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Present knowledge of ophthalmology in relation to aviation

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OUR PRESENT KNOWLEDGE OF OPHTHALMOLOGY
IN RELATION TO AVIATION

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Our Present Knowledge of Ophthalmology in Relation to Aviation.

Introduction:

With the development of civilization through the ages many new experiences have been met by man and to which he has had to adapt himself. Man has long dreamed of flying and has probably envied the flight and grace of the birds since primitive man. This dream has only recently and partially been fulfilled. With mechanical ingenuity man has constructed an apparatus, given the title of airplane, in which he can ride and direct at will through space.

Man primarily was not created for flying but for a terrestrial existence and because of this he undergoes relatively greater strain when performing this act, in his man made machines, than the animals created and designated by nature for flying. Secondarily the normal limits of physiological adaptation have been exceeded by man in his conquest of the air, and although he is not as well adapted he has induced a greater strain on his anatomical makeup through the developement of the airplane. The airplane will fly faster and go higher than any of the creations by nature for flying. Man has also introduced the act of rapid maneuvers at high speeds and at low and high altitudes varying his course and altitude in a matter of seconds, thus straining to the maximum and exceeding the limits of physiological adaptation of the body to compensate for his morphological and anatomical development. The airplane has changed greatly and many advances have been made in aviation since the advent of heavier than aircraft, but during this time man has not changed.

Today flying is the hobby of many individuals, to others it is their occupation, and to the people of the world in general it is a vital implement of war and of peace. With the whole world at war the value of aviation at the present time is very apparent. Military aviation is rapidly, and necessarily so, being greatly expanded. Commercial aviation is proving its worth and value more than ever before, providing rapid transportation for individuals and also as a means of rapid transportation of industrial necessities. In peace time aviation has and will assume its proper position in civilization.

With the entire population intensely interested in aviation as viewed from the industrial standpoint and also the efficiency standpoint, aviation medicine thus comes into a very prominent position. Aviation medicine is concerned with the selection, care and conservation of flying personnel and thus is an essential element in aviation as a whole.

This thesis embodies one of the important aspects of the field of aviation medicine. It will include a short summary of the history of aviation and aviation medicine, general comments concerning the value of the eye in aviation, examination of the eye and approximate standards for disqualification, problems concerned with aviation in reference to the eye, and a short summary.

It may be assumed that undoubtedly great strides are being made in this field every day under the stimulis of present world conditions. In a field so constantly changing and evolving it must be born in mind that even as this is being written new developments are being made, and cannot be embodied in this thesis as it is not available.

History:

The development of aviation medicine and aviation itself go hand in hand with each oher, with some of the basic principles being laid down from time to time by the early workers and the bulk of work taking place since the beginning of the World War I.

We hear very little of any actual attempts to fly from biblical times to the thirteenth century, however, during this latter period many predictions were made by Roger Bacon, a brillant scientist, which have since come true. Leonardo da'Vinci is famous, for his model aircraftof the helicopter type.

In 1782 he Montgolfier Brothers of France constructed a small light silk bag lined with paper and then filled it with smoke and upon its release it floated to the top of the room. From the early models they constructed larger ones in which they sent up respectively, in order of their ascent, a chicken, a duck, and a sheep.

In October 1783, the first actual flight of any consequence to be made by man was made by Pilatre de Rozier, a french nobleman, who ascended in a smoke filled balloon.

Following this two years later Dr. John Jeffreys, an American and Jean Pierre Francois Blancho d, a frenchman made a flight in a Hydrogen filled balloon from D ver England to Calus France; and thus established the first transo eanic flight. However, since Dr. Jeffreys only concern was aviation and not aviation medicine he cannot be given the credit being the first flight surgeon. (32)

In the following years balloons were gradually improved and more flights made by the early men interested in aviation. Due to several accidents that occured aviation medicine was started.

Glaisher and Coxwell, in 1862, made a balloon ascent to an altitude of around 29,000 feet. Glaisher published an account of this and other flights and in these accounts were records of strange symptoms that developed as the two men ascended. Glaisher noticed loss of visual acuity and hearing, paralysis of his legs and arms, and then unconsciousness. Coxwell noticed that his arms were also paralysied. (44)

Paul Bert, a French physiologist, after reading these accounts

and so began a study of this subject. Collaborating with him were Tissandier, Croce and Sevel who made a balloon flight that ended in disaster. Following is the classic description of the latter part of this flight in Tissandiers own Words:

"I now come to the fateful moments when we were overcome by the terrible action of reduced pressure. At 22,900 feet.... torpor had seized me. I wrote nevertheless....though I have no clear recollection of writing. We are rising. Croce is panting. Sevel shuts his eyes. Croce also shuts his eyes,...at 24,000 feet the condition of torpor that overcomes one is extraordinary. Body and mind become feebler. 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. I soon felt myself so weak that I could not even turn my head to look at my companions... I wish to call out that we were 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."

The balloon ascended to 28,820 feet with the flight ending in disaster as only Tissandier survived from the flight.

Following this disaster Bert continued his work with greater effort and three years later published his famous "La Pression Barometrique". This valuable work has been almost entirely overlooked and forgotten in our present day, but many basic ideas were laid down by him which aid in a thorough knowledge of aviation medicine.

Bert's work which was done directly in connection with the problems of aviation medicine and because of this we must confer upon him the honor of being the father, or at least the grandfather, of aviation medicine as well as that of being the first flight surgeon.

Other than Bert's work, medicine had little to do with aviation for several years. Only a few scattered articles, as late as the year 1910, appeared in the medical literature on aviation medicine and those mostly of speculative nature. (1)

Although we have no definite work of any extent being done in aviation medicine in Europe between 1910-1914 we know that the

Germans were studing the requirements necessary for aviators. In 1910 the Germans publishedthe minimum standards required for military pilots, and in June 1913, Ernst Koschell made a further report onthe minimum physical standards for aircraft pilots. A medical contol of avators was functioning regularly in Germany by 1915. (44)

In France there appeared a government circular relative to the medical examination of aviators on September 2, 1912 although the necessityof this was not affirmed un till two to three years later. The first special medical service for aviators was established in Paris under the direction of Doctors Camus and Nepper on November 8, 1917, and shortly afterwards an analogous service at the training center at Chartres was organized.

In the United States the first record of anything pertaining to aviation medicine appeared on February 2, 1912 when the War Department published the first instructions concerning the physical examination of aviators. In general, aviation medicine in the United States lagged behind that of Europe till 1917. (1)

With the expansion of aviation in the military services during the World War I there developed an intense interest in avation medicine and dating since that time rapid advances have been made. The first problem which engaged the attention of the workers was that of selection of pilots, as it had been noted that about 90 per cent of the accidents were due to defects in the pilots themselves. This established the fact that a man fit for general military service was not necessarily fit for aviation. Consequently during 1916-1917 a great effort was made to increase the physical standards for flying training and to determine the attributes which good pilots should be required to possess. (46)

Medical departments as intergral parts of the air services were established by the end of 1917 by the Allies and Germany. Included in these units were the best specialists of their respective counties. Those in England and in Europe who contributed most to aviation medicine during that period were Anderson, Birley, Douglas, Dreyer, Flack, Haldane, and Priestley in England; Aggazzotti, Gradenigo, and Herlitzka in Italy; Beyne, Camus, Cruchet, Garsaux, Nepper, Manblanc, Moulinier, and Ratie in France; and Anders, Koschell, Krnfeld, Von Schrotter, Selz, Stern and Zade in Germany. (44)

In the United States Major Theodore C. Lyster was intrigued with this subject for several years before our country entered the war and to him goes the credit for creating aviation medicine in this country. (24) In 1917 Major T. C. Lyster and Lieut. William H. Wilmer revised the original Army aviation physical examination form and in May, a month after war was declared, an entirely new examination for flying was drawn up by Colonel Lyster and Colonel I. H. Jones. (1)

Shortly after this, physical examination units were assembled in thirty-five of the principal cities of this country to recruit and examine candidates for the Army Air Service. These units were later increased to sixty-seven and approximately 100,000 applicants for flying training were examined during the war. As trained units of the Air Service were sent overseas medical officers were assigned to accompany them.(46) Today very few people realize that we actually entered the war with practically no air service at all. In one year and a half, at the time of the armistice, we had nearly 12,000 pilots; more than all he services of our allies and our enemies combined.(24)

After the recruiting had been established Dr. Lyster and Jones were sent overseas in October 1917 to study aviation medicine in England, France,

information.(46) Concerning the activities of American Flight Surgeons in France during the World War I, Wilmer gives the following

"The practical application of Aviation Medicine proved of so much value in the United States, that early in August, 1918, in response to a cable from General Pershing, a group of 34 officers and 15 enlisted men (who had been trained in laboratory methods) embarked for servie in the A.E.F.

"Colonel T. R. Boggs, M. C., who had made a comprehensive study of the Air Services of our Allies was designated Medical Consulant, Air Service. Colonel Wilmer was designated "Surgeon in charge of Medial Research Laboratories, Air Services, A.E.F." THe Board arrived at Issoudon on September 2, 1918.

"On October 15, 1918, at the officers' meeting the following report was made: In spite of the shortening days and increasing inclement weather, "Excess of flying hours over previous records were per day, 22,11; week, 759.03; month, 1,869.47; and from October 3 to October 15 there had been the best record of 4,436.46 flying hours without a death." On October 17, it was announced that for the first time in the history of the fields, there were 600 planes in commission. To this great improvement in flying conditions, Aviation Medicine contributed largely."(46)

While at home here in the United States, during this period, a "Medical Research Board" was appointed by the Adjutant General's Office of the Army to act as a standing medical board to investigate all conditions which affected the efficiency of military pilots and to consider all matters pertaining to their physical and mental fitness.(24) First action taken by this board was to establish a medical research laboratory and carry on research.

In May 1919, a new section of the Air Service Medical Research Laboratory had been established for the purpose of training Flight Surgeons for duty with Air Service Organizations. This new section was called the "School for Flight Surgeons" and along with the parent organization was moved to Mitchell Field, L. I. , in Nov. of that same year. The school continued to function after the Research Laboratory was abandoned in February 1921. The former was recognized as a Special Service School and, as such, placed on a permanent basis. That year a fire destroyed the school buildings and most of the eqdipment but the work was carried on in temporary quarters. In December, 1922 the name of the school was changed to "School of Aviation Medicine". In June, 1926 the school was moved from Mitchell Field to Brooks Field, Texas and in October, 1931 to Randolph Field, Texas.

