MAYO AERO MEDICAL UNIT

STUDIES IN AVIATION MEDICINE

Volume IV

Serial Reports to AAF:
Series A, 1 to 4m.

MAYO AERO MEDICAL UNIT

STUDIES IN AVIATION MEDICINE

Carried out with the assistance of the

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COMMITTEE ON MEDICAL RESEARCH
of the
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

COMMITTEE ON AVIATION MEDICINE

With the cooperation of the

UNITED STATES ARMY AIR FORCES, MATERIEL COMMAND, WRIGHT FIELD.

Responsible Investigators: Walter M. Boothby, E. J. Baldes and C. F. Code

aided by many associates.

In Six Volumes

These reports, originally in "restricted" classification,
have been declassified and all are now "open."

VOLUME 4: SERIAL REPORTS TO AAF MATERIEL COMMAND, SERIES A, NOS. 1 to 4m

Mayo Clinic and Mayo Foundation for
Medical Education and Research,
University of Minnesota

Rochester, Minnesota
1940 - 1945

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** The major reports of the Acceleration Laboratory will be published shortly in the monograph entitled "The Effects of Acceleration and Their Amelioration," edited by the Subcommittee on Acceleration of the Committee on Aviation Medicine of the National Research Council.

*** From the Department of Aeronautical Engineering, University of Minnesota.

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MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL CENTER
Under Contract No. W535ac-25829

SUBJECT: Observations, Experiences and Recommendations Related to Bailing Out at High Altitudes.

SERIAL REPORT: Series A, No. 1 DATE: October 3, 1942

A. Purposes

1. To determine the need for emergency bail out equipment.

2. To determine the effect of removing the regular oxygen mask and using various types of jump bottle mouthpieces during emergency parachute jumps from 35,000 feet or more.

3. To discover a more satisfactory method of transfer from main oxygen supply to emergency oxygen equipment and reduce the mental and physical efforts of such a transfer to a minimum.

4. To design equipment which will permit aviators to jump from altitudes of at least 40,000 feet, even after intensive exercise and a period of interrupted flow of oxygen, without loss of consciousness.

5. To study the effects of breathing only air at 40,000 feet.

B. Factual Data

1. The details of the simulated parachute jump tests are given in the appendix.

a. Ten of these were carried out by Charles A. Lindbergh who in the past has made four emergency parachute jumps from planes and a number of practice jumps from various altitudes between 350 feet and 14,000 feet.

b. Two simulated jumps were carried out in the pressure chamber by John Hadden and one simulated jump each by William Pongratz and by Kenneth Hoorn of the Willow Run Bomber Plant.

c. Dr. Walter M. Boothby, Dr. Kenneth G. Wilson and Miss Ruth Knutson of the Mayo Aero Medical Unit, Dr. Charles J. Clark, flight surgeon of Willow Run Bomber Plant and Captain P. M. Thomas of Wright Field were the principal observers of the tests.

d. Miss Lucille Cronin, Mrs. Ralph Cranston and Miss Rita Schmelzer were the technical aids inside the chamber and took care of the emergencies that occurred.

a. Motion pictures were taken of No.'s 11, 12, 13 and 14 of the simulated parachute jumps in the low pressure chamber. The camera was placed outside the chamber and the pictures taken through a glass port-hole.

C. Development of High Altitude Emergency Oxygen Equipment

As a result of simulated parachute jumps carried out in the altitude chamber, it is shown that if the jump bottle is connected to the regular oxygen mask and if a break connection is placed in the plane's oxygen line, in the manner to be described, the pilot of a pursuit plane, making an emergency jump at 40,000 feet and pulling his parachute rip cord immediately, will automatically obtain a sufficient supply of oxygen without any thought or action on his part. If a delayed opening descent is to be made with this equipment, or if it is necessary for the jumper to move some distance through the plane before reaching the point from which he leaves, it is only necessary for him to pull the jump bottle release which is attached to his flying suit or parachute harness.

D. Description of High Altitude Emergency Oxygen Equipment

1. Mask. The mask should be of the demand type with a reservoir rebreathing bag around the corrugated tubing with free intercommunicating openings, as described in Special Report No. 1 from the Mayo Aero Medical Unit to the Committee on Medical Research, O.S.R.D.

2. Harness. The harness attached to the helmet for the regular oxygen mask should be constructed so that the mask will stay on under all conditions encountered in leaving a plane for an emergency jump. (It is suggested that tests be made in the wind tunnel.)

3. Jump Bottle and Valve. The jump bottle can be placed either on the flying suit or the parachute harness; the valve is connected by a cable to the parachute pull ring in such a manner that it is opened by pulling the rip cord out a few inches farther than the distance required to release the parachute. The jump bottle valve can also be opened independently of the parachute. (New jump bottle valve must be designed.)

4. Break Connection. A break connection is located in the plane's oxygen line at the jumper's side so that when he leaves his station the jerk on the connection automatically severs the oxygen line; his own end being firmly attached to his flying suit.

5. Emergency Mouthpiece. A connection which can serve as an emergency mouthpiece is located about 8 inches below the lower end of the reservoir bag and just below a strong hook type of fastener (see picture) so that in case the mask is blown away, the mouthpiece will remain and can be inserted into the mouth. Distal to this connection, the tube from the jump bottle is inserted in the corrugated tube. This corrugated tube, leading back to the break connection, should be about 2 feet in length and 1 inch standard minimum internal diameter. This gives a volume of about 450 c.c. which acts like a reservoir rebreathing bag as originally pointed out by Dautrebande. As shown in the drawing, this tube is protected by a pocket-like flap on the flyer's suit.

E. Technic Suggested for Use of this Equipment

1. Pursuit planes and planes where the jumper leaves directly from his station:

> Jumper simply leaves plane and pulls parachute rip cord. In the case of a delayed opening jump, he pulls the jump bottle release at the time of leaving his plane or immediately thereafter.

2. Bombers and planes where the jumper must move some distance through the plane before reaching the station from which he jumps:

> Jumper simply pulls jump bottle release before leaving his station. Nothing else is required until he pulls his parachute rip cord for either an immediate opening or a delayed opening descent. (However, if delay is encountered in leaving plane, it is doubtful that the jump bottle will furnish sufficient oxygen for subsequent descent.)

3. In case the jumper's mask should be blown off during the jump, an emergency mouthpiece is incorporated in the Dautrebande tube, below a point where the tube is clamped to the flying suit. The oxygen tube from the jump bottle is attached in such a manner that full advantage is taken of the Dautrebande tube effect whether the regular oxygen mask or the emergency mouthpiece is used.

4. An additional advantage of this equipment is that it provides an emergency oxygen system, immediately available, which can be used while the plane descends to a safe elevation in case the main oxygen system fails during flight. It is only necessary to pull the jump bottle release to insure an adequate oxygen supply for three or four minutes. (Obviously this leaves insufficient reserve for bailing out.)

F. Conclusions

1. The tests carried on in the altitude chamber demonstrate conclusively that emergency bail-out oxygen equipment is essential for parachute descents from high altitude if unconsciousness accompanied by convulsions is to be avoided.

2. The tests indicate that emergency bail out oxygen equipment is desirable for all altitudes above 21,000 feet.

3. The tests indicate that the present new issue jump bottle will be adequate as a source of oxygen supply providing a quick opening valve mechanism is installed and properly designed equipment used in connection therewith.

4. The tests demonstrate conclusively that parachute jumps from 40,000 feet can be carried out without loss of consciousness when a regular oxygen mask with reservoir rebreathing bag is maintained in place and connected to a standard oxygen jump bottle during descent. The tests show that this can be done even after 30 seconds of heavy exercise before leaving a plane, and 10 seconds without flow of oxygen before jump bottle valve is

opened. It is extremely important, however, that the regular mask be retained, and that it be so firmly attached to the aviator's head that it will not be blown off during the jump. Changing from the regular mask to a jump mask or pipestem causes loss of time in clearing the plane, requires added exertion, increases the mental hazard, interferes with proper breathing, adds to the possibility of mechanical failure of equipment, and markedly increases the danger of anoxia.

5. The tests show that in so far as it is possible, the aviator should make preparations for bailing out while his mask is connected to the plane's oxygen line, and that it is advisable for him to utilize the plane's oxygen supply until the last possible moment before resorting to his jump bottle. The jump bottle oxygen flow, when connected to a properly designed mask, will support considerable activity for two or three minutes at high altitude, but it is doubtful that sufficient oxygen will remain to avoid a state of unconsciousness during a subsequent descent.

6. The tests indicate that:

a. The ordinary jump bottle mouth mask or pipestem mouthpiece is inadequate to prevent unconsciousness accompanied by convulsions during an emergency parachute jump from the region of 40,000 feet if exertion is required prior to the jump.

b. The ordinary jump bottle mouth mask or pipestem mouthpiece is frequently inadequate in the region of 35,000 feet if exertion is required prior to the jump or if there is delay in clearing the plane after the jump bottle has been turned on.

c. That any procedure which involves the removal of the regular oxygen mask from the jumper's face will be of doubtful success at altitudes above 35,000 feet.

d. That the regular oxygen mask is preferable to mouth mask or pipestem equipment for jumping from any altitude where oxygen is needed during the descent.

e. That until new equipment can be obtained for service use, and where jump mask or pipestem equipment must be used, it is advisable for the jumper to make all possible preparations for his jump before changing from his plane oxygen line and regular mask to his jump mask or mouthpiece. If a hatch is to be opened, or if there are disconnections to be made, these items should be attended to, if possible, before the regular oxygen mask is taken off or disconnected from the plan'es oxygen line.

7. The tests show that when a separate jump mask or mouthpiece must be used, a Dautrebande or rebreathing tube in connection therewith adds materially to the efficient use of the available oxygen, and also reduces the tendency to cough and swallow which is caused by a rapid flow of oxygen directly into the mouth.

8. The tests show that:

a. At least four normal breaths or three deep breaths of air can be taken by an aviator in normal conditions, at 40,000 feet, without the loss of consciousness.

b. There is a delay period of approximately 20 seconds after the oxygen mask has been replaced, after breathing air, before the maximum effect of anoxia is felt. This is due to the time required for the oxygen to enter the lungs, oxygenate the blood, and reach the brain. Therefore, the aviator must realize that under similar conditions at high altitudes, even after he begins breathing oxygen again, he will be worse before he is better.

c. Attention is called to the fact that, with the aviator breathing essentially pure oxygen, the partial pressure of the oxygen in the alveolar air at 35,000 feet is about 100 mm., or practically normal, but at 40,000 feet the pressure is reduced to about 55 mm. or to nearly one-half and at 42,000 feet the pressure is about 45 mm. or less than one-half the normal amount. Therefore, around 40,000 feet, if the oxygen is suddenly stopped, the aviator will have only approximately one-half his normal reserve supply of oxygen in his lungs (also less in his blood) and therefore will become unconscious more rapidly than at 35,000 feet.

9. Equipment has been designed which will permit the aviator to bail out and, with a single motion, release his parachute and turn on his emergency oxygen supply. It is also possible to turn on the emergency oxygen supply prior to bailing out if a delayed opening descent is to be made or if, as in the case of bomber crews, it is necessary to cover some distance before reaching the point of exit from the plane.

G. Recommendations

1. That an oxygen jump bottle with proper accessory apparatus, as here described, be a part of the personal issue equipment to all aviators going to high altitudes.

2. That flying personnel be instructed to remain on the plane's oxygen line as long as possible before transferring to oxygen jump bottle at high altitudes.

3. That actual use of the oxygen bail out equipment in a low pressure chamber should be a part of the indoctrination program for all high altitude aviators, especially before going overseas.

Prepared by Walter M. Boothby and Kenneth G. Wilson
Mayo Aero Medical Unit

and

Charles A. Lindbergh & Charles J. Clark
Ford Willow Run Bomber Plant

Distribution: 20 copies to Commanding General Wright Field; 10 copies to Air Surgeon, Office, Chief of Air Forces, Washington, D. C.

Approved by Walter M. Boothby, M. D.
Chairman, Mayo Aero Medical Unit
Rochester, Minnesota

APPENDIX

SIMULATED PARACHUTE JUMP NO. 1
September 24, 1942 M.A.M.U. Flight No. 9

Subject: Charles A. Lindbergh - Jump from 40,000 feet

Personal Report: After 30 minutes of denitrogenization, entered large pressure chamber and ascended to 40,000 feet in 7 minutes, using nasal standard BLB mask with larger than standard rebreather bag and constant flow of oxygen. Remained at 40,000 feet or above for 1 hour and 9 minutes, including one ascent to 42,000 feet for approximately 5 minutes. Walked about and exercised mildly for larger portion of period. Began to notice increasing effect of altitude after about 45 minutes, possibly brought on to some degree by the ascent to 42,000 feet.

At end of 1 hour, 9 minutes, removed face mask and inserted jump mask (mouthpiece in center of oro-nasal mask and 8-inch length of 3/4-inch corrugated tubing for rebreathing) in mouth. Then turned on jump valve and started exercise approximating that required to open a jammed hatch, using only oxygen flow from jump bottle. Intended to continue exercise for 1 minute, but noticed serious lack of oxygen almost immediately. Shut off rebreathing tube (Dautrebande) with one hand, to determine if oxygen flow from jump bottle was sufficient. An attempt to inhale demonstrated flow to be small fraction of that required to avoid inhalation of air. Attempted to continue exercise, inhaling part oxygen and part air, but realized that state of unconsciousness would soon be reached. Gave signal for descent at end of 40 seconds and sat down. Remember nothing more until consciousness returned at 25,000 feet, approximately 1 minute later. Constant flow oxygen mask had been applied during period of unconsciousness. Became alert quickly after regaining consciousness and noticed no later ill effects such as headache, ear trouble, etc.

Abstract of Observers' Notes: Just before subject signalled descent it was observed that he was very cyanotic and rapidly losing consciousness. Almost simultaneously with his signalling to descent, Miss Cronin walked across the chamber, jerked the jump mask with insufficient oxygen flow from his mouth and covered nose and mouth with an emergency mask having large oxygen flow from chamber oxygen line. The subject was entirely unconscious; extensive convulsive jerks of face, neck, arm and leg muscles were observed. The subject gasped and after 30 seconds inhaled rather deeply and in 15 to 20 seconds more regained consciousness. No symptoms of bends at any time.

Rate of Flow of Jump Bottle

M.A.M.U. bottle Time	Liters STPD
During 1st min.	3.2
" 2nd min.	2.7
" 3rd min.	2.3

Oral Temperature of Subject

Time	Elevation	Temp.
10.05	Ground	99.2
10.25	40,000	99.6
10.44	40,000	99.4
10.54	42,000	99.4
11.06	40,000	99.4
11.24	40,000	98.6

SIMULATED PARACHUTE JUMP NO. 2
September 25, 1942 M.A.M.U. Flight No. 13

Subject: Charles A. Lindbergh - Jump from 40,000 feet

Personal Report: After 30 minutes of denitrogenization, entered large pressure chamber and ascended to 40,000 feet in 10 minutes, using chin bag mask and constant flow of oxygen. Remained at 40,000 feet for 7 minutes, walking about and exercising mildly. Shut off main oxygen line to maks and turned on jump bottle line to mask. (Both lines were attached to mask through a T tube and same mask was used for both ascent and jump.) Went through 30 seconds of exercise approximating that required to open a jammed hatch; then sat down during descent of chamber. Found oxygen supply to be sufficient at all times.

Abstract of Observers' Notes: Subject had only slight degree of cyanosis and was in good condition throughout descent. Wearing mask with reservoir bag makes a tremendous difference in the appearance of the subject and makes a parachute jump at high altitude safe as far as anoxia is concerned.

Rate of Flow of Jump Bottle
(Oxygen bottle from Flight Dept., Willow Run Bomber Plant)

Time	Liters STPD
During 1st min.	3.5
" 2nd min.	3.0
" 3rd min.	2.6
" 4th min.	2.2

SIMULATED PARACHUTE JUMP NO. 3
September 25, 1942 M.A.M.U. Flight No. 13

Subject: Charles A. Lindbergh - Jump from 35,000 feet

Personal Report: Remained on oxygen mask for about 20 minutes while waiting for new oxygen emergency bottle to be brought in through lock at about 4,000 feet. This new bottle was the recent issue type and had a higher rate of oxygen flow and was outfitted with standard type wood mouthpiece; an emergency T connection to chamber oxygen line was added for safety. Then ascended to 35,000 feet in 5 minutes, using same chin bag mask as on previous ascent and constant flow oxygen. Remained at 35,000 feet for 30 seconds. Then turned on jump bottle, removed mask and inserted wood mouthpiece between teeth, keeping lips closed around mouthpiece. Went through 30 seconds of exercise approximating that required to open a jammed hatch, using only oxygen flow from jump bottle; then sat down and began descent at rate of 3,000 feet per minute, decreasing descent rate after first minute. Flow from bottle too high for comfortable breathing so decreased it by partially closing jump bottle valve. Drying effect of high oxygen flow in mouth and throat caused tendency to cough. Removed mouthpiece at 25,000 feet and continued to ground level without oxygen.

