorsal type. Both types evidenced a satisfactory ability to sense acceleration of motion vertically upward; slower motion at a sustained rate of speed ensuing upon this acceleration upward was not sensed at all by either type; retardation following motion vertically upward at a sustained rate of speed was sensed as motion downward by both types. Particularly striking was the continuation over long periods of time of the sensing of motion downward by the first type of tabetics when arrest of motion ensued upon retardation vertically upward. Several of these cases continued to indicate motion downward for from 30 to 60 seconds following total arrest of motion. This was not the case with the second type of tabetics, several of whom, however, did indicate sensation of motion downward for a few seconds following total arrest of motion.

DOWNWARD MOTIONS.

12. Acceleration of motion downward from the fortieth floor was correctly sensed by normals, both types of deaf-mutes, and both types of tabetics.

13. Slower motion downward at a sustained rate of speed ensuing upon rapid acceleration downward was sensed by the normals universally, as either complete cessation of motion or extremely slow motion in a downward direction; this was also the case with the second group of deaf-mutes, those in possession of vestibular functions; the first groups of deaf-mutes were unable to sense the character of sustained motion downward accurately, but more frequently guessed "downwards" than "upwards": the tabetic of either type indicated almost invariably arrest of motion.

14. Retardation downward ensuing upon motion at sustained rate of speed downward was sensed as arrest of motion or as slow motion upward by the normal group and by the deaf-mutes in possession of vestibular function and by both types of tabetics. This confusion of sensing between arrest or slow motion upward was consistent with all members of these groups, but individuals in each group varied in their answers, one individual sometimes indicating arrest and at other times indicating slow motion upward.

15. Arrest of motion ensuing upon retardation downward was uniformly indicated as slow motion upward by the group of normals; the group of deaf-mutes in possession of vestibular function sensed this as slow motion upward only for a second or two and then indicated properly total arrest of motion; the group of deaf-mutes totally lacking vestibular perception uniformly indicated correct perception of arrest of motion on the instant; both types of tabetics indicated sensation of motion vertically upward, and this sensation continued for a much longer period of time than in the normal group.

The conclusions from the above-outlined experiments are that (A) the normal individual, the deaf-mute whose vestibular function is unimpaired, and the tabetics whose vestibular functions are unimpaired seem to be almost equally sensitive to acceleration either upward or downward: (B) during slower motion at a sustained rate of speed upward or downward the deaf-mute whose vestibular function has been totally abrogated is totally unable to sense accurately the character of the motion to which he is subjected, but he is keenly sensible of being subjected to some kind of motion; whether this is vertically upward or vertically downward seems to be pure guesswork. The other individuals tested all evidenced sensory illusion and always in the shape of a relative reversal varying in degree between a sense of partial or complete arrest of motion and inception of motion in the opposite direction. This latter was more marked in the tabetic. This would seem to indicate that in general the quantitative perception of motion at a sustained rate of speed lies more particularly within the province of the deep sensibilities; the qualitative perception—that is, determination of the exact direction of the motion—lies within the province of the vestibular component in the total composite of motion-perceiving. (C) Susceptibility to illusion of a motion-perceiving naturally is directly proportionate to the keenness of the ability to make accurate qualitative perceptions; in other words, the illusions of motion in the absence of vision are largely, if not exclusively, attributable to the vestibular apparatus.

It should be added that for the purpose of conducting these experiments especial control was added to the regular control of these elevators, and by means of this the accelerations, retardations, and motions at sustained rates of speed were accomplished with almost complete absence of jarring or friction. The use of magnetic brake control adjusted to extreme nicety and the elimination of all loose connections and joints eliminated sound almost completely; the visual element of motion-sensing was absolutely eliminated by the conducting of the tests in perfect darkness; tactile impulses were almost completely eliminated by lining the entire car with thick blankets, protecting the subjects from access of air currents to the skin throughout the experiments.

EXPERIMENTAL STUDIES ON "THE FEEL OF THE AIRSHIP."

DEAF-MUTES AND NORMALS.

A physiologic function which is peculiarly important in aviation as contrasted with all other branches of the service is that of equilibration. Nothing could better illustrate this peculiar importance of the inner ear than a comparative study of those with normal inner ears as contrasted with those of destroyed inner ears—deaf-mutes. A series of experiments was conducted in actual flights. Those with normal inner ears, when blindfolded, were able to detect motion changes accurately during the flight, whereas blindfolded deaf-mutes with destroyed labyrinths were not.

In order to appreciate the part that the ear mechanism plays in aviation, all that any physician need do is to take a flight in an aeroplane. As you guide an aeroplane in a straight flight, your incessant effort is to correct minute deviations from the level position; the countless and continuous changes of movement in all directions are counteracted by tiny movements of the joy stick. In your first flights, when instructor is guiding the plane, you watch the joy stick in front of you and you notice that it is moving, ever so little, this way and that, in response to stimuli in the detection of changes of position. This sense of the "detection of movement" is what the experienced aviator calls "the feel of the airship"; it is that sense which distinguishes the born flier from the mechanical flier, who is forced to rely upon his sight in the guiding of the plane. The Almighty gave certain sense organs to man; if there is any individual who preeminently needs a normal sensing of movement, it is obviously the aviator. The turning-chair and douching tests enable us to determine whether the internal ears and all the intracranial pathways from the internal ears are functioning normally.

WHAT IS "FEEL OF THE AIRSHIP"?

One of the terms most commonly used in aviation is "the feel of the airship." It had its origin at the beginning of aviation and seems to be a phrase which in the mind of the practical flier covers everything which goes to express a trained aviator's skill in the proper and semiautomatic control and balance of an airship. Some men give evidence of possessing this sense-complex during the first one or two hours of instructions; others never acquire it, and still others show it in such a moderate degree that they are always looked upon with apprehension by instructors, who feel that such men are not to be depended upon in an emergency.

Very few trained pilots can give any clear explanation of what is meant by the term, except to say that if the beginner does not possess it he will never be able to make a first-class pilot. Some explain it by a keen sense of motion, some by general physical dexterity, some by a keen sense of vision, and some would seem to credit it to an inborn special sense of some kind. That some such sense or combination of senses exists, there can be no question. This general fact has been appreciated by scientific men from the start, and much of the work of the Medical Research Laboratory has been directed, consciously or unconsciously, toward scientific explanation of this sense-complex.

Evidently motion-sensing must be intimately related with this proper "feel of the airship." As previously stated, motion-sense is dependent upon information derived from (1) muscle sense, (2) sight, (3) vestibular sense, and (4) tactile sense.

OBSERVATIONS UPON MOTION-SENSING DURING AIRPLANE FLIGHTS.

DEEP MUSCULAR SENSIBILITY STUDIED BY ELIMINATION.

The purpose of this study was to try, by elimination of any two of the first three factors, to estimate the value of the third. The fourth, tactile, may be ignored, being constant in all cases. This can be done as follows: Blindfolding eliminates sight; the use of deaf-mutes with destroyed vestibular apparatus eliminates the vestibular sense; blindfolding these deaf-mutes eliminates sight and vestibular sense, leaving the deep sensibility as the remaining factor. Experimental study with cases of tabes and other similar cases, where the deep sensibility is involved, are now being carried on and will give us further data on deep sensibility.

TILTING PERCEPTION.

It has been shown by various observers, experimenting upon thousands of aviation applicants, that there exists a very clear appreciation of tilting. If a chair, balanced on one point, is so slowly tilted that a man seated in it can not sense the motion, there comes a time when he appreciates that he is tilted. Laboratory experiments of this sort have been repeated in the air under practical flying conditions. At first glance it would seem that the experimental errors in such a study would be overwhelming, but a more extended investigation in the plane, at various altitudes and under various weather conditions, corrects this impression to the extent that for a practical study of the "feel of the airship," theoretical experimental errors can be disregarded.

POINTS IN EXPERIMENTS TO BE NOTED.

In order to get at normal responses under actual air conditions, five points must be observed: (1) Subjects with previous flying experience must be eliminated; (2) normal individuals must be selected, who are not alarmed by the thought of a first flight, and who have trained powers of observation; (3) a professional pilot of years of flying practice must be used whose experience would enable him to appreciate the problems and hold the ship at the given angles with the greatest degree of accuracy in spite of unfavorable atmospheric conditions, and a clinometer used by him to measure angles of tilt; (4) the same plane must be used throughout the experiments; and (5) the intercommunicating phone system must be used between pilot and subject.

KIND OF SUBJECTS SELECTED.

For purposes of study, 15 candidates were selected from the Surgeons in the Medical Research Laboratory. Chart I is a graphic diagram of the results of the experiments on normal individuals who have never had any previous experience in the air. The subjects were blindfolded, were then taken up in the plane, and the maneuvers indicated were carried out. The lower blue line shows the movements actually executed by the plane. The upper red broken line shows the movements the subject felt were being executed.

EXPLANATION OF CHARTS I AND CHARTS II AND III.

There is a very important difference in the nature of carrying out the maneuvers in Chart I and Charts II and III. In the first type of experiments, conducted in Chart I, the positions were changed by markedly quick movements of the plane, i. e., the upward motion was the sudden zoom upward, the downward motion was a quick almost vertical dive downward, the banks to the right and left were done quickly, and the turns on the horizontal plane were made as sharp as possible.

If a quick zoom is made, the feeling is that you are being thrown against the seat by centrifugal force and in a quick steep bank a similar sensation is noticed. In the start of the nose dive one is thrown against the belt by the action of the centrifugal force, and it is not a matter of wonder when the candidate interchanges in his mind movements in which the most prominent element is the centrifugal action forcing his body against seat or belt. We also found

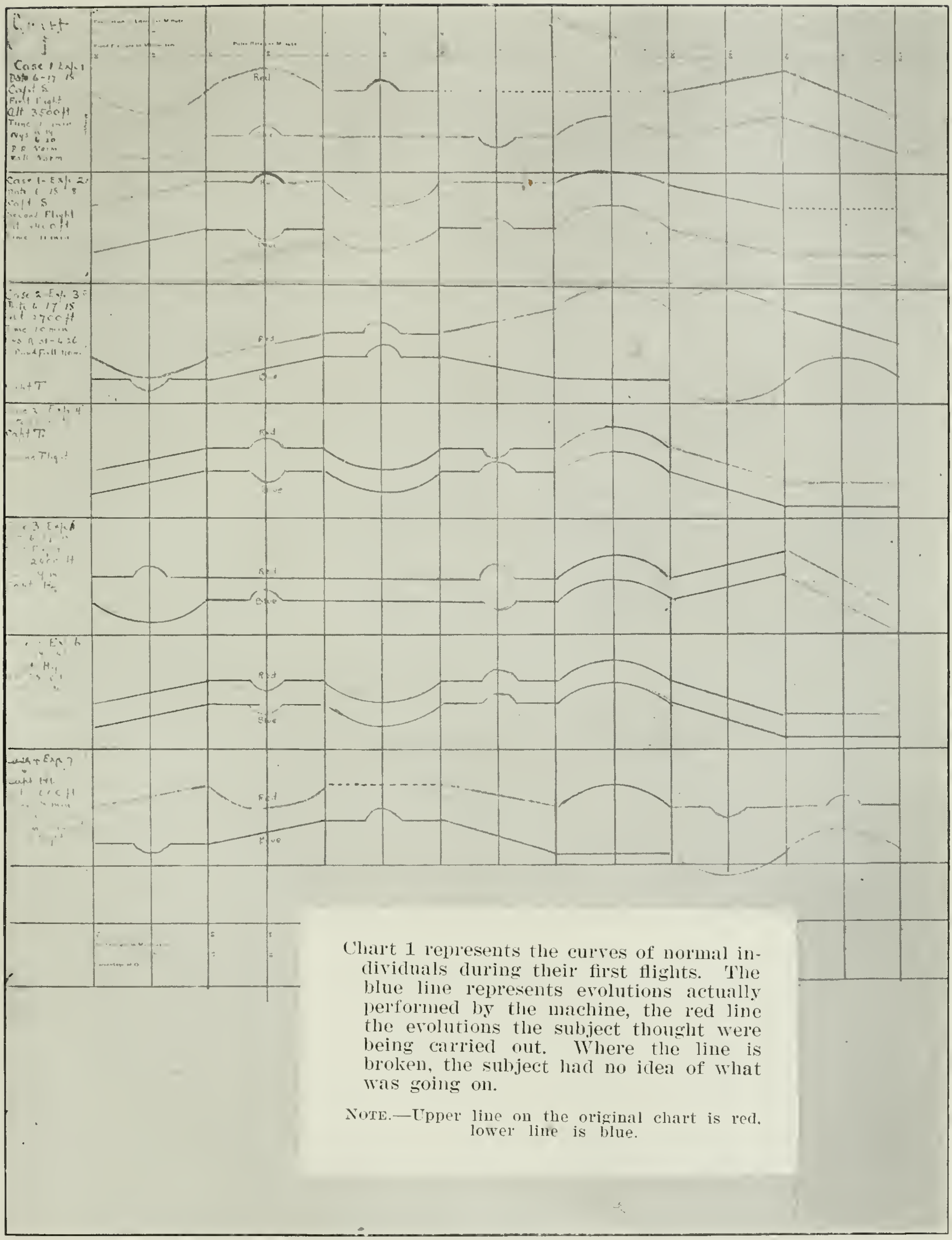


Chart 1 represents the curves of normal individuals during their first flights. The blue line represents evolutions actually performed by the machine, the red line the evolutions the subject thought were being carried out. Where the line is broken, the subject had no idea of what was going on.

NOTE.—Upper line on the original chart is red, lower line is blue.

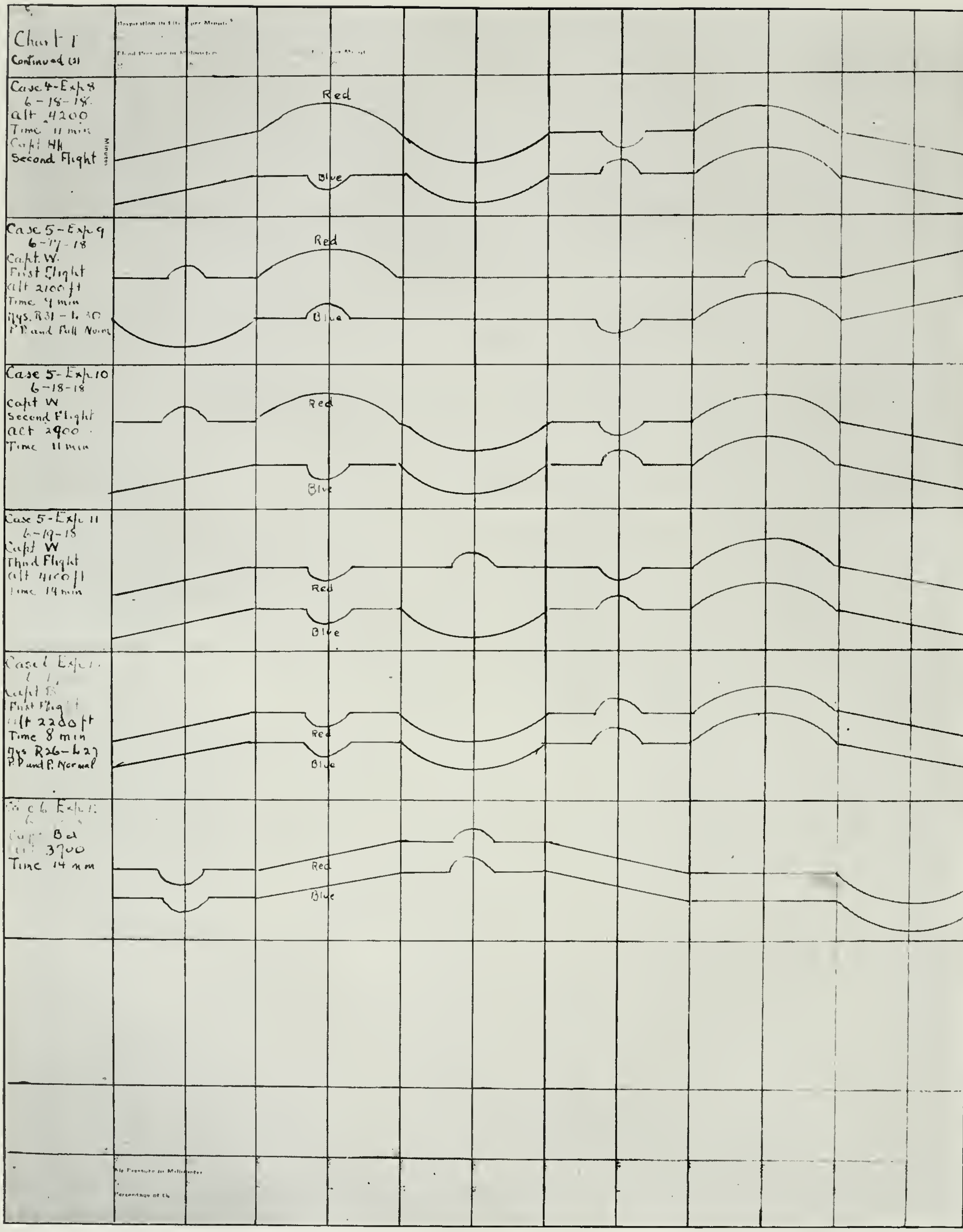
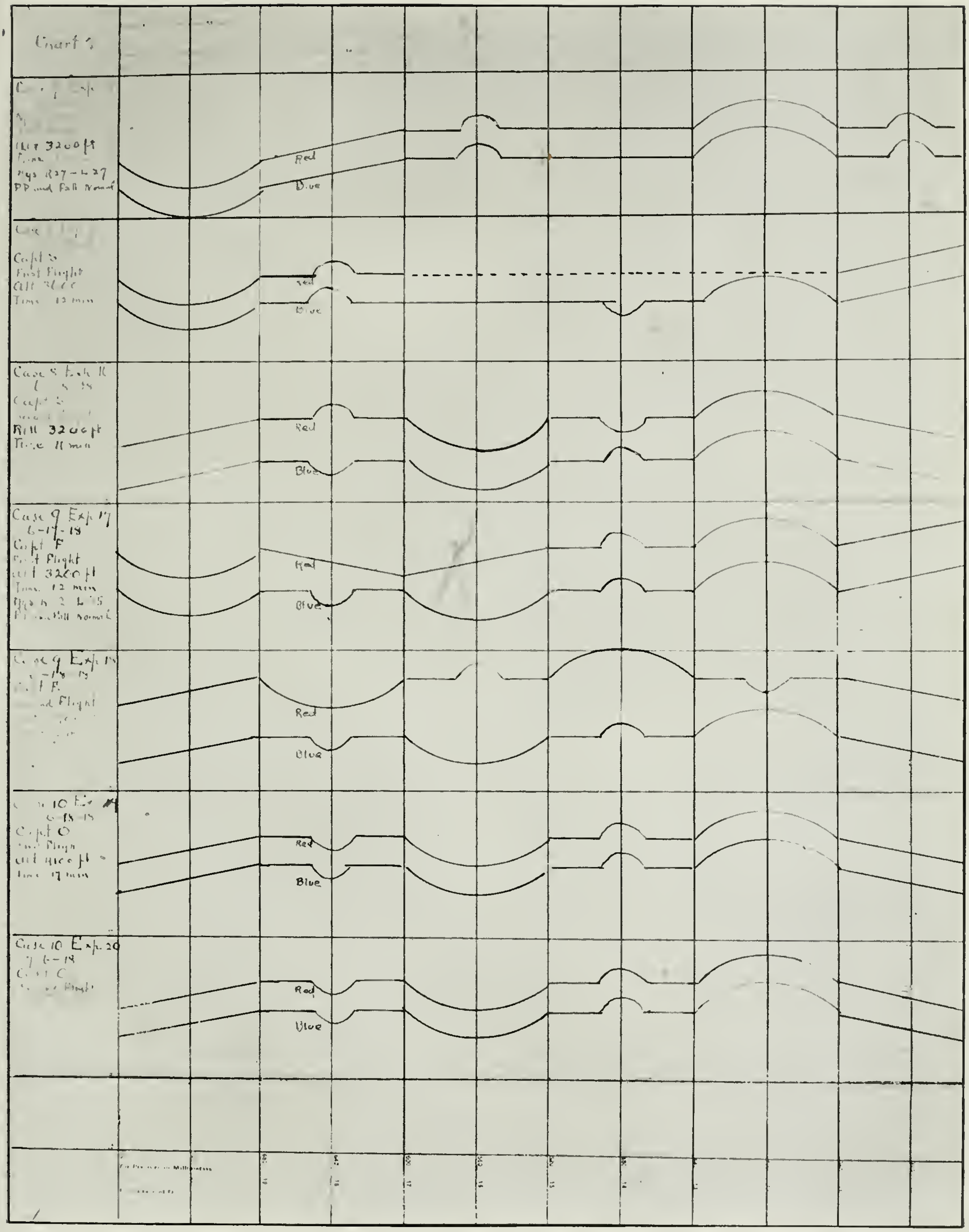


Chart I
Continued (3)
Case 4-Exp 8
6-18-18
alt 4200
Time 11 min
Capt HH
Second Flight
Red
Blue
Case 5-Exp 9
6-17-18
Capt. W.
First Flight
alt 2100 ft
Time 9 min
Nys. R31 - L30
P.P. and Pall Norm
Red
Blue
Case 5-Exp 10
6-18-18
Capt W
Second Flight
alt 2900
Time 11 min
Red
Blue
Case 5-Exp 11
6-19-18
Capt W
Third Flight
alt 4100 ft
Time 14 min
Red
Blue
alt 2200 ft
Time 8 min
Nys R26-L27
P.P. and P. Normal
Red
Blue
3700
Time 14 min
Red
Blue


Red
Blue
Case 9 Exp 17
6-17-18
Capt F
First Flight
Alt 3200 ft
Time 12 min
Case 10 Exp. 20

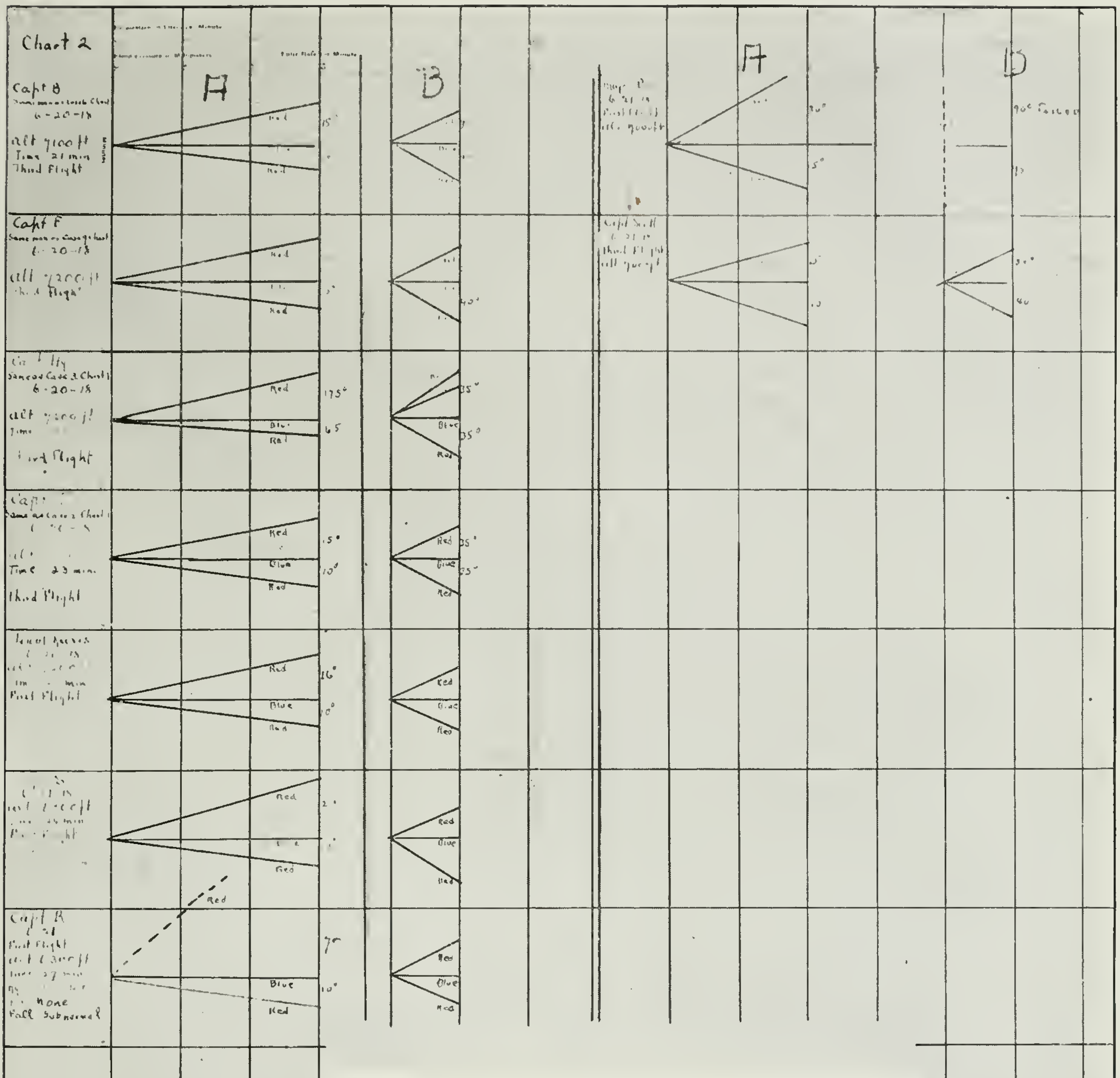


Chart 2 is divided into two parts, A and B.
Chart 2A represents the subjects' appreciation of the smallest angle in a downward or upward direction.
Chart 2B represents the subjects' appreciation of the smallest angle in a bank.
The stalling angle of the machine, past which it is unable to execute these evolutions is 70 degrees up. 40 degrees down. 85 degrees on the banks.

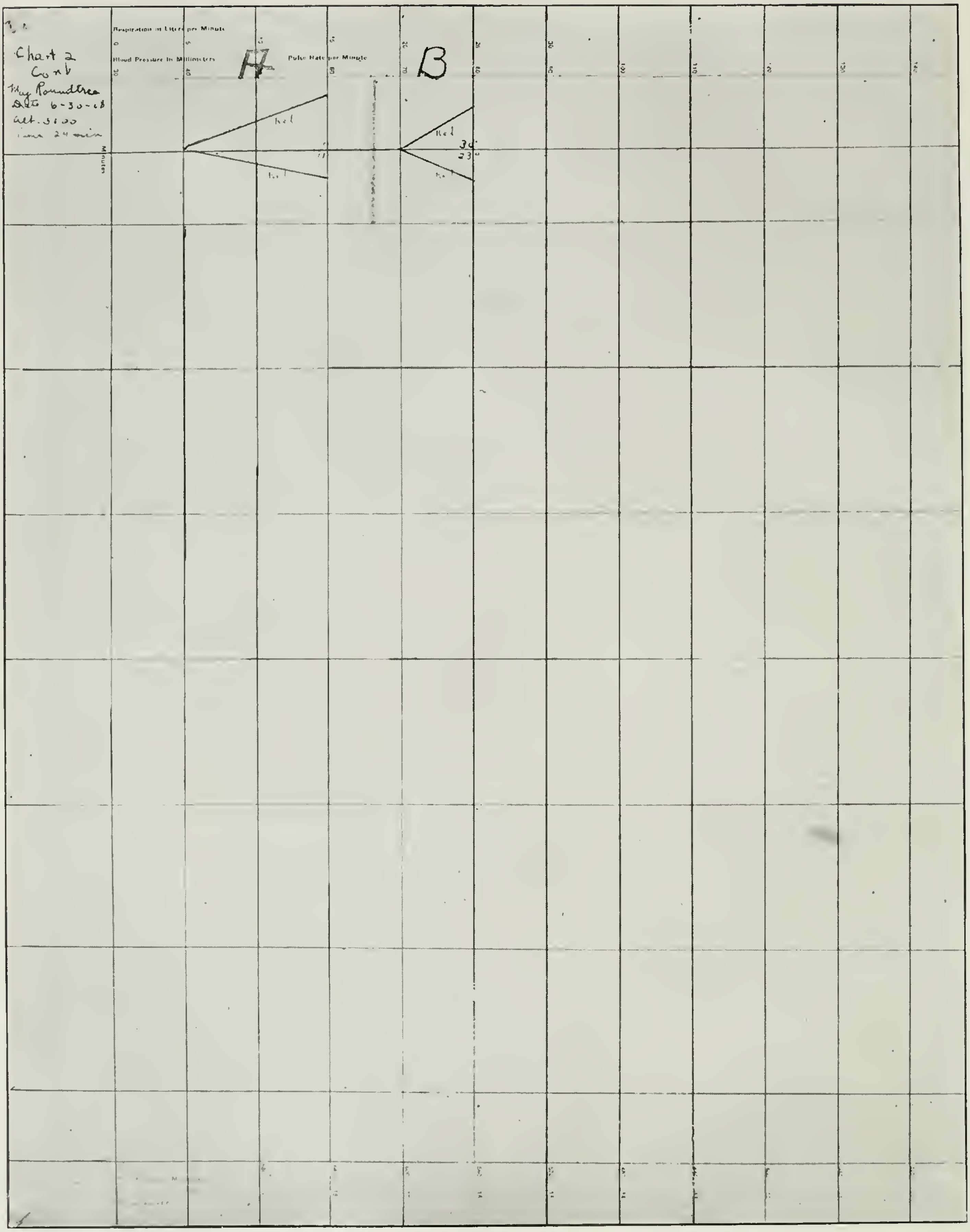


Chart 2
Cont
Date 6-30-18
Respiration in Liters per Minute
Blood Pressure in Millimeters
Pulse Rate per Minute
Minutes
A
B
30
23

that if the right and left turns were kept in a true horizontal plane without banking, that it is very difficult to differentiate between the two on account of the large size of the circle it was necessary to describe in making these turns without side-slip. A short analysis of the different observation flights seem to show that the general powers of observation are not improved during an individual's first flights. In fact, they are frequently impaired on account of excitement and apprehension, and a short analysis of the personalities of these subjects tends to explain many of the errors.

CASE HISTORIES.

Case I, experiments 1 and 2, Chart I.—Young man, not acute observer, though not particularly nervous. Made one fundamental error on first flight and failed to sense banks or slow horizontal turns. On second flight he made no fundamental errors, simply mistaking right and left horizontal slow turns.

Case II, experiments 3 and 4, Chart I.—A middle-aged man, badly scared on first flight and was all at sea. On second flight was calmer and made no fundamental errors, confusing right and left slow horizontal turns only.

Case III, experiments 5 and 6, Chart I.—A cool phlegmatic individual. He mistook turns for banks during the first flight, but made no errors on his second flight.

Case IV, experiments 7 and 8, Chart I.—A nervous individual. Did fairly well on his first flight and improved markedly on his second, making no errors.

Case V, experiments 9 and 10 and 11, Chart I.—A young man, not particularly a good observer and very nervous over his flight. He got very little correct in his first experiment (9), appreciating correctly only horizontal flight, marked upward and downward movements, and entirely missed right and left horizontal turns and right and left acute banks. His second flight showed considerable improvement, appreciating correctly four out of seven maneuvers, as against three in the first flight, but far less than the others. In his third experiment (experiment 13) he made only one bad mistake in appreciating seven maneuvers.

Case VI, experiments 12 and 13, Chart I.—This man has an unusual mentality; he is noted for his muscular dexterity, is an amateur sleight-of-hand performer and a close observer under all conditions. He made no mistakes in either flight.

Case VII, experiment 14, Chart I.—A highly trained clinical observer, has an extremely keen mind, adventurous in spirit, and has large experience in mountain climbing and in laboratory work at high altitudes. He made no mistakes.

Case VIII, experiments 15 and 16, Chart I.—A fair observer only. In his first flight he did not try to guess as many of the more nervous ones did, therefore the dotted line. The second flight showed improvement, making only one fundamental error.

Case IX, experiments 17 and 18.—A man over 50 years of age, was very nervous about his first flight, but improved somewhat during the second, still making several fundamental errors.

Case X, experiments 19 and 20, Chart I.—A trained physiologic observer, cool and calm, and made no mistakes of any kind.

Case XI, experiment 21, Chart I.—Highly strung young man, very tense; made only one error on his only flight.

EXPLANATIONS OF CHART II, III, AND IV.

Charts II, III, and IV represent a study of the ability to detect gradual departures from the horizontal flying line. In contradistinction to the first series of observations the endeavor here was to make the change in the angles so gradual that the candidate would appreciate his change from the horizontal in addition to sensing the forward movement of the plane. The endeavor was to eliminate suddenness in change of direction as much as possible. They were conducted with the greatest care and only during ideal weather. The angles were checked by using a clinometer and every effort possible was made to eliminate experimental error. The intercommunicating phone system was used. As soon as a proper altitude was reached, where the air was smooth, the subject blindfolded himself and as soon as he was able to appreciate whether he was going up or down, or banking to the left or to the right, he would so report to the pilot. The pilot would then maneuver the plane to repeat this angle from 6 to 10 times or until he was positive of the smallest angle that the subject was capable of appreciating, when he would write down his result. The remarkable similarity of the results is in itself proof that the experimental errors were slight, or at least were about equal in all cases and, therefore, to be neglected.

CHART 2–A.—OBSERVATIONS UPON MOTION-SENSING DURING AIRPLANE FLIGHTS.

In this series of experiments some of the subjects had never flown, while others had had a few flights previously in the other series of experiments. It is to be noted that in this series the downward angle was detected in every case more accurately than the upward angle; the upward angle was less accurately detected by men making their first flight. One of these beginners was unable to detect the upward angle even to 70 degrees, the stalling angle of the machine. Subsequent examination showed that this man's vestibular reactions were very much subnormal, as evidenced by 10 seconds' duration of nystag-

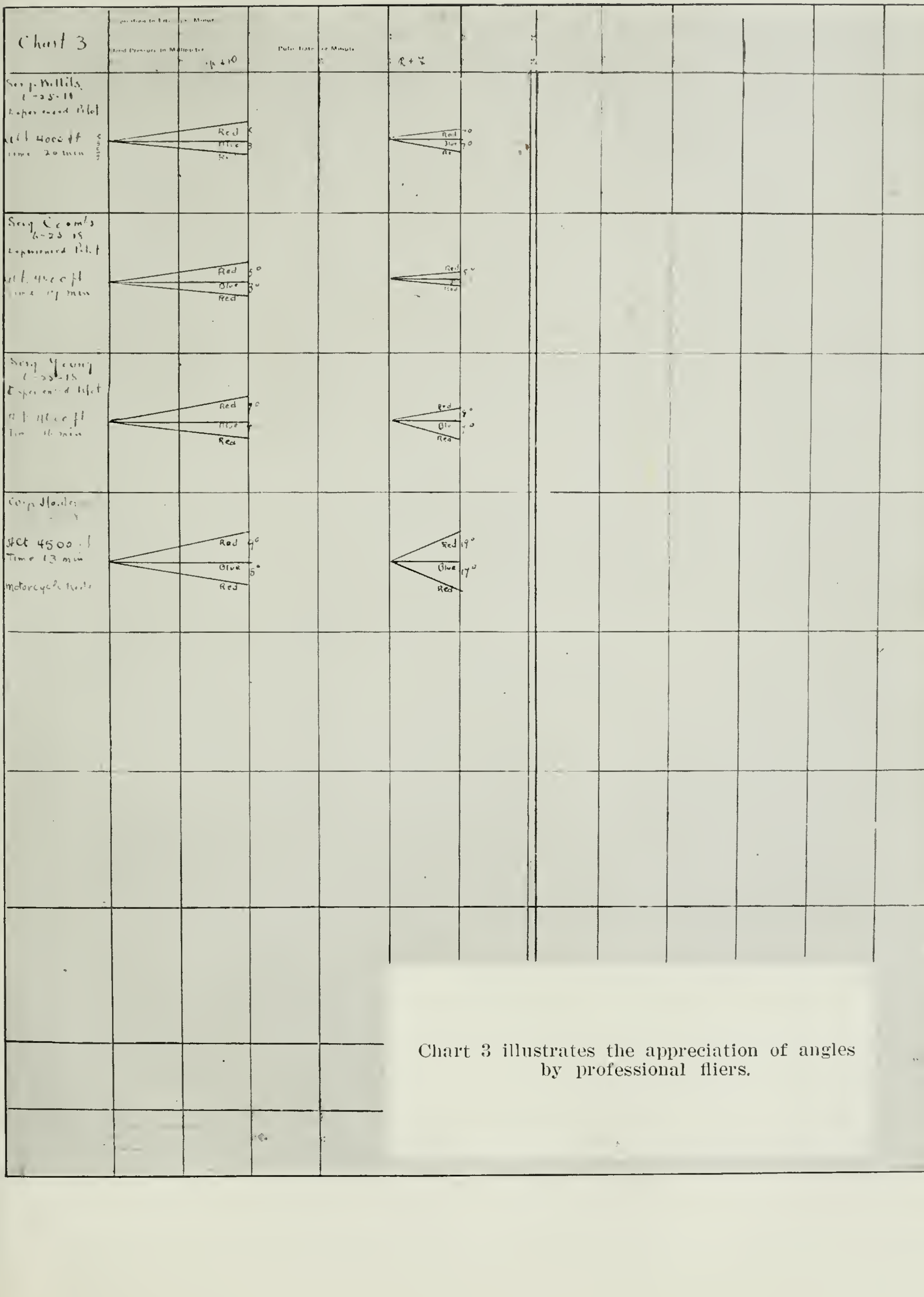


Chart 3 illustrates the appreciation of angles by professional fliers.

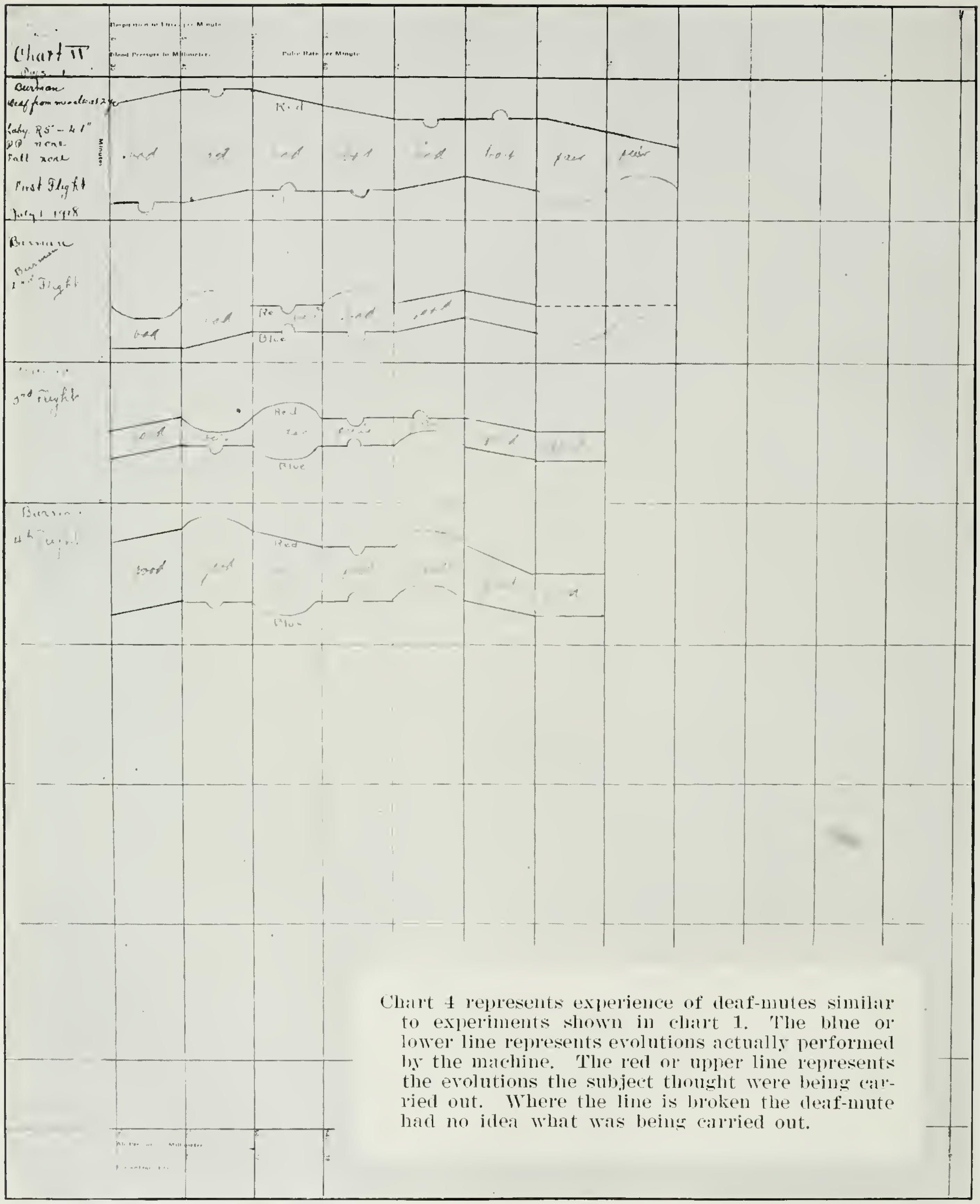
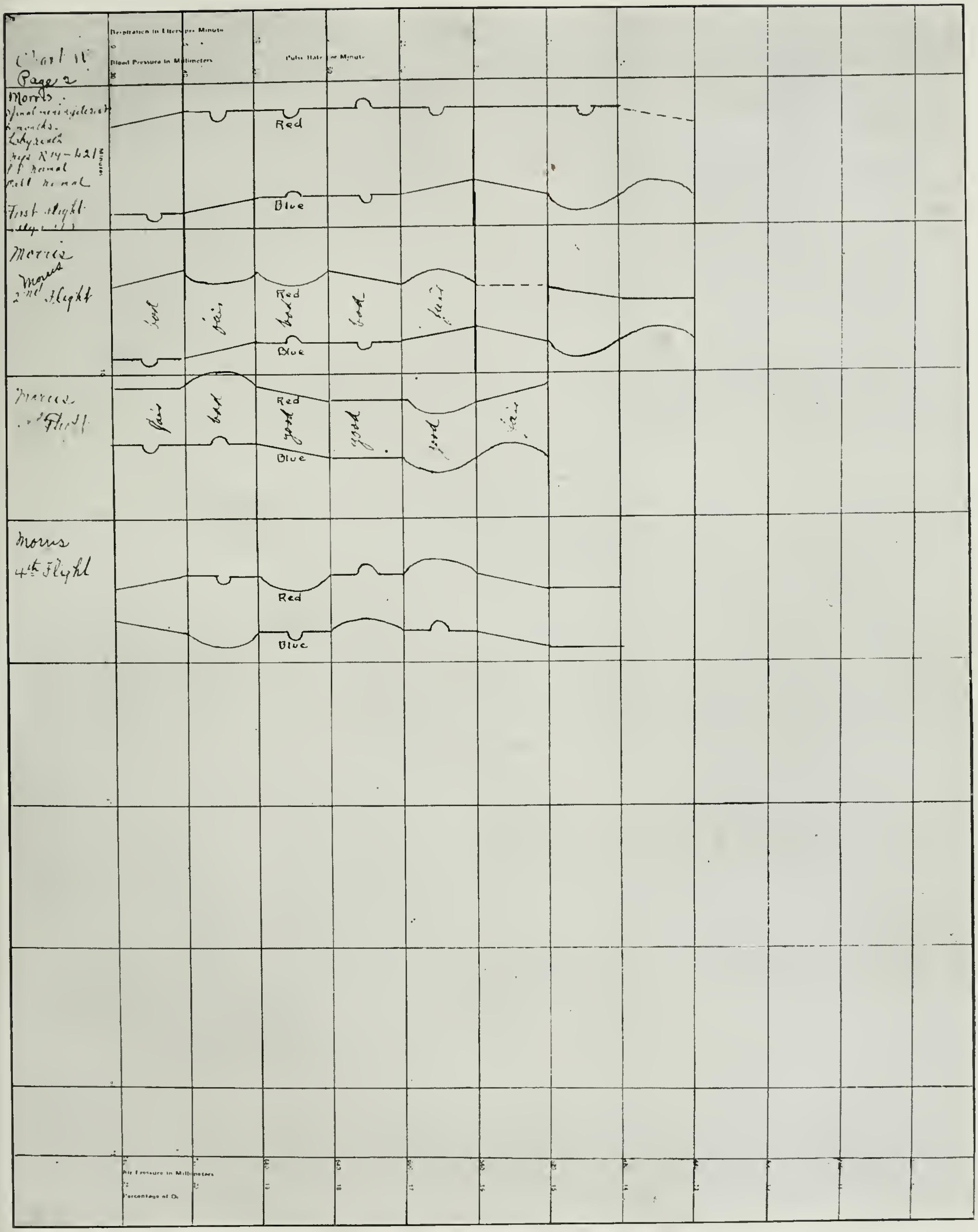


Chart 4 represents experience of deaf-mutes similar to experiments shown in chart 1. The blue or lower line represents evolutions actually performed by the machine. The red or upper line represents the evolutions the subject thought were being carried out. Where the line is broken the deaf-mute had no idea what was being carried out.


Respiration in Liters per Minute
Blood Pressure in Millimeters
Pulse Rate per Minute
Chart IV
Page 2
Morris
First flight
Red
Blue
Morris
2nd Flight
Red
Blue
bad
fair
bad
bad
fair
Morris
fair
bad
good
good
good
fair
Red
Blue
Morris
4th Flight
Red
Blue
Air Pressure in Millimeters
Percentage of O2

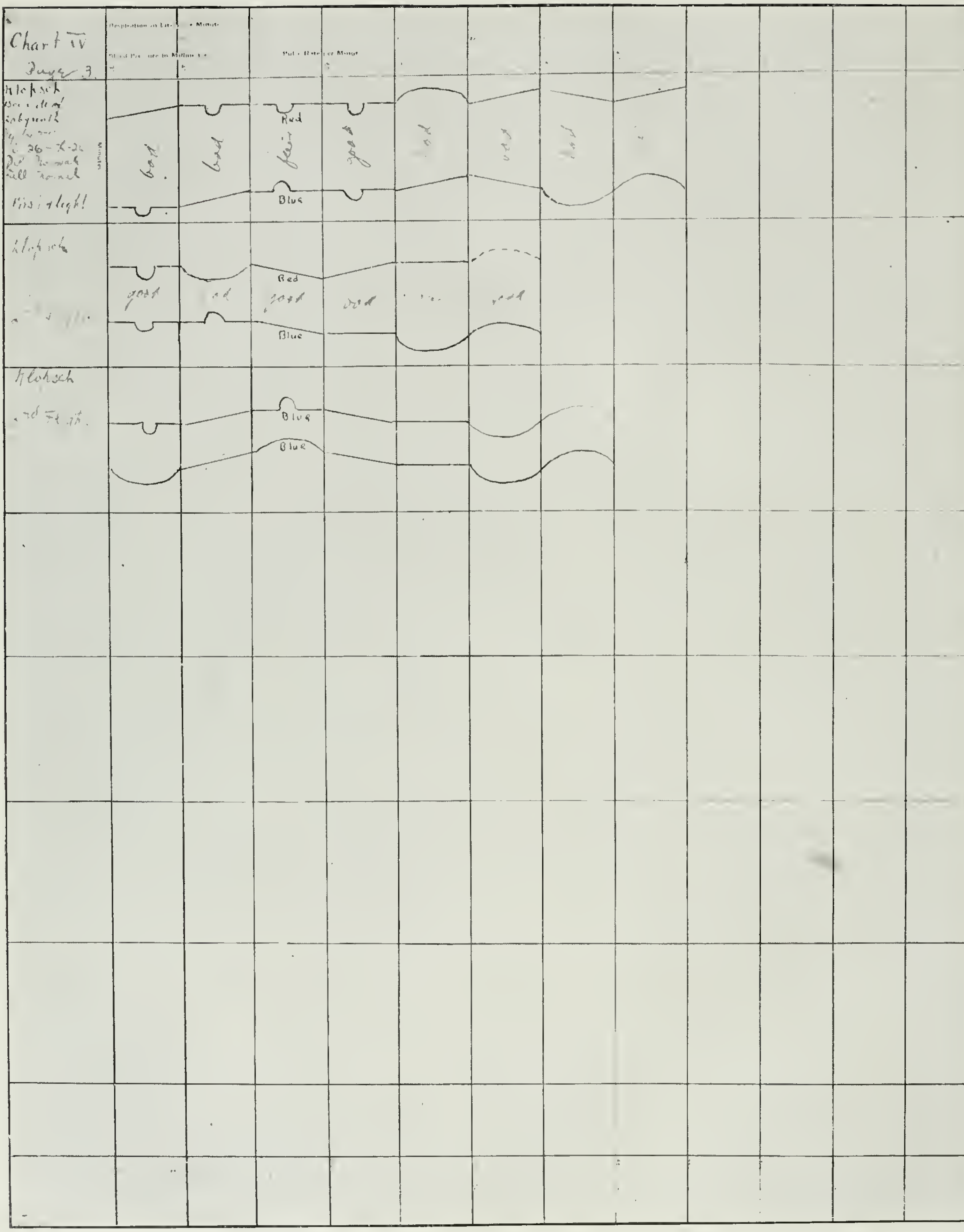


Chart IV
Red
Blue
Red
Blue
Blue
Blue

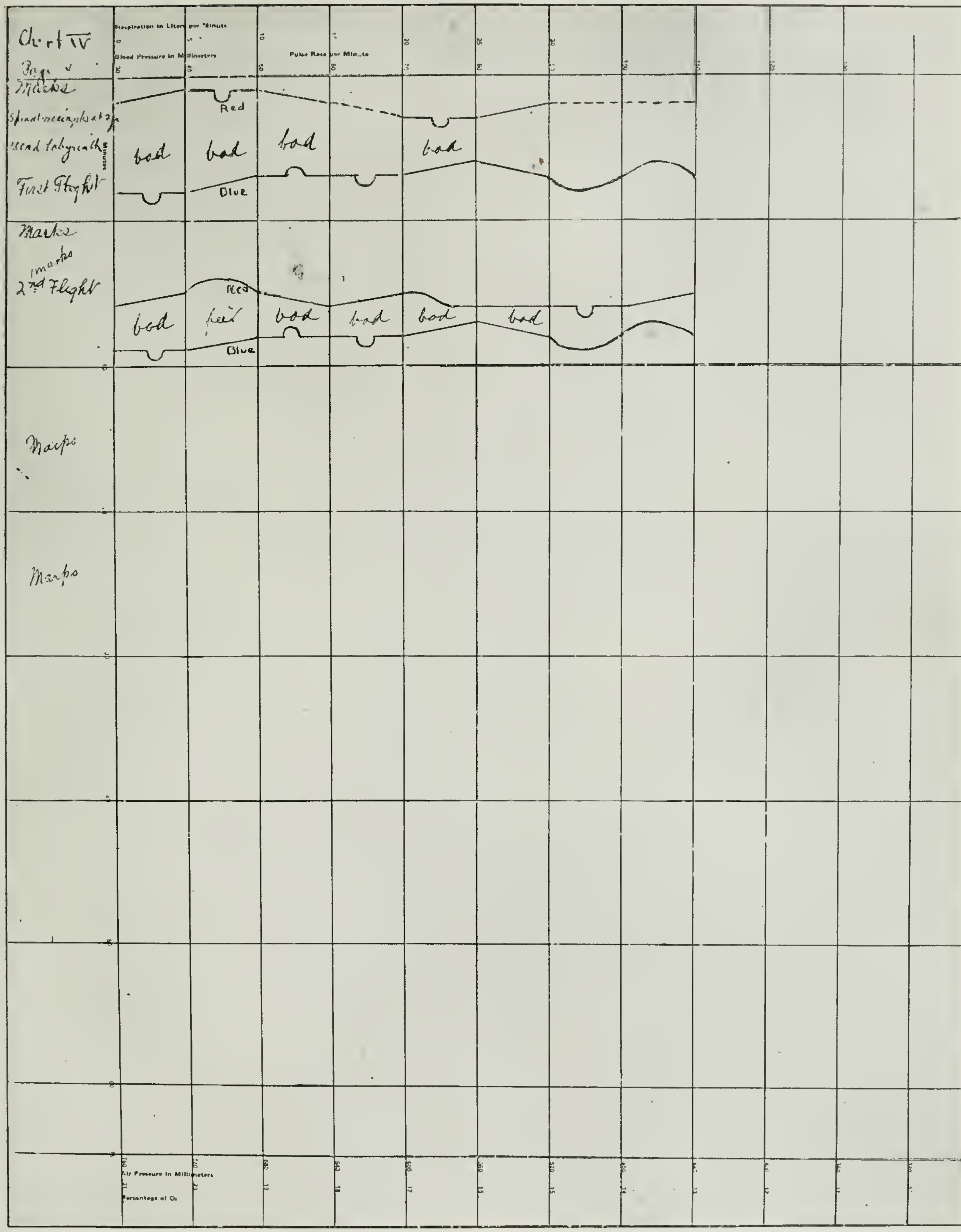


Chart IV
Marks
First Flight
2nd Flight
Respiration in Liters per Minute
Blood Pressure in Millimeters
Pulse Rate per Minute
Red
Blue
bad
Air Pressure in Millimeters
Percentage of O2

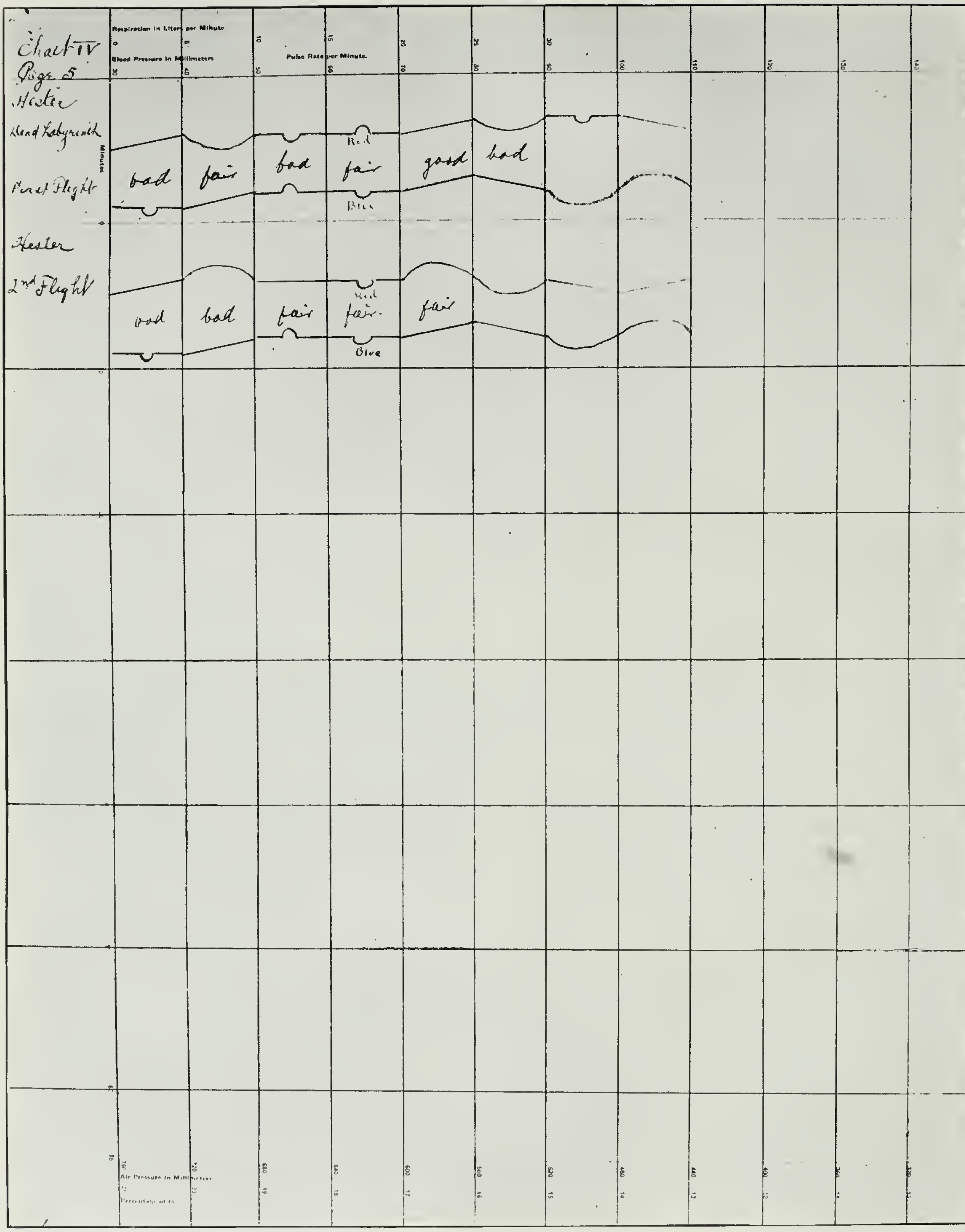


Chart IV
Page 5
Hester
Head Labyrinth
First Flight
Hester
2nd Flight
Respiration in Liters per Minute
Blood Pressure in Millimeters
Pulse Rate per Minute.
Minutes
bad
fair
bad
fair
good
bad
Red
Blue
bad
fair
fair
fair
Blue
Air Pressure in Millimeters

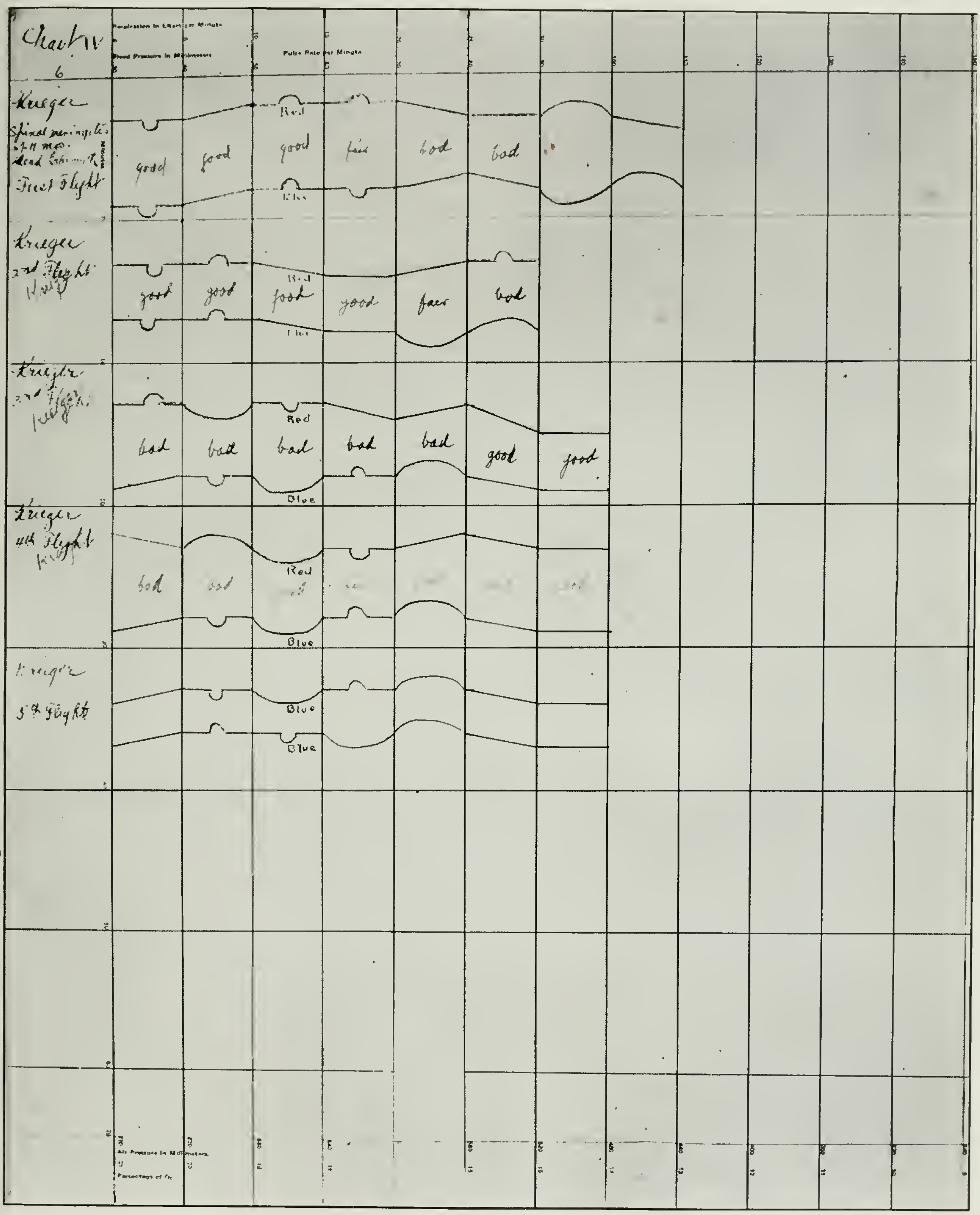
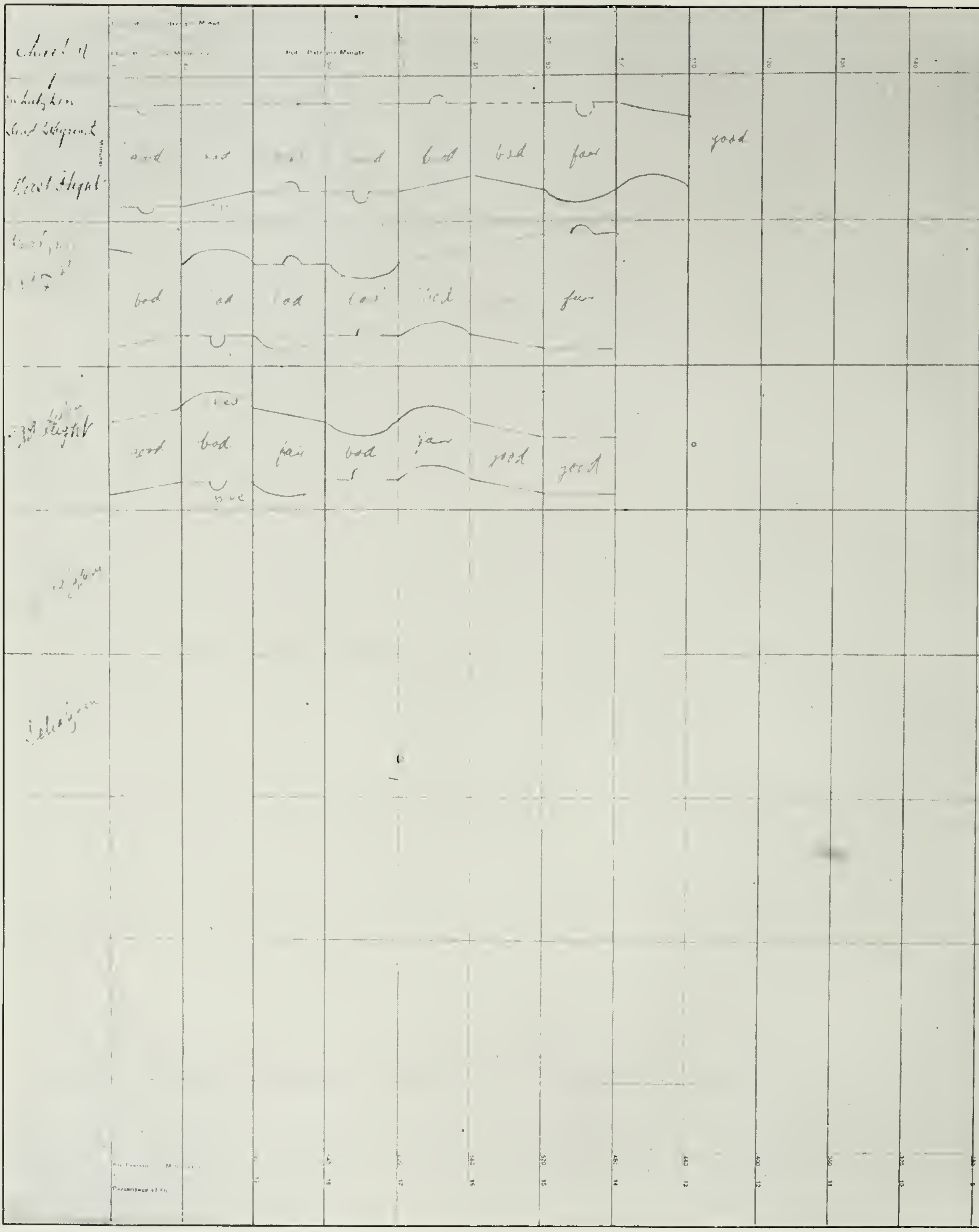


Chart IV
6
Pulse Rate per Minute
Krueger
First Flight
good
good
good
fair
bad
bad
Red
Blue
Krueger
2nd Flight
good
good
good
good
fair
bad
Krueger
3rd Flight
bad
bad
bad
bad
bad
good
good
Red
Blue
Krueger
4th Flight
bad
Red
Blue
Krueger
5th Flight
Blue
Blue


good
bad
fair
bad
fair
bad
fair
bad
good
good

mus, no past-pointing, and only very slight tendency to fall. The general average of these upward and downward experiments show upward angle, 17 degrees; downward angle, 9 degrees.

CHART 2–B.

Chart 2–B represents a series of experiments similar to those just described, except that the angles were banking (lateral) angles instead of upward and downward (forward) angles. This series of experiments showed a similarity in the ability to detect lateral changes from the horizontal. A curious development was that in this series the banks to the left were more accurately detected by the subjects than similar banks to the right.

CHART 4.

Chart 4 shows the most interesting results of all. Seven deaf-mutes were the subjects of these experiments. Two showed normal vestibular function, four showed absolute lack of vestibular function, and one showed a very small amount of vestibular function as represented by three seconds of nystagmus. The results of these experiments upon deaf-mutes are further divided into three groups. The findings of the first groups, those with absolutely no vestibular function, showed total inability to detect changes in the series of movements of the plane in any of the six flights per individual. The results of experiments with the second type of deaf-mutes, in which only a vestige of vestibular function remained, are almost identical with those of the first group. The third type of deaf-mutes, in full possession of vestibular function, showed, however, a marked improvement over the others in successive flights, and practically the normal index as to accuracy of detection of the movements of the plane in the later flights.

CHART III.

Chart III consists of a series of observations carried out under the same conditions upon three professional fliers and one professional trick motor-cyclist. Their superiority in detecting angles is at once apparent. Still more interesting is the fact that the motor-cyclist, who had practically no flying experience, did not detect angles as well as the pilots, but still appreciated them better than did other subjects inexperienced in balancing.

Other experiments with other normals, not noted on these charts, convinced us that the results so far given represent very accurately the general average in such individuals, and, therefore, experiments of a greater number were not considered necessary for this preliminary study.

DEAF-MUTE EXPERIMENTS.

CHART IV.

Chart IV is, as has been said, the most interesting of all. Seven deaf-mutes were selected whose labyrinth findings are given on the edges of the charts. The striking differences between these deaf-mutes and the normal candidates and the still more striking lack of improvement in all their subsequent flights seem to be fairly convincing that for purposes of appreciating changes of position in space a properly functionating vestibular apparatus is of great importance, and further, but little can be expected from deep sensibility when it alone senses motion. These deaf-mutes were all highly interested and were keenly alive to the experiments. Some of them were convinced that they would prove able to qualify for aviation, and when their charts were shown to them their amazement was extreme. Their guesses as to the kind of motion to which they had been subjected were of the wildest character. They had nothing to inform them except their deep sensibility and tactile sense. Nose dives and the "zoom" or upward movements were carried out at such acute angles that it was remarkable that they guessed as inaccurately as they did. On close questioning many of them admitted that they were entirely "in the dark" and felt as if they must tear the bandage from their eyes; in other words, they were completely lost in space, and it is greatly to their credit that they were willing to subject themselves repeatedly to these more or less trying experiences.

One of the most important observations of all is seen in an examination of Chart V. As a matter of interest, before these subjects were sent up, we tried them walking a straight line blindfolded, which they did in a fairly accurate manner, but when they were asked to maintain themselves in equilibrium by standing on one leg with eyes closed, they fell in various directions and none of them were able to stand at all steadily in this position. After rapid rotation with the head forward and eyes closed, they were quite as able to stand as they had been before, showing no tendency toward the normal falling response. They were dependent for sensory information in walking or standing on one leg, etc., upon only two sources—vision and deep sensibility.

In the angle experiment, shown on Chart V, where rapid acceleration of motion was made, not a single subject was able to guess a single correct position in space. The machine was brought up to the stalling angle above, to the extreme diving angle below, and to such an acute bank that the vertical control became the rudder, and because the change was gradually brought about, they were still unable to appreciate any deviation from the horizontal. This preliminary

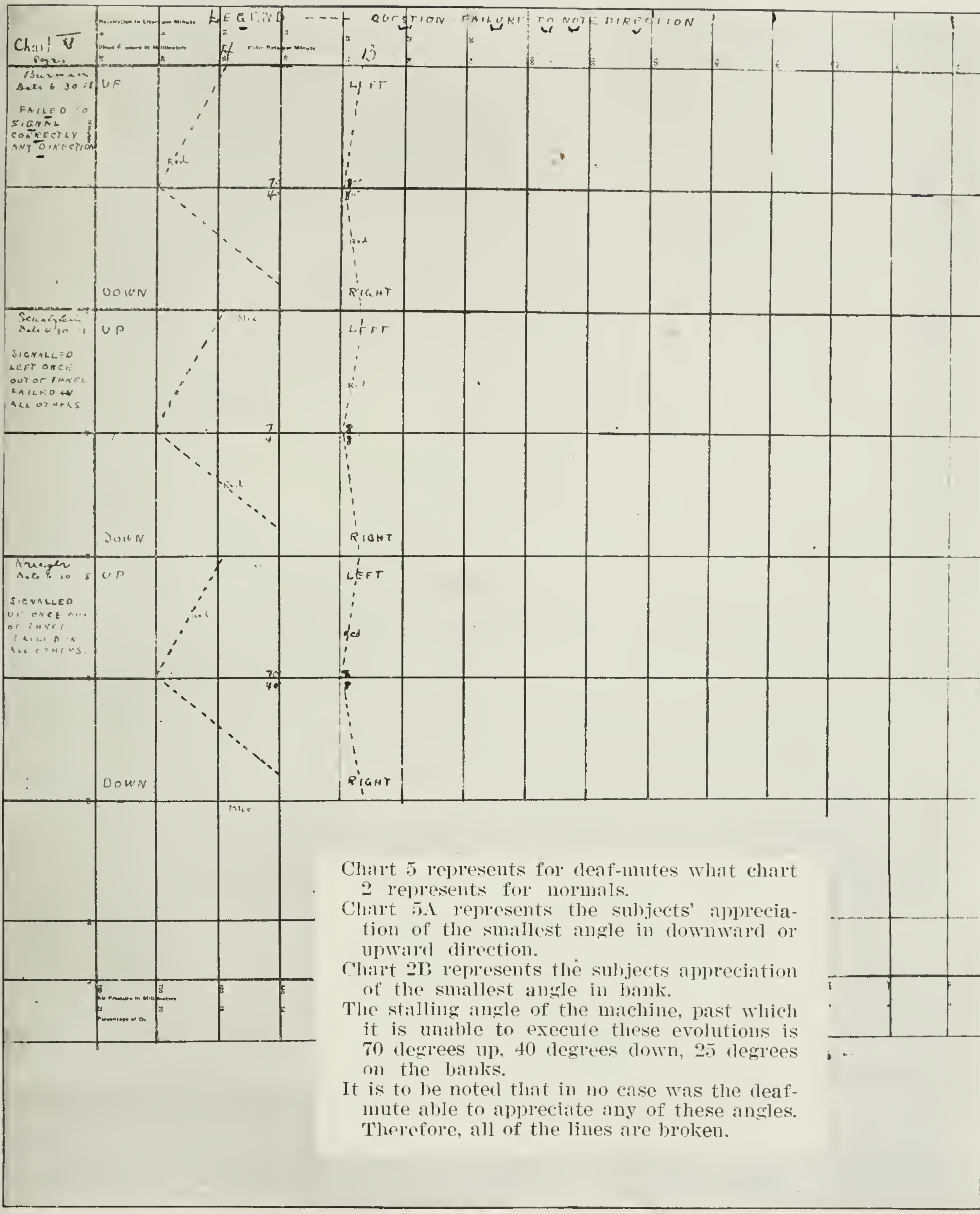


Chart 5 represents for deaf-mutes what chart 2 represents for normals.
Chart 5A represents the subjects' appreciation of the smallest angle in downward or upward direction.
Chart 2B represents the subjects appreciation of the smallest angle in bank.
The stalling angle of the machine, past which it is unable to execute these evolutions is 70 degrees up, 40 degrees down, 25 degrees on the banks.
It is to be noted that in no case was the deaf-mute able to appreciate any of these angles. Therefore, all of the lines are broken.

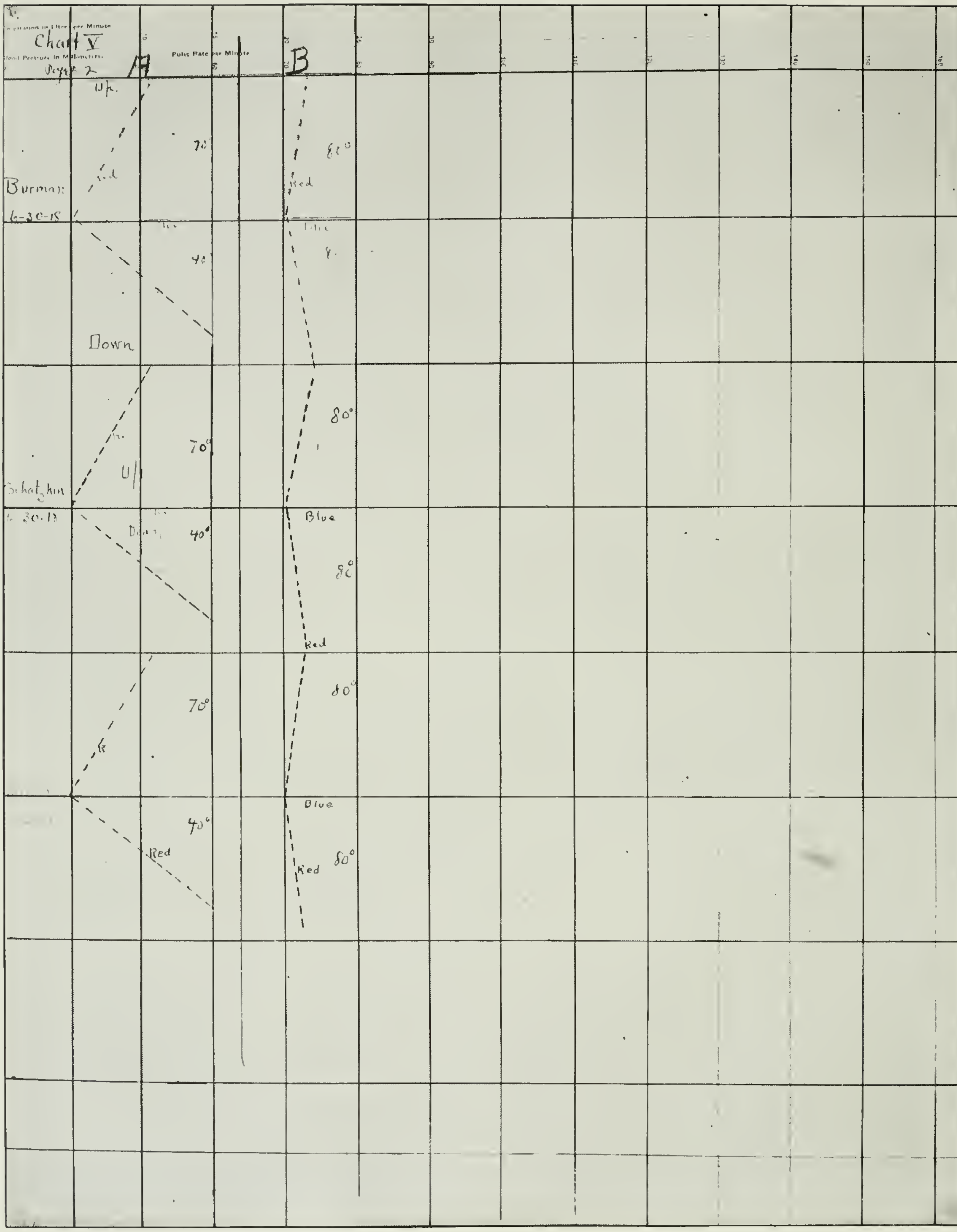


Chart V
Pulse Rate per Minute
A
B
Up.
70°
Red
Burman
6-30-18
40°
Down
80°
Schatzkin
Blue

study was made in the hope that the peculiar impression which has gone abroad and which has done much to block the progress of the selection of aviation candidates—that the less acute motion-sense of the inner ear was the less dizzy, and therefore the better flier the man would make, would be corrected.

The findings (covering seven days of experimental work, including 52 flights) as to the motion-sensing of the two deaf-mutes with normal vestibular reactions give undoubted evidence of gradual improvement in correct sensing of motion; one deaf-mute with a vestige of vestibular function shows some improvement in ability to sense motion correctly; four deaf-mutes with no vestibular function show no evidence of improvement in motion-sensing ability. It must be borne in mind that such a series of experiments should be much greater and should cover a much longer period of time if deductions of a final nature are to be drawn. The injection of so many extraneous influences, such as apprehension, fear, excitement, inability to focus attention, vitiates to a considerable extent the value of the findings in any individual flight. On the other hand, guesswork injects an additional element of unreliability into the findings. While analysis of the charted records shows some surprising inconsistencies, it is at once apparent that normals show no such diametrically opposite consecutive motion-sensing perceptions as the deaf-mutes. It is demonstrated by this series of experiments that man's ability to sense motion is measured by his full possession of visual acuity, deep sensibility, vestibular sense acuity, and tactile sense. And particularly, that the "feel of the airship" which is the sense-complex that makes for a first-class pilot, requires normal vestibular motion-sensing.

4. Experience and Education in Motion-Sensing and Fatigue of the Vestibular End-Organs.

The possibilities of a person accustoming or educating himself by constant rotation to estimate correctly the sensations of vertigo or disturbed relations in space have been considered, and experiments were carried out with a view to shedding light upon this question. The matter is one of practical importance, and upon it the life of an aviator may depend in a critical moment. Adjustment in seasickness, in whirling dances, in acrobatics, and in any other line of work where rapid changes of spacial relations are necessary has long been known. It has been a disputed point as to whether the duration of the nystagmus in such cases actually becomes less and less with the same stimulus. By experiment it was found that nystagmus occurs less in duration after repeated turnings, and the sensation of vertigo becomes less intense. The immediate shortening of duration of nystagmus and the lessening of vertigo in whirling dancers or others ensuing upon excessive stimulation of the vestibular end-organs is a transitory fatigue phenomenon. The average normal, whose nystagmus time when not fatigued is approximately 24 to 26 seconds, is the man who is physically most suitable for flying training. Many experiments concerning acute and chronic fatigue phenomena are now under consideration in this laboratory and will be reported upon later. (*See Editorial Insert, p. 323.*)

The whirling artists, who spend years in professional whirling acts, when not fatigued show full normal responses to tests of their vestibular apparatus. Their art lies in the education and experience which they have gained and in the dexterity they have acquired in the repeated performance of their acts. For instance, a whirling dance may be creditably performed by a novice, but the professional whirling dancer will demonstrate his ability to stop dead still suddenly without a fall, whereas the novice will fall, because of the vertigo (or false sense of motion) he experiences as a result of his whirling. The difference between the artist and the novice lies in the artist's ability to place proper construction upon his false sense of motion, experience and education enabling him to estimate its degree of falsity so correctly that he is able to calculate his voluntary muscular control in a manner that results in his accomplishing a successful standing still. The novice, unpracticed and inexperienced in estimating vertigo, finds himself unable to do so successfully and falls to the floor.

TESTS OF WHIRLING ARTISTS, DANCERS, AND EQUILIBRISTS, FEB. 28, 1918.

"L. L.," whirling artist.

Nyst. R. 26 sec., L. 24 sec.

P. P.	To R.	R. hand 5.
		L. hand 4.
	To L.	R. hand 3.
		L. hand 3.
Falls	R. normal.	
	L. normal.	

"J. S.," equilibrist.

Nyst. R. 26 sec., L. 24 sec.

P. P.	To R.	R. hand 3.
		L. hand 1.
	To L.	R. hand 1.
		L. hand 3.
Falls	R. normal.	
	L. normal.	

"I. B.," tight and slack wire artist.

Nyst. R. 28 sec., L. 33 sec.

P. P.	To R.	R. hand 2.
		L. hand 2.
	To L.	R. hand 2.
		L. hand 2.
Falls	R. normal.	
	L. normal.	

"C. G.," balance equilibrist.

Nyst. R. 25 sec., L. 20 sec.

P. P.	To R.	R. hand 3.
		L. hand 2.
	To L.	R. hand 2.
		L. hand 3.
Falls	R. normal.	
	L. normal.	

Mrs. "E. B.," whirling artist.

Nyst. R. 34 sec., L. 35 sec.

P. P.	To R.	R. hand 3.
		L. hand 3.
	To L.	R. hand 3.
		L. hand 3.
Falls	R. normal.	
	L. normal.	

"C. F.," whirling dancer.

Nyst. R. 29 sec., L. 31 sec.

P. P.	To R.	R. hand 1.
		L. hand 1.
	To L.	R. hand 2.
		L. hand 2.
Falls	R. normal.	
	L. normal.	

"O.," whirling dancer.

Nyst. R. 27 sec., L. 28 sec.

P. P.	To R.	R. hand 3.
		L. hand 3.
	To L.	R. hand 1.
		L. hand 1.
Falls		R. normal.
		L. normal.

"E. M.," head balancer, 41 years old, 20 years' experience.

Nyst. R. 34 sec., L. 31 sec.

