PANEL DISCUSSION

USES OF HIGH ALTITUDE PHOTOGRAPHY*

Chairman and Moderator: Mr. Leon T. Eliel.

Panel Discussants: Mr. Lewis A. Dickerson, Army Map Service; Major Robert A. Patterson, U. S. Air Force; Colonel George G. Northrup, Joint Chiefs of Staff; Mr. Pliny Gale, Jack Ammann Photogrammetric Engineers; and Mr. Revere G. Sanders, Fairchild Camera & Instrument Corp.

The Chairman; Mr. Eliel: I will first introduce the panel discussants.

On my left is Mr. Pliny Gale. He is an executive of Jack Ammann Photogrammetric Engineers which is currently undertaking the high altitude mapping for the Army Map Service. Next to me is Mr. Lewis A. Dickerson who gave an excellent paper this morning. He is in charge of the photogrammetric section of the Army Map Service. On my right is Major Robert A. Patterson, Flight Surgeon of the Army Air Forces. Major Patterson is not only a Doctor of Medicine and qualified to talk to us later on the physiological aspects of this problem, but he is also a jet pilot and knows this subject thoroughly. Next to him is Col. George G. Northrup, serving on the Joint Chiefs of Staff, at the Pentagon Building. The Colonel has had a life-long experience with aircraft and photogrammetry and is well qualified to talk on high altitude flying. Further on is Mr. Revere G. Sanders of the Fairchild Camera & Instrument Corporation who will tell us about cameras and how they function at high altitudes.

I will quickly mention the program agreed upon for this meeting so that you may note the sequence of the subjects. It may be well to discuss each question following the presentation. The first subject is "Airplane Performance Problems at High Altitudes." This is followed by "Navigation at High Altitudes," "Camera Performance and Film Performance," "The Physiological Effects at High Altitudes," "Weather Problems," "The Picture, what we see and what we do not," and "The Map." That is the outline of the agenda. We will take up each phase of the problem, section by section, and those of you who can, will please participate in the later discussion.

The first subject, "Airplane Performance Problems of High Altitude Flying" will be discussed by Col. Northrup.

Col. Northrup: An unsupercharged internal combustion engine develops about one half its rated horse power at 18,000′. As power falls off, speed does also and the ceiling of the aircraft is reached in the low altitude ranges. If high altitudes are desired, supercharging of some kind is a requirement. Costs and maintenance mount as operating altitudes increase; experience on certain aircraft has shown that maintenance doubles at operating altitudes of 30,000′ as compared to operations at 20,000′. The type of supercharging will depend on performance requirement, and aircraft design characteristics. Though the performance increase will be marked, the costs of operation and supply problems —especially on jobs away from home bases—will be commercial features that will certainly have to be taken into consideration in calculating dollars per square mile.

Crew comfort, particularly where precision work is contemplated, increases in importance with altitude. Heat, cabin pressurization, sealing of instruments, ignition harness, supercharging, high specification dielectrics, shielding and bonding, camera operating condition, careful maintenance of cold operating condition unless adequately heated or within the pressurized area, crew clothing, oxygen requirements are items that must have consideration.

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Heat is absolutely essential; without heat, windows and instrument glass frost over, cameras malfunction, films break, condensation occurs on the way down adding another problem to camera, electrical and instrument maintenance.

The entire problem of photography increases with altitude and of course the weather is always against you. The cloud problem above 25,000′ is little greater than below as most weather is below you.

I will not attempt to comment on jet airplane operation, but will leave this entire field to Major Patterson who has had much jet experience—I have not. However the jet is ideally suited for aerial photography because of its minimum vibration characteristics, an old enemy of high quality photography.

Mr. Eliel: I now ask for any questions or problems. I think the Colonel has covered the subject very well. From 28,000′ upward, the performance readily becomes very critical unless everything is working with absolute perfection; if it is not, the equipment will give no end of trouble from that height on up. I have hoped to get lots of questions from those in attendance here.

The next subject outlined for our discussion is the problems of navigation at high altitudes. The discussion will be led by Mr. Pliny Gale.

Mr. Gale: Friends, it would seem to be a proper concept that an increase in altitude would result in an increase in visibility. At low levels this is probably true, but in altitudes now considered "high altitude" for photography we find this is not the case. Many problems confront us, and one of the main ones is the haze encountered because of the great layer of atmosphere through which the earth is viewed.

Nevertheless on our present project we are using contact navigation. Although the forward visibility is reduced by haze, there is still a "maze" of detail visible near the airplane. This detail is small in appearance because of the height from which it is viewed, and therefore a lot is crowded into a small space. This crowding makes it difficult for the pilot to find his check points along his flight line quickly.