Abstract of Observers' Notes: At first the rate of flow was obviously excessive. However, the subject descended without serious difficulty. It must be remembered that at 35,000 feet the subject starts with nearly normal oxygen in the lungs, and therefore has nearly twice as much reserve in his alveoli than if he were at 40,000 feet.

Rate of Flow of Jump Bottle
Issue bottle

Time	Liters STPD
During 1st min.	6.3
" 2nd min.	5.3
" 3rd min.	4.4
" 4th min.	3.8
" 5th min.	3.2
" 6th min.	2.6

SIMULATED PARACHUTE JUMP NO. 4
September 26, 1942 M.A.M.U. Flight No. 14

Subject: Charles A. Lindbergh - Jump from 40,000 feet

Personal Report: After 30 minutes of denitrogenization, entered large pressure chamber and ascended to 40,000 feet in 7 minutes, using chin bag mask and constant flow of oxygen. Remained at 40,000 feet for 10 minutes, exercising mildly during part of time. Turned on jump bottle, removed mask, inserted standard type wood mouthpiece between teeth, and carried on 30 seconds of heavy exercise on jump bottle flow alone, then sat down. Noticed serious lack of oxygen within few seconds. Turned on additional oxygen from chamber oxygen line (which was connected to jump bottle mouthpiece through a T tube) to avoid becoming unconscious. Flow of oxygen from standard type of jump bottle wood mouthpiece is cold and dry, and causes tendency to cough and swallow.

Abstract of Observers' Notes: Subject rapidly became cyanotic and was obviously very near unconsciousness just before he turned on chamber oxygen. For several breaths after the oxygen was turned on, subject became worse and almost passed out but after about 20 seconds he started to improve rapidly. Delayed action of oxygen was due to time needed to fill lungs with oxygen and for the oxygenated blood to get to the head.

Rate of Flow of Jump Bottle
(Standard issue bottle)

Time	Liters STPD
During 1st min.	6.3
" 2nd min.	5.3
" 3rd min.	4.4

SIMULATED PARACHUTE JUMP NO. 5
September 26, 1942 M.A.M.U. Flight No. 14

Subject: Charles A. Lindbergh - Jump from 35,000 feet.
Note: This jump made on same flight in chamber as previous jump.

Personal Report: After descending to altitude of 25,000 feet, rested and reascended to 35,000 feet in 5 minutes, using A-8-B oxygen mask and constant flow oxygen. Remained at 35,000 feet for 8 minutes, exercising mildly at intervals. Turned on jump bottle valve, removed oxygen mask, placed pipestem type wood mouthpiece between teeth, and carried on 30 seconds of heavy exercise on jump bottle flow alone; then sat down. Felt need of additional oxygen for some seconds but was able to retain consciousness and continue descent without turning on chamber oxygen valve. (A T tube, connected to the chamber oxygen line had been placed in the jump bottle line for emergency use.) Removed jump bottle mouthpiece at 23,000 feet and found no difficulty in continuing descent without oxygen.

Abstract of Observers' Notes: Subject became cyanotic and it was suggested that the additional oxygen from the chamber line be turned on; however, it was decided to wait a few seconds longer. Then as he started to improve it was recognized that he would not become unconscious. However, it was a very close shave.

Rate of Flow of Jump Bottle
(Oxygen bottle from Flight Dept., Willow Run Bomber Plant)

Time	Liters STPD
During 1st min.	3.5
" 2nd min.	3.0
" 3rd min.	2.6
" 4th min.	2.2

SIMULATED PARACHUTE JUMP NO. 6
September 26, 1942 M.A.M.U. Flight No. 14

Subject: William Hadden - Jumps from 35,000 feet

Report made by Dr. C. J. Clark: Subject entered chamber after 30 minutes nitrogen desaturation program. Oxygen supply through constant flow, chin bag mask, rate of flow 42,000 feet, active. Ascended to 40,000 feet in 7 minutes. Remained at 40,000 feet for 11 minutes, then descended to 25,000 feet and returned to 35,000 feet within 4 minutes, and remained for 9 minutes. Then prepared for practice jump. At given signal the oxygen mask was removed and pipestem type mouthpiece connected to issue jump bottle was inserted in mouth as source of oxygen supply. (A T tube was in line.) Issue bottle at this point contained 1800 pounds pressure. Immediately upon inserting pipestem subject began exercising, simulating work necessary to get out of airplane, and continued such exercise for 15 seconds after which chamber was dropped at the rate of 3,000 feet for 2 minutes and then at the rate of 2,000 feet per minute to approximate the rate of a parachute drop. Thirty seconds after start of jump subject's color was good and he was very active. No evidence of anoxia. Parachute rate of descent continued to 15,000 foot level, time lapse 8 minutes, during which period subject had no objective or subjective sign of anoxia. Jump bottle turned off at 15,000 foot level, pressure in bottle at this point 500 pounds.

Rate of Flow of Jump Bottle
(Issue bottle)

Time		Liters STPD
During	1st min.	6.3
"	2nd min.	5.3
"	3rd min.	4.4
"	4th min.	3.8
"	5th min.	3.2

SIMULATED PARACHUTE JUMP NO. 7
September 26, 1942 M.A.M.U. Flight No. 15

Subject: Kenneth Hoorn - Jump form 35,000 feet.

Report made by Dr. C. J. Clark: Subject entered chamber after 30 minutes of nitrogen desaturation program and was placed on main oxygen supply using chin type mask and rate of flow 40,000 feet active. A Y tube was connected to bail out system, one side to main oxygen supply, other side to parachute bail out oxygen bottle. The parachute cylinder contained 1750 pounds pressure at time of ascent. The pipestem was the means of securing oxygen flow from the parachute bottle.

Chamber ascended to 35,000 feet in 5 minutes, 30 seconds. Remained at 35,000 feet for 10 minutes, then at a given signal chin type mask was removed from face and pipestem inserted in mouth as source of oxygen supply. Exercise simulating work necessary to escape from a plane began immediately after inserting pipestem. It was noted at once that subject was breathing through open mouth and cyanosis developed quickly after start of exercise. Extra oxygen was immediately given from main supply line through the Y tube connection, and subject sat down, but the pipestem was not replaced by a mask. Subject was instructed to breathe with mouth closed, but it was noted that he did not satisfactorily carry out these instructions. The chamber was dropped after exercise at a rate of 3,000 feet per minute for 2 minutes, then at a steady drop of 2,000 feet per minute to the 23,000 foot level.

Subject remained very cyanotic, even on additional oxygen supply for 2½ minutes, but at no time seemed in danger of becoming unconscious. (He did, however, seem quite apprehensive and displayed inability to carry out instructions.) At 30,000 feet, 2½ minutes after start of additional oxygen, subject seemed much better and was placed again on the jump bottle as his only oxygen source. Descent to 25,000 feet was made during which time color improved and subject seemed more alert.

The rapid development of anoxia in this subject can be placed largely on his inability to breathe with the mouth closed during the exercise period at the start of the jump.

Rate of Flow of Jump Bottle
(Issue bottle)

Time	Liters STPD
During 1st min.	6.3
" 2nd min.	5.3
" 3rd min.	4.4
" 4th min.	3.8
" 5th min.	3.2

SIMULATED PARACHUTE JUMP NO. 8
September 26, 1942 M.A.M.U. Flight No. 15

Subject: W. A. Pongratz - Jump from 35,000 feet.

Report made by Dr. C. J. Clark: Subject entered chamber after a 30 minute nitrogen desaturation program. Purpose of experiment was a practice parachute bail out procedure using the parachute cylinder as means of oxygen supply after leaving the main oxygen source of an airplane. A Y tube was connected to the bail out system, one arm to the main oxygen supply and a 3 turret A-8-B continuous flow type mask, the other arm to the tube from the parachute cylinder and a pipestem mouthpiece. At the beginning of ascent the flow from main oxygen supply was set at 42,000 feet, and the pressure in the jump bottle was 1800 pounds.

This subject remained in the chamber as observer for another experiment prior to his own tests. This required that he remain at 35,000 feet for 10 minutes, descend to 22,000 feet, return to 35,000 feet for 5 minutes and again descend to 25,000 feet, then return to 35,000 feet. He remained at 35,000 feet for 1 minute before start of practice jump.

At a given signal he removed his mask as source of oxygen supply and inserted pipestem from jump bottle system in his mouth as means of oxygen source. Immediately following this he began exercising to simulate work necessary in getting out of an airplane, and here it was noted he did violent exercise, really more than would probably be required in an actual bail out. He continued such exercise for a period of 25 seconds after which he was very cyanotic and quite dyspneic. After exercise period chamber was dropped at the rate of 3,000 feet per minute for 2 minutes, after which the rate of descent was 2,000 feet per minute to approximate actual parachute rate of drop. One minute and 15 seconds after exercise was stopped and subject sat down, he was given additional oxygen from main supply, but pipestem was not removed, being still used as source of oxygen.

Oxygen flow from jump bottle was shut off at 27,000 foot level, pressure in bottle was 1200 pounds, and subject still had considerable cyanosis and apprehension. At 25,000 feet, approximately 5 minutes after start of experiment the 3 turret mask was again placed on subject, and pipestem removed as source of supply. Cyanosis disappeared within 1 minute and general condition returned to apparently normal.

Subject had some ear trouble at 20,500 feet which was alleviated by ascent to 21,500 feet.

It seemed that the cause of his anoxia was due to the violent exercise during the 25 seconds after he had gone on the parachute cylinder as his sole means of oxygen supply. Also, there was some tendency for subject to breathe with his mouth open.

Rate of Flow of Jump Bottle
(Issue bottle)

Time	Liters STPD
During 1st min.	6.3
" 2nd min.	5.3
" 3rd min.	4.4
" 4th min.	3.8

SIMULATED PARACHUTE JUMP No. 9
September 27, 1942 M.A.M.U. Flight No. 16

Subject: William J. Hadden - Jump from 40,000 feet.

Report made by Dr. C. J. Clark: Purpose of test was for practice bail out procedure at 40,000 feet using pipestem mouthpiece and emergency parachute bottle as source of oxygen supply.

After 30 minutes nitrogen desaturation routine, subject entered pressure chamber using chin type, continuous flow mask. Chamber was raised to 35,000 feet where subject remained for a period of 11 minutes; rate of flow 35,000 feet, active. Chamber was then brought up to 40,000 foot elevation, rate of flow raised to 40,000 feet, active. Subject remained under these conditions for 11 minutes.

At a given signal subject changed regular mask for pipestem and went on parachute cylinder as sole oxygen source. He immediately began moderate exercise for 30 seconds. Following this he sat down and chamber descent began at rate of 3,000 feet per minute for 2 minutes, then 2,000 feet per minute to approximate actual parachute drop. Subject looked perfectly normal following exercise period and no signs of anoxia were noted.

Two minutes and 35 seconds after start of test, however, subject began to get dizzy and cyanosis developed. Subject appeared quite apprehensive, and was patting feet on floor in an apparent nervous gesture. It was also noted here that he was hyperventilating, and this fact was later substantiated by the subject when he returned to ground level pressure.

Five seconds after the above symptoms appeared, the subject reached for the emergency mask himself, and although there was moderate cyanosis, there were no other apparent symptoms of anoxia. One minute after using the emergency mask subject looked and felt much better, the color returning to normal. This was at 30,000 foot level, rate of oxygen flow in mask set for 42,000 foot active.

Chamber was leveled off at 30,000 foot level for purposes of further experiments and subject remained at this altitude for 7 minutes before returning to 40,000 feet for 10 minutes. Descent to ground level followed.

This subject stated that at the time he had to resort to the emergency mask, he realized after returning to ground level that he was definitely hyperventilating and that had he thought to stop this syndrome at the time by holding his breath, he might not have had to rely on the emergency mask.

The impression gained from this experiment is that from 40,000 feet the equipment and technic used in this jump was not adequate to maintain normal body functions till a safe altitude is reached. Also, that hyperventilation is a marked aggravating factor in hastening onset of anoxia at high altitude.

SIMULATED PARACHUTE JUMP NO. 10
September 27, 1942 M.A.M.U. Flight No. 17

Subject: Charles A. Lindbergh - Jump from 35,000 feet

Personal Report: After 15 minutes of denitrogenization, entered large pressure chamber and ascended to 35,000 feet in 5.5 minutes, using chin type Bulbulian mask and constant flow of oxygen. Remained at 35,000 feet for 13 minutes, carrying on mild exercise at intervals. Then disconnected chamber oxygen line from mask and replaced it with jump bottle oxygen line. Turned on jump bottle valve and carried on heavy exercise for 1 minute. Then removed mask from face and began breathing air in chamber. Chamber rate of descent of 3,000 feet per minute was started at time mask was removed. Continued to breathe chamber air for 15 seconds; then inserted wood mouthpiece from jump bottle between teeth and began breathing oxygen from jump bottle. After several seconds noticed lack of oxygen but normal feeling returned within the next minute. Discontinued breathing oxygen entirely on reaching 22,500 feet. Continued standard rate of descent and at 15,000 feet again put on oxygen mask to recover from the after effects of anoxia more quickly.

Rate of Descent of Chamber after Mask Removed

1st minute	3,000 feet
2nd minute	2,500 feet
3rd minute	2,000 feet
4th minute	2,000 feet
Thereafter	1,000 to 1,500 feet per minute

Rate of Flow of Jump Bottle
(Issue bottle)

Time		Liters STPD
During	1st min.	6.3
"	2nd min.	5.3
"	3rd min.	4.4
"	4th min.	3.8
"	5th min.	3.2
"	6th min.	2.6
"	7th min.	2.3
"	8th min.	1.6
"	9th min.	1.6
"	10th min.	1.4

SIMULATED PARACHUTE JUMP NO. 11
September 28, 1942 M.A.M.U. Flight No. 18

Subject: Charles A. Lindbergh - Jump from 40,000 feet.

Personal Report: After 30 minutes of denitrogenization, entered large pressure chamber and ascended to 40,000 feet in 7 minutes, using Bulbulian demand type mask with rebreather bag, Dautrebande tube, and jump bottle tube attached near tip of Dautrebande tube. Used constant flow of oxygen for ascent. Remained at 40,000 feet for 10 minutes. Then carried on 30 seconds of exercise, lifting steel cylinder (simulating effort required to open jammed hatch and jump out of plane -- amounting to 486 foot pounds in 30 seconds.) Then broke connection attaching mask to chamber oxygen line. (Here, chamber started descending at parachute rate.) Remained without any flow of oxygen to mask for 10 seconds (simulating time required to pull parachute rip cord). Then pulled parachute rip cord, thereby opening jump bottle valve and startimg flow of oxygen from jump bottle to mask. Chamber continued to descend at parachute rate to 20,000 feet. Then reconnected oxygen mask to chamber oxygen line to prepare for next ascent. Noticed no serious lack of oxygen at any time.

Abstract of Observers' Notes: During jump subject had perfect color and the bag on the mask did not fully collapse so that he would be getting practically 100 per cent oxygen. Condition excellent.

SIMULATED PARACHUTE JUMP NO. 12
September 28, 1942 M.A.M.U. Flight No. 19

Subject: Charles A. Lindbergh - Jump from 35,000 feet.

Personal Report: Remained on oxygen mask at ground level for several minutes after Flight No. 11 until oxygen bottle was refilled. Then ascended to 35,000 feet in 5.5 minutes, using same mask as on previous ascent and constant flow of oxygen. Remained at 35,000 feet for 5.5 minutes. Then carried on exercise for 30 seconds, lifting steel cylinder -- 459 foot pounds in 30 seconds. Then broke connection attaching mask to chamber oxygen line and removed face mask. Chamber started descending at parachute rate. Had intended to remain without oxygen for 15 seconds, but error in timing increased this period to 35 seconds. Then pulled parachute rip cord which should have opened jump bottle valve, but valve was excessively tight and did not open. Failed to notice this and attempted to obtain oxygen through emergency mouthpiece. Soon realized that unconsciousness was approaching and held chamber emergency mask to face. (Mask with high oxygen flow was kept at hand for such an emergency.) Signaled for chamber to be dropped rapidly. Reached the verge of unconsciousness, then, as oxygen entered circulation, senses returned rapidly to approximately normal condition. Dropped chamber to 20,000 feet, and held at that altitude for 10 minutes in preparation for another attempt.

Abstract of Observers' Notes: This illustrates precautions needed to prevent serious accident when confusion or mistake in experimental procedure develops.

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SIMULATED PARACHUTE JUMP NO. 13
September 28, 1942 M.A.M.U. Flight No. 19

Subject: Charles A. Lindbergh - Jump from 35,000 feet.