P. P.	To R.	R. hand 3.
		L. hand 2.
	To L.	R. hand 3.
		L. hand 4.
Falls		R. normal.
		L. normal.

"P. A.," perch act, 20 years old, 13 years experience.

Nyst. R. 31 sec., L. 38 sec.

P. P.	To R.	R. hand 2.
		L. hand 1.
	To L.	R. hand 5.
		L. hand 6.
Falls		R. normal.
		L. normal.

"C. A.," perch act, 28 years old, 13 years experience.

Nyst. R. 21 sec., L. 24 sec.

P. P.	To R.	R. hand 1.
		L. hand 1.
	To L.	R. hand 2.
		L. hand 3.
Falls		R. normal.
		L. normal.

"Mrs. S.," whirling act.

Nyst. R. 31 sec., L. 25 sec.

P. P.	To R.	R. hand 3.
		L. hand 3.
	To L.	R. hand 3.
		L. hand 3.
Falls		R. normal.
		L. normal.

"Mrs. H.," whirling act.

Nyst. R. 22 sec., L. 24 sec.

P. P.	To R.	R. hand 2.
		L. hand 2.
	To L.	R. hand 1.
		L. hand 1.
Falls		R. normal.
		L. normal.

CONVERSATION WITH "G" AND "B," PROFESSIONAL BALLET DANCERS.

"Very little dizziness even when learning, but individual variation; conquest of dizziness depends upon acquisition of ability to jerk head as dancer revolves. Revolving with head not jerking, eyes open or shut, causes dizziness. Refused to revolve jerking head with eyes shut, because it would be sure to cause dizziness and nausea; they were sure it was much worse."

"Mrs. S.," aerial flying trapeze, 50 years old, 30 years in circus.

Nyst. R. 17 sec., L. 18 sec.

P. P.	To R.	R. hand 3.
		L. hand 2.
	To L.	R. hand 2.
		L. hand 3.
Falls		R. normal.
		L. normal.

"L. M.," head balancer, 18 years old, 8 or 9 years experience.

Nyst. R. 37 sec., L. 30 sec.

P. P.	To R.	R. hand 3.
		L. hand 2.
	To L.	R. hand 2.
		L. hand 4.
Falls		R. normal.
		L. normal.

Cases "A" and "B" were tight-rope walkers.

"A."

Nyst. R. 26 sec., L. 26 sec.

P. P.	To R.	R. hand 3.
		L. hand 3.
	To L.	R. hand 3.
		L. hand 3.
Falls		R. normal.
		L. normal.

"B."

Nyst. R. 26 sec., L. 26 sec.

P. P.	To R.	R. hand 3.
		L. hand 3.
	To L.	R. hand 3.
		L. hand 3.
Falls		R. normal.
		L. normal.

Cases "C," "D," "E," and "F" were motordrome whirling racers.

"C," 26 years old, 6 years' experience.

Nyst. R. 22 sec., L. 24 sec.

P. P.	To R.	R. hand 3.
		L. hand 3.
	To L.	R. hand 3.
		L. hand 3.
Falls	R. normal.	
	L. normal.	

"D," 23 years old, 5 years' experience.

Nyst. R. 26 sec., L. 26 sec.

P. P.	To R.	R. hand 3.
		L. hand 3.
	To L.	R. hand 3.
		L. hand 3.
Falls	R. normal.	
	L. normal.	

"E," 26 years old, 6 years' experience.

Nyst. R. 26 sec., L. 26 sec.

P. P.	To R.	R. hand 3.
		L. hand 3.
	To L.	R. hand 3.
		L. hand 3.
Falls	R. normal.	
	L. normal.	

"F," 24 years old.

Nyst. R. 8 sec., L. 8 sec.

P. P.	To R.	R. hand T.
		L. hand T.
	To L.	R. hand T.
		L. hand T.
Falls	Falling absent.	
	Falling absent.	

Applicant "F" was a vigorous, robust young man and from all appearances the most promising applicant of the day. The caloric test was given 68° douche in both right and left ears with same subnormal reaction. This man had formerly ridden a motorcycle at the rate of 50 miles per hour on circular wall on motordrome and had never experienced nausea or dizziness. A 4+ Wasserman and history of recent chancre explained the reactions.

Many important practical applications may be the outcome of these experiments. It may ultimately become a routine method of accustoming the young pilot to the sensations of the spinning nose dive and the rolling motion of the airship by revolving exercises. Most important of all may be the possibility of teaching the prospective flier the sensations of the loop, tight spiral, and spinning nose dive and how to control himself during the incidental vertigo by daily practice in some such apparatus as that devised by Ruggles.

The most common revolving motions of the aeroplane are the spiral, spinning nose dive, and the roll. In the spinning nose dive, or tight spiral, the aviator may have his horizontal canals or his vertical canals chiefly affected according to the position he assumes. Since every individual is more accustomed to the horizontal canal stimulation than the vertical canal stimulation, it is better that he assume a position in which the horizontal canals are mainly stimulated. In spiral turns, if the aviator sits upright, the horizontal canals are the ones mainly stimulated, and these very slightly, because of the large circular turns. In the spinning nose dive the ship noses vertically down, due to the heavy engine and if the aviator remains in the same upright position as in horizontal flying he will then concentrate stimulation upon his vertical canals. But if he bends forward as the French aviators are instructed to do, he will practically be upside down so that again he will concentrate stimulation upon the horizontal semicircular canals. Physical directors have advised turning movements as practice exercises; but after all this is only of preliminary value, because experienced fliers become so accustomed to turnings and air antics that they, like acrobats, know where they are at all times and are at home in the air.

Space does not permit in this article to quote from the histories of aviators at the disposal of the otologic department cases where, following impairment of the labyrinth due to mumps or syphilis, a man's flying ability has been lost or badly impaired coincidentally with the rapid deterioration of his vestibular sensory acuity. This is additional corroborative evidence of the most convincing nature.

RÉSUMÉ.

General condition of aviator's ears, nose, and throat must be good.

The ground soldier can stand still. The aviator can not. Motion assumes great added importance to the aviator.

Motion-sensing, therefore, assumes great additional importance to the aviator.

Of the senses concerned in motion-sensing, the vestibular sense is the only one whose utility remains constant; hence the necessity of determining the aviator's possession of requisite vestibular sense.

Vestibular tests not only determine functional condition of this portion of the internal ear but give definite information concerning the integrity of parts of the medulla oblongata, pons, cerebrum, and particularly the cerebellum.

It has been determined that up to 18,000 feet there occurs no marked functional change in the vestibular apparatus.

Observations made in an extensive series of blindfold experiments on normal persons, on persons with nonfunctionating vestibular apparatus, on persons lacking hearing only, and on persons with impaired deep sensibilities indicate that perception of motion in a linear direction—

(*a*) During acceleration, is sensed most accurately by those whose vestibular apparatus is functionating;

(*b*) At a sustained rate of speed is sensed accurately by each group except those lacking deep sensibility;

(*c*) During retardation is sensed accurately by those whose vestibular apparatus is functionating;

(*d*) Arrest of motion ensuing upon motion in a linear direction is most accurately detected by the group lacking vestibular function but in possession of unimpaired deep sensibilities.

Experience in aeroplane flights shows that blindfolded normal persons perceive motion changes accurately; that blindfolded persons lacking normal vestibular apparatus do not.

Transitory fatigue may be observed after excessive stimulation of the vestibular end-organs.

Special ability to estimate correctly the degree of falsity of oft-repeated motion-sensing illusions may be developed in normal persons through experience and education. This special ability enables its possessor to maintain safe bodily relation with his environment during the existence of the motion-sensing illusions with which he has become familiar through long experience.

A superficial observation might suggest that possibly the safest aviators would be those lacking vestibular function, such as deaf mutes, inasmuch as they are incapable of developing motion-sensing illusions which, in normal persons, ensue upon spinning nose dives or other whirling aeroplane maneuvers. Possession of normal functionating sensory end-organs always entails the possibilities of subjective sensory illusions, but to argue the advantage of lacking such special sense end-organs is to reach the reductio ad absurdum.

One who shows good responses in the turning-chair shows good detection of movement in the air; one who shows poor responses in the turning-chair shows poor detection of movement in the air. There is this direct relation between the chair and the air and the air and the chair.

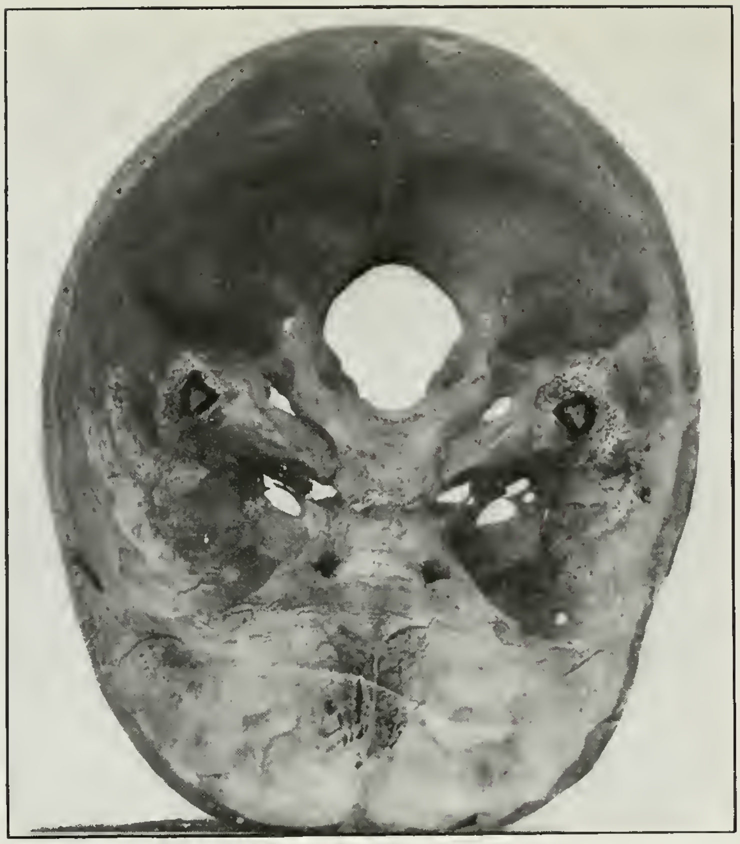
THE EAR IN STUNT FLYING.

Crashes that occur during "stunt" flying are usually the result of something having gone wrong with the pilot. Hence it is a pertinent matter for medical investigation. Just what this something is, is not always clear. Poor judgment, a sense of bravado, carelessness, "stunting" at low altitudes, and sudden faintness are among the reasons generally offered in explanation of these accidents. Direct testimony of the pilot is not always available, since many of the crashes result fatally. Neither are pilots who have crashed and survived always able to give a clear and concise account or analysis of the causes of the accident.

Underlying them all, however, there runs a story of momentary loss of faculties, resulting in a manipulation of controls without deliberate judgment. Most accounts of crashes read, "The pilot went into a tail spin and failed to come out." The story of Lieut. J. M. M. is quite typical of those collected by this department.

While flying he went into a tail spin. This produced such overpowering dizziness that, not knowing what he was doing or why, he grabbed the "joy stick" and pushed it forcibly over and threw himself into another tail spin in the opposite direction. Before he could come out of this he crashed.

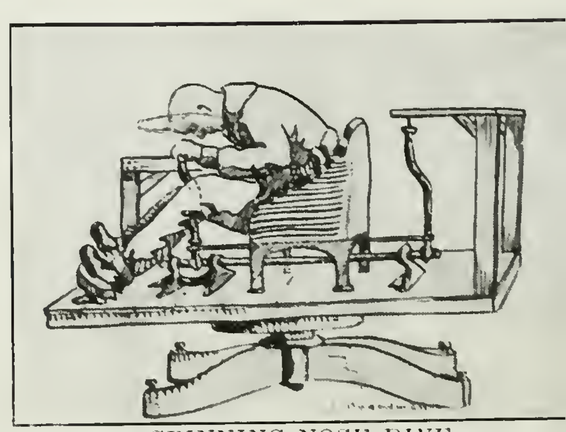
So many of the accounts of crashes given by pilots who did survive emphasize dizziness (or vertigo), that the organ responsible for dizzi-



VIEW OF SEMICIRCULAR CANALS IN BASE OF SKULL.

SPINNING NOSE DIVE.

SPINNING NOSE DIVE.



SPINNING NOSE DIVE.

ness when an individual is whirled around, namely, the ear, was necessarily made the subject of investigation by the Otologic Department of the Medical Research Laboratory at Mineola, N. Y. Experiments which involved the whirling of individuals point conclusively to the fact that Stunt Flying is essentially an Ear Problem.

By visualizing the position of the pilot as he is whirled in the various stunt evolutions, it was found that by reproducing a similar whirling in the apparatus it was possible to simulate all the subjective effects of stunt flying.

Lieut. J. F. D. (150 hours in the air) was placed in a certain position and whirled. He volunteered the information that his sensations were identical with those experienced when coming out of a spinning nose dive. When placed in the apparatus in a certain different position and whirled, he stated that his sensations were those experienced when coming out of a tight spiral. Lieut. W. E. R., an experienced pilot, when placed in the same position as Lieut. D.'s first position made the statement that his sensations were identical with those of his predecessor, saying, "That is exactly like coming out of a spinning nose dive." When placed in another position and whirled he said, "Now I feel like coming out of a loop." These facts were confirmed by similar experiments on other aviators.

Since being whirled in an aeroplane produces effects identical with those resulting from being whirled in a laboratory device, such as the turning-chair, or other forms of apparatus, designed for that purpose, we are furnished with an accurate and convenient means of studying the various vertigo effects of ear stimulation produced by evolutions in the air, and deductions derived from this experimental stimulation are true and applicable to stunt flying. The facts gleaned were so exactly in accordance with our knowledge of the ear as a "motion-sensing apparatus" that they were simply corroborations of certain well-known otologic principles.

Now, what are these established facts or principles?

1. In each ear we have three semicircular tubes or canals, containing fluid, so placed that they are at right angles with each other. Because of this arrangement, no change of position of the individual is possible without producing some movement of fluid in one or more of the canals. Movement of the fluid in these canals sends messages to the brain which are there interpreted as body movement. Hence, the ears constitute the motion-sensing organs of the body.

2. When an individual is whirled, be it in the laboratory or in an aeroplane, there is produced a circulation of this fluid in certain definite canals and planes. Now, if the turning be suddenly altered or stopped or if the aeroplane comes out of rotating maneuver, the fluid in the canals continues to move in its former plane by sheer

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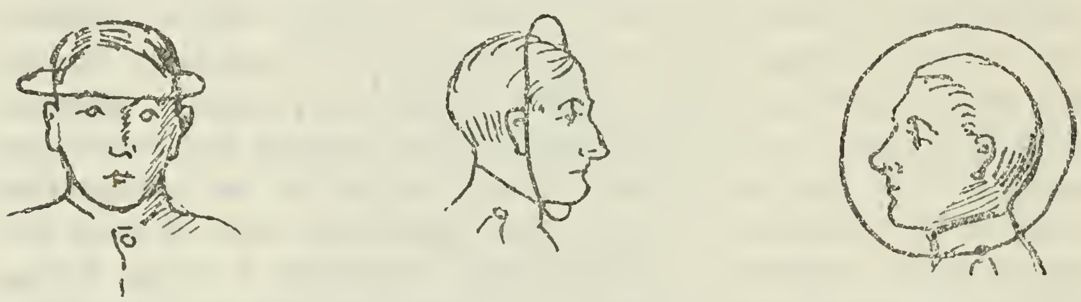
force of its momentum. This circulation of the fluid (by momentum) is interpreted by the brain as body movement, but not being in accordance with fact, the body having ceased to revolve, constitutes vertigo or dizziness, and is disturbing to the individual.

Labyrinthine vertigo, therefore, is a false sensation of motion similar to the visual illusion of motion observed when watching a moving train from the window of a stationary coach, both being unavoidable phenomena of normal special sense mechanisms, which, however, the subject easily learns to interpret and disregard.

One must not fall into the error, however, of thinking that the lack of a normal ear mechanism would be advantageous to the flier, because of the immunity of vertigo which this condition would confer. The absence of such an essential organ as a motion-perceiving apparatus is too great a handicap to the man traveling in an "air medium" even to think for a moment that he could dispense with it for the sole benefit of a vertigo immunity, especially since the normal individual can acquire such an immunity without much difficulty.

VERTIGO EFFECTS OF EAR STIMULATION.

1. There are three cardinal planes of vertigo—horizontal, frontal, and sagittal.



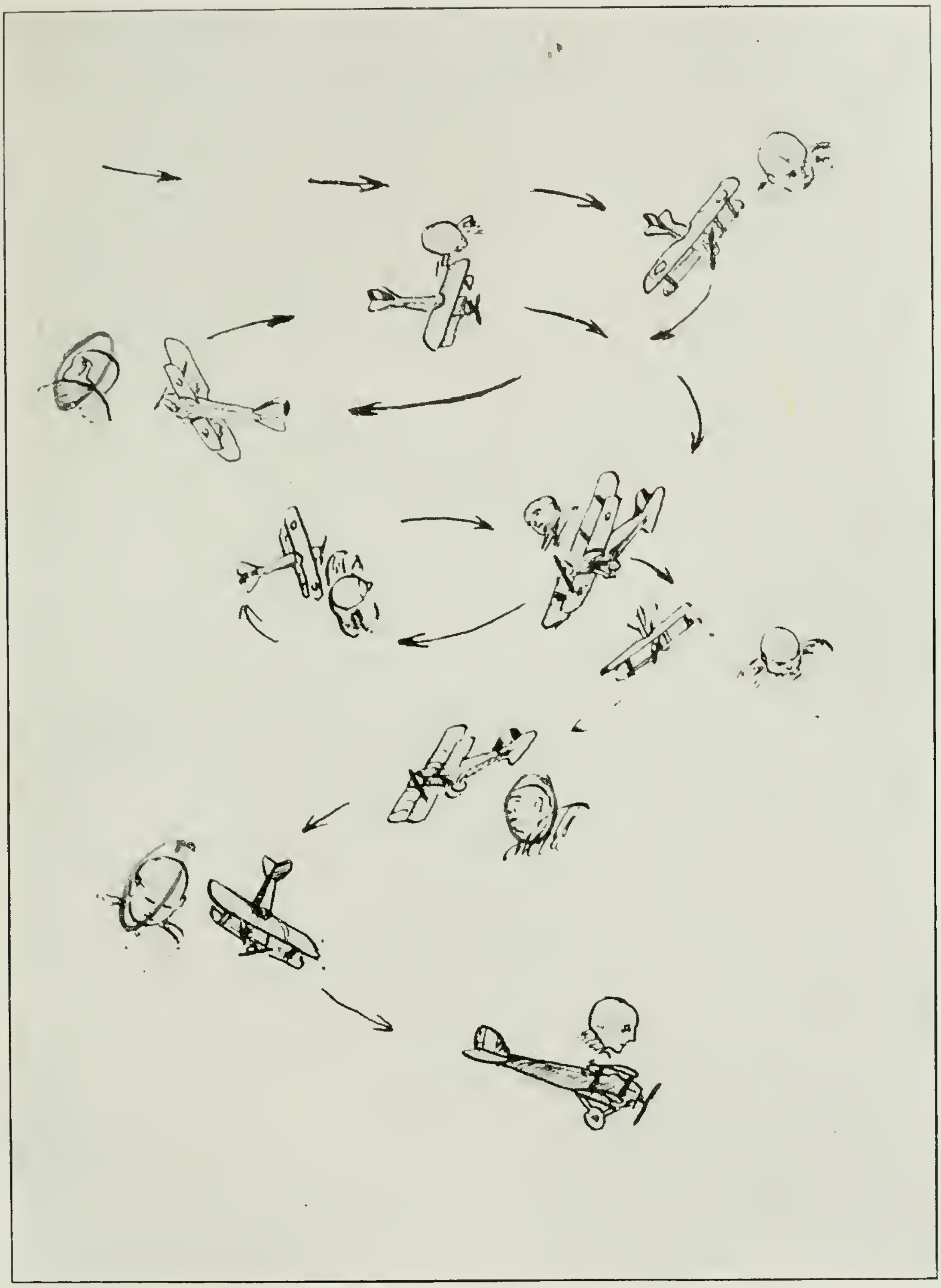
2. A sense of being turned in a horizontal plane—horizontal vertigo—is less disturbing than a sense of being whirled in a vertical plane—vertical vertigo. Each semicircular canal, if stimulated, produces a vertigo in its own plane. Therefore, with the individual in an upright position, stimulation of the horizontal canal is much less disturbing than stimulation of the vertical canals.

3. When a disturbing or disabling vertigo is induced in the vertical semicircular canals the effect can be greatly ameliorated by bringing the vertical canals in a horizontal position or plane, which can readily be done by bringing the head forward.

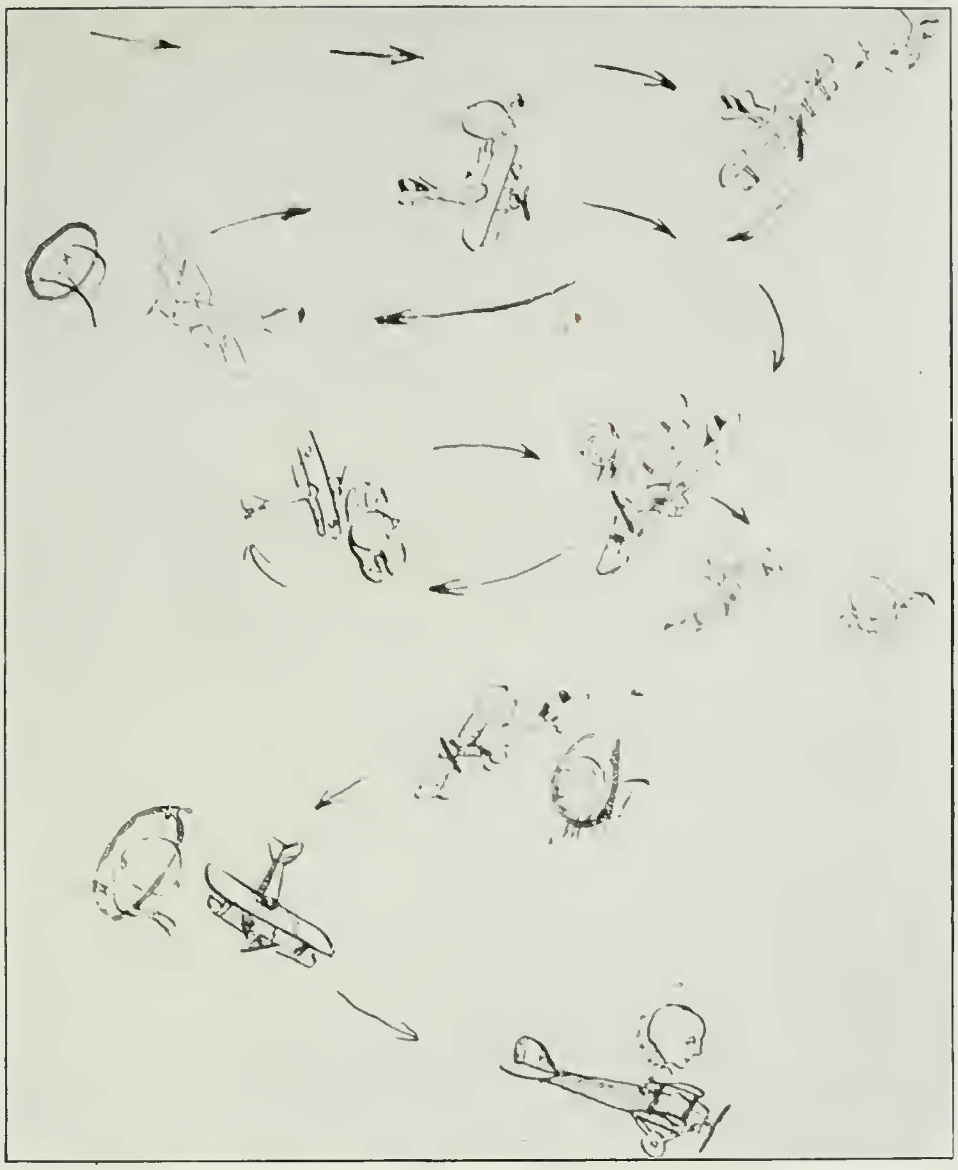
4. All types of vertigo, no matter how induced, are made less and less disturbing by continual repetition.

PRACTICAL APPLICATION OF VERTIGO STUDY TO STUNT FLYING.

Let us consider how the knowledge of the various effects of vertigo gained in the laboratory can be correlated and applied to various stunts.

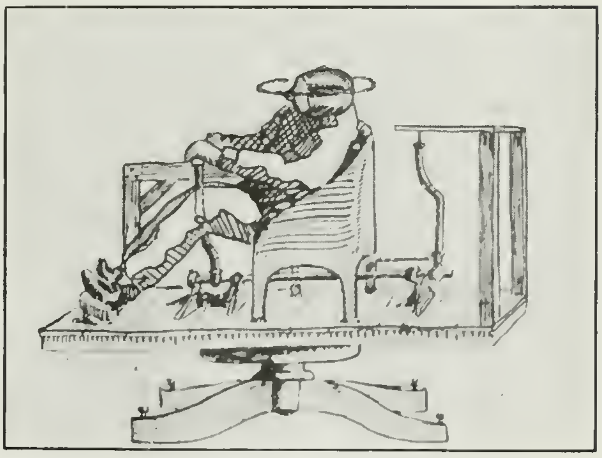


TIGHT SPIRAL.

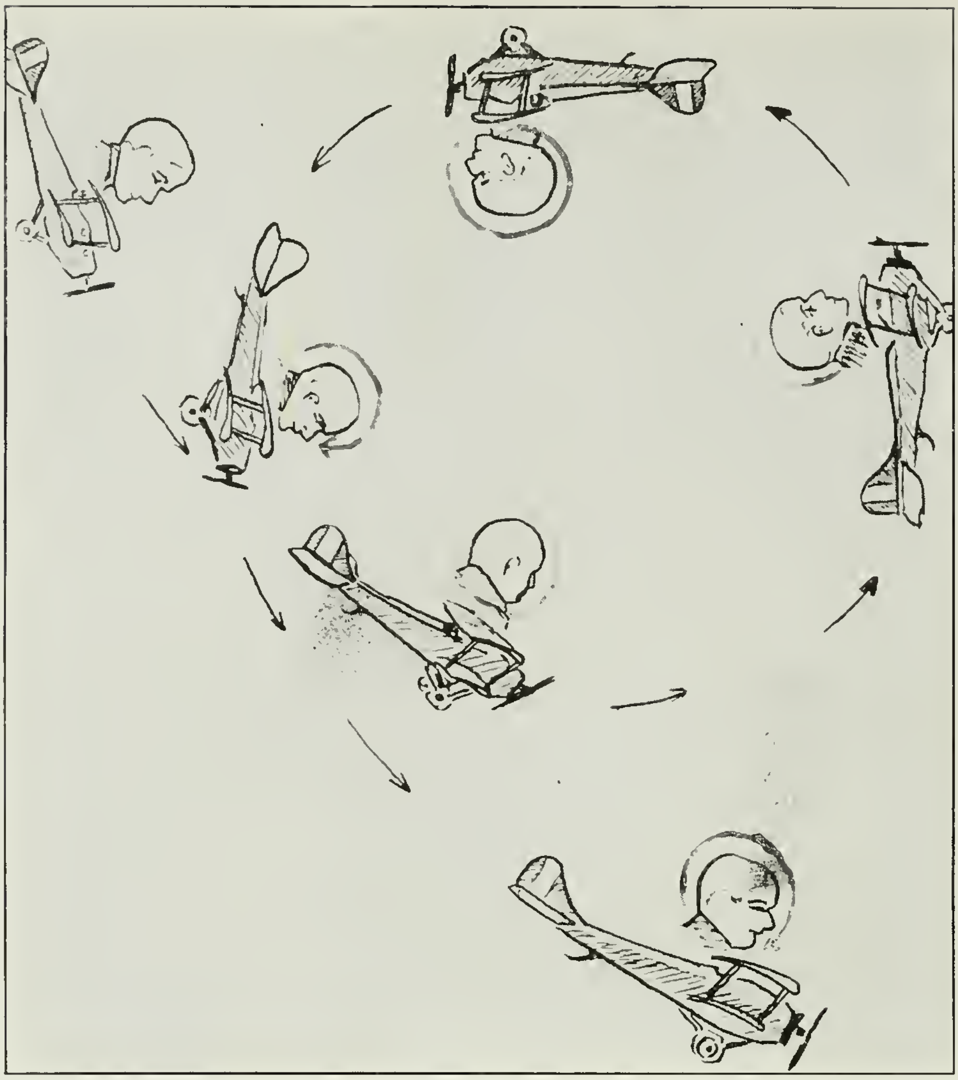


TIGHT SPIRAL.

TIGHT SPIRAL.

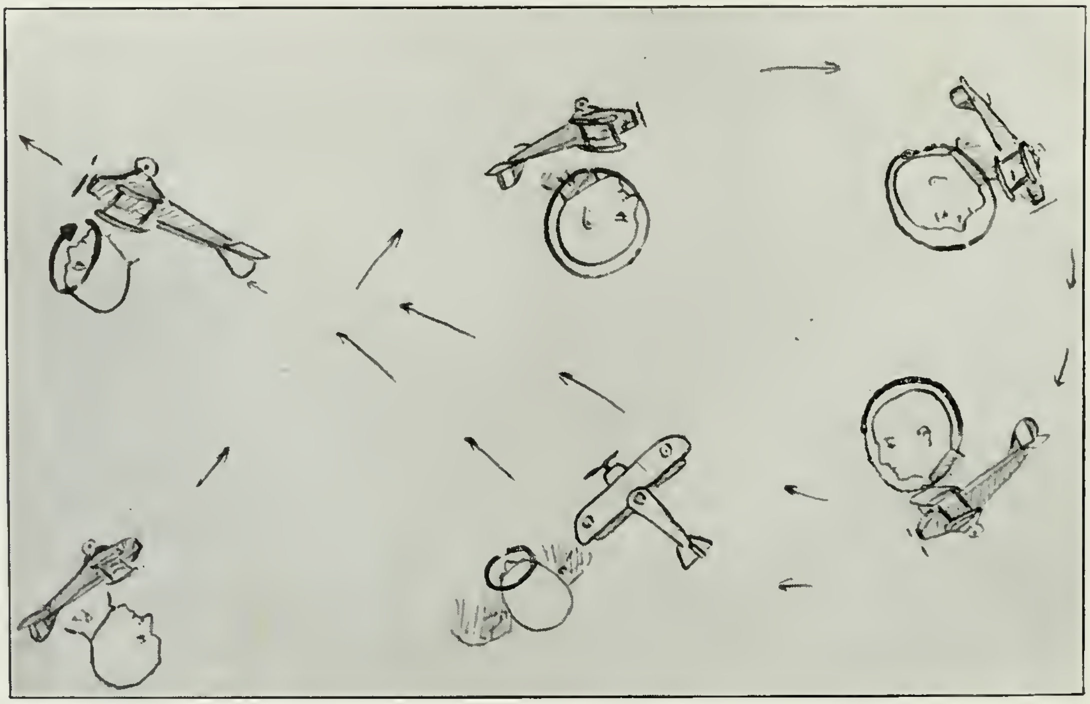


TIGHT SPIRAL.



" LOOPING."

Arrow indicates plane of vertigo.



" LOOPING."

Circles indicate plane of vertigo—sagittal first, then frontal.

SPINNING NOSE DIVE.

In this maneuver the aviator, face downward, is whirled about an axis with his head and body practically parallel to the ground, as shown in the accompanying sketch. In this position there is a stimulation of the vertical semicircular canals in a frontal plane, corresponding to turning in the chair in the position shown below.

When he " comes out " of the spin, the plane of vertigo, which until now has been parallel to the ground, becomes vertical in a frontal plane, i. e., from side to side, so that instead of feeling that he is turning horizontally, he feels that he is whirled in an up and down plane; this being very disturbing, he is apt to lose himself momentarily and attempt to correct this illusionary movement and so throw himself into another spinning nose dive in the opposite direction. When this same experiment is carried out in the chair, i. e., when he is turned with his head forward, simulating his position during this spinning nose dive, and attempts to sit erect, he similarly changes his horizontal vertigo, with which he started, into a sensation of whirling in an up and down plane. In attempting to correct this false impression he throws his body to one side with such violence that unless caught by the examiner he would fall to the floor. It is easy to imagine what havoc would be raised with the controls of an airship under similar conditions. The obvious remedy in both cases is to keep the head down, as it was in the beginning, so that the vertigo remains in the horizontal plane.

TIGHT SPIRAL.

In this maneuver the aviator is whirled about an axis with his head and body practically parallel with the ground but facing the horizon. The stimulation occurs in the vertical canals but in a plane practically parallel with the ground as long as the spiral lasts. When he comes out, however, the plane of vertigo, horizontal until now, becomes vertical in a sagittal (from before backward) plane, so that he feels himself pitching forward or backward and may again meet with disaster in attempting to correct for this illusion.

In the turning-chair this maneuver can be simulated by turning the individual with his head sharply inclined over the shoulder as illustrated.

The obvious remedy for the aviator in this case is to tilt his head sharply to one side when coming out of the spiral, since by so doing he will prevent the vertigo from assuming an up and down whirl.

LOOP.

In this stunt, as shown in the accompanying sketch, the vertical canals are stimulated in the saggittal plane (as in the spiral, but to a lesser degree). The correction is accomplished by tilting the head sharply over one shoulder.

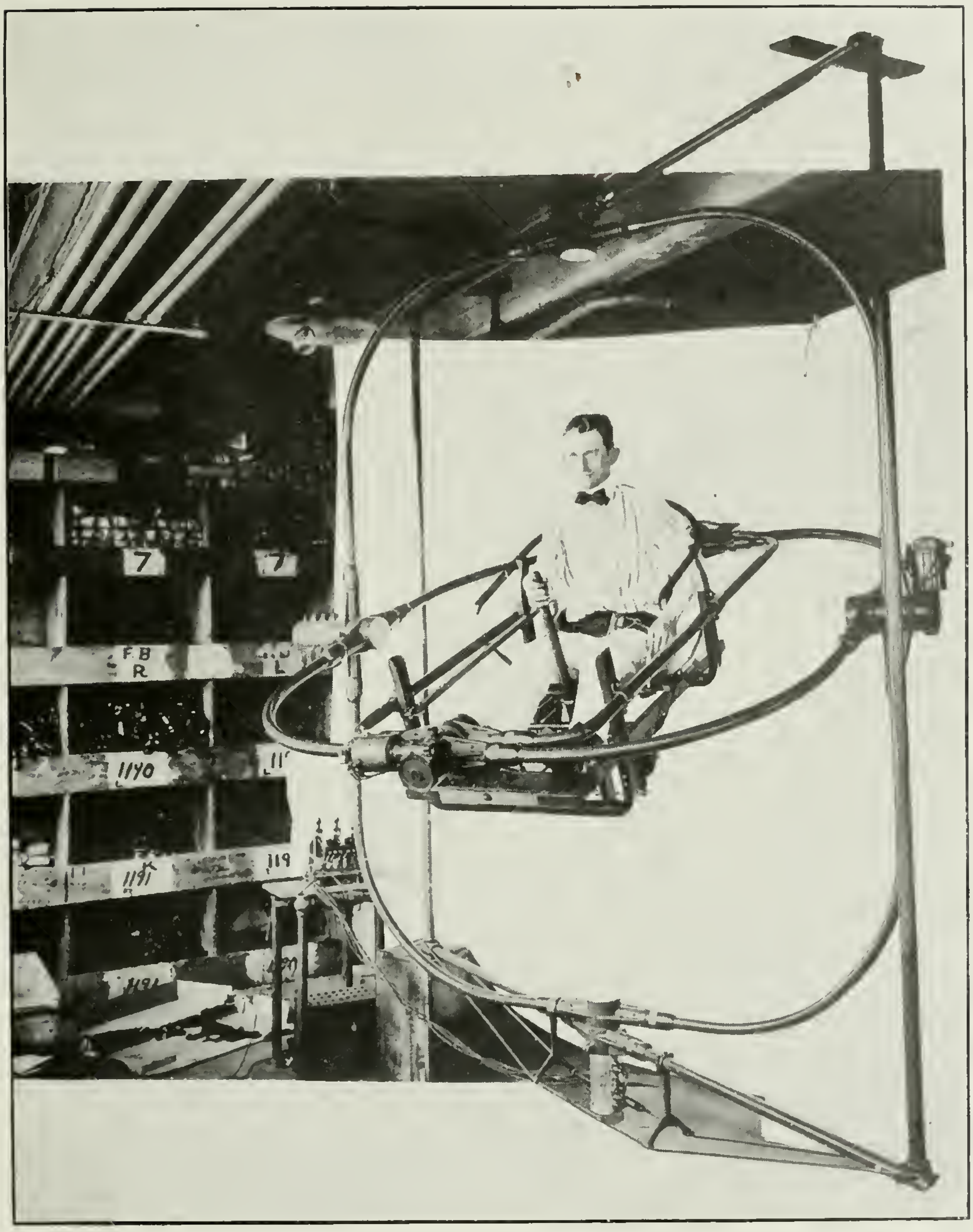
IMMELMANN TURN.

In this evolution, as shown in the foregoing sketches, we have a compound maneuver. During the first or loop portion the vertical canals are stimulated in the sagittal plane, followed in the second part of the stunt by a stimulation of the vertical canals in the frontal plane. The effect of the first portion is lost during the remainder of the stunt so that on emerging the aviator has only to deal with the vertigo induced by the last part, namely vertigo in the frontal plane. The obvious correction is to throw the head forward while " coming out." In a similar manner the vertigo induced by the " barrel roll," " falling leaf," " wing over," and other stunts can be readily analyzed.

It is, of course, true that the experienced stunt flier is not, as a rule, upset by the vertigo induced by these stunts because of the many hours of practice he has had, but no matter how well trained and experienced he may be he may occasionally find himself, especially in actual combat, doing more whirling and at a greater rate of speed than his training has prepared him for, and an understanding of these principles might be the means of saving his life. As a matter of fact, stunt fliers develop instinctively certain maneuvers which neutralize the disabling effects of vertigo; thus one flier found by practical experience that by leaning as far forward as possible, so that his head was practically inverted, a spinning nose dive gave him practically no disabling vertigo. Another found that going into a straight nose dive immediately following a spinning nose dive saved him from any uncomfortable dizziness.

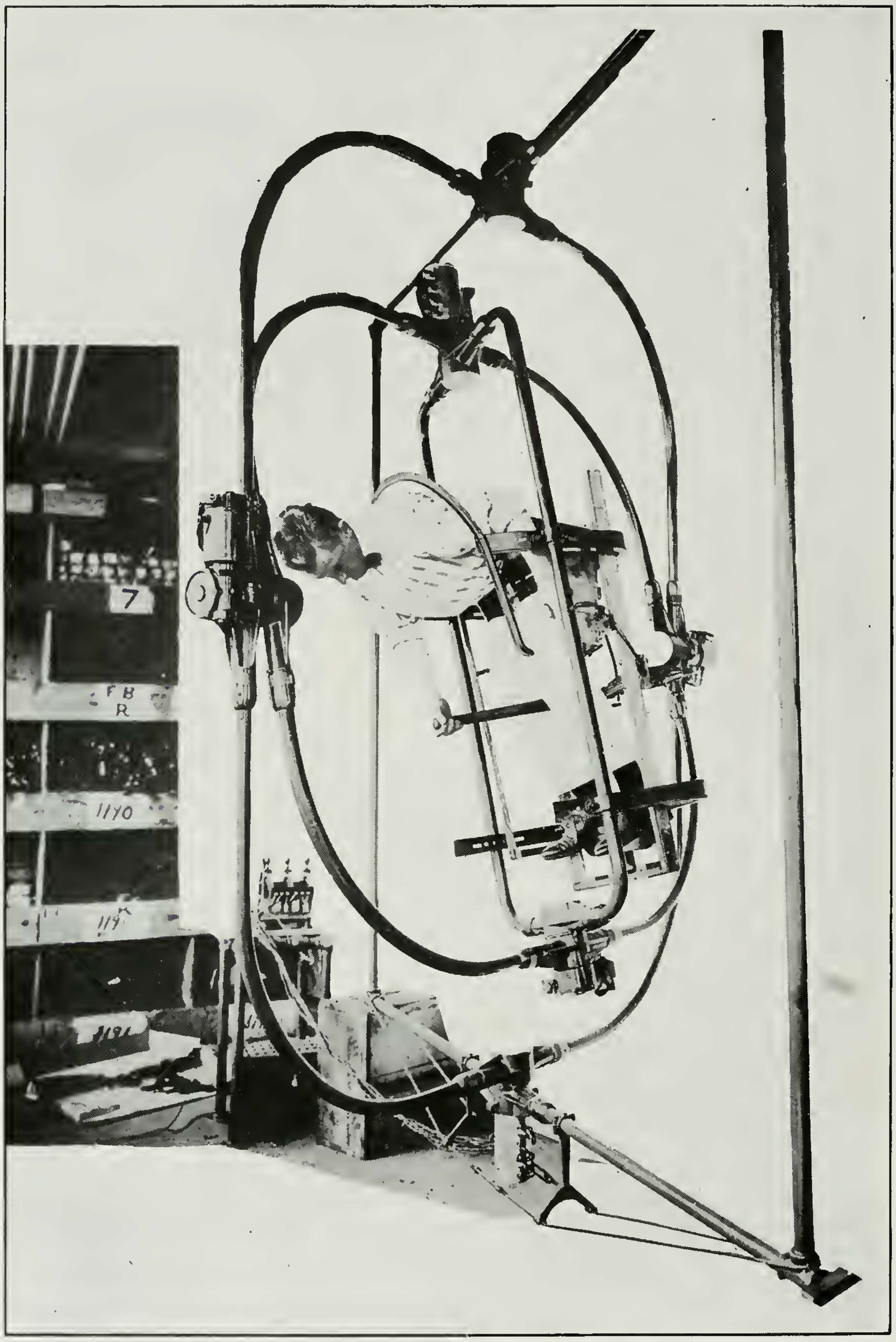
These fliers have instinctively adopted means which at all times kept the vertigo in a horizontal plane—procedures based on sound otologic principles. Experienced aviators, on being put through the various stunts in the laboratory, when shown how easily the effects of vertigo are neutralized by certain changes in the position of the head, are of the unanimous opinion that such knowledge is of the greatest practical value, especially in stunting. It is obvious that to the less experienced this knowledge is of even greater importance.

The greatest usefulness of the knowledge that "stunting" is an ear problem lies in the fact that the flier may be educated to disregard the vertigo effects of his stunts in the laboratory instead of among the clouds, and without danger, acquire a tolerance to evolutions to a degree impossible in the air. This can be accomplished by the use of an otologic apparatus known as the Orientator. In its construction it is like the cockpit of an aeroplane suspended in concentric rings after the manner of a ship's compass. The movements (or changes of position) which are possible in all directions except actual forward progression are governed by the individual seated in the machine using a set of controls resembling those of an



"RUGGLES ORIENTATOR."

(Supplied through the courtesy of the Naval Consulting Board.)



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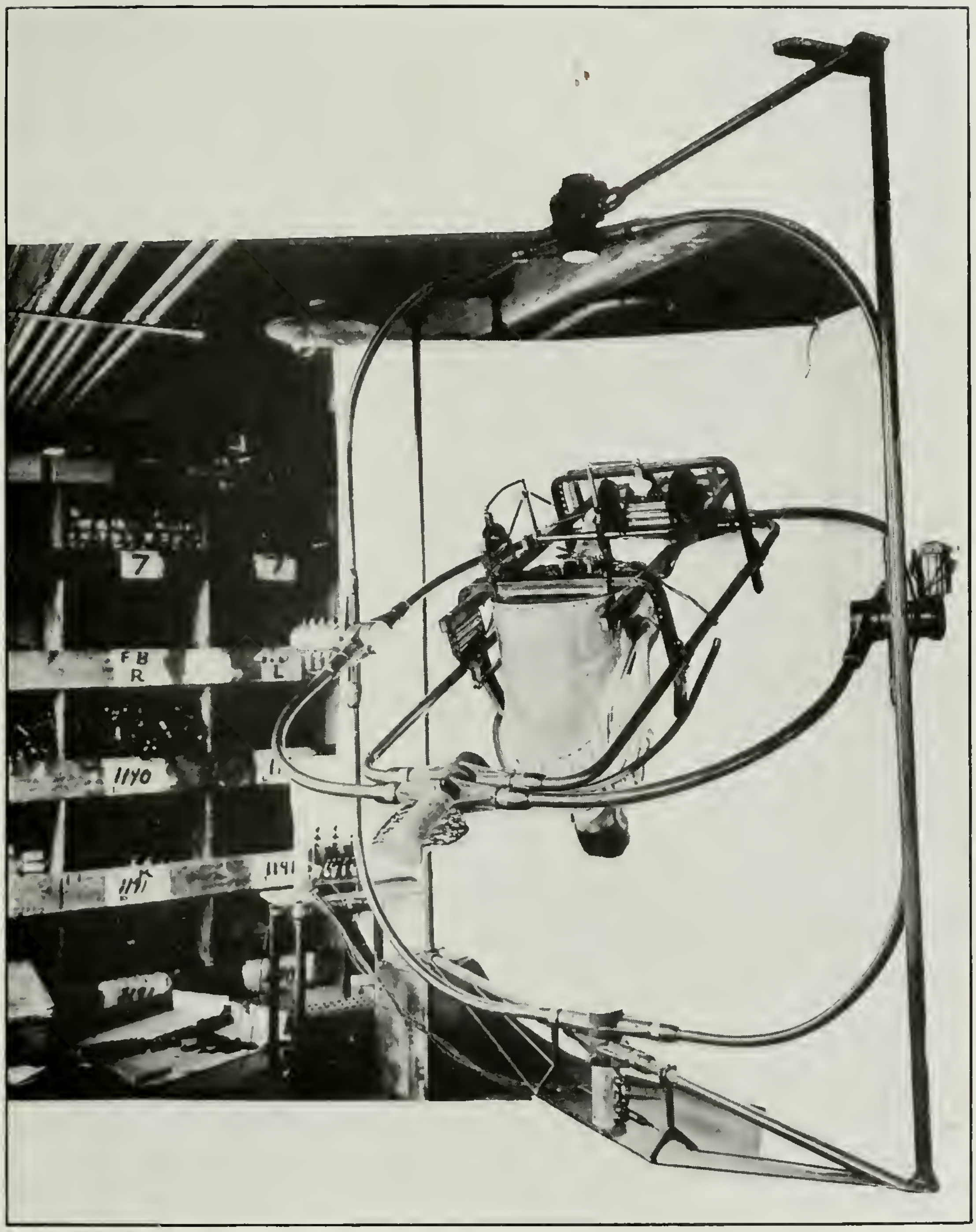

"RUGGLES ORIENTATOR."

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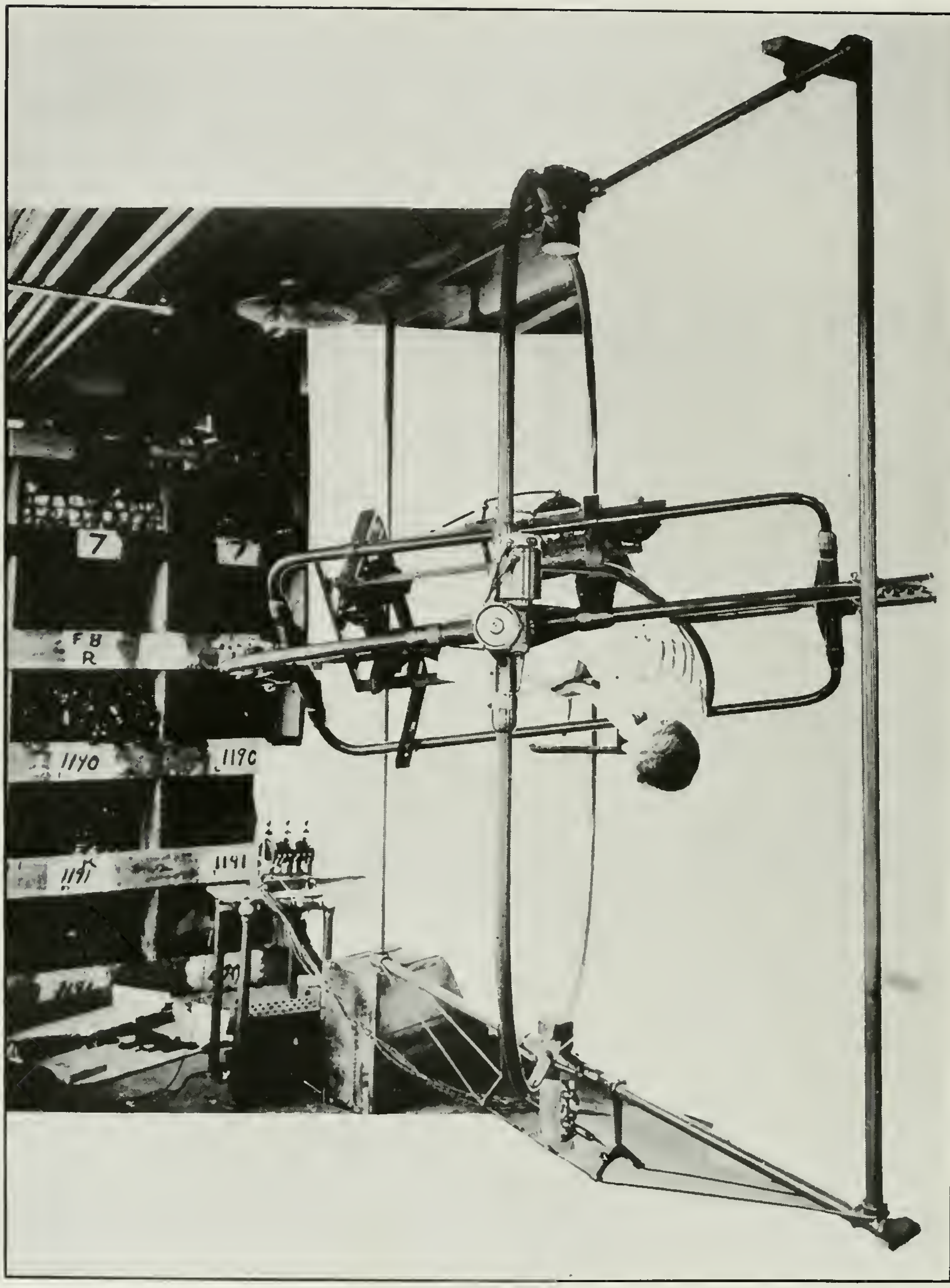

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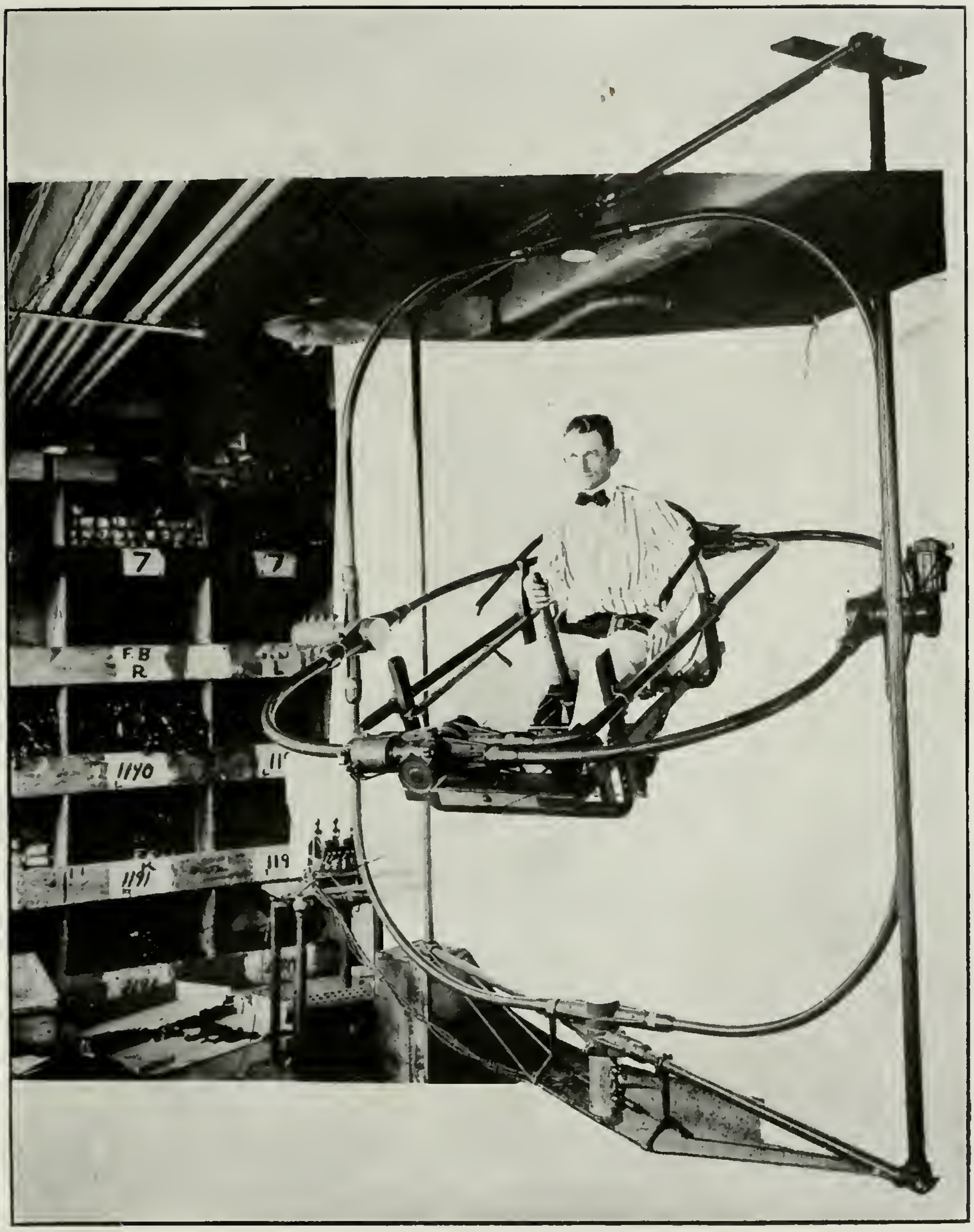


"RUGGLES ORIENTATOR."

(Supplied through through the courtesy of the Naval Consulting Board.)

aeroplane. Strapped in this machine he is enabled to execute any evolution, such as the loop, spiral, etc., at any desired rate of speed for any number of turns and thus acquire in absolute safety a tolerance for the disturbing effects of vertigo induced by these evolutions instead of acquiring this tolerance and knowledge by actual flying with its consequent crashes and possible loss of life. In addition, it will enable him to adapt himself to new and most unusual conditions. He will learn to orientate himself in new and rapidly changing positions of the body and to perform properly the complicated acts necessary to control an aeroplane while flying with his head down, etc., which entails an entirely reversed relation to external objects, a condition in itself most disturbing and pregnant with possibilities of disaster.

The orientator placed in the ground- and flying- schools will save many lives and machines, shorten materially the time of flying instruction, and develop a large number of stunt fliers.

V.—THE MANUAL OF THE OPHTHALMOLOGICAL DEPARTMENT RESEARCH LABORATORY.

THE SELECTION OF THE AVIATOR.

In answer to the first call for fliers approximately 100,000 men, the pick of the youth of this country, applied for service in the Aviation Section, Signal Corps, United States Army. Due to the genius for organization and tireless energy of the medical officers of the Regular Army, these men were carefully examined by 500 physicians, working in 67 examining units, and a sufficient number were selected.

It is safe to say that these men, by reason of this careful method of selection, are physically fit, and it is well that this is the case, for an aviator must not only be physically perfect to begin with, but also be kept in training. It is certainly more important to have an aviator in perfect physical condition than a football player. Every flier should be under the care of a medical man thoroughly trained in the care of the aviator and the symptoms and dangers of the lack of oxygen.

If we study for a moment the routine employed in the examination of the eye we will easily see that any man who could pass these tests must have eyes as nearly perfect as nature permits.

PHYSICAL EXAMINATION OF APPLICANTS FOR DETAIL IN THE DEPARTMENT OF MILITARY AERONAUTICS.

I. *History.*—Question the candidate carefully concerning previous or present eye trouble, use of glasses, lachrymation, photophobia, and diplopia. If glasses are worn, symptoms when not wearing correcting lenses.

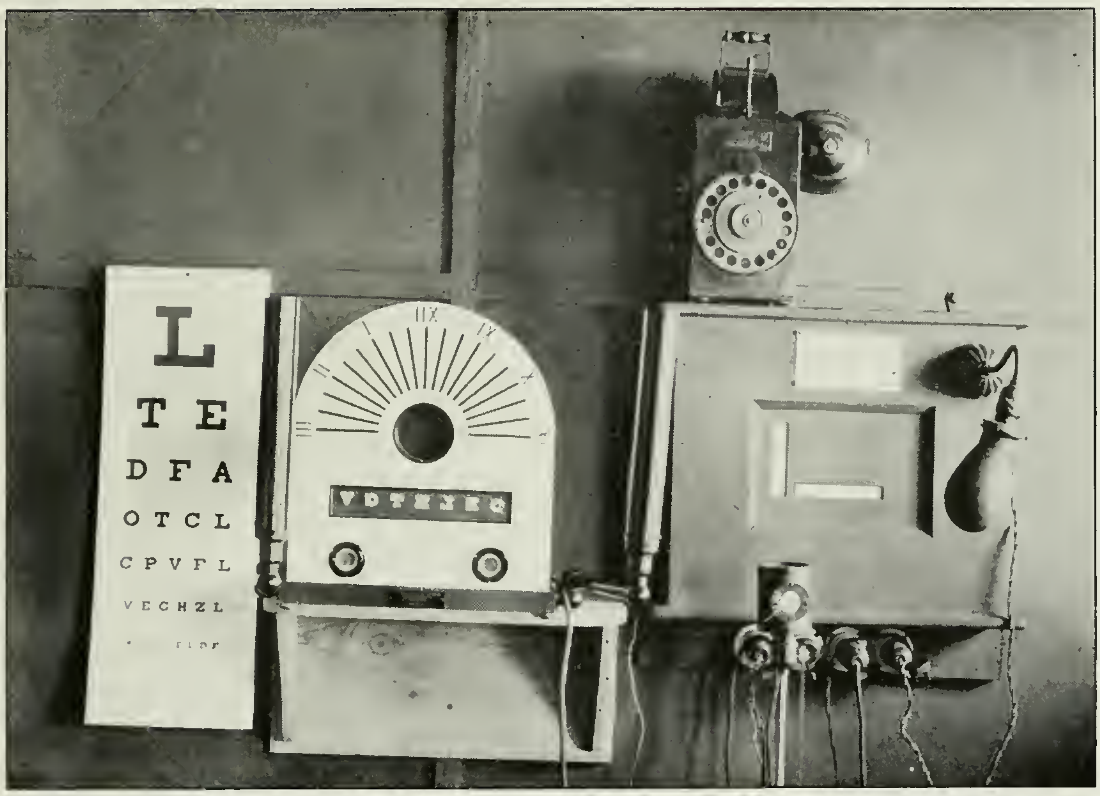
II. *Stereoscopic vision.*—The ability to appreciate depth and distances by means of binocular vision. The ordinary stereoscope may be used. The cards should be clean and flat. The candidate should have a good light coming over the shoulder directly on the card. The card should be moved back and forth until the point of greatest distinctness is attained. Have the candidate name the sequence of objects from before backward, as he sees them through the stereoscope. This should be done readily and without error, keeping in mind the fact that even though the usual order of seeing the objects on the original card is 9–1–7, 3–2–4, 5–6–8, and 10, the confusion of 4 and 5, 9 and 1, and 8 and 10 occurs in people with normal stereoscopic vision. In case of doubt, use in addition the smaller objects on individual pictures, e. g., on No. 9 from before backward is seen cross, balloon, and flag; No. 8, balloon, cross, rod, and pennant; No. 10, pennant, balloon, and cross. Inability to stereoscope properly is a cause for rejection.

III. *Ocular movements.*—These are tested roughly by requiring both eyes of the candidate to be fixed on the examiner's finger, which is carried from directly in front of the eyes to the right, to the left, up and down. The ocular movements must be regular and identical.

IV. *Pupillary reactions.*—These should be regular and equal when responding to (1) direct, (2) indirect light stimulation, and (3) to accommodation. Face the candidate, who should be looking into the distance, and place a card as a screen before both eyes. Uncover one eye after a short interval and allow bright daylight to shine into this eye. The resulting contraction of the iris of this eye is called a direct reaction. Repeat the test, but now observe the iris of the shaded eye. If this iris contracts, it is termed the indirect or consensual reaction. Repeat tests on the other eye. With both the candidate's eyes open and uncovered, have him fix on a distant object, then focus on a pencil point held approximately 10 centimeters in front of the eyes. Both irides should contract, which is called the reaction to accommodation.

V. *External ocular examination.*—Place the candidate facing a good light and examine each eye carefully with the aid of a hand lens, noting any abnormality. The eye should be free from disease, congenital or acquired, such as lesions of the cornea, iris, or lens, including affections of the surrounding structures, such as pathological conditions of the lachrymal apparatus, conjunctival deformities, or any affection which would tend to cause blurring of vision if the eyes, unprotected by glasses, were exposed to wind or other unfavorable atmospheric conditions.

VI. *Ocular nystagmus.*—If it occurs on looking straight ahead or laterally, 40° or less, it is a cause for rejection.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(*a*) Spontaneous ocular nystagmus produced by extreme lateral rotation of the eyes, 50° or more, is not a cause for rejection, as it is found in the normal individual. It is usually manifested by a few oscillating movements, never rotary, which appear when the eyes are first fixed in extreme lateral positions. Select a scleral vessel near the corneal margin as a point for observation.

VII. *Field of vision.*—The confrontation test may be used to determine roughly the limits of the visual field. The field is tested separately for each eye. Place the candidate with his back to the source of light and have him fix the eye under examination (the other eye being covered) upon the examiner's, which is directly opposite at a distance of 2 feet. For example: The candidate's right eye being fixed upon the examiner's left eye; the examiner then moves his fingers in various directions in a plane midway between himself and the candidate, until the limits of indirect vision are reached. The examiner thus compares the candidate's field of vision to his own, and can thus roughly estimate whether normal or not. A restricted field of vision or marked scotoma should be confirmed by the use of a perimeter, as it would be a cause for rejection.

VIII. *Color vision.*—Should be normal. A Jennings test is required. If confusion, the eyes should be tested with a Williams lantern. The Jennings blank, properly filled out, should form a part of the physical record. If the candidate is suspected of having learned the Jennings test, the card and blank may be turned over and punched from the unfinished side.

IX. *Muscle balance at 20 feet.*—A phorometer, with spirit level or maddox rod and rotary prism attached, should be used. Muscle balance is satisfactory, provided there is not more than 1 degree of hyperphoria, 2 degrees of exophoria, or 6 degrees of esophoria (if in this latter case there is a prism divergence or abduction of not less than 6 degrees). In all cases of heterophoria the duction power of the muscles must be taken and recorded.

(*a*) The screen and parallax test: In case the above-described apparatus is not available, the following method may be used until the proper instruments are obtained:

The candidate is seated 6 meters from a 5-millimeter light on a black field or a 1 centimeter black dot on a white field, which he fixes intently. Shift a small card quickly from eye to eye and note any movement of the eye as it is uncovered and ask the candidate to describe any movement of the eye or the light. Orthophoria obtains if there is no apparent movement of the eye or the light. Movement of the test object or eye with the card signifies exophoria, against the card, esophoria, and vertical movement hyperphoria. Prisms are placed with the base in for exophoria, out in esophoria and up or down in hyperphoria, until the test object and the eye just begin to move in the opposite direction. The weakest prism which causes reversal of the movement, minus 2 prism degrees, is the measure of the heterophoria. If there are less than 5 degrees of heterophoria, only 1 prism degree is subtracted.

(*b*) Near point of convergence: A 2-millimeter white-headed pin or a 1-millimeter black dot on a white card is carried toward the subject along a millimeter rule from a distance of 50 centimeters, and the point noted at which one or both eyes cease to fix or diplopia is first noted by the candidate. This point is measured in millimeters from the anterior surface of the cornea. Keep the test object in the mid line, a few degrees below the horizontal plane. A near point greater than 65 millimeters at 25 years of age, and 85 millimeters at 30 years of age is a cause for disqualification.

X. *Visual acuity.*—(*a*) Acuity for distance: Test each eye separately, 20 feet from a well-illuminated card with Snellen letters. Full twenty twentieths vision in each eye is desired, but a candidate may be allowed to miss three letters on the 20/20 line with one eye, provided the other has full 20/20 vision, and all other tests are normal. Visual acuity should be taken without the use of correcting lenses.

Place a plus 2.00D sph. before each eye successively while the other eye is covered. A candidate who can still read 20/20 with either eye is disqualified.

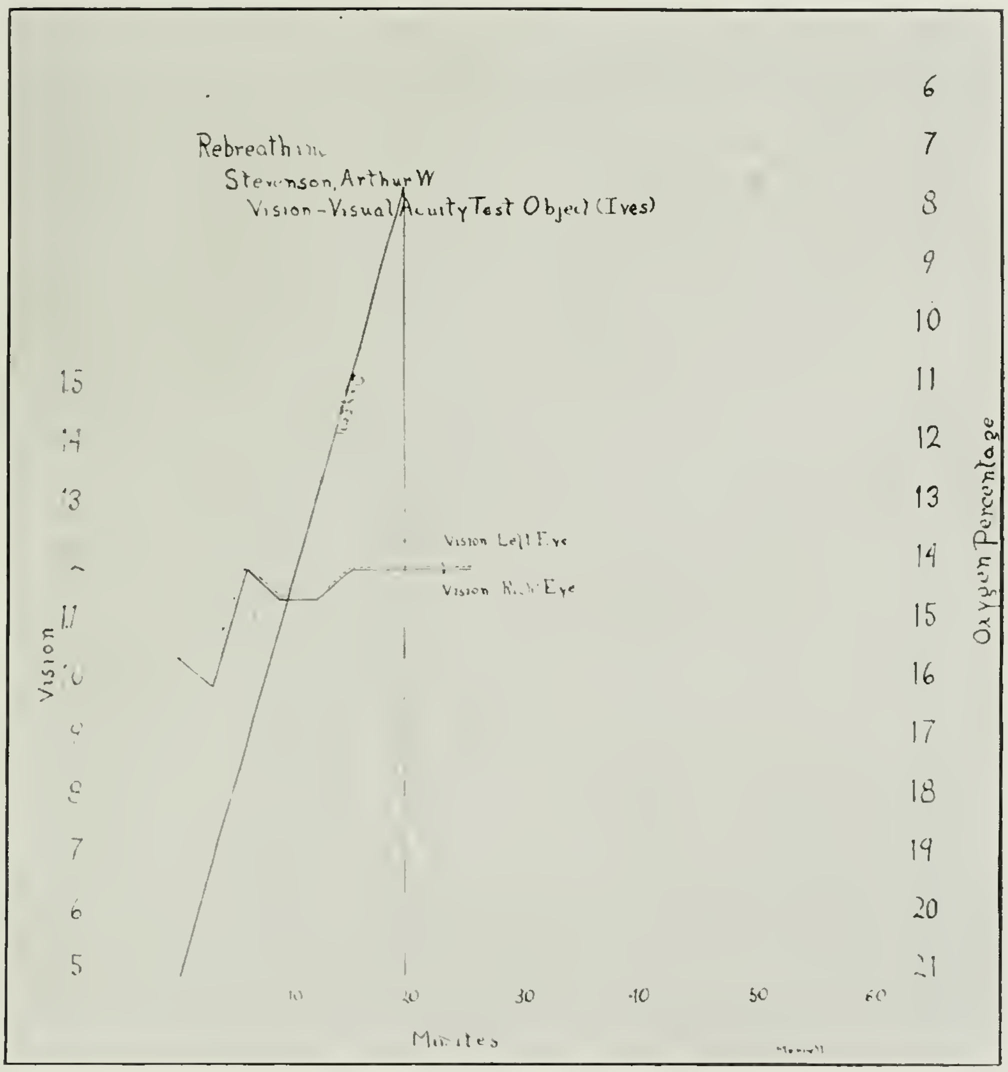
(*b*) Near point, or acuity for near vision is determined separately for each eye by requiring the candidate to read, in a good light, Jaeger test type No. 1, gradually bringing the card toward the uncovered eye until the first blurring of the print is noted.

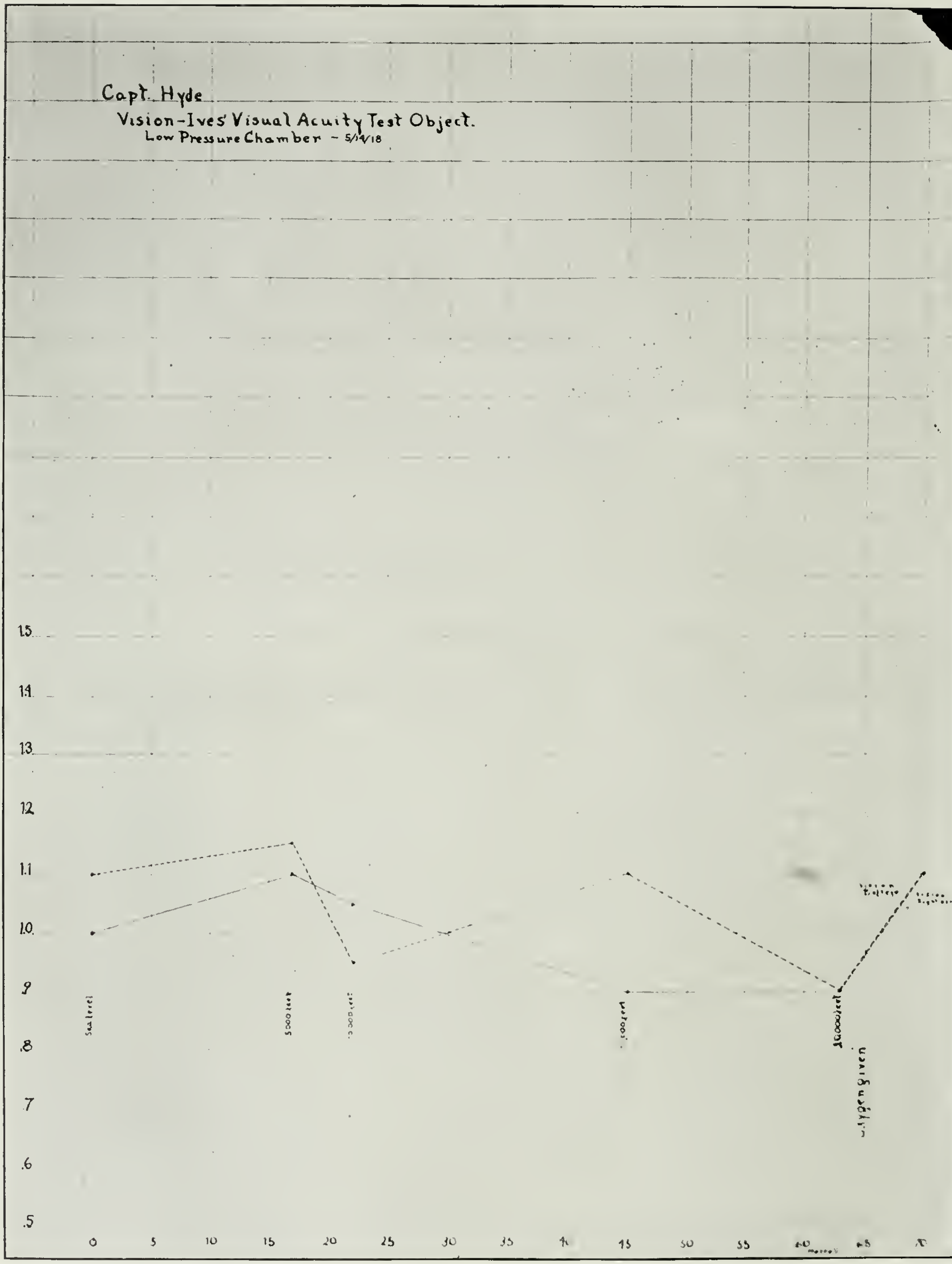
The distance of this point from the anterior surface of the cornea, measured in centimeters, is the near point. A distance greater than 11 centimeters at 19 years of age, greater than 13 centimeters at 25 years of age, or greater than 15 centimeters at 30 years of age, disqualifies.

XI. *Ophthalmoscopic findings.*—Drop one drop of a 5 per cent solution of euphthalmin in each eye. Have the candidate keep his eyes closed. After 15 minutes repeat the drops, then examine 15 minutes later. A solution of cocaine, 4 per cent, may be substituted, cautioning the candidate to keep his eyes closed between installations. A pathological condition of the fundus, active or quiescent, is a cause for rejection.

VALUE OF THE EYE IN AVIATION.

I. *Judgment of distance.*—Judgment of distance is assisted by the power of stereoscopic vision, and for this reason the eyes of all candidates for admission into the Aviation Section, Signal Corps


Rebreathing
Stevenson, Arthur W
Vision - Visual Acuity Test Object (Ives)
Vision Left Eye
Vision Right Eye
Vision
Oxygen Percentage
Minutes



Capt. Hyde
Vision-Ives' Visual Acuity Test Object.
Low Pressure Chamber - 5/14/18
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
0
5
10
15
20
25
30
35
45
50
55
60
65
Oxygen given

of the United States Army, have had their binocular vision tested by means of a stereoscope. Inability to stereoscope quickly and accurately is considered a cause for disqualification. We know that if a man loses one eye he is often able to judge distance very accurately with the remaining one, but it requires time for him to develop this power. It would therefore seem logical, at least while we are able to select our men carefully, to accept only those with normal stereoscopic vision.

Speaking of error of judgment in flying as a cause of aeroplane accidents, Anderson states that this error may occur in getting off the ground, in the air, or when landing. Of the 58 crashes in the "V" series, this cause accounted for 42—4 in getting off the ground and 38 in landing.

Of the many examples of error in judgment in flying, perhaps the commonest is when, on landing, the pupil misjudges his distance from the ground and either flattens out too soon and "pancakes," with a possible crash, depending on the height, or else flattens out too late and strikes the ground at a great angle, usually overturning and wrecking the machine.

It is difficult to estimate and account for these errors of judgment. In some cases it may be due to insufficient instruction. In other cases, even after prolonged instruction, the pupil may still misjudge distance, and on examination one occasionally finds that his standard of vision is below normal; but, on the other hand, he may be found physically fit, with normal vision and normal muscle balance. In the latter case Anderson believes it may be a question of delayed reaction time, and especially the visual reaction time, upon which the aviator is so much dependent. Normally this reaction time is nineteen one-hundredths or twenty one-hundredths of a second. It may be delayed by fatigue and excesses, but in some individuals who are otherwise physically fit it is found to be much slower than in others.

Hence, in the selecting of candidates for aviation the visual and other reaction times should be normal. By the French medical authorities on aviation candidates are rejected if simple reaction times are found to be of the delayed type. The Italians also seem to lay considerable stress upon simple reaction time. The men who have done the most work in reaction time in this country, are of the opinion that simple reaction time is of little value in the selection of candidates for aviation. The accurate determination of the visual discrimination reaction time and other complex reaction times might be of considerable value. It would seem as though physical condition on a given day and the added strain of low oxygen tension should be taken into consideration in seeking the cause of these accidents. We know that there might be a temporary visual disturbance or weakening of the external ocular muscles, and this might account for some of the accidents. Naturally, examination of the eyes later on might show nothing.

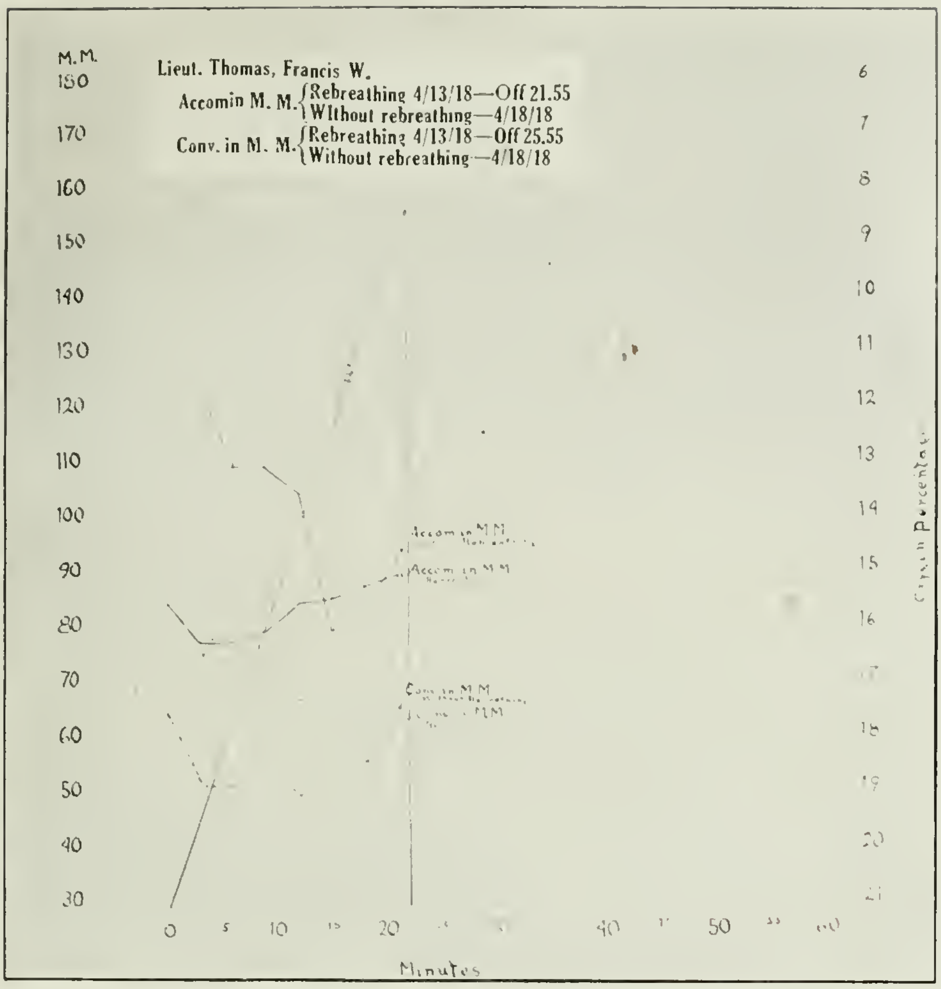
II. *Normal visual acuity.*—As long as we can in this country select only those men with practically perfect vision it would seem well to do this. A man with poor vision will not be able to see an enemy plane as soon as a man with perfect vision. He will not be able to accurately differentiate objects seen from the air in selecting a landing place, and when he has reached the ground he will not see obstructions in his path as clearly as he should. The latter may result in the plane being "nosed over." In a recent discussion of the "Physical Qualities of Aviators" all the British officers and physicians taking part agreed that the factor of vision was of the greatest importance, and Clark pled for the use of a cycloplegic in making examinations for admission to the flying corps. During the low oxygen tension test visual acuity diminished in 28 per cent of the normal men examined and in 37.5 per cent of the men who were ocularly disqualified for flying.

III. *Normal color vision.*—It is important that the flier have normal color vision in order that he may accurately determine the markings of the different planes, differentiate between signal lights, and in helping him to make landings at night. During the day the discrimination between the color of a building, field, forest, or swamp is essential in selecting a landing place. There has been no change in color vision during the rebreathing test or in the low-pressure chamber.

IV. *Field of binocular fixation.*—It is important that the aviator be able to carry the eyes as far as possible in various directions without turning his head and without seeing double. If a man has a contracted binocular field of vision, it certainly impairs his efficiency, whether observing, fighting, or flying. In 50 per cent of the subnormal men examined during the low oxygen tension test we have found contraction of the field of binocular fixation, the contraction being most marked in the upper field.

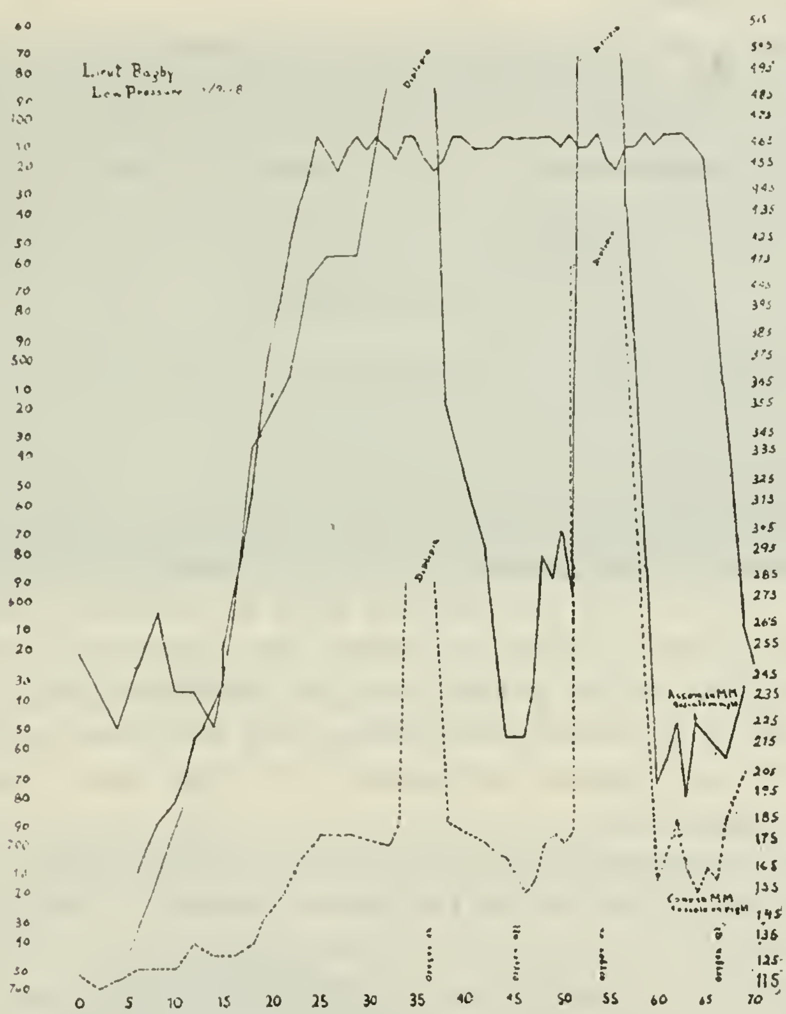
V. *Muscle balance.*—Normal muscle balance should be insisted upon, for even a small defect may be accentuated by the strain of flying and lack of oxygen and result in diplopia or at least a marked contraction of the field of binocular vision at low altitudes. Exophoria and hyperphoria have been shown to be the most important, due to the fact that the weakness of the ocular muscles caused by the lack of oxygen produces diplopia more readily in exophoria and hyperphoria than in esophoria.