Work in research along various lines has been carried on constantly since the establishment of the school and much has been accomplished by it in the field of aviation medicine.

The flood of papers on aviation medicine being published between 1918-1920 had dropped to a bare trickle by 1925 and these mostly a review of earlier works. In 1926 Major David A. Myers of the Army Medical Corps did the original research on the physiology of blind flight. This work established the basic principals on which our present blind flying equipment is based, and also has had a effect on technical development of flying.

There were few developments in the field of aviation itself, both in this country and in Europe, following the War up to 1926. However, about this time new developments in the field of aviation were being made in this country and were being paralleled by similiar activities in most of the other leading countries of the

aviation medicine and the result was renewed interest with an increase in the number of contributions to periodicals.

Publications directly connected with aviation medicine came into being when in 1929 an association of flight surgeons was formed in the United States and its official publication, the Journal of Aviation Medicine, established. It has been published regularly since March 1, 1930. In 1932 the Polish Review of Aviation began publication in Warsaw and from 1933 to 1936 the Acta Aerophysiologica was published in Hamburg. In 1935 Schunert of Prag published his Physiologie des Menschen im Flugzeug. Since 1936 Luftfahrtmedizin has been published in Berlin. On January 1, 1937 the School of Aviation Medicine began the issue of Flight Surgeons Topics "A medium for the exchange of ideas, wherein one need not hew to the line but can let the axe fall where it may."

Around 1933 a new interest in aviation medicine brought on a general re-establishment of aero-medical research laboratories throughout the world and by 1938 these laboratories were well developed and in full swing in most of the major countries of the world.(1)

In the United States in the first three years of the Laboratory's existence over sixty research projects have been completed and it has exerted a profound influence on the design, construction, and operation of military and commercial aircraft and also aircraft equipment in so far as the human element is concerned.

On April 15, 1938 it was officially announced that a second research laboatory for aviation medicine was under construction in this country. This was the Medical Science Station of the Civil Aeronautics Authority which has now been established at Kansas City, Mo.; and whose main purpose is to study the research problems in aviation medicine with specific reference to civil aviation.

Work in aero-medical problems has also been carried on generally in medical research laboratories in the past few years and the major air lines have also established laboratories for the use of their Medical Directors.

Thus the recent rapid advance in our knowledge of aviation medicine is related not only to the expansion of the military air forces in this country, but also the rapid growth of commercial air transport through which the general population is now being exposed to the effects of flight. This in turn has created a need among the general medical profession for an understanding of the principals of aviation medicine and there is definite evidence of a rapidly growing interest being manifested by this group.(1)

General Comments Concerning the Value of the Eye in Aviation:

It would be well at this time to present several reasons for the growing interest in aviation medicine and also the necessity of such a field in the Medical World: First, quite a few members of the medical profession are authorized medical examiners of airplane pilots for the United States Department of Commerce and the Civil Aeronautics Department of Commerce and the Civil Aeronautics Authority; second, aviation is the subject of worldwide discussion at present and the younger generation is very much air-minded. Practically all the high school boys in the nation and probably throughout the World would take up flying tomorrow if they had such an opportunity; third, this nation must, for its own safety, maintain a air force of many thousands of pilots, and first line pilots at that, ready for any emergency. Young pilots must replace the older ones yearly, for flying is truly a young man's game. (7)

Aviation Medicine, as it has come to be termed, is really a specialty comprising certain phases of several other specialities. There is a certain amount of ophthalmology, otology, internal medicine, psychology, neuropsychiatry, and physiology as applied to flying, required by the specialist in aviation medicine, who has been termed in the United States, the "Flight Surgeon". It has been shown in the brief review of the history of development that this field of study is relatively new, that the bulk of the work has been accomplished in the past few years, that certain active periods of time in which more interest in the subject has existed and now exists, and that it has followed the development and aided in the development of aviation itself.

Since this thesis concerns Our Present Knowledge of Ophthalmology in Relation to Aviation, the further discussion of aviation medicine as a whole will be dispensed with, at the same time realizing that in this field the thorough understanding of individual and subject matter of all aviation medicine are intimately related as in any other phase or field of medicine, all is associated.

In order for a pilot to operate any type of aircraft safely and efficiently, his combined visual elements must function in a manner to insure full visual efficiency without undue nervous or muscular stress.(43)

Nothing is of greater importance to the pilot than his eyes;(25) and it is generally agreed among authorities in aviation medicine that a normal optical system is one of the primary requisites for safety in aviation.(1) As stated by Bean: "In aviation, as in no other occupation or industrial activity, perfect eye sight or normal vision is essential for the highest efficiency and safety."(7)

It is at once obvious to those interested in aviation that the optical requirements of the aviator are much more than merely "good sight"; for when man undertook the conquest of the air, many adjustments in his visual and psycho-visual reactions became necessary in order to accomplish mastery of this new experience.(33) With the ever increasing complexity, of the unnatural task, of piloting a heavier than air mechanism demands a good deal more of its practioners than a good sense of "balance in the pants" good balanced vision is of primary importance. (39)

When flying was in its infancy certain regulations were adopted as the ocular requirements. Flying was a new field and the ocular requirements could not be based on experience relative to flying and were, therefore, more or less arbitrary. These requirements are the assumed limits believed by ophthalmologists to be within which ocular efficiency can be maintained under varying conditions.

From a purely scientific standpoint it has never been demonstrated, in aviation, that these limits are justified in all instances. The lack of conclusive proof does not, however, warrant relaxation of the ocular requirements because the basis on which they are founded are sound. It may be said that the more efficient the ocular equipment of a person the more reliable he will be as a flier and more enduring will be his flying career.

As the eyes are of the utmost importance in aviation, the routine ocular examination is searching, particularly so when student pilots are examined.(43) Examination by the flight surgeon must be understandingly and strictly applied for all the required tests in order to determine the presence or lack of mormal visual acuity in the candidate for flying. Much of the responsibility must be accepted by the flight surgeon in the selection of aviation trainees and in their care after graduation. The flight surgeon must be thoroughly aware of the physical standards demanded of the pilots, and must strictly apply them. In so doing he discharges a high duty to the individual, his fellows, and the Government.(39) Any visual defects present in the individual about to take flight training or the trained pilot must be recognized; for if he goes up in the air, without the defects being recognized, the result might be a serious collision or other accident.(25)

The ophthalmologist and the flight surgeon know that all persons are not equally sensitive to ocular defects, either under normal conditions or while under nervous, mental or ocular stress. One person may tolerate, seemingly with full efficiency and without the slightestdiscomfort, surprisingly large defects, while another under identical conditions cannot tolerate a defect one quarter as large without the greatest discomfort and without impairment of function. Because of this disparity in tolerance it becomes difficult to evaluate the importance of seemingly trivial defects. Therefore it is necessary, in order to reduce to the minimum the number of persons who may become incapacitated later, that a certain high standard be maintained that is applicable to all.(43)

Knowing the importance of the eyes in flying the examiner tries to make sure that the muscle balance and visual judgement of the pilot are perfect or fullfil all the requirements of regulations, to insure careful and accurate flying, yet changes may occur shortly after the surgeon passes on the pilot. Often these changes in the eyes and development of the visual defects are slow but progressive; and they do not become apparent to the pilot or the flight surgeon until something unusual occurs.(25)

While ocular efficiency is recognized as being essential to the efficient flier, there are exceptions. There is on record one person who, having lost an eye, not only learned to fly with this defect but became remarkably proficient and internationally famous as a pilot. It is reported that an exceptional amount of training was necessary in order to compensate for his ocular defect. The aforementioned record does not, however, lesson the importance of ocular efficiency. To assume that all persons with monocular vision can become safe and proficient pilots is equal to assuming that all persons afflicted as is Miss Helen Keller can equal her achievements. (43)

Good visual acuity alone is not adequate to qualify for flying training and the total function of the eye must be investigated and examined.(1) This is necessary for the pilotage of heavier than aircraft in that the high speed at which airplanes travel; the necessity of avoiding obstacles in the air; the judgment of distance in take-offs and landings; the necessity of correctly interpreting colored signals and lights; the ability to recognize the gray horizon or the false horizon at night; and the necessity of focusing the eyes on distant objects, then the instrument panel and from there to the maps on the knees and back again.(25) The difference in scope between the eye examination for ground officers and for flying officers of the United States Army, can best be realized when it is known that the former consists of three tests while the latter consists of no less than fourteen.(1)

The duties of all aviators are not of the same nature and the conditions under which they fly differ in many respects. Because

in the choice of pilots for civil and for military aviation.

In commercial flying the pilot is entrusted with the lives of a number of passengers. The primary demand is for saftey and reliability, and safety factors must not be sacrificed in the interests of speed. There is little or no demand for risky maneuvers and none

railway bridges, have a degree of strength and stab ly sufficient to meet much more than the expected demands.

In military aviation the planes are and must be capable of much higher speeds and are subjected to the strains of much more complicated and risky maneuvers. When one considers the demands made by military aviation, especially on the pilots of fighting planes, and the need for extreme rapidity of observation, and improvised action, one realizes the necessity for a most highly developed flying sen s, and it is obvious that more visual acuity is not of such paramount importance.

Whatever form of flying aspirants wish to follow, it is of the utmost importance that the standards for acceptance should be such as will exclude those who are likely, on account of some functional disability, be a danger to themselves or to others. But the choice of the standards is by no means easy. It presupposes that the faults which are responsible for flying accidents are known, those mainly due to errors in landing, but there are certain obvious difficulties in the way of determining these causes, especially in fatal cases.