Personal Report: After 10 minutes breathing oxygen at 20,000 feet, reascended to 35,000 feet in 2.5 minutes, using same mask as on first ascent and constant flow of oxygen. Remained at 35,000 feet for 5.5 minutes. (Condition not as good as on Jumps No. 11 and 12.) Then carried on exercise for 30 seconds, lifting steel cylinder. (432 foot lbs. in 23 seconds.) Then broke connection, attaching mask to chamber oxygen line, and removed face mask. Chamber started descending at parachute rate. Remained without oxygen for 15 seconds. Then pulled parachute rip cord, thereby opening jump bottle valve. Detached emergency mouthpiece from fitting and began breathing oxygen from jump bottle. Found that in addition to its increased oxygen efficiency, the Dautrebande tube greatly reduced the tendency to cough and swallow which was caused by the regular pipestem type mouthpiece. Noticed lack of oxygen at 32,000 feet, but was able to continue descent at parachute rate and condition soon began to improve. Removed mouthpiece at 25,000 feet and discontinued breathing oxygen until 15,000 foot level was reached. Then went back on oxygen to avoid "hangover."

Abstract of Observers' Report: Color was very poor throughout the jump. Apparently the fatigue of previous jumps made it much harder for subject to carry on.

Rate of Flow of Jump Bottle
(Issue bottle)

Time	Liters STPD
During 1st min.	6.3
" 2nd min.	5.3
" 3rd min.	4.4
" 4th min.	3.8
" 5th min.	3.2
" 6th min.	2.6
" 7th min.	2.3
" 8th min.	1.6
" 9th min.	1.6
" 10th min.	1.4
" 11th min.	1.2
" 12th min.	1.0
" 13th min.	0.81
" 14th min.	0.70

SIMULATED PARACHUTE JUMP NO. 14
September 29, 1942 M.A.M.U. Flight No. 20

Subject: Charles A. Lindbergh - Jump from 35,000 feet.

Personal Report: After 30 minutes of denitrogenization, entered large pressure chamber and ascended to 35,000 feet in 5 minutes, using Bulbulian demand type mask with rebreather bag, Dautrebande tube, and jump bottle tube attached near tip of Dautrebande tube. Used constant flow of oxygen for ascent. Remained at 35,000 feet for 10 minutes. Then carried on 30 seconds of exercise, on chamber oxygen line, lifting steel cylinder (459 foot pounds work in 30 seconds). Then broke connection attaching mask to chamber oxygen line and removed mask from face (to simulate mask being blown away during jump). Chamber started descending at parachute rate. Remained without oxygen for 20 seconds. Then pulled parachute rip cord, thereby opening jump bottle valve. Detached emergency mouthpiece from fitting and began breathing oxygen from jump bottle. Chamber continued to descend at parachute rate. Removed mouthpiece at 25,000 feet and discontinued breathing oxygen entirely until 15,000 foot level was reached. Then went back on oxygen to avoid "hangover." Adequate oxygen reserve throughout entire jump.

Abstract of Observers' Notes: The set up used in this experiment was made with the finally perfected apparatus and had a larger Dautrebande tube for rebreathing. This set up is very much better than previous ones both for oxygen efficiency and for ease and safety in use.

Rate of Flow of Jump Bottle
(Issue bottle)

Time	Liters STPD
During 1st min.	6.3
" 2nd min.	5.3
" 3rd min.	4.4
" 4th min.	3.8
" 5th min.	3.2

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SPECIAL EXPERIMENT No. 1
September 27, 1942 M.A.M.U. Flight No. 16

Subject: Charles A. Lindbergh - Alveolar Airs at 35,000 and 40,000 feet.

Abstract of Observers' Report: Subject was denitrogenized for 30 minutes and then:

1. Ascended in chamber to 35,000 feet in 7 minutes, wearing A-8-B mask with oxygen flow set at 35,000 feet inactive, and after about 6 minutes at sitting rest gave first alveolar air.
2. Oxygen flow was increased to 35,000 feet active and subject exercised and gave second alveolar air.
3. Chamber was raised to 40,000 feet in 2 minutes, and after 5 minutes third alveolar air sample taken with oxygen flow at 40,000 feet inactive.
4. Oxygen flow increased to 40,000 feet active and subject exercised and gave fourth alveolar air.

ALVEOLAR AIR

Elevation	Subject	O_2 Flow set at	CO_2 %	CO_2 mm.	O_2 %	O_2 mm.
35,000	Inactive	35,000 inactive	24.69	33	72.67	96
35,000	Active, doing about 2,000 ft. lb. work in the minute, ending about ¼ minute before the alveolar air.	35,000 active	24.25	32	70.29	93
40,000	Inactive	40,000 inactive	33.52	32	63.66	60
40,000	Active, doing about 1,000 ft. lb. work in next to last half minute before alveolar air.	40,000 active	33.23	31	65.41	61

It is to be noted that the oxygen pressure in all four alveolar airs was exactly at the theoretically perfect level.

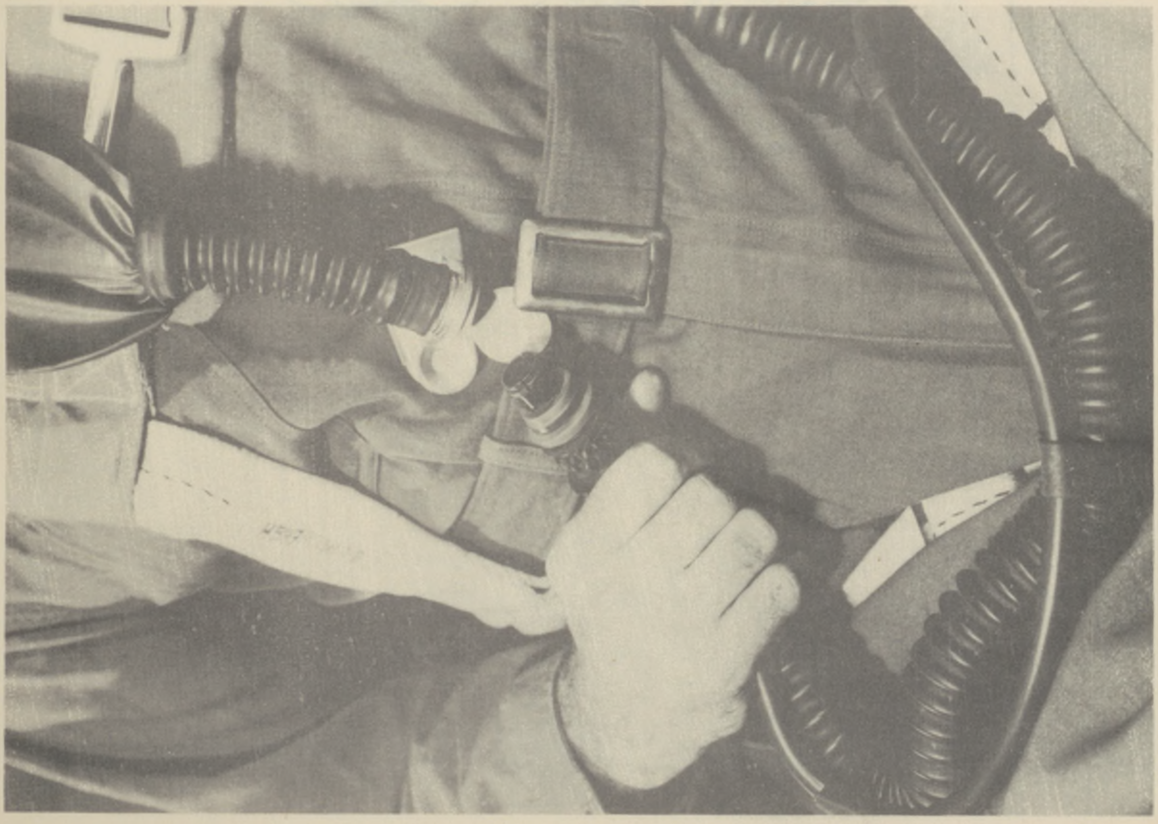
SPECIAL EXPERIMENT NO. 2
September 27, 1942 M.A.M.U. Flight No. 16

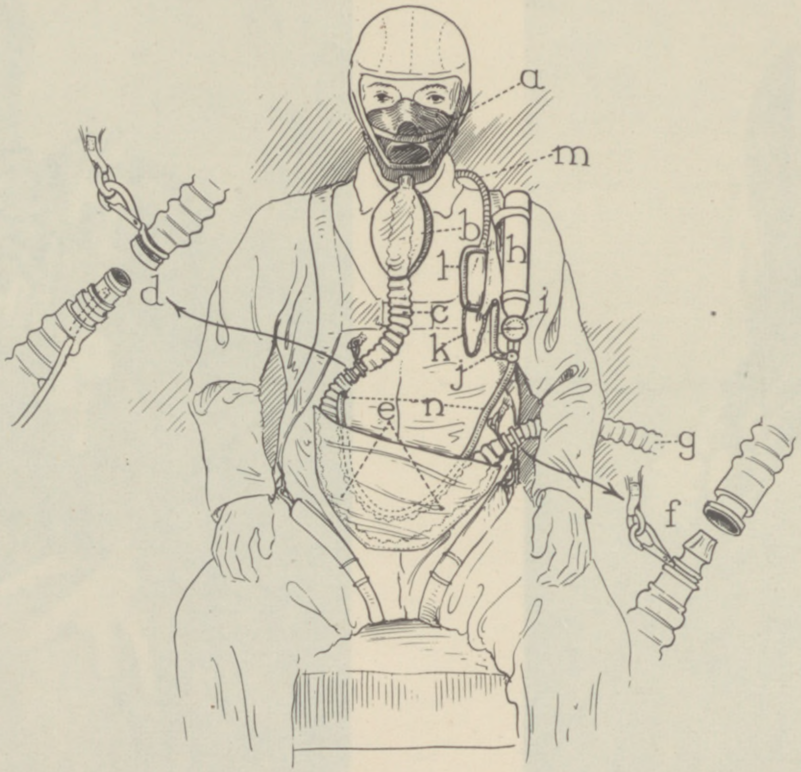
Subject: Charles A. Lindbergh - Effect of breathing air at 40,000 feet.

Personal Report: After 30 minutes of denitrogenization, entered large pressure chamber and ascended to 40,000 feet in 18 minutes, using A-8-B oxygen mask and constant flow of oxygen. Alveolar air samples were taken at 35,000 and 40,000 feet. (See Special Experiment No. 1) W. J. Hadden carried on simulated parachute jump (See Jump No. 9) from 40,000 feet during which the chamber dropped to 30,000 feet. Reascended to 40,000 feet.

1. Removed mask and took 1 normal breath of air in chamber, then replaced mask; noticed no effect.
2. Two minutes later, removed mask and took 2 normal breaths; noticed slight effect, starting several seconds after replacing oxygen mask.
3. Two minutes later removed mask and took 3 normal breaths; noticed definite effect starting several seconds after replacing oxygen mask and increasing for several seconds thereafter.
4. Three minutes later removed mask and took 4 normal breaths; noticed strong effect, starting several seconds after replacing oxygen mask and increasing for several seconds thereafter.
5. Three minutes later, removed mask and took 1 deep breath of air in chamber; noticed slight effect, starting several seconds after replacing oxygen mask.
6. Three minutes later, removed mask and took 2 deep breaths; noticed definite effect starting several seconds after replacing oxygen mask and increasing for several seconds thereafter.
7. Three minutes later, removed mask and took 3 deep breaths; noticed strong effect starting several seconds after replacing oxygen mask and increasing for several seconds thereafter.

The fact that the subject continued to get worse after putting the oxygen mask back on, in every instance, is important for the aviator to remember. If for any reason the aviator's oxygen is cut off at high altitude, he will progressively and rapidly become anoxic; he will continue to get worse and may become unconscious for a few seconds before he starts to improve, even after the oxygen is again started, because, as we discussed with Dr. Boothby, it takes some time to rebuild the oxygen pressure in the alveolar air and for the reoxygenated blood to get to the central nervous system. The lag seems to be about 15 to 20 seconds.

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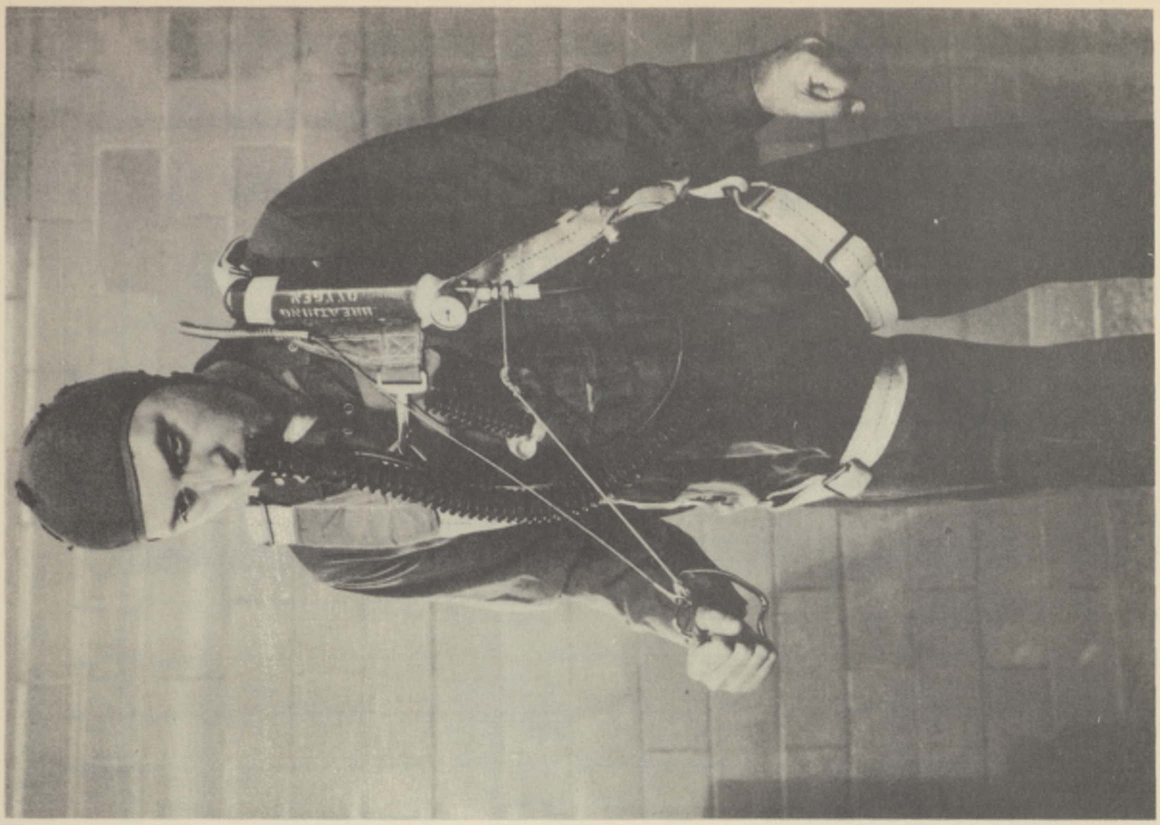


RESTING — FLOW = 0.8 L/min. = 15,000 Inactive

WORKING — FLOW = 1.8 L/min. = 15,000 Active

ALTITUDE = 15,000 feet

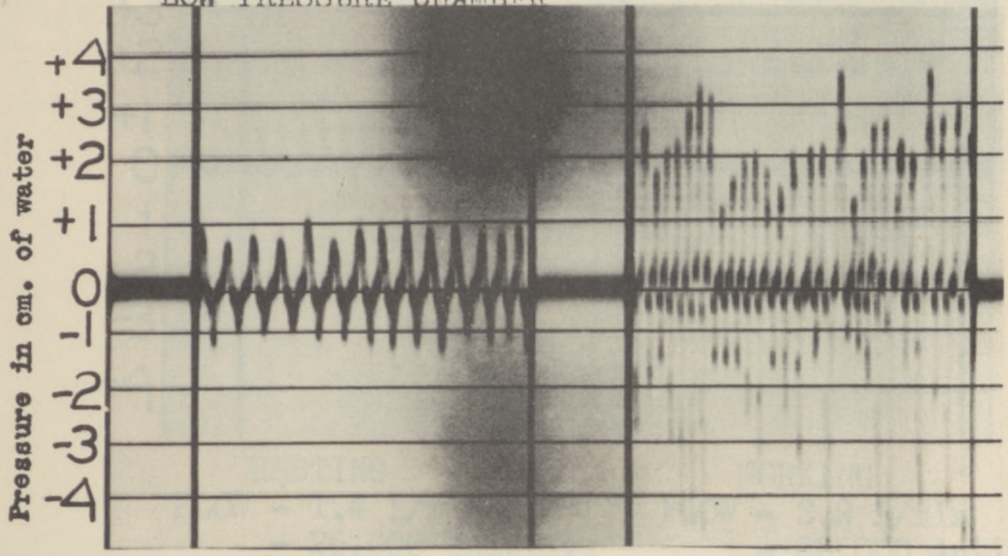
ALTITUDE = 30,000 feet

PRESSURE CHANGES IN BLB CHIN TYPE MASK

AT REST AND AT WORK(1200 ft.lbs./min.)