VI. *Field of vision.*—The field of vision should be normal, as the aviator's safety depends to a great extent upon his ability to detect


M.M.
Lieut. Thomas, Francis W.
Accomin M. M. {Rebreathing 4/13/18—Off 21.55
Without rebreathing—4/18/18}
Conv. in M. M. {Rebreathing 4/13/18—Off 25.55
Without rebreathing—4/18/18}
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
6
7
8
9
10
11
12
13
14
15
16
18
0
5
10
20
40
50
Minutes

enemy planes or in training his own plane in the various fields while his gaze is fixed straight ahead. The aeroplane and the goggle also do harm in that they restrict the field of vision, and many accidents result from this. Everything should be done to improve the construction of goggles and planes so that the visual field will be restricted as little as possible.

VII. *The perception of motion and its direction.*—The perception of motion and its direction is of great importance to the aviator. Appropriate tests for measuring this have been devised. The best pilots say that they finally develop the power to use the periphery of the retina so that it is of greater value in detecting enemy planes



VIII. *The importance of the eye in maintaining equilibrium.*—Before going into this, first let it be stated that the subject of equilibration is a complex one and that those of us who have an interest in it from a practical standpoint appreciate the difficulty of the subject and realize that although the aviator may fly when one part of this mechanism is deranged or destroyed, we believe that in selecting men for flying positions that it is well to make sure that all the senses used in this complex act are normal. The most important factors in receiving impressions are deep sensibility, tactile sense, the vestibular apparatus, and the eyes. The central nervous system connections must functionate perfectly to use the information it receives to the best advantage. Finally, the muscles should be in condition to carry out the commands of the central nervous system.

That many aviators depend largely upon their visual impressions in the maintenance of equilibrium is evidenced by the fact that they often tie a piece of string as a streamer to one of the forward struts, so that they may more readily note the first evidence of a side slip when they are flying in a cloud. In spite of the fact that we miss the visual impressions when they are not received, we are still able to control the plane if the remainder of the balance mechanism is functioning normally.

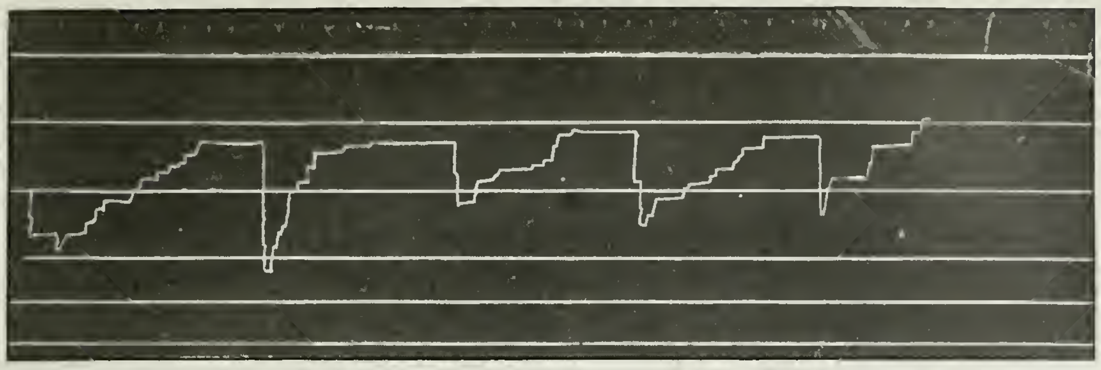
IX. *Retinal sensitivity to light.*—It is important that the retina be sensitive to light impressions, especially for those men who are carrying out night bombing expeditions. With this in mind, most of the allied nations require special tests for retinal sensitivity. A test of the contrast sensitivity of the retina is believed to be the most useful for our work, and only men who have normal sensitivity in this respect will be selected for night flying.

THE CARE OF THE FLIER AND THE EFFECT OF ALTITUDE AND THE STRAIN OF FLYING ON THE EYE.

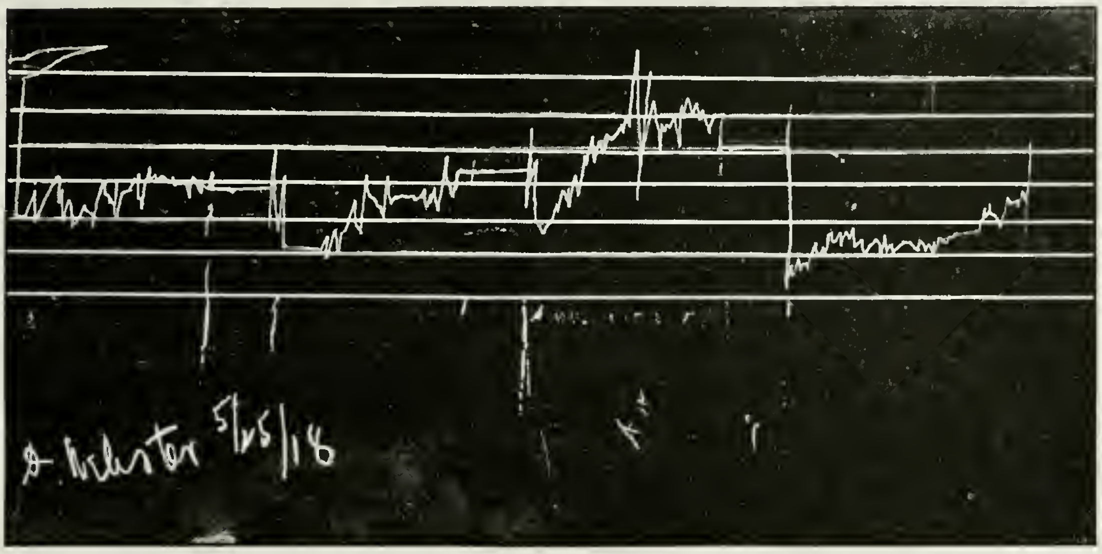
Even though our aviators have been examined with the greatest care and their eyes are as nearly perfect as nature permits, the adapting mechanism of the human machine, including the eye, was designed for use on earth, and altitude adds an unusual strain. Medical men agree that definite physiologic changes occur in man living at high altitudes which permit them to withstand lack of oxygen, but they believe from the examinations that have been made of fliers that they do not become acclimated, but often show rather rapid physical deterioration.

The most important ocular symptom is failing vision. The pilot complains that he can not see the ground clearly in landing and has difficulty in picking out enemy planes. There may be no defect in vision, but there is usually some slight error which was previously correctable by an unconscious muscular effort. The muscles become fatigued, due to the strain of flying, and the defect shows itself. A few days' rest has been sufficient in the few cases Maj. James L. Birley, R. A. M. C., has seen, to restore normal vision.

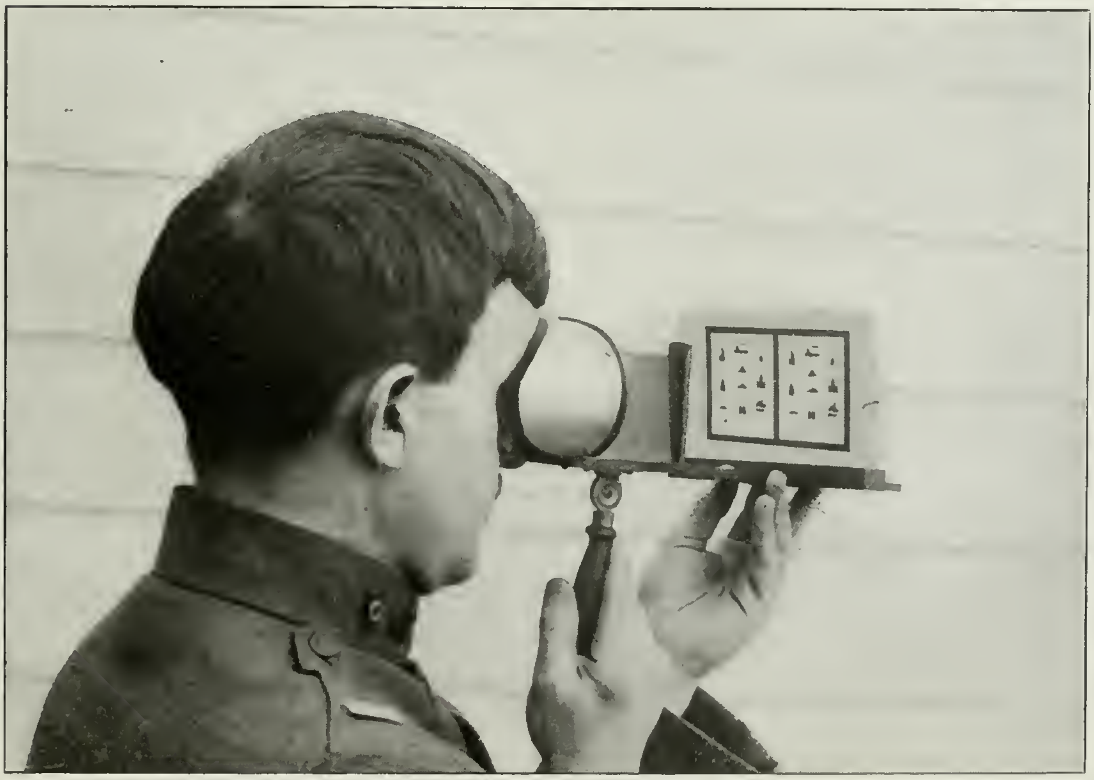
Certain individuals with apparent perfect acuity of vision are ocularly weak in that they are unable to make use of both eyes, due to some defect in binocular vision or fusion sense. This interferes somewhat with judgment of distance, and the disability tends to increase under the strain of aviation and lack of oxygen, resulting in



Lieut. Johnson's visual acuity test with subject on rebreathing apparatus. Oxygen at end of experiment, 10%. Lower parts of curve indicate maximal vision. Subject observes test object for periods of three minutes, with one minute intervals of rest.



Test object observed during periods of three minutes with one minute intervals of rest. Amyl nitrite (2 minims) inhaled during third period. Lower excursions of curve indicate clearer vision.



CADET D. W. MILLS, 5/9/18.

bad landings, "crashes," and consequent loss of personnel and material. These conditions may often be improved by treatment.

Irritation, congestion, and inflammation of the conjunctiva and epiphora were common complaints of the fliers at Chanute Field. Most aviators realize the necessity for wearing goggles, but many of them fit poorly, allowing the cold air to strike the eye with great force, most often near the internal canthus where the lachrymal puncta are situated. This probably accounts for the disagreeable symptoms noted. The remedy is found in the wearing of properly fitted goggles and the use two or three times daily of a 2 per cent boric acid solution containing 1 grain of zinc sulphate to the ounce. In some instances 1 grain of cocaine and 10 to 30 minims of 1-to-1,000 adrenalin chloride may be added to the ounce.

GOGGLES.

I. *The glass*—

(*a*) Should have an optically plane surface.

(*b*) Should have a light transmission of 90 per cent or over for plain white glass.

(*c*) If a colored glass is desired, Noviol "C," made by the Corning Manufacturing Co., of New York, with a light transmission of 87 per cent, is excellent. Euphos has given great comfort and the glass passes a good test. The retina of the eye is sensitive to the glare, and that is probably one of the causes for physical fatigue of the aviator. The colored lenses shut out most of the ultraviolet rays, and some consider them of great value in bright sunlight, in snow, on water, and above the clouds. Many aviators object to any tint in their lenses, due to the fact that they say they are unable to see as well in a fog and that the color in the lenses changes the color of objects looked at, especially the German uniform and the fields in making landings, resulting sometimes in the selection of poor landing places or in the misjudgment of distance.

(*d*) Thickness of the glass: The lenses should be 2 or 3 millimeters thick.

(*e*) Many aviators insist upon some form of so-called nonbreakable glasses, which is nothing more than two pieces of glass with a piece of celluloid between. This piece of celluloid cuts down the transmission of light between 16 and 19 per cent, and no matter how clear the celluloid is originally, it deteriorates with age and becomes yellow and less transparent. When these glasses are struck with considerable force the glass on the posterior surface splinters off and flies into the eye. Even with these disadvantages, some men insist upon the nonbreakable feature, and perhaps not without reason, for even though the splinters do fly off the back of the glass, the eye closes immediately in an accident, and these small particles would hardly penetrate the lids, and there is no doubt that in some instances the celluloid prevents the driving of large pieces of glass toward the eye.

II. *Visual field.*—It is most important that the aviator have a broad field of vision, and for this reason a large curved glass is desirable. Without a broad field of vision the aviator may not see one of his own planes in time to prevent an accident. Pilots who are doing actual fighting demand a broad visual field above everything else.

III. *Visual acuity.*—It is important that the aviator have keen vision, and for this reason glass with optically plane surfaces should be furnished and a determination made of how much visual acuity is cut down by celluloid.

IV. *Safety to the eye.*—The parts of the goggle which come in contact with the brow, nose, and cheeks should have round edges and be protected by a soft cushion.

V. *Lightness and strength.*—The goggles should be light, so that they will not cause discomfort. They should be simple in construction and yet strongly made.

VI. *Comfort.*—The goggles should not press upon the bridge of the nose so as to produce pain, and the elastic which holds the goggles in place should not be drawn too tight. An adjustable interpupillary distance might be valuable.

VII. *Cleansing.*—Goggles should be easily cleaned, and there should be no place for vermin to hide.

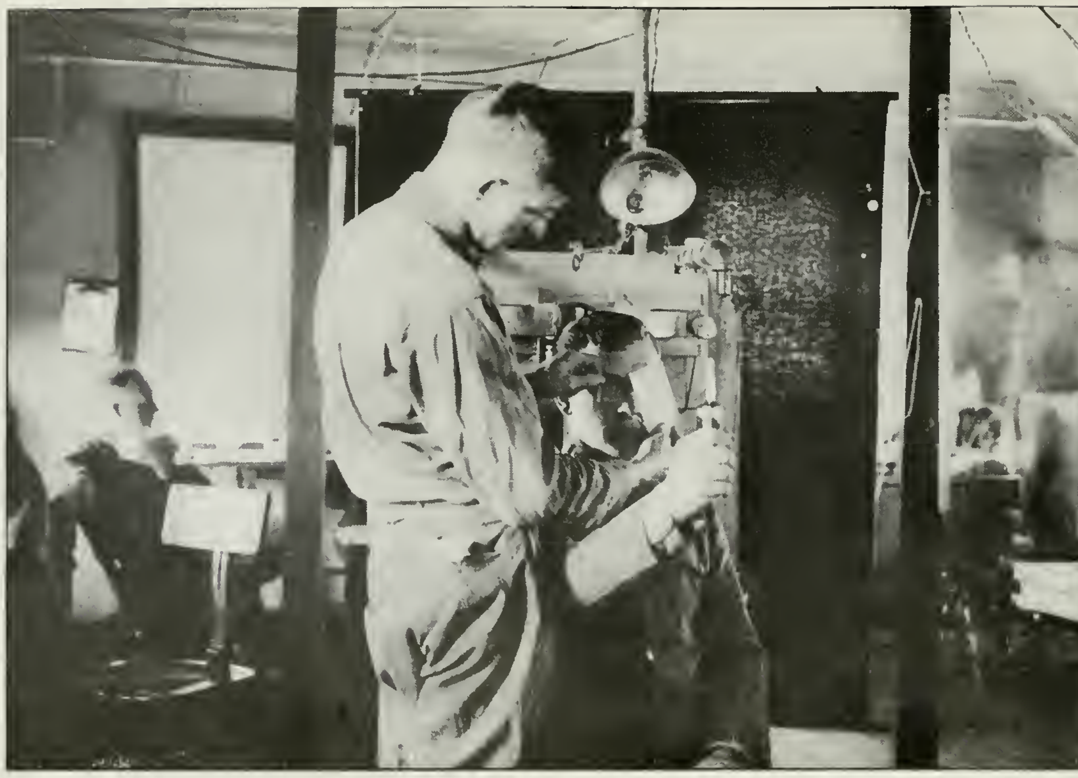
IX. *Protecting sinuses.*—There should be sufficient covering in connection with the goggles to protect the frontal sinus. Aviators often complain of pain in this region when it is left exposed.

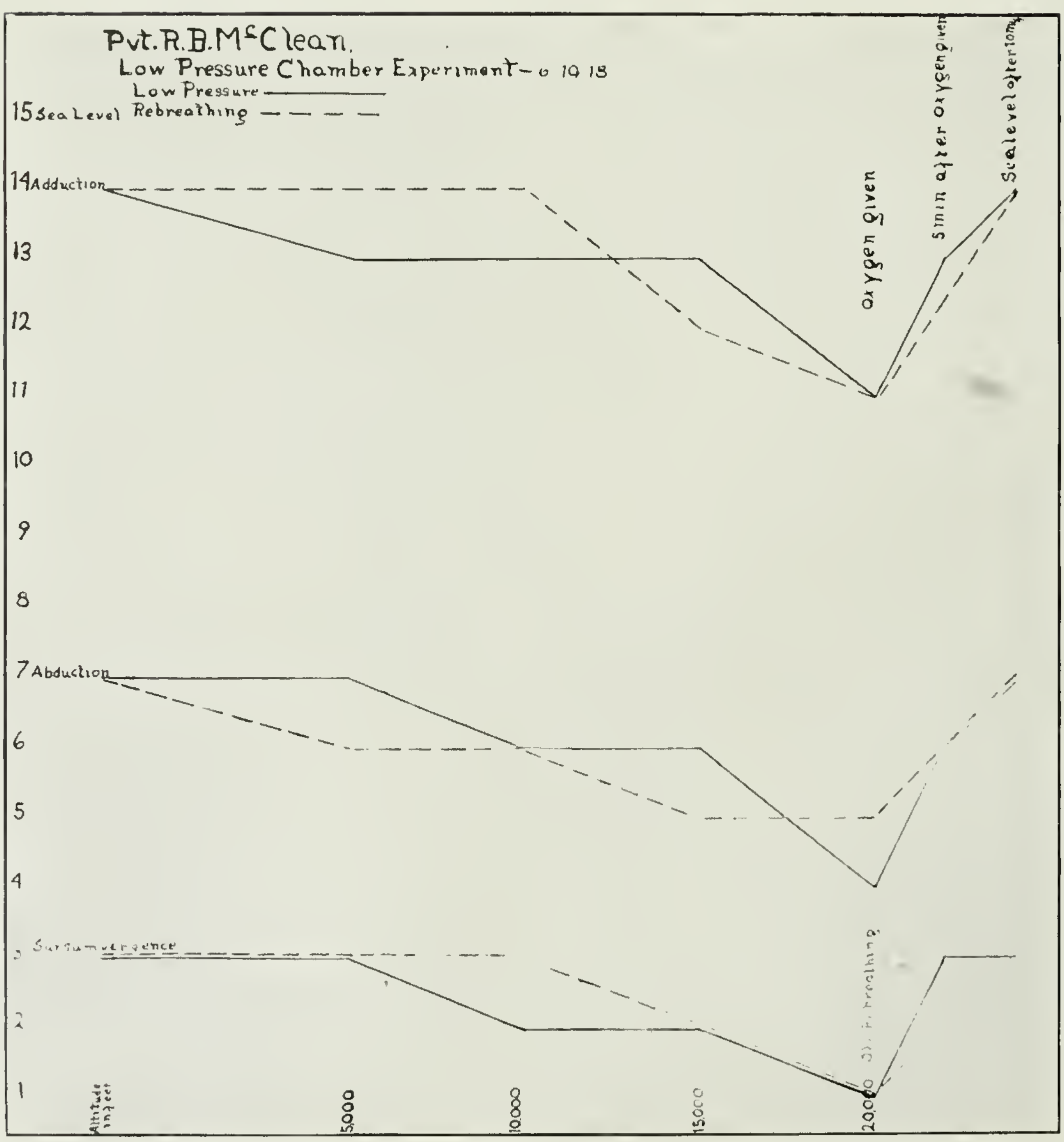
X. *Ventilation.*—The goggles should be carefully adjusted so that there are no leaks, especially near the nose, which would permit the wind to strike the internal canthi directly. Most of the aviators who have done fighting at high altitudes believe that the goggles should be equipped with some indirect method of ventilation.

XI. *Material for lenses.*—Glass is best. Celluloid and gelatin smear too easily and celluloid deteriorates too rapidly. Mica chips and cracks.

XII. *Noninflammable.*—The material of which the goggle is composed should be noninflammable and for this reason any wooly material is dangerous, as it burns readily. Incendiary bullets are now being used, and they cause great damage when they strike a gas tank.

XIII. To further prevent injury to the aviator, all parts of the fuselage or control system which he is liable to strike in falling should be protected by pneumatic cushions.





Pvt. R. B. McClean.
Low Pressure Chamber Experiment — 6 10 18
Low Pressure
Sea Level Rebreathing
15
14 Adduction
13
12
11
10
9
8
7 Abduction
6
5
4
2
1
Oxygen given
5 min after Oxygen given
Sea level after 10 min
Altitude in feet
5000
10000
15000
20000

"Doctors and professional aviators have noticed that during the ascent respirations become more rapid and the heart beats faster up to an altitude of 1,500 meters. At this altitude the vision may become less clear, although a French observer states that at 2,000 meters the visual acuity usually increases by a third by reason of the congestion of all the organs of the head and in particular of the choroid and of the retina." Visual acuity tests carried out under low-oxygen tension on the rebreathing apparatus and in the low-pressure chamber have not shown any marked increase in vision. On the contrary, the improvement, when it occurred, has usually been slight, but more often the vision has remained unchanged and in a few cases has fallen off considerably.

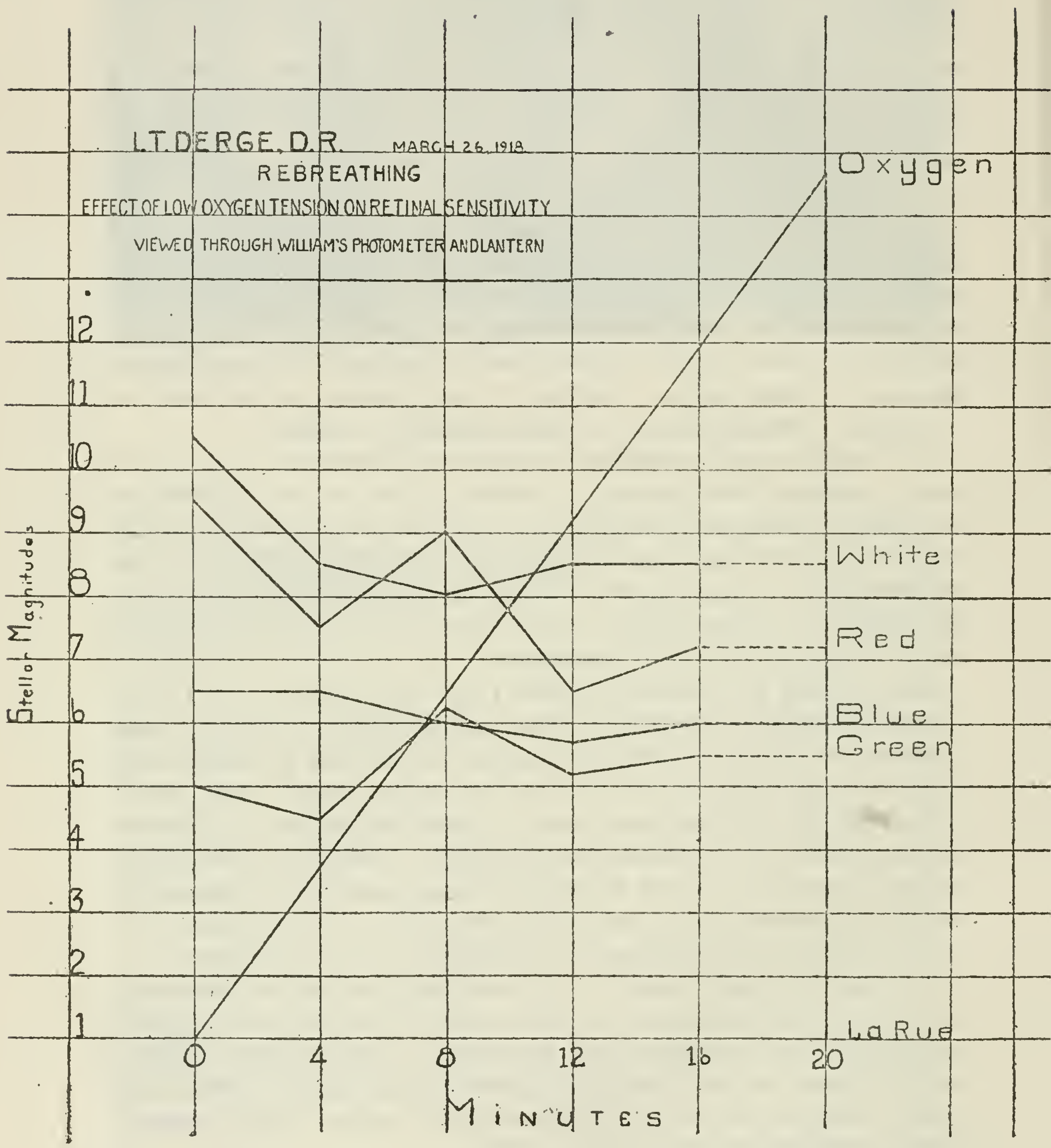
"During the descent, there is another series of phenomena which increases as one approaches the ground. It is first the sensation of smarting of the face with redness and very high color. The eyes sting and are injected. The nostrils are moist and then comes a headache, or more exactly a sort of heavy feeling in the head with a sensation of obstruction. Swelling in the pharynx at the level of the larynx. Finally there is a strong tendency to sleep."

"To explain these difficulties during the descent, one may admit that an airman who falls to the earth in four or five minutes or less, after having attained 3,000 or 4,000 meters of elevation in 20 minutes, had not had time to adapt his circulatory system to the different barometric pressures." From the experimental work done, the change in oxygen tension would seem to be the most important factor in the production of symptoms.

The question of correcting lenses is an important one and most ophthalmologists feel that it is better in principle not to have vision corrected by lenses, at least as long as we are able to obtain men with nearly perfect vision. The aviator needs perfect vision and a normal ability to distinguish colors, a rapid valuation of distances and the faculty of accommodating rapidly. There have been many accidents described as due to hyperopia, myopia, and astigmatism, and it is a question if it would not be well to use a cycloplegic in the examination of all candidates for admission to the flying corps.

The research work done in this laboratory has shown definitely that a flier's life depends, to a great extent, upon his ability to keep in condition, both mentally and physically. Loss of sleep, dissipation, or illness will so lower his resistance that his eyes break more readily under the added strain of low-oxygen tension, which, in actual flying, would frequently result in death.

When every flier understands this fact we will have a more efficient flying corps and fewer accidents.



LT. DERGE, D.R. MARCH 26, 1918.
REBREATHING
EFFECT OF LOW OXYGEN TENSION ON RETINAL SENSITIVITY
VIEWED THROUGH WILLIAM'S PHOTOMETER AND LANTERN
Oxygen
White
Red
Blue
Green
La Rue
Stellar Magnitudes
12
11
10
9
8
7
6
5
4
3
2
1
0
4
8
12
16
20
Minutes


L
T
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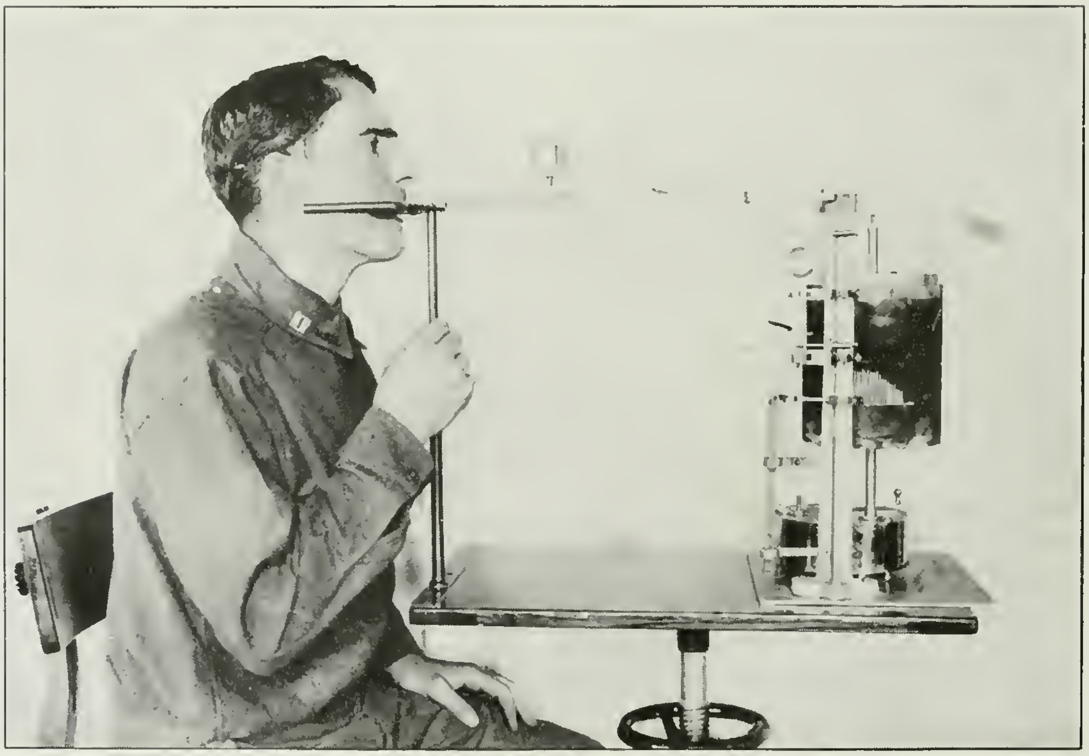

OPHTHALMOLOGICAL EXAMINATION OF THE FLIER DURING LOW-OXYGEN TENSION EXPERIMENT.

PRELIMINARY.

Visual acuity.—A Snellen test card is hung on a level with the candidate's eyes, at a distance of 20 feet. Uniform illumination is obtained by the use of a 75-watt nitrogen daylight lamp, placed 1 foot from the card, at an angle of 45 degrees.

The left eye is covered and the vision of the right eye recorded in feet. (Ex. 20/20, or if three letters are missed in the 20/20 line, 20/20–3.) The right eye being covered, the vision of the left eye is determined and recorded in the same manner. Place a trial frame before the eyes and cover the left eye, place a high plus sphere before the right eye and add minus spheres until the best line read without the use of a lense is again distinct. This procedure is repeated for the left eye, and the strongest convex lens which still permits clear vision is recorded.

RETINAL SENSITIVITY.

A. *Contrast sensitivity.*—(1) This is the test to be used in the routine preliminary examination. The test object is made by pasting a 1-inch square of gray paper on a 2-inch square of lighter gray paper where there are 13 perceptible differences between the two squares. The two squares are mounted on a 5-inch square of heavy cardboard for handling. The test object is placed slightly above the level of the subject's eyes at a distance of 20 feet. A 75-watt, 110-volt daylight lamp at a distance of 8½ inches and at an angle of 45 degrees is used to illuminate the test object. The Reeve's wedge is made by coating a neutrally dyed gelatine in a wedge shape on plate glass so that the absorption of light varies with the thickness of gelatine deposit. A cover glass is cemented over the gelatine for protection. The subject is told the principle of the wedge and what to look for when viewing the test object through the wedge. Before making any readings the subject should be shown how to keep his pupil in line with the aperture in the wedge case. The subject, with both eyes open, then draws the wedge from its case until the contrast just disappears and the larger square appears uniform. When the pupil is in line the examiner should give the word for the wedge to be drawn out of the holder. The rate of movement should be so regulated that the contrast disappears in not less than five nor more than eight seconds. Repeat until three readings have been obtained and if these results are not too discordant their average represents the threshold for the subject.

(2) A 20/50 Snellen illiterate "E" is used instead of the smaller square and the subject should be able to tell which direction the "E"

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points when it is shifted—as he observes it through the wedge. This test is to be used in special cases; suspected malingering, etc.

B. *Threshold sensitivity.*—This procedure may be employed to check the contrast sensitivity test.

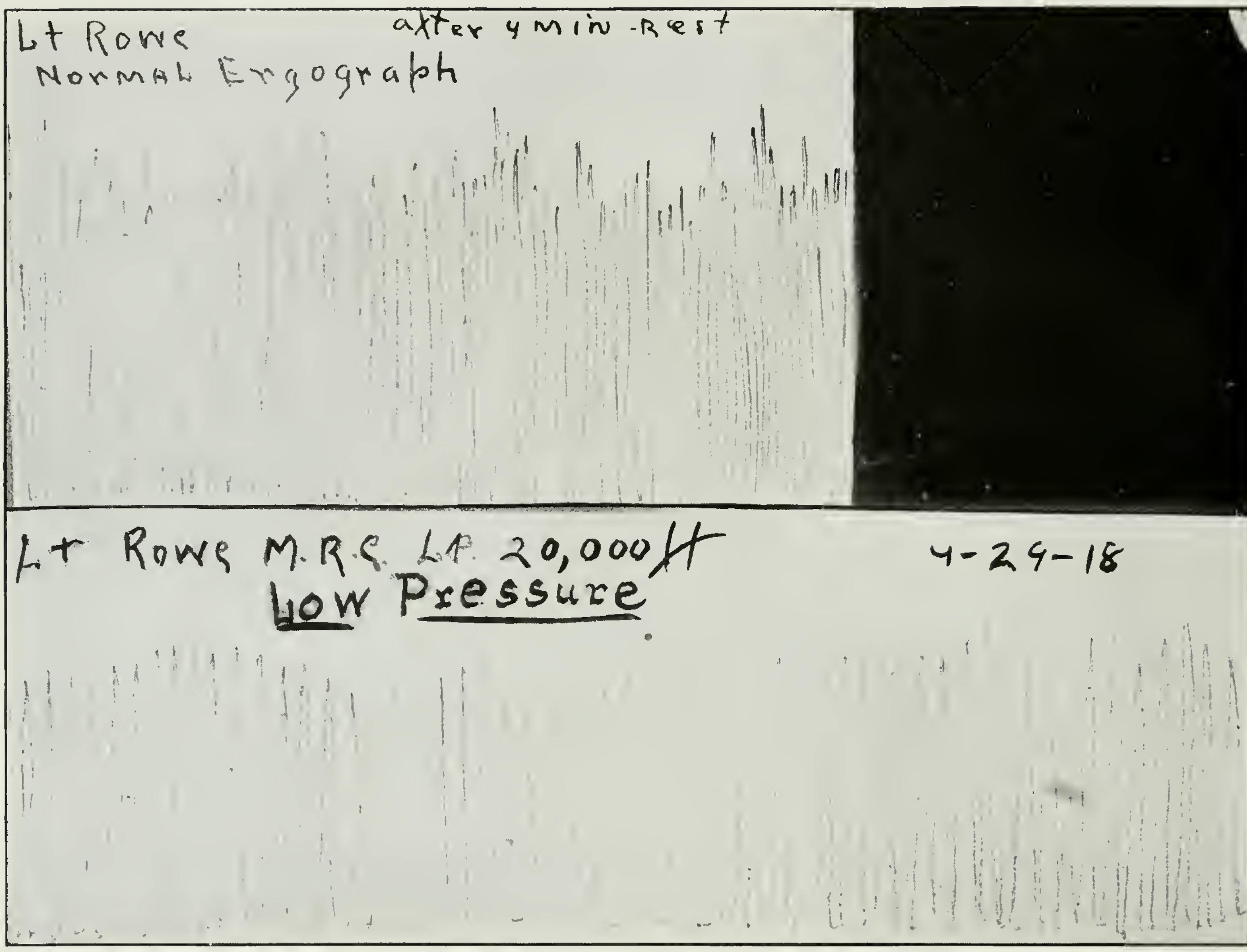
At the regular distance of 20 feet, with the Reeves wedge before the right eye, the observer looks at a 3-millimeter aperture in the iris diaphragm on the De Zeng stand. A 36-watt 110-volt Mazda lamp with a frosted globe is used as the source of illumination, the candidate looking through the aperture in the wedge with the right eye. The wedge is drawn out until the light just becomes invisible, the rate of movement to be the same as in the determination of contrast sensitivity. The reading of the scale on the wedge represents the threshold for the adaptation to the brightness of the room. (The absolute threshold would be represented by a similar procedure when the eyes were completely adapted to a total darkness.) At least three readings should be taken for this threshold and, if the results are too discordant, the examiner should repeat directions and closely supervise the procedure. When giving directions, the examiner is getting the aperture in the wedge apparatus centrally aligned with the pupil. This threshold value represents the least that can be seen for the particular adaptation of the retina. (The examiner should always bear in mind that the threshold value differs greatly for different brightness adaptations and different states of adaptation to the same brightness.) The average reading for the wedge should be determined for special conditions found at each laboratory. If the eye is to be adapted in an absolutely dark room, for practical purposes, the adaptation would be complete in 20 minutes. If the candidate is to be adapted for a light room of known brightness, for instance, a 75-watt nitrogen daylight lamp in a dark room, 15 by 10 by 8 feet, 5 minutes' adaptation would be sufficient.

MUSCLE BALANCE—THE ROUTINE.

The subject's eyes should be on a level with and directly facing a 1-centimeter black dot on a white card or the 1 centimeter opening in the iris diaphragm on the De Zeng stand, 20 or 25 feet distant. It is most important to see that the candidate's head is held in the vertical plane if errors in determining the amount of hyperphoria are to be avoided. If a phorometer or Maddox rod is used, it is well to check the findings with the screen and parallax test.

MADDOX ROD TEST.

A trial frame with a red multiple Maddox rod, properly centered before the right eye, should be carefully adjusted so that there is no sagging from the horizontal plane. The eyes are fixed on the light source and the left eye is covered to make sure that the single bar


Lt Rowe
after 4 min Rest
Normal Ergograph
Lt Rowe M.R.C. L.P. 20,000 ft
4-29-18
Low Pressure

of light is accurately observed, running horizontally, when the rod is vertical, and vertically when the rods are horizontal. The left eye is uncovered and the candidate states the exact position of the red line in relation to the light. If the red line, when vertical and horizontal, runs directly through the light orthophoria obtains for distance. If the vertical red line is to the left of the lights (crossed diplopia) there is exophoria. If the line is to the right of the lights (homonymous diplopia) there is esophoria. The prism, placed base in before the left eye in exophoria and base out in esophoria, which causes the line to run through the lights is the measure of the horizontal imbalance. If the horizontal line is above the light there is left hyperphoria; if below the light, right hyperphoria; and the prism, base up or down, which causes the line to run through the light, is the measure of the vertical imbalance. To remember that high eye means low image; and, when the eyes are uncrossed, the diplopia is crossed, may help one in the study of the heterophorias.

Some candidates may not understand the rod test, or they may have been coached to say that the rod runs through the light, so always check the findings with the screen and parallax test or use the rod in combination with a prism which would produce a known deviation of the line.

SCREEN AND PARALLAX TEST.

The candidate is seated 6 meters from a 1-centimeter light on a black field or a 1-centimeter black dot on a white field, which he fixes intently. Shift a card quickly from eye to eye and note any movement of the eye as it is uncovered and ask the candidate to describe any movement of the eye or the light. Orthophoria obtains if there is no apparent movement of the eye or the light. Movement of the test object or eye with the card signifies exophoria; against the card, esophoria; and vertical movement, hyperphoria. Prisms are placed with the base in for exophoria, out in esophoria, up before the right eye in left hyperphoria, and down in right hyperphoria, until the test object and the eye just begin to move in the opposite direction. The weakest prism which causes reversal of movement, minus 2 prism degrees, is the measure of the heterophoria. If there is less than 5 degrees of heterophoria, only 1 prism degree is subtracted.

N. B.—In hyperphoria first correct the horizontal imbalance and then superimpose the square prisms to determine the amount of vertical imbalance. The prism which just stops the movement gives the measure of the hyperphoria.

If muscle imbalance of more than 1 degree is found in either plane, the Maddox rod and screen and parallax tests should be made at 14 inches, using a 2-millimeter black dot on a white card or the light of the Hare-Marple ophthalmoscope as the test object. The converging, diverging, and sursumverging power should also be taken and recorded on back of the 5 by 8 history card.

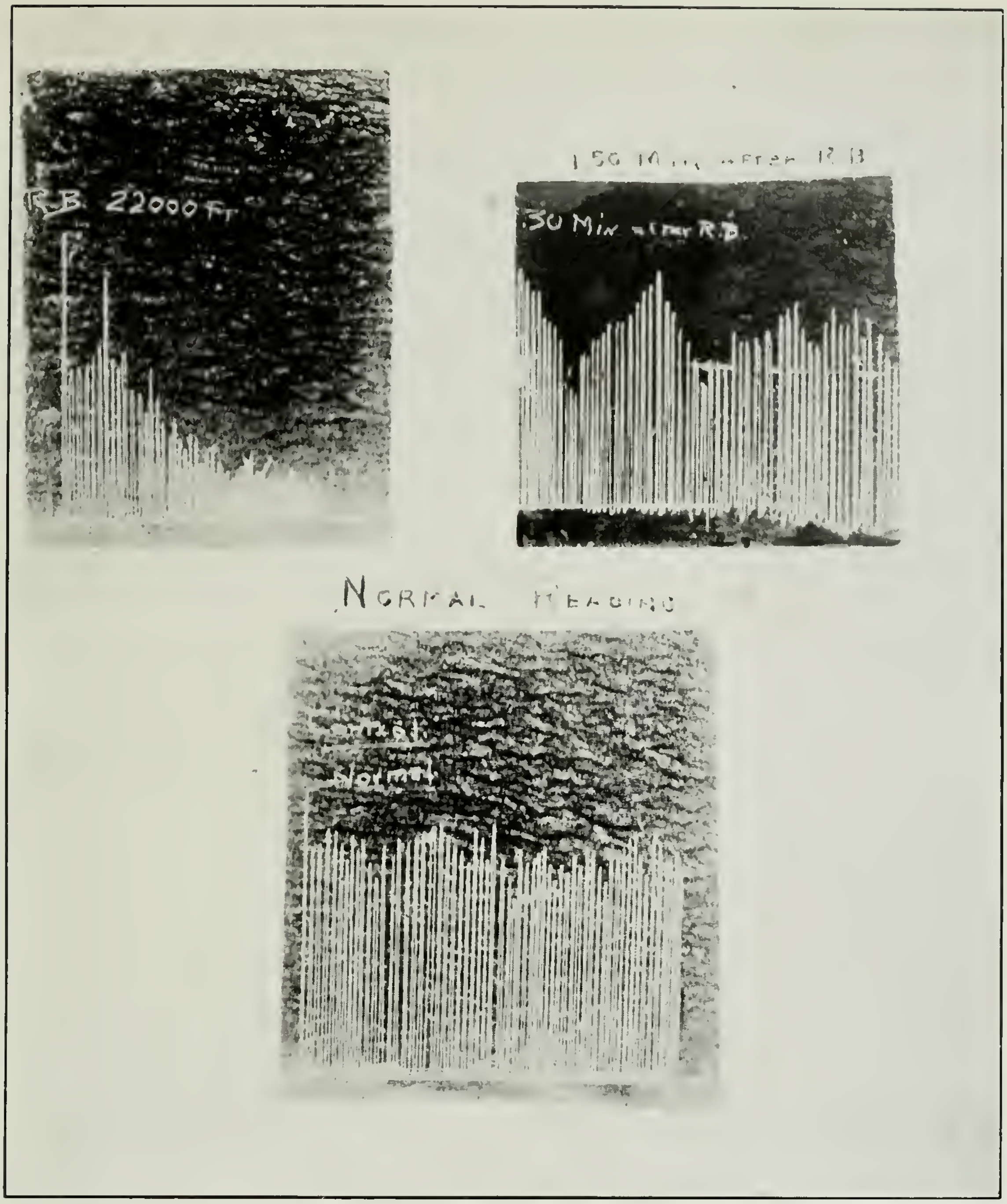
Example.—In testing the power of convergence the subject fixes the 1-centimeter black dot at 20 feet, and prisms of increasing strength are placed, base out, before either eye until the diplopia produced can not be overcome. The strongest prism through which binocular single vision is obtained is the measure of the converging power. Practice is important, especially in determining the power of convergence. It is well to begin with a very weak prism and gradually increase the strength, permitting the subject to close his eyes and then open them quickly when he has difficulty in fusing the test object. In testing the diverging power, prisms are placed base in and gradually increased in strength. To make certain that the candidate is really fusing, the prism may be rotated a little, producing a vertical diplopia, and then brought back to the horizontal, or the eyes may be screened alternately and any movement of the unscreened eye noted. The right sursumverging power is tested with the prism base down. Before making a definite statement as to the strength of the muscles it is well to have the candidate return several times, for, as has been said, practice and knack play a great part in this examination. Always test the divergence first, then the sursumvergence, and finally the convergence.

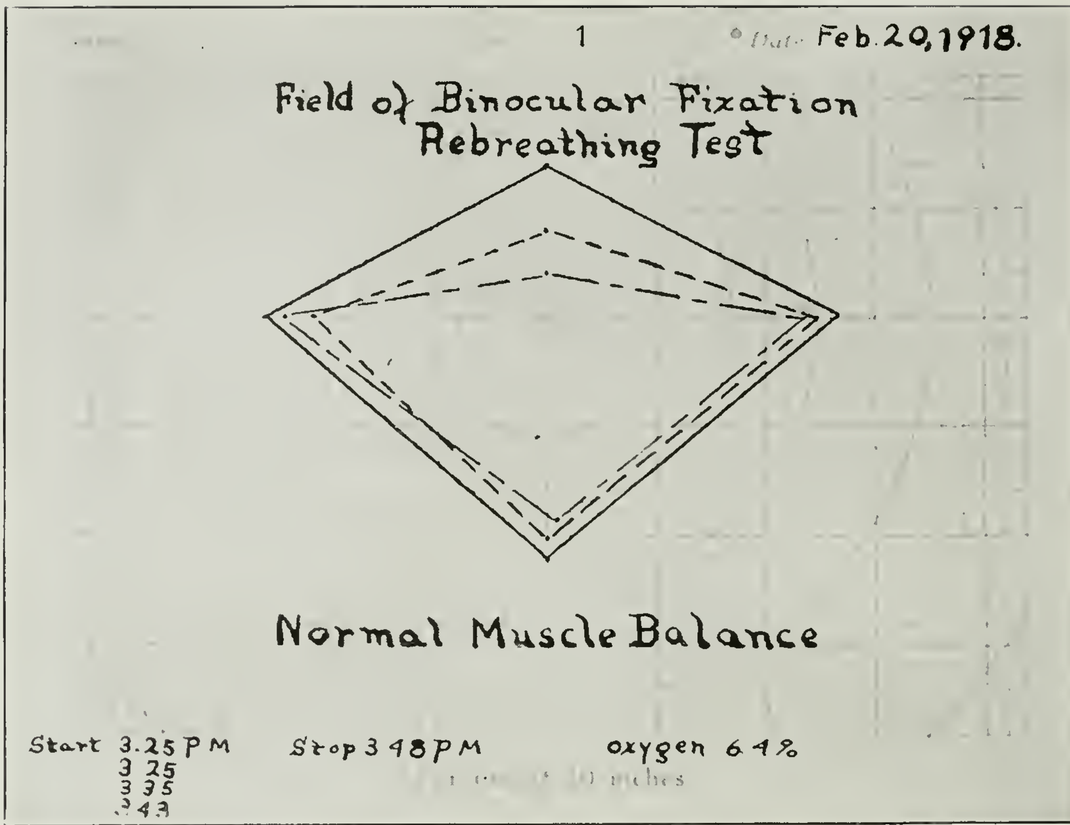
MUSCLES.

If there is a marked imbalance of the ocular muscles, it will be well to use a black wall as a tangent screen and make a record of the diplopia in the various fields as obtained by the use of the ruby glass and light at a distance of 30 inches from the wall. This should be recorded on the tangent screen charts which have been provided and filed with the 5 by 8 history card.

ACCOMMODATION (NEAR POINT).

The near point accommodation is measured by means of the Prince rule, using the type Jaeger No. 1, or the Duane disk, as the test object. The Prince rule has been gouged out at one end to permit its use in the midline, as in this way it can be placed over the nose, in contact with an ink mark which is 12 millimeters in front of the cornea. This point is measured by placing a millimeter rule alongside the forehead and, with the gaze fixed straight ahead, 12 millimeters are measured off. The point thus determined is marked on the nose. The test object is brought slowly toward the eye until the first sign of blurring is noted. This procedure is repeated several times, instructing the candidate to exert all his power so that the test object


R.B. 22000 Ft
NORMAL READING


1
Feb. 20, 1918.
Field of Binocular Fixation
Rebreathing Test
Normal Muscle Balance
Start 3.25 PM
3 25
3 35
3 43
Stop 3 48 PM
oxygen 6.4%

may be brought as close to the eye as possible, for we know that the first contraction of a muscle is seldom its strongest. The reading at which the test object was brought closest to the eye is recorded in millimeters. It is well to have a good light from a 75-watt nitrogen daylight lamp shining directly on the type, and the test is more accurate if the test type is held slightly below the horizontal plane.

PUPILLARY DIAMETER.

With the candidate seated in the chair in which he is to be tested, and with the same light that will be used later on, he is asked to fix a distant object. A millimeter rule is inverted above the pupil with a plus 2.75 sph. superimposed, and the reading is made while looking through the lens. If greater accuracy is desired, a pupillometer should be used.

COLOR VISION.

For this purpose Jenning's color test is used. The method of making the test: The cover of the green side of the box is removed, the color board is lifted out, a record sheet inserted, and the color board replaced. In replacing the color board CARE MUST BE TAKEN TO SEE THAT ITS TOP, MARKED ON THE BACK "NO. 1 GREEN," CORRESPONDS TO THE TOP OF THE RECORD SHEET. The box is now turned around several times until all sense of direction is lost. The green test skein, fastened to the inside of the box lid, is placed at a distance of 2 feet and the candidate is given the stylus and requested to look along each row of colored patches and when he sees the test color, or one of its lighter or darker shades, he is to place the point of the stylus in the opening and punch a hole in the paper beneath. Have him understand that he is not expected to find an exact match for the test skein but that he is to indicate all the color patches that appear to him to be same general color as the test skein, both those that are lighter and those that are darker in shade. Having completed Test No. 1, the record sheet is removed, the cover is replaced, and the box turned over, exposing Test No. 2, the ROSE. The same record sheet is placed under the rose color board, CARE BEING TAKEN TO HAVE THE TOP OF THE RECORD SHEET AND THE TOP OF THE COLOR BOARD, MARKED ON THE BACK "NO. 2 ROSE," correspond. The rose test skein is now displayed and the test proceeds as before. If the candidate seems to have been uncertain in the selection of colors or you suspect that he may have been coached in the test, turn the card with the colored wools and the blank on the reverse side and have another reading made. Another way to confuse the subject is to cut a circle in a piece of paper and place it over the peripheral skeins.

REACTION OF THE IRIS TO LIGHT AND ACCOMMODATION.

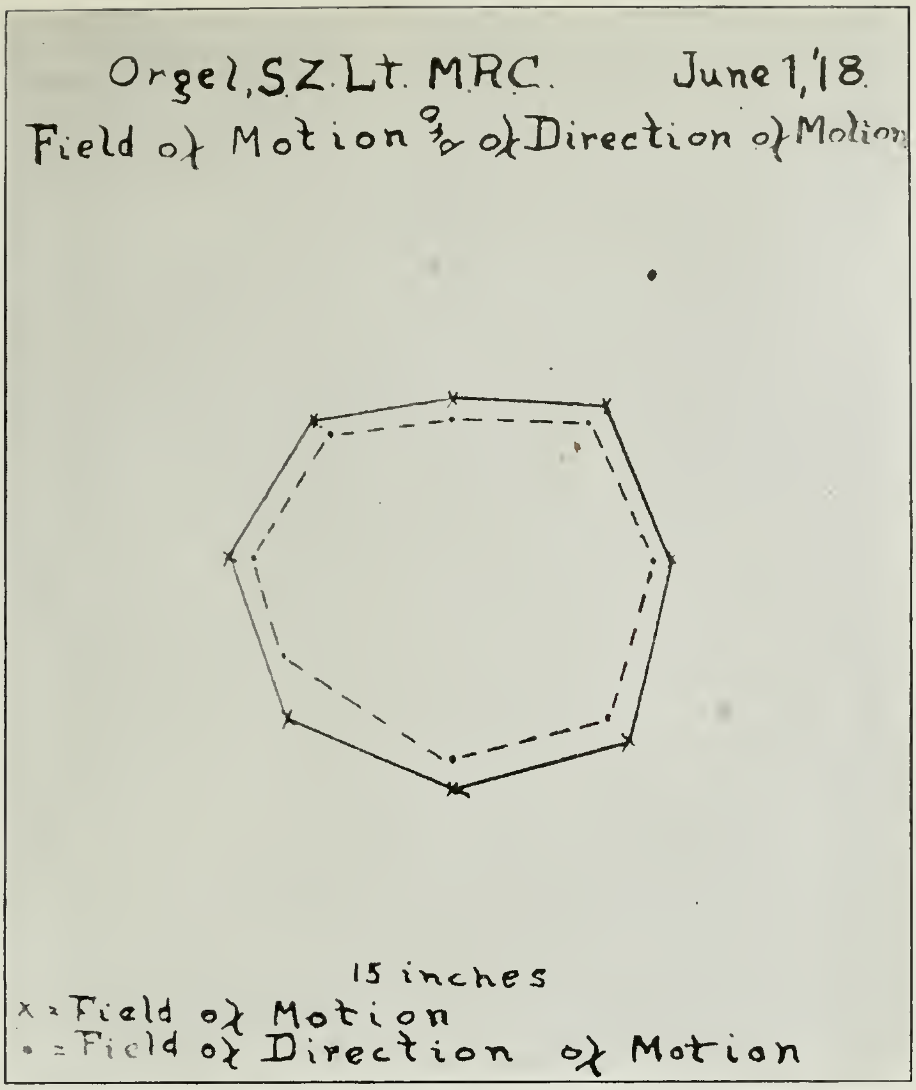
The reaction of the iris to direct and indirect light and accommodation is noted and recorded as plus (meaning reacts) 1, 2, and 3, being increased reaction, minus 1, 2, and 3 meaning degrees of sluggish reaction, and 0 no reaction. The reaction to accommodation is determined by requiring the candidate to look in the distance and then fix on a 2-millimeter black dot on a white card held 10 centimeters in front of the eye. The reaction to light is best taken in a dark room, requiring the candidate to look into the distance and directing light from the Hare-Marple ophthalmoscopic mirror through the pupil and noting the reaction in both eyes. It may be taken more roughly, with the candidate facing a window and fixing a distant object, both eyes being covered; the covers are removed alternately and the reaction to direct and indirect light noted.

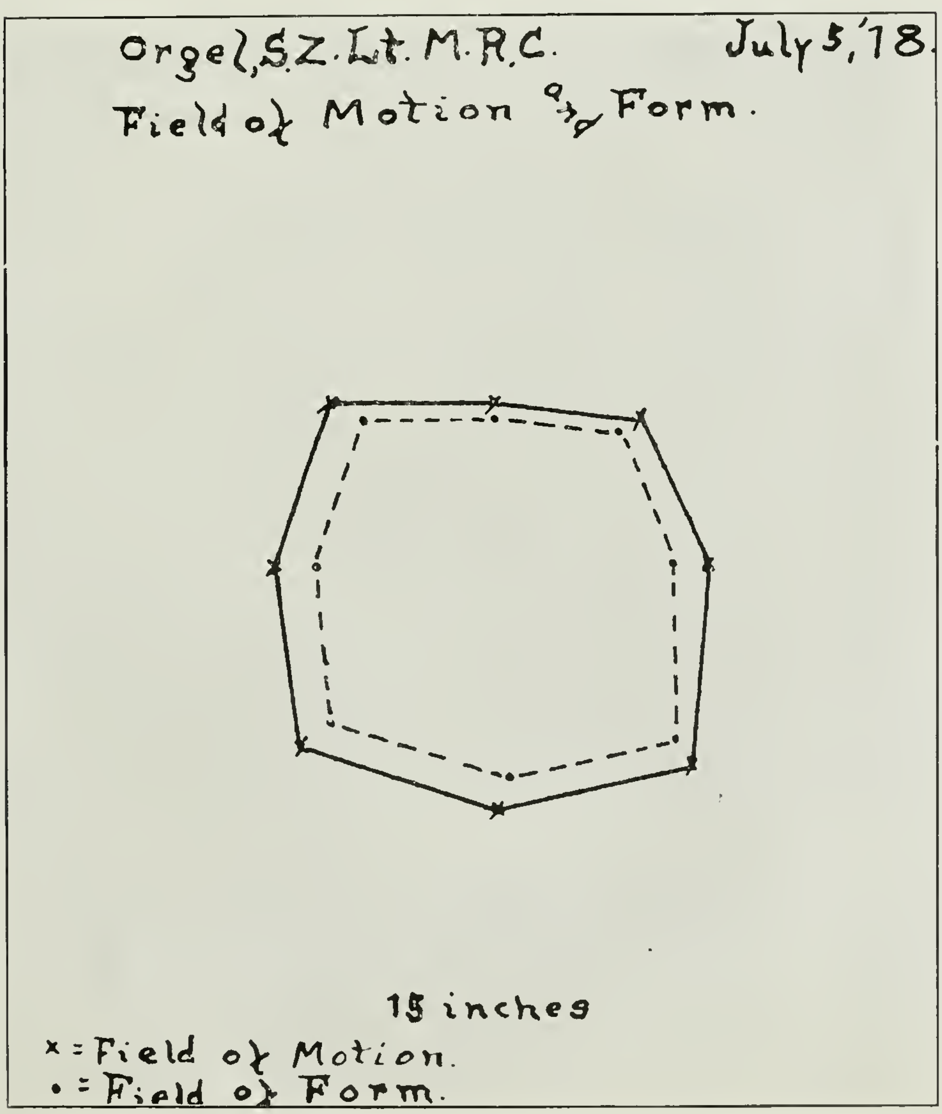
NEAR POINT OF CONVERGENCE.

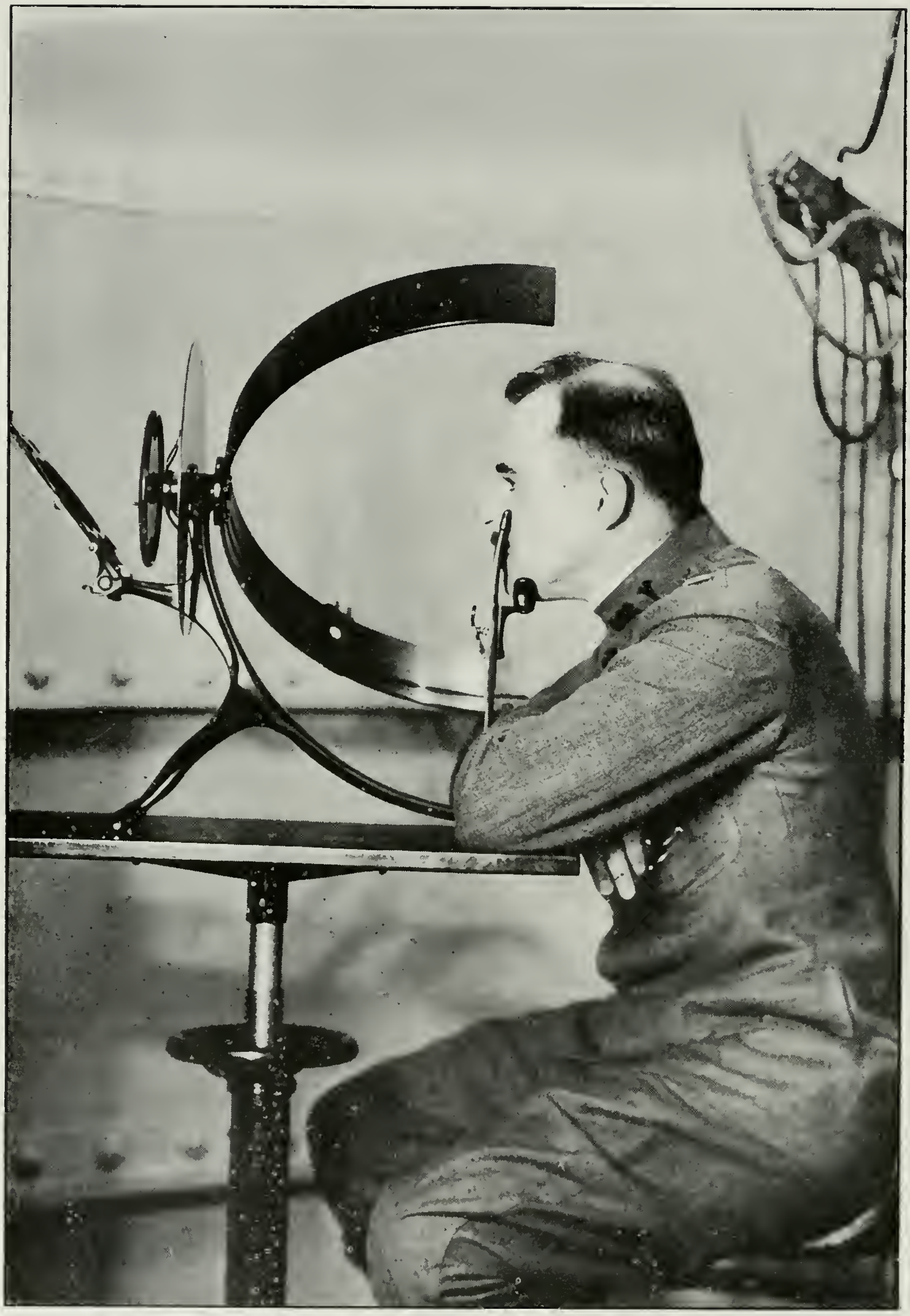
The Prince rule and a 2-millimeter black dot as a test object are used. The end of the rule rests across the bridge of the nose at a point 12 millimeters in front of the cornea. The test object is brought slowly toward the eyes slightly below the horizontal plane until there is a doubling of the dot or one or both of the candidate's eyes ceases to fix. The test is repeated several times, instructing the candidate to exert his maximum effort, and the reading which was closest to the eye is recorded.

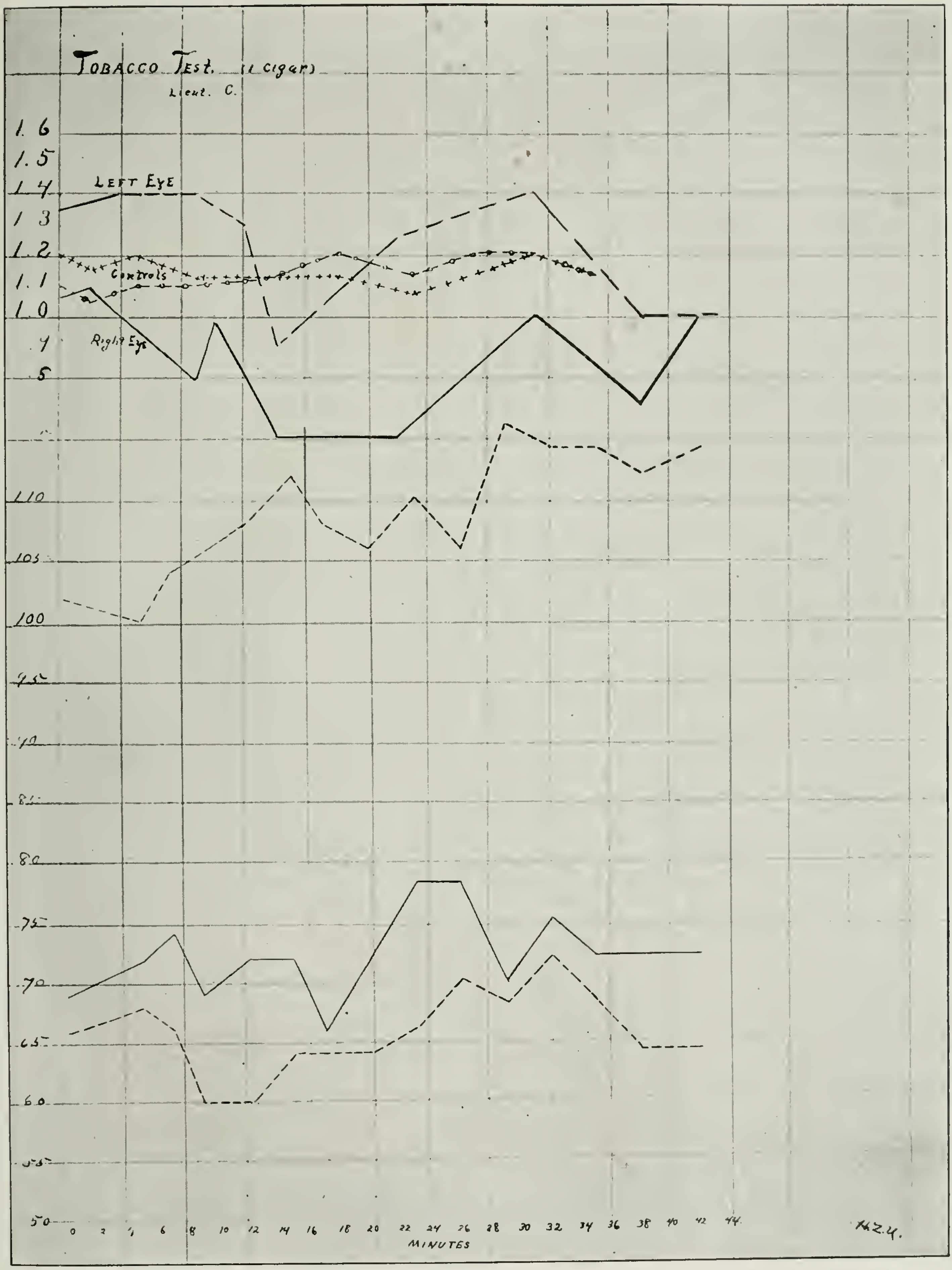
STEREOSCOPIC VISION.

An ordinary stereoscope and the A, B, and C cards are furnished. The stereoscope should be held away from the candidate's eyes and gradually brought up to them, instructing him that he is to look at the pictures just as he would look at objects in a show case in a store window. He is then asked to move the card backward and forward until the point is reached at which the pictures are most distinct, and his eyes are most comfortable. He is then asked to name the objects by number as he sees them, from before backward. The usual order with the A card is 9–1–7, 3–2–4, 5–6–8, and 10. Confusion of 4 and 5, 9 and 1, and 8 and 10 is permissible. To further test the candidate on the same card, he may be asked to name the smaller objects on No. 9, from before backwards, they are cross, balloon, and flag. On No. 8, balloon, cross, rod, and pennant. No. 10, pennant, balloon, and cross. The usual order for the B card is 7–5–9, 3–4–2, 1–10–8, and 6; for the C card, 10–9–2, 7–8–6, 4–3–1, and 5.

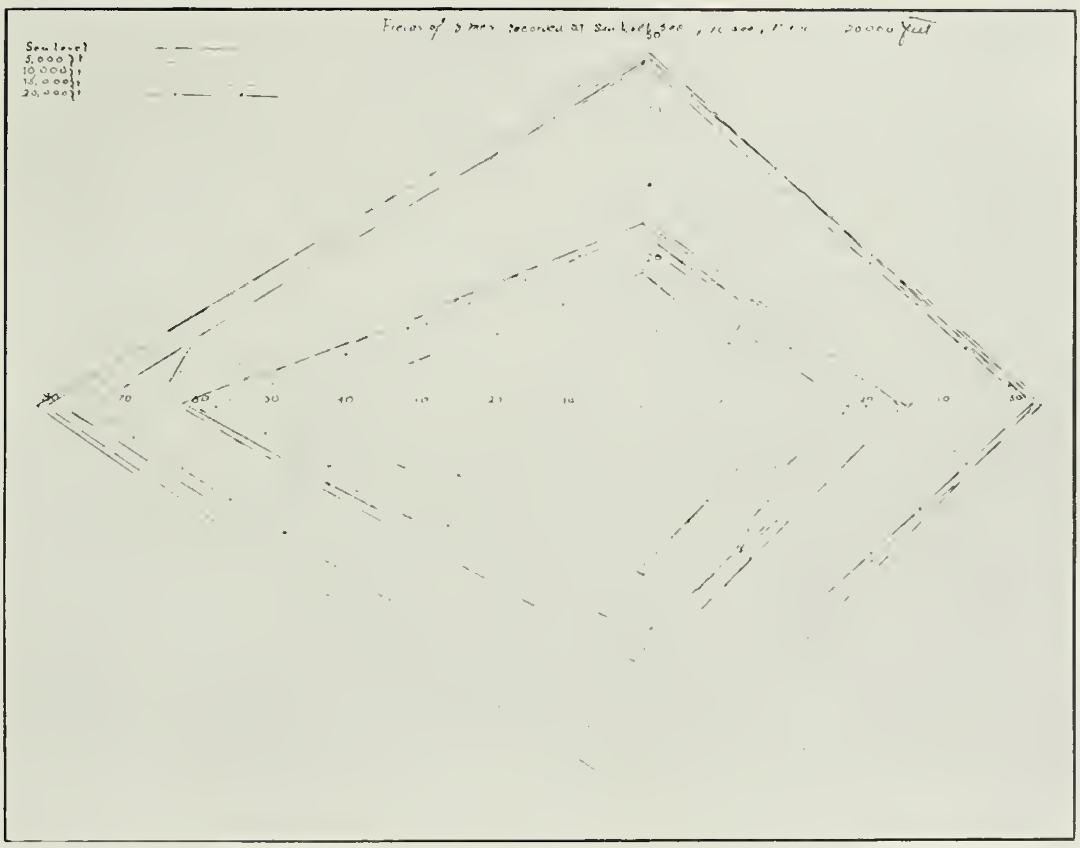

Orgel, S.Z. Lt. M.R.C. June 1,'18.
Field of Motion & of Direction of Motion
15 inches
x = Field of Motion
• = Field of Direction of Motion

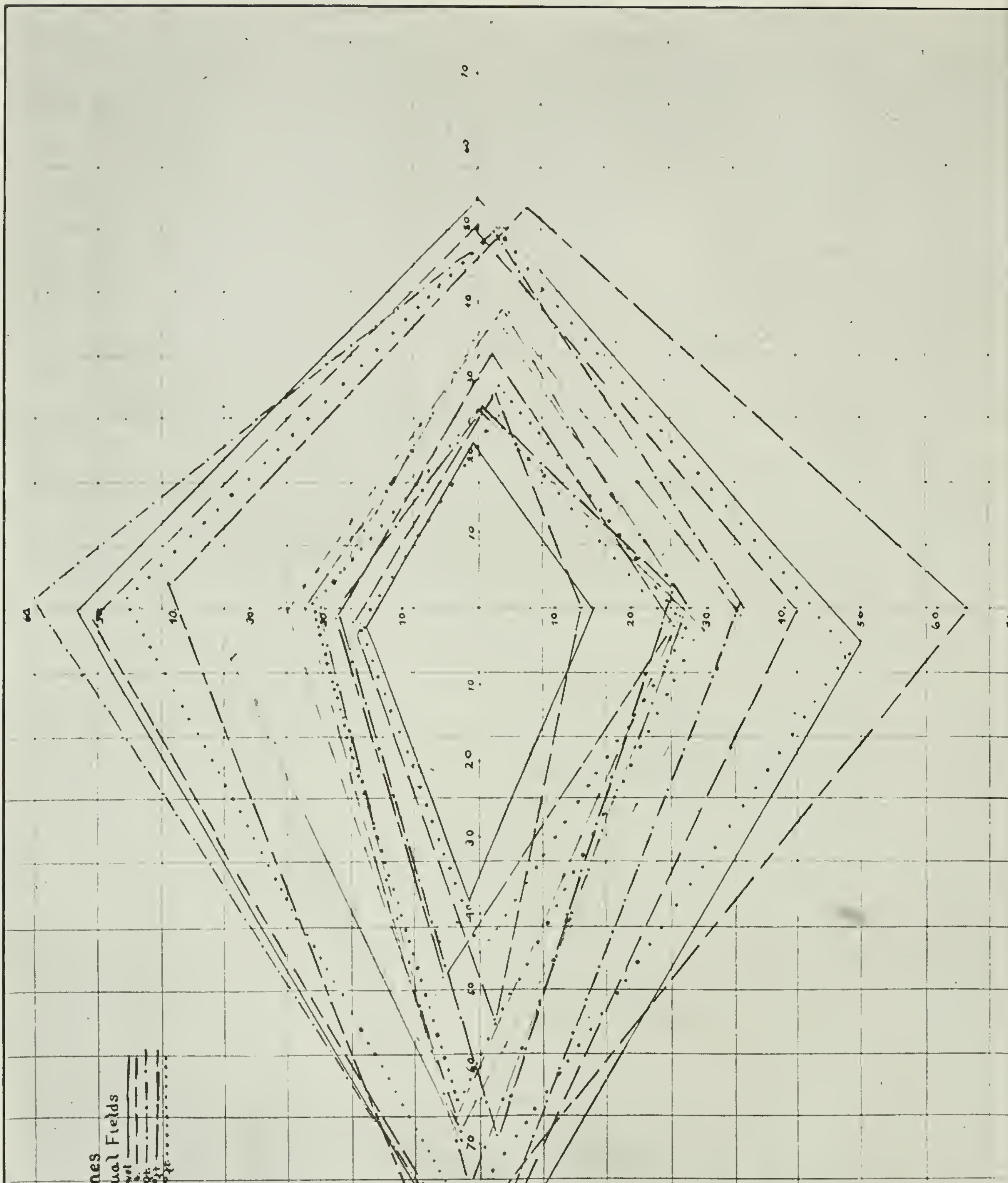

Orgel, S.Z. Lt. M.R.C. July 5,'18.
Field of Motion & Form.
15 inches
x = Field of Motion.
• = Field of Form.





Tobacco Test. (1 cigar)
Lieut. C.
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
Left Eye
Controls
Right Eye
110
105
100
95
90
85
80
75
70
65
60
55
50
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
MINUTES
H.Z.Y.


Sea level
5,000 ft
10,000 ft
15,000 ft
20,000 ft


Raines
Visual Fields

OPHTHALMOSCOPIC EXAMINATION.

The direct and indirect methods should be used, noting any changes in the lens, media, or fundus.

PRELIMINARY REPORT OF THE RESEARCH WORK OF THE OPHTHALMOLOGICAL DEPARTMENT, MEDICAL RESEARCH LABORATORY, JULY 17, 1918.

Although the number of men examined has been few and the research work carried out under adverse conditions, an outline of the results so far accomplished may prove of some value in helping us care for the flier in a more scientific manner.

The most important problem is the one of visual acuity, and it is absolutely essential that the pilot or observer have as nearly perfect vision as nature permits under normal conditions, and furthermore that the visual acuity will not show a marked deterioration due to the lack of oxygen.

Visual acuity has been studied using Ives' test object and Johnson's visual acuity test apparatus and also with the ordinary Snellen test type. The Ives' visual acuity test object has been found to be of the greatest value for taking the visual acuity on the rebreathing apparatus, due to the fact that the subject could raise his hand when he first perceived the lines. In the low-pressure chamber it has also proven of value, for the first surface mirror could be used to increase the reading distance.

Forty-four subjects were examined on the rebreathing apparatus and in the low-pressure chamber. They were classified as normal and subnormal; i. e., those who could pass the examination for the Department of Military Aeronautics and those who would be ocularly disqualified. The 13 subnormal subjects were so classified because of defective vision arising from errors of refraction.

	Normal.	Subnormal.
Vision improved	3 (10 per cent)	
Vision decreased	8 (26 per cent)	5 (38.5 per cent).
No change	20 (64 per cent)	8 (61.5 per cent).

One of the French observers claimed that the visual acuity increases at an altitude of 2,000 meters and that this was probably due to congestion of the head and in particular of the choroid and retina. Normal visual acuity readings were taken, using the Johnson apparatus, then a three-minim pearl of amyl nitrite was inhaled to produce congestion. Twelve men were examined and there was impairment of vision during the period of maximum nitrite effect in all except one, a myope. During the first stage of the action of the drug there was a slight increase in visual acuity in most instances.

The effect of tobacco upon the visual acuity has also been studied. Smoking one strong cigar or inhaling one or two cigarettes, controls were made in most instances. Twelve or 75 per cent showed falling off in visual acuity over the control, 6 per cent showed a rise, and three, or 19 per cent, showed no change. This subject will be taken up in full under the effects of tobacco on the eye.

REACTION TIME.

The French and Italians have laid great stress upon the determination of the reaction time, and it is undoubtedly important that the pilot or observer act and think a little more rapidly than his adversary, if he is to have the advantage. All the men who have done the most work in reaction time in this country believe that some form of complex reaction time will prove of value, but they are skeptical as to the results obtained with the simple reaction time tests employed by the French and Italians. With this in mind the ——— visual discrimination reaction time experiment with four possible correct reactions and five possible stimuli has been chosen. The subject presses the telegraphic key the moment the stimulus appears upon the ground-glass plate. The ——— chronoscope starts recording time the moment the light appears on the ground glass and is stopped by the subject's reaction. The chronoscope records time in 0.12 of a second and the average discrimination reaction of a normal subject is approximately one-half second, and for simple reaction time one-fifth of a second.

JUDGMENT OF DISTANCE AND STEREOSCOPIC VISION.

There are many factors involved in the judgment of distance, but undoubtedly stereopsis is of importance in the accurate performance of this complex act and therefore it has been considered important that the stereoscopic vision be tested under conditions of low-oxygen tension.

The stereoscopic vision was tested on the rebreather and in the low-pressure chamber by use of the ordinary stereoscope containing 7-degree prisms, base out, with a plus 5.50 sphere superimposed. The ability to maintain perfect stereopsis at high altitudes was noted.

Nineteen normal subjects were examined on the rebreather with a loss of stereopsis in only three of them, or 15.7 per cent. Readings were taken at six-minute intervals throughout the run. Of seven men ocularly disqualified stereopsis was lost in only one. In no case was a change noted below 20,000 feet.

Seven "normals" and nine "subnormals" were examined in the low-pressure chamber. Here readings were taken at 10,000, 15,000, and 20,000 feet. All seven normals remained unchanged and only one subnormal showed any confusion in stereopsis. This change was noted at 15,000 feet, but normal stereopsis was promptly restored by the administration of oxygen.

COLOR VISION.

Color vision is considered important for the flier by most of the allied nations, and certainly it plays an important rôle in judging the color of fields and swamps in landing. To accurately determine the color of roofs, chimneys, lights, etc., particularly colored lights at night, good color vision is surely necessary. We have endeavored to determine the effect of low-oxygen tension upon color vision. Stillings plates were used in these tests. Five subjects were carried to 20,000 feet or over in the low-pressure chamber and five above 20,000 feet on the rebreathing apparatus. There was no change in color vision during these tests.

FIELD OF BINOCULAR SINGLE VISION AND FIELD OF BINOCULAR FIXATION.

The field of binocular single vision has been tested by means of a tangent screen. The field of binocular fixation has been tested by the use of the modified Schweiger perimeter and small dots on a white card. One hundred and twenty-two men with normal eyes were examined and 16 who were ocularly subnormal. Seven and thirty-seven one-hundredths per cent of the normals showed contraction of the field of binocular fixation. Fifty per cent of the subnormals showed this contraction. Contraction of the field was more marked above.

MUSCLE BALANCE AND MUSCLE STRENGTH.

It is important for the flier that his muscle balance be as nearly normal as possible, for small defects are accentuated by the strain of flying and lack of oxygen, resulting in a marked contraction of the field of binocular single vision, and sometimes diplopia is produced, even at low altitudes. Research work has demonstrated that exophoria and hyperphoria are more objectionable than esophoria.

To determine the effect of lack of oxygen upon the ocular muscles 35 men, acceptable for the Air Service, have been examined on the rebreathing apparatus and the findings checked by repeating the test in the low-pressure chamber. The muscle duction was taken at sea level, 5,000, 10,000, 15,000, and 20,000 feet, and at this point oxygen was given in the low-pressure chamber for five minutes, and on the rebreathing apparatus the mouthpiece was taken out, allowing the subject to breathe normally. Oxygen or breathing atmospheric air caused a return of the muscle strength to normal in from three to five minutes. The general averages of the strength of the muscles at sea level is as follows:

	Superduction. 2.8°		Abduction. 6.2°		Adduction. 16.8°	
	°	*P. ct.*	°	*P. ct.*	°	*P. ct.*
Loss of strength during the rebreathing test:						
15,000 feet or 11.8 per cent oxygen	1.1	(39)	1.5	(24)	1.8	(9.5)
20,000 feet or 9.7 per cent oxygen	1.9	(70)	1.83	(29)	2.94	(17)
Loss of strength during low pressure chamber test:						
15,000 feet or 11.8 per cent oxygen	1.05	(37)	1.35	(21)	1.75	(10)
20,000 feet or 9.7 per cent oxygen	1.7	(64)	1.8	(29)	2.8	(16)

In all the subnormal subjects examined, particularly those with convergence insufficiency alone or combined with divergence excess, there was a marked loss in the power of adduction, and diplopia often occurred between 10,000 and 15,000 feet. Men with over one degree of hyperphoria, particularly when combined with exophoria, showed a rapid reduction in muscle strength, often resulting in diplopia. Subjects in the subnormal group should be cared for by muscle exercises and operations where it is found necessary.

FIELD OF VISION.