Continuous research is being carried out on the ophthalmic side of the research laboratories to ascertain if possible the ocular defects which make for faulty flying and which are therefore inadmissible; and in what way and to what extent these defects can be remedied.(4)

It becomes increasingly apparent as one reviews certain published figures relating to the cause of flying accidents that the importance of visual standards has not been overestimated. It has been the general experience in all countries that the vast majority of flying accidents (variously estimated at from 60 per cent to 90 per cent) were due to failure of the human factor, and a comparatively small number to mechanical or technical failures. Among such accidents, ocular defects, especially errors in estimation of depth and distance, bulk very largely.(4)

Showing the very high percentage of visual defects present in those presenting themselves for examination are certain reports issued by various writers. One report states that, of 512 applicants taking the original examination for primary flying training, there were 633 disqualifying defects found in the physical examination. Seventy-three and fourteen hundredthes per cent of those defects were found in the eye part of the examination.(20) Another report shows that in analysis of the cause of disqualfication of 500 rejected applicants for flying training that sixty-two per cent of all applicants examined at March Field have been physically disqualified, and of these the defects of the eye accounted for sixty-two and two tenths per cent of the rejections.(8) Brown states from 19 years experience in the United States Army Air Corps, "that more candidates are disqualified for poor visual acuity than any other reason; next, ocular muscle imbalance and defective depth perception, and following this are the defects of the other anatomical parts".(9)

There is the growing conviction that the pilot is an important factor in the increasing number of airplane crashes, and it seems that more attention should be paid to him. It has been the policy that a exceedingly great amount of care was lavished entirely on the plane and seeing that it was in perfect condition before a flight and very little attention given to the condition of the pilot. While it is true that a human being cannot be treated as a machine, it is true that more attention can be given to seeing that the pilot is fit at all times to pilot the plane.(16) In order that this factor may be overcome all pilots of aircraft, whether military or commercial, are required to undergo a physical examination every six months. The physical requirements vary somewhat with the type of flying the person is authorized to pursue.(43) Also, there are those who advocate still more frequent examinations for the pilot be given in order to lesson defects and disturbances that may be present, and which might result in disaster to the pilot and the passengers who depend upon him for their safety.(25)

The flight surgeon is doing much to lesson the number of accidents and check on the pilots physical condition. Without his intelligent cooperation, the art of flying could hardly be highly developed as it is today and the number of accidents due to the pilots condition lessoned.(39)

Examination of the Eye and Standards for Disqualification:

The examination of the eye is both of a subjective and objective nature and includes an examination of its gross anatomical condition along with its functional condition.

Inspection of the eye is entirely objective in nature and it involves an examination of the external and internal structures of the eyes and their adnexa. If any defect is noted then it should be classfèd as to whether it is temporary or permanent. In case a temporary defect is noted, the candidate should be advised to have it corrected and allowed to return at a later date for examination.

Examination of the eyelids should be held in good daylight, and the following conditions should be noted: ptosis, blepharitis, trichiasis, entropin, ectropian, chalazion, and hordeolum.

Inspection of the conjunctiva should include both the palpebral and bulbar portions. Conditions looked for are: pterygium, pinguecula, concretions, ecchymosis, hyperemia, chemosis, xerosis, cysts, tumors, and conjunctivitis.

The examination of the globe includes the position of the globe within the orbit, the presence of exopthalmus or enophthalmus and deformities or deviations of the globe itself. This examination also includes the tension of the globe taken by palpation.

Examination of the sclera to reveal any evidence of scleritis, episcleritis or staphylomota.

In examining the cornea such defects are looked for as abrasions, depressions, ulcers, nebula, macula, leukoma, pannus, interstitial keratitis, degenerative changes, and anterior synechiae. The importance of an opacity of the cornea depends on whether it is located centrally or peripherally and if vision is interfered with. Also, if there is a deformity of the curvature of the cornea causing astigmatism.

An examination of the iris should include the anterior chamber for depth and any foreign material that may be present. The presence of iritis, posterior synechia, and persistent pupillary membranes are noted.

Examination of the pupils should include a test for their reaction to light and accommodation. Unusually small pupils may be due to central nervous system diseases, use of drugs locally or internally, a past iritis, or syphilis. Large pupils may be due to the use of drugs locally or internally, complete optic atrophy, glaucoma, cervical sympathetic irritation, or trauma.

The examination of the lens and vitreous is best handled at the time when the pupil has been dilated with a mydriatic in preparation for refraction.

When it comes to interpretating the findings of the examination, a distinction should be made between defects considered as being of a temporary or of a permanent nature, and notation made as to interference with function. Any defect, disease, or abnormality that actually materially interferes with the normal ocular function should disqualify. (1)

A high standard of acuteness of vision is necessary to the individual in aviation. The flier is required to see objects clearly, and he must be able to locate them accurately as to positions and in their relations to one another. His ability to judge distance is dependent, in part, on his acuteness of vision. If a pilot is required to make an emergency landing he must be able to judge the character of the terrain and be able to tell whether or not there are humps, depressions, holes or other obstacles present on the choosen ground and this duty can only be accomplished with accuracy when the vision is acute. The importance of accurate decisions becomes apparent when it is remembered that, flying speed and altitude having been lost, landing frequently must be accomplished regardless of the character of the chosen field. A pilot must be able to read at a glance his instrument board and finely printed maps. There are a multiplicity of conditions besides those mentioned that require acute vision. The military pilot must recognize and locate objects when he is on photographic missions, combat details and other duties.(43)

The visual acuity is the ability of the eye to appreciate form; and this is measured by utilizing the visual angle, which is the angle formed by the intersection of two axial rays crossing at the nodal point of the eye when two points are seen as being separate and distinct. Thus two points at a distance may be so close together that the rays of light from them pass through the optical center of the dioptric system of the eye and both fall on a single cone of the retina. With the stimulation of a single cone, only one image is registered in consciousness with the result that the two points mentioned above are thus seen as a single point. When two cones are stimulated the result is the formation of two separate images. In the normal eye where the retinal images are clear and distinct two points appear separate when the visual angle formed by the crossing of the two axial rays is a minmum angle of one minute. In the ametropic eye the retinal images are blurred and indistinct and a visual angle of more than one minute is required to distinguish two separate points.

Factors which tend to lower visual acuity are errors of refraction, the size of the pupil, the amount of illumination, and pathologic changes in the eye or optic tract.

The simplest and most commonly used method of testing the visual acuity is by the Snellen test letters and it is normally conducted at 20 feet.(1)

There is a difference between the visual standards that are required by the armed forces and the Department of Commerce. In the armed forces all applicants for training in flying are subjected to a refraction with the use of a cycloplegic on determining the refractive state. The Department of Commerce does not require this as a routine.(43) Military pilots must have normal vision without correction. Commercial pilots must have at least 20/50 vision correctible to normal with glasses, as correction is permissible. Private pilots must have a corrected vision of at least 20/30 in each eye.(6)

Depth perception is an element of vision that must function efficiently if the pilot is to continue flying and retain his health. In importance it must be considered as equal to acuteness of vision. It is this element of vision that enables the flier to level off his ship at the proper distance from the ground when making landings; to take off with the necessary margin of safety over trees, buildings, fences and other obstructions; and for the military pilot to fly in close formations and take part in aerial combat when engagement of enemy ships at close quarters is necessary.(23) Not only must the estimation of distance be accurate, but is must be rapid, when one remembers that the landing speeds of even the slower planes are in the neighborhood of 50 miles an hour.(4)

Depth perception may be defined as the ability to appreciate or discriminate the third dimension, to judge distance, and to orient oneself in relation to other objects within the visual field.(1) There are many factors involved in depth perception. With some of these factors ophthalmologists are, at least theoretically, familiar, while undoubtedly there are many factors involved of which they are totally ignorant. Some of the known factors constitute a part of the physical and psychic equipment of the individual; they are constant and when considered together may be termed inherent depth perception. Other factors involved exist outside the body; they are common to all persons; they are varible, and they operate independently of the individual. These factors may be referred to as adjunct factors utlized to enhance the already existing inherent sense.(41) There are eight separate factors concerned in depth perception four of which are inherent, and four which are adjunctive.(1)

The first group of factors consist of: 1. Physiologic diplopia, 2. accommodation, 3. convergence, 4. binocular parallax.

Physiologic diplopia is the ability to recognize differences in distance between two objects within the visual field based on the fact that all objects in the field closer or farther away than the object fixed gives rise to diplopia, and this diplopia is not recognized as such in consciousness but is interpreted in terms of distance nearer or farther away than the object fixed.

Accommodation is the faculty of increasing the dioptric power of the lens and is the factor that enables the normal eye to focus near objects at less than infinity on the retina to form a clear image. If for any reason there is failure of accommodation the images of objects at less than 20 feet on the retina are blurred and thus depth perception is interferred with.

Convergence is the ability of the two eyes to fix on an object at a distance less than infinity. Greater convergence is required as any object gets closer to the eye. Failure of convergence causes a blurring of vision or a pathologic diplopia with a resultant decrease in depth perception.

Binocular parallax is the impression of relief or solidity given to an object by the slightly different view of it which is obtained by the fact that the right eye sees a little more of the right side of the object and the left eye a little more of the left side of the object, and this difference in consciousness is interpreted in terms of relief and depth.

The second group of factors are: 1. size of the retinal image, 2. motion parallax, 3. terestrial association, 4. aerial perspective.

The size of the retinal image varies inversely as the distance of object from the eye, therefore, the closer an object is to the eye the larger the retinal and the further away the smaller the image. The size of the retinal image is a measure of the distance of an object from the eye but it has been found that this factor operating alone is quite inaccurate.

Motion parallax is based on the same general phenomena seen in binocular parallax but differs in that the former depends on motion of the observer or of the object being observed, and with this motion of the observer or the object different views of the object are attained either to the right or the left, above or below, and these different images on the retina are interpreted in consciousness in terms of distance.(1)

Terrestrial association is an acquired characteristic that develops with training and experience and is dependent on the association of ideas. This factor consists of a linear perspective, overlapping of contours, and light of which reflections and shadows are important. This is utilized in the judgment of distance.

Aerial perspective is also an acquired characteristic that develops with training and experience. This factor is utilized and interpreted in terms of distance by the use of the changes with respect to color, brightness and contrast which different objects undergo on account of variations in the clarity of the intervening atmosphere.