AT VARIOUS SIMULATED ALTITUDES. IN THE

LOW PRESSURE CHAMBER



RESTING
FLOW - 0.8 L/min.
- 15,000 Inactive

WORKING
FLOW - 1.6 L/min.
- 15,000 Active

ALTITUDE - 15,000 feet

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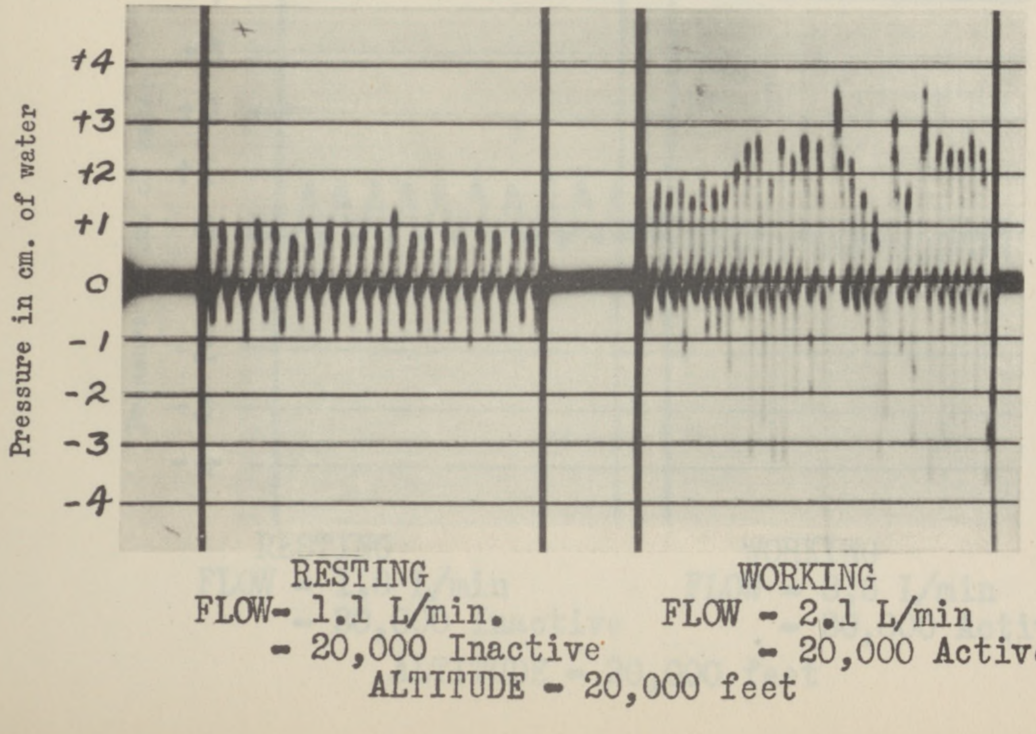
Boothby, Flinn and Bratt
May 15, 1942

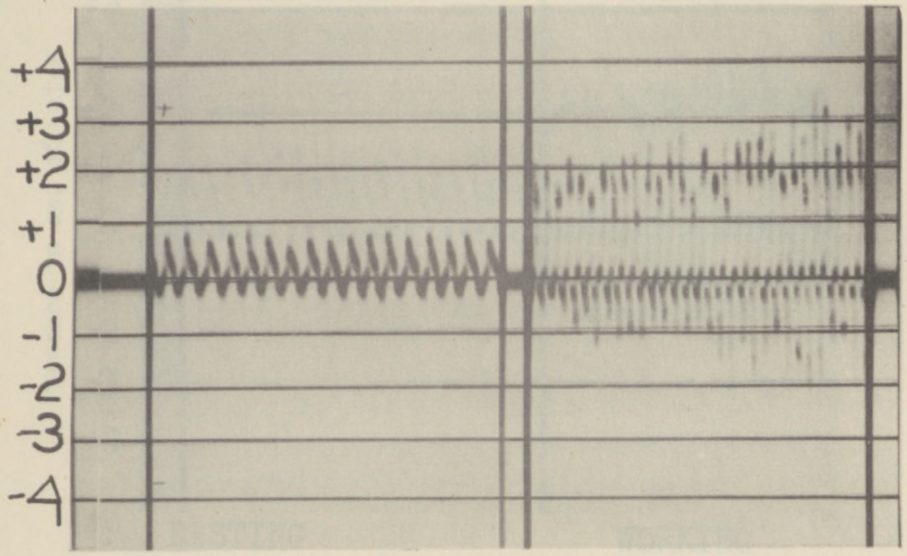


RESTING
FLOW- 1.1 L/min.
- 20,000 Inactive

WORKING
FLOW - 2.1 L/min
- 20,000 Active

ALTITUDE - 20,000 feet

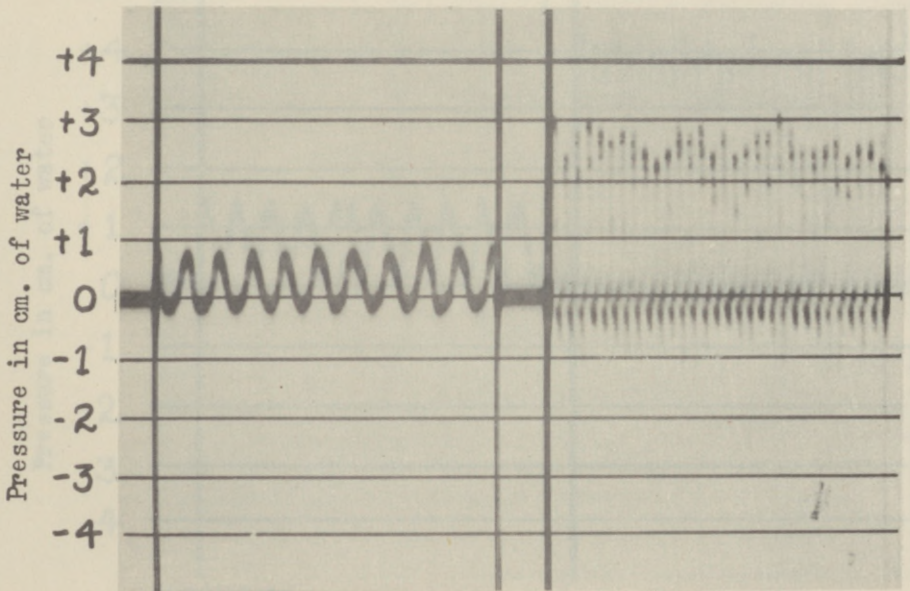
Mayo Aero-Medical Unit
Boothby, Flinn and Bratt
May 15, 1942



RESTING
FLOW - 1.4 L/min
- 25,000 Inactive

WORKING
FLOW - 2.9 L/min
- 25,000 Active

ALTITUDE - 25,000 feet



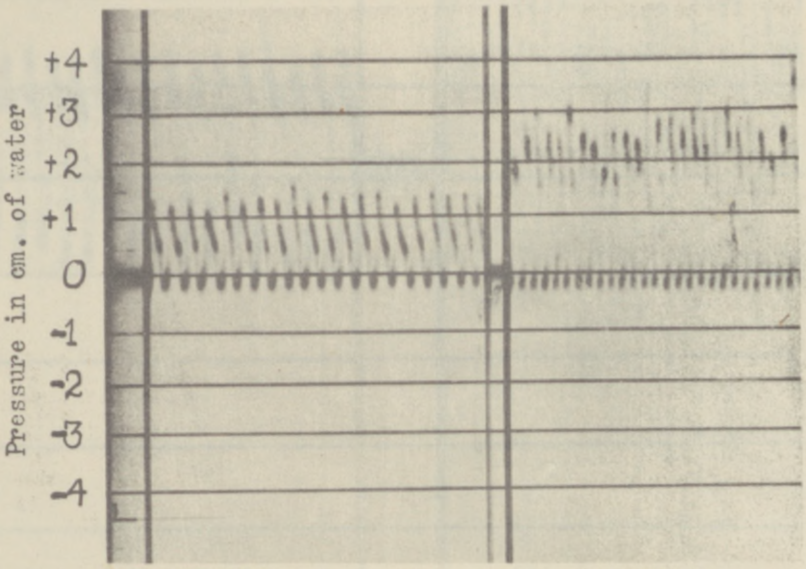
RESTING
FLOW - 1.8 L/min
- 30,000 Inactive

WORKING
FLOW - 3.6 L/min
- 30,000 Active

ALTITUDE - 30,000 feet

16

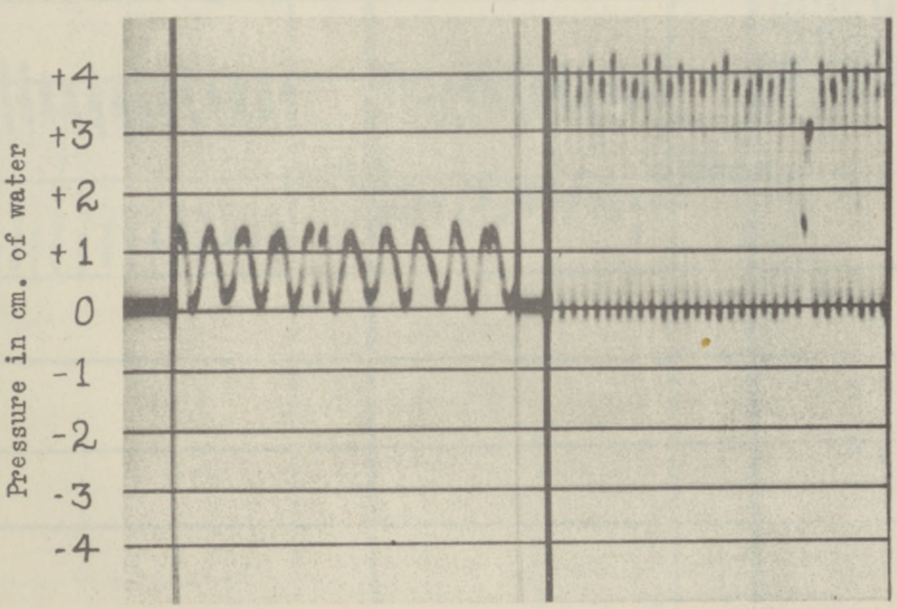
Mayo Aero-Medical Unit
Boothby, Flinn and Bratt
May 15, 1942



RESTING
FLOW - 2.2 L/min
- 35,000 Inactive

WORKING
FLOW - 4.4 L/min
- 35,000 Active

ALTITUDE - 35,000 feet

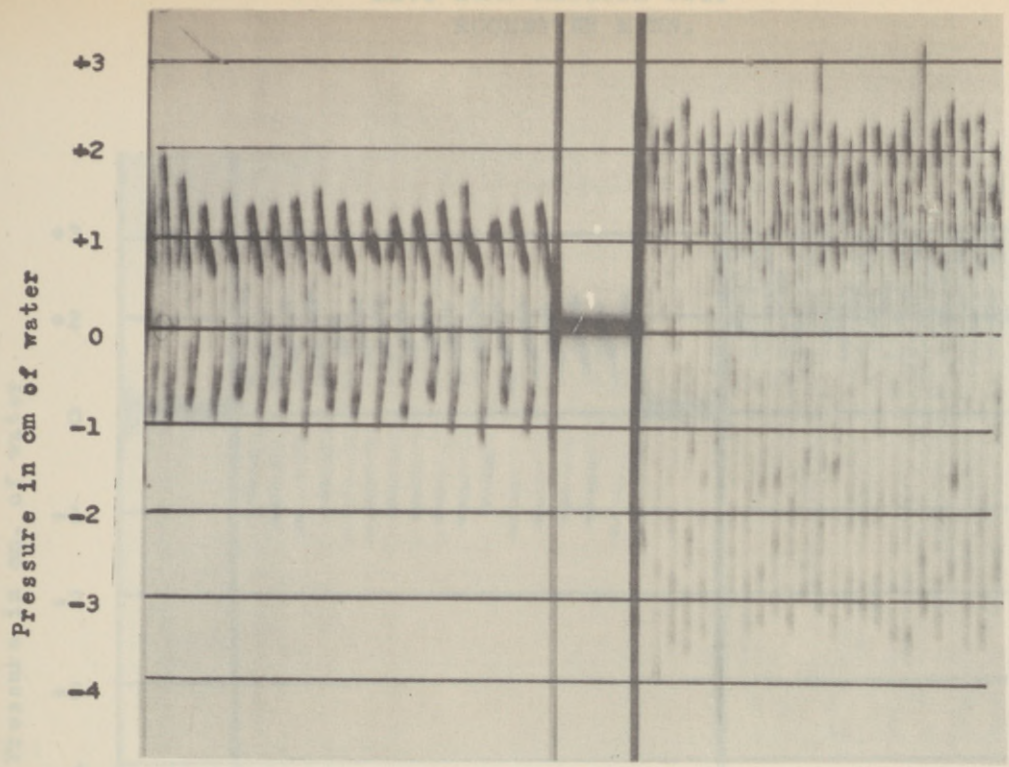


RESTING
FLOW - 2.5 L/min
- 40,000 Inactive

WORKING
FLOW - 5.0 L/min
- 40,000 Active

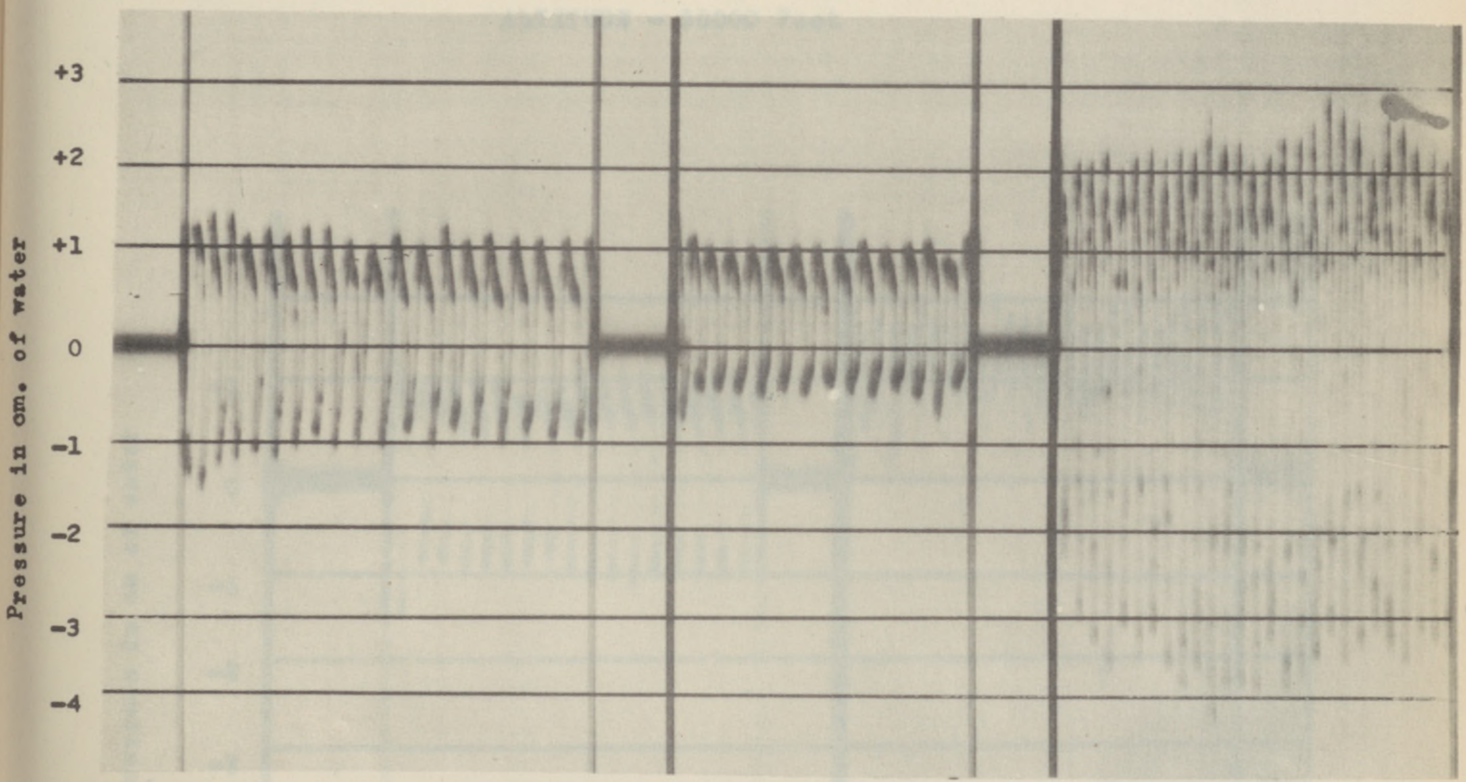
ALTITUDE - 40,000 feet

MAYO AERO-MEDICAL UNIT
ROCHESTER, MINN



RESTING WORKING(1200 ft. lbs/min.