We have found that one of the best maps to use is the regular sectional aeronautical chart commonly seen around any airport. It is true that the scale is small, but generally the detail shown is reasonably accurate in position. High altitude photography is being used to cover large areas because of the relatively small number of photographs required. This generally means, then, that the flight lines are long. For long flight lines, a lot of map would be required if the map be of large scale; since it is desirable that the pilot have as little map as possible, a small scale for the chart is an advantage.

Aside from visibility, there are many conditions that make actual operation of the airplane much harder than at the average altitudes. These are both mechanical—affecting the airplane—and physiological—affecting the crew. These handicaps make it very desirable to reduce the amount of high altitude operation to a minimum and call for careful advance-of-flight planning. We want to fly as few flight lines as possible, and to have them as accurate as possible so that reflying may be minimized. To help the pilot get on line and stay there, we use the best compasses and a peloris, in addition to the maps. The peloris is a small optical device with a hairline on it that appears to be the flight line projected onto the ground.

We are aware that there are more advanced instruments being developed than those we are using. I make particular reference to the Shoran instrument that indicates a straight line and holds the ship on a predetermined straight-line course. This is in military use but is not yet available to the commercial contractor.

Our experience to date has been all along the Eastern Seaboard and at 30,000 feet. Some of the other commercial contractors have been working in their parts of the country and at altitudes up to 36,000 feet. These conditions present other, but related, problems which must be met and overcome. Although all of these problems are presented by the increase of altitude, they are not at all insurmountable. The experience we are now getting will contribute to more efficient future operation!

Mr. Eliel: I think Mr. Gale has thoroughly covered a very difficult subject. A question which occurs to me concerns the instruments. Mr. Gale spoke of depending more on instruments than we have in the past. I wonder what particular instruments his organization depends on. I hope he can outline their uses in some detail.

Mr. Gale: I will be glad to as far as I am able. The greater dependability of instruments, in our case, is not as much in new instruments as it is in more than a usual amount being placed in certain instruments such as the directional gyro. Unfortunately I haven't yet seen our airplane being used on our high altitude project and therefore cannot go into detail regarding the exact arrangement of the instruments being used.

I believe that the process of high altitude photography will require everything possible to accomplish the most work in the least amount of flying. Use of such instruments as the Shoran flight line indicator will probably become nearly standard procedure. That is my personal opinion; nearly everything is becoming more highly instrumentalized all of the time.

Mr. Struck: In Mr. Gale's opinion what is the desired height in altitude for photography which he believes it best to start with? He indicated that navigation is the problem. What would be the desired method of navigation in an area in which there are no maps?

Mr. Eliel: That may be a difficult question to answer. Mr. Gale, can you supply an answer?

Mr. Gale: That question requires me to qualify my earlier remarks. As stated, we are operating where maps exist. Therefore we haven't been faced with the difficulty of no maps: that is a problem that must be solved where it exists. Our method along the east coast would not work in certain areas in this country, for instance Utah and the mountainous regions where maps either do not exist or show insufficient detail. It may be necessary to make a flight map by putting in preliminary strips of photography across the area at intervals.

(At this point Mr. Deeg described a test project flown from Pittsburgh to Dayton, maintaining an even side-lap, using a Polaroid Land Camera. Photographs taken on the way out were used for navigation on the return trip. The results were very promising. There was some discussion at this point concerning the possible effect of topography on such a procedure. Nothing definite could be stated due to the absence of experience.)

Mr. Aslakson; Coast and Geodetic Survey: I have worked considerably with Shoran. In discussing navigation instruments, no mention was made of the Shoran straight line indicator for navigation purposes. With certain instruments which we have used, no map of any kind was required. You can draw your flight lines on a space according to your scale of 1:1,000,000 and, without any reference to the terrain whatsoever, you can follow those parallel lines. I have seen a relatively green crew fly a 100 mile flight line with no greater deviation than a couple of hundred feet and sometimes less. Of course these are generally curves as no correction has been made to the horizontal plane. However, excellent results were obtained.

Mr. Eliel: To your discussion of Shoran I will mention that there is not much of the equipment at present. The P-38 airplane is not large enough to carry the equipment and the people who fly that kind of plane will have to depend upon simple methods of navigation.

Mr. Park: I wonder if Mr. Eliel can explain a little about his firm's operations over uncharted and unmapped country.