Some of the factors operating to constitute depth perception are common to monocular and also to binocular single vision, while others pertain to binocular single vision only. The factors common to monocular and binocular single vision are: acuteness of vision, accommodation, the size of the retinal image, motion parallax, terrestrial association, and aerial perspective. The factors operating with binocular single vision only are: physiologic diplopia, binocular parallax, and convergence.(43)

Poor depth perception may be produced by the factors inequality of vision, insufficiency of convergence, accommodation asthenopia and heterophoria.(1) These factors may operate separately or together, and judgment may be consistently poor or it may be erratic.(43) It has been shown with reference to inequality of visual acuity that it affects depth perception more that an equivalent amount of equal defective visual acuity, and this is apparently due to the fact that the greater the inequality of vision the closer binocular depth perception approaches monocular depth perception because of a tendency in the former to lose physiologic diplopia and binocular parallax and hence the perception of relief and solidity.(1)

Early in aviation a test of steroscopic vision, made with an ordinary parlor sterescope was considered sufficient to determine whether or not a person possessed ability to judge distance accurately. The aforementioned type of stereoscope utilized one of the visual elements concerned in the judgment of distance, namely, binocular single vision. Psychic fusion of the two ocular images, which are not identical, is demonstrated by creating an optical illusion, giving rise to an impression of depth where depth does not actually exist. This device, therefore, offers no information regarding actual depth, and since it has been replaced.

It is necessary in applying a test to determine a person's ability in judging distance to utilize only those factors which operate to make for an individual difference, namely; the inherent factors. Experience, training, and that which he may utilize, aside from his inherent equipment, should be left to the subject concerned and to his instructors.

When all external factors and those operating at distances of less than 20 feet are eliminated the following remain to be considered: the size of the retinal image, physiologic diplopia, binocular parallax and convergence.(43)

The Howard-Dolman apparatus is generally employed to measure the binocular parallactic angle, and is designed to utilize principally those factors belonging to the basic group. All external factors, with the exception of the size of the retinal image, which usually operate to assist in judging distances are eliminated.(43) The procedure consists seating the examinee in such a manner that he is facing the depth perception apparatus at exactly 20 feet distance. The movable rod is placed at various distances off center and the candidate is required, by means of the cords, to place it as nearly as he can judge opposite the stationary rod or such that both are equidistant from him. This is repeated several times, the rods being widely separated after each trial. The result of each attempt is read directly off the mm. scale, the results of all the trials averaged, and the average depth perception recorded.

There are certain standards established by the Armed forces and also the Department of Commerce, and in the Armed Forces a depth perception of more than 30 mm. should disqualify.(1)

In selecting candidates for flying training, it is necessary to determine whether or not there is any abnormality in the motility of the eye.(1) Ocular muscle balance is carefully tested, not only because it is undoubtedly related to judgment of distance or its defects may cause diplopia, but because the effort to maintain single vision when phorias are present causes distraction and inattention.(6) Since it is from this world of our civilization that we are asked to select our pilots of aircraft, many of the potential causes of disharmony have been met with by the men in their studies and duties upon the ground. The ledger clerk, the draughtsman, the engineer, the man who follows an occupation calling for monocular estimation, all these have encountered the strain for varying periods. It is really remarkable that it is quite rare to discover any gross defects, which is another way of saying that binocular function has considerable strength and latitude.(28) There are several tests that are employed in order to accomplish this.(1)

In flying as in many other vocations, binocular single vision must be maintained and it must be maintained in all directions of gaze without undue nervous or muscular stress.(42) As the bodily movements are normally very restricted and a wide range of vision can be obtained only by turning the head and eyes. However, it is not only necessary for clear vision that an object be in the visual field but that both eyes are capable of fixing the object so that the retinal image falls on the fovea of each eye. In order for this to be accomplished the two eyes must be parallel in all positions when viewing an object at infinity and they must be convergent when looking at an object at less than infinity with the amount of convergence dependent on the closeness of the object viewed.

It has been found in most cases that one eye first fixes an object and the other then arranges itself in proper relation to the first to give binocular fixation, the first is called the sighting eye and the second the non-sighting eye. The right eye is usually the sighting eye in right handed people and the left eye he sighting eye in left handed people. In pathologic diplopia the sighting eye is always the one that fixes the object viewed and the non-sighting eye is the one that deviates.

When the two eyes fix on an object at infinity in binocular vision the visual lines of the two eyes are parallel and this relationship is maintained by the fusion center in the brain whose nervous regulation normally assures binocular fixation.(1) When, however, binocular single vision is maintained with effort, either consciously or unconsciously, and the fixation points are constantly changed, there is likely to be a slight "wandering off" of one eye from the object fixed, the deviation occuring being insufficient to induce pathologic diplopia but sufficient to stimulate areas of the retina not exactly corresponding to each other. This "wandering off" of one eye alters physilogic diplopia sufficiently to reduce acuteness of depth perception, and maintainence of binocular single vision under such conditions as mentioned induces muscular and fusion fatigue, thereby making binocular single vision increasingly difficult.(12) When the fusion center is not functioning properly the two eyes will remain parallel only if the muscles of the two eyes are perfectly balanced. In all other cases there will be a diplopia with the amount and type dependent on which muscles of the eyes are weak or which are overacting. There are no movements of the eye dependent on any one muscle alone but on a principal muscle and a synergist, and its action opposed by one or more antagonists.

Diplopia consists of two types, one is latent and occurs only when the fusion center is weakened or abolished and the other is manifest and occurs when the fusion center is presumably intact and functioning. The conditions are thus named: 1. Orthophoria, or normal binocular balance; 2. Heterophoria, or latent imbalance and tendency toward deviation of the two visual lines from the parallel position; 3. Heterotropia, or a manifest deviation of the visual lines.

Heterotropia, when it exists, is disqualifying for aviation and it is usually immediately apparent on inspection of the eyes. Heterophoria being latent must be made manifest and since a certain degree of heterophoria is acceptable in aviation its extent and type must be determined.(1) The condition that we style heterophoria must be age-old, but the contest for mastery of the air is, within practical limits, an event of our generation. Racing through space does not itself produce heterophoria, but heterophoria may severely affect safe aerial maneuver.(28) By weakening or abolishing the action of the fusion center and then measuring the resultant deviation of the two eyes heterophoria, if present, will be manifested. This is carried out by the use of a multiple Maddox rod and a rotary prism mounted in a phorometer trial frame.

The multiple Maddox rod consists of a series of section of glass rods superimposed with their axes parallel and in the same plane and mounted in black opaque frame. If a small point of light is looked at through this rod, the light is refracted such that the point of light appears as a streak or line of light at right angles to the long axis of the rod.

A rotary prism is two prisms of equal value mounted superimposed and arranged to rotate in opposite directions by turning a milled thumbscrew. With this arrangement any prismatic effect from zero to the sum of the value of the two prisms may be obtained and the base of the prism may be placed in any position.

As one looks at a spot of light with a Maddox rod before one eye and he other eye is uncovered the light appears as two entirely different objects, that is, it looks like a line of light to the eye looking through the Maddox rod and a point of light to the uncovered eye. With this effect there is a tendency to abolish or weaken the action of the fusion center and any latent deviation of the eyes then becomes manifest.

The amount of this deviation can be measured by means of the rotary prism. This proceedure is carried out by placing multiple Maddox rod and a rotary prism before one eye while the other eye is left uncovered. In looking at the spot of light at 20 feet distance the streak of light will usually be seen either to the right or to the left of the spot of light. Then by rotating the prism, the streak of light will appear to move laterally and when it has been placed so that it passes exactly through the spot of light, the amount of heterophoria may then be read directly from the prism scale which is graduated in prism diopters. The term prism diopter is used as the measure of strength of a prism and one prism diopter is that which will deviate a beam of light one centimeter at one meter distance and equals 34.37 minutes.

If the eyes are perfectly balanced the scale should read zero when the streaks and spot are superimposed.

When the above test is applied at a distance of 33 cm. any latent deviation at reading distance will be uncovered and also some information gathered as to the existence of refractive errors, insufficiency of convergence, and reduction of fusion control.(1)

The associated parallel movements of the eyes may be tested either by means of the tangent curtain or by means of the red lens. In cases where underaction or overaction is revealed by gross examination, diagnosis can be made or verified by the use of these tests.

There is another type of motility defect differing from the latent and manifest deviations that must be tested for. This is underaction or overaction, aparesis or paralysis, or the external ocular muscles. When the eyes are rotated so as to bring all of the ocular muscles into play this condition is made apparent and a defective muscle is detected by noting whether or not one eye lags or overshoots.

The tangent curtain test is normally employed to accurately determine the muscle or muscles involved and the amount of impairment, if any, is present. A tangent curtain consists of a cloth panel 60 by 72 inches, white on one side and black on the other, and mounted on a rigid frame. The white side of the curtain is marked off in 2 inch squares, each square amounting to a dieviation of 5 degrees at 75 cm. distance from the screen. From a point midway between the sides of the curtain and 30 inches down from the top, radiating lines pass out at angles of 15 degrees.

In the examination with the use of the Tangent curtain, the examinee is seated 75 cm. from the black side of the curtain with a red glass in front of his right eye. A black pin is placed in the center of the curtain, and the eyes at the same level and looking straight ahead are directed at the center pin. A small electric light is then carried over the curtain in the six cardinal directions that corresponds to muscles action. The point at which diplopia occurs in each meridian is noted by thrusting in a black pin at the point of the light itself and a light-colored pin at the site of the other image. This latter is evidently the false image and if it is red it is known that the left eye is fixing and if it is white that the right eye is fixing. In the great majority of cases the examinee fixes with the eye not covered by the red glass. The left eye is then tested in the same manner.

The individual undergoing examination should be disqualified if the underaction or overaction of any of the extrinsic ocular muscles produce diplopia except in the extreme positions. A small separation of the images may be disregarded. Nystagmus should disqualify if it is demonstrated except in extreme positions.

The red lens test may be substituted to check the associated parallel movements of the eyes without the use of the tangent curtain. The examinaion is carried out by seating the examinee in a dark room and then a spectacle trial frame is adjusted in place. A red lens from the trial lens case is placed in one of the cells of the trial frame, and a small lamp is held directly in front of his eyes 75 cm. away and at the level of his eyes. The presence or absence of diplopia in this position is noted. The light is then slowly moved in the six cardinal directions for a distance of 50 cm. from the primary position. The presence or absence of diplopia is noted in these meridians. Diplopia should not occur in any meridian within 50 cm. of the primary position, and if present it should disqualify. Where diplopia does occur within 27.30 cm. of the primary position, a more accurate determination may be made upon a blackboard or wall. (1)

In the examination of the United States Air Corps personnel for flying duty, the use of the Rotary prism is an established proceedure as it is in the examination of other individuals for flight training. The rotary prism is used in estimating the abduction of the visual axis as "prism divergence."(38) A low prism divergence indicates an underaction of the external recti or overaction of the internal recti or both.