ALTITUDE - 15000 Feet



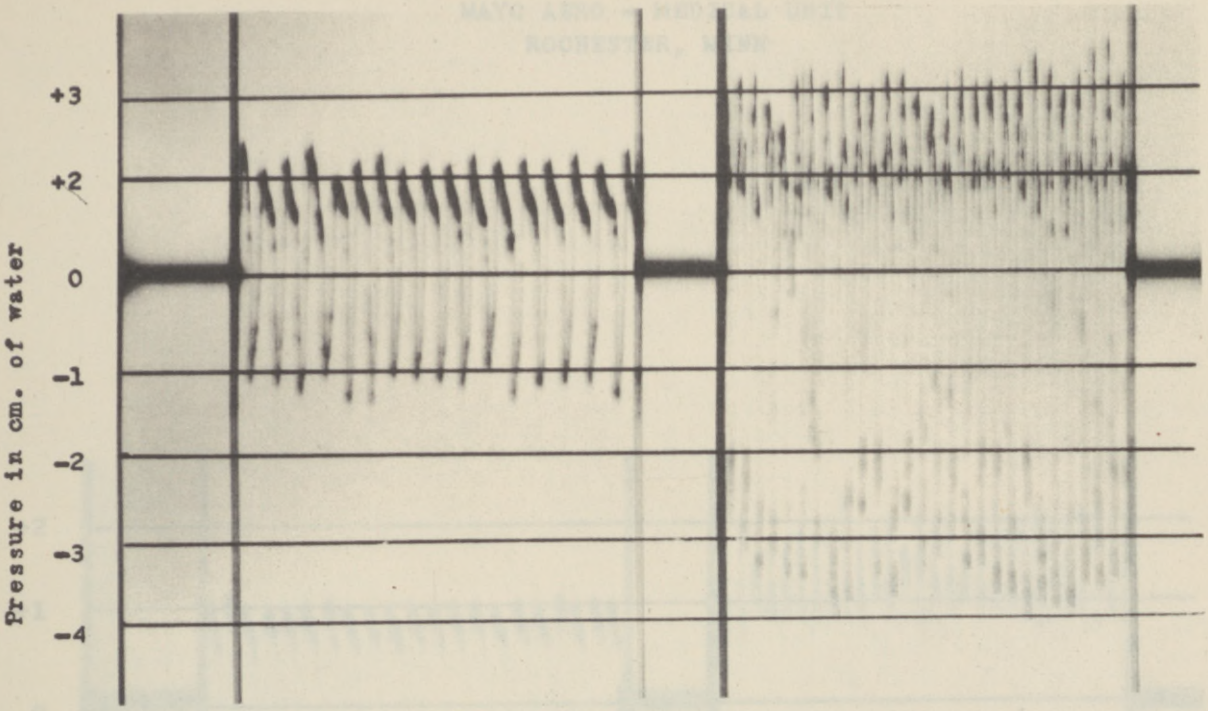
RESTING RESTING (AUTOMATIC REGULATOR TURNED OFF) WORKING (1200 ft. lbs/ min)

JUNE 3, 1942

ALTITUDE - 25000 Feet

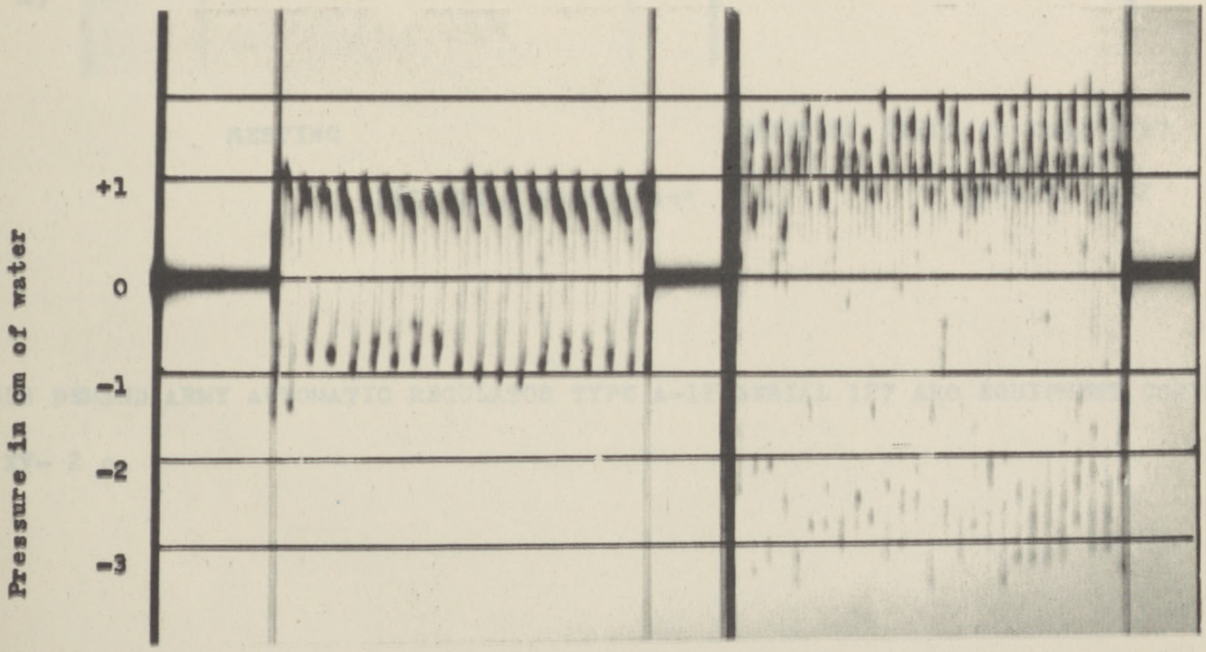
BLB DEMAND ARMY AUTOMATIC REGULATOR TYPE A-12 SERIAL 127 ARO EQUIPMENT CORPORATION

MAYO AERO-MEDICAL UNIT
ROCHESTER MINN.



RESTING WORKING (1200 ft lbs/ min)

ALTITUDE - 30000 Feet



RESTING WORKING 1200 ft. lbs/ min)

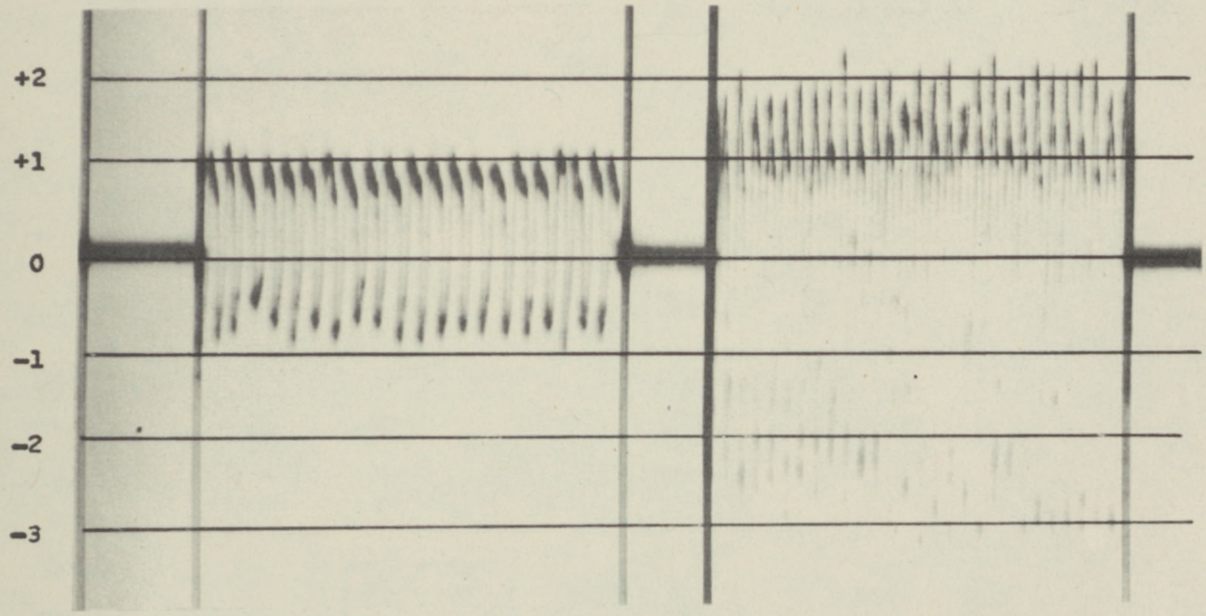
ALTITUDE - 35000 Feet

JUNE 3, 1942

DEMAND ARMY AUTOMATIC REGULATOR TYPE A-12 SERIAL 127 ARO EQUIPMENT CORPORATION

XV 2 b

MAYO AERO - MEDICAL UNIT
ROCHESTER, MINN



RESTING WORKING (1200 ft lbs/ min)

ALTITUDE - 40000 Feet JUNE 3, 1942

BLB DEMAND ARMY AUTOMATIC REGULATOR TYPE A-12 SERIAL 127 ARO EQUIPMENT CORPORATION

XV- 2 c

No. 2

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT

to

ARMY AIR FORCES MATERIEL COMMAND
Under Contract No. W535ac-28529

SUBJECT: Report on positive pressure breathing (a) constant pressure and (b) pulsating pressure (chest compression up to 4 cm. Hg for short periods 3 to 4 times during expiration) by Boothby and Lindbergh.

SERIAL REPORT: Series A, No. 1a DATE: October 3, 1942

A. Purposes.

1. To determine the effect of positive pressure breathing on ability to go to high altitudes.

2. To determine whether or not a pulsating or rhythmic type of pulsating breathing has an added advantage.

B. Factual Data.

The details of the experiments conducted on producing pulsating breathing on Col. C. A. Lindbergh are given in the appendix.

a. Experiment No. 1, October 1, 1942, in the individual low pressure chamber. An altitude of 36,000 to 42,000 was maintained for 3 hours and 27 minutes using new type pulsating pressure breathing (short compressions of chest against increasing manometer to 4 cm. Hg).

b. Experiment No. 2, October 2, 1942, in the large low pressure chamber. An altitude of 30,000 feet was maintained for 2 hours and 27 minutes and 40,000 feet for 43 minutes. Alveolar airs were obtained at 30,000 feet and 40,000 feet.

c. Experiment No. 3 in the large low pressure chamber. An altitude of 40,000 to 45,000 feet was maintained for 16 minutes and stayed at 45,000 feet for 6 minutes.

C. Conclusions.

Positive pressure breathing experiments were conducted on Col. C. A. Lindbergh. Some were done with constant pressure apparatus consisting of a weighted spirometer. Those on Col. Lindbergh were carried out by stopping up one sponge rubber disc on constant flow mask and producing pulsating type of flow by closing and opening the other sponge rubber disc with hand. The latter seemed to gain some improvement in general condition at altitudes above 40,000 feet and Col. Lindbergh thought it could be of some help for short time in an emergency.

Prepared by Walter M. Boothby, M.D.
Chairman
Mayo Aero Medical Unit

c1

EXPERIMENT NO. 1

October 1, 1942, Mayo Aero Medical Unit

Two man chamber

Controlled either inside by subject or outside by observer.

Subject: Col. C. A. Lindbergh wearimg nasal BLB with 2 sponge rubber discs.

Time	Elevation	O_2 flow	Body temperature: no exercise	Body temperature: after exercise	Remarks
11.09	Ground		98.5	98.3	
11.24	40,000	35 act.			
11.28	40,000	35 act.	98.4		
11.35	40,000	35 act.			Color good
11.40	"	"	98.5		
11.41	"	"			25 minutes above 30,000 ft. and 17 minutes at 40,000 ft.
11.50	"	"	98.3		Color good
12.00	39,000	"			Chamber dropping although valves all closed (pump too warm)
12.05	38,400	"	98.4		At 40,000 ft. for 41 minutes
12.08	38,000	"			
12.10	37,500	"	98.5		
12.12	37,000				Chamber still dropping
12.15	37,500	30,000 act.			Chamber all right now
12.20	37,500	30,000	98.5		
12.24	37,000	30,000			37,000 to 40,000 ft. for 1 hour.
12.26	36,800	30,000			Pressure dropping again
12.30	36,400	38,000 act.	98.5		
12.35	36,800	38,000			Climbing again slowly. Water cooler was half empty. Ice cubes put in water also.
12.36	37,600	40,000 act.			Pressure all right now.
12.38	38,000	40,000 act.			
12.40	38,500	40,000 act.	98.5		
1.10	40,000	41,000 act.	98.2		
1.20	40,000	41,000 act.	98.1		
1.24	40,000	"			2 hours above 36,000 ft.
1.30	40,300	"	98.3		
1.35	40,200		98.3		
1.50	"	"	98.3		
2.00	40,000	35,000 act.	98.7		Col. Lindbergh has been trying a new kind of breathing. He has held each breath and compressed chest 2 or 3 times intermittently in attempt to produce a positive O_2 pressure in lungs. He feels this might be helpful to a lone aviator who felt he was not getting enough O_2 at high altitudes (40,000 or above).
2.07	40,000	35,000 act.			
2.09	42,000	"			Will try positive pressure breathing.
2.15	40,000				Says he could notice an improvement in the way he felt and would like to try it at 44,000 ft. Will try this in large chamber only.
2.20	"	"	98.8		

Experiment No. 1 (continued)

Time	Elevation	O_2 flow	Body temperature		Remarks
			no exercise	after exercise	
2.24	40,000	35,000 act.			3 hours above 36,000 ft. Still using positive pressure breathing. Color entirely normal and feels good. Checking pressure exerted with each compression on mercury manometer inside. Is using 4 cm. mercury pressure with each compressure and is doing 3 compressions with each inspiration.
2.07	"	"	98.8		Col. Lindbergh says he definitely feels much better today at 40,000 ft. after being here over 3 hours than he did the other day after 1 hour and 10 minutes at 40,000 ft.
2.43	"	"	98.9		
2.44	"	"			Pulse 96
2.45	"	"			Check on pulse 96
2.50	"	"	98.9		3 hours and 25 minutes above 36,000 ft.
2.51					Start down
2.52	Ground				

Down from 40,000 ft. to ground in 1 minute and 30 seconds.

EXPERIMENT NO. 2
October 2, 1942, Mayo Aero Medical Unit
Large low pressure chamber
Flight No. 21

Subject: Col. C. A. Lindbergh — Wearing nasal BLB constant flow. Decompressed for 31 minutes.
Observer: Henrietta Cranston — Wearing nasal BLB constant flow. Decompressed for 20 minutes.
Observer: Rita Schmelzer — Wearing A-8-B. Decompressed for 20 minutes.
Air lock

Time	Elevation	O_2 flow	CO_2%	mm.	O_2%	mm.	Remarks
2.37	Ground	active 42,000 inact.					
2.48	30,000	30,000					
2.54	"	"	17.94	32	75.35	135	
2.59	"	"	18.07	32	78.13	140	Starting pulsatin. breathing
3.03	"	"	. . . . . .				Respirations 5/min. 3 pulsations
3.04	"	"	17.73	32	46.08	82	
3.07	"	"	. . . . . .				Respirations 5/min.
3.09	"	"	19.06	34	48.77	87	Tc wait a minute or two to get back to normal breathing. With pulsating breaths usually take in bigger breath than he was able to get out of bag.
3.11	"	"	. . . . . .				Respirations 4/min.
3.12	Starting up						
3.12		42,000 act.					
3.13	35,000						
3.15	40,000 corr.	40,200	. . . . . .				2 hours and 27 min. at 30,000 ft.
3.19	"		. . . . . .				Respirations 13/min.
3.20			32.35	30	62.05	58	
3.25			33.82	32	63.01	59	Grade I minus cyanosis
3.25	Still 40,000	42,000 act.	. . . . . .				Start pulsating breathing 3 resp. 6/min.
3.29	"	"	. . . . . .				Cyanosis gr.I -1st we noticed
3.30	"	"	Alv.air no good - wait 4 min.				
3.33	"	"	. . . . . .				Lips quite blue, Gr.II cyanosis
3.34	"	"	36.37	34	61.16	57	Grade II cyanosis.
3.38	"	"	. . . . . .				Now breathing naturally
3.42	"	"	. . . . . .				Cyanosis no better, maybe worse
3.42	"	"	. . . . . .				Hand over 1 sponge disk
3.44	"	"	. . . . . .				H.C. thinks C.A.L. is starting to get better
3.46	"	"	. . . . . .				Respirations 12/min.
3.48	"	"	. . . . . .				H.C. thinks he is better probably now Gr. I
3.48	"	"	. . . . . .				Hands over both sponge rubber disk
3.50	"	"	. . . . . .				Color seems better -also marked change in color of lips, just about normal
3.51	"	"	. . . . . .				Now breathing through 2 sponge rubber disks (releasing pressure)
3.52	"	"	. . . . . .				Becoming more cyanotic
3.52	"	"	. . . . . .				1 pulsation per breath
3.53	"	"	. . . . . .				Definitely worse
3.54	"	"	. . . . . .				Lips and nails blue
3.56	"	"	. . . . . .				Lindbergh doing something different

Time	Elevation	O_2 flow	CO_2%	mm.	O_2%	mm.	Remarks
							He tried to create a slight negative pressure but it did not work
3.58	Start down - free fall						
	From 40,000 to ground in min. and 12 sec.						43 min. 40,000 ft.