Mr. Eliel: As a preface I wish to mention a few of the problems in high altitude work. At 36,000 feet, navigation is difficult because the higher the altitude the more the country flattens out, and it becomes more difficult to read the map. A pilot can see the ground only about 30 miles ahead of him; also he can't see very close at each side. About the only things that he can see are major features such as very high mountain peaks, bodies of water, rivers, the smudges that represent towns and things that are a little small and too light for photographic navigation. I may say that on large projects we had 60% of reflights. Those are some of the difficulties of navigation under the conditions that were present. Another thing about high altitude flying is the very high wind; we sometimes experienced wind velocity of 150 miles per hour. We had always thought that the air would be quite smooth. Actually that was not the case; we encountered a great deal of very rough air, so bad at times that you could hardly regulate the throttle. The wind was very changeable: the crab angle was 15 degrees off on various flight lines. We also have experienced trouble on the overlap. We have not been able to decide whether this trend was really due to variable wind which caused the plane to change the ground speed, or electric equipment misbehaving. The flying suit, due to the cold and rarified air, loses the insulating effect it ordinarily has at sea level, and consequently the pilot is susceptible to mistakes due to cold. We believe that in flying over uncharted terrain, the pilot needs automatic navigation aids, especially when visibility is bad, as it quite often is, and we are rather alone perhaps in the theory that we should have especially heated equipment. Mr. Gale made some reference to the instruments we now use, but it is difficult navigation which is a complication; on this recent high altitude work, contact navigation was inadequate, whence the pilot was entirely dependent on instruments of the plane.

Mr. Allen C. Bock: Mention was made of the trouble with the end lap and forward lap. It was stated that it might be the result of the effect of cold temperatures on the equipment. Am I correct in assuming that the equipment is being operated at nearly outside temperature or is the airplane heated?

Mr. Eliel: The equipment is protected from the outside temperature only by the skin of the ship, as far as our personal experience is concerned. We provide the camera man with a heated suit and give the camera a heat jacket. The inside of the plane is not heated.

Mr. Dickerson: Part of my question has already been covered. In our special project, tolerance for overlap, and side lap as well, is 10%. Thus far we have not departed from previous practice at lower altitudes. My question of Mr. Gale is, do we need to loosen up on these tolerances in order to take care of the difficulties at the higher altitude.

Mr. Gale: Of course from the commercial operator's standpoint, it would be better to have more tolerance, and particularly more overlap. However, to do that has not given us as much trouble in proportion at the high altitude work as in the lower altitude.

Mr. Eliel: It is always easier from our standpoint to have more latitude to work with. The tighter the specifications, the more the overlap, the more the navigation problems.

Mr. Gale: We have heard reports from two or three speakers who have had experience in navigation at high altitude. I should like to have Mr. Bock describe his experiences and difficulties.

Mr. Bock: I think Mr. Miller is better qualified than I am. Fortunately he is here; his knowledge is more first hand than mine. Mr. Miller will give us some information about his high altitude experiences. He has been making 36,000 foot flights in his P-38.

Mr. Miller: Our experiences in the navigation at high altitudes are based primarily on the same type of instruments that Fairchild is using. We have found that contact navigation, on which Mr. Gale indicates his crews are relying at the moment, can be properly applied at 30,000 feet. However, our work at 36,000 feet is an entirely different proposition. The type of instrumentation that Mr. Eliel suggested is adequate. When it is possible, however, we believe that vertical angle observations, when they are available, are certainly more satisfactory and highly desirable, presupposing that a man is capable and has the opportunity and time to use them. We have used them to some extent. However, I must admit that our experience on the Army Map Service contracts has been where the roads, highways and railroads run parallel to section lines and to our direction of flight. Therefore our problem has not been nearly as acute as that of Fairchild or Jack Ammann. However, those are the things that we anticipate, and we feel that they are problems that can be easily overcome with the technique that I suggested.

Mr. Eliel: Mr. Miller's comments are interesting. I think that the trend of his comments pertains to a large area. We are operating in a sizeable project. Each one's problems obviously apply to his own area. We realize quite well the difference between the mechanical problems in flights of 30,000 feet and 36,000 feet and the difficulties that the extra 6,000 feet bring up.

(Mr. Sanders' paper, which was presented next, is not available at this time. It will be printed in the next issue if then available. The subject is camera performance at high altitudes—*Ed.*)

Major Patterson: The physiological effect of high altitude flying is a complicated subject. I will try to cover it briefly, providing a basis for discussion, and to limit it generally to aspects of your current operational problems. As Colonel Northrup mentioned, a plane requires supercharging at about 18,000 feet. At this level a human being is getting only half as much oxygen as he should. We, in effect, have to start at about 10,000 feet in supercharging the human being with additional oxygen. There are many pilots who have flown at 17,000 or 18,000 feet without oxygen, but it is a very inefficient process. A rejection rate of 60 or 70 per cent on pictures has been mentioned here today. Above 17,000 feet it is entirely possible that some of these rejections are due to impairment of crew efficiency by physiological factors.