It is of the utmost importance that the aviator have the broadest possible field of vision, for we know that the visual field is contracted slightly, due to the lack of oxygen, and that marked constriction of the field is produced by poorly constructed goggles as well as by blind angles in aeroplane construction. The fields for form and color have been taken in the low-pressure chamber at 5,000, 10,000, 15,000, and 20,000 feet, and when contraction is noted at 20,000 feet oxygen is administered. To make sure that the changes are not due to fatigue, controls have been taken at sea level, corresponding in time of day and in time interval to those taken in the low-pressure chamber. At 5,000 and 10,000 feet there is usually a slight enlargement of the fields for form and color, at 15,000 feet a slight contraction, and at 20,000 feet a marked contraction. Twenty men have been examined, and at 20,000 feet the fields for form have shown a contraction of 14 per cent of their original size below, 3.5 per cent in the temporal field, 4 per cent above, and 6 per cent nasally. The green, 4.5 per cent in the lower, 5 per cent in the temporal, 5 per cent above, and 25 per cent in the nasal field. Five minutes after returning to sea level fields are normal in size. Giving oxygen at 20,000 feet for four or five minutes caused a return of the fields to normal. Several fields have been taken on the rebreathing apparatus, and the results are fairly comparable with those found in the low-pressure chamber.

PERCEPTION OF MOTION BY THE RETINA.

It is important that the aviator note the approach of an enemy plane before the enemy sees him, and therefore the keen sense of perception of motion by the retina is a valuable asset to the flier. It has been our endeavor to provide some method of taking and recording these fields in the hope that something of practical value might be found.

These fields were taken in a dark room with no illumination other than that of the test object, for which purposes a May ophthalmoscope battery handle with the cap removed was used.

The subject was seated at a distance of 15 inches from the center of the screen. The test object was held on the opposite side of the screen from the object and gradually moved until it came into the field of vision. In this manner the place at which the motion of the light could be first seen was noted, and then at what point the correct perception of direction of motion could be ascertained. Lastly, the field of form was taken, i. e., the first point at which the stationary light could be recognized.

The relative sizes of these three fields can be seen by the average figures of 10 cases:

	Field of motion.	Field of direction of motion.	Field of form.
Up	33	$31\frac{1}{3}$	$29\frac{2}{3}$
Down	$47\frac{1}{3}$	45	$42\frac{1}{3}$
Right	45	42	40
Left	47	43	$42\frac{2}{3}$
Up and right	42	40	35
Up and left	41	38	36
Down and right	48	45	43
Down and left	47	44	43

The field of motion is approximately 3 degrees larger than the field of direction of motion, which, in turn, is about $1\frac{1}{2}$ degrees larger than that of form. It is evident, then, that a moving object can be seen $4\frac{1}{2}$ degrees sooner than a stationary one. That is, the field of motion is $4\frac{1}{2}$ degrees larger in every direction than that of form. This relationship is apparently a constant one, independent of the size of the field. In other words, if motion is perceived at a certain point, you expect to find the perception of form $4\frac{1}{2}$ degrees farther in toward the center. In a like manner the field of perception of direction of motion bears a rather constant relationship to that of motion and of form.

INTRAOCULAR TENSION.

Intraocular tension has been studied in the low-pressure chamber. Fourteen men have been examined in the low-pressure chamber. No correlation has been found, either between intraocular tension and the blood pressure or lowered oxygen tension and various cardio-vascular changes, for the intraocular tension has sometimes gone up as the barometric pressure was lowered and sometimes it has gone down with the lowering of barometric pressure. This also holds true for the blood pressure. However, before definite conclusions should be made more work should be done.

ACCOMMODATION.

The flier must continually observe the instruments on the inside of the fuselage, particularly at night, and therefore it is important that the accommodation should not fall off too rapidly, due to lack of oxygen. The rule of accommodation in visual acuity and in judgment of distance is also important.

The near point of accommodation has been taken every two minutes in the low-pressure chamber and on the rebreathing apparatus, using a Prince rule with Jaeger test type or the Duane disk as a test object. Normal runs have been made without the low oxygen tension effect for the purpose of comparison. One hundred and forty-eight men, acceptable for the Aviation Service as fliers, were examined on the rebreathing apparatus: 44.6 per cent showed a receding of the near point, 18 per cent showed improvement, fluctuating changes in accommodation were noticed in 14.4 per cent, and no change in 23 per cent. Eleven subnormal cases were examined, and 63.7 per cent manifested a decrease in accommodative power, 18.3 per cent an apparent increase, 9 per cent showed no change, and 9 per cent variable reactions. The low pressure chamber findings were practically the same as those with the rebreather. Of 17 normal men examined, 47 per cent showed decrease in accommodative power, 11.7 per cent increase, 23 per cent fluctuation, and 7.8 per cent no change. Three subnormal subjects were examined in the low-pressure chamber; two showed a decrease in accommodative power and the other gave a varying reaction. When the subject is brought to sea level the accommodation comes back rapidly in some and slowly in others. The inhalation of oxygen invariably causes a return to normal, even though the subject may be kept at 20,000 feet in the low-pressure chamber.

That these changes do not follow the cardio-vascular reactions is shown by the fact that 57 men, exhibiting acceleration of pulse rate and maintenance of pulse pressure, showed in 42.1 per cent decrease in the power of accommodation, 15.8 per cent increase in power of accommodation, 15.8 per cent fluctuation in accommodation, and 26.3 per cent no change in accommodation. Our researches would lead us to believe that hyperopes and subjects with a marked amount of hyperopic astigmatism show the most marked changes in accommodation.

Fatigue of accommodation has been studied with an ophthalmic ergograph. Normal three-minute runs were made without the low oxygen tension effect as controls, then three-minute runs with same time interval were made in the low-pressure chamber and on the rebreathing apparatus. The findings on the rebreathing apparatus and in the low-pressure chamber showed, at 15,000 feet, a more rapid onset of fatigue than was evidenced by the controls, and at 20,000 feet the fatigue was marked. The administration of artificial oxygen rapidly restored the normal tone of the ciliary muscle.

CONVERGENCE.

If the near point of convergence falls off markedly during flying, the aviator's ability to make landings properly will be impaired, and, therefore, the near point of convergence has been taken during the rebreathing test and low-pressure chamber experiment.

A U-shaped piece was cut out of the Prince rule to fit over the nose and a 2-millimeter black dot on a white background was used as a test object for making this determination. Readings were taken without low-oxygen tension effect, with low-oxygen tension effect, and the effect of the administration of oxygen was determined. Readings were taken every two minutes and charted. One hundred and forty-seven men with normal eyes were examined on the rebreathing apparatus.

50.3 per cent decrease in convergence power.
17.6 per cent increase in convergence power.
11.5 per cent fluctuation in convergence power.
20.6 per cent no change in convergence power.

Of 11 subnormal men examined 6 were disqualified for visual acuity and 5 for muscular imbalance; 45.7 per cent showed decrease in power of convergence. Increased converging power, fluctuating changes, and no change in the near point of convergence were each noted in 18.1 per cent. Of 16 normal men examined in the low-pressure chamber 50 per cent showed falling off in power of convergence, none showed increase, fluctuating reactions were present in 12.5 per cent, and 37.5 per cent remained unchanged. In the subnormal group the recession of the near point of convergence was very marked, sometimes resulting in diplopia.

An attempt has been made to show what relationship, if any, exists between the convergence and the cardio-vascular reactions to low-oxygen tension.

Seventy-two cases showing an increase in pulse rate and a maintenance in pulse pressure gave these convergence changes, which would seem to indicate that ocular changes can not be predicted by the cardio-vascular reaction and vice versa.

54.2 per cent decrease in power of convergence.
15.3 per cent increase in power of convergence.
9.7 per cent fluctuation in power of convergence.
20.8 per cent no change in power of convergence.

The results would indicate that the rebreathing apparatus and low-pressure tank give almost identical findings, and in each case the determining factor seems to be the lowering of oxygen tension as the administration of oxygen soon causes the convergence near point to return to normal, irrespective of the barometric pressure.

Fatigue of convergence has been studied with Howe's ophthalmic ergograph. Normal 3-minute runs as controls were made without the low oxygen tension effect, then 3-minute runs with approximately the same time interval were made in the low-pressure chamber and on the rebreathing apparatus. The findings on the rebreathing apparatus and in the low-pressure chamber showed a more rapid onset of fatigue than occurred with the controls. At 15,000 feet and at 20,000 feet the fatigue was marked, as was the case with accommodation. Here also the administration of oxygen caused a rapid return of converging power.

RETINAL SENSITIVITY.

The Italians have laid considerable stress upon retinal sensitivity for those men who must fly at night, and Lieut. ——— has devised a test for the contrast sensitivity of the retina which has proven most useful and practical.

It is important that the retina be normally sensitive to light impressions, especially for those men who must fly at night, notably bombers and fliers doing patrol duty. A test for the contrast sensitivity of the retina has proven most practical for our work, and only men who have normal sensitivity in this respect will be selected for night flying.

In this laboratory tests to determine the threshold sensitivity for white and colored lights and for contrast are conducted in the following manner:

The ——— wedge is made of two pieces of glass at a known angle, between which is run a solution of gelatine and neutral dye. The wedge is calibrated in millimeters, which is translatable into per cent of light transmitted.

To test the threshold sensitivity to light the subject is placed 20 feet from a spot of light 3 millimeters in diameter. Holding the wedge before the right eye, he slowly draws the slide from its cover, and as the light just disappears a reading is taken. This reading is in millimeters and is then translated to per cent transmission.

The threshold for color is taken the same as the above, using red and green light, which are practically monochromatic.

The test of contrast sensitivity is made with a ——— wedge and ——— contrast square. The contrast square is made by placing a square of dark gray paper upon a larger square of lighter gray, there being 13 perceptible differences between the two shades. An illiterate "E" with the same perceptible differences is used as a check of the findings. This is lighted by a 75-watt nitrogen daylight lamp at a given angle and distance from the test object and the subject is placed 20 feet in front of the object. The reading on the wedge is taken just as the contrast between the squares disappears. The average readings taken with the contrast sensitivity square give 34 millimeters and the illiterate "E" 32 millimeters. To date, the normal for the light threshold of 35 cases is 65 millimeters.

Under the rebreathing test the threshold for light has shown an improvement in 25.9 per cent; 44.5 per cent show neither improvement nor falling off; and 29.6 per cent show a falling off in sensitivity.

In the study of the threshold for colors the red and green both show a falling off in 71.4 per cent and neither a gain or loss in 26.6 per cent.

In former tests with a blue light, which was not absolutely monochromatic, there was improvement in 66.6 per cent and falling off in 33.4 per cent.

ACCOMMODATION TEST OBJECT.

It has been important for our work to determine the best possible test object for determining the near point of accommodation.

The object of these tests is to determine the comparative value of various test objects used in determining the near point of accommodation. Tests were also made to determine the difference, if any, between a black and white dot in determining the near point of convergence. The objects used in these tests were as follows:

1. Radiating squares.
2. Illiterate "E."
3. Numbers.
4. Jaeger type, No. 1.
5. Duane disk.
6 Prince rule.

Two separate examinations were made for each test object. Twenty-five men were examined, and a general average gave the following results of difference in readings

	Millimeter.
Radiating squares	$14\frac{1}{3}$
Illiterate "E"	$4\frac{1}{2}$
Numbers	$5\frac{1}{2}$
Jaeger, No. 1	$4\frac{1}{2}$
Duane disk	$3\frac{3}{4}$

The Duane disk is the best test object for general use. It is found, however, that during the rebreathing test it is difficult for the subject to quickly recognize the faint black line on the disk, and the later readings are not satisfactory. Tests of black and white dots in finding the near point of convergence show no appreciable difference between them.

As Jaeger type is not standardized, and as the various units should have some standard in order to obtain uniform results, a plate has been made with two sizes of standard type. This type is made up of mixed letters and numbers. The smaller type is 0.6 millimeter and the larger 0.8 milimeter, so, should the accommodation fall off late in the tests, the larger type can be seen. Above the letters is a black dot for use in determining the near point in convergence, thus eliminating a certain amount of delay in changing cards during the test.

ASTIGMATISM.

The effect of lowered barometric pressure and lack of oxygen upon astigmatism has been tested in several instances, and so far no change has been shown in astigmatism due to lack of oxygen or lowered barometric pressure.

EXAMINATION OF THE FUNDUS DURING REBREATHING AND LOW PRESSURE EXPERIMENTS.

There has been very little change noted in the fundus' appearance, but at the end of the rebreathing run of above 20,000 feet in the low pressure chamber the retinal vessels have shown some congestion.

IRIS REACTION DURING REBREATHING AND LOW PRESSURE EXPERIMENTS.

The object of these tests is to determine the change in reactions of the iris and pupillary diameters during rebreathing.

Fifteen men were examined for this experiment and carried from 18,000 to 28,000 feet. The changes were not altogether uniform, as certain of the cases reacted more strongly to light than to accommodation, and vice versa. Some changes, however, seem to be fairly constant.

Below 10,000 feet no changes are noted; above this, varying in different individuals as to height, there is an increase in reflexes for both light and accommodation. This holds until late in the experiment and then slowly diminishes, and if the subject is allowed to remain on the machine near fainting point, reflexes are entirely abolished. The pupil slowly dilates, usually beginning above 15,000 feet and remains so during the remainder of the experiment. If allowed to remain on the machine too near the fainting point, the pupil is quite widely dilated.

EFFECT OF TOBACCO UPON THE EYE.

The problem, as taken up by the Ophthalmological Department of the Medical Research Laboratory, Hazelhurst Field, was to determine what effect, if any, tobacco has upon vision, reaction time, retinal sensitivity, accommodation, and convergence of habitués, and nonsmokers. Although this investigation is still uncompleted, it is believed that a preliminary report is desirable.

The widespread, increasing, and unrestricted use of tobacco in the Army and Navy furnishes the practical incentive and justification for the investigation.

APPARATUS EMPLOYED THUS FAR.

A. For visual acuity: (1) Ives apparatus at 20 feet. (2) Snellen test card. (Unsatisfactory and abandoned for this purpose.)

NOTE.—20/20 vision is equivalent to 1.00 on the Ives apparatus.

B. For circulation effects: A standard sphygmomanometer, stop watch, and stethoscope.

C. Accommodation and convergence (near point): The Prince rule, with Jaeger test type, and a 2-millimeter black dot on a white field.

D. Retinal sensitivity and contract sensitivity: For these, the photometric wedge was used, employed in such a manner as to blend within a period of 5 to 8 seconds, two gray squares, one within the other, differing from each other in tint by 13 perceptible shades. The squares must be highly illuminated by a shaded nitrogen daylight lamp, and observed at a distance of 20 feet.

TESTS.

Visual acuity: This was very carefully taken on the Ives apparatus every four minutes during smoking, after having previously taken several preliminary observations at two-minute intervals. Where possible, control tests lasting a half hour or more were taken later in order to compare the regularity of the curves with those of the tests while smoking. Several observations were made after the subject had ceased to smoke.

In all cases vision was taken separately for each eye, with the subject wearing his usual correcting lenses. Variation of the direction of the lines in the Ives apparatus was tried but was discontinued as unsatisfactory and the lines were maintained in one position during the test (generally vertical). This was to avoid variation in readings due to slight astigmatic errors.

Blood pressure.—This was taken every four minutes after at least three preliminary observations, two minutes apart, and was con-

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tinued until the cigar was consumed with one or more final observations, two to four minutes afterwards. The systolic and diastolic pressure was taken by stethoscope method.

Pulse.—Normals and test observations at four-minute intervals.

Convergence and accommodation.—These were taken generally every 10 minutes, as was also retinal sensitivity to contrast.

Results.—Of 16 subjects tested and their records charted and curves plotted, results are as follows:

A. Visual acuity: Twelve (75 per cent) showed a fall, the average of which was 0.17 (Ives's apparatus).

One (6 per cent) showed a rise; three (19 per cent) not changed.

NOTE.—Curves showing both a rise and a fall are classed according to which predominates. A slight preliminary rise occurred in nine cases, the dominant effect of which, however, was a fall. The duration of lowered vision was very brief, lasting at most only a few minutes after cessation of smoking.

B. Systolic and diastolic blood pressure: Both were affected and in general similarly, though not in equal degree. Both showed a rise of 69 per cent in 16 cases. In 3 (19 per cent) there was a fall of the systolic and 4 (25 per cent) of the diastolic pressure. The average rise of the systolic was 9.3 millimeters, of the diastolic 7 millimeters. The average fall of the systolic was 8 millimeters, of the diastolic 5.5 millimeters. Here also the effect was temporary, usually lasting but a few minutes.

C. Pulse: A rise in pulse rate was nearly constant, 14 cases out of 16 (87½ per cent) showing an increase, the average of which was 14.3 beats per minute. Two cases showed a fall averaging five beats.

D. Accommodation: Of 13 subjects, 5 (38 per cent) showed a loss, this loss averaging 33 millimeters. Two showed an improvement averaging 12 millimeters; 6 (46 per cent) showed no change. Those showing the greatest loss were presbyopic.

E. Convergence: Of 12 cases, 50 per cent showed more or less falling off; 5 (42 per cent) showed no change. One apparently improved by 10 millimeters. It will be seen that the effect upon convergence and accommodation was much more uncertain than in the cases of visual acuity and blood pressure. The same may be said for superduction and adduction as tested by prisms.

F. Retinal contrastivity: The use of the wedge elicited no changes under tobacco, so far as could be ascertained, except in two cases, which showed a loss of 10 millimeters.

Conclusions: Observations to date indicate that approximately 75 per cent of smokers have definite though temporary effects upon vision from a single cigar, and almost an equal proportion show a rise in blood pressure, while there is an increased pulse rate in nearly

90 per cent. This effect is also temporary, although John, in 1913, reported that the use of two cigars caused a rise of blood pressure lasting for two hours after the cessation of smoking. In 1907 Hesse found similar pressure effects. Nonsmokers have not as yet been tested in numbers to afford a report. Only one enters this series. He showed a fall of 0.3 in visual acuity. Accommodation fell off 15 millimeters. There was apparent reduction in retinal contrastivity of 1 millimeter. Some giddiness occurred at 18 minutes from start, accompanied by slight nausea.

Aviation medical authorities in the war zone have remarked that aviators were using tobacco excessively, smoking while in the air as well as incessantly while on the ground. It has further been reported that soldiers on the western front have frequently complained of night blindness. Some of these cases may be due to excessive tobacco without the occurrence of a typical tobacco amblyopia. Practically the same results as have been obtained by smoking one cigar have been produced by the inhalation of one or two cigarettes.

VI.—PSYCHOLOGY DEPARTMENT.

I. THE RELATION OF PSYCHOLOGY TO THE AVIATOR.

The function of psychology in respect to the aviator is to study his adaptability to the work required of him. Assuming that the determinable structural qualifications of the aviator are adequate, that his more mechanical physiological functions are satisfactory, it is yet necessary to determine the conscious or integrative action of his organism, with regard to the adaptations which contribute to the composition of a good flier; and further, his adaptability to one or another set of requirements for different departments of the flying work.

Obviously, these determinations may be made by the trial and error method (which in this case is merely a survival method), and this has been followed to a large extent in several foreign air services. The candidates are roughly selected, and those who do not successfully adapt themselves to the general or specific requirements practically eliminate themselves. This method is, however, believed to be wasteful, and undoubtedly a more economical method can be successfully followed.

The contribution which psychology can make to the efficiency of the Air Service, in view of the foregoing, can be summarized under eight heads:

1. The adaptability of the individual to the general requirements of the service may be determined. Some of these requirements may be enumerated in a list not intended to be exhaustive.

I. Perception (including discrimination). The ability to perceive accurately and quickly through the various senses (visual, auditory, tactile, muscular and articular, and visceral), which are important for the flier, depends not merely on the perfection of the sense organs, but also on the integrative action by which definite and useful perceptual reactions are achieved.

II. Control of "voluntary" activity, i. e., of that activity which must vary in its expression according to the variations in the environment. Such activity is truly integrative and is in general a part of the perceptual process.

III. Maintenance of equilibrium, and orientation. The complex mechanism by which the flier preserves his balance, and the more complex mechanism by which he finds his way about, are so interconnected that they necessarily must be treated together, although the functions are widely different. To a large extent these functions are automatic (mechanical), yet both involve all the senses enumerated above and involve in both cases more or less integration of the nervous system.

IV. Memory (in the sense of retentiveness) is dependent on conditions which are apparently in part constitutional, and in part subject to control, although the detailed basis of these conditions is not at present known.

V. Associative thinking, which depends on retentiveness and expresses itself in the various forms of judgment, inference, and decisions, is an integrative function closely connected with perception, but by no means varying directly with it in efficiency. It is becoming more and more clear that thinking, like perception, is a conscious reaction of the organism, and can be adequately treated only as such.

VI. Emotional response: Emotions are directly connected with the driving force of the organism, and are in the highest degree important in all mental processes. The Darwinian point of view of emotion (as developed by James, Sutherland, and especially by Lange), that it is a bodily (chiefly viceral) condition or process, is more and more becoming indispensible for practical consideration of the emotional life.

VII. Attention, which is the direct expression of the degree and completeness of integration, is of especial importance. Not only the extent to which the flier can subordinate all other reactions to the vital reaction of the moment, and the length of time during which the vitally important details of the situation which confronts him can continue to dominate his nervous system in spite of distractions (the power of sustaining attention, as we commonly express it); but also the proper balance in integration (the power of attending efficiently to several distinct details in a situation), need to be studied very carefully.

VIII. Habit formation, or learning, which is the modification of the integrative system (it may be the modification of perception and motor control, or of thinking process), is a topic of especial importance in flying and is one concerning which psychologists have acquired a large amount of information in recent years.

A knowledge of the precise requirements for the flier in all these directions is yet to be obtained. Various opinions have been expressed as to the requirements, but psychologists are unanimously of the opinion that any conclusions in these matters should be reached by systematic observations and experiments. In this laboratory work on these problems is being carried on by men who have so far attained results which are distinctly encouraging, but not yet in a stage where the communication thereof is feasible.

2. The adaptability of the aviator to special requirements of the different departments of flying work: The same work is not required of observers as is required of pilots, and bombing and combat do not require exactly the same sort of pilot work. The list of special qualifications will probably grow, as aviation develops, but so far little has been done in the way of determining and measuring the special qualifications. Work has been undertaken in this line and results will be forthcoming in due time.

3. Special conditions to which the flier may be subjected: Probably the most important special condition is the combination of cold and low oxygen tension encountered at high altitudes. While nothing has yet been done in the Medical Research Laboratory on the temperature problem, a great deal has been done on effects of insufficient oxygen supply. In addition to the physiological effects of asphyxiation, there are distinct psychological effects which have been carefully studied by the psychology section. Although we have recognized from the beginning that tests for asphyxiation effects, and the grading of fliers on the basis of their endurance of oxygen deprivation, are of minor importance as compared with tests in the other directions indicated above (since the evil effects of the low oxygen tension of the upper atmosphere can in most cases be obviated by administering oxygen to the flier), nevertheless it was necessary to get this problem out of the way before other problems could be attacked. Full details of the psychological tests and ratings for oxygen shortage are given in a later chapter.

4. Deterioration: Assuming that the individual flier is fit for his job and properly trained, we nevertheless find that he may suffer deterioration, both of a temporary sort and of the more lasting sort, which is frequently designated as "staleness." The fact that an individual when in his best trim is a high-class flier and efficient in his especial department of flying does not promise that he will re-

main such; the fact that an individual shows high capacity for endurance of oxygen shortage does not signify that he is in good flying condition, although it is known that deterioration in certain conditions requisite for flying will reduce the individual's ability to withstand oxygen shortage.

Although it is believed that in certain cases psychological causes (worry, fear) may be responsible for deterioration, there is probably a more important range of physiological causes operative. In all these cases, however, mental symptoms are produced, since it is precisely in the failure to integrate properly rather than in specific failure of sense organ or muscles, that "staleness" shows itself. The discovery of the symptoms and the development of tests which shall reveal them as early as possible is undoubtedly one of the most important contributions psychology can make to aviation, since it is important that the symptoms be detected in the earliest possible stage. The task is being undertaken, and we have reason to be confident it will be successfully carried out if the work continues.

From the foregoing presentation it should be evident that a number of diverse problems confront us. The requisite tests of general ability and of special abilities must be worked out conjunctively, but are not capable of combination. Certain of these tests which are capable of repetition may be useful in determining an aviator's condition (for detecting deterioration), but the applicability of these or any other tests for deterioration must be worked out independently. It is especially important to note that psychological tests for endurance of special conditions (oxygen shortage), if adequate for their purpose, can not give any reliable evidence on general or other special qualifications or on deterioration.

II. PSYCHOLOGICAL RATING OF AVIATORS FOR ALTITUDE LIMITS.

OUTLINE OF CONDITIONS.

The work on oxygen deficiency has so far been principally under the conditions established by the rebreathing apparatus, with some check experiments in the low-pressure chamber. With this apparatus it is possible to produce the oxygen tension in respired air equivalent to the tension for any elevation up to that at which the patient can no longer endure the deficiency.

The chief respiratory differences between the rebreathing conditions and those actually obtaining in the upper atmosphere are (1) the greater density, (2) the greater moisture (practically saturation), (3) the higher temperature of the air in the rebreathing machine, and (4) the method of breathing, through the mouth, with the machine. While it is possible that one or another of these differences (most probably the third) may make a difference in the case of prolonged holding of the patient at certain altitudes, for rapid "ascents" (i. e., passages from normal to low oxygen tension), the first two differences do not seem important. There has been as yet no means of testing the contributory effect of temperature, and it has not been possible to make a sufficiently thorough comparison of the effects of rebreathing with those of the low-pressure chamber. The discomfort of the mouth breathing is undoubtedly important in individual cases, and hence interferes somewhat with the adequate rating of the aviators, but in the cases of experienced subjects is a minor matter and has no important bearing on the scientific conclusions.

PSYCHOLOGICAL EFFECTS.

The psychological effects of oxygen deficiency.—The effects of oxygen insufficiency upon the psychological process have been from the beginning of our work studied empirically, with the least possible hypothetical guidance. A wide range of details of mental life have been investigated, the order and method of investigation being practically directed by the working tests which were available or which we have been able to devise. Hence our results are capable of throwing a light on the fundamental principles of psychology.

These results square distinctly with the conception of psychological processes as integrative, i. e., as dependent on the integration of the central nervous system, the working together of the system as a whole, rather than on the action of any specific parts of the system.

The basic and important psychological effects of asphyxiation are on voluntary coordination and attention. Until asphyxiation reaches the stage in which the integrative mechanism is rapidly approaching the condition of complete unconsciousness, no effects are demonstrable which are not clearly the failure of the one or the other, or both, of these two mental factors. In the prefinal stages perception is as efficient as the muscular control of the sense organs and organs of expression and the power to attend to the stimuli permit. Discriminative judgment, likewise, shows no falling off in rapidity or accuracy except as impaired motor control and attention produce it. Memory, with "immediate memory," as tested by the ability to produce what has been perceived or learned immediately before, and "true memory," as tested by the ability to produce something which has been "latent" for a certain interval after being learned are apparently not affected except as the inability to attend to the details in learning or in reproducing or inability to control the muscular mechanism of expression may enter.

The efficiency of limited neuro-muscular groups, as indicated by dynamometer tests, is not impaired in the prefinal stages of asphyxiation.

As instances of tests involving perception and discrimination, we may cite the copying of a list of work and the translation of words into code. In both of these cases speed and accuracy are maintained up to the final stages of asphyxiation, provided the muscular mechanism of accommodation and convergence are not seriously affected, although the mechanism for handwriting may be so affected that the written results of the list are legible with difficulty.

In more complicated discrimination, where rapid and accurate recognition and classification of material are required, the results are similar. Ability to remember and to chart correctly the relative spacial position of objects remains normal within the limits of ability to make adequate movements of the hand in charting.

It is interesting to note that the sensitivity and acuity of the sense organs shows no consistent impairment and that apparently the speed of simple reactions (the simple reactions do not in general require a high degree of integration) is not intrinsically reduced. More work remains to be done on simple reactions, however, before definite statements can be made. The distinctive effect on the nervous system, in short, seems to be a change in its integrative action and not a change in the irritability or efficiency of any particular part or unit. In this respect the whole picture of asphyxiation from a psychological point of view is strongly suggestive of the picture of progressive alcoholic intoxication.

There is some evidence that practice in enduring asphyxiation has value in increasing the efficiency of the individual under a certain degree of asphyxiation. Expressed in untechnical terms, the individual may learn to husband his resources and by applying his capacity to the tasks in hand accomplish more at a certain level than he could without practice. More definite statement on this point can not be made on the basis of the present material. It is not possible that habituation to the effects of alcohol (not to regular dosages) may be a help in acquiring ability to maintain motor and attention efficiency in certain degrees of asphyxiation.

Training of another sort may also be advantageous. "Grit" counts in the maintenance of efficiency, or rather the maintenance of efficiency in the face of serious oxygen deficiency is "grit," and if "grit" in one task or situation can be acquired or increased by training in other situations (which is by no means certain), then such training is advantageous.

PRACTICAL REQUIREMENTS.

Under the practical requirements of rating, tests must be single and brief during progressive depletion of the oxygen supply. If many individuals are to be examined it is not practicable to spend even several hours on each one. Hence it is not possible to hold the subject at a moderately high altitude so that asphyxiation effects will eventually appear. Nor is it possible to repeat a briefer test a number of times. Hence, the subject must be allowed to rebreathe rapidly (during not much over a half hour at most), to a low point of oxygen tension, reaching his maximal altitude for that rate of "ascent." It follows that the method used must be one which is not approved for psychological work under other conditions and which, for want of a better term, is called clinical. Thus, since the subject's condition is rapidly changing from minute to minute, the examiners must be able to determine the psychological condition at any minute and can not use the method (more exact under other conditions) of determining the average speed and accuracy of work done during a period of several minutes.

A final composite reason for using a clinical method comes from the need for rapid work. Graphic methods might be employed, but would largely hinder the expedition of the work on account of the time and labor needed for their interpretation. Moreover, in such rapid work fineness of gradation in rating would be seriously misleading, hence the greater exactness of the graphic method would be largely illusory. For research purposes, on the other hand, the matter is entirely different.

Fatigue, also, must enter into the test as little as possible, else the deterioration in performance due to fatigue will confuse the determination of the asphyxiation effects.

Since the test can not be repeated, it is important that there shall be little practice effect in the work required, else the individual variation in rates of learning will prevent the fair determination of the relative susceptibility of the different subjects to the oxygen deprivation, which is the sole point to be considered.

It was early discovered that under asphyxiation, as under alcoholic intoxication, it is possible for a reactor to "pull himself together" for a brief space of time (a minute, or even several minutes), during which his efficiency on a set task may be as high as (or even higher than) his normal, at the termination of the task sinking to a relatively low level of efficiency. If given a series of tasks, with brief resting intervals between, the reactor may therefore accomplish a performance which is practically normal, even up to a minute or two before the point at which complete lapse of integration occurs. In this way his real psychological deterioration may be masked. It is necessary, therefore, to set a task which, although minimally fatiguing, is practically continuous, allowing the reactor no expected periods in which no work will be demanded of him, and thus preventing him from making use of attention peaks as the phases of "pulling himself together" may justly be called.

In determining the sensitivity or acuity of sense organs, on the other hand, the "attention peaks" are precisely in order, and pause should be taken to present the stimuli at the highest peaks.

Many tests which otherwise would be applicable impel the subject (reactor) to hold his breath during the crucial moments of the test. The conventional steadiness test is of this character. If the reactor, already suffering from oxygen deficiency, holds his breath for 20 seconds, or largely reduces his breathing during that period, he makes an important change in his oxygen supply, a change, moreover, which can not be measured. Hence the purpose of the test is largely defeated. The steadiness test, and others in this class, which may show marked effects of low-oxygen tension, can not be used.

Although it is desirable that the test employed shall in some degree correspond to the aviator's actual task in flying, it is important that it shall not use any of the movements or discrimination involved in flying, else it would be impossible to rate fairly both those with and without experience in planes.

A final composite reason for using a "clinical" method comes from the need for rapid work. Graphic records might be employed, but would largely hinder the expedition of the work on account of the time and labor needed for their interpretation. Moreover, in such rapid work fineness of gradation in rating would be seriously misleading, hence the greater exactness of graphic methods would be largely specious. For experimental work the matter is entirely different.

In addition to general limitations of method and apparatus due to necessary working conditions, there are specific limitations imposed by the rebreathing apparatus and the cardiovascular work which must be simultaneous with the psychological.

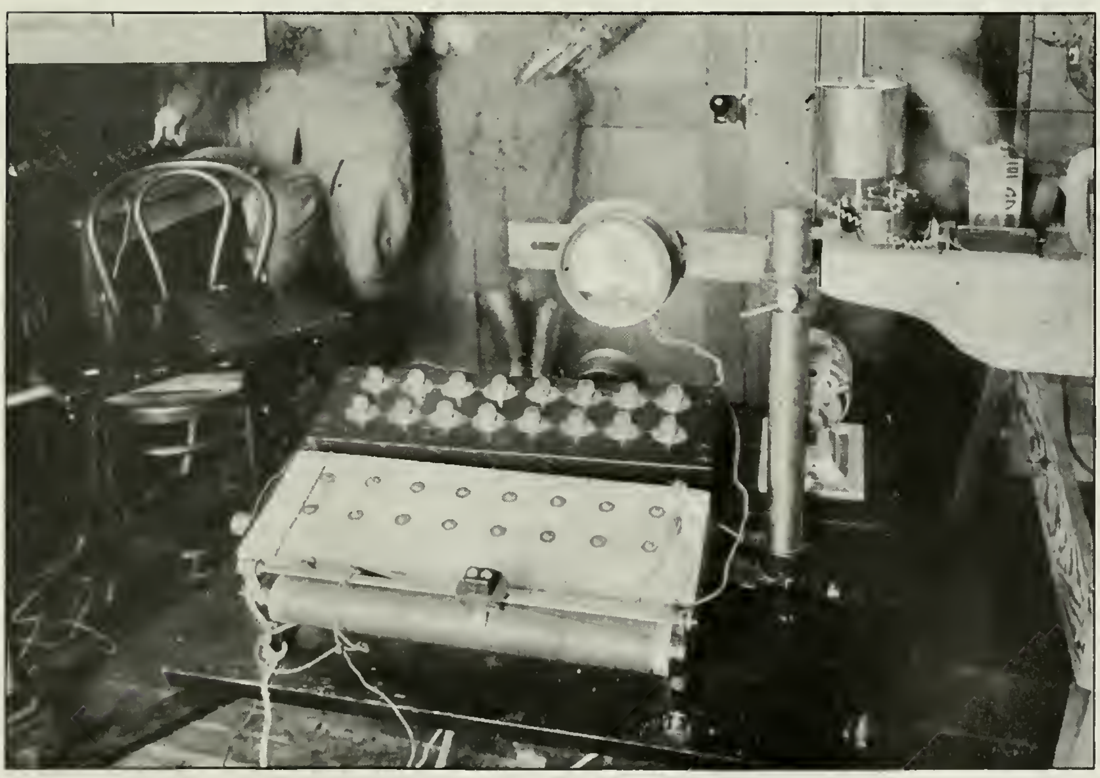
I. The reactor can not speak on account of the mouthpiece. This excludes such tests as the association reaction, which otherwise might be highly useful.

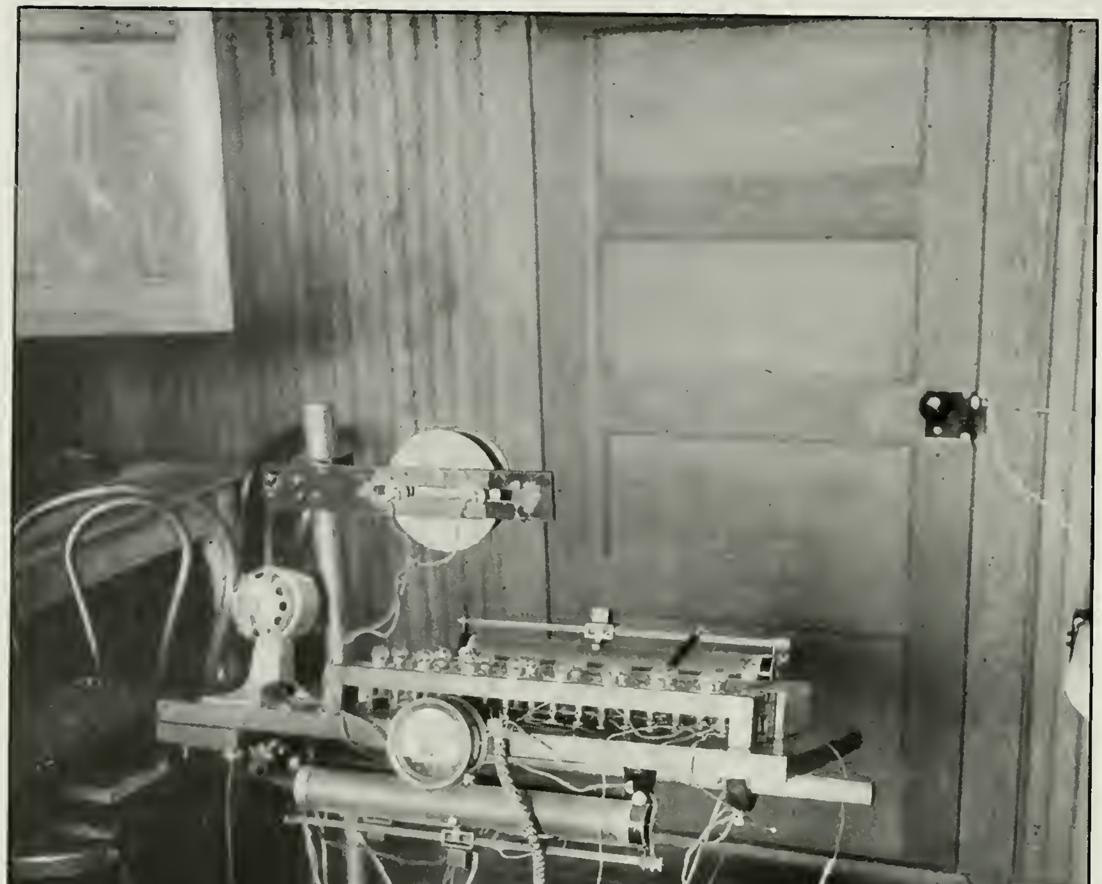
II. The reactor's head movements are narrowly limited and his field of view correspondingly restricted. This is not a very serious limitation.

III. The blood pressure, which is taken throughout the test, is taken from the reactor's left arm. This further limits the reactor's means of expression to one arm and his feet.

APPARATUS FOR THE STANDARD TEST.

The apparatus used for the psychological tests consists of two groups, (*a*) and (*b*). The (*a*) group includes a number of pieces assembled on a specially designed table, adjustable in height and slope, and swinging on a single heavy post mounted on a cast-iron base. This table is designed to furnish a sufficiently rigid mounting





and at the same time give greater convenience than could be afforded by a table with legs.

(*a*) The apparatus mounted on the table form three separate units, (1) a series of 14 stimulus lamps (2 c. p.) arranged in two rows of seven each, with two similarly arranged rows of contact buttons; each surrounded by a washer; a green check lamp and a red error lamp; and a stylus with a hard rubber handle and metal tip. These parts of the unit are so wired electrically that when a stimulus lamp lights the corresponding contact button is "alive," and if touched with the metal tip of the stylus causes the check lamp to light. If the washer surrounding any of the buttons is touched with the stylus at any time, the error lamp lights.

(2) Two ammeters mounted on a metal arm above the table top are connected in series with two rheostats, one on the upper side of the table top at the edge nearer the reactor, the other underneath, at the edge nearer the psychologist. One ammeter faces the reactor, the other the psychologist. A change in the resistance made by the psychologist at his rheostat, causing a change in the ammeter reading, may be compensated for by a change in the reactor's rheostat, by which the original ammeter reading may be restored.

(3) A small electric motor mounted on the upper side of the table top is connected in series with a third rheostat underneath the table. A two-way lever switch mounted underneath the table at the edge next to the psychologist and a rocking pedal two-way switch on the floor under the table are connected with the rheostat by a three-wire system, so that a part of the resistance of the rheostat can be cut out (thus increasing the speed of the motor) by either switch and again cut in (thus restoring the lower motor speed) by either switch.

(*b*) The second group of apparatus, on a small table in any convenient part of the room, consists of either a button board having 14 buttons, corresponding to the 14 stimulus lamps, or of an automatic distributor which lights the stimulus lamps in selective order and times their duration. With the button board an automatic flash timer may be used, requiring an assistant merely to select the buttons, or the assistant may time the flasher with a stop-watch as well as select the buttons.

The (*a*) and (*b*) groups of apparatus are provided with transformers to adapt the electric current to the 2 c. p. lamps, and are electrically connected with either and with the source of 120 volt a. c. current by flexible cables.

Method of conducting the test. The rebreathing machine should be adjusted by the physiologist to give a "standard run," which will vary in time according to the individual and his method of work, but which will bring a reactor of the A class to 7 per cent of oxygen in 25 minutes on the average. For this standard run the quantity of air in the tank at start is 60 liters.

The reactor, being seated in proper position before the (*a*) apparatus, is given the following instructions in printed form:

INSTRUCTIONS.

READ CAREFULLY.

You have three things to do:

1. *Lights.*

When a light flashes, touch with the stylus the top of the corresponding button. Do *not* touch the washer.

2. *Ammeter.*

Watch the ammeter and by adjusting the slide of the rheostat (using the right hand) keep the ammeter at the designated mark.

3. *Motor.*

Keep the motor at low speed by maintaining the proper positions of the pedal. When the motor speeds up, push the pedal from whichever position in which it may be (heel down, or toe down), into the opposite position, and leave it in the new position until the speed again increases.

NOTES.—(*a*) The lights are of first importance, i. e., if a light appears when you are reacting (or about to react) to the ammeter-hand, react to the light first and then go back to the rheostat.

(*b*) When you touch with the stylus a contact-button corresponding to a light, the movement of hand and arm should be a "free" one (neither arm nor hand should touch table, rheostat, or board). The hand may, at other times, rest on the slide of the rheostat.

(*c*) Do your work with ACCURACY, NEATNESS, and PROMPTNESS. Do not bang, slam, or jab.

While the reactor is reading the instructions, the psychologist is ready to explain any detail of the apparatus or method in which the reactor may show interest; and after the reactor has finished, the psychologist further explains the procedure and verbally emphasizes the important points in the instruction.

When the rebreathing machine is ready and the blood-pressure recorder has secured the requisite preliminary readings, the mouthpiece and nose clip being in place, the external opening of the mouthpiece is closed by the responsible clinician and the test commences. The psychologist and all others concerned in making the test start their stop watches at the moment when the rebreathing commences. The psychologist should record if possible the time which elapses between the insertion of the mouthpiece and the commencing of the breathing, unless a regular routine for this time be adopted.

During the first three minutes of the test the psychologist coaches the reactor if necessary and estimates his comprehension of the task

and instructions, his power of attention, and his composure (freedom from excitement or nervousness), entering these on the record sheet then or later as good, fair, or poor. He should also note the motor tendencies of the reactor, and if these fall in one or more of the following categories this also should be entered.

MOTOR TENDENCIES.

To be put on original record sheet *at bottom;* on official sheet under *general impressions, psychological;* on psychology record card under *notes:*

(1) Tremor.
(2) Tense.
(3) Impulsive.
(4) Steady.
(5) Rapid.
(6) Slow.
(7) Hesitant.
(8) Accurate.
(9) Inaccurate.
(10) (Combinations of above.)

Enter merely the appropriate type word or words; it is not necessary to write "motor tendencies."

In addition to these general tendencies, it is important that the psychologist take notice of the specific tendencies shown by the reactor, and if definite types of error are shown, watch during the succeeding five or six minutes for improvements in these details. In this way the "M" and "A" determination described below may be accurately noted as deterioration from the normal proficiency of the reactor, and not as failures with regard to an absolute standard. This is important, since the rating on these tests is valid only as an index of the effects of asphyxiation and not as an index of efficiency or inefficiency in any other respect. The comprehension, attention, composure, and motor entries are, however, worth recording in order that this data may be used later for purposes other than oxygen rating.

Normally the test continues until complete inefficiency is reached, at which point the psychologist must sharply notify the responsible medical attendant in order that the reactor may at once be given air, and so prevented from undergoing the collapse which would ensue in a minute or so.

The recognition of complete inefficiency is a matter on which the psychologist must carefully train himself. In general it shows in a definite way, as described below, but may show in forms which are readily recognized by the trained observer but described with difficulty.

In many cases the responsible medical attendant will find it necessary to stop the test because of dangerous cardiovascular symptoms before inefficiency is reached.

In commencing work on the reactor it is advisable to allow him to react to the lights alone during the first minute and add successively the changes in the motor noise and in the ammeter readings. He should be working on all three tasks by the middle of the third minute.

In observing, the psychologist needs to attend as constantly as possible to the behavior of the reactor, and hence must reduce the labor of recording to a minimum. For this purpose and for the purpose of standardizing the method of observation the following symbols have been adopted:

SYMBOLS AND THEIR SIGNIFICANCE.

→	Rebreathing starts.
W	Work begins.
V	First significant effects on "voluntary coordination."
♀	"Fumbling"; clumsy; inaccuracy in touching targets.
ʔ	"Groping"; approaching target with corrective movements. Usually a compensation for ♀.
E	Increased "effort" or force in applying stylus to targets.
Ǝ	Decreased effort.
I	"Impulsive" or uncontrolled movements: a, on the outward movement; to the target. b, on the return movement.
S	Slowing of reactive movements.
F	Speeding of reactive movements.
V	First significant effects on "attention."
dl	"Distraction" from lights, neglects lights.
dl-v	Neglects lights for voltmeter.
/	(Contraction for dl I.) Reactor delays initiating stylus movement so long that he fails to light check lamp.
//	Reactor delays so long that he touches the target after light has gone out.
///	Reactor starts movement after light has gone out.
////	Reactor makes no attempt to initiate light reaction.
dv	"Distraction" from the dial; neglects to note and adjust the position of the index hand.
dn	"Distraction" from the noise; neglects to control the speed motor.
/Cl/	Confusion between rows of lamps; but finally touches the right target.
$\overline{\underline{Cl}}$	Confusion between columns of lamps; but finally touches the right target.
/$\underline{wl}$/	Selecting target in wrong row.

wl Selecting target in wrong column.
Wv Wrong direction on the dial.
WN Wrong shift of pedal.
◇M Two of the symptoms, ♀, ʔ, I, and E, repeatedly. In certain cases, exaggeration of *one*.
◇A Two of the symptoms, dl, dv, dn, ///, /Cl/, Cl, Zv. In certain cases, exaggeration of *one*.
O "Inefficiency." Inability to control any of the three tasks. The reactor sometimes stares at the lights without making any attempt to touch the target; or makes merely irrelevant touches. Completely disregarding L and N. Sometimes he develops severe tremors or jerks which render it impossible to work. Occasionally a reactor develops unique symptom at this point.
* Breakdown. Reactor ceases to work and commences to collapse. This comes very soon (30″ to 2′) after 0; is qualitatively a much more serious condition.
X Reactor "taken off." Air or oxygen given him.

ADDITIONAL SYMBOLS FOR SYMPTOMS WHICH MAY BE OF DIAGNOSTIC AID.

∿∿ Tremor of the hand.
VVW Jerkiness of the hand.
H Swaying or drooping of the head.
T Taps button more than once.
R Rests hand or fingers while touching button.
K Keeps stylus on button after making touch.

In general, the "arrowheads" (→) and "diamonds" (◇) are not inserted until after the test is finished.

On the completion of the test the entries on the record sheet are completed, and the material is now ready for rating, which is done on the following basis:

RATING SCHEME.

1. Take 25 minutes as the standard duration of a run. If the O or X appears before the end of 25 minutes, debit one point for each minute; similarly, credit one point for each minute in case O or X appears after 25 minutes.

2. Assume as a standard of altitude 7 per cent of oxygen for O or X. Debit or credit one point for each $\frac{1}{10}$ of 1 per cent.

3. As in the case of 1, take 25 minutes as the standard time for the appearance of both of the two diamonds. Debit or credit one point for each minute as above.

4. Assume 15 minutes as the standard time for the appearance of both the two arrowheads. Debit or credit for each minute as above.

5. If the record of the subject tested be such that either arrowhead or either diamond can not be entered, compute the symbol in question as if it fell at the point of O (or X, if O be not reached; see paragraph 6, below).

6. Add the debits and credits, and assign to class as follows:

+n	0	Class A+
0	—12	Class A—
—12	—30	Class B
—30	—n	Class C

7. Where an oxygen tension of 8 per cent or less is not attained in less than 30 minutes, a grade above B shall not be assigned. For runs reaching a low percentage (below 7 per cent) in less than 22 minutes, discretion may be exercised in debiting for earliness of symbols. Such short runs are especially to be avoided if possible.

8. For a definite rating O must be used. However, in case the test was stopped by the clinician without reaching O, the tentative rating may be computed from X. If this tentative rating is A, it is to be entered as such. If, however, the tentative rating is of a lower class, it is to be entered with the addition "or higher." This phrase "or higher" shall always indicate that the reactor was removed before reaching (O), and not at the instance of the psychologist. It is not to be entered in any other case.

On first glance the rating scheme seems to be based on time rather than on oxygen percentage, but this is only apparent. If every reactor was run through at the same rate, for example, a rate of oxygen depletion at which 7 per cent would be reached in 25 minutes, it would be immaterial whether the oxygen percentages or the times at which the arrowheads, diamonds, and circles are reached should be used, since there would be a fixed correspondence between these. Since rates vary in accordance with the individual rates of oxygen consumption, and since a faster rate enables the reactor to reach a lower percentage, and a slower rate brings inefficiency at a higher percentage it is necessary to make allowance for the variations in rate. This can be done either by computing in oxygen percentages, and then making a correction for the time, or more simply, as in the scheme actually employed, by computing in times, as if the oxygen change followed a line of the same slope in each case, and then correcting for deviation from this slope in terms of the final oxygen percentages reached.

The rating scheme is adequate to classify the reactors in the four groups (A–plus, A–minus, B, and C), provided the psychologist who does the observing also does the rating, and exercises due judgment, based on his general observation of the reactor's work, in rating those cases which lie near the limits of the several classes. The scheme should be an assistance to the psychologist's final judgment, not a hampering condition, although the most satisfactory results will be obtained by relying on it very substantially.

The chief difficulty with this method of testing is in the heavy and exhausting labor entailed on the psychologist. Necessarily his attention is kept at a high level throughout the test, and it has already become evident that a full daily program will not be possible as a continuous thing. It is hoped that it will be possible to supply two psychologists with each testing unit of which heavy duty is required, in order that they may relieve each other and maintain the efficiency of the unit.

In making the test, diligent care must be exercised to prevent the reactor from being anxious or alarmed as to the experience he is to undergo. Hence no remarks must be made in his presence as to danger or serious discomfort, and, if necessary, assurance should be given that the test makes no great demands on the reactor. It is also important that instructions be given in a routine way, the same for all reactors; otherwise the purposes of the test as a relative rating scheme are in part defeated.

The temporary physical condition of the reactor is also a matter which should be carefully considered. Loss of sleep, worry, dissipation, or other causes which reduce general resistance are apt to reduce the capacity for endurance of oxygen deficiency, and produce an earlier onset of psychological inefficiency than would occur under better conditions.

On the other hand, the reactor may be in bad shape physically or mentally (from worry, etc.) and yet make a very good record. One reactor, for example, who made an unusually good record, with fine motor control and efficient attention down to a low percentage of oxygen, had had but a few hours sleep in 48 hours, felt in "rotten" shape, and expressed himself anxious to come back when he felt better, "to see what he really could do on the test."

In short, the test gives a measure of endurance of oxygen deficiency solely, and while this endurance may be affected by a variety of factors, it gives no measure of these factors.

Some incidental results of the work on rebreathing.—It is apparent that a great deal which has come to light in the course of the work will be of value for work more or less closely allied. Findings in regard to the precise effect of oxygen shortage, and the concealment of these effects through "attention peaks" point to an application, with a possibility of clearing up certain puzzling results of earlier work. The same application may be made in studies of fatigue, in which in the past no great success has been attained with psychological tests. Alcohol and drug effects may also be attacked anew in the light of the present work.

The relation of certain emotional states to systolic pressure has also appeared in an interesting way. The conspicuous thing which has come out is that apprehension—the feeling which can be described as "now we are off; I wonder just what will happen to me"—is associated with a temporary rise in systolic pressure. Observation in these effects in rebreathing led us to experiment with various expected stimuli (pretended doses of drugs, threatened stimuli of undescribed kinds) with quite uniform results. Where fear enters, the systolic rise tends to be sustained. An interesting series of observations has been started on the systolic effect of announcing to cadets, waiting on the field for instruction, their turns for flight. It is possible that very practical results may be obtained in this way, in information concerning the temperament of the cadets.

III. THE PSYCHOLOGICAL QUALIFICATIONS OF THE FLIER.

It was pointed out above that the flier needs not only to fly, but also needs to be able to perform definite tasks—observing, signaling, operating a machine gun, etc.—without which the ability to pilot a plane would be of little military use. It is desirable, therefore, to determine, in so far as it may be possible, the aptitude of the candidate for the acquisition (in the ground school) of the fundamental training which may fit him for the required range of work, and to determine his capacity for learning and performing adequately the tasks for which the ground school work is intended to fit him.

To a certain extent a survey of the candidate's school and college training is a means for the determination of his possibilities, since the specific sorts of training he has already received are thereby revealed, and since, moreover, such schooling is in itself a process of elimination of those who are not intelligent and adaptable. This method of determination might well be supplemented by "intelligence tests" of the customary type; but even these additions would not take the place of specific tests of the functions which are known to be important in flying.

The important problem is the discovery of the tests which shall be practicable. The plan which we have followed in this work is, first, to develop tests which promise to be applicable to the aptitudes it is desired to investigate; and second, to give the tests so developed to a large number of fliers whose actual flying ability can be definitely known. By comparison and correlation of the results of the tests with the actual efficiency ratings of the fliers, it is possible to determine the applicability and usefulness of the tests. In some cases the development of the test itself is a difficult experimental undertaking; in other cases the tests are easily obtained, requiring merely the application and correlation.

Evidence of flying ability is obtained, for the purpose of comparison with the results of the tests, from the men who have trained the fliers tested, and have observed their individual progress in the work of aviation. The value of any test of a specific function which may be important for aviation must ultimately rest solely on this comparison. No theoretical considerations of the qualifications of a flier can be substituted for the empirical determination of the relative flying abilities of men differing in respect to the qualifications in question.

Experimental work on the problem of flying qualifications has been done at San Diego and Berkeley and is in progress in this laboratory. Some of the points attacked are:

(1) Reaction to auditory, tactual, and visual stimulations, and to changes of position of the body: The time required for reaction to the stimuli of the sorts mentioned is measured, and the individuals are rated on their average reaction times of each sort, and their variability. While nothing important is to be expected to result directly from the measurement of the simple reaction times to sound light and touch, even the negative finding, if it occurs, is important.

(2) Discrimination time: The time required to discriminate accurately between different stimuli suddenly presented.

(3) Association reaction time: The time required to reply to a spoken word with another word which is related to the stimulus word in a prescribed way. For example, nouns may be given and the reactor required to respond in each case with an adjective appropriately modifying the noun; or verbs may be given and the reactor required to respond to each with the name of an object appropriate for the action indicated by the verb. In this work the time is measured and the appropriateness or accuracy of the response is evaluated as well.

(4) The rate at which a person can learn a certain complicated muscular coordination involving the hands and feet in somewhat the way required in piloting a plane.

(5) The sensitivity to gradual changes in the position of the body in horizontal and vertical planes. Several important researches are in progress on points connected with the analysis of the highly complicated psycho-physical mechanism involved in the maintenance of equilibrium.

(6) The capacity to acquire certain simple forms of dexterity.

(7) The temporal and other conditions of the appearance of the signs of fatigue.

There are also in progress experiments on orientation; the ability to find one's way about, and to know, from moment to moment and from position to position the direction and distances of important near and far features of the environment. This may readily be granted to be a topic of the highest importance for aviation, although the various tests which are being developed are not yet in the stage of application to aviators, by which application only, as indicated above, can the practical value of the tests be determined.

PSYCHOLOGICAL INVESTIGATIONS WITH LOW OXYGEN TENSION.

1. *Judgment.*—A test of judgment has been carried out under supervision by enlisted psychologists. On each of a large number of blank playing cards, a nonsense syllable was printed in large letters: PEL, GUJ, KIM, CEZ, etc. A card rack with five compartments (fig. 4) was made, into which stacks of the cards fitted conveniently. In the second compartment from the right, the shuffled cards were stacked, separated into groups of 13 by blank cards. Over the three compartments at the left, the following labels were pasted:

1.	2.	3.
JEL DIM	MAX FOD	TID LEF

The reactor was required to take the cards from the stack one at a time and file each card in the compartment under the label to which the syllable on the card had the greatest resemblance. For example, PEL belongs in the first compartment, having two letters in common with the first label, only one in common with the third, and none in common with the second label. Cards which belonged in none of the three compartments were to be filed in the compartment at the extreme right.

The psychologist took with a stop-watch the time for the sorting of each set of 13 cards, and signaled to the reactor to begin a new set every two minutes from the beginning of the test. By using a fixed "headway" in this way, the amount of work done is uniformly distributed through the series.

At the end of the series, the filed cards were checked for errors. Normal and rebreathing series were taken on 12 reactors. In the "normal" series, the reactor sat before the rebreathing machine, with the mouthpiece and nose clip in place, but breathing normal air. The typical results in one subject, showing the practice effect, and lack of consistent oxygen effect up to the beginning of general psychomotor decline are presented in figure 5.

2. *Tactual discrimination.*—A test of tactual discrimination was carried out under supervision in the following way: Cards were prepared, each having a diamond-shaped hole cut in it in one of four positions (fig. 6). The card rack as described in the preceding experiment was used with a screen so arranged that the reactor could not see the cards nor his hands. Above each of four of the compartments of the rack was fixed one of the four types of cards and in view of the reactor. The cards to be sorted were shuffled, arranged in sets of 20, separated by blank cards in the fifth (right-hand) compartment.

The reactor was required to take the cards off the stack, one at a time, identify them by feeling them with the fingers, and file them in the proper compartments. Time was taken on the sets, and subsequent check of the sorted cards made for errors, as in the judgment experiment. "Normal" series on 10 men were conducted with the mouthpiece and nose clip of the rebreathing apparatus in place, but with the reactor breathing normal air, and other series taken on the same men while rebreathing. In this test no "headway" was used, the reactor commencing on another series as soon as one was finished. A typical result of the normal and rebreathing series on one man is presented in figure 7.

3. *Code test.*—A code test gave results similar to the foregoing tests, except that in the reading of the material to be coded adjustments of accommodations and convergence are important, and deterioration in these functions in some cases seriously affected the results.

8–B

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

H U M C B L Y E S I D K N A X W P T V Q R O J G Z F

K X B K P G S I Z R Y U L K E H Q X E G B D W V

O I X W T B A Y K E B D E G K G

FIG. 8.—Code test.

In this test, the codes used, and the material to be coded, were arranged on a series of cards as in figure 8, and these cards were presented in succession to the reactor, who was required to write the coded message in the lower part of the card.

4. *Dynamometer test.*—In order to find the effect of asphyxiation on the muscular force capable of exertion by limited systems, a series of dynamometer tests were run through. In these tests, the reactor was required to exert his maximal effort on a hand dyna-

mometer every two minutes. Normal and rebreathing series were taken on 10 reactors. Typical results on one reactor are presented in figure 9.

5. *Handwriting.*—In order to measure the effect of oxygen hunger at different barometric pressures, and the completeness of the restoration process attained by the administration of oxygen, a simple handwriting test was devised and carried out in the low-pressure chamber. A standard psychological vocabulary test of 100 words was used in making up the test cards. The 100 words of the standard vocabulary test were cut up and put in a hat and shuffled. As the words were drawn from the hat they were typewritten on a standard library card. By this method three test cards of 100 words each were obtained. The task of copying these cards offered the same difficulty to the subject since the same words were used on each test card only the order being different. Since the copying of words is an old-established habit, there was little improvement through practice.

The test was carried out as follows:

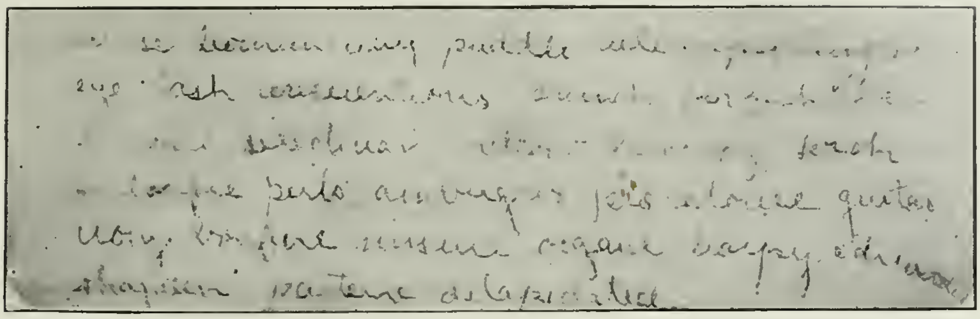
The subject was seated at a table in the tank. On a given signal the motor of the tank was started, but the pressure was not changed. The subject was handed card No. 1 and was asked to copy it as neatly, as rapidly, and as accurately as he could. As soon as this task was completed, the time of writing the card was taken. (This gives the normal record.) The signal for ascent (decrease in pressure) was then given. The ascent was made at the rate of about 1,000 feet per minute. After the subject had reached the given height he was kept at that level for 15 minutes with the motor running (to keep the noise constant). At the end of the 15-minute period at the given height the subject was asked to copy the second test card. After completing the copying, his time was taken as before. (This gives the oxygen-hunger record.) The subject was then given oxygen for two minutes and was then asked to copy the third test card. (This gives the oxygen-restoration record.) Upon the completion of the latter, the signal for descent was given.

The results from these handwriting tests were then treated as follows: First, they were measured (with reference to general form and legibility) on the scale for handwriting. This scale, as is well known, enables one directly to measure the quality of a given handwriting production in terms of certain units. For example, his normal might correspond to unit 12 on the scale; his oxygen-hunger record might correspond to unit 8 on the scale.

In rating the tests on the various subjects a penalty of 20 was attached for each unit lost on the scale. In addition to this rating on the scale, the following penalties were also imposed:

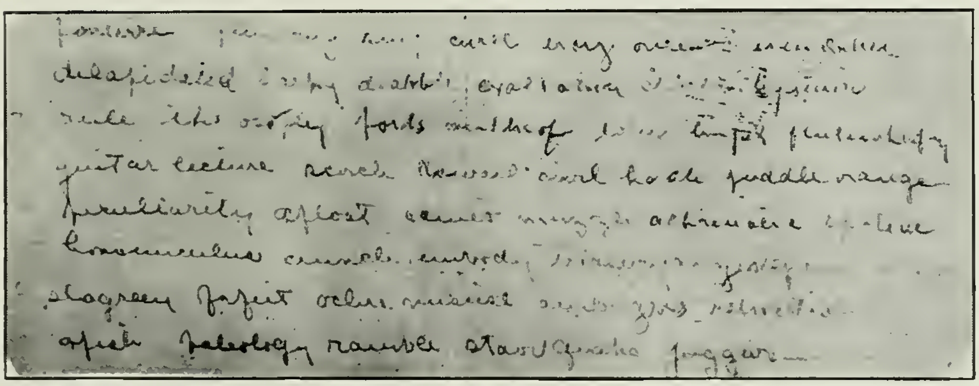
CAPT. BORING. (Fig. 10a.)

Handwriting, standard card—normal. 14,000 ft.



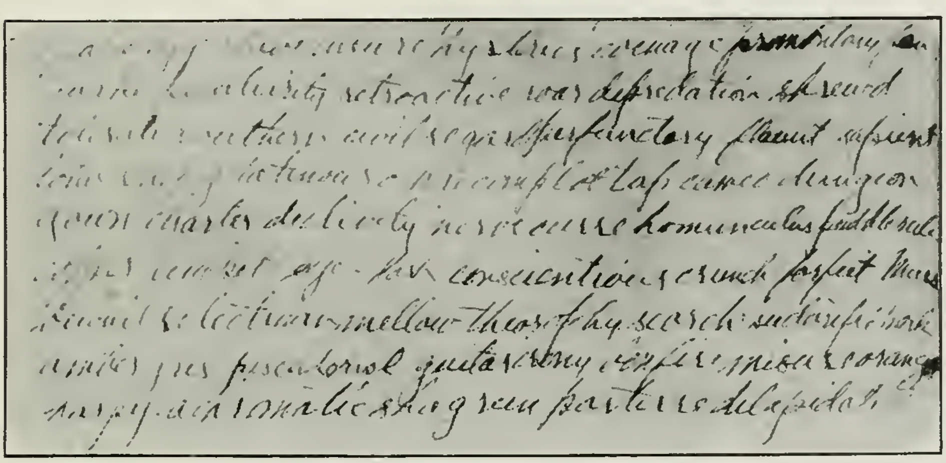
CAPT. BORING. (Fig. 10b.)

Handwriting, standard card—oxygen hunger. 14,000 ft.



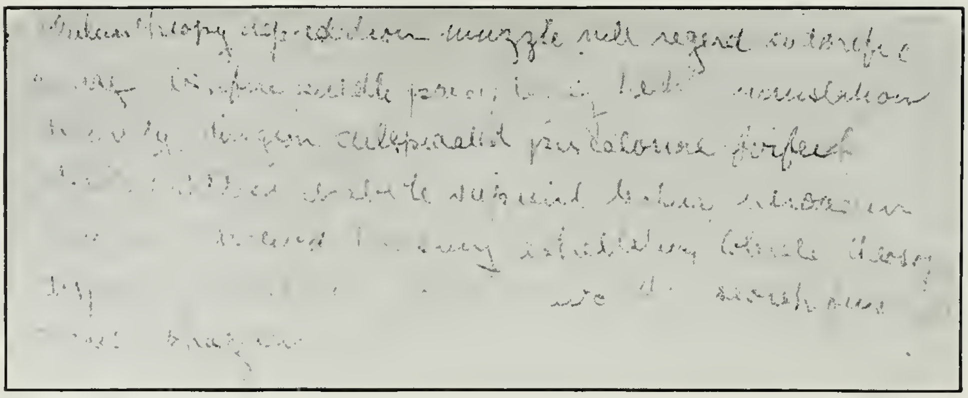
CAPT. BORING. (Fig. 10c.)

Handwriting, standard card—oxygen restoration. 14,000 ft.



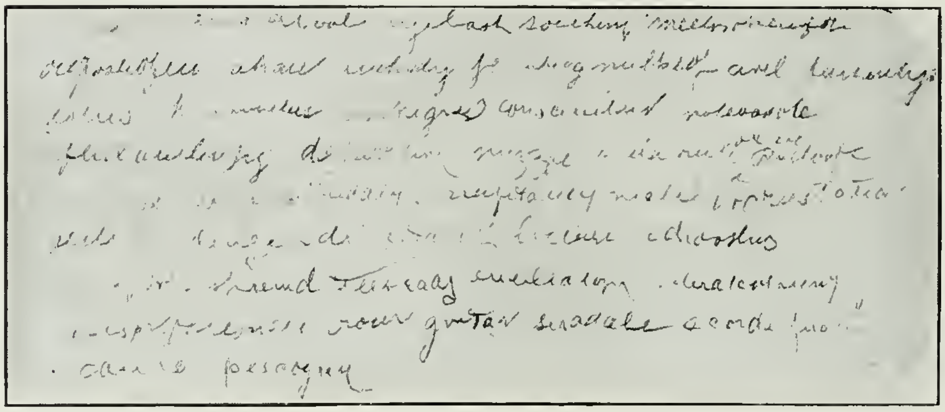
PVT. WICKMAN. (Fig. 11a.)

Handwriting, standard card—normal. 18,000 ft.



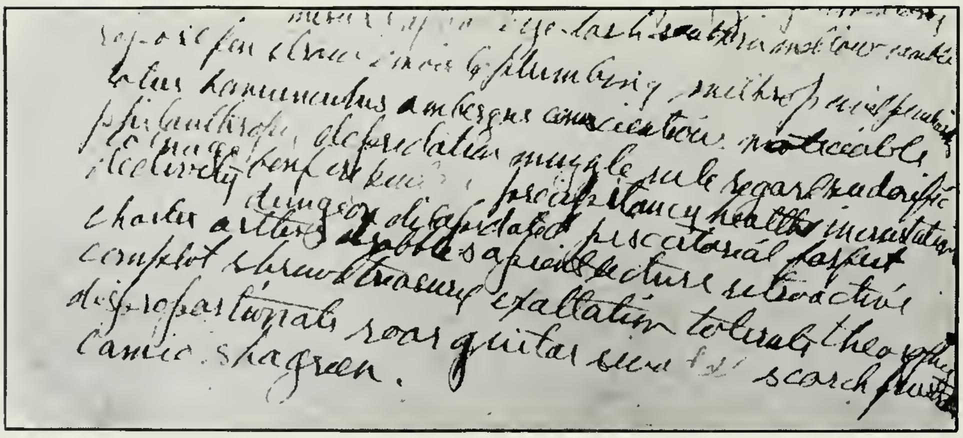
PVT. WICKMAN. (Fig. 11b.)

Handwriting, standard card—oxygen hunger. 18,000 ft



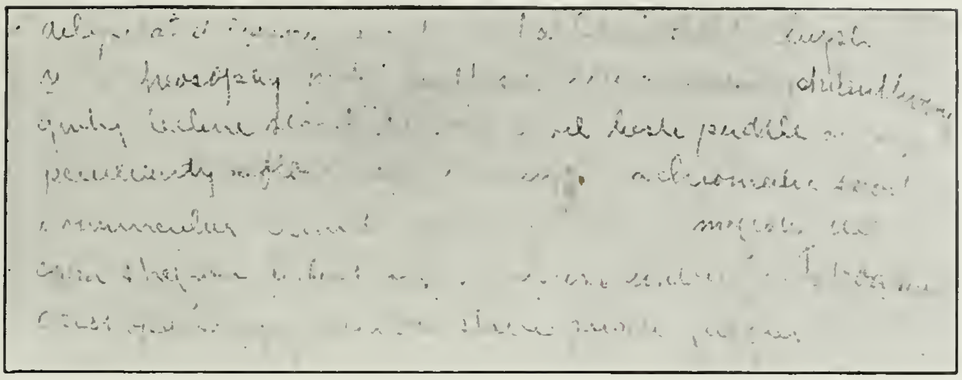
PVT WICKMAN. (Fig. 11c.)

Handwriting, standard card—oxygen restoration. 18,000 ft.



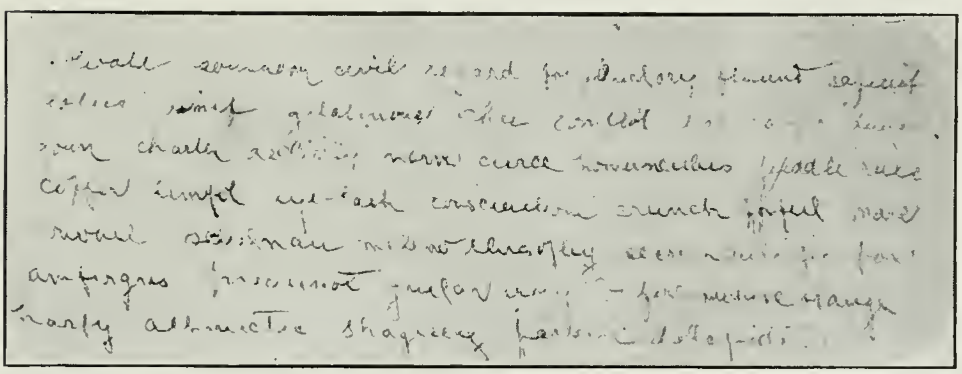
CAPT. DAVIS. (Fig. 12a.)

Handwriting, standard card—normal, 22,000 ft.



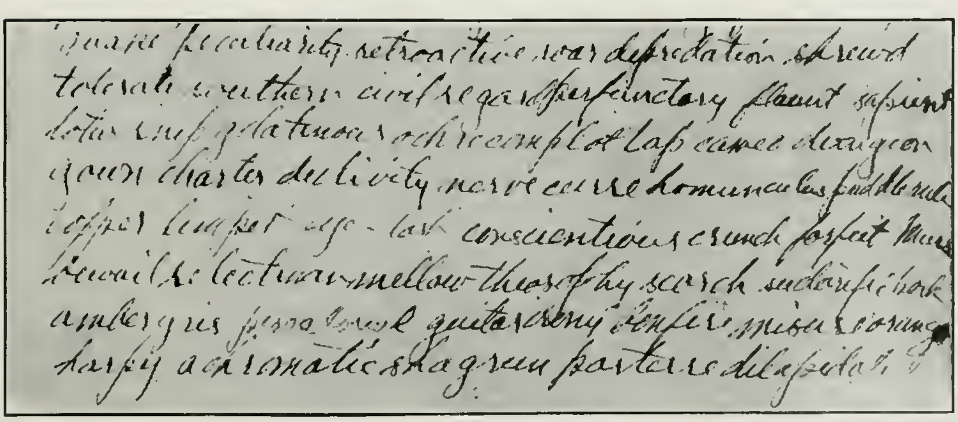
CAPT. DAVIS. (Fig. 12b.)

Handwriting, standard card—under oxygen hunger. 22,000 ft.



CAPT. DAVIS. (Fig. 12c.)

Handwriting, standard card—oxygen restoration. 22,000 ft.



For each word omitted, a penalty of 2.

For each word misspelled or wrong word used, a penalty of 2.

For each word crossed out and rewritten, a penalty of 2.

For each word careted in, a penalty of 2.

For each word or letter thereof written over, a penalty of 2 each word.

Failure to follow line as well as original, a penalty of 2.

For each 10 seconds' increase in time over the normal, a penalty of 1.

For each 10 seconds' decrease in the time of writing, a credit of 1 was given.

It will thus be seen that errors in the normal are estimated as well as those made under oxygen hunger or after oxygen administration. A typical record follows:

Record of Pvt. Wickman, altitude 18,000 feet.

	Normal.	Under oxygen hunger.	Two minutes after administration of oxygen.
Legibility rated on scale, last 8 lines only (penalty of 20 for each unit lost on scale; credit of 20 for each unit gained)	0	− 80	0
Word omitted (penalty of 2 each word)	0	− 12	0
Word mispelled or wrong word used (penalty of 2 each word)	− 2	....	0
Word scratched out and rewritten (penalty of 2 each word)	0	− 2	0
Word careted in (penalty of 2 each word)	0	....	0
Word (or any part thereof written over, penalty of 2 each word)	− 4	− 6	0
Failure to follow line as well as original (penalty of 2 each line on last 8 lines)	0	....	0
Time, penalize 1 for each 10 seconds increase or credit 1 for each 10 seconds decrease	0	....	+ 3
Total penalties or credits	− 6	− 100	+ 3

These tests have been made at 14,000 feet, 16,000 feet, 18,000 feet, and 22,000 feet. While complete records are not in, the results so far obtained show that at 14,000 feet the effect of oxygen hunger is exceedingly slight (see fig. 10); at 16,000 feet the effect is scarcely more noticeable; while at 18,000 feet, on some subjects, at least, the effect is extremely marked (see fig. 11, the same subject). The handwriting—in some cases—becomes difficult to read, whereas other errors in spacing, following the line, omission of words, etc., are very marked. At 22,000 feet the first two subjects fainted, and it was not possible to continue the experiment. So far only one record has been obtained at 22,000 feet (fig. 12).[1]

In every case, except those where heart dilatation and fainting occurred, the 2 minutes' administration of oxygen completely restored the handwriting to normal.

[1] It should be noted that the altitudes are given by altimeter readings, and should be considerably increased if allowance is made for the difference in temperature of the air in the tank and that corresponding to the same pressures in the upper atmosphere.

It was planned to continue this experiment by the same method with the machine-gun camera and with a telegraph recording outfit, and to obtain and contrast a similar set of records on the rebreathing tank and the refrigerated pressure chamber. It was thought that the results on the handwriting test, the machine-gun camera, and the recording telegraph would give a tangible picture to the aviator of just what difficulties he would meet with in the air in writing messages, in sending them, and in the accuracy of his machine-gun work, and how these difficulties could be overcome by the use of oxygen.

6. *Memory.*—Various tests on memory were employed. For immediate memory, series of from 5 to 12 consonants are numbered, and series of from 2 to 5 observations, each made up of a color name and a number, were employed. Samples of the consonant series and observation series are given below:

RKZWT
CXWNZF
JLXBRVN
NHBDZVCR
VJSRBLTMW
HRKGWMDPTL
ZXWKDTNVSHQ
YPCQDKWZMTBJ

The observation series were made up in pairs of series, the same color name not occurring in both series, and in the tests the two members of a pair were given in succession, in order to avoid confusion between successive series.

The "observation tests" were especially satisfactory as tests and may be used successfully where immediate memory tests are required. Neither test, however, showed any deterioration in immediate memory due to asphyxiation.

a.		b	
white	63	ecru	81
russet	84	black	52
gray	47	green	24
amber	28	lilac	73
violet	96	orange	35
red	58	blue	74
tan	14	buff	29
gold	85	rose	95
azure	46	drab	62
yellow	69	purple	79
scarlet	57	crimson	13
straw	25	slate	68
brown	18	pink	37
lavender	36	indigo	92

For visual memory the position memory board (fig. B) was used. This board has mounted in a vertical plane 49 miniature lamps arranged in a square pattern, the individual lamps 3 inches apart, vertically and horizontally. By means of a plug board and master key behind the board any number of lights from 1 to 14 can be lighted simultaneously in any chosen position. In practice the reactor was shown from three to seven lights for three seconds, and then required to chart the positions on a printed form (fig. 14). The lights were presented before or during the rebreathing test, and the charting was done immediately, or after a short or long interval. While no effects of asphyxiation were demonstrable up to the time at which the marking of the chart became impossible on account of disturbance of motor control, the method appears valuable for other than the rating work.

7. *Mathematical tests.*—Several mathematical tests were employed, the most satisfactory being the attention test. In this test two sheets, each containing 16 lines of 45 digits each, were used. Each of the 32 lines of digits was carefully made up so that the lines two sheets, each containing 16 lines of 45 digits each, were used. Each of the 32 lines of digits was carefully made up so that the lines presented equal difficulty. Before commencing the test a standard number of 12, 13, 14, or 15 was written before each line and the reactor required to add the digits in each line, beginning at the left, until the progressing sum equaled the standard number or one over that number, drawing in each case a line between the last digit of the group added and the next digit and writing the difference, if any, between the sum of the group and the standard number over the group. By changing the order of the standard number, 128 lines are available. A typical sheet of this test is shown in figure 15.

This test showed no definite asphyxiation effects prior to the period of general psychomotor decline, and is affected somewhat by eye conditions and practice effects. It has shown possibilities of advantageous use for other practical purposes, however, and work will be continued with it.

8. *Auditory tests.*—Tests on the sensitivity and acuity of the various sense organs. By using brief tests which permit the attainment of "attention peaks," it is demonstrable that the efficiency of the various sensory mechanisms does not show appreciable deterioration until the general psychophysical breakdown. Our detailed work has been principally on auditory efficiency, with some work on visual efficiency done before the ophthalmological section was organized.

Tests on the range of auditory perception of 12 reactors, with a set of 22 steel cylinders, with range up to 32,000 vibrations (fig. 16), showed no difference between normal and rebreathing series up to the point of general psychomotor inefficiency. Tests with the acumeter (fig. 17) for sensitivity to the note of 256 vibrations are at present being carried on, and so far indicate no consistent deterioration of sensitivity until the late stages of asphyxiation. In other words, the reactor can hear as faint a sound, up to a late stage of asphyxiation, as he can in normal condition if his attention is good at the moment of listening. As has been previously explained, the "attention peaks" can be evoked even in relatively late stages of asphyxiation if the experiment is conducted by the methods usually employed by trained psychologists.

9. *Continuous reaction.*—The continuous-reaction board (fig. 18) which was used in one of our early tests, and which was, as a matter of fact, the starting point from which our final apparatus for the rating tests (LVN apparatus) was developed, could not be used for rating work because of the rapid but variable improvement with practice in its manipulation. In this apparatus 24 miniature lights are arranged in a circle, with a two-way switch at the base of each. By a master switch, a lamp is lighted; the reactor is required to turn off each lamp as soon as it lights by moving the appropriate switch; the turning off of one lamp turns on another at some point in the semicircle determined by the previously arranged interconnection of a switchboard concealed within the apparatus so that the reaction is a continuous one until the twenty-fourth lamp has been turned out, or may be continued through a longer period.

IV. FURTHER PSYCHOLOGICAL INVESTIGATIONS OF PROBLEMS OF AVIATION.

1. *Decrease of after-nystagmus times with successive rotations.*—The importance assigned, in the examination of aviators, to certain ocular movements which follow upon rotatory movements of the head and body has suggested an experimental investigation into the effect upon these ocular movements of rotations continued for several days or weeks together. Experiments have made it apparent that under certain circumstances persistent rotation in the clinical revolving chair leads to a considerable reduction in the violence and the duration of these characteristic ocular movements. In one case the duration of the after-nystagmus, e. g., as observed during May, 1918, fell from about 25 seconds to 11 seconds after several daily series lasting for a few minutes a day at a constant rate of one revolution in 2 seconds.

Further to investigate the effect of repetition upon ocular movements, six enlisted men were turned ten times a day (five times right and five times left) between June 6 and July 13, 1918. Two of the men were begun later than the others and intervals of one or more days interrupted here and there the continuity of the diurnal trials. The results are given in the accompanying Table I (fig. 19) and chart.

TABLE I.