EXPERIMENT NO. 3
October 3, 1942, Mayo Aero Medical Unit
Flight No. 22

Subject: Lucille Cronin — Wearing A-8-B mask and positive pressure apparatus (consisting of a weighted spirometer)

Observer: C.A. Lindbergh — Wearing the chin bag type mask, constant flow. Mask has 2 sponge rubber disks but one of them was replaced with a cork. To try pulsating breathing and observe L.Cronin on clinical positive pressure apparatus

Observer: Rita Schmelzer in air-lock. — Wearing A-8-B mask.

Time	Elevation	Remarks
10.55	Start up	Lucille Cronin on positive pressure apparatus.
10.58	14,500 ft.	Oxygen flow beyond reading on flow meter. Dead space in mask expanding so have to cut a hole in the mask.
11.05	25,000 ft.	Still easy to breathe.
11.10	40,000 ft.	Feels all right.
11.15	42,000 ft.	Subject does not look comfortable.
11.17	42,000 ft.	Subject does not notice much difference between 40,000 and 42,000 ft. as on other runs.
11.21	44,000 ft.	Color just as good as when at ground. Mask very uncomfortable.
11.23	45,000 ft.	Not as comfortable as at 42,000 ft. but feels all right.
11.24	40,000 ft.	
11.26	45,000 ft.	Subject feels as good at 43,000 ft. as at 40,000 ft. with regular mask. Feels better at 45,000 ft. than first time at 45,000 ft.
11.28	45,000 ft.	Lindbergh holding other port on mask - good reaction.
11.29	45,000 ft.	Lindbergh looks better. Subject is pulsating port with thumb. Better without pulsation.
11.29	45,000 ft.	Subject Lucille Cronin color all right.

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL COMMAND
Under Contract No. W535ac-25829

SUBJECT: Indoctrination of 21 crews of the ~~370th~~ 307th Bombardment Group

SERIAL REPORT: Series A, No. 2. DATE: October 30, 1942

A. Purposes:

Through arrangements made by General Olds and Colonel Matheny and with the help of Colonel Benson of the Aero Medical Research Laboratory, Wright Field, the Mayo Aero Medical Unit carried out an indoctrination of 203 men of the 307th Bombardment Group in the use of oxygen and in the general physiology of high altitude flying including the methods of decreasing the danger from bends.

B. Factual Data:

1.
21 crews
203 officers and men
44 crew flights
23 men incapacitated by bends - - = 11%
20 flights jeopardized by bends - = 46%
24 flights not jeopardized by bends = 54%

2. The officers and enlisted men came in units of one complete crew from the Souix City Air Base to Rochester for instruction in the low pressure chamber. Forty-four crew flights were made which gave a total of 380 man flights to 35,000 feet or over. Four crews made 3 flights each, 16 crews made 2 flights and 1 crew made 1 flight. Sixteen of these flights lasted 3 hours, 14 flights 2½ hours, 3 flights 2 hours, 7 flights 1½ hours and 4 flights 1 hour.

3. Twenty-three men were incapacitated by the bends and had to be taken down in the air-lock. This is a comparatively small number, only 11%. The details are given in the summarized individual flight reports attached herewith. A new point, however, which has not been brought out before is the distribution throughout the crews of these men who were incapacitated by bends. It was found that out of the 44 crew flights the mission in 20, or 46%, of the flights was seriously jeopardized by at least one man becoming incapacitated. This left only 24, or 54%, of the flights in which there was no serious interference with the missions from individuals becoming incapacitated from the bends.

4. Time was not available for testing the men with and without denitrogenation. However, in several instances we were able to show the individual men who had the bends that they had less difficulty if they were denitrogenized. This part of the data, however, is too meagre to refer to in direct numbers or to attempt to work out in percentages.

5. At lectures and during the indoctrination runs emphasis was placed on the practical management of their oxygen equipment and the necessity of each aviator watching his "life-line" and oxygen supply. Also each individual member of the crew was instructed in the procedures to be carried out if another member of the crew should have difficulty. It was pointed out that at 35,000 feet, if the subject was working, there is hardly more than 35 seconds before the subject becomes unconscious if the oxygen supply fails and a lesser time at 40,000 feet. With the aviator inactive, it would take nearly twice as long for the subject to become unconscious.

6. One flight was taken to 44,300 feet, 4 to 44,000, 6 to 43,000, 4 to 42,000, 1 to 41,500, 17 to 40,000, 1 to 39,000, 1 to 38,000 and 9 to 35,000 feet. The experience of going to high elevations is valuable as it gives the aviator confidence in his equipment if he is adequately trained in its care and use; he realized that his ceiling so far as anoxia is concerned is definitely above 40,000 feet.

7. Method of bailing out was illustrated by movies.

8. The above indoctrination course was rendered possible by the enthusiastic cooperation of the staff of the Mayo Aero Medical Unit consisting of Drs. Wilson, Robinson, Cunningham, Code and Wood, Mr. Bratt, Miss Knutson, Miss Cronin, Mrs. Cranston, Mrs. Larson, Miss Campion and Miss Weinhold.

Prepared by: Walter M. Boothby, M.D.
Chairman, Mayo Aero Medical Unit
Rochester, Minnesota

MAMU FLIGHT NO. 23

Monday, October 5, 1942, from 2:12 P. M. to 5:08 P. M. (2°56')

Squadron 370, Crew 1, Flight A

			Decompression	Mask
1.	Pilot	Capt. L. F. Krebs	None	A-8-B
2.	Co-Pilot	1st Lt. J. Nowell	None	A-8-B
3.	Bombardier	2nd Lt. J. D. Newman	None	A-8-B
4.	Tail Gunner	Sgt. E. F. Gartland	None	A-8-B
5.	Radio Operator	S/Sgt. A. S. Hatfield	None	A-8-B
6.	Engineer	Sgt. M. E. Hatfield	None	A-8-B
7.	Asst. Engineer	S/Sgt. R. N. Furtwangler	None	A-8-B
8.	Asst. Oper. Off.	2nd Lt. K. M. Kidder	None	A-8-B
9.	Extra	Pvt. M. Casoria	None	A-8-B

Condensed Log of Flight

Duration Hrs.	Min.	Elevations
	52	30,000 - 34,000 feet
1	27	35,000 - 39,000 feet
	6	40,000 feet
Total, 2 hr.	25	over 30,000 feet

Highest Elevation 40,000 ft.

Results

4. Bombardier, Newman

41 min.	35,000 - 40,000 feet	Developed pain right ankle (35,000).
42 "	35,000 - 40,000 "	Pain better.
58 "	35,000 - 40,000 "	Pain very bad.
1 hr. 1 "	35,000 - 40,000 "	Pain so severe he entered air lock and was taken to ground. Nose bleed in air lock.

9. Asst. Oper. Off., Kidder

53 min.	35,000 feet	Slight pain in knees but not incapacitating.

Navigator - Had cold so did not take the flight.

The other seven men had no symptoms.

Summary: Bombardier incapacitated in 55 minutes at 35,000 feet and to this extent jeopardizing the object of the mission.

MAMU FLIGHT NO. 24

Monday, October 5, 1942, from 7:35 to 9:12 (1°37')

Squadron 370, Crew 1, Flight A

			Decompression	Mask
1.	Pilot	Capt. L. F. Krebs	21 min. exercycle	Drinker
2.	Co-Pilot	1st Lt. J. Nowell	22 min. 3 mi./hr.	A-8-B
3.	Bombardier	2nd Lt. J. D. Newman	27 min. 3 mi./hr.	A-8-B
4.	Tail Gunner	Sgt. E. F. Gartland	14 min. ball	A-8-B
5.	Radio Operator	S/Sgt. A. S. Hatfield	None	A-8-B
6.	Engineer	Sgt. M. E. Hatfield	15 min. 3 mi./hr.	A-8-B
7.	Asst. Engineer	S/Sgt. R. N. Furtwangler	None	A-8-B
8.	Asst. Oper. Off.	2nd Lt. K. M. Kidder	19 min. 3 mi./hr.	Drinker
9.	Extra	Pvt. M. Casoria	None	A-8-B

Condensed Log of Flight

Highest elevation 44,000 feet.

Duration Hrs.	Min.	Elevations
	17	30,000 - 34,000 feet
	46	35,000 - 39,000 feet
	2	40,000 - 41,000 feet
	3	over 42,000 feet
1	8	over 30,000 feet

Results

1. Pilot, Krebs

34 min.	35,000 feet	Slight pain at knee.
49 min.	35,000 feet	Pain gone.

2. Co-Pilot, Nowell

	42,000 feet	Choky feeling.

3. Bombardier, Newman

20 min.	25,000 feet	Nose bleed. Pain at knee
24 min.	35,000 feet	Pain at knee worse.
26 min.	35,000 feet	Went down in air lock.

6. Engineer, A. S. Hatfield

	42,000 feet	Pain over right eye.

The other five men had no symptoms.

Summary: Bombardier in this flight was forced down by pain in a shorter time than yesterday in spite of decompression.

MAMU FLIGHT NO. 25

Tuesday, October 6, 1942, from 9:25 to 11:29 AM (2°5')

Squadron 370, Crew 1, Flight A

		Decompression	Mask
1. Pilot	Capt. L. F. Krebs	15 min. 3 mi./hr.	A-8-B
2. Co-Pilot	1st Lt. J. Nowell	None	A-8-B
3. Bombardier	2nd Lt. J. D. Newman	30 min. 3 mi./hr.	A-8-B
4. Tail Gunner	Sgt. E. F. Gartland	None	A-8-B
5. Radio Operator	S/Sgt. A. E. Hatfield	None	A-8-B
6. Engineer	Sgt. M. E. Hatfield	None	A-8-B
7. Asst. Engineer	S/Sgt. R. N. Furtwangler	None	A-8-B
8. Asst. Oper. Off.	2nd Lt. K. M. Kidder	None	A-8-B
9. Extra	Pvt. M. Casoria	None	A-8-B

Condensed Log of Flight

Highest elevation 38,000 feet

Duration Hrs.	Min.	Elevations
	4	30,000 - 34,000 feet
	43	35,000 - 38,000 feet
	48	Over 30,000 feet

Results

7. Asst. Engineer, Furtwangler

34 min.	38,000 feet	Pain in right foot.

9. Extra, Casoria

19 min.	35,000 feet	Pain in left arm.
	30,000 "	Better.
5 "	38,000 "	Slight pain left elbow.
18 "	38,000 "	Pain in elbow and fingers left hand.

The other seven men had no symptoms.

3. Bombardier, Newman, who had to come down in both previous runs not affected this time, probably because decompression was more efficiently carried out.

Summary: No interference with mission from bends.

MAMU FLIGHT NO. 26

Tuesday, October 6, 1942, from 1:50 p.m. to 4:53 p.m. (3°3')

Squadron 371, Crew 1, Flight A

			Decompression	Mask
1.	Pilot	Capt. E. T. Lippincott	None	A-8-B
2.	Pilot	Capt. C. J. Lamothe	None	A-8-B Rebr.
3.	Co-Pilot	2nd Lt. S. E. Schreiber	None	Demand Rebr.
4.	Navigator	Capt. C. G. Benes	None	B. Demand
5.	Tail Gunner	Sgt. P. C. Williams	None	A-8-B
6.	Tail Gunner	Sgt. D. Carpenter	None	A-8-B
7.	Radio Operator	Sgt. J. G. Pope	None	A-8-B
8.	Engineer	Sgt. H. W. Dumas	None	A-8-B
9.	Asst. Engineer	Sgt. R. E. Jamason	None	A-8-B

Duration Hrs.	Min.	Condensed Log of Flight Elevations	Highest elevation 40,000 feet
	8	30,000 - 34,000 feet	
2	19	35,000 - 39,000 feet	
	7	40,000 feet	
2	34	over 30,000 feet	

Results

1. Pilot, Lippincott

	21 min.	35,000 feet	Pain left hand.
	23 "	35-40,000	Hand worse (at 40,000).
	30 "	35-40,000	Pain to elbow (at 35,000).
	41 "	35-40,000	Flow up, exercising.
	44 "	35-40,000	Pain bad (at 40,000).
	48 "	35-40,000	Pain shoulder (at 35,000).
	49 "	35-40,000	Some relief (at 35,000)
	59 "	35-40,000	Pain worse (at 40,000).
		30,000	Pain gone.
1 hr.	35 "	30-40,000	Pain returned (at 35,000).
1 "	54 "	30-40,000	Still has pain (at 35,000). Did not have to come down because of pain but was uncomfortable.

3. Co-Pilot, Schreiber

	30 min.	35,000 feet	Pain thumb.
		40,000 "	Feels better.
2 hr.	32 "	over 35,000	Pain right knee. Pain left when started down.

4. Navigator, Benes

1 hr.	27 min.	over 35,000	Chest pain came on suddenly. Bad chokes. Taken down in air-lock.

5. Tail Gunner, Williams

2 hr.		over 35,000	Pain in thigh and itching.

6. Radio operator, Pope

2 hr.	32 min.	over 35,000	Pain in knee.
		32,000 feet	Pain gone.

7. Engineer, Dumas

1 hr.	53 min.	35-40,000	Pain both arms; red areas.

8. Asst. Engineer, Jamason

	6 min.	35,000 feet	Gas pains.

Two men had no symptoms.

Summary: Navigator seriously incapacitated by bends in 1 hr. 25 min. With the navigator out and with severe bends in five other members of the crew, the mission would have failed.

MAMU FLIGHT NO. 27

Tuesday, October 6, 1942, from 7:37 to 9:20 p.m. (1°43')

Squadron 371, Crew 1, Flight A

			Decompression	Mask
1.	Pilot	Capt. E. T. Lippincott	30 min. exercycle	A-8-B
2.	Pilot	Capt. C. J. Lamothe	None	B. Demand Rebr.
3.	Co-Pilot	2nd Lt. S. E. Schreiber	None	A-8-B
4.	Tail Gunner	Sgt. D. Carpenter	None	A-8-B
5.	Tail Gunner	Sgt. P. C. Williams	None	A-8-B
6.	Radio Operator	Sgt. J. G. Pope	29 min. 3.5 m/hr.	B. Demand Rebr.
7.	Engineer	Sgt. H. W. Dumas	30 min. 3.5 m/hr.	A-8-B
8.	Asst. Engineer	Sgt. R. E. Jamason	None	A-8-B

Condensed Log of Flight

Highest elevation 44,000 feet

Duration Hrs.	Duration Min.	Elevations
	14	30,000 - 34,000 feet
	41	35,000 - 39,000 feet
	15	40,000 - 41,000 feet
	1	42,000 feet and over
1	11	over 30,000 feet

Results

2. Pilot, Lamothe

19 min.	35,000 feet	
9 "	20-30,000	
33 "	35-39,000	Pain in left knee (39,000).
12 "	40-44,000	Pain better and no further trouble, even at 44,000 feet.

7. Engineer, Dumas

16 min.	35-42,000	Pain in left arm gr. II at 42,000
	Came down 35,000	No better
	" " 30,000	Somewhat better; dizzy.
	" " 25,000	Very dizzy

35 min. after beginning flight came down in air-lock.

The other six men had no symptoms.

Summary: Mission interfered with by incapacity of Engineer

NAMU FLIGHT NO. 28

Wednesday, October 7, 1942, from 9:51 a.m. to 12:56 p.m. (3°5')

Squadron 371, Crew 1, Flight A

		Decompression	Mask
1. Pilot	Capt. E. T. Lippincott	None	A-8-B
2. Pilot	Capt. C. J. Lamothe	None	B. Demand Rebr.
3. Co-Pilot	2nd Lt. S. E. Schreiber	None	A-8-B
4. Tail Gunner	Sgt. D. Carpenter	None	A-8-B
5. Tail Gunner	Sgt. P. C. Williams	None	A-8-B
6. Engineer	Sgt. H. W. Dumas	None	
7. Asst. Engineer	Sgt. R. E. Jamason	30 min. 3 mi./hr.	A-8-B

Condensed Log of Flight

Highest elevation 35,000 feet.

Duration Hrs.	Min.	Elevations
	36	30,000 - 34,000 feet
2	6	35,000 - 39,000 feet
2	42	over 30,000 feet

Results

1. Pilot, Lippincott			
	48 min.	35,000 feet	Pain in shoulder, wrist, left leg and foot.
	59 "	35,000 "	Pain about the same.
1 hr.	30 "	35,000 "	Took 8 breaths with mask off to test effect of anoxia. Took mask off again for 10 quick breaths after a few minutes. Felt severe kick.
1 "	32 "	35,000 "	Pains worse, probably result of the anoxia due to testing. Came down in air-lock.
2. Pilot, Lamothe			
1 hr.	56 min.	35,000 feet	Pain left leg, knee and ankle; uncomfortable.
2 "	4 "	35,000 "	Pains better relieved by a temporary lowering of altitude..
5. Tail Gunner, Williams			
2 hr.	2 min.	35,000 feet	Pain in right arm bad.
6. Engineer, Dumas			
2 hr.		35,000 feet	Very uncomfortable, restless.
2 "	3 min.	35,000 "	Chest sore; hard to breathe. May be getting chokes.
2 "	7 "	35,000 "	Started down in air-lock as he was coughing badly.