I have here three charts. On Figure 1 has been outlined a standard atmosphere. This chart is not concerned with physiology alone, but merely shows standard atmospheric conditions from sea level to 70,000 feet. Two changes in the atmosphere as we go to altitude are the basis of most of our physiological problems. Number one is pressure decrease and the other is temperature decrease. On Figure 1 the decrease in pressure in pounds per square inch and in millimeters of mercury is recorded on the right hand margin of the chart. In the lower right hand corner, the usual temperature gradient from sea level to 38,000 feet is given. Also on this chart is a dotted line, plotted against a second scale from left to right at the bottom, showing the average length of consciousness of an individual when suddenly deprived of supplemental oxygen at various altitudes.

As for the problem of cold, an adequate cabin heater in an airplane is the best answer. Heavy clothing is an impediment to the accomplishment of any task. In addition, it is not feasible at 40,000 feet to make clothing sufficiently heavy to keep a man comfortable in an unheated plane. Therefore, for use in unheated or unsatisfactorily heated planes we have developed electrically heated suits which, I think, Mr. Eliel said he was using in his operations. With an electrically heated suit, a man can easily be kept as comfortable as he would be with about eight or nine times the amount of clothing we are wearing here now. With such a suit of the latest design, a man would also be comfortable at minus 40 degrees for an hour even though the current goes off. The other difficulty

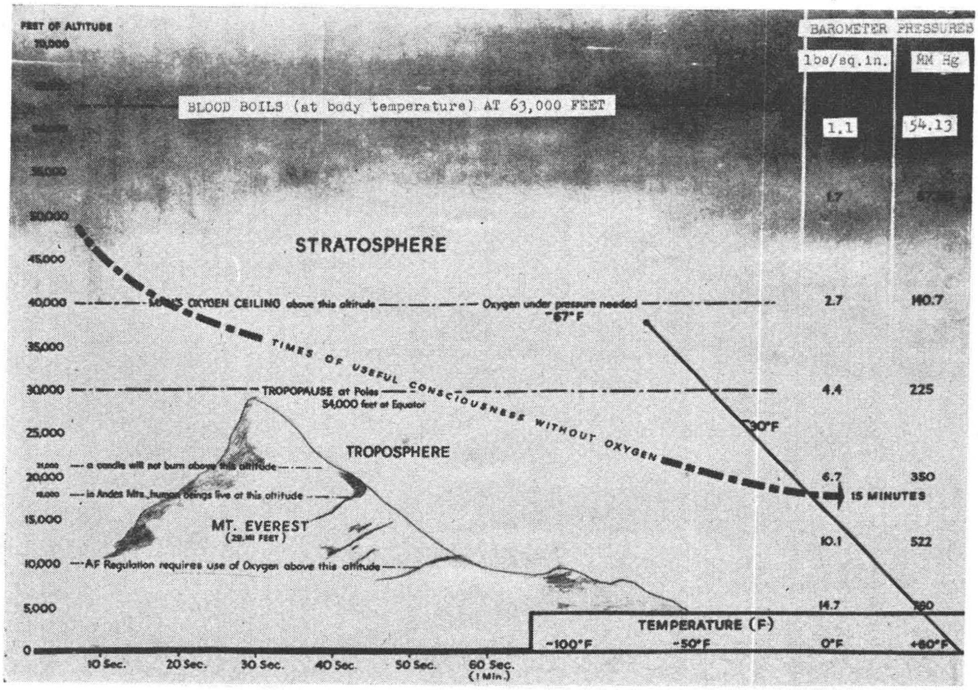

FIG. 1

with low temperature is that in operating complicated machinery, such as manually operated cameras, there is danger of frostbite. If a man takes off his glove at altitude, and touches a cold object, frostbite can occur almost immediately. An attempt to work without gloves at altitude, except in a heated cabin, is exceedingly dangerous as regards frostbite. Also, if a bail-out is necessary from high altitude, frostbite is a serious problem, unless the individual is well protected by clothing, gloves, etc. So much for problems of temperature.