The examination is accomplished by the use of the rotary prism placed at 20 feet distant from a splitlight, and the prism set at zero before the non-sighting eye and with the thumbscrew in the up position the spotlight is fixed by both eyes. As the prism is rotated slowly, base in the ray of light is refracted toward the apex of the prism, result being that the image of the light ray shifts to the nasal side of the fovea of the non-sighting eye and it must rotate outward so that binocular single vision will be maintained. Since the fusion center is functioning, the eye continues to rotate outward as the prism is rotated until the limit of divergence is reached when the eye swings back parallel to the sighting eye and diplopia results. The onset of diplopia marks the limit of prism divergence and, hence, the power of abduction. Prism divergence of more than 15 or less than 3 prism diopters is disqualifing for the Military forces and certain standards are established by the Department of Commerce.(1)

Another test employed in the testing the motility of the eye is that of measuring the angle of convergence. Adduction of the eyes is not measured in the same way as abduction because the findings in the former case are inconsistant and because accommodation plays an important part in convergence. A more reliable and satisfactory method is to determine the angle of convergence and this angle is computed from the near point of convergence and the interpupillary distance.

The near point of convergence is the point directly in front of, and closest to the center of rotation of the eyes to which the two eyes can fix an object without diplopia. Since the center of rotation of the eyes is 13.5 mm. back of the cornea the near point is computed from that point as a baseline.

The interpupillary distance is the distance in mm. between two corresponding points on the pupils of the two eyes.

From the above two measurements the angle of convergence is computed. If there is present an angle of convergence of less than 40 degrees then the individual applying for flight training should be disqualified.(1) It is believed that habitually observing the tendency towards head tilting among pilots will indicate to the examiner the possibility of eye muscle impairment and lead to critical studies. That commonly the veteran pilot may be observed to indulge in narrowing of the palpebral fissures is probably the physical demonstration of the fixed habit of visual concentration and alertness. This squinting habit has resulted in the laity referring to the pilot as one with "eagle eyes".(21)

Along with the other standards that have been established there is the necessity of certain standards for accommodation for those that take up aviation. Accommodation is the process of increasing the dioptric power of the lens of the eye. By means of the mechanism of accommodaton addiional focusing power for rays of varying divergence is provided. Such a mechanism must be capable of exceedingly rapid and almost inconceivably delicate adjustments, since these must be of different degrees for each object fixed by the eye. Since in the resting emmetropic eye parallel rays are focused on the retina, divergent rays from near objects must be focused behind the retina. To bring this focus forward to the level of the retina, the effect of stronger positive dioptric power must be given to the eye.(19) This increase is accomplished by contraction of the ciliary mscles which in turn causes an increased convexity, especially of the anterior surface, of the crystalline lens. This change in the dioptric system of the eye is accompanied by a convergence of the two eyes and a contraction of the pupils.

In the normal eye, the amplitude of accommodation is the difference between the dioptric power of the eye when accommodation is completely relaxed and when it is exerted to its utmost. The amplitude of accommodation depends on the difference of the far point and the near point at which an object can be distinctly seen but it is customary to convert this distance into its dioptric equivalent which is the recipocal of the focal distance in meters. Thus in an emmetropic eye, the far point is located at infinity and the dioptric value is zero. If the near point is a 10 cm. then the accommodation of the eye is 10 diopters.

There are several factors that may affect accommodation and these are: oculomotor paralysis, irido-cyclitis, glaucoma, ciliary spasm, general debility, atropine, homatropine, and cocaine.

In the interpretation of the findings, certain values have been worked out for the various age groups. A table has been compiled that gives the mean value of accommodation in diopters from 18 to 50 years of age. These values have been computed on the basis of emmetropic individuals. Accommodation may be considered as within normal limits provided it is not more than 3 diopters below the mean for the examinee's age. The examinee should be disqualified if his accommodation falls more than 3 diopters below the mean for his age, but before an examinee is disqualified his accommodation should be taken on three sucessive days and an average of the three findings taken. Low accommodative power may be indicative of accumulative fatigue, staleness, or of a debilitating condition either of a transient or permanent nature.(1)

A deficiency in the appreciation of color values in numerous individuals has long been known to exist. However, it was not until 1798 when John Dalton, a chemist, studied his own case, that general interest was aroused in this question and since then much work has been done on this subject.(45) Color vision is another important factor in flying safety and this must be examined for any defects.(25) Accurate and rapid discrimination of colors becomes important to the flier when selecting emergency landing fields, recognizing colored signal lights, navigation lights, lights denoting the limits of landing fields, and daylight panels, and in reading colored maps. In selecting landing fields the character of the terrain may be determined to an important degree by its color. The color presented enables the flier to determine whether the selected field is dry, swampy, newly plowed or covered with stubble and many other facts of importance. The rapid and accurate recognition of colors attain its maximum efficiency in the hexachromic person. A person to whom the spectrum appears to contain less than six bands, or in whom one or more of the bands deviate from the normal, cannot be relied on under all circumstances, as is necessary in aviation.

An aviator may be defective in his discrimination of colors and fly with comparative safety so long as he is flying over terrain and in and out of fields with which he is familiar. However, when he enters unfamiliar territory, when ground panels, colored signals and other devices are resorted to, he is likely to fall into grave difficulties. Therefore, it cannot be considered safe for a pilot with defective color vision to assume responsibility for aircraft flight, because emergencies frequently arise, and pilots may be called upon at any time to fly over unfamiliar terrain, in and out of strange landing fields and in rain and fog. (43)

The term "color-blind" is applied to those whose color perception is different from normal and in general more limited.(1) In the investigatin of color blindness, it must be remembered that the appreciation of color is a psychological problem and that no individual can accurately assess the sensations of another; we can only study differences in the ju ment of others when compared with our own when reacting to the s e stimuli, but we cannot compare physiological sensations or eir psychological counterparts.(45)

The solar spectrum to he person th a fully developed sense of color discrimination, consists of six bands of color of unequal length, each band merging by fine gr ations into the adjacent band or bands. The colors, reading f om left to right, are red, orange, yellow, green, blue and viole . The six band, or normal spectrum, is seen by about 80 per ce of the entire population. The spectrum to the remaining 20 per ent is either composed of less than six bands or one or more of the six bands deviate from the normal in one respect or another. 43) Color blindness may be complete or incomplete, congenital or acquired. Acquired color blindness is rare and since it is a c mplication of grave intoxication or a serious ocular or neurolo ic disorder it need not concern us here. Congenital color bl ndness exists to a moderate degree in about 1 per cent of the ca es. However, only about 3 percent of the opulation are suffi iently defective in color perception to be f any great signifi ance.(1) Thus, a person in whom color vision s defective may go hrough life quite unconscious of his inferiority and without making any incriminating mistakes, differentiating objects by their size, shape, and luminosity, using all the time a complete color vocabulary based on his experience which teaches him that color terms are applied with great consistency to certain objects and to certain shades, until circumstances are arranged to eliminate these accessory aids, and he realizes that his sensations differ in some way from the normal. It is the elimination of these accessary aids which is the object of tests for the detection of the color blind.(45)

A great number of tests have been devised for the detection of defective color perception with two types being commonly used and it is on these that we rely in our examinations. These tests are the Ishihare test and the Holmgren yarn test or one of its many variants.(1)

A letter from the Chief, Medical Division, Office of the Chief of the Air Corps, dated August 9, 1935, makes the use of the Ishihara test for color blindness official for all original examinations in the army. It has been their experience that this test is more selective than the tests previously used, and along with this it has the further advantage of being simple in application and relatively cheap. It has the disadvantage in that malingering is possible in certain of the plates. The recent publication of the Ishihara test in color in one of the Sunday supplements of a great newspaper chain did not help in the least in this respect.(22)

In the consideration of the interpretation of the findings of these tests, very slight degrees of color blindness as manifested by minor errors may be ignored and moderate or gross defects of color vision should disqualify.(1)

The visual field of the pilot must be as wide as possible since he must be able to see any aircraft or other objects in his vicinity. He must also have good vision of the peripheral fields in order to be able to judge the position of the craft in relation to laterally placed stationary objects.(25) The modern planes fly at terrific speed and when two planes are approaching each other at speeds of over 300 miles an hour, it is often a case of whoever sees the other first that wins or gets away safely.(6) Since the outside limit of vision of man is greater than half of the space in which he is placed, and his eyes can move accurately with the greatest precision to any object in any part of his field of vision, and he sees distinctly only that at which he directly looks, peripheral vision assists him in discovering moving or other objects to which he may direct his gaze and this is mandatory in an airplane pilot.(7)

The flier with only one eye has a tremendous handicap; and yet he can land accurately. In landing his "spot vision" shows objects becoming larger and larger; his "field of vision" on the other hand becomes narrower and narrower. This is how the one-eyed man gets a comparison enabling him to judge distance. A one-eyed man also learns about distance by the size of objects that he approaches. But even at best, it is a difficult feat for the individual with only one field of vision.(24)

The peripheral portion of the retina is of great importance and its function must be determined in all cases, although normal visual acuity is well defined only in the foveal region. This peripheral vision differs from central vision in two main ways. In ordinary light central vision is the most acute while in low illumination peripheral vision is the most acute, and the peripheral portion of he visual field is remarkably sensitive to moving objects which acts as a valuable protective device in all forms of locomotion. In addition, the periphery of the retina is sensitive to color in a decreasing manner from the fovea outward.

The examination of the visual field for form and color is accomplished by having the eye fix on an object directly in front of it and bringing the test objects toward the eye from the periphery until they are identified and then the results are plotted on a form. The perimeter is used to carry out this proceedure.