The other three men had no symptoms.

Summary: Mission seriously handicapped by Engineer becoming incapacitated from chokes. A pilot was incapacitated, due in part to voluntarily removing mask to see effect of breathing air; the resulting anoxia aggravated the previously mild degree of bends so that he too was incapacitated.

MAMU FLIGHT NO. 29

Wednesday, October 7, 1942, from 1:50 to 4:52 p.m. (3°2')

Squadron 372, Crew 2, Flight A

		Decompression	Mask
1. First Pilot	2nd Lt. S. M. Foster	None	A-8-B
2. Pilot	2nd Lt. J. L. Jacobs	None	A-8-B
3. Pilot	1st Lt. G. F. Mozette	None	A-8-B
4. Navigator	2nd Lt. C. H. Roeman	None	A-8-B
5. Bombardier	2nd Lt. J. W. Nicholson	None	A-8-B
6. Radio Operator (Gunner)	S/Sgt. E. E. Hoover	None	A-8-B
7. Radio Operator (Gunner)	T/Sgt. W. W. Richardson	None	A-8-B
8. Eng. Gunner	T/Sgt. J. F. Holsey	None	A-8-B
9. Asst. Eng. Gunner	Sgt. R. L. Barratt	None	A-8-B
10. Armorer (Gunner)	S/Sgt. L. A. Schichner	None	A-8-B

Condensed Log of Flight

Highest elevation 35,000 feet

Duration Hrs.	Min.	Elevations
	26	30,000 - 34,000 feet
1	58	35,000 feet
2	24	over 30,000 feet

Results

1. First Pilot, Foster

	30,000 feet	When reaching 30,000 gas pains, so dropped to 25,000 feet.
9 min.	35,000 "	Pain in left shoulder.
13 "	35,000 "	Pain in left shoulder gone.

3. Pilot, Mozette

55 min.	35,000 feet	Severe gas pains.
57 "	35,000 "	Less gas pains.

4. Navigator, Roeman

1 min.	35,000 "	Pain left wrist very severe. Went down air-lock - 35 min. after going up - exercycle 27 min. and went in main chamber again. No further troubles.

7. Radio Operator, Richardson

2 min.	35,000 feet	Gas pains.
	30,000 "	Gas pains relieved by temporary decrease in elevation.

The other six men had no symptoms.

Summary: Navigator incapacitated from bends, thereby interfered seriously with mission; however, after descent in air-lock he denitrogenized and returned to 35,000 feet without further trouble.

MAMU FLIGHT NO. 30

Wednesday, October 7, 1942, from 7:42 to 9:12 p.m. (1°30')

Squadron 372, Crew 2, Flight A

			Decompression	Mask
1.	First Pilot	2nd Lt. S. M.Foster	11 min. 3-4½ m/hr.	A-8-B
2.	Pilot	2nd Lt. J. L. Jacobs	15 min. 3-4½ m/hr.	A-8-B
3.	Pilot	1st Lt. G. F. Mozette	None	B.Demand Rebr.
4.	Navigator	2nd Lt. C. H. Roeman	None	A-8-B
5.	Bombardier	2nd Lt. J. W. Nicholson	None	Drinker
6.	Radio Operator (Gunner)	S/Sgt. E. E. Hoover	None	A-8-B
7.	Radio Operator (Gunner)	T/Sgt. W. W. Richardson	23½ min. 3½-4½ m/hr.	B.Demand
8.	Eng. Gunner	T/Sgt. J. F. Holsey	None	A-8-B
9.	Asst. Eng. Gunner	Sgt. R. L. Barratt	17 min. 3-4½ m/hr.	Drinker
10.	Armorer (Gunner)	S/Sgt. L. A. Schichner	None	B.Demand Rebr.

Condensed Log of Flight

Highest elevation 44,000 feet

Duration Hrs.	Min.	Elevations
	14	30,000 - 34,000 feet
	28	35,000 - 39,000 feet
	9	40,000 - 41,000 feet
	1½	42,000 feet and over
1	3	over 30,000 feet

Results

3. Pilot, Mozette

10 min.	35,000 feet	Gas pains very bad.
27 "	35,000 feet	Went in air-lock and came down to 35,000 while main chamber went to 42,000. At 30,000 main chamber coming down and level with air-lock - door to chamber open and air-lock and main chamber came down together.

The other nine men had no symptoms.

Summary: Pilot's gas pains severe and mission would have been interfered with if it had been necessary to go above 35,000 feet.

MAMU FLIGHT NO. 31

Thursday, October 8, 1942, from 9:18 a.m. to 12:16 p.m. (2°58')

Squadron 372, Crew 2, Flight A

		Decompression	Mask
1. Pilot	2nd Lt. S. M. Foster	None	Drinker
2. Pilot	2nd Lt. J. L. Jacobs	11 min. 5 mi./hr.	Demand Rebr.
3. Pilot	1st Lt. G. F. Mozette	20 min. 5 mi./hr.	A-8-B
4. Navigator	2nd Lt. C. H. Roeman	None	B. Demand
5. Bombardier	2nd Lt. J. W. Nicholson	None	A-8-B
6. Radio Operator	S/Sgt. E. E. Hoover	None	Demand Rebr.
7. Radio Operator	T/Sgt. W. W. Richardson		
8. Eng. Gunner	T/Sgt. J. F. Holsey	None	Drinker
9. Ass. Eng. Gunner	Sgt. R. L. Barratt	13 min. exercycle	A-8-B
10. Armorer (Gunner)	S/Sgt. L. A. Schichner	None	

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Min.	Elevations
	6	30,000 - 34,000 feet
2	23	35,000 - 39,000 "
	6	40,000 feet
2	35	over 30,000 feet

Results

4. Navigator, Roeman
2 hr. 30 min. — 35,000 feet — Pain left knee.

7. Radio Operator, Richardson - Did not go up on this run.

8. Eng. Gunner, Holsey
35,000 feet — Dizzy when arrived at 35,000 feet. Emergency oxygen mask turned on followed by improvement.

The other seven men had no symptoms.

Summary: No interference with mission by bends.

MAMU FLIGHT NO. 32

Thursday, October, 8, 1942, from 1:42 p.m. to 4:53 p.m. (3°11')

Squadron 424, Crew 9

			Decompression	Mask
1.	Pilot	1st Lt. D. D. Deuchare	None	A-8-B
2.	Pilot	1st Lt. C. A. Friend	None	A-8-B
3.	Pilot	1st Lt. R. W. Rowe	None	A-8-B
4.	Navigator	1st Lt. C. R. Wade	None	B. Demand Rebr.
5.	Bombardier	1st Lt. P. C. Crane	None	A-8-B
6.	Tail Gunner	Cpl. J. F. Magri	None	A-8-B
7.	Gunner	Sgt. N. A. Ward	None	A-8-B
8.	Radio Operator	S/Sgt. E. J. Beaupre	None	A-8-B
9.	Engineer	S/Sgt. F. A. Woods	None	Drinker
10.	Engineer	S/Sgt. K. C. McCarthy	None	A-8-B

Condensed Log of Flight

Highest elevation 42,000 feet

Duration Hrs.	Min.	Elevations
	16	30,000 - 34,000 feet
1	2	35,000 - 39,000 feet
	2	40,000 - 41,000 feet
1	20	over 30,000 feet

Results

1. Pilot, Deuchare

	32 min.	35,000 feet	Pain both knees; flow up, exercise, no better.
	43 "	35,000 "	No better.
		30,000 "	Went down; no better.
1 hr.	12 "	35,000+ "	Still has bends (35,000).
1 hr.	46 "	35,000+ "	Bends better (35,000).
		30,000 "	Bends gone.

6. Tail Gunner, Magri

	24 min.	35,000 feet	Cramps stomach while sitting; better standing.

10. Engineer, McCarthy

		35,000 feet	Pain calf, ankle and foot of left leg; exercised.
1 hr.	4 min.	35,000+ "	Bends better.
		30,000 "	Coming down bends gone.

The other seven men had no symptoms.

Summary: Pilot, Tail Gunner and Engineer had severe but not incapacitating bends.

MAMU FLIGHT NO. 33

Friday, October 9, 1942, from 8:49 a.m. to 11: 46 a.m. (2°57')

Squadron 424, Crew 9

			Decompression	Mask
1. Pilot	1st Lt. D. D. Deuchare			
2. Pilot	1st Lt. C. A. Friend			
3. Pilot	1st Lt. R. W. Rowe			
4. Navigator	1st Lt. C. R. Wade		None	A-8-B
5. Bombardier	1st Lt. P. C. Crane		None	B. Demand Rebr.
6. Tail Gunner	Cpl. J. F. Magri		24 min. 3 mi./hr.	A-8-B
7. Gunner	Sgt. N. A. Ward		None	A-8-B
8. Radio Operator	S/Sgt. E. J. Beaupre		None	Drinker
9. Engineer	S/Sgt. F. A. Woods		29 min. 3 mi./hr.	A-8-B
10. Engineer	S/Sgt. K. C. McCarthy		17 min. exercycle	A-8-B

Condensed Log of Flight

Highest elevation 43,000 feet

Duration Hrs.	Min.	Elevations
	15	30,000 - 34,000 feet
1	32	35,000 - 39,000 "
	1	40,000 - 41,000 "
	2	42,000 - 41,000 "
1	40	over 30,000 feet

Results

1. Pilot, Deuchare - Refused to go up - claustrophobia.

2. Pilot, Friend - Did not go up - had a cold.

3. Pilot, Rowe - Did not go up - had a cold

Summary: None of the men had symptoms. Mission successful.

MAMU FLIGHT NO. 34

Friday, October 9, 1942, from 1:22 to 4:28 p.m. (3°6')

Squadron 370, Crew 7, Flight C

		Decompression	Mask
1. Pilot	1st Lt. U. J. Newman	None	
2. Co-Pilot	2nd Lt. R. J. Kissel	None	A-8-B
3. Navigator	2nd Lt. J. A. Newton	None	
4. Bombardier	2nd Lt. W. L. Shirey	None	Drinker
5. Tail Gunner	Sgt. A. T. Klester	None	
6. Radio Operator	S/Sgt. H. R. Wolf	None	A-8-B
7. Asst. Radio Opr.	S/Sgt. F. J. Deflo	None	A-8-B
8. Engineer	Sgt. J. L. Knisley	None	A-8-B
9. Asst. Engineer	S/Sgt. G. W. Gathers	None	Drinker
10. Asst. Oper. Off.	2nd Lt. Kidder	30 min. 3 m/hr.	A-8-B
11. Flight Surgeon	Capt. M. C. Spoeneman	None	B. Demand Rebr.

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Min.	Elevations
1	20	30,000 - 34,000 feet
1	10	35,000 - 39,000 feet
	9	40,000 feet
2	39	over 30,000 feet

Results

2. Co-Pilot, Kissel

23 min.	35-40,000 feet	Pain right shoulder; chest pain.
27 "	35-40,000 "	Pain right shoulder severe (40,000)
28 "	35-40,000 "	Came down in air-lock. Exercised 30 min. on exercycle. Went up in air-lock to main chamber again.
3 "	35,000 "	Pain left shoulder.
7 "	35,000 "	Pain better
8 "	35,000 "	Pain left elbow.

3. Navigator, Newton

45 min.	35-40,000 feet	Pain left knee; exercised (35,000).
1 hr.	30-40,000 "	Pain left knee no better (30,000).
1 hr. 20 "	30-40,000 "	Pain left knee very bad, exercising (35,000).
1 hr. 21 "	30,000 "	Some relief.

4. Bombardier, Shirey

45 min.	35-40,000 feet	Pain left forearm (35,000)
56 "	30-40,000 "	Pain left forearm better (30,000).
1 hr. 19 "	30-40,000 "	Bends left arm (35,000).

The other eight men had no symptoms.

Summary: Co-Pilot incapacitated from bends and this would have interfered with mission. Navigator and Bombardier also severe but not incapacitating bends.

MAMU FLIGHT NO. 35

Friday, October 9, 1942, from 4:46 p.m. to 6:34 p.m. (1°48')

Squadron 371, Crew 2, Flight A

			Decompression	Mask
1.	Pilot	Lt. J. R. Irby	None	Demand Rebr.
2.	Co-Pilot	Lt. L. M. Esmond	None	B. Straight Demand
3.	Navigator	Lt. M. E. Smith	None	A-8-B
4.	Bombardier	Lt. R. I. Priester	None	A-8-B
5.	Rear Gunner	Sgt. T. A. Hopper	None	A-8-B
6.	Radio Operator	Sgt. R. W. Drew	None	Drinker
7.	Asst. Radio Opr.	Sgt. H. R. Leffew	None	A-8-B
8.	Engineer	Sgt. D. J. Howell	None	A-8-B
9.	Asst. Engineer	Sgt. L. F. Duster	None	A-8-B
10.	Asst. Operations Off.	Lt. R. W. Holland	None	B. Demand Rebr.

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Min.	Elevations
	9	30,000 - 34,000 feet
1	9	35,000 - 39,000 "
	3	40,000 feet
1	21	over 30,000 feet

Results

2. Co-Pilot, Esmond

	35,000 feet	Did not look good.
53 min.	35,000 "	Coughing; may be chokes but says he is all right.
1 hr. 1 "	35-40,000 feet	When reached dropped immediately to let subject out in air-lock. At 14,000 pain cleared up.

4. Bombardier, Priester

1 hr.	35,000+ feet	Pain below knee (40,000).
	30,000 "	Came down, better.
1 hr. 8 min.	35-40,000 feet	Knee worse.
	25,000 feet	Pain gone.

6. Radio Operator, Drew

1 hr. 8 min.	35-40,000 feet	Pain at knee; went down immediately (40,000).
1 hr. 10 "	35-40,000 "	Pain better.
	25,000 "	Pain gone.

8. Engineer, Howell

	35,000 "	Unconscious - oxygen must have been turned off accidentally. Dropped 28,000, emergency mask on; all right. Did not know he passed out.

9. Asst. Engineer, Duster

1 hr. 7 min.	35-40,000 feet	Pain in right ankle (40,000).
1 " 10 "	35-40,000 "	Better
	25,000 "	Pain gone

The other five men had no symptoms.

Summary: Co-Pilot incapacitated by chokes and thus seriously jeopardized mission.

MAMU FLIGHT NO. 36
Saturday, October 10, 1942, from 7:46 to 10:27 a.m. ($2^{o}41'$)

Squadron 370, Crew 7, Flight C

			Decompression	Mask
1.	Pilot	1st Lt. U. J. Newman	None	B. Demand Rebr.
2.	Co-Pilot	2nd Lt. R. J. Kissel	30 min. exercycle	A-8-B
3.	Navigator	2nd Lt. J. A. Newton	21 min. 3 m./hr.	A-8-B
4.	Bombardier	2nd Lt. W. L. Shirey	---------------	-------
5.	Tail Gunner	Sgt. A. T. Klester	None	Drinker
6.	Radio Operator	S/Sgt. H. R. Wolf	None	B. Demand Rebr.
7.	Asst. Radio Opr.	S/Sgt. F. J. Deflo	None	B. Demand Rebr.
8.	Engineer	Sgt. J. L. Knisley	None	A-8-B
9.	Asst. Engineer	S/Sgt. G. W. Gathers	None	A-8-B
10.	Flight Surgeon	Capt. M. C. Spoeneman	21 min. 3 m./hr.	A-8-B

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Min.	Elevations
	2	30,000 - 34,000 feet
2	6	35,000 - 39,000 "
	2	40,000 feet
2	10	over 30,000 feet

Results

1. Pilot Newman

	10,000 feet	On way down twitching leg above knee. Put mask on, no change. Oxygen did not help.

2. Co-Pilot, Kissel

1 hr. 16 min.	35-40,000 feet	Chest pressure (40,000).
1 " 21 "	35-40,000 "	Still chest pressure (35,000).
1 " 50 "	35,000 feet	Slight chest pressure (35,000).

8. Engineer, Knisley

1 hr. 9 min.	35,000 feet	Slight pain right knee, exercised.
1 " 16 "	35-40,000 feet	Pain worse (40,000).
1 " 20 "	35-40,000 "	Pain better (35,000).
1 " 28 "	35-40,000 "	Knee all right (35,000).
1 " 34 "	35-40,000 "	No pain in knee (35,000).

4. Bombardier, Shirey
Did not make flight because of ears.

The other six men had no symptoms.

Summary: Mission correct and satisfactory.