As regards the problem occurring from decrease of pressure, there are two main headings: (1) deficiency in oxygen; and (2) bends or aeroembolism and pain in the sinuses or digestive tract from expansion of gas. In Figure 2 aeroembolism and gas expansion are outlined. Pressure decreases from 14 lbs. per square inch at sea level to about 1 lb. per square inch at 60,000 feet. Mr. Miller, who is now flying missions at 36,000 feet, can very possibly describe experiences with bends. At this altitude they are not infrequent. Bends are caused by an excess of nitrogen in the body which, at decreased pressure, turns into bubbles just as bubbles are formed in sparkling water. At 30,000 feet, a glass of water will begin to show gas bubbles, and at 63,000 feet, body temperature blood will actively boil. Consequently, it can be seen that a human being will be dead long before he reaches the 63,000 foot level unless he is protected against decreased pressure. Bends usually show themselves by pain around joints, or itching of the skin, or by a sensation of choking which is also known as "chokes."

In Figure 2 on the left is a column on Aeroembolism. Progressing from the bottom towards the top of the chart illustrates the increasing difficulty with this problem of bends. The factors involved in the bends are listed in the bottom part of this column. The chart is somewhat self explanatory showing that below

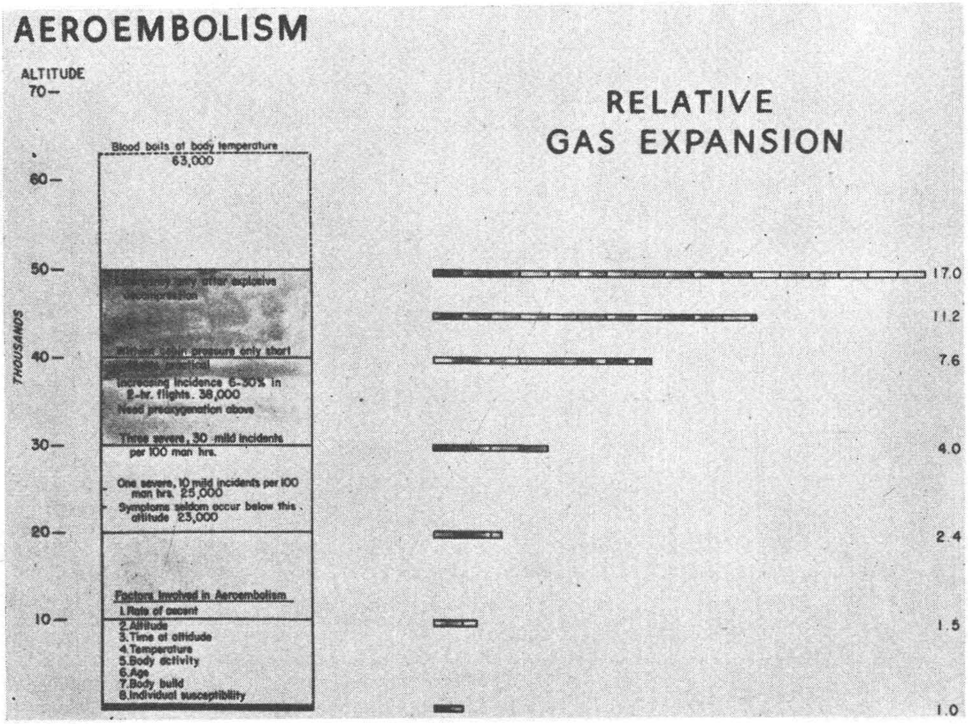

FIG. 2

23,000 feet, bends seldom, if ever, actually occur. At 25,000 feet there are one severe and ten mild incidents per hundred man hours. At 30,000 feet this figure has tripled, and at 38,000 feet there are about 30 per cent incidents in unprepared individuals. If people are prepared for altitude by preoxygenation, that is, breathing 100% oxygen for from 30 to 40 minutes prior to reaching altitudes above 20,000 feet, the incidence can be cut remarkably. This preoxygenation is just as effective between sea level and 20,000 feet as it is at ground level, so that under ordinary circumstances a pilot can preoxygenate himself during his climb to altitude.

At 40,000 feet without pressure cabins, bends become a serious problem and protracted flight is not practicable. However, on reconnaissance missions during the war, many short flights were made at altitudes above 40,000 feet, and pilots were able to perform satisfactorily. In general, from 40,000 to 50,000 feet, routine flights without cabin pressure are not practicable and our primary concern has to do with emergency loss of cabin pressure in pressurized aircraft.

Gas expansion in the inner ear, the sinuses and the digestive tract is a problem at this altitude. As can be seen from Figure 2 one pint of gas at sea level becomes 17 pints at 50,000 feet; so this can easily cause difficulty. However, if an individual is on a good dietary regime, gas in the digestive tract is seldom a serious problem, and unless individuals have colds, air displacement in the sinuses and ears seldom causes serious difficulty.