In interpreting the findings, the examination any marked contraction of the color or of the form field should disqualify for flying. Other pathologic alterations of the visual field should also disqualify for flying such as nasal contraction or scotomata. Normally the visual field for form, using white test objects is the largest; those for blue, red, and green are successively smaller in the order given; a frequent reversal of green and red is fairly common and may be considered normal unless accompanied by other signs of abnormality. The color fields should be nearly concentric with the form field.(1)

The ophthalmoscopic examination is conducted to detect any congenital or pathologic abnormality in the media, iris, disc, blood vessels, or retina of the eye. Any abnormality discovered on examination that materially interferes with the normal ocular function should disqualify. Any defects found should be classified and described accurately, and where possible substantiated by subjective findings.

Refraction of the eyes is done to determine whether they are emmetropic or ametropic and if the latter the kind and degree of ametropia. Since many ametropic eyes may have normal visual acuity because of the action of the muscles of accommodation, these muscles must be paralyzed and the eye tested in a state of rest. The use of a cycloplegic is used only in the military examination and some of the Commercial pilots.

A subjective examination should follow retinoscopy at once. In the interpretation of the findings if more than 1½ diopter correction in any meridian, in order to read 20/20 in each eye, with accommodation paralyzed or a cylindrical correction of more than 0.5 diopter in meridian, whether plus or minus in order to read 20/20 with accommodation paralyzed should disqualify in the armed forces. The

Department of Gommerce does not always require these standards depending on what branch of aviation the examination is for.(1)

Problems Concerned with Aviation in Reference to the Eye:

Since the advent of aviation the men of the medical profession that have been interested in the care of the flying personnel have been presented with many problems. Many of these problems have had a vital interest in the high development of aviation itself and many have been in the care of the pilot and relative to his physical condition at the time, and protecting him for the future along with the development and perfection of protective flying equipment. The flight surgeon has to try and find out in what way the human body is affected by the process of flying and then assist engineers in developing planes to such a point so as to try and overcome any deleterious conditions. He must also keep the fliers in the best possible physical condition and find ways in which to aid them in this difficult undertaking, to develope equipment for their protection and comfort and make the strain less in every way. As vision is so very important and must always be at the highest efficiency many problems have come up in this field.

One of the first problems to be presented to those interested, concerned the effect of altitude and of oxygen want. Many ideas and proncipals concerned in this problem were laid down by Paul Bert, in his famous "La Pression Barometrique".(1) With the further development of aviation and of aviation medicine more work on this subject has been done. Besides work on the general physiology of the body, under such conditions, experiments on the special subject of ocular functions have been performed and the results recorded.

Probably the first accurate test made of the ocular functions under the conditions of lowered oxygen tension was carried out at the Research Laboratory at Haselhurst Field on December 20, 1917. The experiment was accomplished by subjecting a young individual, with normal eyes, to an artificial altitude of 19,000 feet. Examination of the eyes then revealed a loss in the strength of the ocular muscles and their co-ordination; the near point of accommodation receeded from four to seven inches; there was also marked limitation of the field of binocular fixation; the pupillary reactions, first exaggerated, later became sluggish; and upon the very sudden return to normal oxygen supply, some symptoms of oxygen intoxication appeared.(46)

Other experiments have been carried out following the same general scheme and the results have been quite similiar to those that were first reported. It has been shown that the chief effect is a disturbance of the muscular apparatus of the eye, although it is possible that sensitivity is lessened at extreme altitudes. Up to 10,000 feet ocular changes noted are not constant. Beginning weakness of the ocular functions is usually noted between 10,000 and 15,000 feet, and changes are nearly always more marked at 20,000 feet and over. It appears that at lower altitudes the ocular functions may possibly be stimulated for a brief time but at higher altitudes weakness results. The stimulating effect may be due to the factor of excitement in the first few minutes of a new experience and this accounting for the greater muscular effort, and it is doubted that the early changes are due to oxygen want. At increasing altitudes, depending upon the individual, the eye ceases to function. This is secondary to cerebral or circulatory breakdown.(3) When repeated exposures to 12,000 feet were given to individuals it was shown on measurement of the external eye muscle imbalance that the results were variable, some individuals showing a slight improvement and others a slight aggravation of latent imbalance. However the results of experiments with individuals subjected to acute altitude sickness showed that the power of the external ocular muscles were définitely decreased above 15,000 feet.

During ascent to high altitudes the field of binocular fixation is somewhat contracted in 50 per cent of abnormal eyes but in only 7 per cent of the normal eyes. There is a decrease of accommodative power in about 50 percent of the cases and a more rapid accommodative fatigue. The visual acuity and light perception becomes lessoned but some vision is retained up to the point of unconsciousness.(1)

Experiments of Goldmann and Schubert showed that the visual field contracts on diminished oxygen tension or combined diminution of oxygen tension and lowered atmospheric pressure, especially in the nasal and upper section. However, when these experiments were repeated by others the results differed somewhat. These workers found that on the diminution of oxygen concentration in the inspired air there is no contraction of the visual field beyond unavoidable limits of error of 1-3 degrees. Experiments in the negative pressure chamber also showed that even on marked lowering of atmospheric pressure there was no constriction of the visual field, if the subject's attention could be held, the latter weakening considerably on beginning altitude sickness. On the basis of these findings some doubt has been cast on the assumptions of Goldmann and Schubert of an organic diminution of retinal function on the temporal side.(26) Another group of workers found that on oxygen deprivation the central visual acuity remained unaffected, even at the peak of oxygen of deprivation, and that angioscotoma present widened progressively with progressive oxygen deprivation until it obliterated the visual field except for a region 8 to 10 degrees about the macula. Also there is considerable variation in the extent and rate of widening of the angioscotoma, not only between individuals, but also to a lesser degree in one eye as compared to the other eye of the same individual. (14) It has been suggested that the presence of the angioscotoma may be best explained on the basis of dysfunctioning of the synapses in the retina due to lack of oxygen. (13)

The occurrence of headaches, blurring of vision and demonstration of congested retinal veins following altitude flight has usually been attributed to the effects of anoxemia. The suggestion was made that these conditions might be referrable to the expansion of intracranial and intraorbital liquid media at the high altitudes. This matter was referred to Captain Harry G. Armstrong, Director, Army Laboratory of Physiological Research, Wright Field, Dayton, Ohio. Captain Armstong demonstrated among animals at least that manometric spinal fluid studies indicate a definite increase of spinal fluid pressure.(21) The intraocular pressure showed no significant increase even under the most extreme barometric pressure changes, in tests conducted using rabbits as subjects and measureing directly from a manometer connected to a needle introduced into the vitreous humor of the eye and then the animals placed in a low pressure chamber.(29) Therefore, along with other observations of brain trauma, due to other causes, it seems possible that in high altitude flying, if the pilot is unprotected, there may result a neurological syndrome, comparable to slight brain concussion, with a further possiblility, if the stresses have been sufficiently violent, to induce microscopic brain hemorrhages, or brain swelling from edema and which may account for the ocular manifestions.(21)

For a time it was believed that ascents to high altitudes produced changes in the anterior lens surface of the eye when it was noted that in rabbits these structures showed beautiful radial laminations of hexagonal prisms on histopathologic examination. Control studies, showed that these prisms occured normally in the rabbit.(1) Another experiment consisted of exposing young male rabbits to altitudes of 18,000 feet for four hours daily for five weeks. It was observed that the pathological studies showed no changes in the eye findings from normal.(2)

The administration of oxygen prevents the onset of changes due to altitude and quickly restores ocular functions to normal even when there is lowered atmospheric pressure.(3) On ascent the dulling of vision normally takes place gradually without the individual being aware of its disappearance and if , at high altitude, oxygen is given one is usually surprised to notice the marked improvement of vision, the apparent increased brightness of the sky and sun.(1) An interesting account in relation to this is given by Schroeder in his writing of his altitude record flight: "When I reached 25,000 feet I noticed the sun growing very dim....the trend of my thoughts was that it must be getting late, that evening must be coming on, and that was the reason for the sun's getting so dim....as soon as I started to inhale the oxygen the sun grew bright again....and the day seemed to be a most beautful one."(35)

The physiological disturbances to which the pilot is exposed result only in part to the altitude to which he is exposed and to a great degree to the acceleration and speed of the machine.(4)

A study of the visual acuity immediately following acrobatic flights at slight altitudes revealed an increase in the visual acuity for reading black signs on a white background in 91.5 per cent of all cases. In general this increase surpasses 0.1. Also an increase in visual acuity in reading white signs on a black background was noted in 81 per cent of the cases which did not, however, surpass 0.1.(40) Another worker found that when he divided his cases into two age groups there was a difference between the two. In the older group (29-36 years) after prolonged flight of 45 minutes to 1¼ hours there occured a diminution of visual acuity persisting for one to two hours. No such diminution was noted after short flights. In the younger group visual acuity

The changes in the visual acuity were insignificant, averaging only about 0.05.(37)

There were no significant changes in accommodation noted and the aviators examined had not been exposed to any anoxemia.

A factor which may play an important part is increased irritability of the cerebral cortex, which is exposed to various influences during flight (noise of the motor, excitement, and vibrations of the plane). These influences likewise affect the optic field of the cerebral cortex, exciting it, and consequently after such a flight a slight stimulus suffices to create a visual sensation on the retina.(40) The condition may be caused by the changes in the circulation of the blood occurring in rapid flight and the accelerated changes in direction of flight.

These changes noted in the various age groups are better compensated for and disappear sooner in the younger pilots.(37)

Of the general physiological effects, those which have the greatest importance are the disturbances of the circulation. In those maneuvers which result in increased "normal" acceleration, there is a displacement of the blood from the upper to the lower parts of the body. In consequence of this there is the tendency to emptying of the vessels of the upper part of the body, especially of the head. The heart itself may be emptied, so that even though the normal heart-beat persists, the circulation is at a standstill. With a limited value of the centrifugal force involved, the normal physiological mechanism asserts itself.