		Brown.		Caplan.		Rahill.		Stewart.		Wichmann.		Ackermann.	
		Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.
June 6	R	26.6	1.9	23.2	2.6	22.2	2.2	24.3	6.7				
	L	27.6	1.7	29.4	2.5	20.6	1.5	25.6	1.5				
	1-5	27.2	2.2	27.6	3.9	22.8	2.2	22.0	4.0				
	6-10	27.0	1.6	25.0	2.8	20.0	.8	28.0	3.0				
7	R												
	L												
	1-5												
	6-10												
8	R	22.3	2.9			20.8	1.4	22.0	2.6				
	L	25.0	2.0			20.2	3.4	23.6	3.1				
	1-5	24.0	4.0			21.6	2.3	19.7	.9				
	6-10	16.7	4.3			19.4	2.7	26.0	1.3				
9	R												
	L												
	1-5												
	6-10												
10	R	20.2	.6	19.6	1.9	20.2	3.4						
	L	21.4	1.3	23.0	1.2	19.0	3.6						
	1-5	21.0	1.6	22.2	2.0	20.6	2.9						
	6-10	20.6	.5	20.2	2.2	18.6	3.4						
11	R			14.5	1.3	15.0	2.4	17.6	2.1				
	L			20.0	1.3	13.4	3.0	17.0	2.4				
	1-5			17.5	2.5	17.0	2.8	19.2	1.4				
	6-10			16.5	2.5	11.2	1.4	15.4	1.7				
12	R	22.0	2.8	17.0	2.0	15.8	1.4	16.4	1.9	28.0	5.2		
	L	22.8	2.2	20.7	1.8	13.8	2.2	16.0	1.6	28.0	4.0		
	1-5	21.4	2.9	18.3	2.8	16.0	1.2	17.0	1.8	32.2	5.6		
	6-10	23.4	1.9	17.5	2.3	13.6	2.1	15.4	1.5	23.8	2.6		
13	R					12.8	1.7	14.0	4.0	28.6	2.1		
	L					11.4	2.3	14.4	1.5	29.4	4.7		
	1-5					13.6	1.9	16.6	2.1	31.8	2.2		
	6-10					10.6	1.7	11.8	1.8	26.2	3.0		
14	R	18.0	1.6	14.2	.6	12.4	1.5	9.6	1.7	23.4	2.0		
	L	16.8	1.4	19.2	1.8	11.0	1.2	9.2	1.7	24.6	1.3		
	1-5	18.6	1.1	17.0	2.8	13.2	.7	10.8	.6	25.4	.7		
	6-10	16.2	1.4	16.4	2.5	10.2	.6	8.0	.8	22.6	1.3		
15	R			14.2	2.6	10.8	1.0	6.8	1.0				
	L			15.0	2.0	10.6	1.5	7.8	.9				
	1-5			15.2	3.0	11.6	1.3	6.6	.9				
	6-10			14.0	1.6	9.8	.6	8.0	.8				
16	R												
	L												
	1-5												
	6-10												
17	R	24.4	2.7	13.0	3.0			8.8	1.8	27.6	2.7		
	L	21.8	3.4	18.0	1.0			9.8	1.5	29.0	1.6		
	1-5	22.6	2.5	16.0	.0			10.8	1.0	27.4	2.1		
	6-10	23.6	4.5	15.0	5.0			7.8	1.4	29.2	2.2		
18	R			14.4	1.5	14.2	2.6	10.8	2.1	23.2	2.2		
	L			16.2	1.6	12.8	2.4	10.0	2.0	22.8	1.8		
	1-5			15.6	1.1	14.0	2.8	12.0	2.0	24.6	2.1		
	6-10			15.0	2.0	13.0	2.4	8.8	.7	21.4	.7		
19	R	18.4	2.1	14.8	2.6	14.8	2.2	7.6	.5	23.6	1.9		
	L	16.2	1.4	15.2	1.4	13.4	.9	7.8	1.4	23.6	2.5		
	1-5	18.0	1.9	16.4	1.7	15.2	1.8	8.2	.6	23.6	2.5		
	6-10	16.0	1.2	13.6	2.5	13.0	.4	7.2	.6	23.6	1.9		
20	R			11.4	1.1	13.4	1.8	5.6	1.5	19.0	2.0		
	L			11.4	.9	11.0	2.0	5.0	1.2	22.2	1.4		
	1-5			12.0	.8	14.0	1.6	6.6	.9	21.6	1.3		
	6-10			10.8	.6	10.4	1.3	4.0	.0	19.6	2.5		
21	R	15.2	1.0	9.4	.7	7.2	.6	1.6	1.9	15.8	1.4		
	L	13.4	.5	11.2	1.0	7.8	.6	1.0	1.6	17.2	2.6		
	1-5	14.6	1.3	10.2	1.0	7.6	.9	2.6	1.0	17.0	2.4		
	6-10	14.0	.8	10.4	1.3	7.4	.5	.0	.0	16.0	2.4		

TABLE I—Continued.

		Brown.		Caplan.		Rahill.		Stewart.		Wichmann.		Ackermann.	
		Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.
June 22	R			10.0	.8			5.4	.9	17.0	2.4		
	L			10.8	1.7			2.2	1.7	18.8	2.2		
	1–5			10.2	.7			4.8	1.4	18.8	1.9		
	6–10			10.6	1.8			2.8	1.1	17.0	2.4		
23	R												
	L												
	1–5												
	6–10												
24	R	11.6	1.5	7.0	1.2	7.6	2.1	1.4	1.4	15.0	2.0		
	L	11.2	1.0	8.4	1.5	7.2	1.8	.6	.9	16.0	2.4		
	1–5	11.8	1.0	8.0	.8	8.6	1.4	1.2	.8	16.4	1.3		
	6–10	11.0	1.2	7.4	2.4	6.2	1.8	.8	.5	14.6	2.3		
25	R			7.8	1.0	7.6	2.3	.0	.0	12.8	2.2		
	L			8.2	1.0	6.6	1.7	.0	.0	14.2	1.8		
	1–5			8.4	1.1	2.3	1.5	.0	.0	15.4	1.9		
	6–10			7.8	1.2	1.7	1.7	.0	.0	11.6	1.3		
26	R	10.8	1.4	6.6	1.3	8.6	.5	.0	.0	10.4	1.7		
	L	9.4	.5	8.6	2.5	6.8	1.0	.0	.0	10.8	1.4		
	1–5	10.8	1.4	8.2	2.2	7.4	1.1	.0	.0	11.4	1.5		
	6–10	9.4	.7	7.0	2.0	8.0	.8	.0	.0	9.8	2.2		
27	R											29.4	2.3
	L											31.2	2.6
	1–5											31.4	2.3
	6–10											29.2	3.0
28	R											23.4	1.3
	L											29.8	1.0
	1–5											25.2	1.8
	6–10											26.0	2.4
29	R											21.6	1.1
	L											22.6	2.1
	1–5											20.6	3.3
	6–10											16.6	1.9
30	R												
	L												
	1–5												
	6–10												
July 1	R	14.8	1.8			10.4	1.9			20.8	1.4	18.2	2.6
	L	14.4	1.7			7.4	2.5			23.4	2.9	19.0	3.2
	1–5	13.0	1.2			7.6	2.5			24.0	2.4	20.6	3.3
	6–10	16.2	1.0			10.2	1.4			20.2	1.0	16.6	1.9
2	R	15.4	.5			6.0	1.6			17.8	3.6	14.2	1.9
	L	14.8	.7			6.0	.8			18.4	1.1	16.8	1.4
	1–5	15.2	.3			6.8	1.0			17.4	2.1	16.4	2.7
	6–10	15.0	.1			5.2	1.4			18.0	2.2	14.6	1.3
3	R	13.4	1.5							14.2	3.4	15.8	1.8
	L	13.8	1.1							13.6	1.9	15.2	1.2
	1–5	14.2	1.0							14.2	3.8	16.2	1.4
	6–10	13.0	1.6							13.6	1.5	14.8	1.4
4	R												
	L												
	1–5												
	6–10												
5	R					8.4	1.3			17.4	2.3	13.2	1.4
	L					6.8	1.0			15.2	2.2	14.4	.9
	1–5					8.8	1.0			15.4	2.5	13.8	1.0
	6–10					6.4	.9			17.2	2.2	13.8	1.4
6	R					8.4	.7			13.0	1.6	12.0	1.2
	L					6.2	1.0			14.2	.3	14.6	.5
	1–5					8.2	.6			14.0	1.2	13.0	1.2
	6–10					6.4	1.3			13.2	1.0	13.6	1.4
7	R												
	L												
	1–5												
	6–10												

TABLE I—Continued.

		Brown.		Caplan.		Rahill.		Stewart.		Wichmann.		Ackermann.	
		Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.	Av.	M.V.
July 8	R	18.0	2.0			12.6	1.3			18.4	2.1	12.2	2.2
	L	16.4	1.9			10.6	1.9			17.0	.4	12.2	1.0
	1-5	15.8	1.8			13.4	.5			17.4	1.8	12.2	2.2
	6-10	18.6	1.5			9 8	1.0			18.0	4.0	12.2	1.0
9	R	13.4	1.9			10.6	1.3			11.8	1.8	10.8	1.4
	L	11.6	1.9			9 4	.9			10.6	1.4	12.4	1.1
	1-5	14.6	.9			10.2	1.1			12.0	1.6	12.6	.9
	6-10	10.4	.9			8.8	.6			10.6	1.5	10.6	1.3
9	R											8.2	1.0
	L											8.2	1.0
	1-5											8.8	1.0
	6-10											7.6	.7
10	R									9.2	1.8	11.0	.4
	L									9.8	2.6	9.8	1.0
	1-5									8.4	1.7	10.0	.8
	6-10									10.6	2.3	10.8	1.0
11	R					9.6	.9					9.6	1.3
	L					9.0	.4					8.4	1.1
	1-5					10.0	.4					9.6	.9
	6-10					8.6	.5					8.4	1.3
12	R					8.6	.8					9.2	.5
	L					8.2	.3					9.0	.4
	1-5					8.8	.6					9.4	.4
	6-10					8.0	.4					8.8	.6
13	R					7.2	.3					7.6	1.5
	L					6.8	.6					6.8	.6
	1-5					7.2	.6					7.8	1.3
	6-10					6.8	.3					6.6	.9
14	R												
	L												
	1-5												
	6-10												
15	R											6.4	.5
	L											6.6	.7
	1-5											6.6	.7
	6-10											6.4	.5
16	R												
	L												
	1-5												
	6-10												
17	R											7.6	.5
	L											7.2	.3
	1-5											7.6	.5
	6-10											7.2	.3
18	R												
	L												
	1-5												
	6-10												

The method of observation and record[1] was improved (1) by timing the rotatory movement of the chair with the sound of a seconds' met-

[1] In adopting a definite standard technique for the conduct of a large number of examinations to be held at scattered stations by many examiners under varying conditions, the use of complicated instruments of precision is, of course, neither necessary nor practicable. Intervals of a day or more between turnings were sometimes inevitable owing to the military duties of the men examined. It will be noted that there occurs quite a variation in the readings from day to day. This may be due to slight variation in the stimulation employed or to inaccuracies in reading the nystagmus. The former factor was overcome as far as possible by timing the rate of turning with a stopwatch, while the latter was minimized by having all the readings taken by one observer. These variations, however, do not vitiate the main results as stated above.

ronome used to replace a stop watch and (2) by recording the later phases of nystagmus upon a revolving drum with time marker, Jacquet seconds clock, and telegrapher's key. The auditory-kinaesthetic rhythm incited by the metronome forms a much more natural and accurate control for the rotation of the chair than the stop watch, and the graphic record of eye movements eliminates the double error of anticipating and delaying the cessation of nystagmus, an error inherent in the single movement of the thumb or finger upon the stem of the watch. This double error may amount to several seconds. The usual stop-watch method offers no means of control over the variable errors of expectation and habituation and the constant errors of time. All of these errors are, of course, scrupulously calculated in any recognized method of science.

These experiments were conducted by assistants in the laboratory. From time to time the method was inspected, and occasional readings were made of after-nystagmus with the stop watch. In the table each average time for 5 right turns and 5 left turns is given, as well as the average of the first 5 and the last 5 turns in each series. Mean variations are calculated in each case. In every instance the rate was 10 turns in 20 seconds. Intervals of two minutes (between right and left) and three minutes (between pairs) were observed. In a few cases the regular series was interrupted or shortened by severe organic disturbances revealed by nausea, qualmishness, pallor, excessive respiration, and general distress.

The results bear evidence of the decline of the duration of after-nystagmus (1) from day to day and (2) from trial to trial within a single period of experimentation.

The average times for the four observers who began on June 6 run as follows from day to day:

	Seconds.		Seconds.
June 6	24.9	June 18	13.0
8	22.3	19	13.5
10	20.6	20	9.6
11	16.2	21	8.3
12	18.0	22	7.1
13	13.6	24	6.8
14	13.8	25	5.0
15	10.8	26	6.3
17	15.9		

In 20 days, then, the decrease in time exceeds 18 seconds (24.9—6.3 seconds). The drop in time is fairly consistent in spite of the fact that it proved to be impossible to arrange, without exception, the daily program. The temporal decline is graphically expressed in the chart, which is based upon the nystagmus for the first, fifth, tenth, and fifteenth turning days, regardless of calendar dates, for all six subjects. The initial times for all subjects fell within 22–31 seconds; and they decline at somewhat unequal intervals for the different men. The total range of decline expressed in whole numbers for the first 10 days stood as follows:

Subject A	30—12=18 seconds	Subject R	21—14= 7 seconds
Subject B	27—10=17 seconds	Subject S	25— 8=17 seconds
Subject C	26—11=15 seconds	Subject W	28—15=13 seconds

The difference is not very great, save in the case of R, whose times were least shortened within this limited time. R dropped sharply (14 to 8 seconds), however, within the next five days, while S fell off to zero.

To revert to the decrease in time of the ocular movements during the period of experimentation each day, the times nearly always decline during the 10 trials, as in the case of the May experiments made upon the single subject. The few negative cases are significant. The most striking case appears in S's first two days. On these two days the subject became so violently nauseated that the trials had to be broken off after the sixth turn. Thereafter the ocular movements grew, from day to day, much less violent and of smaller excursion, qualmishness disappeared, and the nystagmus rapidly lessened in duration. All of the other negative cases of more than a second or so occurred just after two or more blank days and they fell in with an absolute increase in nystagmus time, and usually with a greater violence in the general organic effects of rotation. These blank days were coincident with holiday leaves for the subjects during which their daily routine was interrupted. The disturbance of routine may very well have led to a physiological disturbance producing a cumulative effect and masking the usual decline during the last half of the period.

It seemed altogether probable that the change of after-nystagmus, which occurred not only from turn to turn, but also from day to day, should be a function of elapsed time as well as of repetition. The accompanying table (II) gives the relative frequency of increase and decrease in after-nystagmus after intervals and immediately after turning days. The totals for all subjects suggest that the blank days retard the gradual decline to which attention has been called. But a scrutiny of the table will make it apparent that virtually all the positive evidence is confined to the figures for the last two subjects (R. and W.), who also reported an increased violence in the apparent visual movements and in organic disturbances after intervals of rest.

TABLE II.

	After interval.		After no interval.	
	Increases.	Decreases.	Increases.	Decreases.
Ackerman	1	5	3	16
Brown	8	12	2	4
Caplan	1	7	7	13
Stewart	2	6	4	16
Rahill	9	5	6	24
Wichmann	8	2	6	22
Total	29	37	28	95

It is impossible, then, to generalize upon the effect of time interval. Repetition of turning certainly leads, under certain circumstances, to a decrease in after-nystagmus. But that the decline depends in any fixed way upon the length of the temporal interval can not be maintained upon the basis of the evidence at hand. The decline is not to be laid to a simple process of adaptation in the receptor organs of the labyrinth, for such sensory adaptations as are best known—visual, tactual, and thermal—are of brief duration, and, furthermore, they rapidly disappear with the lapse of stimulation. Still less is the effect of repetition to be disposed of as a case of "fatigue," a term which the uncritical lay reader might readily suggest. Nothing like fatigue (used in the sense of waste products and lowered metabolism) is here observed; and the proposal of that term as an hypothesis would be a loose use of the argument from analogy, which explains nothing. If genuine fatigue were actually induced by rotation, its effects would scarcely remain unmodified for four or five days. The explanation of the observed decline in nystagmus remains, therefore, for further experimentation made under more favorable technical conditions than the department has been able to command.[1]

The present experiments have demonstrated (1) that organic disturbances tend to disappear under rotation day after day and (2) that the after-nystagmus is reduced in violence and in duration under repetition (*a*) within a single experimental series—a total rotation of about three minutes—and (*b*) day by day. In 10 turning days, with 10 observations made each day, the average decline for six subjects was approximately 15 seconds, or more than half the original duration finally. The experiments have illustrated (3) the fact that

[1] Unquestionable evidence now available (see editorial insert immediately following) disproves the statement that "repetition of turning certainly leads to a decrease in after-nystagmus." Of the six individuals used by the psychologic department for these experiments not one was examined physically beforehand; two of these six were discovered subsequently to be pathologic, the other four had meantime been lost sight of. This failure to establish positively the normality of the individual subjects before proceeding with the series of tests is most unfortunate as it makes it impossible to draw any scientific conclusions from the data obtained.

casual observation of nystagmus involves a number of observational errors which may be eliminated by the standardized procedures of the psychological laboratory.

EDITORIAL INSERT.

The foregoing sets forth the result of certain ear investigations which were undertaken in the department of psychology. Neither the findings in the individual cases herein reported nor the deductions drawn from the series are in accord with the findings and deductions of the otologic department.

Several thousand reexaminations of fliers, made by skilled otologists who have been occupied with daily turning chair examinations of the internal ear for unbroken periods covering 12 to 18 months, do not indicate reduction in the duration of nystagmus following rotation. A carefully analyzed report of 541 consecutive cases examined by a single observer on three of the southern flying fields follows:

One hundred and fifty-six men examined. Flying period, 0 to 25 hours. Average nystagmus—turning to right, $25\frac{49}{156}$; turning to left, $25\frac{25}{156}$ seconds.

One hundred and sixty-nine men examined. Flying period, $25\frac{1}{2}$ to 50 hours. Average nystagmus—turning to right, $25\frac{85}{169}$; turning to left, $25\frac{40}{169}$ seconds.

Fifty-nine men examined. Flying period, $50\frac{1}{2}$ to 75 hours. Average nystagmus—turning to right, $19\frac{1}{59}$; turning to left, $18\frac{37}{59}$ seconds.

Thirty-seven men examined. Flying period, $75\frac{1}{2}$ to 100 hours. Average nystagmus—turning to right, $24\frac{19}{37}$; turning to left, $25\frac{4}{37}$ seconds.

Twenty-one men examined. Flying period, $100\frac{1}{2}$ to 150 hours. Average nystagmus—turning to right, $25\frac{18}{21}$; turning to left, $25\frac{8}{21}$ seconds.

Thirty-four men examined. Flying period, $150\frac{1}{2}$ to 200 hours. Average nystagmus—turning to right, $26\frac{4}{34}$; turning to left, $25\frac{8}{34}$ seconds.

Thirty-two men examined. Flying period, $200\frac{1}{2}$ to 250 hours. Average nystagmus—turning to right, $23\frac{5}{32}$; turning to left, $23\frac{12}{32}$ seconds.

Fourteen men examined. Flying period, $250\frac{1}{2}$ to 300 hours. Average nystagmus—turning to right, $23\frac{9}{14}$; turning to left, $25\frac{5}{14}$ seconds.

Nineteen men examined. Flying period, $300\frac{1}{2}$ to 1,000 hours. Average nystagmus—turning to right, $26\frac{4}{19}$; turning to left, $25\frac{11}{19}$ seconds.

The average nystagmus of accepted applicants among 75,000 examinations showed on turning to the right, 23 seconds, and on turning to the left, 23.1 seconds. It will be noted that the average nystagmus of the above series is somewhat higher. It will also be shown by the fact that without dividing these cases by the hours of flying, the average on turning to the right, was 24.6 seconds, and turning to the left, 24.4 seconds.

A series of daily observations made by otologists who have had years of daily practice in the application of turning chair tests of the internal ear was conducted in the laboratory at Mineola. The subjects of this series of tests were 10 adult individuals carefully determined by previous physical examination to be normal. (No evidence exists as to the normality of four subjects of the tests conducted by the psychologic department; the other two, A and S, were

S9118—19——22

found upon physical examination to be pathologic. It must be especially emphasized that pathologic conditions of the internal ear not affecting hearing may be of a nature very difficult to detect by ordinary observations; for example, the sequelæ of mumps, lues, typhoid fever, and other acute infectious diseases.) Six subjects were turned each morning (10 turns to the right in 20 seconds and 10 turns to the left in 20 seconds) and four subjects were turned in the same manner both morning and evening. It was noted as the subjects became accustomed to the vertigo induced by turning that with the proficiency attained in executing voluntary motor coordinations manifest in pointing tests and fall tests, a commensurate proficiency became apparent in voluntary fixation of the gaze through daily practice. This acquisition of an increased fixation control of the voluntary eye movements resulted in a lessening of the duration of the resulting nystagmus in some cases. That this was in no sense the result of change in character or intensity of the vestibular stimulus was proven by placing before each subject's eyes a pair of plus 20 lenses which rendered fixation of the gaze impossible. Observations of the resulting nystagmus, made not only through these lenses but behind them, confirmed beyond question the finding that there was no reduction in the duration of the nystagmus following nine weeks of uninterrupted tests.

FREY, J. C.

Date.	A. M.		P. M.		Date.	A. M.		P. M.	
	Right.	Left.	Right.	Left.		Right.	Left.	Right.	Left.
Sept. 26	23	22	21	20	Oct. 26	20	....	20	....
27	20	22	24	28	28	21	22	21	20
28	23	....	17	....	29	19	17	18	16
30	21	20	19	18	30	20	19	21	18
Oct. 1	19	19	17	18	31	25	22	19	19
2	20	18	18	18	Nov. 1	21	17	18	16
3	19	21	18	19	3	19	....	20	....
4	20	21	21	19	4	20	19	19	18
5	19	....	18	....	5	22	19	19	18
7	20	21	20	18	6	22	....	20	....
8	23	17	19	17	7	24	....	21	....
9	17	21	19	20	8	21	21	20	22
11	18	19	21	17	11	21	26	18	20
12	21	....	19	....	12	27	26	25	20
14	21	19	20	19	13	21	....	19	....
15	20	22	18	23	14	19	....	19	....
16	19	19	19	19	16	21	....	20	....
17	22	20	21	18	18	20	....	21	....
18	24	18	19	16	19	21	....	20	....
21	19	20	19	18	20	22	25	19	20
22	21	18	19	21	21	19	....	19	....
23	21	20	19	21	22	24	21	20	20
24	22	18	17	17	25	23	....	20	....
25	23	....	19	....	26	20	....	19	....

SCHNEIDER, T. G.

Sept. 28	25	....	20	....	Oct. 8	20	16	18	16
30	26	25	23	22	9	19	20	21	20
31	26	....	25	....	10	21	25	24	16
Oct. 1	29	....	21	....	12	22	....	19	....
2	28	28	19	24	14	19	17	18	19
4	19	25	18	21	15	21	22	18	21
5	18	....	20	....	16	22	25	19	15
7	23	26	16	17	17	28	26	25	21

SCHNEIDER, T. G.—Continued.

Date.	A. M.		P. M.		Date.	A. M.		P. M.	
	Right.	Left.	Right.	Left.		Right.	Left.	Right.	Left.
Oct. 18	23	18	23	19	Nov. 7	26	....	21	....
19	19	....	24	....	8	27	26	22	24
21	19	18	16	19	9	25	....	27	....
23	17	20	18	18	12	26	....	22	....
24	24	24	19	18	13	26	27	22	28
25	20	20	17	18	14	28	26	24	24
26	27	....	21	....	15	25	....	24	....
28	27	24	24	23	16	30	....	27	....
29	22	24	21	29	18	28	....	24	....
30	26	23	28	29	19	24	25	26	21
31	29	27	27	24	20	27	23	23	20
Nov. 1	21	17	21	....	21	25	29	25	21
4	29	28	26	26	22	30	....	25	....
5	31	27	27	24	25	25	....	20	....
6	21	29	28	30	26	27	....	24	....

ENNIS, L. E.

Date.	A. M.		P. M.		Date.	A. M.		P. M.	
	Right.	Left.	Right.	Left.		Right.	Left.	Right.	Left.
Sept. 26	26	26	20	19	Oct. 19	18	....	18	....
27	30	24	28	18	20	18	20	20	20
28	30	....	26	....	22	25	26	26	27
30	31	25	28	25	23	20	16	19	20
Oct. 2	24	24	22	30	24	22	20	21	20
3	27	24	31	26	25	17	18	15	20
4	....	23	....	20	26	28	....	25	....
5	22	....	16	....	28	19	21	25	23
7	20	....	23	....	29	23	30	25	27
10	25	21	26	19	30	26	21	23	25
11	24	22	19	19	31	20	24	24	20
12	23	....	21	....	Nov. 3	21	....	22	....
14	24	21	19	21	4	28	....	24	....
15	20	21	21	19	5	18	24	20	23
16	20	20	19	16	8	28	28	29	23
17	24	29	23	23	9	26	....	28	....
18	22	17	19	16					

LONG, C. M.

Date.	A. M.		P. M.		Date.	A. M.		P. M.	
	Right.	Left.	Right.	Left.		Right.	Left.	Right.	Left.
Sept. 26	26	24	26	26	Oct. 25	15	....	16	....
27	25	24	27	20	28	19	16	18	18
28	24	....	22	....	29	19	19	18	20
30	23	27	21	22	30	21	20	20	20
Oct. 1	25	....	23	....	31	24	23	24	23
2	26	23	24	20	Nov. 1	18	23	17	24
3	25	25	21	20	3	23	....	24	....
4	19	16	20	16	4	27	....	26	....
7	17	14	19	20	5	18	20	18	18
8	18	....	18	....	6	21	20	20	18
9	18	....	18	....	7	18	....	18	....
10	16	16	18	16	12	22	21	20	19
11	17	18	17	16	13	21	20	23	20
12	20	....	18	....	14	24	....	21	....
14	18	17	17	16	16	25	....	25	....
15	19	....	18	....	18	22	21	21	22
17	20	19	19	16	19	25	23	24	22
18	20	22	19	18	20	19	24	18	21
19	22	....	21	....	21	26	....	24	....
21	21	17	19	16	22	23	20	30	19
22	21	25	18	19	23	18	....	18	....
23	16	18	17	16	25	23	....	20	....
24	14	22	19	17	26	20	....	18	....

TRIMMER, H. M.

Date.	Right.	Left.	Date.	Right.	Left.
Sept. 26	24	28	Oct. 24	21	24
27	20	28	25	21	23
28	26	25	28	22	23
30	25	27	29	25	27
Oct. 1	27	22	30	25	25
2	22	25	31	28	26
3	21	20	Nov. 1	19	23
4	18	21	3	20	22
5	21	21	4	27	26
7	20	23	5	24	23
9	20	22	6	25	23
10	24	23	7	20	19
11	18	21	8	29	28
12	24	20	9	22	24
14	18	24	11	24	30
15	20	22	12	24	24
16	19	22	13	25	21
17	24	27	16	26	24
18	25	21	18	26	28
19	24	24	19	22	26
21	20	18	21	24	23
22	21	22	22	22	21
23	22	28	26	25	21

McCABE, C. J.

Date.	Right.	Left.	Date.	Right.	Left.
Sept. 28	27	27	Oct. 28	22	25
Oct. 1	33	25	29	25	28
2	27	27	30	23	22
3	22	23	Nov. 1	26	29
4	20	19	3	26	25
5	23	20	5	30	30
7	20	21	6	27	29
8	23	21	7	23	21
9	24	24	8	21	19
10	22	22	9	27	26
11	24	23	11	25	22
12	23	20	12	24	21
14	23	22	13	27	25
15	21	19	14	26	28
16	22	24	16	24	23
17	22	23	18	25	22
18	24	19	19	26	22
21	23	23	21	25	24
22	19	24	22	21	24
23	18	21	23	25	23
24	17	19	26	24	21
26	25	24			

BROWNING, E. L.

Date.	Right.	Left.	Date.	Right.	Left.
Sept. 26	26	28	Oct. 25	20	91
27	22	26	26	30	28
28	24	25	28	26	24
30	27	23	29	18	19
Oct. 1	25	24	30	22	23
2	27	24	31	22	27
3	22	20	Nov. 5	27	26
4	22	21	8	27	26
5	21	20	9	25	22
7	23	19	11	30	30
8	21	20	12	25	27
9	22	23	13	20	23
10	25	21	14	26	28
11	16	20	16	25	26
12	20	21	18	23	24
14	23	21	19	21	22
15	20	16	20	24	25
22	24	19	21	30	30
23	22	21	22	26	27
24	16	19			

HAYMAN, G. C.

Date.	Right.	Left.	Date.	Right.	Left.
Sept. 28	40	37	Oct. 30	28	29
Oct. 2	38	36	31	30	20
3	24	30	Nov. 1	30	28
7	31	30	3	23	27
8	33	30	4	26	28
9	31	34	5	32	33
10	32	34	6	30	26
11	30	33	7	27	21
12	30	30	9	29	26
14	32	28	11	30	28
15	30	32	12	29	26
16	23	27	13	36	30
17	31	30	14	29	27
18	26	25	16	30	27
19	25	....	17	30	27
21	27	25	18	31	30
23	33	29	20	28	28
24	23	32	21	34	29
25	24	23	22	30	25
26	34	27	26	30	26
29	34	34			

BRAMLEY, R. H.

Date.	Right.	Left.	Date.	Right.	Left.
Sept. 28	30	33	Oct. 23	20	22
Oct. 1	29	33	25	19	23
2	40	31	26	25	31
3	25	29	28	21	23
7	29	29	29	26	28
8	24	29	30	28	26
9	25	26	31	24	28
10	29	29	Nov. 1	25	24
11	27	28	3	25	24
12	22	24	4	27	28
15	22	21	5	25	28
16	25	24	7	26	29
17	28	26	8	26	28
18	27	32	9	35	37
19	21	22	12	30	38
21	19	21	14	32	30
22	22	28			

JAFFA, B. B.

Date.	Right.	Left.	Date.	Right.	Left.
Sept. 28	26	34	Nov. 1	26	26
Oct. 2	28	31	3	27	27
3	34	30	4	26	25
11	31	31	5	30	29
12	28	29	6	25	27
14	22	26	7	31	30
15	26	30	9	31	28
16	30	33	11	36	28
18	27	30	12	30	28
19	25	25	13	32	34
21	25	24	14	29	30
22	30	30	16	25	27
23	20	21	18	27	26
24	23	21	19	28	27
25	20	23	20	28	26
26	24	23	21	31	32
28	24	25	22	31	29
30	28	27	26	30	26
31	22	25			

It is of supreme importance for the reader to note the cardinal difference between the series of 541 examinations of fliers here reported, in whom no reduction in the duration of nystagmus was encountered, and the turning chair tests conducted upon 10 subjects for 9 consecutive weeks. The flier *can not* practice the fixation of gaze owing to the variability of conditions under which he flies; the subject in the turning chair *must* fix his gaze accurately after each turning, thereby undergoing a very intensive practice in gaze fixation.

It follows, therefore, that *when a marked reduction in duration of nystagmus is encountered it must be regarded as indicating a definite departure from the normal.* Examples in point are the following three cases:

M, flying instructor, reported that his cadet students were prone to level off with left wing down; officer in charge of flying and post commander observed that M always leveled off with the right wing down. He was ordered up for physical examination, which revealed pathologic condition of his internal ear, evidenced among other findings by 6 seconds' duration nystagmus after turning right.

W, a flier, who had been determined by a physical examination to be normal; after completion of flying training in England had several months' combat service on the western front, giving daily evidence of satisfactory flying ability. Officer in charge of flying noticed gradually increasing loss of flying ability; three weeks' rest was not followed by the expected improvement, and he was ordered up for a reexamination. His nystagmus record on entering flying training was 26 seconds after right turn, 26 seconds after left turn; on this reexamination it was found to be 7 seconds right turn, 9 seconds left turn. Further examination revealed luetic internal ear disease; the aviator then stated he had acquired syphilis since admission into the service.

Lieut. X under flying instruction, was reported by instructor as a very dangerous pupil, having repeatedly leveled off with left wing down; instructor refused to take further risks. Officer in charge of flying upon looking up record of physical examination found that through clerical error this man had been reported fit for flying training instead of unfit for flying training owing to subnormal nystagmus following turning. In all three of these cases the diagnosis of internal ear abnormality was made by the flying instructor solely upon the evidence furnished by the *flier's* performance in the plane. Further evidence of this character was discovered in certain of the flying fields following epidemics of mumps, a condition affecting the internal ear with especial frequency. [End of editorial insert.]

2. *Orientation.*—Methods have been devised for determining the promptness and the accuracy with which the aviator gets his bearings, finds his way, and remembers his course in the air. The ability to keep directions and to maintain a correct orientation on the ground or in flight differs widely from individual to individual, and since both personal safety and successful execution depend upon clear and prompt orientation, the test of a pilot's ability in this regard is of great importance. Various typical means of orientation distinguish one flier from another. The main "types" discovered and described

include (1) the compass type, or those individuals who get their bearings by the cardinal directions; (2) the mapping type, individuals who refer places and directions to an imaginary map upon which north is always before and east at the right of the observer; (3) the pointing type, which depends upon kinæsthetic factors for orientation; (4) the pathfinding type, which relies upon the recognition of landmarks; (5) the fragmentary type, which is oriented only in certain regions and under certain circumstances; (6) the disoriented type, which includes the habitually confused and muddled; and (7) the lost type of individual, who takes little or no account of spatial clues to position and direction and who can not be trusted to explore new regions or to search out a new objective. Both the accuracy of exploration and the appropriate method of instruction in map making and map reading and in reconnaissance depend upon the flyer's orientational type.

Apparatus (figs. 20 and 21) has been built in the laboratory for discovering whether the pilot or the observer is easily lost or disoriented, whether he knows and keeps his compass points, and whether he is capable of translating verbal orders to fly to a named objective into a plan of flight, or of charting a terrain from his aerial observations, or of retracing his course of flight by the observation of landmarks.

The test of the methods evolved has made it evident that it is possible to determine within a few minutes the "type" of the aviator with respect to orientation, and also his facility in getting his bearings and in maintaining his directions under the exigencies of flight.

3. *Association reaction times.*—A large amount of work has been done on the association reaction test using the chronoscope and voice keys (fig. 22). In this test a word, "stimulus word" spoken by the psychologist, starts the hand of the chronoscope in rotation, and a word, "response word" spoken by the reactor, stops the hand. The time between stimulus and reaction, the time required to "think of the reply" is then read directly on the dial in thousandths of a second. psychologist, starts the hand of the chronoscope in rotation, and a response word of definite rotation to the stimulation word (e. g., verb naming action which could be exerted by whatever is designated by the noun) is required. In this way a rating on the basis of the time required for the answer, and also on the reliance and specific appropriations of the answers is possible. These vary according to the general mental ability and the particular condition (fatigue, etc.) of the reactor. So far, the work has been largely directed to the development of standard lists of stimulus words (which in itself requires a large amount of research) and the perfecting of a rating scheme.

The foregoing enumeration by no means exhausts the immediate possibilities and needs of investigation of the points of general and special fitness and adaptability noted in an earlier summary (Chap. I). Nor does it include all the work on these topics which is under way in the psychological laboratory. It indicates, however, the scope of the work in the direction of classificatory tests, and together with the preceding statements will serve as a guide to psychologists in the various fields in observing fliers and flying conditions and collecting information useful for further development of practical aid to the service.

VII.—DEPARTMENT OF NEUROLOGY AND PSYCHIATRY.

The work of this department touches the aviation problems at three vital points: (1) By the detection in the aviator of symptoms of nervous and mental diseases; (2) by the recognition of latent trends of temperament which, if not recognized in time and treated rationally, increase the liability of the flier either to become inefficient or to lose morale and esprit de corps, and (3) finally by supplementing the information already obtained in other departments in regard to the aviator's potential flying capacity with additional data bearing upon his temperament and personality. This knowledge to be used in the selection of fliers for special tasks.

The examiner should keep constantly before his own mind the fact that the chief purpose of these personality studies is to determine the fitness of an aviator to withstand the nervous strain of flying at the front. For this reason, although clinical methods of examination are used in taking these histories, they should not be judged by ordinary clinical standards—as the purpose is not to carry the analysis of the aviator's personality further than is necessary to estimate his potential as a flier under war conditions.

The chief sources of information for data upon which judgment of the personality is based are (1) the Aviator under examination, (2) other Departments in the laboratory, (3) the Flight Commander, and (4) the Flight Surgeon. A spirit of sympathetic cooperation is necessary in gathering this data and neurologists and psychiatrists should remember they are attempting merely to supply some of the links in a relatively long chain of evidence.

In estimating the nervous capacity to withstand strain the examiner should give particular attention to the following points:

(1) What were the chief reasons influencing the aviator in choosing this branch of the service? Did the love of adventure, desire for independent action, or interest in machinery, or a combination of all these elements enter into the decision? Does he feel that he is making good and is he satisfied with his original decision? The

statements of experienced aviators show how much success in flying depends upon making that particular decision clean cut and then accepting it as final. Indecision, a sense of inadequacy, or idle regret at having chosen work for which he is not fitted temperamentally may lead to a chain of symptoms culminating in a psychosis or psychoneurosis.

(2) Impressions of the aviator's readiness or disinclination to face difficult situations fairly and squarely should be recorded. Evidence of a tendency to dodge critical events in life, a habit which if not corrected may become the starting point for morbid fears and obsessions, should be noted. An experienced and daring aviator may lose nerve suddenly as the result of not having definitely settled some relatively trivial event of a personal nature. States of irresolution and doubt as well as compulsions antagonistic to efficiency often develop out of buried mental complexes.

(3) The question should be asked whether the members of the immediate family approve or disapprove of his flying, making it easy or difficult for the aviator to devote his entire attention to his work.

(4) Notice should also be taken of the occurrence of nervous or mental disorders in the family history.

Associated with the effort to present brief records containing only the essential facts in each case, there should also be a clear appreciation of the number and variety of factors which may affect the behavior of the aviator. Each analysis should be based on the consideration of the active forces influencing behavior in critical situations. The restriction of the investigation merely to taking a cross section of life at any single level in the life curve is not sufficient. Remotely antecedent events in life, such as attacks of disease, accidents, circumstances giving rise to bad habits, or poor educational opportunities, may have a direct practical bearing on the performances of the aviator in a plane.

The following cases are cited to illustrate the advantages of a very brief summary of the life history.

CASE 1.—Personality rating, "A." No indication that he will require any special attention nor be predisposed to collapse under strain.

——— ———, 1st lieut., A. S. S. C.

Aviation history: No "repeats" in ground school. Licensed pilot. 80 hrs. flying to date. No accidents.

Personal history: No serious illness nor accidents. Public-school education; not college graduate. Has worked hard for living and enjoyed it. No grouches. Normally optimistic. Advised by his captain in Infantry to transfer to aviation. Glad he did so; enjoys flying; feels he is making good.

Physical examination: Height, 5 ft. 6 in.; weight, 132; age, 23. Nothing abnormal.

Tests (low tension): Very good, "A."

Personality study: Stocky, muscular type; look steady, countenance cheerful, but not overemotional. Activity, good; discipline, good; willing to take chances if necessary. Stability under strain probably excellent. Good judgment.

Case 2.—Personality rating, "B." Safe if watched for development of nervous symptoms.

——— ———, flying cadet, A. S. S. C.

Aviation history: Ground school; difficulty with wireless (has poor musical sense). 8 hrs. flying to date. No accidents.

Personal history: Nothing of importance in family history except "mother worries greatly about me" and writes to him on this subject. College graduate (4 yrs.), Harvard, A. B.; worked his way through college and has also worked in munition factory. No pronounced reasons given for choosing aviation. Unmarried.

Physical examination: Height, 5 ft. 6 in.; weight, 140 lbs.; age, 24. Nothing abnormal noted.

Tests (low tension: —.

Personality study: Short, well knit; regular features, mobile, expression tense but under control; anxious to understand and please. Manner tense and high strung. Keen sense of responsibility. Ambitious and keenly interested in his work, but inclined to take even trivial events too much to heart. Will do his duty but needs careful watching when he gets to the front. Should be watched for signs of staleness or beginning nervousness, loss of sleep, etc.

Case 3.—Personality rating, "D." Probably not safe if flying at the front.

——— ———.

Aviation history: No trouble in ground school; work in ground school described as easy.

Personal history. Bright at bookwork; high-strung always; exceedingly popular with friends. Has had most of children's diseases; no complications nor accidents. Great interest in athletics. Public schools and college. Entered service from junior class. Unmarried.

Physical examination: Very active knee jerks. Pupils show secondary expansion, after dilatation. Height, 6 ft.; weight, 155; age, 24.

Tests (low-tension):

Personality study: Decidedly self-conscious; slightly aggressive manner; very high-strung and overemotional. Lacks normal subjective feeling of fatigue after hard exercise. Talks a great deal and rapidly. Gives the impression of working under great pressure. Is decidedly nervous and lacks voluntary control of expenditure of energy. Reserve store of energy limited. Would probably not stand strain of active service at the front.

Accompanying each history a personality summary is made on a separate slip in order to present the essentials in as brief form as possible for the use of the Commanding Officer. If more detailed information is required, this can be obtained by reference to the laboratory records.

PERSONALITY SUMMARY. No. —.

HAZELHURST FIELD, MINEOLA, N. Y.

Aviation history ____________________

Personal history ____________________

Physical examination ____________________

Tests (low-tension) ____________________

Personality study ____________________

Rating:

Personality ____________________

Tests (low-tension) ____________________

A summary of the cases already examined in this department with an explanation of ratings follows.

The object of the personality study is to determine: (1) Whether neuroses or psychoses actually exist or (2) whether there are any indications in the temperament or personality of the aviator suggesting that tendencies now latent under the stress of war conditions may give rise to symptoms of nervous shock, diminishing efficiency and impairing morale.

Personality:

"A".—Safe. Nervous and mentally stable.
"B".—Safe, with limitations.
"C".—Questionable; no definite conclusion reached.
"D".—Needs special attention.
"E".—Unsafe.
Not rated.

Tests (low-tension):

"A".—No restrictions.
"B".—Should not fly above 15,000 feet.
"C".—Should not fly above 8,000 feet.
"D".—Should not fly at all.

Personality studies:

Rating "A"	46
Rating "B"	29
Rating "C"	16
Rating "D"	1
Rating "E"	1
Not rated	18
Total	111

Low-tension tests:	
Rating "A"	27
Rating "B"	26
Rating "C"	14
Rating "D"	6
Not rated	38
Total	111

Agreement, personality rating, and tests	36
Nonagreement personality rating and tests	29
One or both ratings absent	46
Total	111

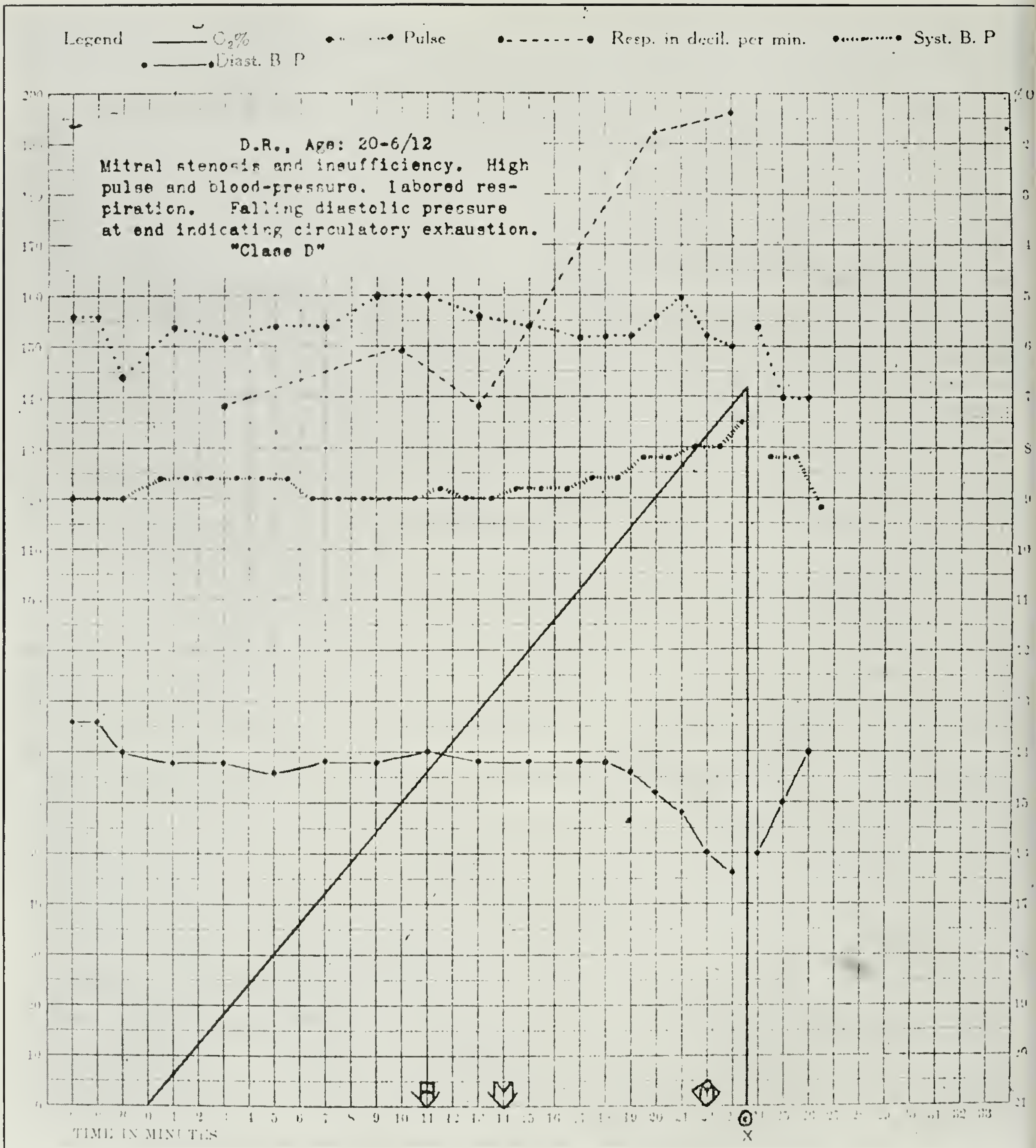
The discrepancies noted between personality ratings and test ratings are no evidences of marked differences. The low-tension tests are made with the object of determining the aviator's capacity to meet changes incident to variations in barometric pressure, whereas the aim of the personality studies is to determine, if possible, the resisting capacity for nervous and mental shocks.

In collecting this material for records great care should be taken not to suggest imaginery troubles to the person being examined. Babinski and Froment (Hystérie-Pithia-tisme et troubles nerveux d'ordre reflexi Collection Horizon. Précis de Medicine et de Chirurgie de Guerre. Masson & Cie., 1918) have emphasized the increased danger of "suggestion" as an etiological factor of nervous diseases in the life of the soldier. A great deal therefore depends upon the tact and good judgment of the examiner.

A very important function of the work of the department is to make clear the value of good mental hygiene in increasing efficiency in assisting in the maintenance of discipline on rational grounds in strengthening morale and contributing to the esprit de corps essential for a complete and final military victory.

Informal conferences on the subject of the mental hygiene of the aviator should be of practical value. The demoralizing influences of intemperance, using the word in a broad physiologic sense, the paralyzing effects of worry over unsolved personal problems, of the failure to get square with life, of anxiety about anticipated events, and the shock caused by suddenly awakening to the realization of the fact that the lure of wish-directed thoughts make an individual incapable either of judging or facing reality.

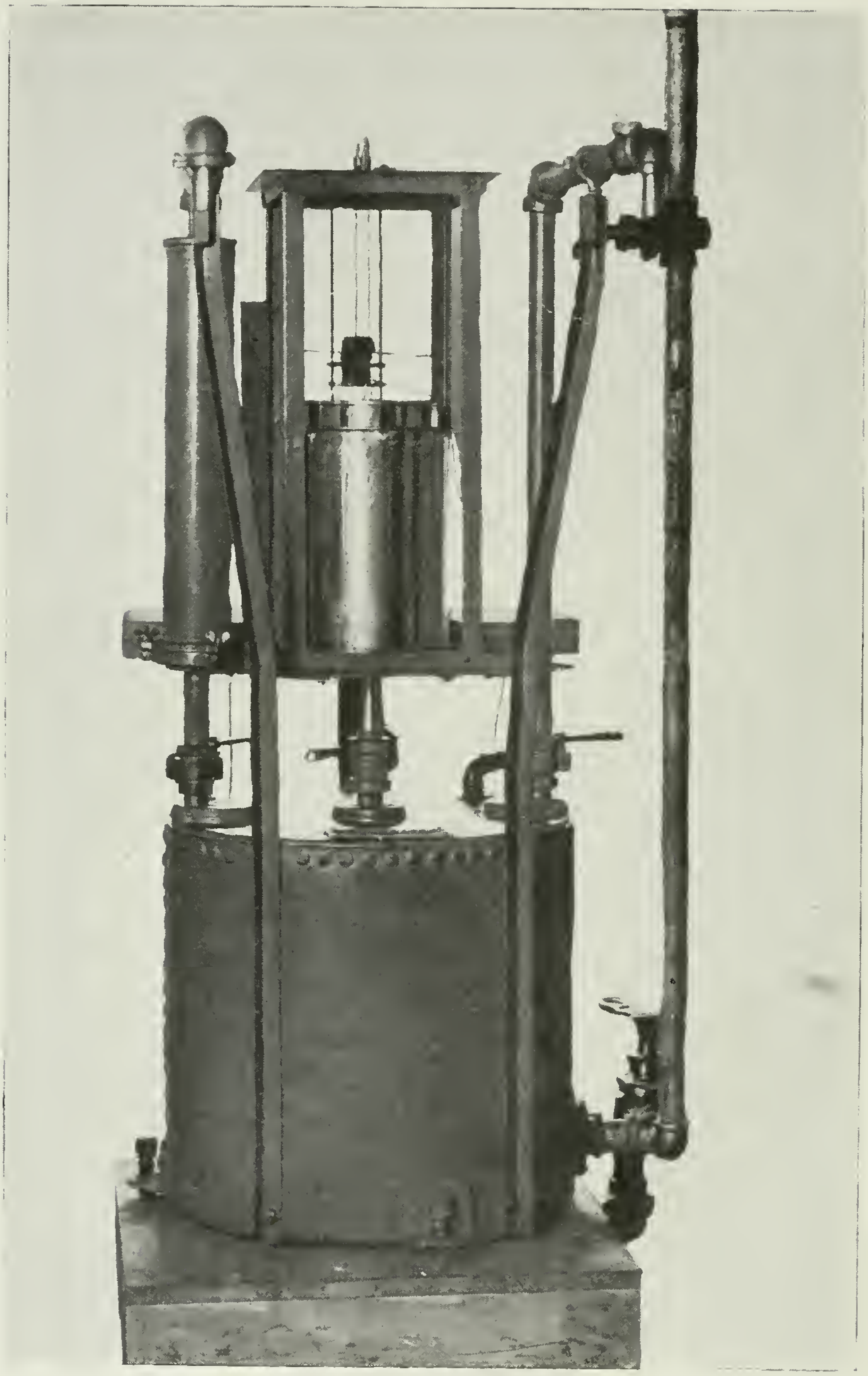
The casualty list in the Aviation Service can be greatly reduced by insisting upon the necessity of cultivating a frank, open attitude of mind in the treatment of the various problems which are forced upon the attention of the flier. Staleness, loss of confidence, various phobias, and increasing emotional instability are insidious enemies.



No. 217.—D. R. CADET. Age 20 years, 6 months.

There was a roughening of the first heart sound heard before the test. No demonstrable enlargement, second sounds equal. During the test a definite systolic murmur developed and the pulmonic second was accentuated. There is no doubt of the diagnosis of mitral insufficiently well compensated.

The chart is typical of most cases of valvular lesions. The pulse is high throughout the test. The systolic pressure is high and uniform. Diastolic pressure begins to fall between 9 and 10 per cent, but is in control at all times. Respiration shows rather a marked response. Efficiency is well preserved, the psychological note being A. This is accomplished at the expense of marked overwork of the heart. Although this is well borne at the present time, the presumption is that the subject would soon show the effects of wear, and permanent damage to the heart might easily result. Class D.



Aviators should be familiar with the methods of preventing the formation of some of the mental influences disorganizing both to temperament and character. The difficult task of keeping their nerve should not be made unnecessarily difficult by the failure to appreciate and apply a few of the principles of good mental hygiene.

HELPING THE AVIATOR TO KEEP HIS NERVE.

No one doubts the desirability of maintaining within the aeroplane and its motor the conditions essential for maximum flight efficiency. There are only a few people, however, who recognize the necessity for detecting and remedying the disturbances of the delicate nervous and mental adjustments of the aviator controlling the machine. In the air service of the allied armies the lists of casualties due to preventable and unknown causes are very much longer than the ones containing the names of aviators killed in battle. Many of these fatalities are due to the failure of those directing the activities of the aviator to take cognizance of his imperfect emotional and mental adjustments.

A long list of accidents, however, is not the only deplorable effect of the failure to assist the aviator to keep his nerve and his head in critical situations. The human machine loses efficiency much more rapidly through neglect to provide the conditions essential for good headwork than the motor does when it is not well oiled or its parts are not kept thoroughly adjusted. If even half as much care as is now given the machinery of the planes was devoted to finding out whether the emotional and mental balance of the aviator was equal to the strain to which it is subjected it would be possible to develop the fighting efficiency of the air forces to a much higher degree than exists at present.

The aviator in action has to be heart and soul in his work. Neither his attention nor interests can be divided, even for an instant.

Very brief periods of distractibility, uncertainty, or slight anxiety at critical moments may end quickly in a catastrophe. In many occupations, even in military life, these momentary lapses may not end disastrously, but the chances of their doing so while the aviator is in the air are a thousand times greater. The emotional and mental balance of the aviator should be so very delicately adjusted that it responds instantly and accurately whenever the unexpected strain of the critical situation is thrown upon it. The aviator has practically no opportunity to correct his mistakes. A wrong impulse, uncontrolled emotion, or thought not related to the situation may be the cause of disaster. This principle is equally true whether the aviator is high in the air or approaching the ground.

Disasters resulting from hesitation or indecision in the comparatively difficult though necessary procedure of landing may be and undoubtedly are often due to a certain mental or nervous instability not generally demonstrated by the ordinary methods of observation or medical supervision. These disturbances of the mental balance are demonstrable and capable of being ameliorated by neurologic or psychiatric methods. The dangers of indecision or divided attention when in combat or even when in the usual "formations," now the rule in aerial warfare, may be easily visualized and can hardly be overestimated. In the illustration (the jackals, p. 19) the importance of maintaining position in "formation" is emphasized. This maneuver requires great mental alertness and good judgment. The danger of possible collision with other fliers in the "formation" can only be avoided by unswerving attention and coordinated and instantaneous action.

What are some of the causes which lead to momentary but often fatal inefficiency? Anxiety, worry, straining to repress harassing memories of personal trouble, a sudden and temporary but overwhelming sense of inadequacy in facing a crisis very often interfere with the transmission of the coordinated motor impulses from the brain. An aviator having an excellent record, though trying hard but unsuccessfully to repress any recollection of worry over personal problems, may lose his nerve and refuse to fly, or, on the other hand, he may attempt to fly while the mental conflict is still acute and end his career with a fatal crash. An aviator struggling hard to repress and forget these nerve-wrecking, disorganizing ideas and anxieties is a menace to himself and the whole organization until by frankly talking the matter over with some sensible person he "gets it off his chest." The first step in the restoration of efficiency and nerve consists in facing squarely the real cause of his anxiety instead of trying to evade it.

Even the aviator who is mentally and physically fit, may be thrown into a condition of mental irritability and anxiety, which he is not able to control, upon the receipt of depressing, unreasonably solicitous, or even threatening, letters from home. Frequently states of apprehensiveness and anxiety affect the aviator to a far greater extent than he realizes or is willing to admit even to himself.

There are different types of personality which, on account of their special intellectual qualities, are now generally recognized as possessing the temperamental qualities antagonistic to success in aviation. Among the types which require special supervision are men with decided variations in mood or emotional tone. We all know men, in our own circle of acquaintances, in whom such variations are marked; men who may be classed at times as extreme optimists, at other times swinging over to the opposite or pessimistic pole of emotional experience. Within certain limits and under intelligent medical supervision, this group of men may, and probably do, furnish some of the most versatile and daring of the aviators. On the other hand, we are confronted by the fact that these same men if permitted to swing to the extremes of the emotional arc will certainly become casuals or casualties. They may develop on the one hand into the cases of unbalanced manic-depressive make-up, latent hysterical trends, and many cases showing symptoms of the anxiety neuroses.

The question of mental hygiene, as related to the aviator, should be given a great deal of attention. The reduction of the efficiency of the soldier through any form of intemperance is now generally recognized; and similar effects, but to a far greater extent, are observed in the case of the aviator. The type of man making the successful aviator is often high strung and impulsive and requires plenty of outlet for his energies. These outlets can be easily provided in ways entirely satisfactory to him and conducive to his efficiency without injuring the brain and the nervous system as does dissipation. He, himself, does not seek dissipation; but, having an enormous amount of unexpended energy, he seeks some channel—any channel—for its discharge. Adequate provision should, therefore, be made for recreation and suitable forms of mental relaxation if the dangers of dissipation are to be avoided.

The supervision of the aviator outlined above has been definitely included as a part of the duties of the Flight Surgeons. It is planned that the Flight Surgeons shall receive instruction and advice relative to the methods of observation and examination of the fliers at the Medical Research Laboratory or other centers of instruction. That specialists in psychiatry can not be trained in the short time available is clearly recognized. On the other hand it is possible for the Flight Surgeon to obtain a certain point of view toward his problem and for him to become definitely informed concerning the types of personality referred to in the preceding paragraphs. The problem of the training of the Flight Surgeon therefore resolves itself into one of method of observation and examination.

The neuro-psychiatric examination is brief; sufficiently brief to get it all on one page. First is given an account of the aviator's entrance into the Air Service, of his aviation school work, and the chief causes which led to his selection of this branch of the service. It is important to know whether the choice of this branch of the service was made voluntarily and enthusiastically; whether he drifted into it and is more or less indifferent or even unhappy in it. Then follows an account of his Army life preceding his entrance into aviation. Finally in this part of the investigation a note is made of the number of hours of flying, and also whether there have been any accidents. A brief personal history follows the family history, with reference to the diseases or injuries he has had. Comparatively slight disorders may be the cause of great harm. Tonsillitis is an example. Attention is paid to his school and college record, with mention of his athletic record. These data tell us something as to the sports in which he was proficient and give us a fair idea of his skill as well as of his temperament qualities.

The attitude of the family, especially the mother and wife, are noted, whether it is one of sympathetic approval or disapproval, and this has an important influence upon his capacity to keep his nerve. We also try to ascertain whether he has definite cause for worry. Sometimes there are periods when the aviator prefers not to fly, but, on the other hand, he is usually very keen for his work, and it is only when something has gone wrong that his enthusiasm wanes; sometimes disturbing influences emanate from home; sometimes he feels "fed up" and wants a holiday. Many influences, both internal and external, may, if powerful at the critical moment, throw him off his mental balance. The aviator's balance and alertness must be maintained at the highest efficiency while he is flying. At intervals, when for any reason his full potential efficiency is not maintained, he should not fly nor until he is again at his best, both physically and mentally. Great tact should be exercised in gathering the data. A great deal of information of importance, often of a personal nature, would not be divulged unless the examination brought it easily to light and demonstrated to the aviator its importance.

Third, a brief physical examination is made. The reactions of the pupils and extrensic muscles and the knee jerks for evidence of hypertension or hyperexcitability are recorded. Sometimes we get signs of fatigue in these reactions; sometimes signs of emotional hyperactivity. The presence of tremor in the extension of the hands and in the handwriting, as well as in the process of drawing horizontal and vertical lines freehand, is also mentioned.

Tests for dermagraphia before and after flying or before and after the rebreathing tests are made. Definite conclusions relative to these tests have not been reached as yet, but our attention has been drawn to certain groups of symptoms. We have looked upon a tendency of the line to spread or blotch as rather connected with other signs of fatigue and disability. This reaction is frequently accompanied, though not always, by nervous, very lively knee jerks and an emotional instability. A secondary pupillary reaction is sometimes associated with this group of symptoms.

Occasionally after the rebreathing or after flying a blushing is observed a finger's width on either side of the line. This seems to be of more or less importance, taken in conjunction with the other symptoms mentioned. But whether this deduction can be borne out by further observation remains to be seen.

Lastly, we record our impression of the aviator's personality. We observe whether he is open and frank in his talk or reserved and inhibited. We note his emotional state, trying to determine whether he is in a contented frame of mind or whether he is disgruntled and does not want to say so or whether he is "fed up." It is important to determine as closely as possible what the reason is that he is on edge or out of sorts. With this object in view, a record is kept of even slight fluctuations of moods.

Frequently we run across men in a state of mental anxiety mild or acute. A little tactful questioning will usually bring out the causes. These causes may be simple and easily removable, or they may be complicated and persistent. The points bearing on the case must be talked over frankly and conscientiously. Late hours, loss of sleep, too many cigarettes will easily lower the resistance. Worry and anxiety of any sort in the otherwise perfectly healthy and well-set-up man will surely reduce his efficiency. Even steady attendance upon his work to the point where he is "fed up" will, if persisted in, produce signs of mental and nervous strain and soon render him a danger in the air.

In a short study of the personality we determine whether the flyer is aggressive or on the defensive, whether he has initiative and courage or is reckless and irresponsible, whether he makes quick or slow decisions, whether he is a high-pressure engine under control, and whether his judgments are likely to be good. His reactions during the examinations are important. He may give active cooperation, and this is a good sign, or he may leave us with the impression that the result of the examination was unsatisfactory; even this indefinite finding may later have an important bearing on the personality study and should be recorded. These and other items help us to gain a fairly definite impression of our man.

Nervous states nearer the border line of the psychoses are occasionally observed. The importance of detecting these cases and weeding them out is apparent, and we should appreciate how easily they may escape recognition. Many cases which under conditions of ordinary life do not develop into psychoses in all probability will take this unfavorable turn under the strain and stress of war.

Our whole object is to determine any undesirable psychomotor or other reaction that indicates that the man is wholly or in part unfit for flying. We accomplish this in as brief, direct, and practical a way as possible. After the examination the man is classified according to estimated efficiency, judged from the neurologic and psychiatric point of view. The classifications are A, B, C, D, E.

Explanation of personality rating:

A=Safe, nervous, and mentally stable.

B=Safe, with limitations.

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C=Questionable; no definite conclusion reached.

D=Needs special attention.

E=Unsafe.

In order to illustrate some of the different types and give an indication of the methods of making personality studies the following cases are cited:

PERSONALITY RECORD.—No. 194.

WHITE FIELD, N. H., *June 3, 1918.*

H. R. S., 1st lt., RSSR., pilot.

Aviation history: Officers' Training Camp June to July 30, 1917; ground school to Aug. 5, 1917; to E. Field to Dec. 20, 1917; to J. Field March 31, 1918; commissioned Feb. 6, 1918; to S. Field to date. 260 hrs. flying to date. No crashes.

Personal history: Measles and scarlet fever, good recovery. Appendicitis 1915, operation successful. Father dead, age 53, chronic nephritis; mother living and well; 1 sister living and well. Mother does not approve of aviation, believing it too hazardous for her son. Mother's concern has "modified his actions; more careful." This is doubtful. Not particularly athletic. Education, high school and college.

Physical examination: Ht., 69; wt., 136; age, 24. Knee jerks active. Fine tremor in fingers, constant; pupils react normally to light and accommodation. No secondary dilatation.

Personality study: Quiet, some reserve; has to be interested in flying to follow it or make it a success; deeply interested in flying; anxious to get across; "getting tired of wasting further time in training." Was disappointed three weeks in not being transferred to Columbus and in not getting leave of absence. Wants aerial gunnery; has had 100 hrs. formation; getting disgusted; feels physically tired from continued flights and frequent trips to New York. (Impatient.) Emotion easily excited toward end of examination.

Rating: Personality, "E." Tests, low-tension.

PERSONALITY RECORD.—No. 207.

Station ———, Date ———.

B., R., 2d lieut., — squadron, pilot.

Aviation history: Enlisted aviation section Sept., 1917; graduated from ground school Jan. 20, 1918; Kelly Field, San Antonio, Tex., to June 10, 1918; to R. F. to date. 150 hrs. flying to date. 2 accidents. 2 crashes, both from low altitude in high wind, 2 days following first solo flight. Not injured.

Personal history: Father and mother alive and well. Glad to have him in aviation. Athletic training, track, basketball, horseback, mountain climbing. 6 to 10 cigarettes daily, not inhaled. Education, high school, university 2 yrs. Civil occupation, civil engineering. Unmarried. Res., Ogden, Tex.

Physical examination: Ht., 66; wt., 125 (usual weight); age, 24. Pupils normal to light and accommodation. Tonsils operated in childhood; visible stumps, enlarged cervical glands. Knee jerks lively. No tremor of hands.

Personality study: Wears an expression of slight apprehension. Looks tired, a little pale, and not fit. Says he turns in at night at 12 or 2 usually. Nearly fainted yesterday while being examined (at medical department).

He seems direct and frank, but I can not feel sure of this. Gives the impression of being mentally and physically tired. Should be seen again and certainly not to fly at present. He realizes he is not in best of condition. Can not say positively there is any psychic evidence of his lack of condition. May be due to tonsils.

Rating: Personality, "E" (temporarily on account of tonsils and fainting).

PERSONALITY RECORD.—No. 193.

BLACK FIELD, Date ———.

J., H. Q., 1st lt., ASSRC., pilot.

Aviation history: Ground school July 1st, 1917, to Oct. 1, 1917; transf. to Black Field to May 30, 1918. 315 hrs. flying to date. No crashes.

Personal history: Typhoid at 13 yrs. Fractured right humerus near shoulder joint, 10 years ago. Athletic training, foot and base ball, swimming, tennis; always in training. Education, 4 yrs. high school, 3 yrs. college. Unmarried. Res., Philadelphia, Pa.

Physical examination: Ht. 70; wt., 154; pulse 64, high tension; pupils, equal active, slight secondary dilatation; knee jerks; active, easily exhausted.

Personality study: Has been flying constantly since last year; has felt feeling of staleness; "loss of pep" for 1 month. No worries or fears, merely the wearing of the steady grind, no variety; at present only formation work. Quick, accurate responses. Wants change; rest for a week or two. Should be watched during convalescence period. Optimistic as to future. Increased motor activity; sweating localized; face flushes easily. Has dreamed of flights only recently; of being in tail spin.

Rating: Pensonality, "E."

PERSONALITY RECORD.—No. 204.

———

——— Field, ———.

P. J., 1st lieut., pilot.

Aviation history: May, 1917, Tech School, X Field—to date. 70 hrs. flying to date. No crashes.

Personal history: Measles, pneumonia, and recurring tonsillitis until this year. Broken leg 2 yrs. ago. Father living and well, 1 sister living and well. Family firmly opposed to flying. Wife greatly depressed over aviation. 2 small children. Married. Res., New York, N. Y.

Physical examination: Ht., 68; wt., 165; age, 25. Knee jerks; very active. Pupils react normally to light and accommodation. Slight secondary dilatation after primary dilatation, after primary contraction.

Personality study: An excellent type; open frank, genuine forceful, courageous. Has personal worries and has good cause for them.

Rating: Personality: "E."

PERSONALITY RECORD.—No. 189.

E. FIELD, *June 29, 1918.*

S. E. J., 2nd lieut., pilot.

Aviation history: Ground school July 17–Jan. 18, 1918. O. Field, Feb. 6, '18–May 30, '18. M. Field, to date. 310 hrs. flying to date. No accidents.

Personal history: Measles and malaria during childhood; typhoid at 15, pneumonia 16. Athletic training, football, basket ball, and track. Education, high school, 2 yrs. college. In Army since 1915. No leave.. Tobacco, 15 cigarettes daily. Alcohol, moderate. Family, father and mother living and well; 3 brothers living and well. No opposition. Unmarried. Res., Rock Hill, Ark.

Physical examination: Ht., 71; wt., 174; age, 23. Can't relax so it is difficult to obtain knee jerks unless attention is diverted Pupils active. Marked secondary dilatation.

Peronality study: Feels stale and shows some emotional instability. Says he has not had an accident, but knows one is coming. Probably does not take very good care of himself. Is unsafe for flying on account of present condition. Should have vacation.

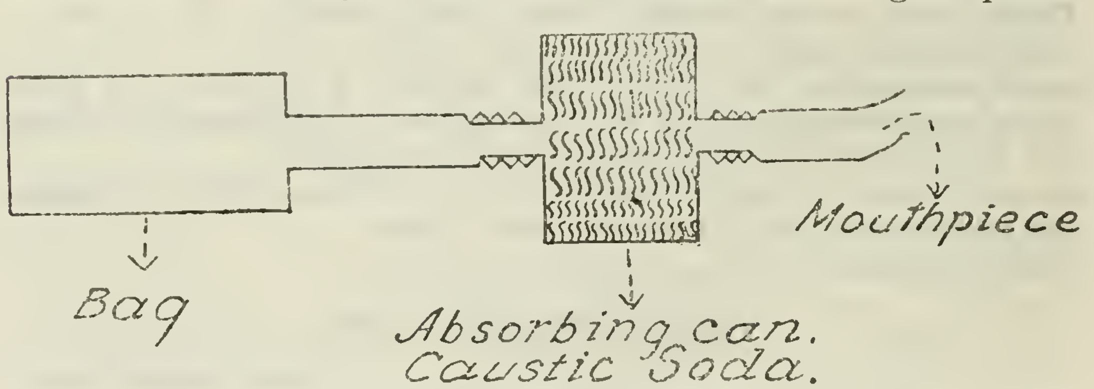
Rating: Personality: "D."

VIII.—THE REBREATHING MACHINE.

The rebreathing machine in its simplest form consists of a bag filled with air, connected by a tube to one side of an absorbing can containing caustic soda (see fig. 1). A tube leads from the other side of the can to a mouthpiece. A clip having been placed on the subject's nose and the mouthpiece in his mouth, he breathes into and out of the bag, the air passing through the caustic soda, which removes from it all of the exhaled carbon dioxide. Inasmuch as a part of the oxygen contained in each breath is absorbed by the body and the carbon dioxide is removed by the caustic soda, the volume of air in the bag gradually decreases and the percentage of oxygen in the mixture grows progressively less. Starting with 60 liters of air in the bag, the average subject will reduce the oxygen to 7 per cent in about 30 minutes.

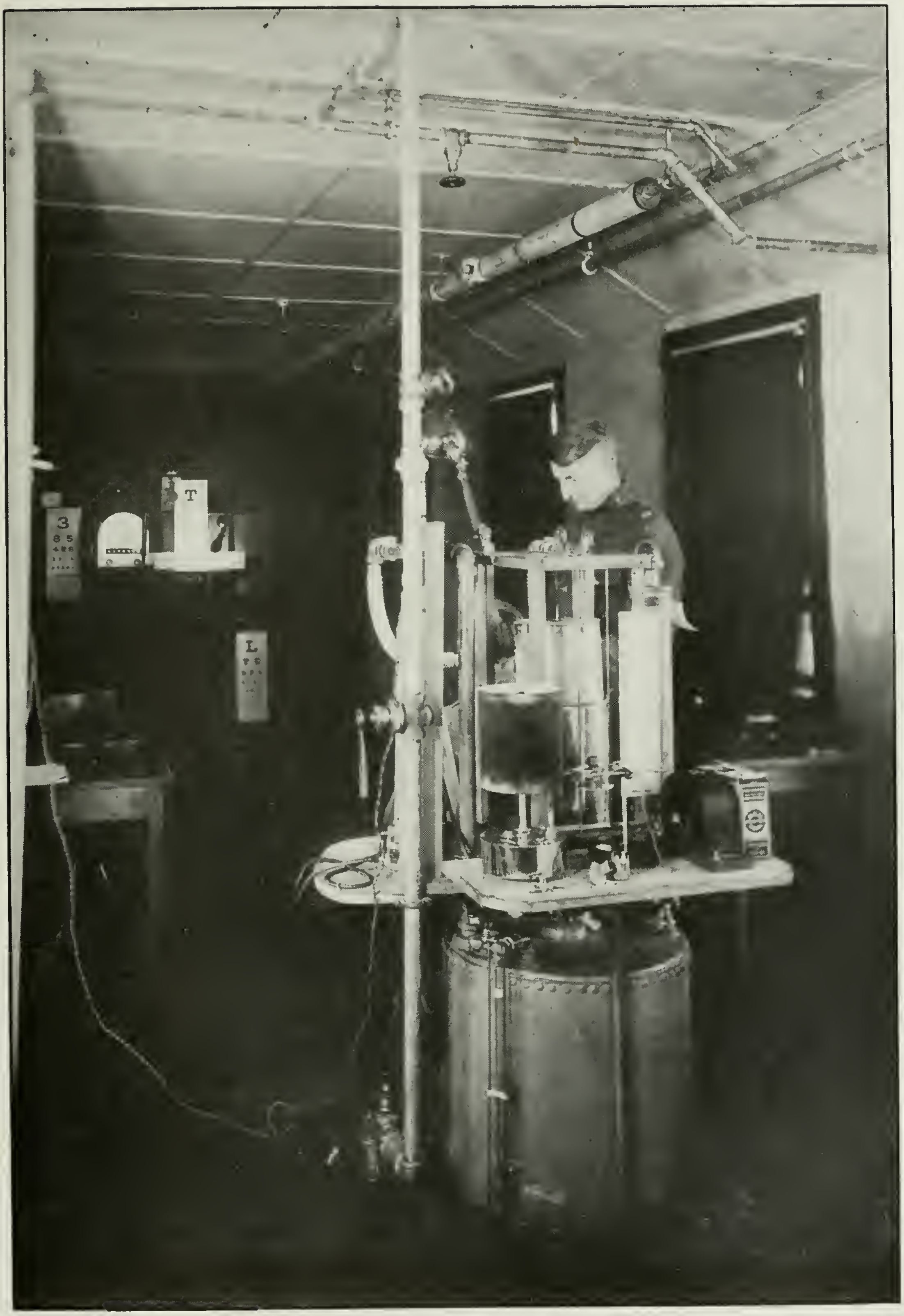
SIMPLE FORM OF REBREATHING APPARATUS.

The rebreathing machines in use in the laboratories of the Medical Research Board embody the same principle as the simple apparatus shown above, but they are built of metal and are designed particu-

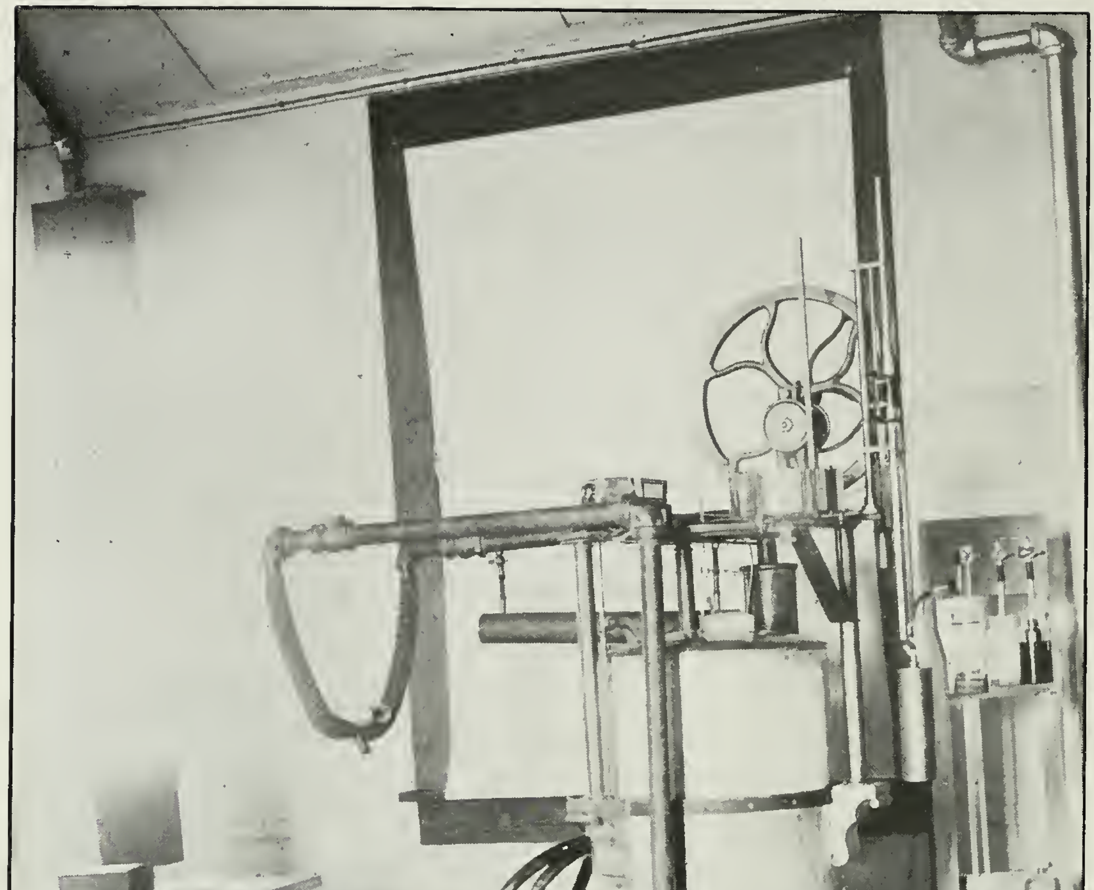


SIMPLE FORM OF REBREATHING APPARATUS.

larly for the routine testing work of the board. There are at present three forms of the machine in use, called respectively type A (serial Nos. 2–13, inclusive), type B (serial Nos. 14–22, inclusive),



THE REBREATHER.

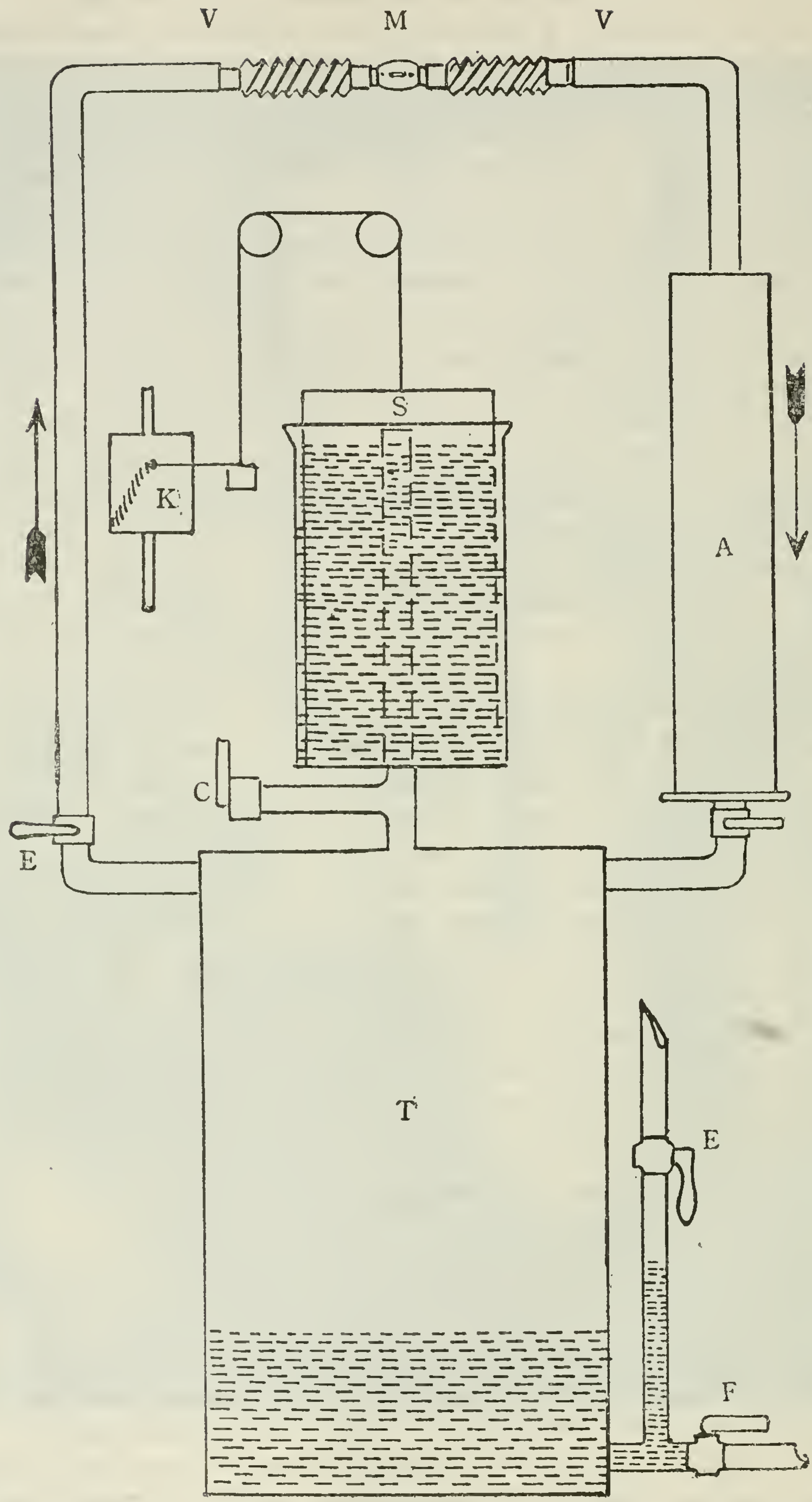


and type C (serial Nos. 23–37, inclusive), but they differ only in details and a description of one will serve for all (see fig. 2). The base of the machine is a steel tank (T) of 60 or 80 liters capacity, according to the type. Type A has 80-liter, and types B and C 60-liter tanks. Air is inspired from the tank through the pipe at the left, and is expired back into the tank through the pipe and absorbing cartridge (A) at the right. The valves (VV) keep the air stream flowing always in the proper direction. In order to maintain the contained air at approximately atmospheric pressure and to allow for changes in volume, a wet spirometer (S), carefully counterbalanced, is mounted on the tank and communicates freely with its interior through the vertical pipe (P). A stylus attached to the counterweight records the movements of the spirometer upon the smoked drum of the kymograph (K). Water is admitted to the tank through valve (E) to replace the volume of the used oxygen and also to flush out the tank after an experiment. The water is drained away to the sewer by means of valve (F). Valve (C) affords a free opening to the atmosphere for flushing the tank of the rebreathed air. Valve (D) should invariably be closed while flushing the tank, otherwise water will enter the absorption cylinder (A) and ruin the cartridge. The cartridge is a cylindrical paper tube filled with solid caustic soda, cast in thin shells so as to expose a large surface to the action of the gas. It is prepared for use in the machine by punching the ends full of quarter-inch holes with a pencil. The brass ring is then inserted in the lower end of the cartridge, the rubber ring fitted over the end, and the whole inserted into the absorption cylinder. Cartridges should never be used without both rubber ring and brass ring in proper position. Valve parts may be removed from the air valves (VV) by means of the brass spanner wrench, which, together with two new valve parts, is furnished with each machine. Counterweight slide rods should be frequently greased with vaseline and the pulleys oiled. In setting up a machine care should be taken to level it properly, so that the inner can of the spirometer hangs freely in the outer can and does not rub against the side.