Lack of oxygen is the problem which can cause the greatest danger. An individual at sea level carries about 95% oxygen saturation in the blood stream. At 10,000 feet this has dropped to 90%, and if he goes to 12,000 or 14,000 feet without supplemental oxygen, it drops to 80%. At 10,000 to 12,000 feet without supplemental oxygen, an individual will notice little or no effect, but he is running low on oxygen and is becoming less efficient. At 12,000 to 14,000 feet he has become appreciably handicapped. It has been demonstrated that a man who is paying close attention to a detailed task doesn't do quite as well, at these altitudes, as when he is well oxygenated.

We must keep a crew well oxygenated at all times if they are to do efficiently the complex tasks that have been outlined here on this mapping program. Repeating, at 10,000 feet without oxygen everything is going well. Above 10,000 feet a definite handicap increases to a severe handicap at 18,000 feet. Adequate oxygen from 10,000 feet up will keep an individual as well oxygenated up to 33,000 feet as he is at sea level. At 33,000 feet using 100% oxygen, an individual is getting only the same amount of oxygen as he would in breathing air at sea level. Above this elevation the oxygen saturation of the body again begins to fall below normal, and at 40,000 feet on pure oxygen the body is in the same condition as at 10,000 feet when breathing air. As a consequence, 40,000 feet is called "man's oxygen ceiling."

During the war we were interested in flying between 40,000 and 46,000 feet without cabin pressure. As a result it was learned that oxygen under pressure could be pumped into an individual's lungs, thereby increasing the amount of oxygen he could absorb. A normal individual can stand as much as 12 inches of water pressure against his lungs but only for short periods of time. In this way he can stay sufficiently oxygenated up to 45,000 feet. However, at these altitudes the bends are exceedingly frequent and will cause aborting of missions.

During the war an attempt was made to select people who could fly to high altitude without bends, but it was never possible to get a consistent or satisfactory answer. There are some people who show a superiority in resistance to bends; but there is such a great change in the same individual from day to day, and superior people are so few and far between, that the selection process was dropped. Between 46,000 and 50,000 feet, missions without cabin pressures are flown only on an emergency basis. As can be seen on Figure 3, at 50,000 feet a man can remain conscious only one minute with 14 inches of water pressure over outside pressure forcing oxygen into his lungs. During this minute it would be essential to get down to 40,000 feet. The answer appears to be that we can operate up to 40,000 feet with the equipment we now have if a man is well prepared by preoxygenation and is well indoctrinated into using his equipment before he goes up. Above that we will run into trouble if we don't have cabin pressure. Operations above 40,000 feet without pressure are not a day-to-day operation.

As regards bailout from high altitude, there is a standard high pressure (1,800 lbs. per square inch) bailout oxygen cylinder, type H-2, in use by the Air Force. This is fastened to the flying suit and supplies a man with sufficient oxygen for descent from 36,000 feet down to the ground. Oxygen is supplied by pulling a rip cord on this bailout bottle, and it feeds automatically through a connection to the A-13 oxygen mask. Without such a cylinder, loss of consciousness will occur when leaving a plane above 30,000 feet, and if a parachute is opened at altitude without bailout oxygen, death can result from anoxia.

The essential thing in high altitude physiology is not how high you can push a man, but how efficiently you can keep him above 30,000 feet. Without proper heating and oxygen equipment, efficiency drops off tremendously and can seriously impair the mission.

Mr. Eliel: A most interesting and comprehensive outline of problems of flying among the Air Force personnel! I have one question that I should like