When the disturbing force (for example, the centrifugal force involved in coming out of a fast and steep dive or in a tight loop) is excessive, the physiological power of adjustment may fail. In any case these reflex adjustments take some time, a matter of seconds, and may not be rapid enough to meet the sudden emergency.(4)

The ophthalmological interest of all this lies, of course, in the fact that the visual mechanism, the retina, optic nerves, and cerebral optic centers are particularly sensitive to anoxemia and when a marked reduction in blood pressure in the vessels supplying these areas occurs, disturbances of visual function are a natural consequence, and perhaps loss of consciousness if the cerebral circulation is greatly reduced.(1) In military aviation, with the increasing speed of airplanes and the more exacting maneuvers necessary in aerial combat, the sudden loss of vision known as "blacking out" has become a familiar phenomenon, and one whose danger to the pilot and to those depending on him, is very obvious.(4)

The condition of "black out" is a definite clinical entity, which occurs in varying degrees from temporary diminution of visual acuity to a sensation of complete blackness lasting for some seconds. Some pilots describe the sensation as arising in the course of a sudden power-dive, while others associate it with a reduction of speed and the return to the horizontal at the end of this maneuver.(33) Also there is the pilot that states that everything went black and he had no recollection of landing his ship, and he then collapsed immediately after landing with a loss of vision present for several hours.(5) Generally the eyes feel as though they are about to be shoved from their sockets and there is a dry gritty feeling to the eyelids.(1) The blindness may last for a few seconds to a longer period and the return of vision may be sudden and dramatic as its disappearance or it may not return in such a dramatic or rapid way with effects more severe and prolonged. Fortunately occurrence leaves no injurious after effects, but it is not without danger since it involves temporary loss of control.(4)

In 1918, Garsaux experimented with dogs, and turned them at a rapid rate. The dogs were then autopsied and some showed actual brain damage due to pressure of the brain against the skull. Others showed a cerebral anemia and engorgement of the splanchnic area.(5) Another experiment with animals at about 5-6 G's and higher forces showed some changes that occur in the eye. Pathologic findings found in animals show: The general appearance of the animal to be normal except for hemorrhage from the nose and congestion and hemorrhages of the conjunctiva of the eyes. The gross appearance of the external surface of the eyes shows them to be congested and the vessels of the conjunctiva stand out prominently. The lids are congested and swollen and there is increased lacrymation. Sub-conjunctival hemorrhages are not uncommon. Internally there is no evidence of abnormality. Microscopically the eye is negative except for those changes noted in the gross examination.(1)

Experiments performed on human beings placing them in the sitting and recumbant positions at the Aviation Institute in Berlin found that, in the sitting position prolonged acceleration beyond 5 G produced visual disturbances. When the person was in the recumbant position visual disturbances develaped at 14-15 G's although brain and consciousness were not affected.(15) With a great amount of work done on this subject and still greater amount being done all the time it has neen found that the most usefull method to combat t is condition of "black out" is for the pilot to develppe by traini the use of his abdominal muscles and the firm contraction of th . (4)

Von Diringsho en claims that the visual disturbances of the flier are due to h static changes, a fall in blood pressure in the cerebral arter es as compared with blood pressure at the level of the heart.(5) t would seem that the condition is the result of some temporary vascular abnormality due to the effect of centrifugal force, but it is still a matter of speculation as to whether it is a disturbance located peripherally in the eye or centrally in the visual cortex.(33)

The influence of illumination on visusl acuity is of considerable importance in aviation. This has created several problems some of which have been worked out and others are still in the experimental processes. It has been found impossible to derive an exact formula to express the relationship between the factors of illumination and visual acuity, but it has been found that from zero illumination visual acuity increases rapidly up to 5-6 mean candle power, then more slowly up to a maximum between 30 and 50 candle power. Beyond 30-50 candle power visual acuity diminsishes due to light aberration or blinding. The problem of light in aviation therefore resolves itself into maintaining as nearly as possible an optimum illumination.(1)

In daylight flying, only glare need be considered which is a disturbing factor in the vision of air pilots, giving rise to disturbance of visual acuity, accommodation and fields. Flying into the sun, above clouds, overwater, or in the tropics on a sunny day exposes the pilots eyes to glare and in metal aircraft this may occur when the suns rays are reflected from a part of the aircraft structure into the pilot's eyes.(4)

With ascent the sun gradually loses its yellow color and becomes whiter and whiter, at the same time, because of the decrease of dust particles and gas molecules, the sky appears relatively dark. By actual measurement the sun has been found to be brighter as altitude is increased such that at 72,000 feet it is 1.2 times that at sea level. The suns spectrum grows longer with altitude and the short ultra-violet vaves are notable increased.(1) With continuous or frequent exposure to the more actinic effects of sky and sunlight at high altitudes may produce conjunctival irritation or even conjunctivitis.(4)

The glare from the reflections may be eliminated to a large degree quite satisfactorily by covering the offending part or parts with a coat of dull paint. Also glare may be reduced by the use of tinted lenses in goggles in open airplanes or by the use of sun

of the best ophthalmic crown glass, free from visible or effective striae, bubbles, or flaws which might impair the optical or visual qualities of the lens. The tinting of the glass should conform to that known as "calobar", or its equivalent. The dominant hue of the glass should be sage green, and there should be no strong absorption band in the visible spectrum but a high absorption throughout the ultra-violet and near infra-red regions of the spectrum. The lenses should be mounted in the frames without strain and the frames should be of such a material and construction that the lenses will not get out of position with relation to the eyes or to each other.(1)

With a decrease in vision in the twilight hours there has been an attempt made to find suitable filters to increase vision during this period of the day without diminishing day vision, as the sensibility of the eye is of great importance to the flier at these hours and for nocturnal flying. Smoked glasses and yellowish green Fiesal glasses of 20 per cent permeability have been found best, and an increased sensibility up to a 55 per cent maximum could be maintained for three hours.(47)

The question of illumination at night is complicated by the fact that both glare and under illumination may exist. This is due to the fact that the pilot should at all times be able to clearly read his instruments and maps in the cockpit and at the same time be able to see the terrain in the darkness below. It has been found that these two requirements are incompatible with each other and it has been necessary to adopt a compromise. At the present time there are several methods employed in cockpit lighting but the two most common are by indirect individual lights and by a single flood light located back of and above the pilots head. Both of these methods utilize as low a degree of illumination as possible so that interference with outside vision is reduced. A new method of instrument lighting that is undergoing tests at this time consists of ultra-violet illumination directed onto the instrument panel which contains instruments having radium paint dials. The practicability of this latter method or proof that the ultra-violet light used is not injurious to the eyes has not as yet been definitely determined.(1)

Another worker describes a series of experiments in using red, blue, and white lights for pilot's cabins and comes to the conclusion that the highest sensibility exists towards the white light, the lowest towards the red. The difference between red and blue light is so small that it is of no significance, but the white light gives us better conditions for distinguishing the details, makes our vision more acute, and is less fatiguing. He finds that the advantage of red(or blue) light as compared with white is greatly diminished by its drawbacks, so he offers after all to use the white light, but it should be eased by opal glass and the light should not exceed 5 ex. The lighting of the airdrome should be similarly arranged, the lamps protected by opal glass and then should not be brighter than 5 ex. so as to adapt the pilot's eyes before the start.(27)

The present methods of illuminating instrument panels and cockpits are capable of improvement. This is shown by the large number of complaints of eye strain among pilots engaged in night flying. This strain is caused not only by the low illumination of the cockpit instruments, the necessity for the pilot's eyes to continuously accommodate for near and light in the cockpit and for far and darkness outside, but also it may originate from beacons, signal lights, flares, floodlights, and search lights shining into the pilot's eyes.(1)

While this is more of an engineering problem than a medical problem it is one in which the medical profession and those in aviation medicine are interested in very much.(22)

Of particular interest in night flying is the presence or absence of night blindness or dark adaptation. Dark adaptation, as the term implies, is the ability of the eye to adapt itself to darkness.(1) The phenomenon of adaptation to the dark is a very definite function of one's visual apparatus and although this ability has been the subject of much study in physiological laboratories, its possible importance in relation to airplane pilots has been neglected till very recently.(30) The eye is capable of two types of vision. The first is form and color sense for which good illumination is necessary, and the second is light sense which is detected in subdued light or twilight and is concerned with night blindness. Numerous studies have shown that there is a definite relationship between visual purple regeneration in the eye and Vitamin A and between avitaminosis and poor dark adaptation.(1) Ferree and Rand have recently studied the problem of night flying in its relation to dark adaptation and reached the following conclusions:

"In determining fitness for night flying important functions to be tested are (a) the ability to see at night and at low illumination and the effect of dark adaption on this ability and (b) the amount and speed of dark adaption. In the latter function, the speed of adaption seems to be more important than the amount. The night flier needs especially the power to change his vision quickly from the illuminated cockpit and instrument panel to the outside world and back again. Normal or better than normal sensitivity in light adaption is of course also important. The eyes that are needed for night flying are the best of what might be called the normal group, that is, of those that have both good dark and good light vision. More important than speed and range of adaption, however, is the place in the scale of sensitivity in which the change occurs. That is, it is quite possible that a candidate might have a good range and speed of adaption and still a poor power to see at low illumination both at the beginning and at the end of the period of dark adaptation. Such a person would be obviously unfit for night flying. To be fit for night flying the candidate must have a normal or better than normal rating in power to see at low illumination at the beginning of the period of dark adaptation and throughout its course.

"Two functions are involved in the ability to see, namely, the ability to sense light, or to discriminate difference in light and brightness, and the ability to discriminate detail, or what is commonly called visual acuity. Either of these may be used in testing the ability to see at low illumination and the effect of dark adaptation or this ability."(17)

High speed of the modern airplane have given such a value to time in its relation to space that any delay to visual reception can at times prove hazardous, and if a pilot is slow in his adaptation he is necessarily flying blinded for a period greater than normal.(30)

At the present time there is no generally accepted instrument with which to measure night blindness, no standard examination procedure, nor has an average normal been agreed upon but with the great amount of work being done it is reasonable to assume that these matters will be clarified shortly.(1) Also it will be necessary to adopt some practical standard test for determining retinal sensitivity and adaptation of the eye to nocturnal conditions, or a test for visual efficiency under night flying conditions.(22)

There is the problem of those pilots who have flown successfully and suddenly experienced difficulty with the final stages of their approach. An approach which errors whithin so small a degree as plus or minus five feet can end in severe accident.(28) As Chase has said: "An eye with latent hyperphoria (of more than one diopter) will quickly tire and fail to see maps and instruments correctly, expecially since accommodation is greatly diminished in the low oxygen of high altitudes, and because the effort to focus the ray of light on the retina is apt to induce a tonic action of the ciliary muscle of accommodation, as well as the internal recti muscles which turn the eyes in when viewing objects at close range. This tonic action produces errors of distance judgement and leads to crashes in landings."(10) The repetition of these events calls for a very careful examination of the binocular state. The disharmonies that heterophoria may produce in air-pilotage are well known and proved, but on these very grounds a false jump to conclusions must be carefully avoided. Every discovered phoria with a history of flying trouble is not for certain the absolute root cause. Mental and physical fatigue; the first indication of some illness of slow onset; a growing dislike to flying; neurathenia- all these must be eliminated. It usually happens that the pilot with a pure ocular muscle defect is anxious to return to the full duties of his branch and resents the visual handicap which is confining him to the ground.