IX.—THE LOW-PRESSURE CHAMBER.

The low-pressure chamber at the Mineola laboratory is a cylindrical steel tank, 8 feet in diameter and 10 feet high, standing on end. It is entered through a full-sized doorway in the side, and forms a commodious and comfortable room in which five or six investigators may conduct physiological, psychological, and ophthalmological tests under conditions of reduced atmospheric pressure.

The reduction of pressure is brought about by means of a motor-driven vacuum pump of 10 horsepower, capable of rarefying the atmosphere within the chamber to a barometric pressure of 140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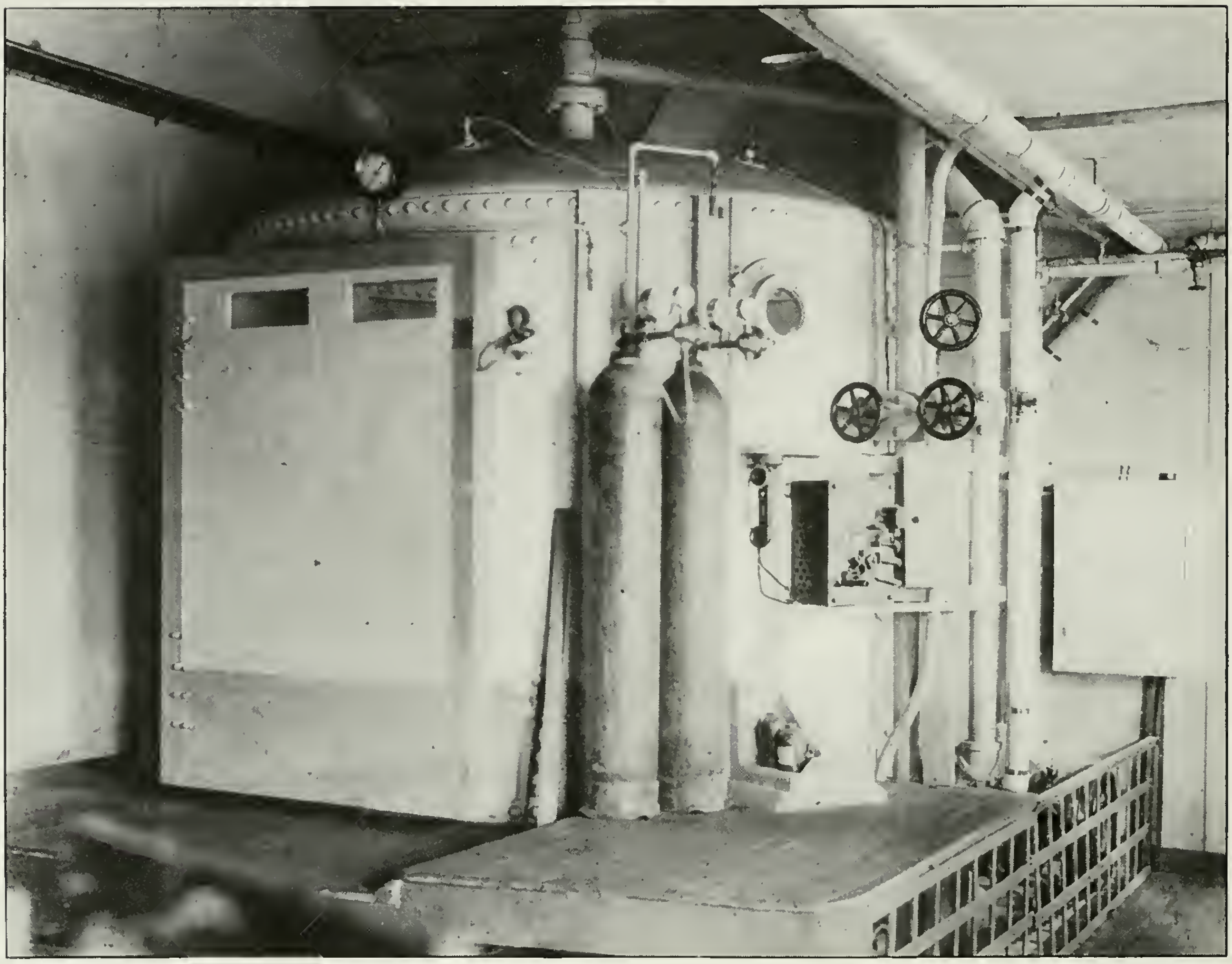


millimeters of mercury (equivalent to 35,000 feet above sea level) in five minutes. This is more than sufficient for any tests upon human beings.

The pump withdraws air from the tank through a 3-inch pipe at the top; at the same time fresh air is admitted at the bottom, the amount being regulated by means of a valve. The admission of air in this manner serves the double purpose of ventilating the chamber and of determining the rate at which the pressure is reduced. That is, if the valve is wide open, pressure remains normal; if the valve is closed, the pressure drops rapidly. Thus by manipulating one valve any rate of pressure rise or fall may be secured.

The inside of the chamber is finished in a flat, neutral tint and lighted by tungsten "daylight" lamps. Several windows of thick glass allow experiments to be watched from without.

An oxygen supply is piped through the wall into the chamber to a distributing board, with an individual tube and mouthpiece for each observer. A check valve in the pump line prevents a material drop of pressure within the tank if, for any reason, the pump is stopped.

For ease and efficiency of operation the control has been centralized. Directly before the operator is a small window and a telephone, enabling him to observe and communicate with those inside. At the left of the window is the mercury manometer indicating the barometric pressure within the tank, expressed in millimeters of mercury and in feet above sea level. At the operator's left hand are the valves regulating the oxygen supply; the valves at his right hand control the flow of air, and below them is the switch for the motor. The operator need not leave his post from beginning to end of an experiment.

Figure 12 is a view of the chamber.

X.—THE CLASSIFICATION EXAMINATION.

The test for classification of aviators is an outgrowth of the research work on the physiological effects of low atmospheric pressure. It was found that there were wide variations in the resistance to such effects, and the task was undertaken of determining which individuals were most suitable for the branches of work which involve flying to the higher altitudes.

The method of rating adopted corresponds well with the military needs of the service. In the first place are the fighters, the pursuit pilots, who commonly fly about 15,000 feet, often above 20,000 feet. In the second, the bombers, who fly comparatively high but rarely above 15,000 feet. Third, the observation planes keep mostly in the lower levels, rarely going above 8,000 or 10,000 feet. The results of the low-oxygen test are expressed in ratings A, B, and C, corresponding to the above requirements. Class D includes men who for one reason or another ought not to fly at all; such cases are occasionally found, though the purpose of the test is classification of flying personnel rather than elimination of any. After several hundred tests have been made it was found that the number of men passed in class A (about 50 per cent) was much greater than the need of the service for pursuit pilots. Since choice had to be made among these men anyway, it was felt that a still higher rating was desirable which should include the particularly hardy specimens who ought by all means to be chosen first. For this reason a rating of AA is given to about 10 per cent of men examined.

The examinations are being made at the central laboratory at Mineola and at a number of the flying schools in this country. It is hoped later to send examining units to every flying field here and abroad, and also to make the examinations at an earlier period in the career of the flier by installing examining units at ground schools or other concentration points for candidates.

The examining unit consists of four officers and six enlisted men. The officers are a physiologist who has general charge of the conduct of the test and sees that the technical details are carried out; a clinician who passes on the general physical fitness of the subject both before and during the test, especially on the reaction of the heart and circulation; a psychologist who determines the effects on general efficiency as expressed by the apparatus work; and an ophthalmologist who makes a careful preliminary examination of the eyes and determines any effects of low oxygen upon the vision. The enlisted men manage the rebreathing machine, make air analyses, record pulse and blood pressure during the test, and do the clerical work on the reports.

The routine test is carried out as follows: A careful history is recorded and a general physical examination made, special attention being given to the circulatory apparatus. The reaction of pulse and blood pressure is measured when reclining and standing, after standard exercise (stepping up five times upon a chair), and two minutes after exercise. It is hoped that these simple tests will be found useful when repeated later in the career of the flier to determine whether he has remained in good condition. It may be stated that a normal behavior in these reactions has been found to be a very fair index of the subject's ability to pass the low-oxygen test. A careful examination is now made of the eyes.

The next step is the rebreathing test itself. The evidence is sufficient that this test is a perfectly reliable index of tolerance to low atmospheric pressure, and the low-pressure chamber has been used not as a routine method of examination but only as a means of checking up the results of the other test and for scientific purposes.

The rebreathing machine is so adjusted that the average run will be between 25 and 30 minutes. During the run the subject does the psychological work as described elsewhere and is carefully observed by the psychologist to determine the earliest effects on attention and motor coordination, as well as the time of appearance of more marked effects and of total breakdown.

Every three minutes the capacity of the external and internal ocular muscles is retested during the run (near point of convergence and near point of accommodation). During the whole test the pulse and blood pressure, systolic and diastolic, are measured every one or two minutes. The clinician keeps close watch of these figures and makes frequent examinations of the heart. The respiration is recorded during the test on a kymograph.

The test ends when the psychologist has determined that the subject has reached the point of complete inefficiency, or when the clinician finds that the condition of the circulation makes prolongation of the test undesirable. The latter contingency usually means either that the heart is abnormal or that fainting is about to occur unless the test is stopped. At the close of the run the air remaining in the apparatus is analyzed to determine the oxygen percentage reached, which can be translated roughly into terms of altitude. A few subjects have exhausted the oxygen to 6 per cent or a little lower; 7 per cent is a frequent figure, while poor subjects either become inefficient or faint at considerably higher percentages.

The results of the test are summarized in a plot of which the abscissa line represents minutes of time, and the ordinates are per cent of oxygen, and figures representing pulse, blood pressure, volume of respiration, millimeters of near point of convergence, etc. The appearance of different degrees of inefficiency by the psychological tests is indicated by symbols placed at the proper time on the abscissa line. It is assumed (with reasonable correctness) that a straight line connecting the oxygen per cent at beginning and end will represent the per cent at all intervening times. The basis of judgment on the success of the subject is the oxygen percentage at which various phenomena occur, and this is reckoned from the height of the oxygen line at the time in question.

The decision as to rating the subject is made by consensus of opinion on the basis of the ratings made by each separate department and is ordinarily the lowest rating assigned by any one of them. No man is passed in class A who has any considerable disqualification from any point of view. For example, a deficiency in vision whether ordinarily present or only developing as the result of the test would disqualify for combat work no matter how well the candidate performs otherwise.

Aside from ocular deficiencies or general physical conditions of a distinctly abnormal nature, the rating of a subject depends on the answer to two questions. How well does he adapt himself to the unusual environment, i. e., how well does he preserve his efficiency at altitudes (as expressed by the psychological tests) and, second, at the expense of how much strain on his circulatory system does he do it? Many subjects will compensate admirably, preserving their efficiency to a very high altitude, but only by means of a very high blood pressure, high pulse, or violent vasomotor reactions such as would lead us to expect that this man would wear out quickly in service or, perhaps, actually have a circulatory collapse in the air and faint.

As to the first question, that of general condition and the proper functioning of the compensatory apparatus, our most delicate criterion is the performance on this psychological test. If a man is able to keep his brain clear, he is certainly compensating against low-oxygen effects, for the brain is not only the most important tissue to protect, but it is also the most sensitive to defective nutrition. After much experimentation with different systems of rating a fairly empirical method of computation has been adopted (fully described elsewhere) which takes into account the percentage of oxygen at which various effects appear and the duration of the test, since longer exposure to moderate oxygen deficiency may produce more profound effects than a short exposure to a high degree. The rating is based both on the early slight signs of abnormal effect and on the more pronounced manifestations up to complete inefficiency. One man may be moderately inefficient from 8,000 feet up, but only break completely at 25,000 feet. Another may remain perfectly clear until 20,000 feet and then suffer a complete loss; probably the second man would be a more useful flier than the first.

The second question, that of the amount of circulatory strain involved in preserving compensation, is answered largely by the behavior of pulse and blood pressure and by the sound of the heart during the test.

A fuller discussion will be found elsewhere of the method of rating based on circulatory effect. A subject who has a definitely diseased heart, no matter how well compensated, is put in class D, and it is recommended that he be kept at ground work. No man is passed in class A whose blood pressure is so high that the heart will be continually undergoing severe strain. Signs of circulatory exhaustion or fainting are causes for rating in class B or C.

It should be stated that some of these circulatory reactions are signs not of constitutional inferiority but of temporary lack of condition. They none the less give a clear index of how the man may be expected to behave in the air, and such a temporary rating should be followed until a better general condition can be demonstrated. It is hoped that it will be possible to apply the test at rather frequent intervals to the aviators in service and thus determine whether they are remaining in good condition or becoming "stale." For this reason it has been arranged that the report of the examination is to accompany the aviator wherever he goes and be accessible to the Flight Commander and the Flight Surgeon.

An analysis has been made of the results of 374 routine examinations. The results are given in the tables below.

The first table shows the percentages of the various ratings among various classes of subjects examined. Pilots and cadets show almost identical figures for the higher ratings, but more absolute disqualifications were recommended among the latter. Nonfliers make a considerably poorer showing.

TABLE No. 1.—*Analysis of 374 examinations.*

	AA		A		B		C		D		Total.
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	
Pilots	15	9.4	52	32.7	58	36.5	32	20.1	2	1.3	159
Cadets	16	9.7	54	32.7	58	35.1	27	16.4	10	6.1	165
Total fliers	31	9.5	106	32.7	116	35.9	59	18.2	12	3.7	324
Observers	1	4.3	5	21.7	6	26.1	10	43.5	1	4.3	23
Others	1	3.7	7	25.9	7	25.9	7	25.9	5	18.5	27
Total	33	8.8	118	31.7	129	34.6	76	20.3	18	4.8	374

The average age of the various classes is interesting. This was tabulated for 193 cases passed above D.

TABLE No. 2.

	Number.	Age.	
		Yrs.	*Mos.*
Class AA	22	23	9
Class A	61	25	1
Class B	69	25	1
Class C	41	24	7

Among 109 cases of fliers rated class B the reason for not giving A was as follows:

	Number.	Per cent.
Circulatory exhaustion	37	33.9
Psychic deterioration	36	33.0
Both of above	27	24.8
High blood-pressure	9	8.3
Total	71	100.0

Among 65 cases of fliers rated C the reason therefor was:

	Number.	Per cent.
Circulatory exhaustion	31	47.7
Psychic deterioration	23	35.4
Both of above	3	4.6
High blood-pressure	5	7.7
Defective vision	3	4.6
	65	100.0

Of 18 men rated in class D the causes were:

Valvular heart disease	9
Ventricular extrasystoles	3
Deficiency of vision or ocular muscles	3
Color blindness	1
Vertigo of unknown cause	1
Neurotic constitution, poor vasomotor tone	1
Total	18

XI.—DIRECTIONS FOR THE CLASSIFICATION EXAMINATION.

ROUTINE FOR EXAMINATIONS.

1. Each unit will consist of four officers and six enlisted men, viz:
   1. Physiologist.
   2. Clinician.
   3. Ophthalmologist.
   4. Psychologist.

   Enlisted men, A, B, C, D, E, and F.

2. The ranking officer of each unit will exercise military command and will coordinate and expedite the work of the unit. He will not, however, usurp the right of other officers to decide matters, especially such as involve rating, which lie in their own departments. Technical or scientific matters or such as involve general policy will be referred to the Mineola Laboratory through the chiefs of the respective departments.

3. The routine test for aviators will consist of (*a*) preliminary test by clinician and physiologist including history, (*b*) preliminary test by ophthalmologist, (*c*) test on the rebreathing apparatus during which the subject's performance and condition are observed by clinician, ophthalmologist, and psychologist. Technical details of the test are the responsibility of the physiologist who supervises the work of the enlisted men on the machine and in taking pulse and blood pressure. He will not examine the subject during the test.

4. The test will normally be continued until the subject has arrived at a point where he clearly shows low oxygen effects or his efficiency as determined by the psychologist, and when this point is reached, the experiment will be terminated. In case, however, his general

condition demands it, the subject should be removed before this time. The necessity for interrupting the test before its natural termination is to be decided by the clinician though all others present should call his attention to unfavorable indications. This applies especially to the physiologist and the enlisted man taking pulse and blood pressure, who should promptly report to the clinician any noteworthy change in these observations or in the respiration.

5. No test should be prolonged beyond the point where the final rating can be determined. For example if the subject's heart puts him in class C or D, it is a matter of no great interest whether he ranks A or B on the psychological test. It is important that the test be so conducted that subjects will not have the expectation in advance of undergoing anything dangerous or disagreeable; for this reason tests should rarely be prolonged to the point of fainting, unconsciousness, or great discomfort.

6. All members of the unit must exercise diligent care to prevent the prejudicing, alarming, or exciting of the subject. This applies not only to subjects being tested, but to all fliers and candidates who may be later subject to test. Even chance remarks, which might give the impression that there is danger or discomfort in the test, or that many men are disqualified as a result of the test, must be scrupulously avoided. Unfortunate remarks which seem unimportant to the person making them, do in many cases produce such an effect on the subject that his performance on the test is materially modified.

7. Instructions to the aviator concerning the operation of the psychological apparatus, will be given by the psychologist only. Additions by other members of the group are detrimental.

8. During the first three minutes of the run, the aviator will be coached by the psychologist.

9. Stop-watches of the psychologists, ophthalmologist, and cardiac observer will be started simultaneously, and all records will be kept in terms of elapsed time after watches are started.

10. Beginning at the sixth minute, and at three-minute intervals thereafter, the psychological work will be stopped for 30 seconds, to allow the ophthalmological and cardiac examination. It is important that the ophthalmologist keep track of the time so that he shall be ready promptly.

11. Full instructions as to the ophthalmological tests must be given previous to the commencing of the run, so that no instructions will be necessary in the 30-second period.

12. In case the clinician feels that the subject's physical condition demands more frequent examinations these shall be made in such a way as to disturb the psychological test as little as possible.

13. Rebreathing tests may be made separately for the purposes of the different departments, but in rating fliers a single test will be made as a routine. If it seems desirable an unsatisfactory test may be repeated.

14. Results should not be indicated to the aviator except in the most general form—especially to be avoided is any statement of "how far he went" in terms of thousands of feet altitude. It may be made plain there is no direct parallel between oxygen percentage in the rebreathing test and low atmospheric pressure, and that in the rapid progression of the test the results would be very fallacious if applied to active working conditions at high altitudes.

15. The duties of the officers are:

(*a*) The physiologist will have immediate charge of enlisted men A and B, see that their work is being done properly, that all apparatus is in order, and that necessary supplies are kept in sufficient stock. He will take pulse and blood pressure before the rebreathing test in the manner prescribed on page 2 of the history. He will pass on the character of the pulse, respiration, and blood pressure, conferring with the clinician as to their bearing upon the normality of the circulatory apparatus. He will enter this judgment on these matters under "summary" on page 2 of the history.

(*b*) The clinician will carefully read the history prepared by enlisted men C; go into more detail as to points suggested, especially as to the exact condition at time of test. He will then make a physical examination and fill in the entries on the history form or dictate them. He will be present at each rebreathing test, following carefully the condition of the subject, interrupting the test if he considers that the subject's physical condition demands it, being the one man responsible for ending the experiment. On completion of the test he will enter on the blank (p. 3) the exact condition at beginning and at close of test (especially whether unconscious, fainting, etc.), note manner of recovery, and any other remarks as to progress of test. He will summarize on page 2 the behavior of the subject's general physical fitness both before and during the test, especially the behavior of the heart. He will consult with the physiologist as to respiration, pulse, and blood pressure.

(*c*) The ophthalmologist will conduct preliminary tests, and tests during the rebreathing experiment. He will base his rating on the results of both tests.

(*d*) The psychologist will observe the performance of the subject during the test. He will plainly signal to the clinician when he is ready to terminate the experiment, and the clinician will ordinarily take the subject off at this time. He will base his rating on both the preliminary performance and on performance under low oxygen.

16. The duties of the enlisted men are as follows:

A will have the care of the rebreathing machine during the test and will be responsible that it is kept in order. He will make analyses and record them on the history sheet, page 3.

B will take and record pulse and blood-pressures during the test and attach this record to the history sheet. He will fill in the names at the top of page three of the history. He will be responsible that all papers are taken to be plotted as soon as above entries are made.

C will receive candidates, give them directions as to procedure, take their history, assist physiologist and clinician in their examinations. He will also assist E with copying and keeping in order the histories.

D will be responsible for making three copies of the charts in each case.

E will be clerk, writing such letters, etc., as may be ordered, and being responsible that three identical copies of each record are prepared, and that they are mailed after approval to their appropriate destinations.

F will have charge of the psychological apparatus and will manipulate the lights during the test. He will assist in the plotting and copying.

17. The Commanding Officer of the unit may readjust the assignments of the enlisted men as he deems wise; e. g., A and B should be interchangeable, and it may be necessary that C, D, and E assist each other somewhat.

ROUTINE FOR RECORD KEEPING.

1. Candidates will report to enlisted man C.

2. C will enter candidate's name in the journal, take the history and attach to it the check slip. The history (original copy) will be either written in ink or typewritten. The two copies will be typewritten. Entries by the various departments are to be made only on the original and the original is to be signed by each officer, military rank being added and designation as "Physiologist," etc.

3. Each step afterwards is to be initialed on the check slip as it is made.

4. Preliminary pulse and blood pressures to be taken by the physiologist.

5. Physical examination to be made and entered (or dictated) by clinician.

6. Preliminary eye examination made and entered by ophthalmologist.

7. History to go to rebreathing room with the subject, to be delivered to B. B is to be instructed that no test is to proceed until the history is in his hands and until all procedures up to this point are checked on the check slip.

8. At the close of the test the names of observers are to be entered by B; any remarks about the test may be entered by the physiologist or the clinician; the clinician will enter condition at beginning and close of experiment and at this time he will usually enter his remarks, under the summary on page 2. The air analyses will be entered by B, who obtains them from A, as well as the exact time of day and the duration of the test.

9. At the close of the test all papers (history, check slip, pulse and pressure notes, duplicate of psychologist's notes, kymograph tracing) are pinned together and taken to plotting room by B, and placed in folder marked "Plotting room. To be plotted."

10. Three identical plots are made by D.

11. D takes all papers to ophthalmologist's desk and places them in folder marked "Ophthalmologist. For notes on histories." Ophthalmological data are to be added to chart and entries made under summary on page 2.

12. Papers taken in turn to similar folders on desks on psychologist, physiologist, and clinician, who similarly make their additions to chart and history.

13. Each department should attend to this clerical work as expeditiously as possible, and see that papers are forwarded at once to the next department.

14. When notations are complete all papers are to be placed in basket on C's desk marked "Examination complete. Plotted. Notes made. To be rated."

15. A conference of all officers on rating is to be held at frequent intervals, preferably each day. The rating is decided on concensus of opinion, being ordinarily the lowest rating of any department. The subject is to be assigned to one of four classes, viz: A (no restriction as to altitude), B (should not fly above 15,000 feet), C (should not fly above 8,000 feet), and D (should not fly at all). Further recommendations of the board in greater detail will at this time be dictated to E, who will later see that such entry is made. It is desired that recommendations be made as explicit and detailed as possible, advising as to the exact kind of work the subject can do best.

Entries under recommendations of the board should be made in language understandable to the laity. (In the rest of the report this is not important since the data is primarily for reference on repeat examinations or for collation.) The definite figures established as to altitude are to be given as above. It is a good usage to explain by a phrase or so all ratings below A. For instance, if the psychologist gives a rating of B, the following phraseology may be employed: "Class B (should not fly above 15,000 feet), becomes inefficient before highest altitudes are reached." In case of heart strain:

"Class C (should not fly above 8,000 feet). Preserves his efficiency at moderate altitudes only at the cost of severe heart strain. Would wear out soon if used at high altitudes," etc.

16. Records to be returned to basket marked "Rated. To be copied."

17. E will see that three copies are prepared, identical, except that only the original need be signed. He will then return them to basket marked "Copied. To be inspected."

18. Reports will receive final inspection of Commanding Officer of unit, whereupon E will send the original to the Commanding Officer of the flying field, one copy to office of the Surgeon General, United States Army, and one will be filed in the Medical Research Laboratory. (For the present all three copies and all other papers will be sent to the Medical Research Laboratory at Mineola, where they will be inspected and distributed as above. When this is done, it will be advisable for the unit to keep on file duplicates of the original notes. When the original is sent direct to the Commanding Officer of the flying field and is thus on file at the field, the unit will not need duplicates.)

19. In filing records in Medical Research Laboratory each one as it arrives will be given a serial number and all papers marked with this number placed in a manila folder also marked with name and number, and filed serially. A smaller (3 by 5) card will be made out for each record and kept in a smaller file in alphabetical order.

20. In case the examination has not been completed, the records will be kept in basket marked "Examination incomplete. To return."

21. When it is evident that an examination will never be completed (e. g., if aviator is moved to another station), the history will be filed, not with the completed histories, but in a separate division arranged alphabetically marked "Incomplete. Will not return." A small card (3 by 5) will be made out for such a record and will be filed with the other small cards.

22. Incomplete records on which no rating has been made will not be sent to the Commanding Officer at aviation field nor to the Chief Surgeon, but will be kept by the unit unless the aviator has been transferred when they should be sent to the Mineola Laboratory.

23. Any correspondence relative to an aviator is to be filed with the other reports at Mineola.

DIRECTIONS TO CLINICIAN AS TO CONDUCT OF REBREATHING TEST.

The clinician is to be present throughout the test and is primarily responsible for the subject's condition. It will almost always be possible to keep sufficiently accurate track of the heart action by listening during the eye examination in order to avoid interference with the psychological test. In case the safety of the subject demands it, however, he should not hesitate to examine the heart more frequently, especially toward the close of the test.

The clinician will be the one to terminate the test by removing the mouthpiece or nose clip. About four times out of five probably this will be at the instance of the psychologist, who will plainly indicate as soon as his results are satisfactory. When this point has been reached the subject is probably within a short space of insensibility and the mouthpiece should be removed without delay.

The clinician may terminate the test before the psychologist has got his full results if he considers that safety demands it, but such an occurrence should be infrequent if proper judgment is used, because any abnormal circulatory condition will give an early psychological effect and it is usually safe to let the test go to this point. An exception is any case of cardiac arrhythmia (except sinus arrhythmia), which increases during the test. In this case the experiment should be terminated very early from the possibility of ventricular fibrillation.

When a definite cardiac lesion can be determined it is unnecessary to prolong the test, for if the clinician's rating is C or D it is a matter of small importance whether the psychologist's rating is A or B.

The physiologist may suggest terminating the test if something is manifestly wrong, as e. g., with the apparatus.

The indications for interference by the clinician are two: First, that he has determined a disqualifying cardiac condition; second, that the subject is on the verge of fainting. To guard against this latter the clinician should carefully watch the pulse and blood-pressure record and should instruct the observer to call his attention at once to any marked change. Blood-pressure readings every minute are desirable toward the end of the test. Subjects who have had an excessive response in pulse and blood pressure, those whose hearts are evidently working too hard throughout the test should be especially carefully watched, but even in these cases it is always safe to allow the test to go on either until the psychologist is satisfied or until there are definite signs of fainting. Rapidity in pulse or moderate increase in blood pressure is not an indication for stopping the test.

The first sign of fainting will be a sudden drop in diastolic pressure, followed later by a drop in systolic pressure, then a drop in pulse. It is often possible to remove the mouthpiece when the diastolic fall has occurred, but before the other two. A slow and steady decrease in diastolic pressure is to be regarded as normal if not excessive, especially when the systolic pressure is not increasing, but such a steady decline frequently ends with a sudden fall and demands careful watching from minute to minute.

It is highly important to avoid fainting when possible (and even the cerebral type of unconsciousness), though a certain number of cases will faint in spite of the most careful watching; this may occur with great suddenness, especially when coming early in the run.

A middle ground must be taken, giving the psychologist as much opportunity as possible for his observations and yet avoiding disagreeable terminations of the test. As remarked above, the psychologist should terminate the test at least four times out of five.

DIRECTIONS FOR CLINICIAN AS TO RATING.

When a diagnosis of valvular lesion of the heart can be made, no matter how well compensated, the subject should be disqualified. Rarely in the case of a man who has already qualified as a pilot and where the compensation is excellent and the reaction to the test good, he may be passed in class C with explicit directions that he be very carefully watched and be withdrawn later from all air work if he gives any evidence of wearing badly.

Subjects who have or develop arrhythmia are to be rejected (except sinus arrhythmia, which is of no importance).

Subjects who show deterioration of heart sounds (usually due to poor arteries, fatty heart, or flabby heart muscle) should be rejected, or if the deterioration develops late in the test, be rated in class C.

In any of the above cases the experiment should not be prolonged beyond the point where the clinician has fully satisfied himself of an abnormal heart.

The clinician will not be called upon to decide on cases who compensate poorly, since they will receive a low rating from the psychologist, who will demonstrate failure of compensation long before the clinician could. The type of person, however, who because of generally poor constitution fails to compensate at all (no rise in pulse, none in respiration, no change in blood pressure), should be rejected rather than given a low rating. Such cases, however, should be very rarely found in the Aviation Service.

Of the cases who compensate well (probably 75 per cent or more of the experiments) the rating should be based on the amount of circulatory strain involved in maintaining compensation.

It is difficult to establish fixed rules in this regard and much must be left to the judgment of the examiner. Those who become unconscious at less than 8 per cent oxygen without circulatory failure, of course, deserve an A rating. We have passed a few subjects who had a circulatory collapse (either fainting outright or marked drop in diastolic pressure) at less than 8 per cent. Those whose circulation fails between 8 and 10 per cent may be rated B, and those above 10 per cent C. If in doubt, it is safer to give a lower rating, since more fliers will be needed for lower than for higher altitudes, and the late effects of circulatory strain are always to be considered—i. e., the early development staleness. Rating should be very conservative in cases of high blood pressure. If this is above 150, the rate should be B; if maintained above 160, it should be C, especially when there is evidence of circulatory fatigue. The paragraphs on blood pressure in the directions to the physiologist should be carefully followed.

In cases given a low rating on account of circulatory strain, the fact should be made evident under "recommendation of the board" on the report. Some such phraseology as the following may be employed: "Class C (should not fly above 8,000 feet). Maintains his efficiency at moderate altitudes only at the cost of severe heart strain. Would quickly wear out if used at high altitudes."

NOTES ON THE DIAGNOSIS OF VALVULAR HEART DISEASE.

The cases of valvular disease which the clinician of the research board will have to decide will almost always be difficult to diagnose. This is because the candidates have been already carefully examined and selected.

The rebreathing test is a very efficient aid to the more usual methods of examination, and it may pretty safely be asserted that a man who makes a good run on this apparatus can have no serious cardiac lesion.

Overemphasis must not be placed upon single factors. This is especially true of murmurs. Systolic murmurs are extremely common, especially when heard at the base, in cases where there is no organic disease. Roughnesses of the first sound that suggest a slight thrill are also not uncommon.

A clear prolonged diastolic murmur is, of course, almost certainly caused by either aortic insufficiency or mitral stenosis, but even in this case a diagnosis must not be based on the murmur alone. Evidence of hypertrophy and dilatation, either or both, should be present, and in mitral cases a pretty marked accentuation of the pulmonic second sound. The trained ear learns to judge from the character of the heart sounds rather than the murmurs whether there is organic disease or not, but it is difficult to express in words just what the changes in the heart sounds are which prove decisive.

A heart with an organic lesion seems to behave in one of two ways on the low oxygen test. It may fail to compensate almost from the start; in this case there may be no accentuation of the first sound nor of the murmurs, but rather a deterioration of the sounds and a shortening of the first interval. Such a subject will probably become inefficient very early, will get very blue, and be extremely uncomfortable; a number have themselves removed the mouthpiece saying they felt that they were suffocating. This type of reaction, indicating poor heart muscle, will be rarely found among aviators.

Much the commoner type of reaction is that of excellent compensation or rather of overcompensation. In this the heart is evidently on a heavy strain from the start, the sounds loud and booming, the apex impulse heaving, second sounds accentuated. Murmurs are sure to come out much more clearly. For a reason which is difficult to understand, this type of case usually runs a high blood pressure, 140 to 160, occasionally even to 180. Psychological efficiency is often held very well.

Such well-compensated hearts frequently hold out and do their work against the odds up to a very high altitude. When a diagnosis of valvular lesion is clear, however, it would be unwise to prolong the test to the point of cardiac failure, as the latter would involve much greater risk than in the case of the normal man.

Numerous cases have been observed where puzzling murmurs have been present on preliminary examination, which did not become stronger during the test, or even disappeared; in these cases the whole course of the test was normal, there was no evidence of cardiac incompetence nor of overstrain. In such a case the murmur should have no weight at all in assigning the final rate.

While we feel very strongly on the danger of flying to a man with valvular disease, there is bound in every case to be bitter disappointment and dissatisfaction with the ruling of the board. For this reason great care must be exercised in the diagnosis and, when possible, two competent clinicians should argue on the matter. Usually it is best to repeat the test to be absolutely sure.

Probably the chief source of doubt will come from cases of poor condition from other causes (bad cold, diarrhea, etc.) with functional murmurs. In some of these cases an interval of two weeks before a retest will clear up the confusion. In the other cases it may be necessary to have a more thorough inquiry into the general condition at the post hospital or even at a base hospital.

In case of doubt it is safe to err on the side of protecting the man, especially when he is a candidate or a cadet. In case of a finished pilot he may be passed in class C when there is a reasonable doubt, but the recommendation of the board should contain explicit directions that his heart must be very carefully watched, and that he is to be withdrawn from flying if trouble develops. The case should be called to the attention of the Flight Surgeon and the man himself should understand the situation thoroughly—both his own condition and the danger of aviation to a defective heart.

ROUTINE EYE EXAMINATION DURING REBREATHING TEST.

1. Instruct the candidate fully as to the methods of procedure during the rebreathing experiment and the signs that he will make to tell you when his vision is blurred, when he is diplopic, etc. It is well to take time to instruct the candidate in this way so that valuable time may not be lost during the experiment, and the psychological reaction disturbed as little as possible.

2. Beginning of sixth minute, after start of rebreathing experiment, note (*a*) convergence near point; (*b*) accommodation near point; (*c*) field of binocular fixation.

3. Note convergence, accommodation, and field of binocular fixation during first 30 seconds of every third minute, and vision every 6 minutes.

4. Make at least one reading after candidate is removed from apparatus.

5. Make note of reason for removing man from rebreathing apparatus on face of card.

6. Note also on face of card whether man is apparently a desirable candidate as far as the eyes are concerned.

7. All records must be in ink.

8. Make all notes on 5 by 8 history card. Loose papers are undesirable.

9. Make a record of the examination in the cross file under heading "Tests and date."

10. As soon as oxygen percentage is recorded, rate the candidate under the date in this manner, on the back of the 5 by 8 card:

(1) 11 per cent (per cent of oxygen at which first permanent change occurs).
(2) 7 per cent (per cent of oxygen where the candidate is ocularly inefficient from any cause). Eye (A).

Thus: 4–20–18. (1) 11 per cent. (2) 7 per cent. Eye (A).

N. B.—Make notes of rating *a*, *b*, *c*, or *d* on card for tests and dates after man's name.

11. As soon as data is complete to this point, enter it on the three copies of the history and make any necessary recommendation, stating why it is made.

(*a*) Under summary of observations during low oxygen tension test, use scientific terms.

(*b*) Under recommendation of board, use lay expressions.

One copy of the history is sent to the Post Commander, one to the Medical Research Laboratory, Hazelhurst Field, Mineola, L. I., and one to Air Service Division, Surgeon General's Office, Washington, D. C.

12. Make certain that the 5 by 8 card which is retained in the laboratory gives a complete statement of the reason why a candidate was rated *a*, *b*, *c*, or *d*, and what recommendations were made as to his final disposition.

13. Keep 4 by 6 cross file up to date, following some such scheme:

Index (cross scheme for Ophthalmological Department).

Card color scheme: (1) yellow, (2) blue, (3) salmon, (4) white.
Subindex under (*a*) Rebreathing.
(*b*) Name and date and altitude in feet where break was first shown.

(1) Men who have flown. FLIERS. (1) Pilot. (*a*) Have flown.
(2) Observer. (*b*) Have not flown.
(2) Acclimated.
(3) Men who show break in accommodation....................ACCOMMODATION.
(4) Men who show break in convergence....................CONVERGENCE.
(5) Men who (do or not) show break after abuse of alcohol, insufficient sleep, sex excess. (*a*) Yes. (*b*) No. } ....DISSIPATION.
(6) Muscles....................MUSCLES.
(7) Men who show no ocular break....................NORMAL.
(8) Break in field of fixation....................FIXATION.
(9) Refractive errors (break or not). (*a*) Yes. (*b*) No. } ....REFRACTION.
(10) Men show break in vision. (*a*) Acuity of (*b*) Color (*c*) Field of } ....VISION.
(11) Men who (do or not) show break after illness....................ILLNESS.
(12) Men who (do or not) show break after typhoid vaccination. (*a*) Yes. (*b*) No. } ....TYPHOID.
(13) Oxygen given during experiment....................OXYGEN.
(14) Stereoscopic vision....................STEREOSCOPE.
(15) Retinal sensitivity. (*a*) Contrast. (*b*) Treshold. } ....RETINA.
(16) Tension (Intraocular)....................TENSION.
(17) Men who have had accidents....................ACCIDENTS.
(18) Men who are stale....................STALENESS.

ROUTINE MONTHLY EXAMINATION OF THE EYE OF THE FLIER (SUGGESTED).

A record of the completed 609 examination should be kept with the papers of each flier, with the additional record of the near point of convergence and muscle strength finding.

1. Visual acuity: If the visual acuity has altered, ophthalmoscopic examination should be made to determine the cause.
2. Examination of the eye.
3. Muscle balance. (*a*) If change in findings, record muscle strength.
4. Near point of accommodation.
5. Near point of convergence.

N. B.—If alteration is found in any of the above findings, stereoscopic vision should be tested.

OPHTHALMOLOGICAL EQUIPMENT FOR BRANCH LABORATORIES.

1. Two small millimeter rules, 15 centimeters in length.
2. One Prince rule. Illiterate " Es " as test object.

3. One 5-foot centimeter rule, marked in millimeters, and in degreees of tangents of arc.
4. One Hare-Marple battery-handle electric ophthalmoscope.
5. Two dozen batteries and three extra lamps for the ophthalmoscope.
6. One stop watch.
7. One Schweiger hand perimeter, with two extra eyepieces, one for monocular use and one for binocular use.
8. Three 75-watt, 110-volt, nitrogen daylight lamps.
9. Two extension brackets, with two shades.
10. One set of visual acuity test cards. (Black's, F. A. Hardy & Co.)
11. Trial case No. 4072, with a multiple Maddox rod and 1½-inch lens.
12. Trial frame No. 4157.
13. One box square prisms No. 4112.
14. Jenning's color-test No. 1.
15. Reeves's wedge.

Per cent transmission and density of average wedge.

Millimeters	5	10	15	20	25	30	35	40	45	50
Density	0.225	0.466	0.70	0.915	1.14	1.39	1.62	1.86	3.085	2.30
Per cent transmission	59.74	34.28	19.84	12.14	7.20	4.06	2.40	1.38	.83	.50
Millimeters	55	60	65	70	75	80	85	90	95	100
Density	2.57	2.785	3.0	3.28	3.485	3.72	3.945	4.18	4.42	4.65
Per cent transmission	.26	.16	.1	.05	.03	.02	.01	.006	.003	.001

16. Two retinoscopes, with an 18 millimeter plane mirror.
17. One 36-watt, 110-volt, frosted bulb, Edison Mazda lamp.
18. One iris diaphragm on stand (deZeng).
19. Opaque shades for examining room.
20. One 5 by 8 filing drawer and 500 No. 1 cards and 500 No. 2 cards, with alphabetical index guides.
21. One 4 by 6 filing drawer, 50 yellow tabbed cards, 100 blue tabbed cards, 150 salmon tabbed cards, and 300 plain white ruled cards.
22. Copy of per cent transmission and density for average wedge.
23. Copy of cross-filing scheme for ophthalmological records.
24. Charts for recording the field of vision, 100.
25. Charts for recording field of binocular fixation, 100.
26. Jaeger test type, 6 sets.
27. Reeves contrast sensitivity test object.
28. One sterescope and 2–A, 2–B, and 2–C cards.

The board requests that a full report of the work of the branch laboratories be made once a month.

The ophthalmologists at the branch laboratories will be expected to do all the research work possible, keeping the problem of the stale aviator in mind and examining men who have had an accident or are having difficulty in flying or landing. A letter should be sent weekly to the central laboratory at Hazelhurst Field, Mineola, L. I., to the officer in charge of the Ophthalmological Department, reporting the progress of the ophthalmological work, giving details of special examinations made and any suggestions for improving the work.

INSTRUCTIONS TO THE PSYCHOLOGIST.

1. The reactor is given the printed instruction sheet, which he is instructed to read carefully, while care is taken to avoid distracting his attention. During the reading the psychologist should be ready to explain any detail of the apparatus or method in which the reactor may show interest; and after the reactor has finished, the psychologist further explains the procedure and verbally emphasizes the important points in the instruction.

2. As soon as rebreathing commences, the reactor begins to respond to the three sets of stimuli as presented by the apparatus under the manipulation of the psychologist. During the first three minutes of the test the psychologist shall coach the reactor, if necessary, and estimate his comprehension composure (freedom from excitement or nervousness), entering these on the record sheet then or later as good, fair, or poor. He should also note the motor tendencies of the reactor, and if these fall in one or more of the conventional categories, this also should be entered.

In addition to these general tendencies, it is important that the psychologist take notice of the specific tendencies shown by the reactor, and if definite types of error are shown, watch during the succeeding five or six minutes for improvements in these details.

Normally, the test continues until complete inefficiency is reached, at which point the psychologist must sharply notify the responsible medical attendant in order that the reactor may at once be given air, and so prevented from undergoing the collapse which would ensue in a minute or so.

3. The psychologist will record the typical change in the reactor's behavior, using the symbols which are given on the "symbol sheet," so that the recording will interfere as little as possible with the observing. After the test is ended, the entries on the record sheet must be at once completed.

4. Beginning at the sixth minute, and at three-minute intervals thereafter, the psychological work will be stopped for 30 seconds to

allow the ophthalmological and cardiac examination. It is important that the ophthalmologist keep track of the time so that he shall be ready promptly.

5. The psychologist should endeavor tactfully to remind the reactor as to the general conditions of the test, particularly to remove or avoid the impression that the performance required is very difficult. Especial pains should be taken to restore the reactor's composure if he has previously been stirred up by a psychoanalytic or other intimate personal inquisition.

6. All members of the unit must exercise caution that the reactor shall overhear no remarks, serious or jocular, concerning the difficulties, danger, results, or other features of the test which might excite him or cause apprehension or concern. Trivial remarks frequently have a serious effect.

INSTRUCTIONS TO THE PHYSIOLOGIST AS TO THE REBREATHING TEST.

It is the physiologist's duty to provide dependable conditions for a rebreathing experiment. All interpretations of data obtained and the final rating of a candidate require that the oxygen percentage during and at the end of a test be accurately known. The analysis of the air in the tank at the close of a test must be exact. In order to have reliable analysis the gas analysis apparatus must be clean and the samples of air carefully taken.

A perfect experiment requires that the rebreathing machine be in perfect order. Leaks of water and air into and from the machine must be avoided. Water may be flowing into the tank during an experiment through the inlet valve either because it is not perfectly closed or is out of repair. Water may be escaping through the outlet valve for the same reasons. Leaks of air may be due to faulty or improperly closed valves or to loose-fitting mouth parts. Occasionally a candidate may be found who sucks in air and allows it to escape by not keeping his lips closed around the rubber mouthpiece.

The movement of air through the rebreathing machine must be free so that the breathing of the candidate is not hampered. It is necessary to test frequently the resistance offered by the absorption cartridge.

The physiologist is also responsible for the obtaining and the interpretations of all physiological data. These data for the present include the frequency and volume of breathing, the pulse rate, and the three arterial pressures—systolic, diastolic, and pulse.

The respiration data are obtained from the kymograph record of the spirometer's movements. This record is almost valueless if there has been leakage of water or air during an experiment. The calibrating of the spirometer and the drawing of the scale should be accurate in order that the per minute volume of breathing may be determined with exactness. From the varnished kymograph tracing the volume of breathing per minute is calculated for as many separate minutes as will be found necessary in order to determine the curve of respiration throughout the experiment. The volume of breathing should be calculated by the physiologist and the amount and the time of each minute-volume written down and then handed to the "plotter," who will incorporate them in the final record.

The so-called normal pulse and blood pressures are determined three or four times while subject sits at the machine with nose clip on and mouthpiece in place. These normals should be compared with those of the preliminary pulse rate and blood-pressure study. A psychic influence should be avoided if possible. After rebreathing is begun the pulse rate is counted every minute and the arterial pressures determined every other minute until the eighteenth minute, after which they are taken each minute until the end of the experiment. The O space of the record sheet should be left blank and the determination of the first half minute recorded on the line.

The rule to be followed in making the determinations is to count the pulse rate in the interval between 20 and 40 seconds and to record the count on the half minute. The first count, therefore, will be recorded on the line between 0 and 1. The systolic and diastolic pressures should be determined in the interval between 45 and 15 seconds by the stop-watch and recorded as having been taken on the minute. These should be entered on the record sheet in the space between the lines, the first determination in space 1. This system of recording will make it possible for the "plotter" to indicate the time intervals with exactness on the chart. It is important that the exact time of the termination of the experiment be indicated on the circulation sheet so that the man who plots the record may correctly indicate with a heavy line the time the candidate was taken off.

The physiologist should closely watch the respiration and circulation changes toward the end of the test and should inform the clinician when unfavorable conditions develop.

In order that the ratings may be just to all, the volume of air rebreathed should be large enough to require 30 minutes to reduce the oxygen to 7 per cent. To obtain uniformity in the rate of oxygen reduction the water level in the tank should be varied according to the size of the man to be tested. A larger volume of air is required for a large muscular man and a smaller volume than that used for the average for a small man. The physiologist should decide what level of water in the tank of the rebreathing apparatus is necessary to provide the requisite time for the test. Experience will soon make it possible to adjust the volume satisfactorily according to the size of the candidate to be tested.

Rating.—When rating a candidate as to physiological responses, take into account the per cent of oxygen reached and the time required for rebreathing. Ordinarily a lower percentage will be tolerated when the fall in oxygen is rapid and the run short than when the fall in oxygen is slow and the time long. If two candidates who both endured down to 7 per cent oxygen, one reaching it in 15 and the other in 30 minutes, are being rated it would be unfair to the man who made the longer run to grade him on the same basis as that of the short run. This is the reason for demanding that all candidates be given a sufficient volume of air for rebreathing to insure a run of 25 to 30 minutes.

In rating take into consideration also compensation in the breathing and circulation. The reaction of respiration will be recorded as poor, fair, good, or excessive. The majority of the men examined have shown at between 8 and 6 per cent of oxygen, an increase of 5.5 liters in the volume of air breathed.

Such an increase is rated good, an increase of 15 or more liters is regarded as excessive. The respiratory response is most marked after 12.5 per cent of oxygen has been reached. The increase in the frequency of the pulse rate for the majority of men who have reacted well has varied between 20 and 40 per minute at about 8 per cent of oxygen. An acceleration of more than 50 may be regarded as excessive. The degree of acceleration is ordinarily slight until the oxygen has fallen to between 13 and 9 per cent, but from these down the acceleration occurs rapidly. The rise in systolic pressure usually is not more than 20 millimeters, a greater rise is considered excessive. A diastolic pressure fall, when it occurs, will be either a slow controlled drop or of the rapid fainting type which is often spoken of as a break in the circulation.

Candidates are rated AA if the compensations are good down to 7 per cent or less and A if good to between 8 and 7 per cent. They are rated B if the compensatory mechanisms show decided insufficiency or failure between 10 and 8 per cent, and C if the failure occurs above 10 per cent oxygen. The physiologist rarely finds reason for placing a candidate in class D. A high systolic pressure, 150 millimeters and above, throughout the greater part of the test disqualifies the candidate for class A no matter whether he compensates well or not.

THE PRELIMINARY PULSE AND BLOOD PRESSURE STUDY.

The candidate reclines for five minutes. The heart rate is then determined by counting the pulse rate by 20-second intervals.

Counting should continue until two successive intervals give the same result. The arterial pressures are then determined. The candidate then stands, the heart rate is counted as before until it reaches a constant rate, when it is recorded, and the blood pressures then taken.

The candidate then raises himself, by placing his right foot on a chair, five times to the standing position on the chair. The pulse rate, with the candidate standing, is immediately counted and as soon as possible thereafter the blood pressures are determined. The candidate stands at ease for two minutes, after which the pulse rate and the blood pressures are again determined.

The purpose of these observations is to determine whether the candidate shows evidences of staleness. In the physically fit the heart rate does not increase much on standing, but in the wearied or physically stale it increases as much as 44 beats per minute. The vasomotor control of the splanchnic area responds to changes in posture. In the fit subject the splanchnic vasotone increases and the blood pressure is raised about 10 millimeters when he moves from the horizontal to the upright standing posture. Weakness is shown by a decrease in blood pressure and at other times by an excessive increase in the heart rate. A great acceleration in the pulse rate following the exercise is also a result of staleness. The systolic pressure should return to normal within two minutes. The subnormal pressure, and the length of time it continues after exercise, has been attributed to lack of condition.

PREPARATION OF THE REBREATHING MACHINE.

(1) Flush the tank to remove all vitiated air. Do this as follows: Close the gate valve under the CO_2 absorber, and also the valve in the return pipe. Open the valve on the spirometer pipe. Open the inlet valve of the water system and allow the tank to fill slowly. When the tank is full, raise and lower the spirometer drum several times to change the air in its dead space.

(2) Fill the tank with new air as follows: Open the gate valves in the air pipes and close the valve in the spirometer pipe. Let the water drain entirely out. Set the valves as before and refill with water a second time. Let drain as before to the desired level.

(3) Set the machine for the start by opening the valves in the air pipes and closing the valve in the spirometer pipe.

(4) Sterilize the mouthpiece by bringing it to the boiling point. See that the corrugated rubber hose is clean and dry.

PREPARATION OF THE RECORDING APPARATUS.

The excursions of the spirometer indicate the depth and rate of breathing of the subject. A fishline connected to the top of the spirometer runs over a pulley and fastens to a counterbalance for the spirometer can. A writing point is attached to the counterbalance and records the respiration on the smoked drum of the kymograph. The writing point is best cut from celluloid film. The angle of the point should not be less than 60 degrees because very acute points twist easily. The point may be attached to an aluminum stylus by means of beeswax.

A signal magnet, provided with a writing point and connected in series with two cells and a clock interrupter, records equal intervals on the revolving drum—usually half minutes.

SMOKING THE DRUM.

Lay the kymograph paper on the table, glazed side down and glued end away. Hold the drum with the top to the right and lay it across the middle of the paper. Bring both ends of the paper toward each other, letting the glued end overlap. Glue it firmly to the glazed side of the unglued end so that the paper is wrapped tightly around the drum.

Smoke the drum over a 4-inch single-burner oil stove, or a fishtail gas burner. Hold the axis of the drum in each hand and let the drum revolve rapidly toward you, moving the drum from side to side at the same time. Smoke it only until it is coated light brown.

Arrange the drum so that the writing point attached to the spirometer and that of the signal magnet will mark evenly on the drum. The stylus of the signal magnet should be about 1 centimeter above the lower edge of the drum and about 1 centimeter in front of the spirometer stylus.

OPERATION OF THE MACHINE.

Let the subject sit so that the mouthpiece can be held comfortably in the mouth without twisting or pulling in any direction. Close the signal magnet switch. Start the kymograph. See that the valves in the pipes are open and that the gate valve in the spirometer pipe is closed. Put on the nose clip. The physiologist will start the experiment by putting the cork in the mouthpiece at the end of an expiration. The stop watches should be started at this time.

As the experiment progresses the oxygen from the tank is used up progressively. The spirometer stylus will write nearer the top of the drum. Open the inlet valve in the water system and let a little water flow into the tank, sufficient to bring the writing point nearly to the bottom of the drum. Repeat this as often as necessary.

When the experiment is ended close the valves in the air pipes until the air samples are taken.

Write the name of the subject, date, and type of experiment on the smoked drum. It is also convenient to record the oxygen per cent. Remove the paper by cutting through the outer sheet at the lap.

Do not cut through both sheets and scar the drum. Hold the paper by each end, smoked side up, and pass it once through a shellac solution. Hang it up to dry.

CARE OF THE APPARATUS.

Leaks.—If a leak is suspected from the character of the respiration record, first see that the valves of the water system are closed. A leak of water into the tank through the inlet valve will make the lower level of the respiration tracing approach the horizontal. A leak of water out of the tank through the drain valve will make the record approach the perpendicular.

Leaks of air out of the system most frequently occur around the mouthpiece. It may be necessary to tape the rubber portion to the metal part. Leaks of air around plumbing joints may be stopped by using white lead or heavy paint.

The CO_2 absorber.—This is a cylindrical pasteboard carton filled with shell sodium hydroxide. This cartridge is contained in a steel case and is easily replaced. It is effective in removing CO_2 for about 200 to 240 minutes of rebreathing. If the cartridge becomes very warm or the subject breathes excessively do an analysis for CO_2, and if it is present reject the cartridge. Before each experiment the resistance of the cartridge to expired air should be tried by blowing through the cartridge with the air valve below it open and the other valves closed. The spirometer can be easily raised if the sodium hydrate is not caked.

When a new cartridge is inserted, punch both ends full of holes with a pencil, put the loose brass ring inside the lower rim of the pasteboard cartridge, put the rubber gasket around the outside of the lower rim, put the cartridge with the marked end up into the steel case and tighten the thumb screws. Do not use a cartridge without a brass ring and always remove brass ring before rejecting a used cartridge.

Shellac.—Make a saturated solution of powdered shellac and denatured alcohol containing about 1 teaspoonful of castor oil to each 2 quarts of alcohol. The mixture should be shaken thoroughly and a residue of undissolved shellac should always remain in the bottom of the bottle. If the records appear running after shellacing, the solution probably needs more shellac. Do not allow the shellac to stand exposed to the air except while it is being used. The castor oil makes the dried record more flexible.

Kymograph.—The kymograph consists of an aluminum drum revolved by means of a clockwork at its base. The drum slides on a brass sleeve and is held at any desired height by a spring clip. The sleeve ends in a friction plate which rests on a metal disk driven by the clockwork. The sleeve and friction plate revolve about a steel shaft which passes through both of the heavy plates containing the clockwork and is bolted at the bottom plate. At the top of the sleeve is a screw by means of which the drum and sleeve may be lowered until the friction plate rests upon the metal disk. It is always used in this position when driven by the clockwork.

In the clockwork are a pendulum and a ratchet wheel which provide for a slower speed than can be obtained by any of the fans. It may be thrown in gear by raising the pin in the gear peg out of the hole in which it rests. When the screw near the fan pinion is screwed down the clockwork operates as a medium-spring kymograph. When this screw is up the drum revolves approximately once an hour, which is the speed used for rebreathing work.

CALIBRATION OF THE SPIROMETER.

In order that the volume of air breathed during any period may be determined, the relation between the definite volume of air breathed and a certain linear measure (1 centimeter, for example) on the kymograph must be established.

To calibrate the spirometer, remove the can and fill it with water to a depth of 25 centimeters, measuring with a graduate the amount of water used. If a liter or cubic centimeter measure can not be obtained, use a quart or a pint measure. (One quart equals 1.36 liters; 1 pint equals 0.568 liter; 1 fluid ounce equals 28.66 cubic centimeters.) Divide the volume in cubic centimeters by the depth of the water and the quotient will be the volume contained in the can per centimeter of length. To make the relation scale, let 1 centimeter be equivalent to the volume determined above. This may be attached to the spirometer so that the pointer will pass over the scale on each respiration. Or it may be used for plotting.

THE GAS ANALYZER.

DESCRIPTION OF APPARATUS.

The apparatus consists essentially of a 25 cubic centimeter gas burette with a bulb containing about 17 cubic centimeters and a tube below graduated from 18 to 25 cubic centimeters in 0.02 cubic centimeter, so that it can be read easily to 0.01 cubic centimeter. The lower end of the burette connects with a temperature-control tube similar to the gas burette, but not graduated, and a leveling bottle containing 1 to 2 per cent sulphuric or other acid in 50 per cent alcohol. The top of the burette communicates (by means of a capillary tube) with an absorber for carbon dioxide containing 10 per cent sodium hydroxide, and a similar absorber for oxygen, containing a solution of pyrogallic acid in nearly concentrated potassium hydroxide.

There are four glass stopcocks which must always work freely. A two-way stopcock is situated on a T just above the gas burette by means of which a sample may be taken and a contaminated sample expelled. A one-way stopcock is situated just above the bulb of the control tube and should always be kept closed during an analysis. A one-way stopcock is situated above each of the absorbers and should always be kept closed except when the particular absorber is in use.

Around the two bulbs is a jacket which is filled with water at room temperature. The water in the jacket can be mixed by blowing air through a glass tube passing to the bottom. It is important to keep the water thoroughly mixed in order to insure the same temperature and water-vapor tension in the gas burette and the control tube at the time of an experiment.

USE OF THE APPARATUS.

1. Before an analysis is begun it must be assured that the capillary tubes between the gas burette and the absorbers contain nitrogen. This is the case after an analysis for CO_2 and O_2, and it may be necessary to do an analysis for this purpose.

2. At the beginning of an analysis the level of the sodium hydroxide and the alkaline pyrogallate in the absorbers should be a certain height marked by a wire. The level may be adjusted with all the stopcocks closed, except that to the particular observer in which the level is being adjusted. The leveling bottle is carefully raised or lowered and the stopcocks closed when the meniscus of the fluid comes to the wire, or the wire may be set to the meniscus. After an absorption the level is again adjusted to the wire.

3. The level of the fluid in the control tube is next adjusted. A strip of millimeter paper is pasted on the leveling bottle. The top of the gas burette and the control tube are opened to the outside air. The leveling bottle is lifted a short distance so that the level of the fluid in the control tube comes somewhere between 24 and 25 on the scale of the gas burette. The level of the fluid in the control tube and that in the leveling bottle should be the same, and the point is marked by the sliding wire. The stopcock on the control tube is then closed and kept closed during the remainder of the analysis.

4. The stopcock at the top of the gas burette is open to the outside air and the leveling bottle is lifted until the gas is expelled from the burette and a few drops of fluid run out. The stopcock is then turned so as to communicate with the source of gas, and a sample is then taken by lowering the leveling bottle. The sample may be driven back into the collector several time to insure a representative portion. The stopcock is closed. The time is noted at which the column of fluid falls in the gas burette, and no reading is taken until exactly two minutes have elapsed. This is to insure proper drainage of fluid

from the inside of the tube. If large drops stand on the inside after two minutes the tube needs cleaning.

5. Before reading the volume of the sample, or later, when reading the volume of the residual gas in the burette, the leveling bottle is moved up or down on the control tube until the level of the liquid in the control tube comes to the wire. By means of the millimeter paper strip note is made of the height above or below the meniscus in the control tube at which the bottle must be held to bring the gas in the control tube to its original volume (at the wire). The leveling bottle is then held at the same height above or below the meniscus in the burette and a reading taken. In this way the gas in the burette can always be brought to the correct volume per molecule.

6. The sample is now driven into the CO_2 absorber. (Samples from the rebreathing machine should not contain CO_2, so this step may be omitted and the O_2 absorption carried out directly.) With the leveling bottle above the level of the fluid in the burette, the stopcock above the CO_2 absorber is opened and the bottle lifted in order to drive the sample into the absorber. The gas is driven over eight or ten times, after which the bottle is lowered carefully until the level of the sodium hydroxide in the capillary tube comes up to the wire. The stopcock is closed. A reading of the remaining volume is taken in the usual manner after two minutes. The difference in volume divided by the original volume and multiplied by 100 gives the per cent of CO_2 in the sample.

7. The oxygen absorption is now carried out in a similar manner, the level of the alkaline pyrogallate being brought back to the wire and the stopcock closed before a reading of the residual volume is made. This volume subtracted from the volume remaining after the CO_2 has been absorbed (or from the original volume if the sample is ordinary uncontaminated air) gives the volume of O_2 in the sample, which, when divided by the original volume times 100, gives the per cent of O_2 in the sample.

Example:	Volume of sample	24.00	
	After CO_2 absorption	22.52	
		1.48—	6.17 per cent CO_2
	After O_2 absorption	19.14	
		3.38—	14.08 per cent O_2.

SUMMARY OF THE PROCEDURE FOR AIR ANALYSIS.

1. Be sure that the capillary tube contains nitrogen.

2. Bring the level of the sodium hydroxide and the alkaline pyrogallate in the capillary tubes to their respective wires, or set the wires to the menisci.

3. Set the level of the temperature-control tube.
4. Take the sample.
5. After two minutes read the volume of the sample.
6. Absorb the CO_2. Bring the sodium hydroxide to the wire. Read the volume after two minutes. (Samples from the rebreathing machine do not ordinarily contain CO_2, so this step may be omitted.)
7. Absorb the O_2 and bring the pyrogallate to the wire. Read the volume after two minutes.

CARE OF THE APPARATUS.

Cleaning.—Whenever large drops stand on the inside of the glass burette and temperature-control tubes two or three minutes after the fluid has fallen, it is an indication that the tubes need cleaning. This may be done by drawing cleaning fluid into the tubes. The tubes must first be drained by opening the stopcocks, lowering the leveling bottle and disconnecting it. The fasteners at the top and bottom of the burette should be removed and the rubber disconnected at the top of the burette. This will allow the burette, control tubes, and jacket to be moved forward in the slot as one piece. The lower free ends of the two tubes may then be put in a beaker of cleaning fluid and the solution sucked up by means of rubber tubing attached to the top of the tubes. This solution should stand in the tubes several hours, or even over night. All traces of cleaning fluid are removed by repeatedly filling the tubes with water.

The capillary tubing may be cleaned, after dismounting it, by washing it out with cleaning fluid, rinsing it with water, and drying out with alcohol.

Formula for cleaning fluid.—The cleaning fluid commonly used consists of a strong solution of sulphuric acid in which potassium bichromate is dissolved. A layer of solid bichromate should always be kept in the bottom of the bottle. This solution can be used over and over again.

Stopcocks.—The stopcocks should always work freely, but should never be loose enough to leak. A light layer of vaseline or preferably of a lubrication mixture, should be rubbed on the stopcocks. Too much lubricant is liable to plug the capillary tubes. A good grease is made by melting vaseline and beeswax in the proportions of 3 to 1. Another formula is as follows (Dennis, Gas Analysis, p. 115):

1. Melt together 12 parts by weight of vaseline and 1 part of paraffin. Do not heat enough to give off fumes.
2. Take parts by weight of finely chopped soft black rubber.

Add No. 2 to No. 1 slowly as the latter is dissolved, while heating over a low flame. When most of the rubber is added, test it by pulling it between the thumb and forefinger. When it is of the right consistency it should pull into cobwebby threads.

Rubber connections.—Rubber connection pieces should be removed before cleaning fluid is used. If the rubber sticks to the glass it may be loosened by inserting the point of a penknife between the tube and the glass. A drop of water put under the knife blade sometimes helps. New rubber connections will slip on easily if the end of the glass tubing is moistened with water.

If a leak in the system is suspected, raise the leveling bottle until the sample tube is filled with about 18 cubic centimeters, close all the stopcocks and lower the leveling bottle as far as possible. Readings of the maniscus from time to time will be the same if no leak is present. If the level of the sodium hydroxide and the alkaline pyrogallate in the capillary tubes will not stay at the wire when the stopcocks are closed, either the rubber connections or the stopcocks are leaking.

Red rubber should not be used on the connections where alkali will touch it, as it gives off sulphur, which may finally appear as hydrogen sulphide in the burette.

It may be necessary to make the rubber connections tight. This may be done with a flexible wire, or more conveniently with rubber bands. Loop the band around the rubber tube, pull tight, and wrap the free end around the tube several times, finally passing it under the wrapping with the aid of the curved forceps.

A check on calibration, tightness on joints, and the efficiency of absorbents can be made by analyzing atmospheric air. If the apparatus is properly graduated and in good order, the sum of the oxygen and the carbon dioxide in uncontaminated atmospheric air should be 20.96 per cent.

The scale etched in the burette tube may be made more visible if blue crayon is rubbed on it and a piece of white paper put behind it but not pasted on the burette.

The analyst must remember that the accuracy in the use of the apparatus depends more on making sure that absorptions are complete than upon extreme effort to read the burette as finely as possible. It is essential, therefore, after an absorption is supposedly complete, to pass the gas over again into the absorbent and make another reading to be sure that no change occurs.

Solutions used as absorbents.—A 10 per cent solution of sodium hydroxide is used to absorb CO_2. A 10 per cent solution signifies that in each 100 grams of solution there are 10 grams of the substance dissolved. Weigh out about 10 grams of sodium hydroxide and add water to make 100 cubic centimeters.

The absorbent for oxygen consists of pyrogallic acid in a nearly concentrated potassium hydroxide solution in the proportions of 10 grams of pyrogallic acid in each 100 cubic centimeters of KOH of a specific gravity of 1.55. A hydrometer may be used to make up the KOH solution, or 767 grams of 1,000 cubic centimeters of water gives a specific gravity of 1.55.

The absorber should be about two-thirds filled with the absorbent, and a one-quarter inch layer of liquid petrolatum should be used to protect the absorbent from the air. One filling with alkaline pyrogallic will last for more than 100 analyses. When the O_2 absorption becomes sluggish, the pyrogallate should be changed, but mere standing in the pipette does not cause it to deteriorate. The pyrogallate should be made more exactly in the manner described, for both weaker and stronger solutions do not absorb so well.

In renewing the sodium hydroxide or the alkaline pyrogallate, care should be taken not to get the oil on the absorbing surfaces. This may be avoided by first removing the oil with a pipette. Or it may be necessary to siphon off the greater part of the old solution through the capillary tube. In this case the lower surface of the oil should not be allowed to come to the lower edge of the absorbing tube. New solution may then be added through the capillary tube and the oil will remain on top and inside of the absorbing tube as before.

It has been found convenient to use in the leveling bottle a 1 per cent to 2 per cent sulphuric-acid solution in 50 per cent ethyl alcohol. The alcohol reduces the surface tension and permits more rapid and thorough drainage. It also acts as a self-cleaner for the burettes.

CHAPTER VIII.

THE WORK OF THE FLIGHT SURGEON.

When the Flight Surgeons were sent to the various flying schools, it was realized that local conditions in the different schools varied widely, and the following general instructions were therefore issued June 27 for general information regarding duties of a FLIGHT SURGEON.

The "Flight Surgeon" is new. It would be unwise to decide at once as to every intimate detail of his duties.

Each Flight Surgeon is to study all local details of his post and send in a report to this office, as to local conditions, one week after his arrival.

If he has not received the entire equipment for complete reexamination of the fliers, he will notify this office what is lacking.

It is planned that he shall reexamine, routinely, every individual flier in the command once every two months. The reexamination will be limited to the cardio-vascular, turning-chair, and eye tests. In the routine examination of the eye, it will not be necessary to make ophthalmoscopic examination.

The Flight Surgeon is directed to notify this office how many fliers he will be able to examine daily, under the conditions at his post. He will also notify this office regarding the medical personnel under the post surgeon at his school, and state along exactly what special lines these medical officers are able to help him in his work, in addition to their other duties.

There is a sharp distinction between the original examination and this reexamination. In the original examination the duty of the examiner was to eliminate the unfit. This was the primary object, in order that the highest type of men should be selected for our aviation service. In sharp contrast, the primary object of the reexamination is that the aviator may be KEPT IN THE SERVICE for the longest possible usefulness as a flier. The Flight Surgeon is not placed in a flying school for the primary purpose of "weeding out" those who should not have been allowed to enter the service, because of a poorly conducted original examination. It goes without saying that any man who, by the reexamination, proves to be unfit, and who obviously never will be fit to be an aviator, should be recommended for discharge. But this is by no means the essential and primary reason for having a Flight Surgeon in each flying school. In order that no mistakes may be made in this matter, it will be necessary for the Flight Surgeon to consult this office, supplying all necessary information, before he will be allowed to recommend the discharge of any cadet who has already been under instruction. The fundamental principle of the service of the Flight Surgeon must be emphasized and understood by everyone in the command from the Commanding Officer down—namely, the Flight Surgeon's function is to keep the members of the command mentally and physically fit, and by so doing to prolong their usefulness in the service. If the Flight Surgeon were to act as a "watchdog" sent to remove men from the service after they have had experience in flying and are perhaps just about to receive their commissions, his usefulness would be reduced 95 per cent, and the necessary confidence and cooperation on the part of the Commanding Officer and the fliers would justly be withheld.

At certain of the fields the work of the Flight Surgeon will be supplemented by a Branch Medical Laboratory; at many of the fields there will be no such branch laboratory.

The work of the Flight Surgeon and of the Laboratory Unit should be intimately coordinated. There must be established a spirit of willing cooperation; with single-minded assistance on the part of both. There will be assured successful results and efficient progress. The Branch Medical Laboratory will have two uses—one, the examination work for classification of the flier; two, examinations for assisting the Flight Surgeon in his work in the care of the flier. The result of these latter examinations are reported to the Flight Surgeon, who alone makes the decision as to the fitness of the individual to fly.

In preparing the reexamination blank, it was recognized that all tests should be carefully considered. The ideal form of reexamination would include only tests of the essential things; nothing essential must be omitted. At the same time it was recognized that if all the fliers of the Air Service are to be examined according to this blank every two months (and such reexaminations soon run into hundreds of thousands) every unessential item such as height or a study of the joints should, of course, be left out. In this way there would be a great deal of time saved for the Flight Surgeon. With this object in mind, the following reexamination blank was put into use:

REEXAMINATION OF AVIATOR.

Division of military aeronautics.

All officers drawing flying pay will be required to take the following examination semiannually, and it will be filed as a permanent record of the flying status of this officer.

Name________________________ Place________________________

Status________________________ ________________________

Age ___________ Date____________________

GENERAL.

(Stripped to the waist.)

1. Pulse:
   After 5 minutes reclining________________________
   On standing________________________
   After standard exercise [1]________________________
   Two minutes after exercise________________________
2. Breath held, seconds________________________
3. Heart function________________________
4. Blood pressure: Systolic ( ) Diastolic ( )_____
5. Haemoglobin percentage________________________

EAR.

6. Test of internal ears, VIII nerves, brain-stem and cerebellum.
   (*a*) Is nystagmus present on loking straight ahead?____________
   (*b*) Turning-chair. Head tilted 30 degrees forward. Eyes closed.
      (*x*) Nystagmus, after turning to right______left______
      (*y*) Pointing:
         (1) Before turning: Right arm______ left arm______
         (2) After turning to right: Right arm______ left arm______
         (3) After turning to left: Right arm______ left arm______
      (*z*) Falling:
         (1) After turning to right________________________
         (2) After turning to left________________________

EYE.

7. Ocular movements________________________
8. Visual acuity: Right__________________left__________________
9. Muscle balance: Esophoria____Exophoria____Hyperphoria____
10. Near-point for accommodation (each eye separately) R. E.____ L. E.________

[1] Standard exercise will consist of placing right foot on a chair and then stepping up on the chair from the floor five times.

11. Near-point for convergence____________________________________
12. Prism divergence (if any heterphoria present)________________
13. Pupillary reactions: Direct: Consensual: Accommodation:
    (*a*) Right eye____
    (*b*) Left eye____

Remarks:

Name______________________________,
Rank______________________________,
Flight Surgeon.

The Flight Surgeon makes his weekly report on a special blank. The statistics from these reports are then made up on the monthly blank.

WAR DEPARTMENT AIR SERVICE DIVISION, S. G. O.

Care of Flier Report.

Station........................
.... Week ending..................
Commanding Officer.

1. Number of fliers flying at flying school ....
2. Total hours of flying for week..
3. Total number of flights for week ....
4. Number of fliers voluntarily reporting sick to the Flight Surgeon...........
5. Number of fliers found physically unfit either by the Flight Surgeon or the Physical Director ....
6. Number of fliers retained for flying who would otherwise have been disqualified by Flight Commander..
7. Number of fliers who have been permanently disqualified by the Commanding Officer through suggestions from the Flight Surgeon ....
8. Number of hours of physical training given to fliers by Physical Director—this to apply to physical training given in classes only.........................
9. Number of requests made by Flight Surgeon to Commanding Officer for candidates to rest, due to impaired physical condition.................................
10. Number of fatal injuries from crashes..
11. Crashes (special report attached) ....
12. Special cases. (Any unusual cases during the week, or any data which may be of unusual value to this office, note fully on back of this report)...........

....
....
Flight Surgeon.

WAR DEPARTMENT, AIR SERVICE DIVISION, S. G. O.

Special Report by Flight Surgeons.

CRASHES.

Fatal injury________________________
Injured____________________________
Not injured_________________________
Station____________________________
Date of Crash_______________________

____
Commanding Officer.

Name ________________ Age ________________
Type of machine ________________
Weather ________________ Accident occurred {Getting off ________ / In the air ________ / Landing ________}
Time of day ________________
Day of week ________________
Approximate altitude at which trouble began ________________
Was accident due to defect in the airplane {Engine ________________ / Breakage ________________}
Date of last examination of aviator ________________
Total hours dual instruction before doing first solo ________________
Total hours solo ________ Length of flight before crashing ________________
How many flights made previous to crash ________________
Extent of damage to airplane ________________
Amount and nature of work performed before flight ________________
State what was the cause of crash, in your judgment ________________
____

Remarks in full: ________________________________
____
____

____

____

Flight Surgeon.

This being essentially a new type of service, returns are as yet irregular. Although statistics are available for two months only, from a limited number of fields, they already reveal some points of particular value.

During the month of July returns have come in from 14 fields. The average total of fliers at these fields was 3,113. The average number of hours of flying for each person 13.4, the average number of flights for each person per month, 13.5.

The number of fliers who voluntarily reported for advice to the Flight Surgeon during the month was 1,185, or 38.1 per cent of the total number at the 14 fields. This refers to every sick visit, and without doubt many fliers have reported more than once.

The number of fliers found temporarily unfit by the Flight Surgeon or Physical Director and temporarily taken off flying was 269, or 8.6 per cent.

The number of fliers retained for flying by the Flight Surgeon who would otherwise have been disqualified by the Flight Commander was 20, or 0.6 per cent. The number of fliers permanently disqualified by the Commanding Officer through suggestions of the Flight Surgeon, 14, or 0.4 per cent.

The number of requests made by Flight Surgeons to Commanding Officers for candidates to rest, due to impaired physical condition, 137, or 4.4 per cent.

The number of crashes was 87, or 2.8 per cent, and the number of fatal injuries resulting from crashes, 14, or 0.4 per cent.

The number of those who voluntarily reported for advice to the Flight Surgeon, arranged according to field, is as follows:

Field (July).	Average number of cadets at flying school.	Number of fliers voluntarily reporting for advice to Flight Surgeon.
Barron Field	177	136
Brooks Field	157	60
Call Field	122	82
Carlstrom Field	100	18
Carruthers Field	160	....
Kelly Field	592	334
Love Field	177	160
Mather Field	135	4
Park Field	197	125
Post Field	405	180
Rich Field	114	24
Rockwell Field	153	35
Taliaferro Field	114	4
Taylor Field	510	23
Total	3,113	1,185

Fourteen fields have sent in reports for August. The average total number of fliers at these fields was 2,963. The total number of hours flying for each person was 21, and the average number of flights 26.6.

The number of fliers who voluntarily reported for advice to the Flight Surgeon during this month was 1,329, or 44.9 per cent of the number of fliers. This shows an increase of 6.8 per cent over July.

The number of fliers found temporarily unfit by the Flight Surgeon, or Physical Director, was 366, or 12.4 per cent.

The number of fliers retained for flying by the Flight Surgeon who would have otherwise been disqualified by the Flight Commander was 12, or 0.4 per cent.

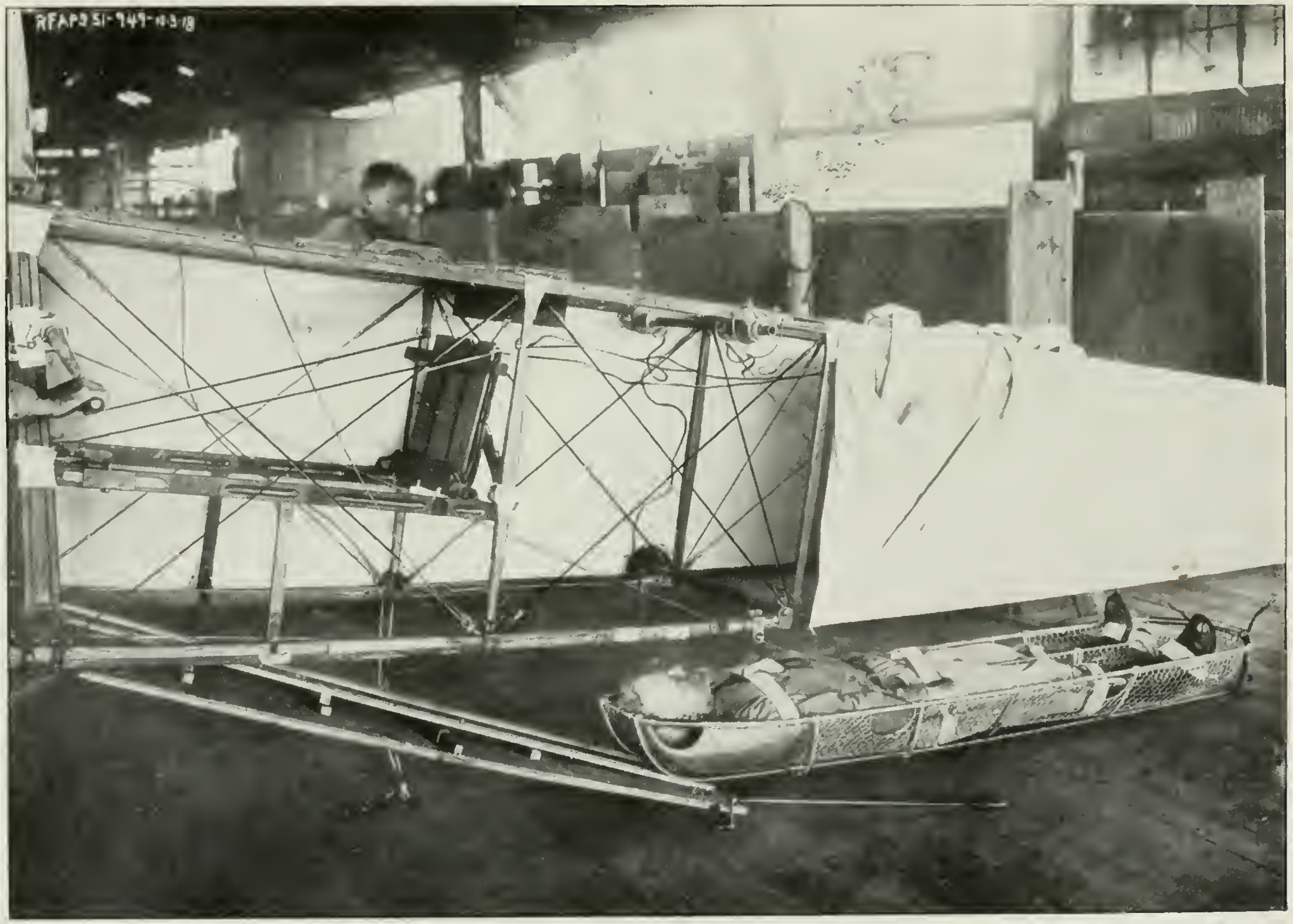
The number of fliers permanently disqualified by the Commanding Officer through suggestion of the Flight Surgeon, 18, or 0.6 per cent.

The number of requests made by Flight Surgeons to Commanding Officers for fliers to rest, due to impaired physical condition, 248, or 8.4 per cent.