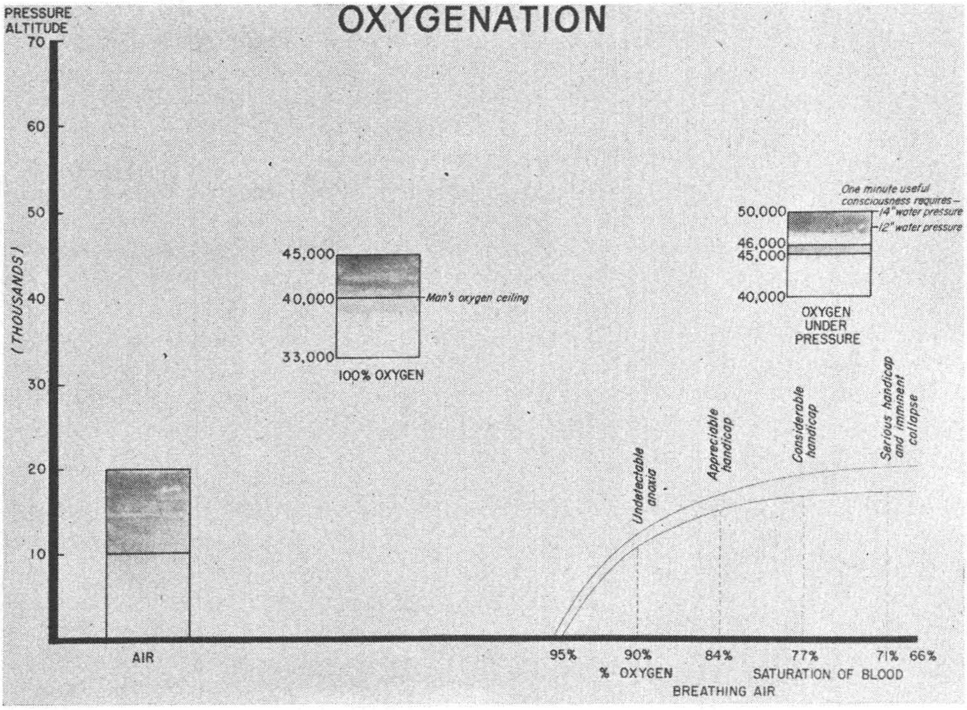

FIG. 3

to ask, this is, in working on oxygen without pressure up to 40,000 feet, is there any evidence that it is possible for a person to impair his health permanently?

Major Patterson: It is the experience of the Air Force that there is no permanent damage from oxygen. There has been a great deal of conversation about oxygen poisoning, and there has been a tremendous amount of safe experience in both the Navy and the Air Force on the use of oxygen in flying. It may be well to note that we now use automatic regulators which give a man only a sufficient percentage of oxygen to keep his blood level at normal, and that we are not on pure oxygen until we get to about 30,000 feet. There are no noticeable effects other than fatigue, and it is a question as to whether the fatigue is due to oxygen or to the other factors of low pressure, cold and high altitude. It is essential also that preoxygenation be used prior to flights from 30,000 feet up.

Mr. Robert Coltharp: Is there a possibility of oxygen bothering the teeth? That is whether the use of oxygen has any effect on good teeth or filled teeth or anything like that?

Major Patterson: Prior to the war, we were using concentration of 100 per cent oxygen through a pipe stem, and so far as I know, noticed no definite evidence of increased dental disturbance. With our present systems, you may be breathing a mixture of 20, 30, or 40 per cent oxygen, increasing with altitude. At 30,000 feet, although you are getting 100 per cent oxygen, it is not through a pipe stem directly on the teeth. We have no evidence that there is an increase in dental disorders from oxygen.

Mr. Coltharp: One more question about bends. In this high altitude flying, how about the total volume of the body at an altitude of 30,000 to 35,000 feet? We have had some very serious effects of bends at those altitudes—Can they be attributed to altitude? In our experience there was collapse of the individual.

Major Patterson: Collapse is a final part of this process we have called bends. If bends are allowed to persist by keeping an individual who has developed symptoms at altitude, they can become severe enough to cause collapse. Certain blood vessels in the body may be blocked by bubble formation or constriction. With severe pain and other changes, circulatory collapse can occur. An individual who develops severe pain with bends and does not descend is very apt to suffer such a collapse. Reducing altitude on the appearance of severe symptoms almost always snaps an individual out of his difficulty. Collapse from bends seldom occurs without warning. In addition to that, these things generally do not cause much trouble in a well prepared individual until we begin getting to 38,000 feet and above.

Mr. Deeg: I wonder if you would care to elaborate on the effect of injury? Possibly a flyer has a sprained ankle or an injury to a muscle. How about some of the commercial people who may not have had a thorough physical examination?

Major Patterson: There has been a considerable amount of comment about bends occurring at the site of old injuries. There has been some feeling that bends occur more frequently around an old joint injury or other injury. It may be true that a freshly injured joint will give more difficulty, and it is certainly true that bends occur most generally around joints. It appears, however, that an old injury unless currently causing trouble, is not more frequently the site of bends than any other area. Listed on the bottom of Figure 2 are the factors involved in the occurrence of bends. These eight factors do have some effect on the occurrence of bends.

Taking them in order (1) Rate of Ascent—the more rapidly you go up the greater the chance to develop bends. This is particularly true inasmuch as it allows less preoxygenation, or in other words, less loss of nitrogen while breathing oxygen on the way to altitude. The slower you go up, the more nitrogen you breathe off, thereby getting rid of the substance which is largely responsible for causing bends. This can also be accomplished by breathing 100 per cent oxygen on the ground for a half hour before flying.