Heterophoria may occur as a result of proasthenia, from malaria, or from head injury. It is not by any means a condition that tends to persist once the primary cause, illness or accident, has cleared up, but there undoubtedly are times when heterophoria remains as a genuine state and requires active attention. It is usually found that such a condition is of the inherent type, which has been kept within bounds in a body physically and mentally sound, but that the constitutional upheaval has left its mark in a potentially weak spot.(28)

Treatment, hitherto, has consisted of improving general physical fitness by the usual hygienic measures, which affects the tonus and coordination of the intra and extraoculr muscles precisely like that throughout the rest of the body and nothing further could be done. Rest from excessive reading, improvement of lighting, and similar suggestions were always recommended where applicable.(36) Lately there has been introduced the use of orthoptic training to aid in overcoming this condition and associated conditions of defective depth perception, deficient angle of convergence, and deficient prism divergence. At the present ophthalmic surgeons are divided into two groups upon the merits of orthoptic treatment; manely, those who consider it most valuable and those who do not. The reason why this devision exists is because too little time is given to analysis and too much to empirical treatment. The great variety of binocular disharmonies that are arranged under the group heading of heterophoria are very real conditions, carrying with them often extreme suffering. The relief that can be given by orthoptic treatment in a great number of these cases is too well established for argument.(28)

Aviators constitute an ideal group for the correction of heterophorias because of their vital interest. The correction of these defects is considered entirely feasible as well as an economical procedure by the intelligent use of orthoptic equipment. The fact that the flight surgeon is attempting to remedy a defect hitherto practically untreated has a beneficial psychological effect and tends further to strengthen the bond between the pilot and his flight surgeon.(36) In any event it is necessary always to form an opinion as to the optimum time to attack the condition by exercises. When symptomless heterophoria exists it is often better left alone, and in symptom-producing cases no matter what the method of treatment no time is wasted that is spent on a complete survey of the patient's mental framework.(28)

Pilots sometimes experience disturbing optical illusions, such as an over-estimation of the sizes of surfaces, the landing ground or stretches of open water, and these may play a part in causing faulty landings. Even in civil flying, passengers especially may be intriqued, if not upset, by false impressions of the position of buildings, the contour of the landing-ground, and the apparent movement of stationary objects. The last named phenomenon is, of course, analogous to the sensation we have all experienced when, in a train which is moving slowly and quietly, we conceive that we are stationary and other trains are in movement. Little in the way of treatment for this condition has been introduced.(4)

In the past goggles have been part of the standard equipment of all pilots. When flying in a plane with an open cockpit goggles must be worn, however, most of the modern types of airplanes are constructed with an enclosed cockpit and thus eliminates the use of the goggles. Goggles from the start have offered several unsatisfactory conditions. They have been uncomfortable and ill fitting, too hot in summer and fog over in the winter, and the field of binocular fixation has been small although this has been impoved somewhat recently. The field of binocular fixation of the standard flying goggle when shown by a composite field constructed from the results of examination of fifty flying cadets gives the binocular field of fixation with this goggle to be slightly more than 20 degrees, extending to 30 degrees in the inferior field. It is evident that this field is sufficiently large for safe and efficient flying, as the greater part of the flying performed the last few years has been with this or a similar type of goggle.(43) Also, Friedenwald has shown that 20 degrees is about the limit of the binocular field utilized by a person under usual circumstances.(18)

The goggle pads should be made from molded sponge rubber and conform exactly to the shape of the face. The fit must be accurate to avoid discomfort from pressure effects or from leakage of air although some ventilation is necessary. The lenses should conform to the requirements and be of high quality. Good lenses are expensive but they are one of the very best investments any pilot can make.(1) Lately lenses have been furnished in which presbyopic segments are inserted, and are placed so there is no interference with distant vision. These have proved to be very satisfactory in reading the instrument board, reading maps while in flight and for similar purposes. Corrections for distant vision have been ground in goggle lenses, but this procedure has not proved as satisfactory as the presbyopic correction. A spectacle frame designed to be worn under the goggle has proved to be satisfactory in many instances.(43) Even the best goggles are inherently unsatisfactory; in the past, and in certain instances quite recently marked eye discomfort and serious eye defects have been traced to the use of improper goggles.(1)

The ocular functions are affected by nose and throat infections and may result in a visual neurocirculatory distrubances. Pilots suffering from nose and throat infections should not be permitted to fly, particularly when there is any enlargement of the blind spots, and the periodic blurring of vision in these conditions are sufficiently common to be the cause of an occasional crash.(3)

Visual disturbances are a common complaint in carbon monoxide poisoning from fumes escaping from the manifold and exhausts coming in around and through the fire-guard into the cockpit or pilots capin and inducing exposure to the gas. These complaints are variable and may be a statement that every light in the boundry line of the airport appears as a huge cross, or a complaint of diplopia and a inability to accommodate. In any event the cause should be remedied so no serious results occur.(11)

Experiments show that alcohol produces ocular manifestations but these are of little significance until indulgence is sufficient to interfere with binocular fixation and this point varies considerably in different individuals. Visual acuity is decreased, in just what manner it is finally affected is not known but it is believed to be due to a blunting of the visual perceptive center in the occipital lobe rather than any effect upon the eye itself. The findings of depth perception are inconsistant and any defect is believed to be mainly due to muscular imbalance. The test with the Maddox rod shows a definite tendency toward esophoria. This finding was constant, gradual and progressive; and it is explained as a weaking of the external rectus supplied by the abducens nerve. This nerve is the weakest of the crainial nerves and is affected in almost any type of cerebral lesion and is probably slightly weakened by alcohol. The act of accommodation shows no appreciable or signficant change. The angle of convergence showed a definite constant and gradual progressive decrease, and is probably due to a diminished muscle tonus and muscular control.

The ocular manifestations of moderate intoxication disappear within a few hours, and the findings of a check up examination done 10 hours later shows practically no variation from the normal findings before the administration of alcohol.(31)

Incident to the ear studies consideration of the oto-optic reflex has resulted in observing that when both ears are violently stimulated there may be observed a dilation of both pupils. This is interpreted as a cervical sympathetic, stimulative reaction. Nystagmoid movements, usually to the left, regardless of whether one has right or left cerebral dominance, a blurring of vision, with the letters apparently shifting slightly to the left and a definite disturbance of depth perception and, in a few cases, a transitory vertigo have also been observed. It is believed, therefore, that there is a possibility of hazard if violent static discharge occurs in both ear phones at a critical moment of passing over obstructions. The pilots seem to have sensed this possibility for they usually remove the ear phones before coming in for a landing and thus eliminating this hazard.(21)

It is also important to bear in mind the effect of fatigue on the ocular muscle balance. The fatigue may result from excessive flying and air activity, or may be due to outside activities of various natures. This fatigue, which is easily measurable, has marked effect on the intergrated activities of the eye muscles; it has a tendency to cause errors in judgement; and has a marked bearing on the speed of adjustment in individuals of all ages, more notably so as age progresses. With the work that has already been done on this subject of fatigue, it shows that those aviators who have a good convergence test usually are able to resist visual fatigue for a longer period than those who do not.(25)

Orthoptic equipment offers possibilities from the standpoint of developing new test for the measurement of the eye functions and the simplification of present tests, and subsequent study may bring out more reliable indexes of fatigue than are available at present. The study of fatigue and the time of recovery is an important phase of the experimental side of aviation medicine that has had only the surface scratched and offers much in the way of a necessary better understanding.(34)

Conclusions:

The field of aviation medicine is a relatively new subject and has developed very largely since World War I, with aviation and aviation medicine being intimately associated with each other.

The value of the eye and its normal functions were recognized very early by those first interested. The piloting of aircraft demands good balanced vision, because of the high speed at which airplanes travel, the necessity of avoiding obstacles in the air, the judgement of distance in take-offs and landings, the necessity of correctly interpreting colored signals and lights, the ability to recognize the gray horizon at night, and the necessity of focusing the eyes on distant objects, then the instrument panel and from there to the maps on the knees and back again.

As the eyes are of the utmost importance the ocular examination is searching. The examiner tries to make sure the visual acuity, muscle balance, depth perception and visual judgement along with other ocular functions of the pilot are perfect and fullfil all the requirements of regulations of the Military Services and the Department of Commerce.

Many problems have been presented to those in care of the flying personnel since the advent of flying. Many of the problems have been worked out satisfactorily while others have only been partially solved. Altitude has a definite effect on the ocular functions and the effects can be remedied largely by the use of oxygen. Speed and acceleration also have definite effects on the eye, and although a great amount of study has been carried out little has been discovered that will control the conditions. Glare from the sun and reflections along with glare at night from the cockpit lights and outside conditions creates a very definite problem. The glare of daylight can be controlled to a considerable degree by the use of dull paint and sun glasses, and at night by good illumination and proper filters. This problem has not been completely solved and much can be done in the way of improvement of the situation. Recently the importance of dark adaptation in airplane pilots has been presented and at present

of heterophoria is well known and the disharmonies well proved and with studies of the subject it has been shown that use of orthoptic training, in certain cases, along with good hygienic measures and rest is of value. Optical illusions occur at times and little has been found to aid this condition. The problem of goggles has long been present and the goggles have been perfected to a degree. At this time the probl is being taken care of largely by the use of enclosed cockpits. Defi ite disturbances of the eyes are caused by nose and throat infectio s. Carbon monoxide poisoning causes disturbances and the condition i controlled by controlling the gas. Alcohol affects the muscle bal ce and flying under its influence is prohibited. Static in the e s from the radio may cause ocular disturbances and this is by removing the ear phones. Last but not least fatigue causes eye upsets and any manner in which fatigue can be condition.

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