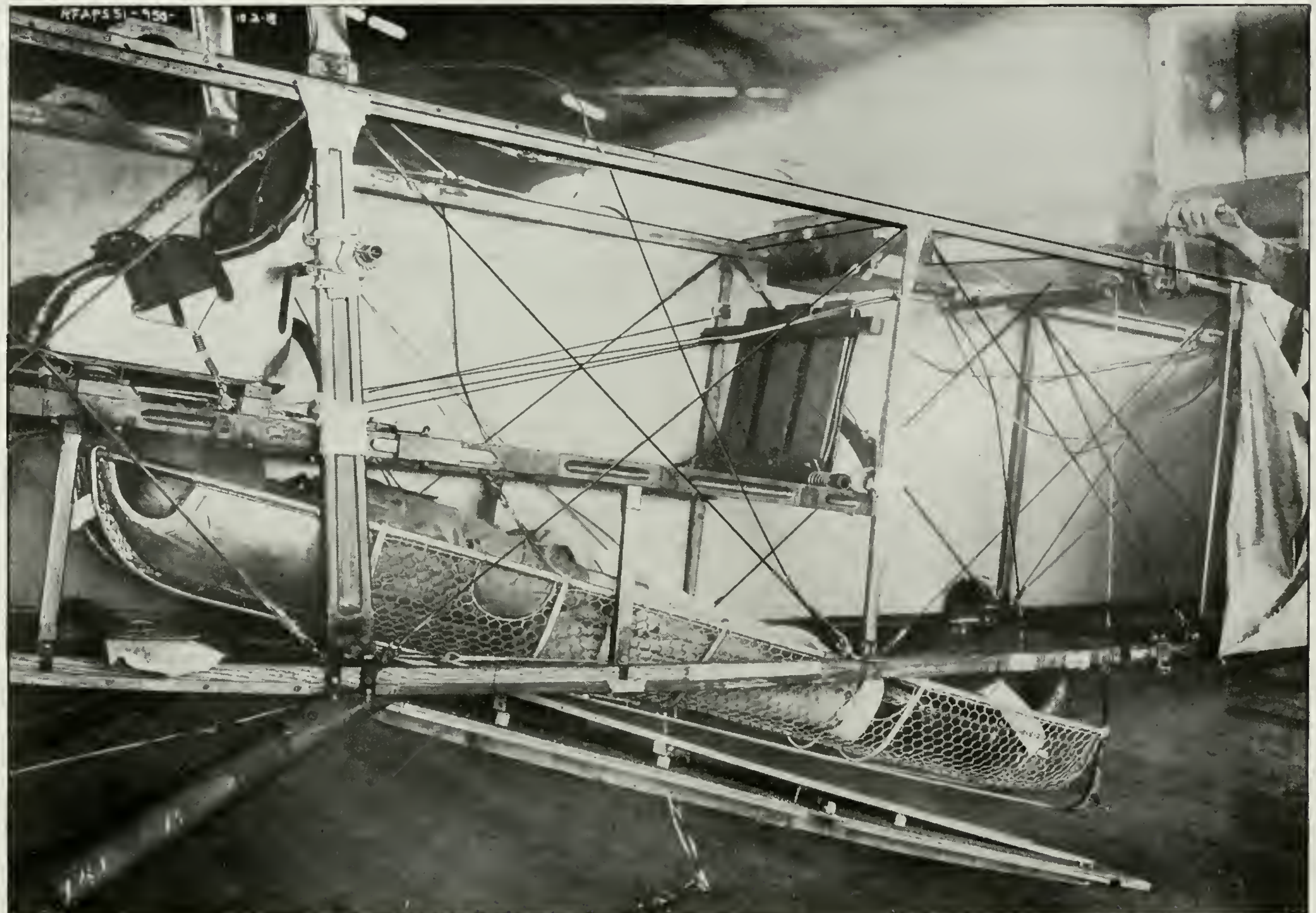
The number of crashes was 141, or 4.8 per cent, and the number of fatal injuries 18, or 0.6 per cent.

The number of those who voluntarily reported for advice to the Flight Surgeon, arranged according to fields, is as follows:

383b-1



HOSPITAL SHIP.



HOSPITAL SHIP.

383b–2

Field (August).	Average number of cadets at flying school.	Number of fliers voluntarily reporting for advice to Flight Surgeon.
Barron Field	166	159
Brooks Field	149	93
Call Field	72	37
Carlstrom Field	42	28
Carruthers Field	160	21
Chanute Field	234	51
Ellington Field	588	144
Kelly Field	569	584
Mather Field	173	29
Park Field	140	32
Rich Field	117	55
Rockwell Field	155	21
Taliaferro Field	263	28
Taylor Field	135	47
Total	2,963	1,329

The Flight Surgeon makes it his particular business to gather from every possible source every bit of information. His reports are to be based upon the opinions of everyone who knows anything of the crashes, from the Commanding Officer down.

From the limited number of flying fields to which Flight Surgeons are already assigned have come reports of 210 crashes. 49, or 23.3 per cent, of these were due to engine defects; 4 to some defect in the body of the machine; and 7, where the cause of crash could not be definitely attributed to a defect in the aeroplane. The crash was reported with reference to the pilot only, no record being made of other passengers.

In these 210 crashes the pilot was fatally injured in 23 cases (10.9 per cent) ; injured slightly or seriously in 64 cases (30.5 per cent) ; in 123 cases (58.6 per cent) he escaped uninjured.

One hundred and forty-eight falls, or 70.5 per cent, were due to "poor judgment." Although some physical or mental unfitness may have contributed to this cause, there is nothing in the report or in the re-examination which would indicate it. No doubt some of them occurred through a temporary condition brought on by fatigue, extreme heat, etc.

It is to be noted that, compared to the 90 per cent—referred to in Part I, chapter 4, of this book—this report shows a comparatively small number of deaths and injuries directly traceable to the physical or mental unfitness of the pilot.

There were two crashes in which "poor judgment through physical impairment" was the cause. In one the pilot failed to level off soon enough. He was rated as "rather poor material, sluggish vestibular apparatus; weak on stereoscope, muscle balance, Exo. 2." The second case was one of fatigue, pure and simple.

Two crashes were due to "acute physical impairment." The first an acute frontal sinuitis. During his examination he told the Flight Surgeon of the accident. Said he could not act quickly enough. Head felt dull, heavy, and not right. It was recommended that he be taken off flying until the condition cleared up. The recommendation was approved, and he was put under the care of the Flight Surgeon.

The other crash was caused by the pilot probably fainting, due to extreme heat.

Of these 210 crashes, there were:

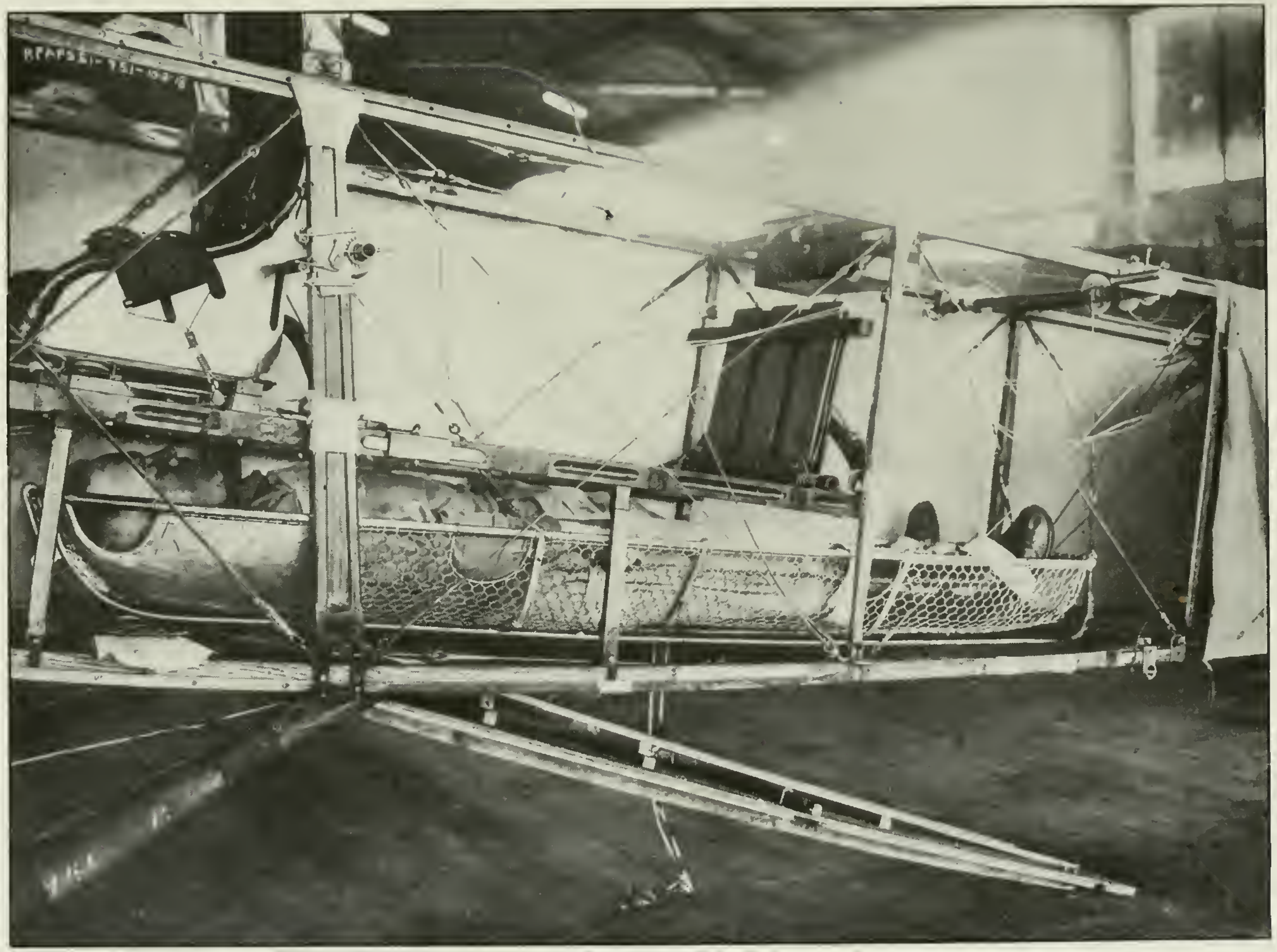
Collisions (in air)	21
Side slips	11
Stalls	18
Tail spins	44
Nose dives	8
Stall and spin	1
Bad landings	81
Taxiing (collision on ground)	11
Unknown	14
Reverse glide	1
Total	210

Of these crashes 38.6 per cent were due to bad landings, 21 per cent to tail spins, and other spins, and 10 per cent to "collisions" in air. There was one crash due to a reverse glide. There are very few cases known. "Ship seemed to go into reverse glide apparently while attempting to loop at an altitude of 2,000 feet. Descended in same position, with one or two attempts to turn, and crashed down. Controls were intact, and no definite reason can be given for cause of accident. Pilot and instructor killed immediately."

It must be emphasized that 21 per cent of all the crashes were directly traceable to failure to come out of spinning nose dives and other turning evolutions. This 21 per cent can be largely eliminated by the Ruggles Orientator. Crashes due to failure to come out of such stunting evolutions occur entirely among cadets who are unfamiliar with the sensations produced by these unusual movements. The Ruggles Orientator will make them perfectly familiar with all these turning sensations before they go up.

The Flight Surgeon is definitely instructed to consider himself authorized at all times to make independent investigations of conditions in any way bearing upon the health and fitness of the fliers and forward such reports direct to the office in order that each Flight Surgeon's experience in this way might be rendered available to the Flight Surgeons in other fields.

All of the above constitutes the official routine of the Flight Surgeon's work. During the early months of the Flight Surgeon's activi-



HOSPITAL SHIP.

ties, naturally, a large bulk of his reports were made up of his own personal observations and methods of making himself valuable to the Commanding Officer and to the fliers. The wisdom of allowing a wide latitude to the Flight Surgeon in developing his work has been proven by the original work that has been done by the various Flight Surgeons on their own initiative. Naturally, when the Flight Surgeon arrived at the fields, each cadet felt that he had come to remove from the service those who were not " absolutely perfect."

This idea was soon disposed of. The Flight Surgeon gained the confidence of the men through informal talks given in the barracks or at the Flight Surgeon's quarters or through personal interviews at his office, where the men were encouraged to come and discuss their personal difficulties. To quote one Flight Surgeon: "If I ever have as many patients in private life as I have here, I will make at least $100,000 a year and buy Liberty bonds. In came the lame and halt and then some. I have had to handle about every thing from a man with a sick mother to a man with imaginary lumps on his chest; from diplopia to love affairs." This same Flight Surgeon picked two typical cases of " staleness " for whom he secured leave of absence. He discovered many others who needed a change of environment for a few days and made this possible by enlisting the interest of a kindly hostess in the adjacent city; these cadets were allowed to visit at this home for week-ends. Others are making wise suggestions as to flying hours during the excessive heat of southern camps; another has arranged a longer period of sleep for his men; one has substituted fruit juices for harmful drinks at the post exchange. The men are being carefully reexamined from time to time, so that any abnormal condition may be alleviated by proper measures. In lectures the necessity of a clean mind in a clean body is being impressed upon them; that success does not follow in the wake of excess.

The following are typical excerpts from Flight Surgeon reports:

> Two fliers had appeared before their Commanding Officer just prior to my arrival. They had been summoned because it had become apparent through the observations of the Flight Commander that they had reached a condition which did not justify continuing them in flying service. Their Commanding Officer decided to order them away for four months. I was able to demonstrate that the first of these fliers was suffering from diplopia ("an eye condition which is incompatible with flying") ; the second was found to be perfectly normal except for obstinate constipation. A dose of castor oil and injections put this man into perfect condition, and he resumed flying duty in a few days.

The Flight Surgeon was in the first instance the means of avoiding continuing as attached to the flying service a definitely unsafe individual, and, in the second instance, was able to restore to the service, within a few days, a perfectly good flier, who otherwise would have been out of the service for four months.

Another case was that of a flier who had within a relatively short time crashed six planes. Examination revealed an eye condition directly responsible for this series of crashes.

In several of the flying schools there occurred epidemics of mumps; one of the complications peculiar to mumps is the impairment of that part of the internal ear which is directly concerned in flying. One of the first reports to come in showed a number of instances of impairment of flying ability traceable directly to this complication. These individuals to all appearances had made perfect recoveries.

A flier with a long record of excellent flying ability was noted by his Flight Commander to be flying progressively worse and worse. After several crashes he was ordered out of active flying service. He then was sent to another post where he was examined by a Flight Surgeon, who found that he had a progressively increasing impairment of his internal ears; this had reached the degree of practical destruction of both internal ears. The Flight Surgeon compared these findings with his record and recognized that some infection must have occurred to destroy this special sense. He then, on careful questioning, succeeded in eliciting the history of specific infection, which had occurred after his entrance into service and only two months prior to this last examination.

The following cases illustrate the value of Flight Surgeon service in analyzing conditions of temperament and mental poise. One flier, on examination, showed slight motor restlessness, decided volubility, general aggressive mental attitude, associated with an assumption of an unusual degree of confidence in his ability. This group of symptoms indicated at once to the Flight Surgeon the probable danger of permitting him to fly, and the Commanding Officer was notified to that effect. Although forbidden to go into the air, within 48 hours after this examination the aviator made a cross-country flight and ended with a bad crash. Following this, the symptoms already noted were greatly exaggerated, and he passed into a well-defined attack of manic-depressive insanity.

The result of the examination of the following case is of particular value: The Flight Commander recommended that a certain flier discontinue flying until a complete physical examination could be made with a view of determining his fitness for flying. At the time, this flier was giving instructions in acrobatics, and his own vicious habits and stunting at low altitudes brought about this recommendation. The Flight Surgeon discovered a very abnormal blood pressure and pulse pressure, and an examination of the urine disclosed disease of the kidneys.

A different type of case is the following: Cadet reported to the Flight Surgeon that he had been losing sleep because of a problem of an intimate personal nature. Examination elicited the fact that his family relations were perfectly satisfactory. His family history was excellent; no hereditary burden; previous home life conducive to healthy growth. He had completed high school and two years of his college course; had had seven hours of solo flying, with excellent record. His general habits were good, and his trouble was purely imaginary, in the matter of the supposed attitude of his fellow cadets toward him. He was nursing an imaginary grievance and this was the only maladjustment in his mental poise. He wanted some powders to put him to sleep. A 3-mile walk, and a cold shower were prescribed instead, and he was given a slap on the back with a hearty "You're all right." Several days later he reported that he had had the first good night's sleep in five weeks, and he was restored to flying status without further attention.

The following constitutes extracts from reports from Flight Surgeons:

CRASH ON LANDING.

Instructor's report: Bad landing caused the machine to porpoise and he did not use his motor or level the machine, but simply allowed it to nose right into the ground.

Cadet's report: Landed too fast, and as we bounced up and down on the ground, the throttle popped partly open.

Flight Surgeon's report: Cadet ——— reported to me after this accident, and I asked him why he did not level off properly or give the ship gas when he bounced. He stated that at the time he knew what he ought to do, but he simply could not bring himself to act quickly enough; his head felt heavy and he "did not feel right."

Examination showed acute sinuitis of the right side. This was sufficient to affect his flying judgment and quickness of decision.

Another Flight Surgeon found that some accidents were occurring particularly during night flying, because those men did not get sufficient time for sleep and he therefore recommended to the Commanding Officer a readjustment of sleeping hours. He has been eating with the men and is convinced that that is a wise thing to do, as it makes an excellent opportunity to learn many things about the fliers that can not be learned in any other way.

He found an instructor apparently unfit for flying duty. Medical examination suggested some toxic-absorption. Further examination revealed badly diseased tonsils. He reported the case of one man who had fear that he would never be able to solo without a crash. After a reassuring talk, he was sent up for solo flight the next day. He made good flights and landings, and was at the time of the report a happy and satisfied pilot. He has no thought of leaving the service, and could not be driven out of it. This cadet was distinctly saved for the service; and it had been decided previously by the Commanding Officer and the officers in charge that he was unfit and should be discharged. No better illustration could be made of the one predominating function of the Flight Surgeon—keep a man in the service.

As far as possible, cadets should be relieved from sitting around at the different stages, as it is monotonous and they become tired out from the inactivity. Sleep is most essential. It should be arranged that the fliers have at least eight hours sleep.

Swimming should be the form of exercise provided. Calisthenics should only be done early in the cool of the morning, and made short and snappy; otherwise they are exhausting instead of stimulating.

The sale of soft drinks should be stopped on the field during flying hours. Many fliers have gastro-intestinal trouble, for which this is directly responsible.

The cowl of the ships should have an 8-inch arc cut away in front with a 4-inch belt stretched across so as to avoid concussion of the brain and fracture of the skull; head injuries constitute the great majority of all injuries from crashes.

Inadequate and poorly maintained drinking water supply for the cadets in barracks and on the field; remedied by supplying large water coolers.

Intense heat prevented the proper number of hours of sleep; remedied by installing ceiling fans in cadet barracks.

Intense heat, 110 degrees in the shade, on the gunnery range; remedied by supplying canvas shelter over each gun.

Consumption of too much bottled soda water and other soft drinks; remedied by supplying lemonade.

Quantity and quality of food is now most satisfactory; many cadets return at noon from their Sunday leave in order to get their dinner at their own mess.

No matter in what part of the world the flying field may be located, the observation of the medical officers leads to practically the same conclusions. This report is from an American flying school in Italy:

> There is a phase of aviation which in every point of view is most important, and which is not receiving the attention which it requires—regular routine examination of aviators—those who are doing advanced flying and those at the front. Much time and expense can be saved if regular examinations are instituted after the cadet has begun flying. The medical officers of all aviation schools should, in my opinion, have a course of instruction in these special medical problems peculiar to aviation. With such instruction to build upon and with proper application and observation, each surgeon connected with the Air Service could quickly develop the ability that will mean much to the Air Service, in the settling of the many intricate difficulties which necessarily face the aviator. It would seem to me that the only way in which to carry out this work is to have a medical officer, who keeps his eye on the flying field and watches after the aviators and examines them from time to time as to their mental and physical fitness.

I get up at 4 a. m. with the cadets and put in the day with them. I hold sick call at 5.30 and try to find out every cadet that is not feeling fit for his day's flying. If I recommend that a man be taken off of flying temporarily, I have him report to me every morning, and then I am able to tell when he is fit to return to the flying field. I have already recommended a man for discharge with a distinct psychoneurosis. I have completed my solo flying sufficiently to be ready for my R. M. A. test. This is fine business and is going to be a great help to me in understanding the conditions of the flying game.

CHAPTER IX.

THE PHYSICAL DIRECTOR.

The motors used in our airplanes are kept in perfect running order by engineers and expert mechanics, and the wings and fuselages carefully watched and trued up and wires kept taut by men who are skilled in this work. Every precaution is taken to have the machine fit at all times, careful inspections being given daily, and by the same token, it is no less necessary to keep the human machine fit for guiding these ships of the air. The great bulk of young men engaged in flying or learning to fly in the United States Army Air Service come from many walks of life. Naturally some are better fitted, both temperamentally and physically, to be made into aerial warriors, and the matter of keeping these men in the pink of condition while in training and at the front as well, has presented some new and highly important problems.

To keep these men fit, physical directors have been provided for the various training fields in our Air Service, and they are cooperating with the flight surgeons not only in keeping our men in the best condition possible, but also in teaching them how to increase their natural strength and endurance. They are likewise training these men to sharpen their powers of alertness and quick, cool action, muscular and mental coordination, and they are teaching this by prescribing proper living and carefully supervised, systematic athletic exercises.

In the last analysis, flying consists of "knowledge of the game, discipline, and physical condition," and the physical directors supervise the training in such a way that it has proven a very valuable adjunct to the other components of flying.

Because the problem of handling the aviator is a comparatively new one, and in view of the fact that the airman's work calls for more or less physical strain under conditions not encountered by land athletes, the foremost experts of the country have devoted many hours to research work along this line since the war broke out. These experts have learned much and are applying their knowledge to great advantage. This research has been scientific and thorough, and thousands of individual cases where airmen have encountered difficulty in keeping fit have been studied minutely to ascertain the exact cause and to determine the particular sort of training necessary.

HIGH PERSONNEL STANDARD.

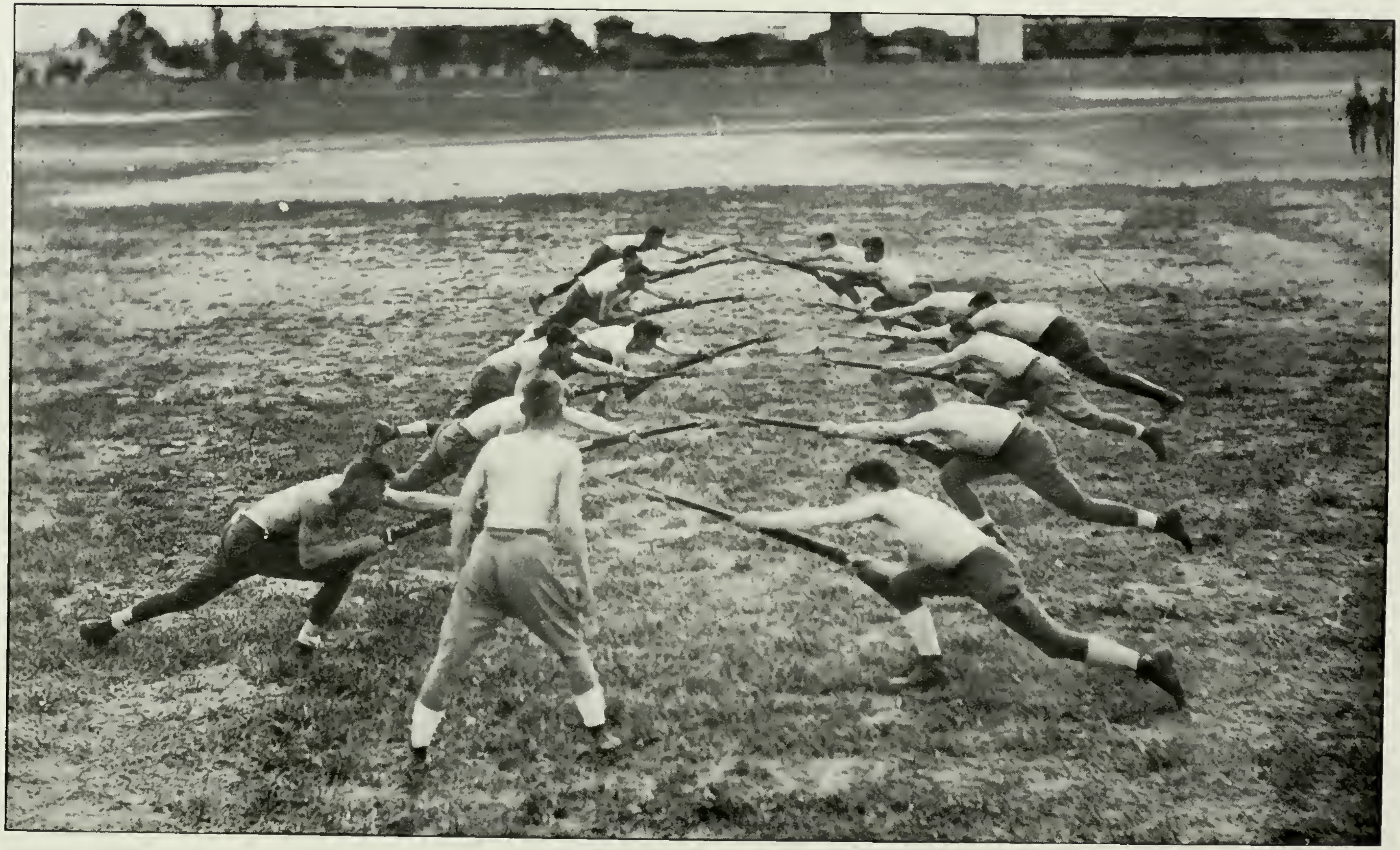
Naturally the men selected as physical directors and commissioned in our Air Service are men who have had wide experience in civil or military life in their respective lines, including both amateur and professional athletics. Trainers of college football, baseball, track teams, and crews; trainers of wrestlers, pugilists, big league baseball trainers, gymnasts, etc., were recruited. These men had learned to study the human machine—how to get the most out of it in an athletic way, how to detect the symptoms of "staleness" and overtraining, and also how to keep the morale and fighting spirit of the team and the individual up to the highest pitch. As far as their work with land athletes was concerned, the ability of these trainers was beyond question.

Then came the work of revealing to them the physical problems of the aviator. "Air sickness," which is practically the same as seasickness on the water, is something encountered by beginners in flying, and this is one of the things which the physical director learned that he must combat. Tendencies to drowsiness in the air caused by the singing of vibrating wires and the hum of the motor had to be counteracted. The effect of rarefied atmosphere at high altitudes; the effect of aerial acrobatics in which the body is required to go through so many unnatural positions and whirled at high speed in various directions, which produces dizziness. The difficulty that flying men in training experience in obtaining sufficient sleep was a topic for study. Learning to differentiate between actually poor physical condition and "ship shyness," a thing induced by lack of confidence on the part of the individual—all of these were problems for the physical director as well as the flight surgeon. Thus, to the large store of knowledge possessed by these physical trainers has been added recently the newer experience obtained at American flying fields. Of course, this study will continue; new discoveries will be made and new methods adopted.

The physical director is immediately put under military discipline as soon as he enters the service in order that he may maintain discipline in accordance with military standards. He goes through and has to master infantry drill work just like any rooky entering the service from civil life. He is instructed with lectures and conferences. His curriculum includes physical training courses, physiology, infantry drill, recreative games, disciplinary drill, Army regulations, customs of the service, Army paper work, psychiatry, cardio-vascular system study and other things as well. From which it will be seen that much is expected of a director both as a physical trainer and a soldier. The interest of commanding officers in these men is note-

BOXING.

393b–2



BAYONET PRACTICE (LONG POINT).

worthy, for the results which the physical experts obtain contribute much to the output of successful fliers.

To the credit of the directors engaged in this work, it may be said without exception that none of these men was ever more earnest and anxious to produce a winning team on gridiron or track than are these same men who are now working with might and main to produce the greatest athletes of the air to be found among the Allies to help score the touchdown at the Berlin goal post.

RIGHT LIVING THE BASIS.

In aviation physical fitness is really more necessary than in other branches of the service, in so far as the personal safety of the aviator and the safety of his plane are concerned. The soldier on land is of course at his best when physically O. K., but he may be below par and yet not show it, and at the same time he may be in no particularly great danger because of this. That depends upon the type of work he is doing. However, this is not true of the aviator. He must be right at all times or his work will reveal his defects. If it is not noticeable to those watching him (as it frequently is), he can not help but be conscious of it himself.

Right living is the basis of physical training. The cadets who have had to pass a most rigid test before being accepted into the service are organically sound and none are physically abnormal, and upon being inducted are constantly under the watchful eye of the physical director, who lives, eats, and sleeps with the cadets and is on the lookout for symptoms of any disorder. Therefore the physical director need not worry about the course of strenuous exercises and flying calisthenics being too severe for the heart nor too much of a strain for muscles and tendons. With correct living the correct amount of sleep is obtained—a minimum of 7½ or 8 hours. Cadets rise about 5 a. m. and at 9 p. m. they are in bed (excepting when on weekly leave, when they stay up later), and when "taps" comes most of the men are so tired that they need no coaxing to retire.

Hot weather may make sleeping difficult, especially in the southern camps during the summer months, where the matter becomes a serious problem. It has been found, however, that a flier can not keep fit without 8 hours sleep out of the 24. A longer night period of sleep than this is conducive to laziness and is not to be encouraged, although of course it is quite desirable for cadets to lie down for a nap during rest hours, particularly when the weather is warm and sleeping at night difficult.

When first learning to fly the cadet may be subject to air sickness, stomachache, and headache, although the new flying calisthenics training is reducing this to a minimum. When such ailments occur, headache powders, laxatives, and drugs of any sort are not recommended. In fact, the physical directors are very much against their use, and the flight surgeons as well. The regulations forbidding the use of alcohol in any form, of course, eliminate a great deal of difficulty which otherwise might be encountered by the director.

OVEREATING AND "PARTIES."

Mess at the various camps is prepared by competent cooks under the direction of dieticians, the meals being scientifically balanced so that there is no danger of indigestion or malnutrition. Work in the air produces very keen appetites, and there is a tendency for some cadets to overeat during their first months of training.

One of the difficulties encountered by the physical trainer is his "blue Mondays." In view of the strenuous work the cadets are obliged to do during the week, it is obviously necessary to give them rest and recreation *ad lib.* from Saturday afternoon until early Monday morning. Many of the cadets go on week-end parties, being invited by friends. These well-meaning friends endeavor to give the boys a good time, and while there is seldom any dissipation indulged in, too much to eat and too rich foods do damage. At camp cadets are kept on a regular simple diet, scientifically prepared. They become used to eating nourishing food and no trash. During the week-end party they are proffered foods which are not nourishing in nature, various dishes being quite indigestible, and the chances of the cadet overeating are fairly certain. Candies and ice-cream sodas may help to undo a great deal that the physical director has built up.

If well-meaning friends of cadets could only be induced to realize that it is a patriotic duty not to feed their visitors rich food and too much of it, the physical director's task would be easier and the cadet's efficiency and comfort oftentimes would be greater.

EXCESSIVE SMOKING TABOO.

Excessive smoking must be curtailed. The harmful effect of nicotine in excess is quite noticeable in the men's work in the air. Sometimes because of homesickness or loneliness, a cadet indulges in smoking, working perhaps on the assumption that it is soothing and quieting. It is shortly noted by the physical director that the man's vitality is lowered and his lung capacity impaired. Lung capacity is vitally important for high altitude work. It must be developed at the same time that muscles and the sinews are being developed. Excessive smoking causes cadets to turn out of bed heavy of head, and this in turn, together with the lowered vitality, causes loss of enthusiasm in their work and has a tendency to break down the morale.

CENTIPEDE RACE.

TUG OF WAR.

At one of the southern camps recently there was a cadet who had acquired the bad habit of smoking black cigars both before and after mess. He had left a wife to whom he was devoted and a small child at home, and frequently thought of his family and found solace in his cigars. That it was very bad for him physically was proved when one day he became befuddled in the air upon getting into a tail spin and could not think clearly or quickly enough to prevent a crash. In fact numerous flying students have been unable to get out of tail spins, not because they were not properly instructed, but because their vitality had been lowered from one cause or another, and upon finding themselves in a dizzy whirl were unable to secure proper coordination, with a crash resulting.

MASS ATHLETICS NECESSARY.

Exercises must necessarily be arranged according to the temperature and weather. Mass athletics are very much to be desired, such as soccer, football, progressive leapfrog, baseball, push ball, basket ball, combined with tennis, handball, wrestling, and boxing. The latter is especially encouraged for the reason that it is one of the greatest exercises for developing quickness of movement, alertness and power to keep one's head cool and his thoughts collected. "Fite nites," as they are called, which have been established as weekly institutions at Camp Dick, Dallas, Tex., and elsewhere, are proving excellent forms of diversion for the men, for these not only develop the fighting spirit and spirit of aggressiveness, but keep the cadets interested in their work and improve the morale.

FLYING CALISTHENICS.

Runners do not train for a race in the same manner as hammer throwers; swimmers prepare for their supreme tasks in a manner quite different from the high jumper. Athletes must be trained for their specialty; their bodies must be put in absolute physical trim for the work required, by exercises and training which will develop the muscles brought into play. Successful athletic trainers systematically lay out the most beneficial exercises for each specialty of athletic endeavor, and the success of such intensive and specialized training is universally acknowledged.

Flying is a feat requiring mental and muscular coordination best found in athletes in prime physical condition, and also in those who have developed a sense of alertness through gymnasium apparatus work and tumbling. The development of this necessary muscle-mental coordination, together with prime physical condition from the usual athletic sense, has been combined in an athletic training course for fliers.

This training has been worked out in a series of flying calisthenics which are taught to flying cadets to train them in advance for the difficulties of the air—to fortify them against dizziness. This course of exercise has been scientifically devised to cover every aerial requirement and actually fits a man on the ground to conquer the new and disturbing sensations a flier encounters. Thus not only his bodily strength is built up, but mentally he is stronger and more confident, knowing he is prepared to resist the influence of dizziness which is a terror to some men who are starting to fly—and by many regarded with such positive dread that their work is affected with proportionate decrease in their efficiency.

Equilibrium as such, from the aerial standpoint, is not merely a sense of balance, but the ability of an individual to accustom himself to the unusual positions which would ordinarily produce dizziness, nausea or air sickness, incapacitating the flier by making him lose muscular and mental control, from which so many crashes result. Those exercises so accustom the flier to these unusual positions that when in the air they do not bother him.

RADICALLY NEW CALISTHENICS.

The course in flying calisthenics is an adaptation of a certain portion of regular Army calisthenics combined with radically new movements, each of which has its special function. The matter of flying calisthenics is not essentially a developer of muscle, although it does this to a large extent. The principle underlying it is based on the scientific development of the flier, not as an athlete, but for the coordination of his mental and physical abilities. It is designed to make more acute his sense of direction, equilibrium and muscle balance, and at the same time keep him in sound mental and physical condition. It prevents his muscles from becoming soft and at the same time carefully avoids overtraining, which would be harmful. There has been much scientific research along this line, particularly regarding the muscles and tendons which are subject to greatest stress while the flier is in the air—muscles and sinews which in ordinary land athletics would not be subject to such hard work.

Beginning with a few simple movements of the head and shoulders to strengthen the neck and shoulder muscles, which are put under strain while flying, the student is taken through a course of evolutions which produce a tendency toward dizziness and later overcomes it through practice. At the outset a very few turns will make a cadet dizzy. All of these exercises are carried up to a point where dizziness is first noticeable, and not beyond that. The training progresses and the turning movements are done for longer periods, the increase being very gradual from day to day until at the end of

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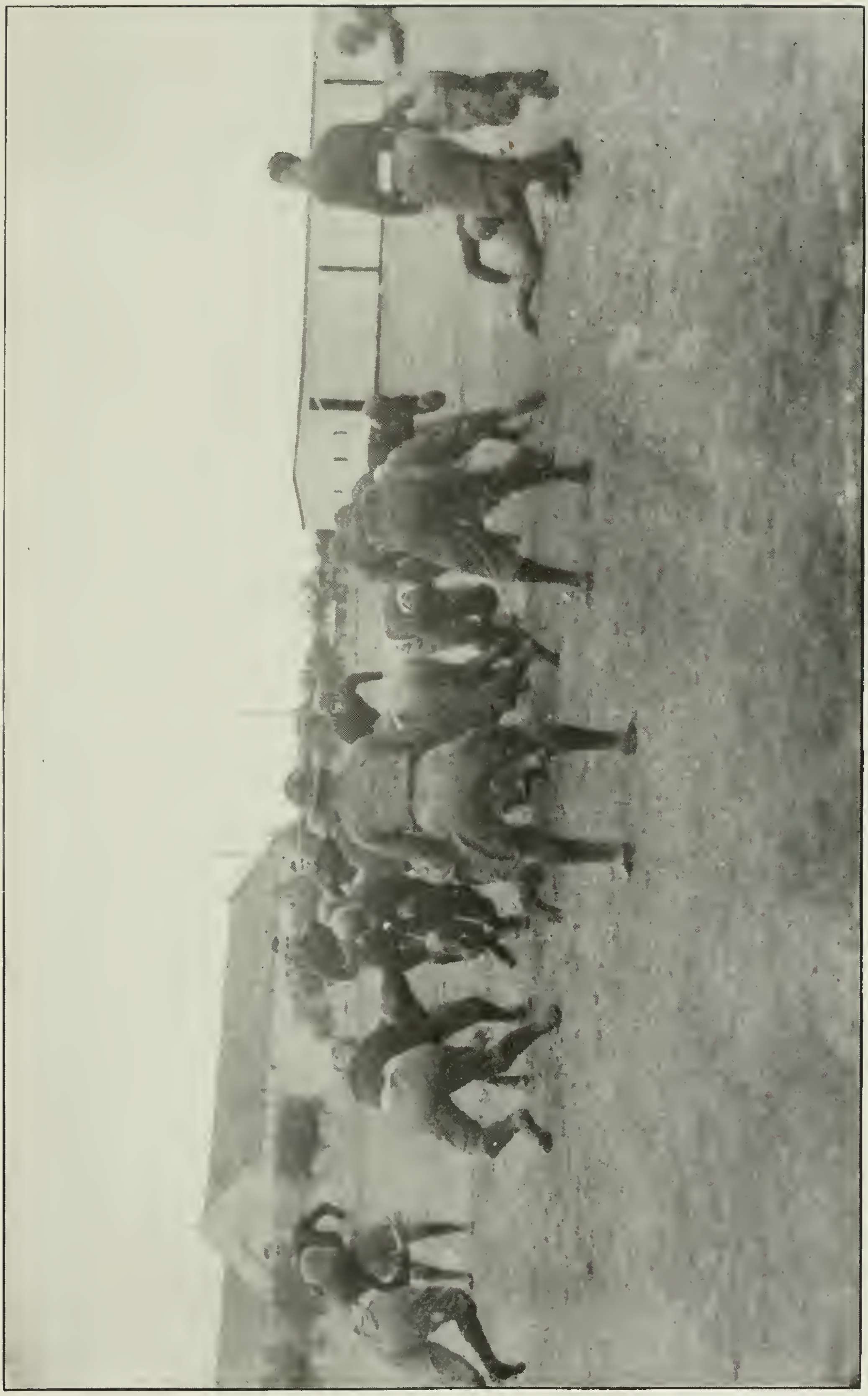

FOOTBALL SCRIMMAGE.

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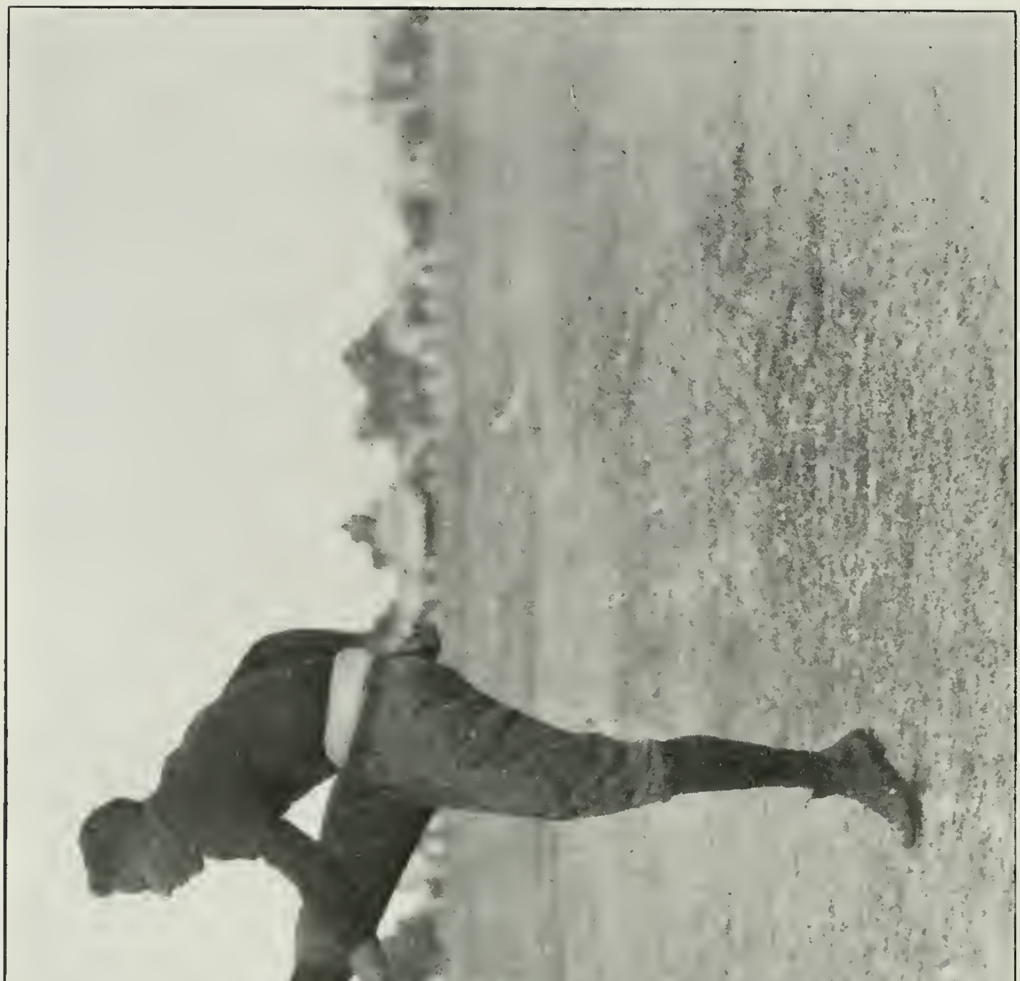

PUNTING

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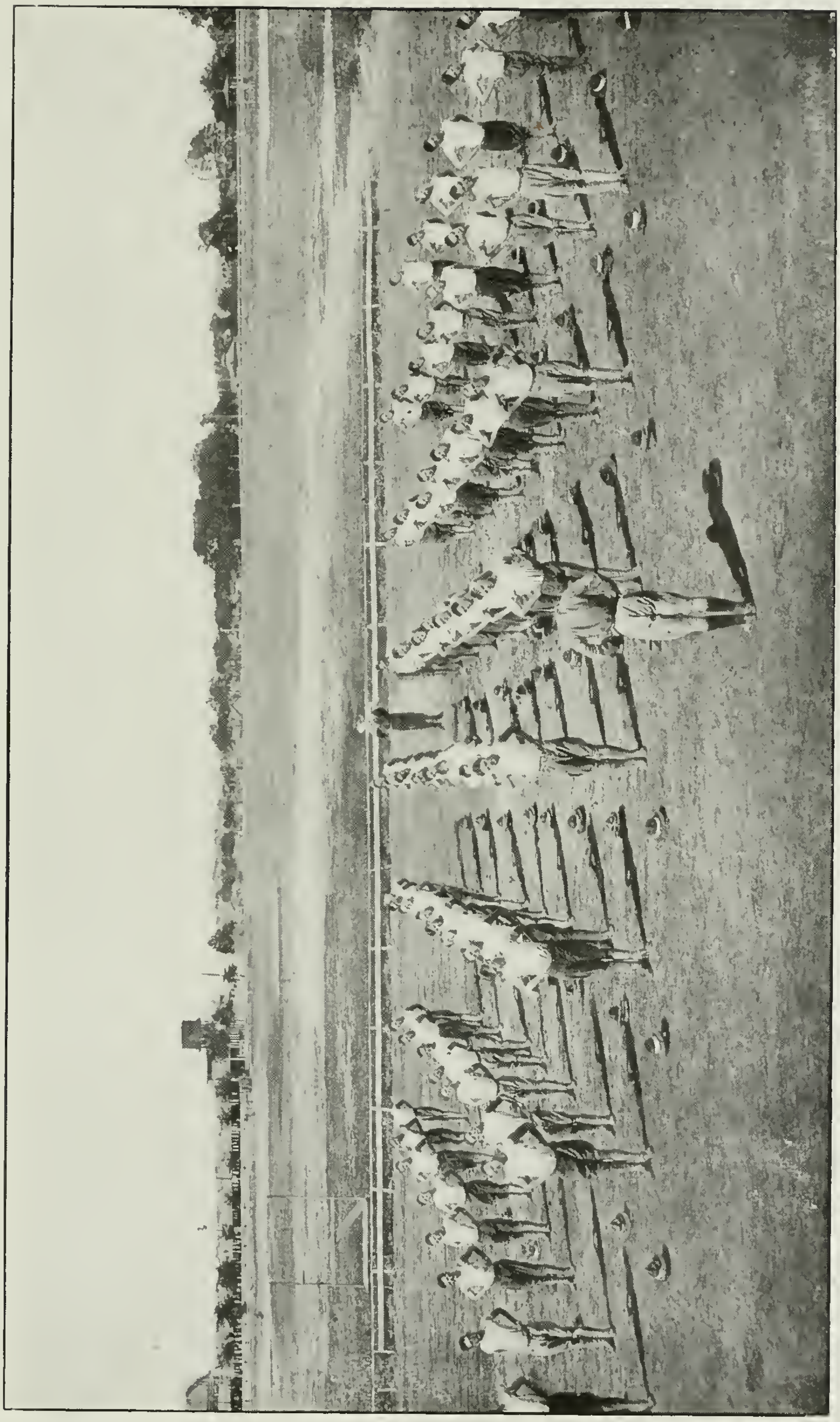
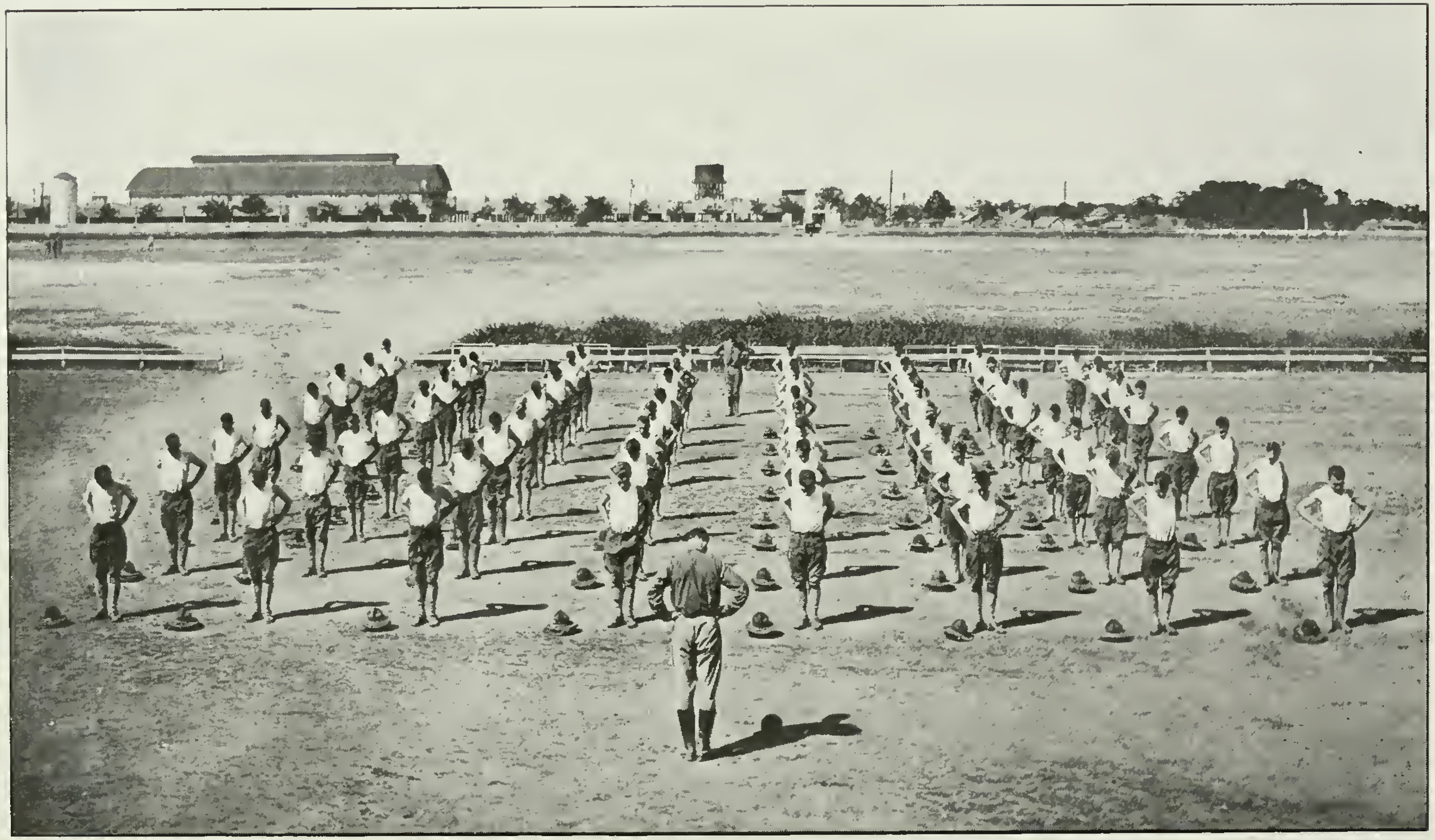


NO. 1. NECK EXERCISE.



NO. 2. NECK EXERCISE.

30 days or so the cadets can do all of these various movements to a fair extent without becoming dizzy.

Among the movements which have been scientifically developed are those to accustom the cadet to the effect of the tail spin and the spinning nose dive. Other movements have been developed to overcome the dizziness and "lost" feeling of the so-called Immelman turn and the vertical spiral. Ordinary somersaults and forward and side rolls are analogous to the loops done in acrobatics. As the instruction progresses in these various movements, orders are given at the completion of the movement, such as to take four or eight steps forward or to the right or left flank, in order to accustom the cadet to doing something definite immediately upon coming out of his unnatural position. This is something which requires mental and physical coordination, and is vital to controlling a ship when coming out of a tail spin or one of the other acrobatic movements. Detailed explanation of these various movements follows:

While, of course, a cadet may find these dizziness exercises unpleasant at first he will soon become so used to them that he will not mind it, just as a sailor becomes used to the action of a ship at sea.

The accompanying illustrations show the exercises which are designed for the purpose of physical development and accustoming the embryo pilot to the unnatural positions which he will encounter sooner or later in flying. They are given with regular calisthenics to put men in the pink of condition so essential to the success of the beginner. The entire series is given moderately at first, the idea being to take the men up to the point where dizziness begins. This is continued until they become used to the sensation and then is gradually increased each week. This training serves an additional purpose in that it provides a moderate endurance test of the men each day, as a man must necessarily be in at least average physical condition, in order to take this work, just as he should be for flying.

FLYING CALISTHENICS.

1. A primary exercise simulating the position of the head in a 45-degree bank.

No. 1.—*Neck exercise.*

1. Hands on hips.—2. PLACE.—[1] 3. Bend head to right and left (forward and back) alternately in 4 counts.—4. In cadence.—5. EXERCISE.

Repeat 6 to 8 times.

2. A primary exercise in changing the head from its normal position and at the same time developing the neck muscles which are put to constant use while flying.

No. 2.—*Neck exercise.*

1. Hands on hips.—2. PLACE.—3. Rotate head in 4 counts.—4. In cadence.—5. EXERCISE. [1](1) Head bent forward. (2) Circle head to right. (3) Back (eyes open, looking up). (4) Left.

Repeat 4 to 8 times.

[1] Position illustrated.

3. The effect secured in this exercise is similar to that produced by a vertical bank. This also develops the abdomen on which such strenuous demands are made in flying.

No. 3.—*Vertical bank exercise.*

1. Hands on hips.—2. PLACE.—3. Circle trunk to right (left).—4. In cadence.—5. EXERCISE. (1) Trunk full bent forward. (2) Move to right side bend position. [1](3) To the back bend. (4) To the left bend.

Repeat 3 to 6 times.

4. An exercise to overcome dizziness by accustoming the student to the motion which produces it.

No. 4.—*Rotation head and body exercise.*

1. Hands on hips.—2. PLACE.—3. Rotate to right (left).—4. Counts.—5. In cadence.—6. EXERCISE. (1) Trunk full bend forward. [1](2) Start to describe a circle about 2 feet in diameter. Number 2 position 90 degrees to right of number 1 position. (3) Ninety degrees counterclockwise from number 2. (4) Ninety degrees counterclockwise from number 3.

Repeat 4 to 8 times.

5. An exercise planned to accustom the student to the sensations derived from an Immelman turn.

No. 5.—*Immelman turn exercise—A.*

1. Hands on hips.—2. PLACE.—3. Backward.—[1]4. BEND.—5. Right (left) (about).—6. FACE.—7. Forward.—8. BEND.

Repeat 3 to 8 times.

6. In a climbing spiral the head is in a position which produces dizziness. Two weeks practice tends to eliminate this condition. It was found easier for the cadets to become used to this exercise with the finger in the illustrated position, thus providing them with a center about which to turn. After the second week the exercise can be executed with the hands on hips.

No. 6.—*Climbing spiral exercise.*

1. Right arm veritcal.—[1]2. POINT.—3. TURN to right about finger.—4. IN cadence.—5. EXERCISE. 1–2–3–4. Completing 3 turns in 12 counts, immediately followed by 4 (to 8) paces forward, in 4 counts. Halt in position of attention on sixteenth or twentieth count.

Repeat 3 to 6 times.

7. Students becoming used to the position of a spin which produces dizziness before experiencing one in the air.

No. 7.—*Tail spin exercise.—A.*

1. Hands on hips.—2. PLACE.—3. To the right (left).—4. IN cadence.—5. EXERCISE. [1](1) Full trunk bend, right (left) finger pointed to ground. (2) Start turning to right (left) completing 3 turns in 12 counts, followed immediately by 4 paces forward, in 4 counts. Halt in position of attention on sixteenth count.

Repeat 2 to 4 times.

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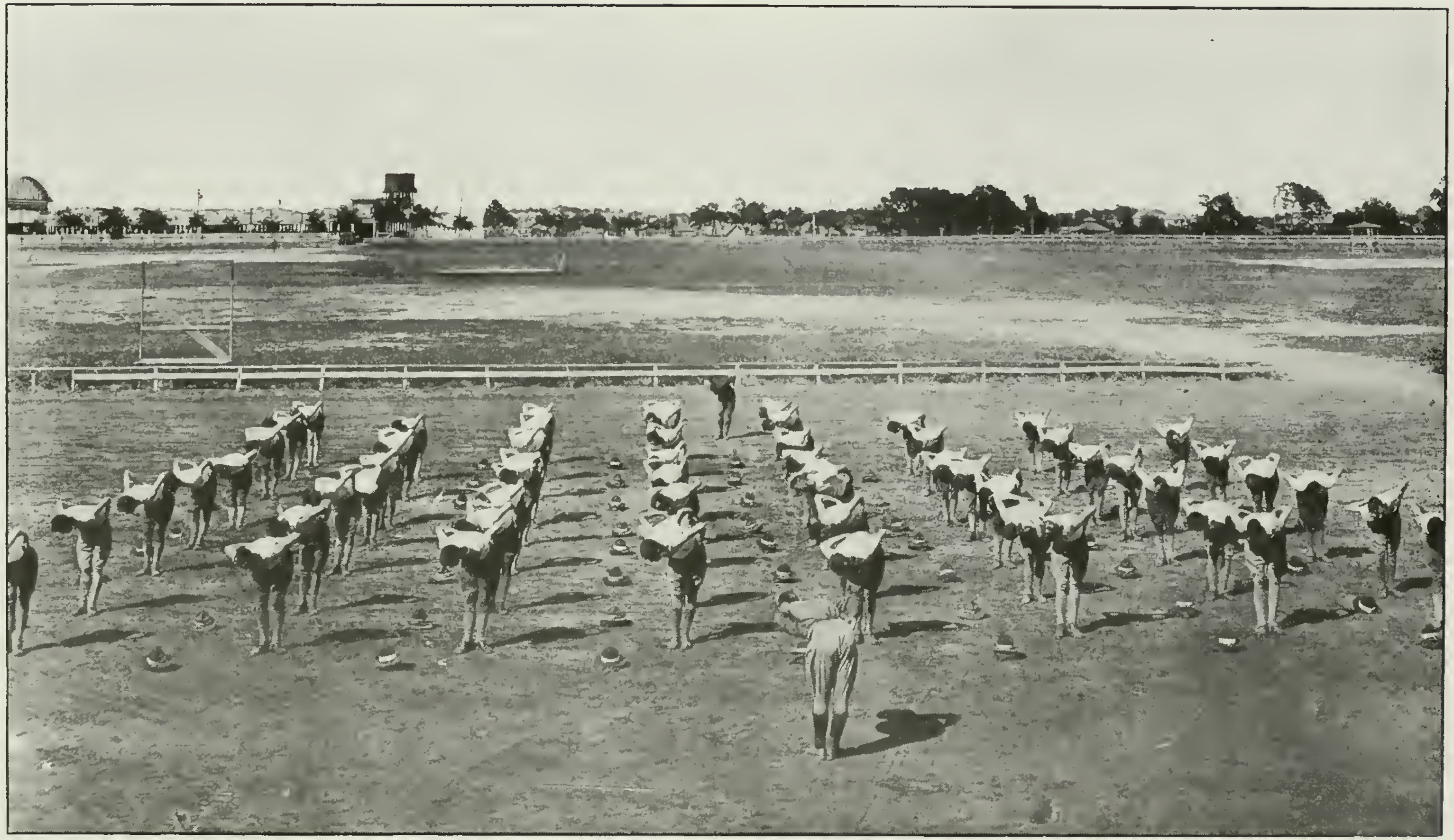
[1] Position illustrated.

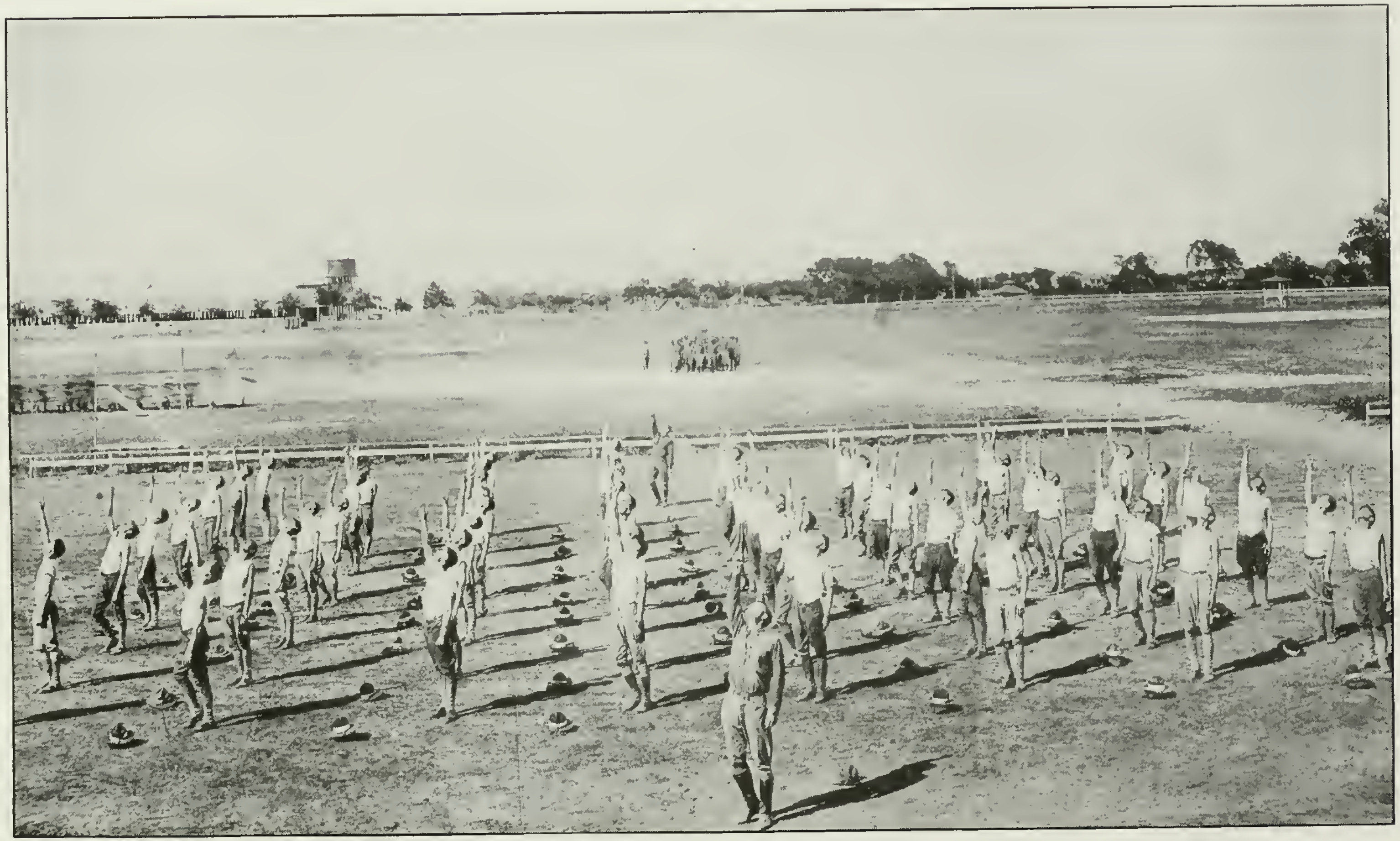

NO. 3. VERTICAL BACK EXERCISE.



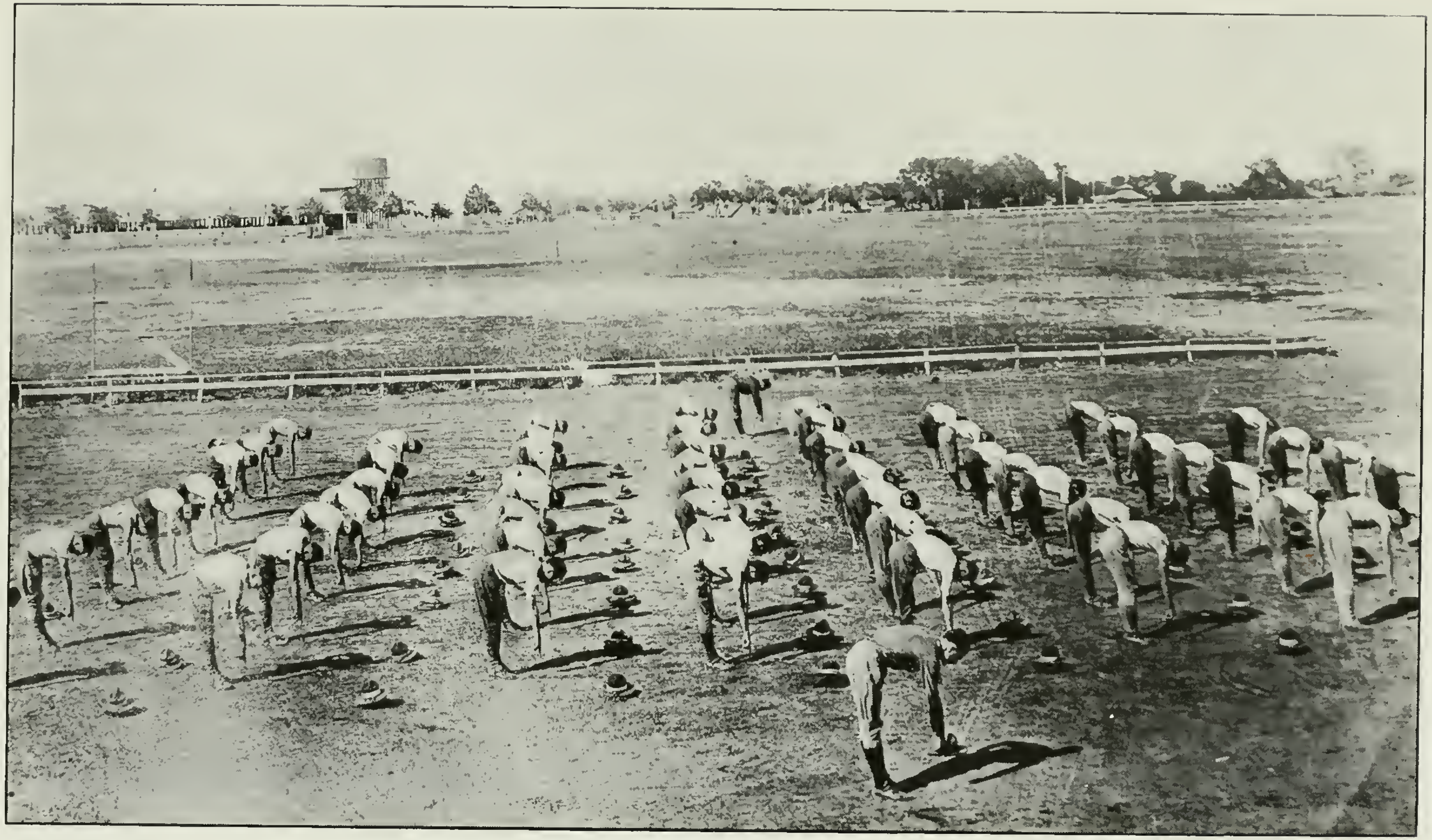
NO. 4. ROTATION HEAD AND BODY EXERCISE.

398b—2

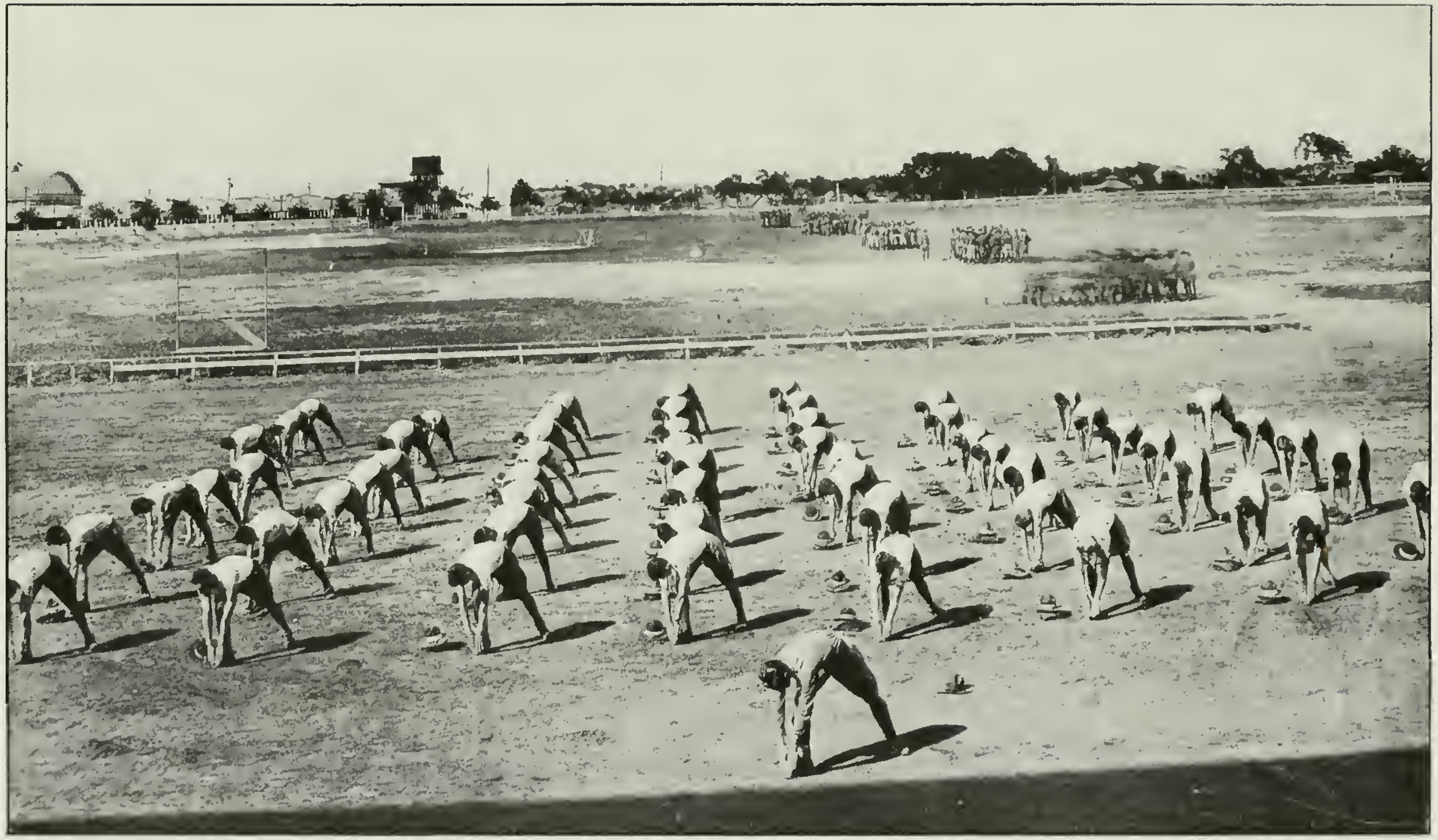
NO. 5. IMMELMAN TURN EXERCISE.



NO. 6. CLIMBING SPIRAL EXERCISE A.



NO. 7. TAIL-SPIN EXERCISE.



NO. 8. HALF-LUNGE EXERCISE.

NO. 9. TAIL-SPIN EXERCISE B.

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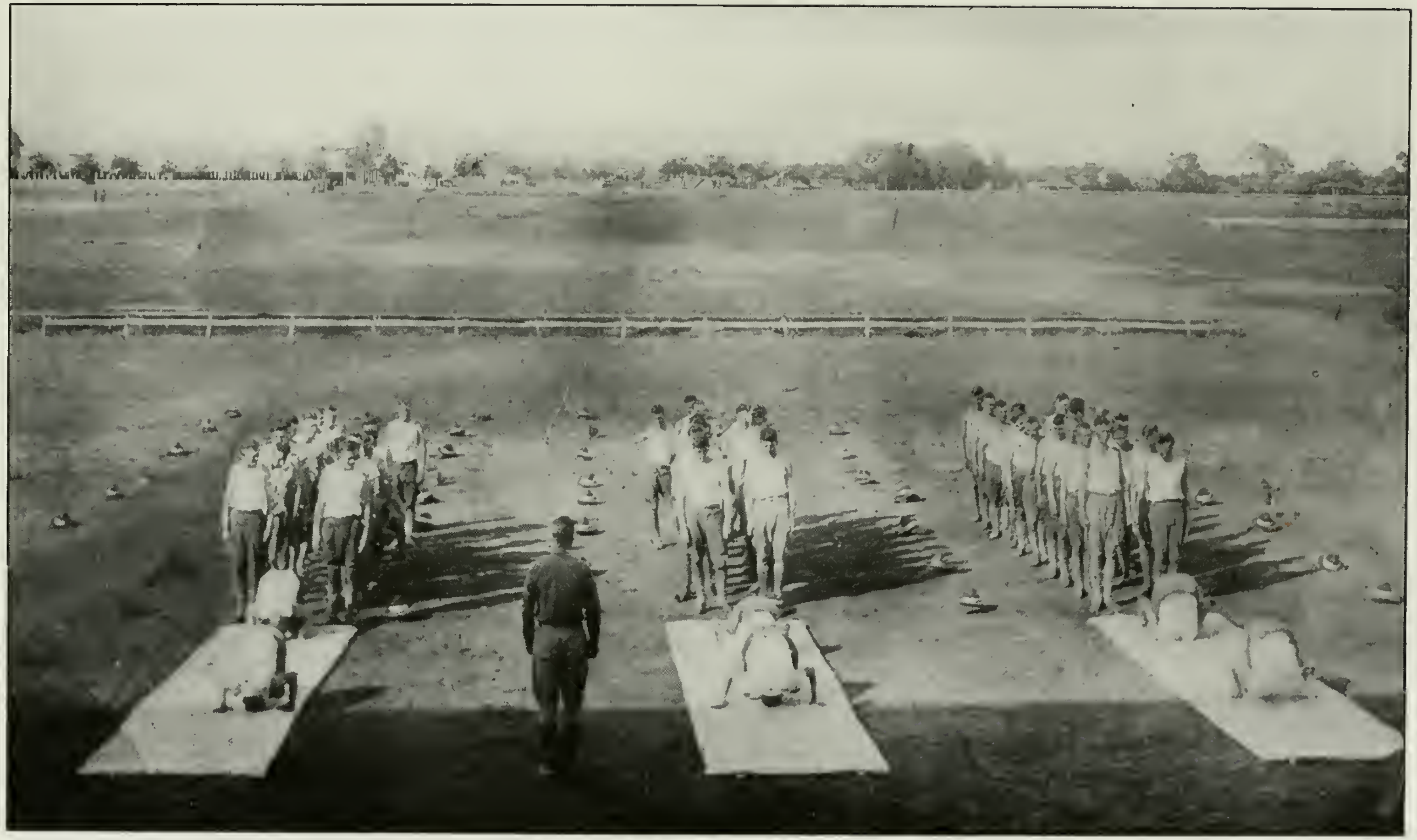
NO. 10. FORWARD-ROLL EXERCISE.

NO. 11. BACKWARD-ROLL EXERCISE.



NO. 12.—FORWARD-ROLL EXERCISE.

8. Changing the head from vertical to horizontal position, also exercising abdominal and back muscles.

No. 8.—*Half lunge exercise.*

1. Hands on hips.—2. PLACE.—3. Lunge to right and left alternately, 4 counts.—4. IN cadence.—5. EXERCISE. [1](1) Half lunge to right, with forward knee bent, touching toe with fingers. (2) Back to vertical. (3) Half lunge to left, with forward knee bent, touching toe with fingers. (4) Back to vertical.

Repeat 5 to 8 times.

9. This exercise is executed with rapid about faces during the third and fourth weeks of training, after the student has become used to No. 7.

No. 9.—Tail-spin exercise—B.

1. Hands on hips.—2. PLACE.—3. Forward.—4.[1] BEND.—5. Right (left) about).—6. FACE.

Repeat 3 to 6 times.

10. Looping the loop on the ground.

No. 10.—Forward-roll exercise.

1. Forward roll.—2. In cadence.—3. EXERCISE. 1–2–3–4. (1)[1] Full knee bent, hands on ground. (2) Head between legs. (3) Body forward by weight of hips, grasping ankles with both hands. (4) Snap to attention.

Repeat 3 to 6 times.

11. Looping on the ground in reverse direction.

No. 11.—Backward-roll exercise.

1. Backward roll.—2. In cadence.—3. EXERCISE. 1–2–3–4. (1) Full knee bend. (2) Straighten legs sharply, sending body horizontally to rear. (3)[1] Roll over backward, head bent forward, hands placed on mat beside shoulders. (4) Land on feet and snap to attention.

Repeat 3 to 6 times.

12. The last part of the physical-training period is devoted to snappy forward, backward, and slide rolls, the positions of which are comparable to loops.

NOTE.—When cadets become used to these exercises, after doing them in one place, they are given 4 to 8 paces forward or by right or left flank.

This is done for the purpose of giving the men a definite thing to do immediately after being in unnatural positions, requiring mental-muscular coordination, which is so vital in the control of a ship when pulling out of a tail spin.

"NOTHING TO DO TILL TO-MORROW!"

A typical sequence in the progressive training of the cadets during the day is as follows, the object being at all times to promote accurate and dependable mental activity:

5 a. m. Reveille.
5.15 to 5.30. Regulation calisthenics.
5.30 to 5.45. Make up quarters.
5.45 to 6.10. Breakfast.

[1] Position illustrated.

6.20. Flying detachment assembles for flying.

6.30 to 7.30. Detachment not on flying list, scholastic work, one hour.

7.30 to 8.30. Gunnery.

8.30 to 10. Scholastic work, practical work on motors, aero repair work, etc.

10 to 11. Flying calisthenics and games.

11 to 12. Shower baths (enforced) and relaxation. (The object of this one hour of relaxation before noon mess is to give the exercised muscles that especially desirable period of rest in which to recover.)

12 m. Mess.

Detachments which have been flying in the morning have their gunnery, scholastic work, and flying calisthenics in the afternoon in approximately the same relative periods.

6 p. m. Mess and recreation.

7 p. m Evening athletics, such as basket ball, squash, tennis, and mass athletics, intersquadron baseball games, etc.

In addition to regular calisthenics and flying calisthenics, and athletic diversion, work on gymnasium apparatus is very desirable as a supplementary course. Horizontal and parallel bars, rings, Indian clubs, etc., are to be encouraged, while tumbling is especially valuable in view of the fact that in it the tumbler simulates positions he will have to assume in acrobatic flying. This also gives exceptional development of muscle balance. Successful tumbling requires that the student know just where he is in the air during every fraction of a second required for the movement.

FREQUENT RECUPERATIVE FURLOUGHS RECOMMENDED.

The men intrusted with the physical welfare of fliers are learning that furloughs and vacations are more necessary for air men than for men in other branches of the service, and also should be given at more frequent intervals. The reason is that flying is such highly specialized work and inclined to produce nerve strain and "staleness." This is particularly true when a man has learned the rudiments of flying and has been in the air for 20 hours or so. At this stage he is called upon to fly day after day, circling in ovals above his field, and this becomes just as tiresome as riding a bicycle around the block. He craves cross-country flying and acrobatics, and yet is not quite ready for this work. As a result he may suddenly grow stale. In fact, if he does not he is an exception, and when the symptoms are noticed he should immediately be given a furlough for complete rest.

There is no doubt that the excessive heat of the southern camp in summer induces staleness, and there is danger at times of heat prostrations or general physical breakdown resulting. The Germans have found the value of frequent furloughs. The late Baron von Richthofen advocated it. In the French Flying Corps "aces" are usually permitted to take a "permission," as it is called, each time they bag an enemy flier, and those who are not aces receive such permission almost as frequently. This is not altogether a means of reward for the fliers, although the French Army idolizes its flying men, including its native sons, Americans and others of the foreign legion as well. The idea is essentially to prevent these very skilled and experienced men from growing stale.

The fact that the United States Army Air Service training is such an intensive one and the discipline so rigid, means that our pilots, both in training and finished fliers, must have rest periods.

WANTED—SWIMMING POOLS.

There is one special crying need at the southern aviation camps, a need which fortunately is to be furnished in the near future. We refer to swimming pools. Various patriotic contributors are interested in the project of providing pools for the southern flying fields which are unbearably hot much of the summer. The athletic training for aviators to make them fit for the strain of flying must necessarily be carried to a certain point even though weather conditions are unfavorable, and without swimming pools it has been impossible to make this training anything like as efficient as it could be made. This is particularly true of camps where the temperature ranges from 90 to 120 degrees, and where the nights are so hot that flying students have difficulty in obtaining the very necessary sleep which they require.

When temperatures are as high as this ordinary athletics and games can not be indulged in to such a vigorous extent as normally, and swimming, which is splendid physical training in itself, is the only substitute.

Aside from the refreshing and purely physical features of swimming, there is another angle which is of great importance. Where pools can be maintained high diving and fancy diving must be taught for the reason that in stunt diving the body is required to go through many of the evolutions experienced in aerial acrobatics, and furthermore the splash produces an effect upon the diver which is desirable, for he becomes accustomed to keeping his thoughts collected and his head clear when interruptions in his general trend of activity occur. This is somewhat analagous to being in the air and suddenly fired upon, in which case the shock of the surprise must not affect the flier's efficiency or headwork.

Those generous people who have said to themselves "I would like to do something substantial toward a healthy diversion for the boys in aviation training" can find no better answer than to assist in the project of providing swimming pools.

One needs but to consider that after a flier has been on the flying field from 6 a. m. until noon in a temperature of 90 to 120 degrees he is well heated. There is nothing in the world that he would rather do than take a shower or play around in a swimming pool for half an hour before noon mess and again late in the afternoon. At the southern fields in summer the cadets do not fly in the afternoon when the temperature is high, and therefore have little else to do except to fidget around in their bunks trying to sleep and wishing for cooler weather and an invigorating swim.

At every flying field there is a certain note which permeates the atmosphere—a note indicative of the mental attitude of the men. At some fields that particular spirit savors of perseverance, joy, or gloom, as the case may be. The question of morale is so important that officers can not afford to neglect it in the least. Without prime physical condition in the men, high morale can not be maintained, for a sick body means a sick mind, and a disordered mind means grumbling and disgruntled feelings—lowered morale, which militates against the highest efficiency of the field.

The physical directors contribute perhaps more to the high morale than might be imagined, for it is these directors who obtain the confidence of the men under them, engage in heart-to-heart conversations and listen to the problems and petty difficulties of the boys in a manner that is not possible between cadets and other officers. There is a kinship existing between physical directors and the men under them—a kinship which is productive of wonderfully valuable results. These men provide "snappy," "peppy" athletics, teach new tricks, show novel and interesting swimming and diving stunts, when swimming pools are available and make the men do something which they like to do—the very things in the way of diversions for which the cadets pine, when they are on terra firma and away from their ships. Hence, these cadets, possessed of enthusiasm inspired by flying, find an outlet for their enthusiasm and can keep cheerful.

Most of these activities are on a competitive basis, providing the true sporting element and the men looking after the bodily welfare of these young soldiers of the air, are constantly so close to their charges and their problems that the wisdom of the inauguration of this new instruction is more than commendable. The value of the physical director is incalculable.

PHYSICAL TRAINING FOR AVIATORS.

This special table is published as a guide to physical directors and their assistants in the training of aviators and cadets, and the chief aim is the procuring of the utmost activity of brain and limb which it is possible to obtain in cadets taken in large classes and without proper clothing and apparatus.

NET BALL.

402b–1

PROGRESSIVE LEAP FROG.

402b–2

402b—3

SOCCER.

Any "setting-up" exercises should be preparatory; that is, make men ready for the serious work of the day, and in no way exhaust any portion of their vitality.