(2) Altitude is the all important thing. Below 23,000 feet bends practically never appear. Symptoms of bends below 23,000 feet would lead cne to suspect psychological trouble rather than actual bends.

(3) Time at Altitude. Flying below 38,000 feet up to 2 hours with preoxygenation should cause little trouble. If attempt is made to prolong these flights, there is an increasing chance of getting bends.

(4) As to the 4th factor, Temperature, there is some evidence that bends don't occur as often at lower temperature as at higher temperature.

(5) Factor No. 5, Body Activity, is quite important. A pilot doing physical

exercise is much more apt to have bends than one who stays quiet and doesn't exert himself physically.

(6) Factor No. 6, Age, does appear to have some relationship to bends, the incidence of bends going up with increasing age.

(7) Factor No. 7, Body Build, appears to have some effect but is not too consistent. It would appear that the small skinny individual, that is, a person with less body area, generally seems to have less tendency toward bends.

(8) Factor No. 8, Individual Susceptibility, has already been mentioned. An attempt was made during the war to pick out the least susceptible individuals, but the day to day variability is such that not too much dependence can be placed on this selection process.

There are a few other necessary things that have occurred to me during this discussion which I should like to mention. Our modern oxygen equipment, i.e., the demand and pressure demand regulators, requires adequate inspection and maintenance. Currently T.O.s require inspection and/or overhaul every 180 days or 500 hours. It is essential that oxygen regulators be kept in perfect condition. This is true because failure of an oxygen regulator at altitude can cause a critically dangerous situation if the pilot does not get an immediate indication of failure. The symptoms of oxygen lack are never apparent to the individual who is suffering from lack of oxygen. However, a loss of consciousness, with possibility of complete disaster, will occur from faulty oxygen equipment or its improper use.

It is strongly recommended that any photographic crew contemplating work at altitudes of 30,000 feet and up, study the subject thoroughly, and if at all possible make practice ascents in a compression chamber.

Mr. Dickerson: Inasmuch as it seems to slide naturally into the next item that Mr. Eliel has indicated for me, I find it difficult to separate them. I should like to slide from one on into the other. The question will be developing along the same lines also. When we have an igloo on the snow field, we have troubles. That is rather a remote example however. In most cases, I believe that the mapping requirement, when we are going to such high altitudes, will be such that perhaps the igloo will not be of much importance. The problem however is there. I referred to it in rather a broad gesture this morning, and said that it simply was a matter of scale. One way to solve this problem is to expose larger scale photography simultaneously with the mapping photography. That is a procedure that we found during the past war that resulted in a lot more detail. That, however, still doesn't result in a fully satisfactory map. If you are only one foot above the ground with your photographs, you can not make the map without going on the ground to check it in order to be sure. You may be able to make a reasonable approximation from the photographs alone. That probably is what we are going to have to discuss here. What is in the picture of course will vary from spot to spot around the country, and even outside the country, and what you need to see from it.

I hope that probably by this time you will have had occasion to examine some of the high altitude pictures in the exhibit rooms and get some ideas as to the detail that can be seen. There is one example in the exhibit showing three photographs flown for the same area, all exposed from 38,000 feet; one of these is the usual mapping photograph taken with a 6-inch lens; the second is twice that scale, taken with a 12-lens; and the third was taken with a 24-inch lens. These photos surely show that it is possible to get a very reasonable approximation of the detail required in the map. I don't think this system of photography has been used on an operational basis however.

I missed the point earlier, however, to take up with Mr. Sanders the matter of increasing focal lengths. He is right that film size goes up and that all of your problems go up if you retain the same angle of coverage. However, we don't need to hold to the same angle. All we need is the same coverage across the flight so that one flying of a strip will give both mapping cover and larger scale cover for interpretation. Probably the best example that I have encountered thus far concerning what we can get out of the photograph is illustrated by one of the projects that I referred to this morning, which was flown at 30,000 feet above terrain with 6-inch photography. The requirement was for 1:25,000 maps meeting usual standards of accuracy and content. This requirement was met although the usual field work was performed.

Although there is no conclusive data available to support me, I do not believe that any small increase in the field work will offset the economy of using the higher altitude photography. The place of photography in mapping, regardless of flight altitude, is largely a result of geometric considerations and the capabilities of the mapping system being employed. We know what the tolerances are for our mapping systems, and it is then a matter of setting flight altitudes so that the application of the tolerances result in a map of the required accuracy. We have checked these tolerances with both high and low altitude photography on tests, and we have confirmed that the flight altitude has no effect on tolerances of our system.

(At this point, Mr. Eliel summarized the discussions and then adjourned the meeting.)