Mr. Walter Camp acting in an advisory capacity, has formulated 12 exercises which take from 12 to 15 minutes to execute. They should not be hurried through, with the idea of completing all of them in this specified time. It is better for the man to master them thoroughly, using a little more time than to indifferently perform all of them in a hurried, incorrect way.

Not more than an hour a day will be allotted to physical training and every aviator, or cadet, should be exercised six days a week.

After these 12 standard exercises have been completed, it will be left entirely to the physical director as to what the balance of the hour period will be used for.

No form of physical training or running training should be done in the early morning unless the men have had something substantial to eat, or until half an hour after breakfast or dinner.

Every effort must be made to organize the physical training on lines which will allow the instruction, once commenced, to continue without interruption for one hour daily for each cadet.

Signs of abnormal distress at the conclusion of any physical exertion should be reported to the flight surgeon immediately by the physical director.

It should be remembered that this table is not given with the view of fitting men for the physical strain of a football game or a long-distance run, but is designed to produce general fitness and a fund of vital resources in the aviator to enable him to better withstand the peculiar strain of flying.

STANDARDIZED TABLE.

The physical director or his assistant will name a definite time for each class to be on parade. All members of the class should be on the ground ready to fall in at that time. Strict disciplinary measures should be taken with any one arriving late.

The instructor will take up a convenient position, give the command "Fall in!" whereupon the class will double to their position in two ranks, palm of left hand upon hip, the extreme right man of the front rank to take a position two paces directly in front of and facing the instructor, the right-hand man of the rear rank will take up his position two full paces in rear of this front-rank man, the remainder of the class falling in on the left of these two markers. A quick dressing by the right should be made, with alignment perfect and the right arm of man resting lightly against the left elbow of the man next on his right, and then the class stand at "attention."

No moving, spitting, or talking should be allowed under any circumstances.

Before giving any lengthy verbal instruction, the instructor should give the command "Rest." No class should be held in the position of "attention" for any length of time, neither should they be held in any position of strain while some movement is being explained.

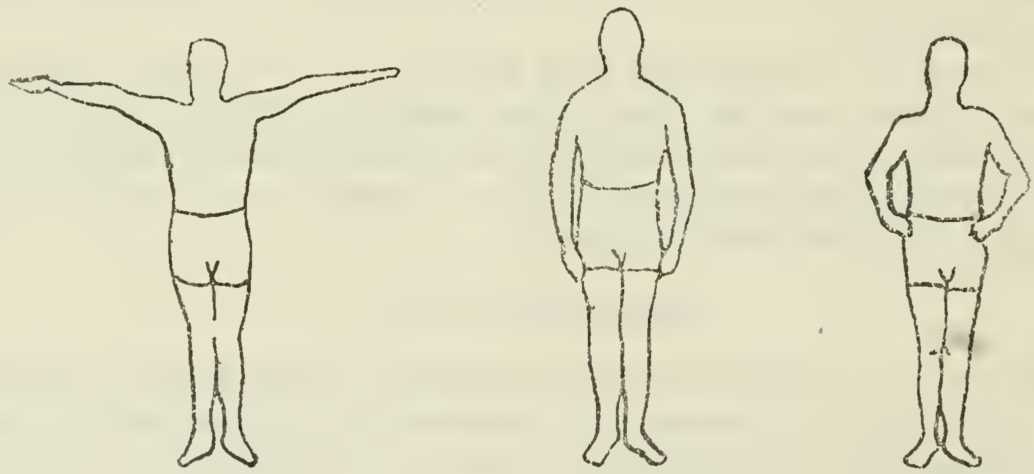
The opening of ranks, so as to place the class in a position allowing of the free movement of arms and legs, will be as laid down in paragraph 63 of the Manual of Drill Regulations.

Each exercise starts from the position of attention. The position of attention will be the same as that for Infantry training, except the fingers will be stretched straight down the sides to their full extent.

Care should be taken that the breath is not held while taking any of the following exercises. Natural breathing is desirable throughout the tables unless a breathing exercise is being given.

GROUP I.

1. **HANDS.—Arms CROSS.** (At arms cross, arms are extended laterally and horizontally, palms down, fingers together, thumb against the forefinger. See figure 2.)



1. Hands. 2. Cross. 3. Hips.

Arms LOWER. (At arms lower, the arms are brought back to a position of attention close to the sides. See figure 1. Especial care should be taken to see that whenever, throughout the exercises, this position is taken—as at the completion of each exercise—full control is retained over the arms, and the hands should not be allowed to slap against the sides audibly.)

2. **HIPS.—Hips FIRM.** (At hips firm, the hands are placed on the hips with shoulders, elbows, and thumbs well back. See figure 3.)

Hands DOWN. (At hands down, the arms are brought back to a position of attention close to the sides. See figure 1.)

3. **HEAD.—Head, Ready, Cross, ONE.** (At one, the hands are placed behind the neck, index finger tips just touching, and elbows forced back. See figure 4.) **TWO.** (Position of attention resumed.) **Rest.**

The above exercises should be executed but a few times each, being preparatory to the speed test.

SPEED TEST.

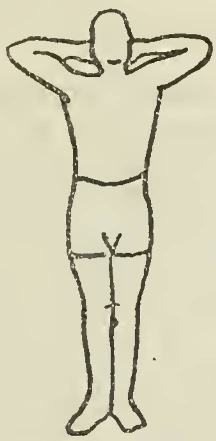
In this, the preparatory command is omitted and the instructor gives the commands, Hands, Hips, Head, etc., in sharp succession, varying them, and occasionally repeating a command in a manner calculated to catch the unwary napping.

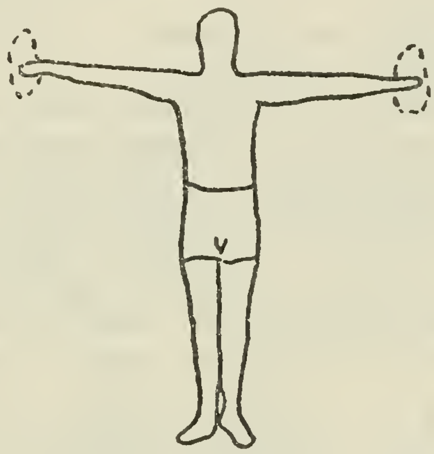
GROUP II.

1. GRIND.—Arms CROSS. (See figure 2.)

Palms TURN. (At turn, the palms are turned up with backs of hands down and arms forced back as far as possible. See figure 5.)

Grind, ONE, TWO, THREE, FOUR, FIVE to TEN. (At grind, and in time with the leader's measured counting, circles of 12-inch diameter are described with the finger tips, which move forward and downward, then backward and upward, the arms remaining stiff, and pivoting from the shoulders. On the backward movement of the circle, the arms should be forced back to the limit. A complete circle should be described at each count.)


4. Head.


5. Grind.

Reverse, one to ten. (At reverse, the same process should be gone through, the circles being described in the opposite direction.)

Arms LOWER. (See figure 1.) Rest.

Ten circles are described in each direction.

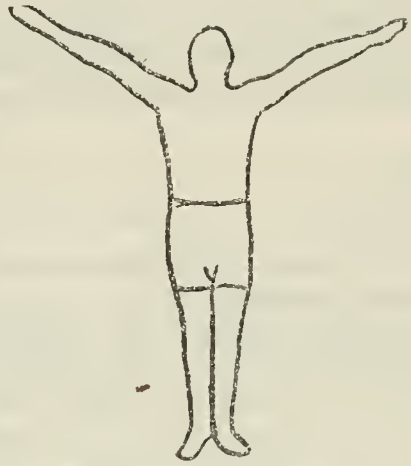
2. GRATE.—Grate, Ready, CROSS. Grate, one, two. (At grate, and as the leader counts one, the arms are slowly raised, as a deep inhalation is taken, to an angle of 45 degrees from horizontal, and at the same time the heels are raised till the weight of the body rests on the balls of the feet. See figure 6. At two, the arms are returned to cross, as all air is exhaled, and the heels are lowered to a normal position. Care should be taken to see that the arms are not allowed to drop below the level of the shoulders or to rise more than 45 degrees.) Rest.

The arms should be raised and lowered 10 times.

3. GRASP.—Head, Ready, CROSS. (Same as 4.) Trunk Forward, BEND. Upward, STRETCH. Backward, BEND (slowly). Upward, STRETCH. (With head up and eyes front, and at command from instructor, the body is bent forward from the waist as far as possible. See figure 7. The body is returned to upright position and at backward bend is bent slowly

as far back as possible from the waist, being returned to upright. Care should be taken to see that this motion is sustained and not jerky.) **Rest.**

The entire movement should be repeated five times.



6. Grate, upper position.

7. Grasp.

GROUP III.

1. **CRAWL.**—Feet **CLOSED.** (Feet are closed, toes brought together.) Arms **CROSS.** (See figure 2.)

CRAWL, one, two, three, four; one, two, three, four. (At crawl, the left palm is turned up, as the reader counts one, two, three, four, the left arm is raised and the right arm lowered laterally until at four the right arm should be in a position of hands, and the left arm should be extended straight up with the palm to the right. See figure 8. Then, as the leader counts one, two, three, the body is slowly bent sidewise from the waist, the right hand slipping down the right leg to or beyond the knee, and the left arm bending in a half circle over the head until the fingers touch the right ear. See figure 9. At four the position of cross is quickly resumed, and as the leader commences to count again the right palm is turned up and the exercise completed in the opposite direction.)

Arms **LOWER.** Feet **OPEN.** **Rest.**

The entire movement should be repeated five times.

8. Crawl, upright position.

9. Crawl, crawl position.

2. **CURL.**—Left foot sideways **PLACE.** (In this movement at the word place, the left foot is carried off about 12 inches from the right foot. The toes should touch the ground first, there being a pause between the toes touching the ground and the heel being lowered.)

CURL, one, two, three, four; one, two, three, four; one, two, three, four. (At curl, and as the leader counts one, two, three, four, the fists and lower arms are bent down from the elbows, which are kept pressed back and the fists are curled into the arm pits. This position should be reached at three, when the head and shoulders should be forced back very strongly, reaching the limit of motion at four. See figure 10. The leader again counts one, two, three, four. At one the arms are extended straight forward from the shoulders, palms down. See figure 11.

At two the arms begin to fall and the body bends forward from the waist, head up and eyes front, until, at four, the body has reached the limit of motion and the arms have passed the sides and have been forced back and (as the trunk assumes a horizontal position) up as far as possible. See figure 18. (Note that in this figure feet are together, which is incorrect for this exercise.) This is the wing position. For a third time the leader counts one, two, three, four, as the body is straightened, reaching an upright position with arms straight forward at three. Cross is resumed at four. As the body is straightened from the wing position, a full breath should be taken, the lungs being filled

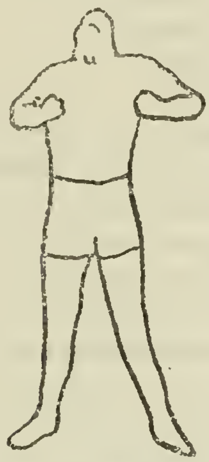


Fig. 10.—Curl—Curl position.

Fig. 11.—Curl—Arms forward.

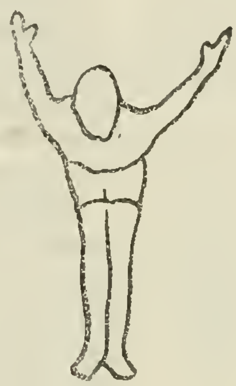


Fig. 12.—Crouch.

to the maximum as cross is resumed at the completion of the movement. This breath should be retained during the curl movement, and exhaled as the wing position is taken. Inhale through the nose. **Rest.**

The entire movement should be repeated five times.

3. **CROUCH.**—Feet closed and full **OPEN.** (Feet closed and then opened to 90 degrees.)

Arms **CROSS.** (See figure 2.)

On the toes **RAISE,** knees bending. (Lift heels from ground.)

Knees **BEND.** (At knees bend, the knees are bent and, with the weight on the toes, the body is lowered nearly to the heels, keeping the trunk as nearly erect as possible. See figure 12.)

Upward **STRETCH.** (The upright position is resumed.)

Heels **LOWER.** (Lower the heels to ground.)

Arms **LOWER.**

Feet close and **OPEN.** (Feet closed and opened to natural attention angle of 45 degrees.) **Rest.**

The entire movement should be repeated five times.

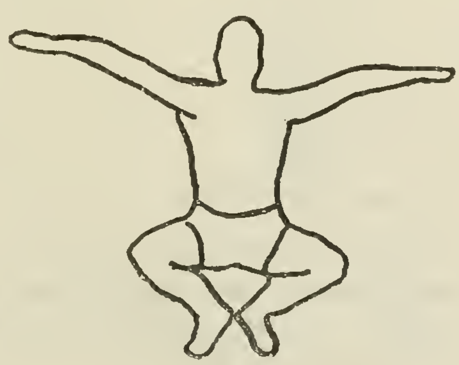
Group IV.

1. **WAVE.**—Feet, **CLOSED.** (Toes brought together.)

Arms, **BEND.** (Forearm brought to perpendicular position; fist closed and in line with the shoulder, elbows well down.)

Arms upward, **STRETCH.** (Arms are stretched upward. See figure 17.)

Hands, **CLASP.** (The fingers interlaced and arms touching the ears. See figure 13.)



13. Wave.

WAVE, one, two, three, four. (Then, as the leader counts one, two, three, four, a complete circle, of about 24 inches diameter, is described with the hands, the body bending only at the waist. The trunk should be bent as far backward as forward and as far to one side as to the other. The body should be forward at one, to the right at two, backward at three, and to the left at four. The motion should be steady and not in jerks.)

Reverse, one, etc. (At reverse, the same movement should be repeated in the opposite direction, i. e., to the left.)

Arms, **BEND**. (As above.)

14. Weave—turn position.

Arms downward, **STRETCH**. (Position of attention.)

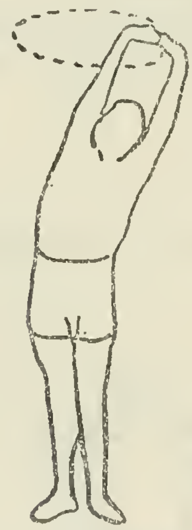
Feet, **OPEN**. (Open feet to angle of 45°.) Rest.

Five circles should be described in each direction.

2. **WEAVE**.—Arms, **CROSS**. (See figure 2.)

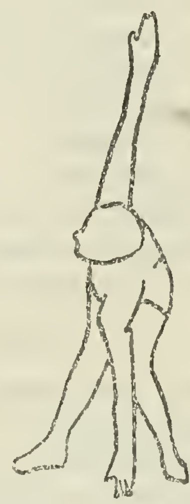
Left foot sideways, **PLACE**. (In this movement at the word place the left foot is carried off about 12 inches from the right foot. The toes should touch the ground first, there being a pause between the toes touching the ground and the heel being lowered.)

WEAVE, one, two, three, four; one, two, three, four. (At weave, and as the leader counts one, two, three, four, the body is turned to the left from the hips, the arms maintaining the same relation to the shoulders as at cross, until at one the face is to the left, the right arm pointing straight forward (in relation to the feet) and the left arm straight backward. See figure 14. At two the body is bent from the waist so that the right arm goes down and the left up, until, at three, the fingers of the right hand touch the ground midway between the feet. The left arm should be pointing straight up, with the face still to the left. The right knee must be slightly bent to accomplish this position. See figure 15. At four the position of cross is resumed, and as the leader again counts one, two, three, four, the same movement is repeated, with the left hand touching the ground this time. Throughout the exercise care should be taken that the arms



17. Wing—stretch position.

15. Weave—bend position.



16. Weave—combination turn.

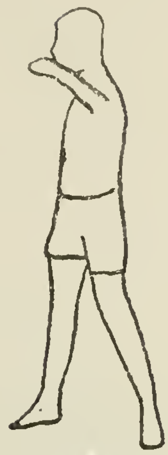
remain in the same straight line, making no separate movement, but changing their position only as the trunk and shoulders are moved and carry the arms along. After this exercise has been thoroughly mastered, the turning and bending movements made on the counts, one and two, should be combined, i. e., instead of making the entire turn, as described above, before bending, turn and bend simultaneously. See figure 16.)

Left foot inward, **PLACE**. (Resume position of heels together smartly.)

Arms, **LOWER**. (See figure 1.) **Rest.**

The entire movement should be repeated ten times.

3. **WING.—Arms, CROSS.** (See figure 2.)



18.
Wing—wing position.

WING, one, two, three, four; one, two, three, four. (At wing, and as the leader counts one, two, three, four, the arms are raised laterally until they are extended straight upward at one. See figure 17. At two the arms begin to fall forward and downward and the body bends forward from the waist, head up and eyes front, until, at four, the body has reached the limit of motion and the arms have passed the sides and have been forced back and (as the trunk assumes a horizontal position) up as far as possible. See figure 18. As the leader again counts one, two, three, four, the body is straightened, reaching an upright position, with arms vertically extended, at three. At four the arms are lowered to a cross position, but with palms up and arms and shoulders forced hard back. Very slow counting is essential to the correct execution of this exercise. All air should be forced from the lungs as the body bends forward to the wing position and they should be filled to capacity as the body is straightened and the arms brought down. Inhale through the nose.)

Arms, LOWER. Rest.

The entire movement should be repeated five times.

CHAPTER X.

THE FOOD PROBLEM OF THE FLIER.

THE CARE OF THE FLIER WITH REFERENCE TO HIS FOOD.

As our experience multiplies we are more and more impressed with the truth of the fact that the flier is a delicately adjusted mechanism and that to obtain the maximum efficiency in that mechanism more than the ordinary care must be exercised. Anything which disturbs either his mental or physical equilibrium serves also to disturb his efficiency. The flier must not only be given physical exercise to keep his body in condition but his causes for worry must be removed; he must have sufficient rest; in fact, everything must be done that will in any way contribute toward putting him in perfect condition and keeping him there.

The flier is subjected to great strain, especially a mental one, during flight and this "keyed-up" nervous condition often leaves him in a state that is more easily affected unfavorably by his surroundings than would be the case with the average able-bodied nonflier, or, in fact, with the flier himself at times when not on flying duty. We should not overlook the fact that a flight of relatively short duration in the case of the student flier may leave him in a state of extreme fatigue, both mental and physical. The writer, though not a flier, has had this experience. It was not occasioned by a sense of fear, for he had perfect confidence in his pilot; but after one to two hours in the air, and while the flight continued, he was gradually seized with an overpowering sense of drowsiness and fatigue. So intense was this feeling that it is doubtful to him whether even the knowledge that an accident was imminent would have served to arouse him to normal mental activity. That the student flier may be seized with a similar feeling is evidenced by cases such as the following: A ship was seen by the tower observer to descend in the distance to apparently a forced landing. Upon reaching the ship, the relief party found it had landed safely, though the flier could give no very good reason for coming down and seemed confused. When found, however, he was fast asleep in the shade of a wing of his ship. He complained of feeling tired. Numerous instances of this or a similar character are encountered on the flying field. A similar strain and a similar state of resulting fatigue may come to the experienced flier during flights of long duration, and especially may this be true of the flier on active duty at the front. The difference between the student flier and the experienced flying officer is largely one of degree. If either man is in anything short of the finest physical condition at the commencement of the flight, the state referred to above will certainly develop earlier.

Again, the flier must rely for his safety and efficiency upon the perfect coordination of action of neuro-muscular mechanisms within his body. By this we mean the following: Information is constantly coming into the brain centers from the outside telling of our relations to our surroundings. For example, they come in through the eye, through the semicircular canal apparatus of the internal ear, and from sensory nerve-endings in the muscles, tendons, and joints. It is through the receipt of all these messages in a continuous stream that we are made aware of changes in our relations to our environment. After the receipt of these messages we make our adjustments to the environment through nerve impulses that travel out from the various nerve centers to the muscles. Through the constant regulation of the relative degrees of contraction and relaxation of various muscles we maintain the erect position, we walk or run, or carry out other activities. That the maintenance of the erect position, for example, is absolutely dependent upon the constant control and adjustment of muscles through the nervous system is proved by the fact that the body becomes at once a "helpless heap" after the brain ceases to exercise its normal control, e. g., after a blow on the head. When visual images falling on the retina warn us that we are falling in a certain direction we contract the proper muscles and bring the body again into a position of balance. If it is dark and we are unable to obtain visual images, we are compelled to depend upon "signals" that come from the internal ear and from the muscles and joints. If we feel dizzy, we may usually find some solid support till the dizziness passes. Or in the dark we may use a third leg (cane) or grasp neighboring objects, such as railings, etc., to assist in making the proper adjustments.

In the case of the flier it is impossible to use all these neuromuscular mechanisms and these solid surrounding objects in the maintenance of equilibrium in exactly the same way the race has been wont to use them through the ages on the solid earth or even on the sea. Air is a medium which the eye can not see. Differences in air density, in direction and in speed of flow, are properties that we know the air possesses but the flier is unable to see these variations as he approaches them. It is only after the wing has actually struck a mass of air of greater density and the ship has been veered from her course that he learns of the presence of the denser air. His problem is now to return the ship to her former course. He can not, especially in night flying, depend upon the sight of surrounding objects in making the adjustment, but must rely upon those impulses that come in from other than visual or contact (touch) sources and his dependence upon them is much greater than would be the case upon the ground. Experiments have shown that those nerve impulses coming in to the central nervous system from the internal ear and from muscles and joints are less definite than those that come in through the eye, and that consequently it is harder to maintain perfect equilibrium when visual impulses are removed. The flier, therefore, has a more difficult task to perform in stunt or in night flying than if he were on the ground. Everything—his life, the return of his photographs or other information—depends upon the perfect coordination between the neuro-muscular mechanisms referred to above. If he loses his sense of direction, becomes dizzy or otherwise mentally confused, he loses the mastery of his ship to just that extent. Unless control is regained through them the consequences are certain.

Among those things that may affect the delicacy of adjustment and therefore the efficiency of the flier there is probably no one thing more important than his food. It is a matter of common knowledge that improper food, along with constipation, tend to produce deficiencies both mental and physical. Some of these deficiencies are visible while others are invisible. We may be able to see the effects of dizziness, of headache, and of mental sluggishness, but there are deficiencies that can not be seen by the eye that are none the less potent; for example, a decrease in mental acuity or of judgment that might be elicited only at the time of an emergency.

The flying instructor who has had considerable experience knows it is not safe for a man to go aloft if he is not feeling " fit " and will advise such men to stay on the ground. To go aloft at such times is extremely dangerous for the student flier or the experienced officer alike. Only recently an officer, one of the best fliers at a certain post, remarked before leaving the ground that he did not feel exactly fit. Upon being told by the officer in charge that he had better not go up, he turned the suggestion aside with the reply: " Oh, it isn't as bad as that. I merely must have eaten something that hasn't agreed with me." He went up. When he came down, he crashed and was killed. Such illustrations are all too numerous. We must not overlook the great importance of supplying all fliers with the proper food. This does not mean that we should stop after seeing that his mess is provided with food of good quality, nor even after seeing that it is well prepared. The flier, like all other men, is a composite of many variables. What he is able to eat at one time may be entirely improper at another. He is, therefore, in need of at least a certain amount of individual attention—certainly is this true when he shows the least signs of being "unfit." He should not be left at such times to the "mercies" of the average Army mess.

In civilian life it has been thought necessary to provide for certain athletes a special table—the so-called "training table." Only the best foods were allowed. Some were forbidden altogether because they might reduce the efficiency of the human "machines" of the team. It is true that there is a distinct difference between the demands these athletes on the one hand, and the flier on the other must meet, but let us see wherein this difference lies. The athlete must build up a muscular apparatus of the best and strongest type and must eat nothing that would tend to interfere with its action.

The flier, however, is not to engage in strenuous muscular work; his effort is a mental one. He must not only be able to apply the maximum of clear judgment, swiftness of thought and muscular control at the proper moment, but must have a central nervous system that can use accurately and without dizziness or other defect those impulses that were referred to above, and that are constantly streaming in from points outside the central nervous system. Only through the perfect control of all of these faculties may he hope to achieve the maximum of success.

In the body the most highly differentiated tissue is that composing the nervous system. Improper food or feeding will affect the efficiency of the most highly differentiated tissues first. It is still possible to obtain a fair amount of work from muscles when the higher brain centers have become relatively inactive. Inasmuch, then, as the fliers' work is mental rather than physical, and the nervous system is more susceptible to the effects of improper food and feeding than the muscular system, it would seem to be even more essential that our student and officer fliers be provided with some form of training-table. The training-table idea arose during peace times from the deliberate judgment that it would improve the physique of athletes and increase their chances of winning in athletic games. That improvement really resulted from the use of the training-table can scarcely be doubted. We wish to point out, however, that the goal aimed at was in no sense as serious or as important as that of the flier, for in the case of the latter, we are concerned with the necessity for every ounce of efficiency that can be obtained in order to win the war with as little delay and loss of life as possible.

There should be provided for every aviation camp a nutrition officer. This officer should be especially well trained in the knowledge of food values in their relation to the body, and the more difficult problems that arise from time to time relating to foods should be referred to him. He should work hand in hand with the flight surgeon and the physical director, and these three men together should exert a powerful influence in every camp. Through the flight surgeon the nutrition officer could establish close contact with the physical condition of the fliers. He should know not only of those who were sufficiently indisposed to report at sick call, but also of those who show the slightest derangement of the digestive tract, and all these men should constitute for him a special problem to be worked out in conjunction with the flight surgeon and the physical director on the one hand and with the mess sergeant of the cadet or officers' mess on the other. The flight surgeon after discovering, for example, that a given flier was out of condition with perhaps constipation, headache, or other early sign of digestive derangement, would report him to the nutrition officer. For a period of possibly one or two meals the flier might be required to fast during purgation or other treatment by the flight surgeon, after which, under the personal supervision of the nutrition officer, he might begin to eat again—but only those things that were prescribed for him. There might well be one or two tables in the mess at which only the men under observation should eat. In the meantime the physical director would have looked after the physical requirements of the "patient," giving him such exercise as he deemed best. During this period and until the flier was pronounced "fit" he should be under orders to stay on the ground. There can be little doubt that through this active cooperation of the three men in charge of the welfare of the flier the aggregate number of hours lost per month by the fliers on account of physical disability would be greatly reduced, for the average individual suffering from such complaints is inclined to let matters take their course and simply "wear it off." What he needs is prompt vigorous attention from all the angles mentioned above. By far more important than the foregoing advantage of an increase in the number of effective hours, however, is the fact that through this type of service the safety of a very large number of men and ships would be greatly increased. The actual expense involved in the assignment of a nutrition officer to each camp for this purpose would be entirely out of proportion to the benefits derived therefrom. In proof of this statement we need only mention the fact that each finished flier has been estimated to represent an expenditure by the Government of not far from $40,000. A nutrition officer of the rank of captain in each of the aviation camps in the United States would represent an expenditure each month of only one-eighth the cost of training a single aviator. If the lives of only two fliers were saved per year throughout the United States there would be saved more than the pay of the whole force of nutrition officers. We have no means of determining at present what proportion of accidents either fatal or nonfatal are due to the lack of a proper supervision of the food and the needs of the individual flier, but the evidence is not lacking that this factor is a most important one. When the greatest speed in the development of our air resources is so essential to success, we can ill afford to neglect this important side of the care of the flier. This would still be true though the cost of that supervision were many times what it would be through the provision of nutrition officers.

The need for trained supervision of fliers' messes is of the greatest importance from entirely a different angle and for several reasons: First, the student flier has been grouped in the aviation camp for purposes of instruction and messing into what resembles superficially a squadron. The men meet together in classes, eat together, sleep and drill together, as do the squadrons, but here the similarity ceases. Unlike the men in the squadrons, they are present as individuals, they arrive at the post individually or in small groups, complete their instruction, and leave as individuals. While they are in the camp they have but one object, namely, to learn to fly. It is impossible to detail any cadet to serve as cook, as this would practically stop his flying instruction. Cooks for these men must therefore be obtained from some source outside the cadet organization. The problem of obtaining a sufficient number of well-trained cooks for our Army messes has been and still is a tremendous one. This is easily understood when we recall the fact that not far from 40,000 cooks are required for each 1,000,000 soldiers; that is, a total of 200,000 for an Army of 5,000,000 men. In various camps different plans have been tried for the operation of cadet messes. In some of them colored civilian cooks were used; in others white civilian cooks; in still others enlisted cooks from the squadrons at the post were detailed; and finally in others a combination of enlisted and white civilian cooks was tried. In a majority of instances conditions in these messes were found to be unsatisfactory; in some of them, especially where colored help was used, extremely so. This was true not only from the sanitary standpoint, but from the standpoints of methods of food preparation and of food wastage. The question of the provision of an adequate mess force for such messes will be taken up a little later. Until such an adequate mess force has been provided for every cadet mess, however, the need for constant supervision by a nutrition officer will be doubly important.

Second, the flying officers in most camps take their meals at the officers' mess, and in many instances the officers' mess has been found to be unquestionably the worst one on the post. In the matter of the commissioned officers' mess we are, it is true, confronted with an established Army usage under which the officers are required to conduct their own mess. This has been and is in line with the requirement that the officer shall provide for himself both food and clothing. Since, however, the Government is so vitally interested in the welfare of the flier as it may be affected by his food, it would seem essential that at least a certain amount of supervision of the officers' mess should be exercised. It is our belief, from experience in the field, that there would result no serious difficulty among the officers themselves if the nutrition officer were to supervise the menus of these messes—if in fact he were to exercise the same close supervision over the food of each flying officer as over that of the flying cadet. This supervision should be carried out in the case of the officer, as in that of the cadet, through cooperation with the flight surgeon and physical director.

There are three messes in every aviation camp, namely, the cadet mess, officers' mess, and post hospital mess, which are different in one respect from all squadron messes. In these three messes the cooks occupy a permanent position. They do not move on with their organization, since these organizations never move; moreover, in all three of them we require the best cooks obtainable. To supply these messes with a proper cooking force would require for our aviation camps alone approximately 500 men. This means the permanent sidetracking in the United States of 500 of our best enlisted cooks. We have advocated elsewhere for all these messes the use of carefully selected, properly qualified, women cooks in order that the 500 enlisted cooks, of which there is such an acute shortage, might be freed for overseas service in hospital and fliers' messes. In a matter as important as the food supply we surely can not afford to provide anything less than the best of cooks for either the cadet, flying officer, or hospital patients' messes, and on account of the shortage of cooks with which we are confronted, the substitution of women for enlisted men in the United States is highly desirable. The extension of the conscription ages to include those 18 to 45 years of age will greatly increase the problem of obtaining good male civilian cooks in any of these messes, for not only will there be a scarcity of men but an increase in the wage demanded as well.

A large part of the time of the nutrition officer would be devoted to the care of the cadets' and officers' messes, but by no means all of it should be devoted to them. The nutrition officer should be charged not only with the duty of providing a proper menu for the fliers and studying the individual needs of these men, but should have general supervision of all food problems in every mess at the post. These latter should include a supervision of the food as to quality when received by the messes; recognition of the early signs of spoilage so as to prevent the use of food unfit for use; the character of the menus; the conservation of foods; the proper refrigeration of foods in the mess; the sanitary side of food handling; in short, he should be in charge of food problems from absolutely every angle. There are many difficult problems that arise constantly in the messes, and it is not sufficient to provide men for the mess who know simply how to concoct dishes. The services of a man who has had special training are required. This is true of aviation camps to an extent that is even greater, perhaps, than it is of the large cantonments, for the reason that the large cantonments have a large medical staff and a well-trained sanitary inspector. Among them will usually be found some one who is capable of handling most problems that arise. In the small, relatively isolated aviation camps, on the other hand, there are very few medical men, and it often happens that there is no one at hand who can handle such problems, with the result that they are either poorly handled or allowed to persist indefinitely. Experience in the field has shown that these unsatisfactory conditions, where they exist, are seldom due to a lack of interest on the part of the men. They are due rather to the fact that we have suddenly assembled a large group of men who find themselves confronted with problems outside their realm of experience. The remarkable thing about it all is that the messes have done as well as they have, and not that they have problems that are seriously in need of attention by men with special training.

Under the direction of the nutrition officer the mess forces of all messes at the post could receive instruction along those lines mentioned above; they could be taught what we mean by the balanced ration; how to make up a menu so that it would fill the requirements of the balanced ration; how to care for the mess equipment; how to handle the mess force to the best advantage so as to get the best results; how to use left-overs; how to prevent the production of left-over food; how to store foods to prevent undue wastage; how to keep a proper accounting system, without which no mess can be operated with the best success. Only the mess in which the exact state of the mess fund is known each day can be operated with the maximum efficiency. Through the cooperation, constant supervision, and encouragement of the mess officer the mess forces throughout the post could be raised in a relatively short time to a high state of efficiency and kept there. It is not sufficient to send a nutrition officer to the post for a brief time and then transfer him to another post. There is too great a tendency for the men to return to old habits unless there is constant supervision, and there rarely is anyone on the medical staff of the post hospital who is qualified to follow up the work of the nutrition officer. Especially is this true of the type of care that the student and officer flier should have.

The cooking forces in aviation camp messes are particularly in need of both the training mentioned above and of constant supervision for a long time after receiving this training, because, in the vast majority of cases, they have never had the advantage of training in the cooks' and bakers' school. There has been an authorization under which commanding officers could detail cooks from the squadrons to attend this school, but in practice there has rarely been an opportunity to take advantage of it. The squadrons have been so short of men that it has been impossible in most cases to spare anyone long enough to permit attendance at the cooks' and bakers' school. Consequently the men have been forced to rely upon their own resources. In general, they have been remarkably successful—some of them, of course, more so than others—but all are in need of just such assistance as could be obtained from the continued presence of a nutrition officer at the post.

In order to bring out more clearly the exact nature of the problems that are constantly arising in the messes, and that demand the supervision of an experienced man, we will state a few of them a little more in detail.

First, the quality of the foods. For the most part the foods supplied to the messes by the Quartermaster Department are of excellent quality. It is quite necessary, however, not only to be able to recognize the early signs of spoilage in various foods but to be constantly on the watch for such spoilage. Some spoiled food may occasionally come along with the fresh supply, or food that was of good quality when received may spoil before being used. This is especially true in the southern camps during the long hot summer months. Again, spoilage is very likely indeed, to be found in foods purchased from extra quartermaster sources, and during the summer season there is a large purchase of these fresh garden foods.

It is necessary for the mess force to be able to recognize "specification beef"—that is, beef that has been cut according to the "Army trim" method rather than the ordinary "commercial cut"; also differences in sex, age, and quality of the beef. This knowledge is especially necesary in the aviation camps, since some of them are located poorly with regard to markets and frequently are unable to buy to advantage. If the mess force knows what constitutes "specification beef" it is much easier to control the supply. The Quartermaster contracts for neither cow nor bull beef, nor for even the cheaper cuts of the steer quarter, such, for example, as the neck, kidney fat, hock joints, and hanging tenderloin. It is very important that the cooks be able to recognize the early signs of spoilage in beef, and especially that they be able to determine the extent of any spoilage that is present. It is fully as important for them to know when to trim away small surface areas that smell badly and use the remainder of the quarter (provided spoilage has been limited practically to the surface) as to know when to throw away the whole quarter. It has happened too frequently that inexperienced cooks have asked to have a quarter of beef condemned when the trimming off of one or two pounds from certain points removed all that showed the least sign of beginning spoilage. In such cases

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the condemnation of the whole quarter would have been an unpardonable waste. The caution displayed by the cooks, in such instances, is laudable for, after all, they are responsible for the quality of food they serve in their mess. It is only necessary to train them. Experience shows that this training is difficult and requires considerable time. We can not afford to furnish a Federal meat inspector for each of these small posts, but, after all, it is unnecessary for this is one of the things a nutrition officer would take over and handle among the many other services he would render the camp.

The above consideration deals with beef only, but it applies with equal force to all meats that are used in the mess. In the case of defective canned goods, of which there have been large quantities during the past summer, the Quartermaster General has provided that all cans showing "defective vacuum" shall be returned for credit—that is, not used in the mess. This places the responsibility for the use of such canned goods upon the mess force but the men must be taught how to recognize such cans and, as a matter of fact, need supervision to properly protect the men in the mess.

The mess force must also be taught how to recognize and eliminate, as far as possible, the spoilage of vegetables. They must be taught the best methods of food storage for different types of foods; the temperatures at which various foods may best be kept; the types of containers that give the best protection for food with the reasons why they are best.

They must learn how to handle the refrigerator. This is an extremely important point since certain kinds of food deteriorate rapidly unless kept cold. In the care of the ice box they must know that fresh meat will keep much longer at a given temperature if its surface is dry than if it is wet; that the ice-box door must never be opened unless necessary and then closed as quickly as possible; they must learn that the principle underlying refrigerator construction is to allow as much space for food storage and as little for ice as possible conducive to proper refrigeration; that, therefore, the space for ice must be kept filled to get the best results, and no ice used from the ice box for the purpose of cooling drinks; they must realize that the refrigerator cools the food by the free circulation of air over the ice and not by a "radiation of cold" from the ice—a view that is not uncommon among men of the mess forces; that, therefore, the meat and other foods must not be hung in the box in such a way as to restrict the movement of air, otherwise it will take the box longer to cool off after it has been opened or warm food has been placed inside. These and a number of other points must be drilled into the men of the mess force. They must be followed up, however, to see that they continue to use the knowledge they have received. That such points are of importance may be illustrated by the experience of one mess in which meat to the value of $21 spoiled within three days during the month of June. Such wastage is important not only from the economic standpoint, but is of the greatest importance from that of the mess where it occurred, for the ration allowance is fixed and if food is wasted through spoilage, or from any other cause, it means the mess must get along on that much less than was allowed for the period.

Again, the mess force must be taught how to run the mess with rigid economy. The average mess will be found to waste from 0.3 to 0.8 pound of edible food per man per day. These figures look quite harmless perhaps when expressed in terms of the waste for each man. An average of 0.5 pound per man per day means, however, a daily waste of 600 pounds in a camp of 1,200 men or 216,000 pounds per year. At a valuation of 8 cents per pound, a low average value, this represents a loss of $17,280. At this same rate of wastage an Army cantonment of 40,000 men would waste 7,300,000 pounds per year, and the rate if maintained throughout the Army would be equivalent to throwing away all the food produced by a fair-sized State. More than this, it would mean that great ship space would have to be used for foods going to France merely to be thrown in the garbage cans of the over-seas Army.

It has been shown by nutritional survey parties in the field that when an effort is made to keep down this edible waste it can without difficulty be reduced to 0.07 to 0.15 pound per man per day. This reduction of the edible waste from an average of 0.50 to one of 0.15 pound per man per day would represent an annual money saving in a camp of 1,200 men of $12,000, and this low level can be reached and maintained through the constant supervision of the nutrition officer. He can make a frequent determination of the edible waste in the various post messes and not only find thereby the actual waste but the waste determination will serve to keep the necessity for food saving ever before the mess force. As a result there would be not only less waste but better messes since the money saved could be spent for delicacies, fruits, etc., that go far in making the mess more satisfactory to the men. The nutrition officer would bring about a high mess efficiency as regards saving, by teaching the cooks to prepare the correct quantity of food so as to avoid as much as possible the production of left-overs; by teaching them how to use up such food as is unavoidably left either in the kitchen or on the platters and vegetable dishes in the dining room; and finally by training the men who eat in the mess to take on their plates no more than they can eat, since food once taken on the private plate can not be used again. These lines of training can be successful in most cases only if there is some one present who is interested, as the nutrition officer would be, and who will follow up the instruction and guard against a return of the mess forces to former careless or inefficient methods.

We have touched upon only a few of the many problems for the proper solution of which the nutrition officer should be provided. These will suffice, however, to show that there is a very real need in each camp for a man who is trained in the problems of food and nutrition.

Let us return for a moment to the special needs of the flier. Flying is still in its infancy and there is still much that we have to learn even with regard to the proper feeding of the flier. We know, however, that he must be fed with care; that he must not be allowed to eat a heavy meal immediately before undertaking a flight, experience having shown that he is then much more susceptible to gastric disturbance—nausea and vomiting—with a corresponding rise in the element of danger. It seems quite evident that the flier's meals must bear a certain time relationship to his flying hours. If he stops flying at noon and will not resume flying until 4 p. m., it is proper for him to eat a heavy meal at noon. It will not do, on the other hand, for him to rush from the flying field to the mess hall for a heavy supper and then back to the flying field for duty immediately afterwards. He should receive only light food in small quantity, possibly a sandwich, at such times and take the full meal, if he requires it, after flying for the day has stopped.

Such problems as these can not be handled by the issuance of a general order for all the fliers in the different camps. It is no more possible to handle them by general order than it would be to accomplish the work of the flight surgeon or physical director in that way. They must be dealt with by placing an experienced man at the post where he can adapt the conditions in the messes to the changing conditions in the camp and to the varying needs of the men themselves. Only in this way will there be adequate supervision. Only in this way, too, may we extend our knowledge with regard to the care of the flier in relation to his food.

CHAPTER XI.

A MESSAGE TO THE FLIER.

1.—VALUE OF OXYGEN TO THE AVIATOR.

To you—for you, Aviator—this message comes. It brings to your attention a matter of vital import; it carries with it an earnest plea that you read with plastic mind. It is a direct appeal for your cooperation in maintaining the efficiency of our Air Force. It relates to the value of oxygen in altitude flying. We, the Medical Officers attached to your branch of the Service, have devoted ourselves to one object—to take care of you; and with this in view, we marshal in logical array, the following facts for your benefit:

Oxygen shortage is one of the serious problems which confronts the aviator, who, owing to the use of anti-aircraft guns in present warfare, must do much flying at altitudes ranging from 16,000 to 20,000 feet.

The human organism is arranged to live in a normal atmosphere which contains, near the surface of the earth, about 21 per cent of oxygen and 79 per cent of nitrogen. The oxygen is that element which gives and maintains life.

As man ascends in the air he leaves his natural environment. The density of the atmosphere becomes successively less and less; each cubic foot of air is made up of the same proportions of nitrogen and oxygen, but the total quantity of each is successively less and less as higher and higher altitude is attained. Thus at an elevation of 19,000 feet the density of the air has diminished to the extent that each cubic foot contains only one-half the amount of oxygen or of nitrogen contained in a cubic foot of air at sea level. Man's bodily requirements of oxygen remain the same as at sea level; hence, each normal intake of breath at this altitude furnishes him with just one-half the oxygen contained in each intake of breath at sea level. Going to still higher altitudes, such as 25,000 to 30,000 feet, this discrepancy in oxygen, with its noxious effect, becomes still more pronounced.

The human organism can, however, by compensatory arrangements, adapt itself, within reasonable limits, to a decreased oxygen percentage. This compensatory quality varies in the individual, for it has been demonstrated that not every flier is qualified to work in a high altitude, marked differences in ability to withstand its effects revealing themselves.

In a man with normal air passages, the breathing is through the nose with mouth closed. Very few air men are able to continue the nose breathing at an altitude beyond 10,000 or 12,000 feet. They have a sense of "lack of air" and open the mouth in breathing to get more air. The breathing becomes quicker and deeper, the heart beats faster and faster. These are compensatory changes. They enable the individual to obtain the requisite amount of oxygen by increasing the volume of air breathed in a given time and by exposing a greater amount of blood to the oxygen in the air cells of the lungs in a given moment.

These compensatory agencies enable the organism, without the individual feeling any marked inconvenience, to adapt itself to fly at altitudes of 20,000 to 22,000 feet, perhaps even higher, for a short period. Before the flier's compensation gives out he will feel dizzy, but is perfectly happy, though he has lost his judgment, and passes into a pleasant condition of semi, or sometimes total unconsciousness.

If one asks a number of pilots who have been regularly flying at 15,000, 18,000, or even 20,000 feet how they are feeling, the usual reply will be "fine," "perfectly all right," "no unpleasant effect." Though this is their personal impression, we know that they are all affected on flights at these heights, more particularly if they remain long at high altitudes or fly repeatedly day after day. A person at an altitude of 15,000 or 20,000 or 22,000 feet may feel perfectly fit and well, but he is in no way as efficient as when he is near the ground. All his reactions become slower; that is to say, he uses longer time to judge distance, to aim his gun, to fire, to control his ship, to maneuver, etc., although he is not conscious of this impairment.

When the compensatory machinery gives out partly or entirely a series of symptoms like danger signals indicate approaching inefficiency.

The most pronounced symptoms of oxygen shortage are in connection with the central nervous system and generally occur after flights at an altitude of over 15,000 or 16,000 feet. Perhaps the most frequently noted symptom is headache, accompanied sometimes by nausea. This may last some hours after the want of oxygen has been removed.

Excessive fatigue, a complete collapse of energy, far beyond the natural weariness induced by flying, also reveals oxygen starvation.

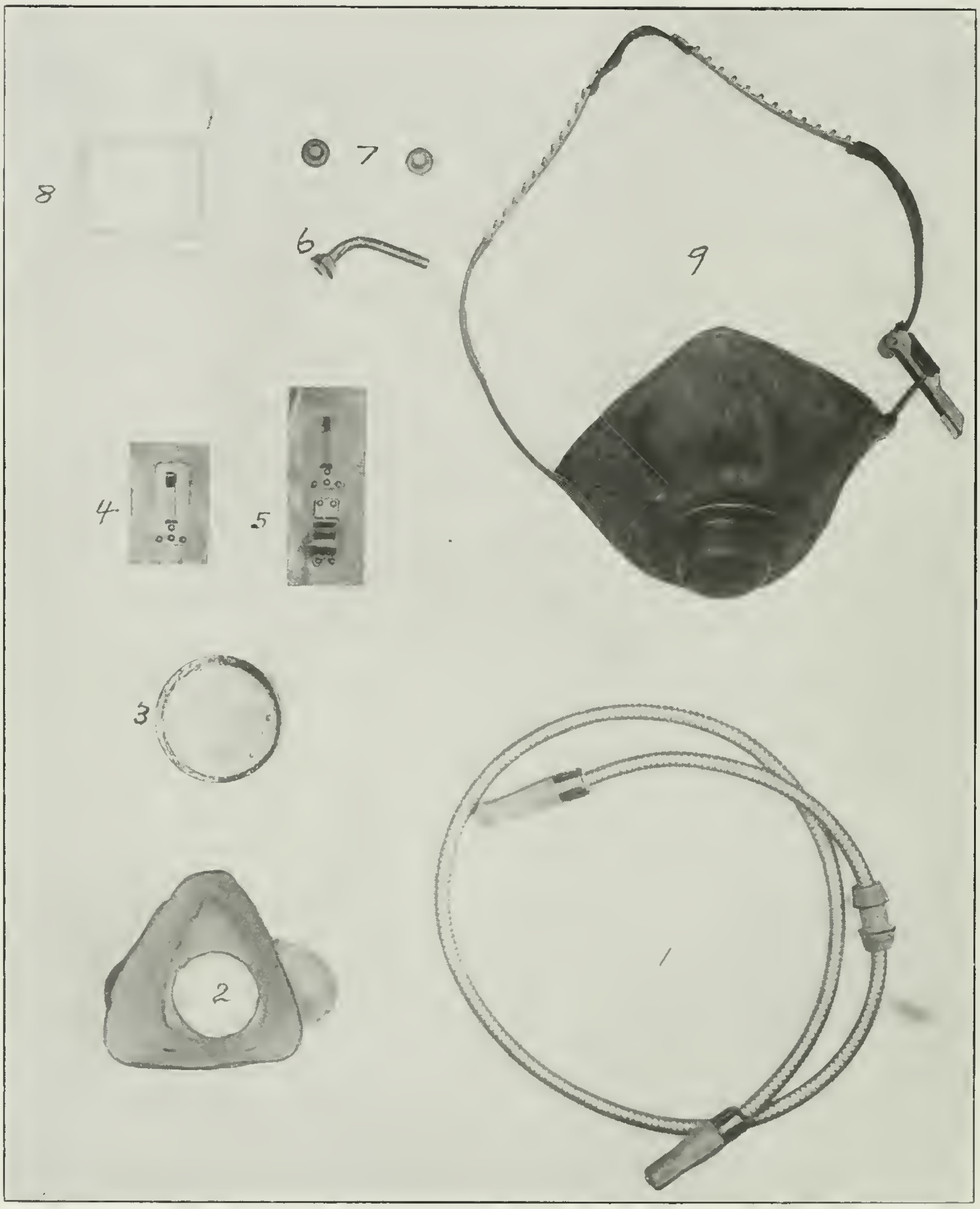
Another common evidence of "thin air" is vertigo, a symptom fraught with potential calamity. Disaster lurks at its heels, for the man with swaying senses is no longer the captain of his ship.

The flier who is suffering from want of oxygen is far from normal. He may be exhilarated, he may be simply dull and sleepy, or, if he is

SHOWING MASK IN POSITION.

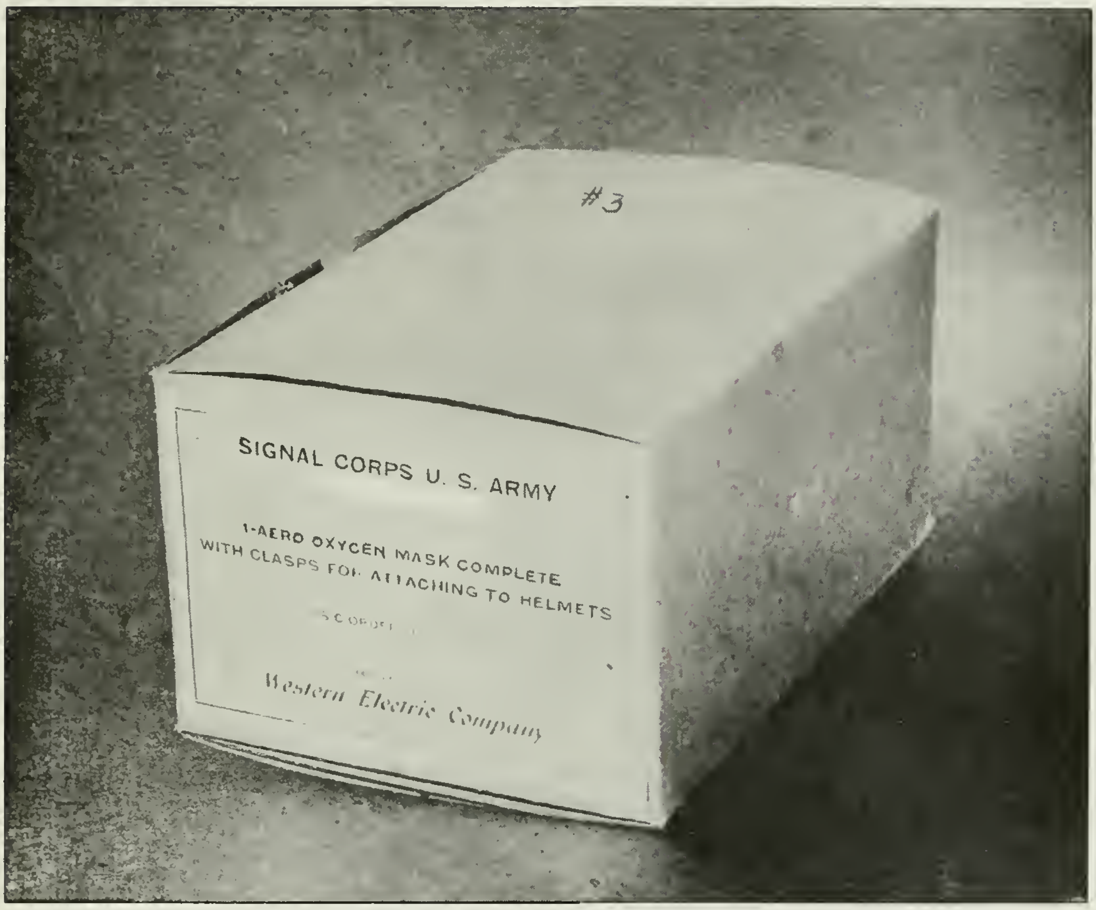
Flexible tubing attached to mask and held on helmet by rubber bushing in clip.

425b—1



1. Flexible metal tubing with rubber end connections and rubber bushing. Pilot, 3′ 0″; observer, 5′ 0″. Bushing fits in clip, Fig. No. 5. 2. Rubber mask. 3. Dummy transmitter (made of wood). 4. Strap clip; to be sewed on helmet. 5. Strap clip and hose clip; to be sewed on helmet. 6. Hose attachment on mask. 7. Metal buttons for holding apron to mask. 8. Box of 12 Winton disks. 9. * Leather apron complete with straps, corrugated strips, elastic, and buckle. All packed in one carton.

* To reduce wind resistance, apron has been cut off on dotted lines.



CARTON CONTAINING MASK COMPLETE AND FLEXIBLE TUBING.

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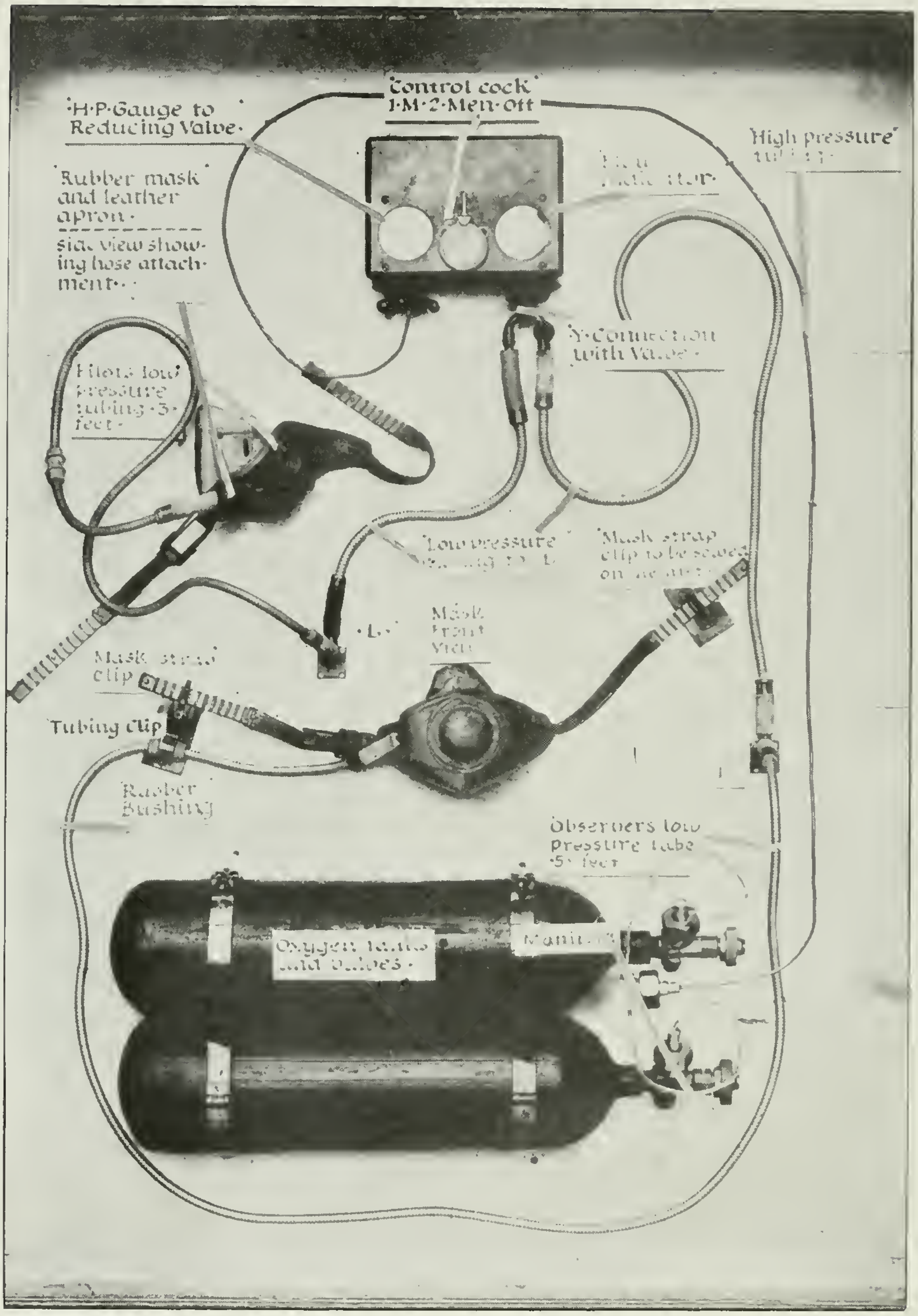
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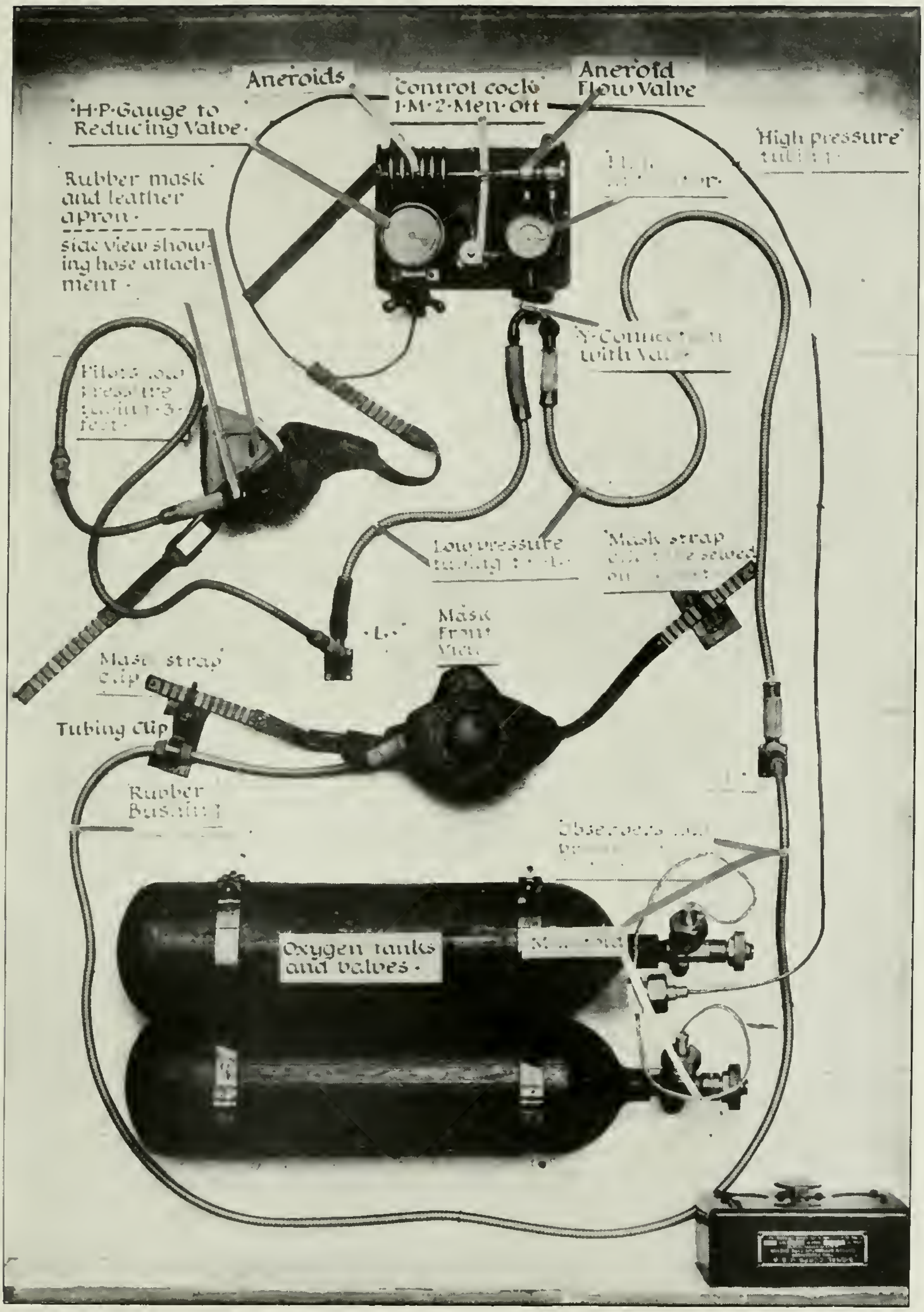
and valves·

425b–4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Mask strap
Mask
Front
Tubing Clip
Rubber
Oxygen tanks
and valves·

425b—5

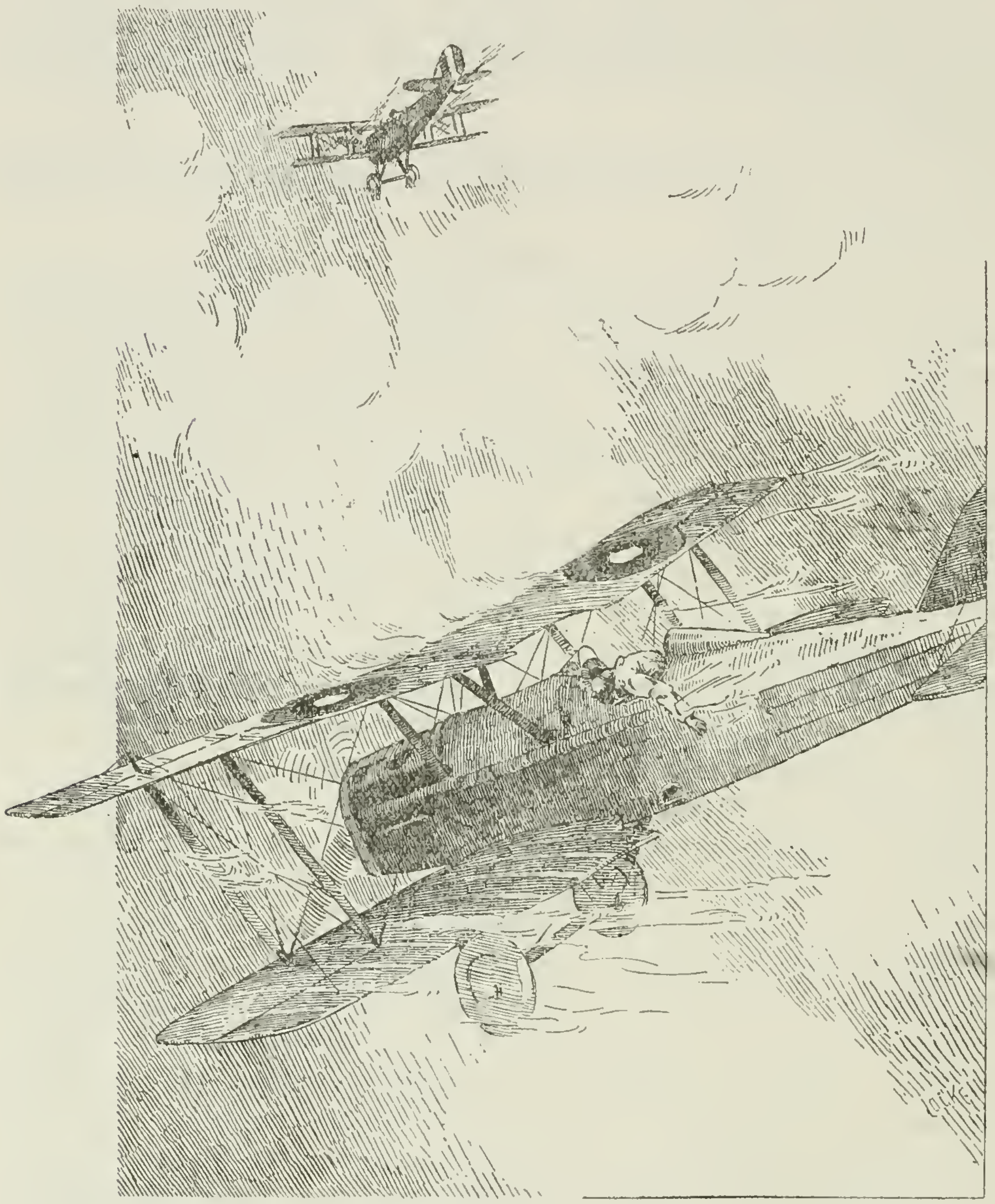
in a position of danger, he may fail to take the measures necessary for the safety of himself and those with him, even when he is well aware of the danger. This extraordinary impairment of judgment is extremely characteristic, the person himself being totally unaware of it and quite confident that his mind is absolutely clear.

Often, too, the perception is affected. One sees things without being able to understand them properly. It is hard to read an instrument, and positions of objects are misjudged. Pain itself loses some of its poignancy.

These symptoms, some trivial, some marked, are the signposts to Flying Fatigue within whose habitat one loses the energy, the will, and the ability to fly.

A striking instance of this was noted during an inspection by one of our officers of a certain hospital in France. One ward was devoted to the care of fliers suffering from "oxygen want." During the week in which he was present there were observed 22 such cases. The entire group of men from all appearances looked perfectly healthy. Here was a ward full of young, active men with no apparent illness, not a single man was injured in body or limb, and according to usual medical standards and usual methods of examination each one of these men would be considered perfectly fit for service. As a matter of fact not a single man was fit for service. They were unable to fly. Their chief complaints on attempting to fly were headache, vertigo, and "lack of confidence." There were two causes—mental strain from long-continued service and the cumulative effect on the nervous system of an insufficient supply of oxygen.

This is but an illustration of conditions which obtain wherever men are flying. All these symptoms are effects of a decrease in the oxygen contained in the air at high altitudes, and can be absolutely and entirely obviated by the proper administration of oxygen to the airman. It should at once be realized that the aviator supplied with oxygen while flying is very much more efficient than the same man flying without oxygen, and becomes therefore, of so much more value as a fighting force. Take, for example, two pilots of equal ability, flying machines being identical in every respect, that man supplied with oxygen will always bring down the other machine because he has retained all his judgment and rapidity of decision and movement unimpaired. He will be able to outmaneuver and outwit his opponent and fire his gun before the other has even made up his mind what to do. Not only that, when he returns to the ground after prolonged flight he will be fresh and able to start out on a new trip, while the man flying without oxygen will be tired out and unable to do any more work that day and possibly the next. The administration of oxygen must of course in no way impair the comfort of the movements of the airman, nor should he have anything further to do while flying, as he already has plenty to look after, in his machine. For this reason the apparatus used must be simple, safe, and entirely automatic; automatic in the sense that while the machine stands on the ground no oxygen is given off, but when it rises in the air the increasing deficiency in the oxygen content of the air is automatically made up for by the delivery of oxy-



" Fainting in the air." A potential calamity if the flier is not physically fit.

gen by the apparatus, without any personal attention from the airman.

Our Government has placed at your disposal an apparatus which meets these tests. It is adapted for all planes flying to high altitudes. It is the Dreyer apparatus designed by Col. Georges Dreyer for the Royal Air Force and adapted by our service. This apparatus consists of:

First, of a steel tank or tanks in which oxygen is stored under high pressure, e. g., 150 atmospheres; in other words, 500 liters of oxygen is put in a small steel bottle of a capacity of only 3.3 liters.

"Wings dropping off plane." All parts of the plane must be well constructed if disaster is to be averted.

Second, of the automatic oxygen apparatus where the pressure of the oxygen is reduced from a high to a low pressure through a special reducing valve and then delivered in increasing quantities as you rise in the air by means of an aneroid-controlled valve, while no delivery takes place on the ground level. The apparatus is regulated in such a manner that the deficiency of oxygen in the air at any altitude is always just compensated for by the oxygen delivered by the apparatus. To visualize to the airman that the apparatus is functioning, it is provided with a flow indicator, which, starting at about 6,000 feet, will revolve faster and faster as the machine rises in the air, owing to the greater and greater amounts of oxygen passing through the apparatus. As long as the indicator rotates quickly the apparatus is functioning properly.

Third, of an india-rubber mask worn over the mouth and nose; in this mask is also embodied a microphone for wireless communication. The mask is connected with the apparatus by means of a light flexible metallic tube. The functioning of the apparatus is perfectly independent of any drop of temperature that may take place in the air as well as whether it is working from a full tank, e. g., 150 atmospheres pressure or a practically empty tank, e. g., a few atmospheres pressure.

The wearing of the mask does not interfere with the pilot's efficiency in managing the plane. It has been tried out by many officers, all of whom stated that the slight discomfort on first putting it on quickly wore off and that when in the air this discomfort was entirely unnoticed. This mask has combined with it an interphone, whereby pilot and observer can continuously talk with ease while in the air. This advantage was a source of delight to all who have used the set. This mask and phone set have been officially adopted by the service and will be ultimately a part of the equipment of all planes.

Experience proves that once the flier has realized the benefits derived he usually refuses or hates the idea of flying without oxygen.

We have given you a simple description of the Dreyer apparatus. In this connection interviews with the Commanding Officers, Fliers, and Observers at the British Front illustrate its value. One message from the British Front tells the story in a sentence:

> The ——— Squadron, which, as you know, has been using the oxygen apparatus for months, is doing six times the amount of work that any other squadron is doing without oxygen.

Maj. D———, commanding officer, ——— Squadron, Royal Flying Corps:

> We advise our men to fix the mask in position before leaving the ground. When using the Dreyer apparatus at an altitude of over 10,000 feet it is best for the pilot to adjust the mask and wear it from the time he starts until the time he comes back and gets out of the plane. There is no question that these men in my command who have used the oxygen apparatus are not by any means as tired as they used to be before they used this apparatus. Since the use of the oxygen the men have not complained of any headaches, fatigue (except what you might call ordinary fatigue), or vertigo.

Maj. D———, commands the squadron of high fliers exclusively, and they have been using the Dreyer oxygen apparatus for two years.

Capt. P———, pilot, who has been flying at an average height of 20,000 feet:

> Before the oxygen apparatus was used I used to suffer a great deal from flying at high altitudes. I would notice a palpitation of my heart not only in the air at this high altitude but also on the ground at a period of 24 hours after flight. I would have a bad headache not only in the air but also after coming down. This would last from five to six hours. I used to get this palpitation of the heart and headache when I would fly over 16.000 feet; I would also feel "rotten and done up," and as time went on it would become so bad I was so tired I could not sleep Monday afternoon, Monday night, or all Tuesday, and I would have my first sleep on Tuesday night. I do not know how to explain why I could not sleep; it was apparently not in any way due to "nervousness."
>
> Since I have used the oxygen apparatus I have had no palpitation, no headache, no fatigue at all, and I sleep normally.

An observer:

> This man says that after flying at an average height of 20,000 feet several weeks, also very active in the use of the machine gun, he did not in any way feel the need of oxygen. But after seeing active service for six months he states he has "vertigo and fatigue," and after he has come down from a great height he now feels "done up."

Isolated cases these, but the British squadron commanders, who have felt the comfort and benefit accruing from the oxygen apparatus have made its use compulsory with their squadrons.

It is this apparatus which has been adopted by the Air Service, United States Army. Men, this is a gift horse, pure and simple. Don't stand on the order of the shape of its mouth, but regard it rather as a trusty friend that will carry you safely at trying altitudes, pull you out of many a rough rut of flagging force, and bring you back to terra firma with the least expenditure of your physical strength and nervous energy. This is the mission of the Dreyer apparatus, one of far-reaching importance. It produces energy, sustains life, and tends to keep you a live wire in our air force.

Can you afford to be less alert than your enemy? Can you refuse to use any weapon placed at your disposal? Have you not need of all your strength when your great moment comes? Then be fit; keep fit! Use your oxygen apparatus.

2.—DESCRIPTION, INSTALLATION, AND GENERAL OPERATING INSTRUCTIONS FOR AERO OXYGEN APPARATUS.

The oxygen equipment used to furnish oxygen to the personnel of the planes consists of the following apparatus and parts:

Oxygen apparatus.
Low-pressure Y connection.
Low-pressure connection tubing.

Low-pressure L connections.
Masks.
High-pressure tubing and its connections.
Manifold connections.
Tanks and valves.
Permanent oxygen crates.

All of this equipment is installed on the plane with exception of crates. There is considerable operating and maintenance equipment which is not used on the plane, such as pumps, refilling stations, large tanks, etc., which are necessary to maintain a constant supply of clean oxygen.

The functioning of the oxygen equipment is to furnish the proper quantity of oxygen to fliers at all times and altitudes for the proper sustenance for maximum human efficiency. The oxygen is stored in the small tanks under a pressure of 2,250 pounds per square inch. This pressure is automatically reduced and the required amount automatically delivered by the apparatus.

All equipment has been carefully designed for complete standardization, continuity of operation, reliability, and maximum efficiency. The entire equipment is automatic. There are no exposed moving parts or elements. All the flier has to do is to turn on the oxygen at the tank and put on his oxygen mask. The apparatus automatically accomplishes the results.

The apparatus now in production is known as the Dreyer type. It was adopted by our Air Service December 5, 1917. It is approximately 6 by 5 by 2 inches high and weighs about 4 pounds. All working parts are contained in a pressed steel case having the necessary openings for connections, gauges, etc. It consists of four elementary parts—the reducing valve, the control valve, aneroid valve, and flow indicator. Mounted on the reducing valve is a higher-pressure gauge, which shows the tank pressure and quantity of oxygen in the tanks. The scale of this gauge is so arranged that when the oxygen is getting low the quantity will indicate so by appearing in a marked danger zone. The reducing valve is a delicate but simple device which automatically reduces the tank pressure from an average of 50 pounds to 2,250 pounds to a final pressure of about 3 pounds gauge. This is accomplished automatically, and no adjustments are necessary.

From the reducing valve the low-pressure oxygen is delivered to the control valve. This is a simple arrangement which controls the flow of oxygen for either one or two men. The handle of this valve extends through the case, is plainly marked, and easily handled. Before flying this valve is set so that the apparatus will deliver oxygen for the required number of persons.

From the control valve the oxygen is delivered to the aneroid valve, which consists of a high-grade cylinder and piston, with the necessary grooves and openings, which are actuated by set of aneroids. This valve controls the required quantity, delivering oxygen for all altitudes up to and including 30,000 feet and for either one or two men.

From the aneroid valve the oxygen is delivered to the flow indicator, which is a simple device indicating that oxygen is flowing. From the indicator the oxygen is delivered to the low-pressure connection.

The low-pressure Y connection is a simple fitting, one side of which is fitted with a cock so that oxygen can be delivered to either one or two men.

Low pressure connection tubing.—Each plane is installed with low-pressure connection tubing, which conveys the oxygen from the Y connection to the L connection for both pilot and observer.

Low pressure L connections are simple L fittings—one located in the observer's cockpit and one in the pilot's cockpit—to which is attached the mask connection.

Masks.—The present type of mask in production consists of a rubber piece which covers both the nose and mouth, into which is fitted the radio transmitter. When radio is not used this transmitter is replaced by a wooden block. The rubber mask is contained in a leather apron. The entire mask is attached to the face by means of straps from the helmet to the leather apron. Each mask is shipped complete with the proper length of low-pressure tubing for both pilot and observer. Necessary attaching clasps which can be used are riveted to helmet.

There is another type of mask which is at the present time being considered, which consists of a rubber piece that covers the nose only and is in no way combined with the radio. This leaves the mouth free for articulation. This type of mask offers no wind resistance whatever and is very light and comfortable.

High-pressure tubing consists of the necessary length of high-pressure copper tubing, to which is attached the proper end connections for connecting to the apparatus and the tanks or manifold connections.

Manifold connection is a flexible T connection and is used to connect two tanks in parallel.

Tanks and valves.—The standard zero tank designed to serve one man has volumetric capacity of approximately 210 cubic inches and contains 500 liters of atmospheric oxygen under a final pressure of 2,250 pounds. This capacity is figured to supply one man with plenty of oxygen at all altitudes for from one to three hours.

Two tanks are used for a two-man plane; they are connected in parallel by means of the manifold connections; each tank is furnished with an extremely light but very strong and rugged valve.

The first tanks furnished weighed approximately 12 pounds each. The later tanks will weigh only 7 pounds each. All tanks will have approximately the same external dimensions; that is, about 19 to 20 inches long by about 3½ to 3¾ inches in diameter.

Permanent oxygen crates consist of a rugged case, which will contain five small tanks, tanks being securely held so that valves will not be damaged. All crates have no external obstructions; can be easily piled upon a truck or carried in a cycle car. These crates have been designed for permanently conveying oxygen tanks from point to point overseas.

Each DH-4 plane is equipped with low-pressure tubing, L connections, holes for mounting the oxygen apparatus, and brackets for containing the tanks. The balance of the oxygen equipment is shipped directly overseas to the Aviation General Supply Depot. With each apparatus is shipped the high-pressure connection, Y connection, and the necessary screws for attaching the apparatus to the plane.

All masks are shipped directly overseas complete. All manifold connections are shipped separately overseas. Tanks and valves are shipped overseas in permanent oxygen crates.

All tubing, both high and low pressure, before shipment, is cleaned. It is vitally necessary that each fitting be thoroughly cleaned before assembly in order to eliminate dirt.

3.—STATEMENT BY AN OFFICER OF A TESTING SQUADRON REGARDING ALTITUDE RECORD WHICH WAS ESTABLISHED SEPTEMBER 18, 1918.*

"In order to take an aeroplane to a higher altitude than any other pilot in the world, I found that it would require more than one or two attempts. I made three attempts. The first one took me to 24,000 feet, the second to 27,000 feet, and the last one to 28,900 feet, but now I feel certain that I can get to at least 30,000 feet.

"The cold thin air is one's greatest adversary. First of all, one must make a study of the performance of his motor at those high altitudes. This I did, and made the necessary changes before trying again. Loss of power, due to rich carburation, thin air, and the cooling of the motor, are the main things to overcome. Rich carburation can be partially overcome by increasing the volume of air going through the carburetor, either by a mechanical process, air bottles, or other induced pressure systems. I believe, however, that high-compression pistons can be fitted very satisfactorily. This, of course, necessitates a throttled motor at low altitudes. An aneroid adjustment could be fitted to prevent the throttle from being opened wide at low altitudes.

* Record made by Capt. R. W. Schroeder.

"I used a set of high-compression pistons and paid keen attention to my throttle, which, however, I was unable to open wide, even at my highest altitude, for I noticed that when I did the motor lost R. P. M. This was due, I think, to rich carburation. I maintained my R. P. M. partially by feeding oxygen into my carburetor. A very efficient set of radiator shutters are needed to maintain the proper motor heat, these I did not have. A very positive oxygen regulator and face mask should be used. These were unobtainable, for the sets I had previously tried out had failed to function above 21,000 feet. Furthermore, the face mask pressed so tight to my face that it interfered with the flow of blood and my face grew numb. So I used a rubber hose direct from the oxygen bottle, which I regulated with a valve on the bottle. The hose was placed in my mouth so that I could breathe air and oxygen at the same time. I also pressed my tongue against the end of the hose in order to tell if the oxygen was still flowing. This method worked very satisfactorily, except that the oxygen bottle and the rubber tube gathered about a quarter of an inch of frost, which made it very unpleasant.

"The following experiences and sensations I noticed during my flight were due mostly to lack of oxygen:

"I took off at 1.45 p. m. Wednesday, September 18, 1918, and made a steady circular climb, passing through clouds at 8,000 feet, 12,000 feet, and 16,000 feet. At 20,000 feet, while still climbing in large circles, my goggles became frosted, making it very difficult for me to watch my instruments. When I reached 25,000 feet I noticed the sun growing very dim, I could hardly hear my motor run, and I felt very hungry. The trend of my thoughts was that it must be getting late, that evening must be coming on; but I was still climbing, so thought I might as well stick to it a little longer, for I knew I could reach my ceiling pretty soon, then I should go down, and even though it were dark I could land all right, for I had made night landings many times before, and so I went on talking to myself, and this I felt was a good sign to begin taking oxygen, and I did. I was then over 25,000 feet, and as soon as I started to inhale the oxygen the sun grew bright again, my motor began to exhaust so loud that it seemed something must be wrong with it. I was no longer hungry and the day seemed to be a most beautiful one. I felt like singing with sheer joy as I gazed about through a small portion of my goggles which had no frost, due to a drop of oil which had splashed on them from the motor.

"It was wonderful to see the very clear blue sky with the clouds thousands of feet below. The frost on my goggles bothered me very much. At times I had to remove my glove in order to put the warm palm of my hand on the glass to thaw the frost. I did this about every 10 minutes, so that I could take the proper readings of the instruments, which I marked down on my data pad. I believe that if my goggles had been better ventilated they would not have frosted. When I was about 27,000 feet I had to remove my goggles, as I was unable to keep a steady climb. My hands by this time were numb, and worried me considerably. The cold raw air made my eyes water, and I was compelled to fly with my head well down inside the cockpit.

"I kept at it until my oxygen gave out, and at that point I noticed my aneroid indicated very nearly 29,000. The thermometer showed 32° below zero C. and the R. P. M. had dropped from 1,600 to 1,560. This is considered very good. But the lack of oxygen was affecting me. I was beginning to get cross, and I could not understand why I was only 29,000 feet after climbing for so long a time. I remember that the horizon seemed to be very much out of place, but I felt that I was flying correctly and that I was right and the horizon was wrong.

"About this time the motor quit. I was out of gasoline, so I descended in a large spiral. When I had descended to about 20,000 feet I began to feel much better and realized that the lack of oxygen had affected me. I passed down through the clouds at 16,000 feet, and as I remember it was snowing from these clouds upon the next layer some 4,000 feet below. I am not positive of this, as I may have been affected by the lack of oxygen. I noticed as I descended that the air seemed to be very thick and stuffy, but very nice and warm. I did not see the ground from the time I went up through the clouds above Dayton, Ohio, until I came down through them again at 4,000 feet above Canton, Ohio, over 200 miles from where I started.

"I was lost beyond a doubt, with a dead engine over very rough country. I landed O. K., and broke the tip of my propeller, which was standing vertical, when I rolled into a depression in the ground. However, I did not nose over or do any other damage to the plane or myself. I flew back to Dayton with a new propeller.

"My lips and four of my fingers were frozen and required medical attention. Electrically heated clothing would have been very well used, but I dressed as light as possible to avoid the extra weight, as I had stripped the entire plane of all unnecessary load. This was done to assist me in climbing.

"Attached are photographs of the performance curves and the barograph curves, also a report of the corrections to show true altitude above sea level, as compiled by Lieut. George B. Patterson, officer in charge of all performance reports of the testing squadron.

"If this record can be made official, it will be the first world's aviation record held by America since August, 1911. At that time the late Lincoln Beachey made a climb to eleven thousand and some odd feet at Chicago, Ill."

INDEX.

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