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MAMU FLIGHT NO. 37

Saturday, October 10, 1942, from 10:37 a.m. to 1:11 p.m. (2°34')

Squadron 371, Crew 2, Flight A

			Decompression	Mask
1.	Pilot	Lt. J. R. Irby	None	A-8-B
2.	Co-Pilot	Lt. L. M. Esmond		
3.	Navigator	Lt. M. E. Smith	None	Demand Rebr.
4.	Bombardier	Lt. R. I. Priester	29 min. 3 mi./hr.	A-8-B
5.	Rear Gunner	Sgt. T. A. Hopper	None	Drinker
6.	Radio Operator	Sgt. R. W. Drew	29 min. 3 mi./hr.	A-8-B
7.	Asst. Radio Opr.	Sgt. H. R. Leffew	None	B. Demand
8.	Engineer	Sgt. D. J. Howell	None	Drinker
9.	Asst. Engineer	Sgt. L. F. Duster		
10.	Asst. Opr. Off.	Lt. R. W. Holland	None	A-8-B

Condensed Log of Flight

Highest elevation 43,000 feet

Duration Hrs.	Min.	Elevations
	4	30,000 - 34,000 feet
1	56	35,000 - 39,000 "
	1	40,000 - 41,000 "
	1	42,000 and over
2	2	over 30,000 feet

Results

6. Radio Operator, Drew

1 hr.	31 min.	35,000 feet	Pain left knee
1 hr.	35 "	35,000 "	Pain left knee better
1 "	41 "	35,000 "	Pain left knee again.
1 "	48 "	35,000 "	Still pain left knee, no worse.
1 "	54 "	35-43,000 feet	Gr. 3 pain knee at 43,000 feet.
		30,000 feet	Coming down, knee better.

9. Asst. Engineer, Duster - Did not go up. Cold and bad ear.

10. Asst. Opr. Officer, Holland

1 hr.	57 min.	35-40,000 feet	Pain shoulder (43,000).
		30,000 "	Better.

The other six men had no symptoms.

Summary: Mission carried out successfully.

MAMU FLIGHT NO. 38

Saturday, October 10, 1942, from 4:00 to 5:13 p.m. (1°13')

Squadron 372, Crew 3, Flight A

		Decompression	Mask
1. Pilot	2nd Lt. J. H. Storer	None	B. Demand Rebr.
2. Co-Pilot	2nd Lt. F. G. Craven	None	B. Demand Rebr.
3.	S/Sgt. B. Gianoli	None	Drinker
4. Bombardier	2nd Lt. N. A. Nelson	None	A-8-B
5. Tail Gunner	S/Sgt. R. O. Scherer	None	A-8-B
6. Top Turret Gunner	S/Sgt. C. I. Knutson	None	A-8-B
7. Radio Gunner	E. J. Bloom	None	B. Demand Rebr.
8. Radio Operator	S/Sgt. D. S. Orlando	None	

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Min.	Elevations
	17	30,000 - 34,000 feet
	20	35,000 - 39,000 feet
	1	40,000 feet
	38	over 30,000 feet

Results

2. Co-Pilot, Craven

29 min.	25-35,000 feet	Feels funny; cannot describe.
30 "	35,000 feet	Color bad. Emergency oxygen on.
32 "	35,000 "	Color bad even with emergency oxygen. Has a painful tooth.
39 "	35-40,000 feet	Pain left leg, hip; painful tooth (40,000).
41 "	30-40,000 "	Color bad (30,000).
	27,000 feet	Color better. Feels better.

3. Gianoli

9 min.	35,000 feet	Pain left knee, exercised.
11 "	35,000 "	Pain worse
14 "	35,000 "	Pain bad; dizzy; color bad; sleepy.
15 "	35,000 "	Passed out a second. Put in air-lock and down 24 min. after starting up.

4. Bombardier, Nelson

39 min.	35-40,000 feet	Pain right foot (40,000).

8. Radio Operator, Orlando

24 min.	35,000 feet	Itching right leg.
38 "	35-40,000 feet	Pain left shoulder (40,000).

The other four men had no symptoms.

Summary: S/Sgt. Gianoli incapacitated from bends in 15 minutes; although a short mission, it would have been handicapped.

MAMU FLIGHT NO. 39

Saturday, October 10, 1942, from 5:22 p.m. to 6:39 p.m. (1°17')

Squadron 424, Crew 8, Flight C

			Decompression	Mask
1.	Co-Pilot	2nd Lt. H. R. Vanderslice	None	
2.	Navigator	2nd Lt. W. M. Carroll	None	B. Demand Rebr.
3.	Bombardier	2nd Lt. D. A. DeClerique	None	Drinker
4.	Tail Gunner	Sgt. J. W. Sargent		
5.	Radio Operator	Sgt. R. O. Smith	None	A-8-B
6.	Radio Gunner	Sgt. L. C. Averitt	None	A-8-B
7.	Engineer Gunner	S/Sgt. W. H. Adams	None	A-8-B
8.	Engineer Gunner	S/Sgt. R. N. Lund		

Condensed Log of Flight

Highest Elevation 43,000 feet

Duration Hrs.	Min.	Elevations
	2	30,000 - 34,000 feet
	54	35,000 - 39,000 "
	1	40,000 - 41,000 "
	1	42,000 - and over
	58	over 30,000 feet

Results

1. Co-Pilot, Vanderslice
   55 min. 35-43,000 feet Slight pain knee (40,000).

3. Bombardier, DeClerique
   55 min. 35-43,000 feet Pain knee (43,000).
   36,000 feet Pain gone.

4. Tail Gunner, Sargent - Did not go up because of cold.

8. Engineer Gunner, Lund - Did not go up because of cold.

The other four men had no symptoms.

Summary: No interference with mission.

MAMU FLIGHT NO. 40
Sunday, October 11, 1942, from 7:43 to 10:32 a.m. (2°49')

Squadron 372, Crew 3, Flight A

			Decompression	Mask
1.	Pilot	2nd Lt. J. H. Storer	None	
2.	Co-Pilot	2nd Lt. F. G. Craven	30 min. 3 m/hr.	A-8-B
3.		S/Sgt. B. Gianoli	30 min. 3 m/hr.	A-8-B
4.	Bombardier	2nd Lt. N. A. Nelson	30 min. 3 m/hr.	B. Demand Rebr.
5.	Tail Gunner	S/Sgt. R. O. Scherer	None	B. Demand Rebr.
6.	Top Turret Gunner	S/Sgt. C. L. Knutson	--------------	-----------
7.	Radio Gunner	E. J. Bloom	None	A-8-B
8.	Radio Operator	S/Sgt. D. S. Orlando	30 min. exercycle	A-8-B

Condensed Log of Flight

Highest elevation 35,000 feet

Duration Hrs.	Min.	Elevations
	29½	30,000 - 34,000 feet
2	2	35,000 feet
2	32	over 30,000 feet

Results

1. Pilot, Storer

1 hr. 41 min.	30-35,000 feet	Pain knee, exercised, somewhat better (30,000).
1 " 56 "	30-35,000 "	Pain worse (35,000).
2 " 12 "	30-35,000 "	Pain gone (30,000).

3. Gianoli

1 hr. 26 min.	35,000 feet	Pain chest. Wants to cough (35,000).
	30-35,000 feet	Came down; feels better (30,000).
1 hr. 56 "	30-35,000 "	Pain right and left knee (35,000).
2 " 2 "	30-35,000 "	Pain about the same (35,000).
2 " 12 "	30-35,000 "	Pain gone (30,000).

4. Bombardier, Nelson

45 min.	35,000 feet	Did not feel so good. Turned flow up.
1 hr. 15 "	35,000 "	Feels and looks sleepy.

6. Top Turret Gunner, Knutson
Did not go up because of cold and bad ear.

The other four men had no symptoms.

Summary: No interference with mission.

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MAMU FLIGHT NO. 41

Sunday, October 11, 1942, from 10:45 a.m. to 1:19 p.m. (2°34')

Squadron 424, Crew 8, Flight C		Decompression	Mask
1. Co-Pilot	2nd Lt. H. R. Vanderslice	None	
2. Navigator	2nd Lt. W. M. Carroll	None	B. Demand Rebr.
3. Bombardier	2nd Lt. D. A. DeClerique	None	A-8-B
4. Tail Gunner	Sgt. J. W. Sargent		
5. Radio Operator	Sgt. R. O. Smith	None	Demand, A-8-B
6. Radio Gunner	Sgt. L. C. Averitt	None	A-8-B
7. Engineer Gunner	S/Sgt. W. H. Adams	None	Drinker
8. Engineer Gunner	S/Sgt. R. N. Lund		

Condensed Log of Flight

Highest Elevation 35,000 feet

Duration Hrs.	Min.	Elevations
	22	30,000 - 34,000 feet
1	19	35,000 feet
1	41	over 30,000 feet

Results

1. Co-Pilot Vanderslice

39 min.	35,000 feet	Pain knee bad.
51 "	35,000 "	Pain knee bad; started down.
	30,000 "	Pain better.
1 hr. 35 "	30,000+ "	Pain right knee getting bad (35,000).
1 " 38 "	30,000+ "	Started down, better.

2. Navigator, Carroll

1 hr. 17 min.	30,000+ feet	Pain right ankle (35,000).

4. Did not go up because of a cold.

5. Radio Operator, Smith

	31,000 feet	On way up unconscious. Emergency mask on. Looked bad. Came down in air-lock. Put on A-8-B and went up again. No further trouble.

6. Radio Gunner, Averitt

29 min.	35,000 feet	Pain right knee, exercised.
30 "	35,000 "	Pain right knee, very bad.
32 "	35,000 "	Came down in air-lock.

7. Engineer Gunner, Adams

2 min.	35,000 "	Felt funny. Turned on emergency oxygen, better
1 hr. 30 "	35,000 "	Pain in left knee.

8. Did not go up because of a cold.

The other man had no symptoms.

Summary: Demand mask or regulator did not function properly and this interfered with mission but not from bends.

MAMU FLIGHT NO. 42

Sunday, October 11, 1942, from 1:40 p.m. to 4:19 p.m. (2°39')

Squadron 371, Crew 3, Flight A

		Decompression	Mask
1. Pilot	2nd Lt. J. R. McCloskey	None	A-8-B
2. Navigator	2nd Lt. H. A. Thorn	None	B. Demand
3. Bombardier	2nd Lt. H. S. Smithson	None	B. Demand
4. Station Gunner	D. P. Apple	None	A-8-B
5. Gunner	Sgt. T. J. Dewberry	None	A-8-B
6. Gunner	N. C. Scott	None	B. Demand
7. Radio Gunner	Sgt. S. I. Walker	None	A-8-B
8. Radio Gunner	Sgt. L. E. Anderson	None	A-8-B
9. Engineer Gunner	Sgt. Dean J. Howell	None	A-8-B
10. Flight Surgeon	Capt. N. R. Groth	None	B. Demand
11. Asst. Oper. Off.	2nd Lt. K. M. Kidder	None	A-8-B

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Min.	Elevations
	3	30,000 - 34,000 feet
2	5	35,000 - 39,000 "
	2	40,000 feet
2	11	over 30,000 feet

Results

2. Navigator, Thorn

13 min.	35,000 feet	Light headed. On constant flow.
14 "	35,000 "	Pain right shoulder.
17 "	35,000 "	Better.

4. Station Gunner, Apple

10 min.	35,000 feet	Pain right shoulder.
29 "	35,000 feet	Pain right shoulder gone; itching skin.

6. Gunner, Scott

57 min.	35,000 feet	Pain right elbow.
1 hr. 6 "	35,000 feet	Somewhat better.

The other eight men had no symptoms.

Summary: No interference with mission.

MAMU FLIGHT NO. 43

Sunday, October 11, 1942, from 4:51 to 7:48 p.m. (2°57')

Squadron 370, Crew 8, Flight C.

			Decompression	Mask
1.	Pilot	S. T. Gregory	None	B. Demand
2.	Pilot	H. C. John	None	Drinker
3.	Navigator	2nd Lt. D. E. Parker	None	A-8-B
4.	Bombardier	2nd Lt. H. A. Sterhel	None	B. Demand
5.	Gunner	Sgt. A. T. Chuchzek	None	A-8-B
6.	Radio Gunner	S/Sgt. W. E. Morgan	None	A-8-B
7.	R. Gunner	S/Sgt. G. F. Parker	None	A-8-B
8.	Engineer	Sgt. W. G. Hardin	None	B: Demand

Condensed Log of Flight

Highest elevation 40,000 feet.

Duration Hrs.	Min.	Elevations
	20	30,000 - 34,000 feet
1	11	35,000 - 39,000 "
	2	40,000 feet
1	33	over 30,000 feet

Results

5. Gunner, Chuchzek

13 min.	35,000 feet	Gas pains - stood up.
15 "	35,000 "	Gas pains better.
26 "	35,000 "	Gas pains worse - went down to 30,000 relieved.
45 "	30,000 - 35,000	Brought down in air lock - toilet - went back up - no more gas pains.

The other seven men had no symptoms.

Summary: No interference with mission.

MAMU FLIGHT NO. 44
Monday, October 12, 1942, from 7:46 a.m. to 10:24 a.m. (2°38')

Squadron 371, Crew 3, Flight A

			Decompression	Mask
1.	Pilot	2nd Lt. J. R. McCloskey	None	B. Demand
2.	Navigator	2nd Lt. H. A. Thorn	19 min. exercycle	A-8-B
3.	Bombardier	2nd Lt. H. S. Smithson	None	A-8-B
4.	Station Gunner	D. P. Apple	32 min. 3 mi./hr.	Drinker
5.	Gunner	Sgt. T. J. Dewberry	None	A-8-B
6.	Gunner	N. C. Scott	19 min. 3 mi./hr.	A-8-B
7.	Radio Gunner	Sgt. S. I. Walker		
8.	Radio Gunner	Sgt. L. E. Anderson	None	B. Demand
9.	Engineer Gunner	Sgt. D. J. Howell	None	B. Demand
10.	Flight Surgeon	Capt. N. R. Groth	None	A-8-B

Condensed Log of Flight

Highest elevation 42,000 feet.

Duration Hrs.	Min.	Elevations
	6	30,000 - 34,000 feet
1	39	35,000 - 39,000 "
	6	40,000 - 41,000 "
1	51	over 30,000 feet

Results

5. Gunner, Dewberry

	42,000 feet	Color bad. Light headed.
	40,000 "	Feels better.

7. Radio Gunner, Walker - did not go up.

9. Engineer Gunner, Howell

45 min.	35,000 feet	Pain left knee; exercised, turned up constant flow.
51 min.	35,000 "	Pain left knee bad
54 "	35,000 "	Pain a little better.
1 hr. 10 "	35,000 "	Went in air-lock to ground. Incapacitated.

The other seven men had no symptoms.

Summary: Engineer Gunner incapacitated and thus interfered with mission.

MAMU FLIGHT NO. 45

Monday, October 12, 1942, from 10:35 to 1:35 p.m. (3°)

Squadron 370, Crew 8, Flight C

			Decompression	Mask
1.	Pilot	S. T. Gregory	23 min. 3 m/hr.	A-8-B
2.	Pilot	H. C. John	None	Drinker
3.	Navigator	2nd Lt. D. E. Parker	None	
4.	Bombardier	2nd Lt. H. A. Sterhel	-------------	-------
5.	Gunner	Sgt. A. T. Chuchzek	22 min. 3 m./hr.	A-8-B
6.	Radio Gunner	S/Sgt. W. E. Morgan	None	A-8-B
7.	R. Gunner	S/Sgt. G. F. Parker	None	
8.	Engineer	Sgt. W. G. Hardin	None	A-8-B

Condensed Log of Flight

Highest elevation 40,000 feet.

Duration Hrs.	Duration Min.	Elevations
	46	30,000 - 34,000 feet
1	19	30,000 - 39,000 "
	3	40,000 feet
2	8	over 30,000 feet

Results

4. Bombardier, Sterhel
   Did not go up - had a cold.

8. Engineer, Hardin

48 min.	35,000 feet	Pain right wrist, gr. 1.
53 "	35,000 "	Pain right arm, gr. 1.

The other six men had no symptoms.

Summary: No interference with mission.

MAMU FLIGHT NO. 46

Monday, October 12, 1942, from 1:46 p.m. to 4:18 p.m. (2°32')

Squadron 424, Crew 2, Flight A

			Decompression	Mask
1.	Pilot	2nd Lt. W. R. Hitchcock	None	B. Demand Rebr.
2.	Co-Pilot	2nd Lt. H. J. Ladd	None	B. Demand
3.	Navigator	2nd Lt. E. J. Bauman	None	Drinker
4.	Bombardier	2nd Lt. W. D. Hughes	None	Demand
5.	Gunner	Cpl. J. W. Wycoff	None	B. Demand Rebr.
6.	Radio Operator	Cpl. B. E. Byrd	None	A-8-B
7.	Asst. Radio Opr.	S/Sgt. L. J. Chialostii	None	A-8-B
8.	Engineer	S/Sgt. D. K. Long	None	A-8-B
9.	Asst. Engineer	Sgt. J. J. Kiback	None	A-8-B
10.	Operations Off.	Lt. R. S. Boydston	30 min. exercycle	A-8-B

Condensed Log of Flight

Highest elevation 43,000 feet

Duration Hrs.	Min.	Elevations
	17	30,000 - 34,000 feet
1	18	35,000 - 39,000 "
	7	40,000 - 41,000 "
	1	42,000 feet and over
1	43	over 30,000 feet

Results

1. Pilot, Hitchcock

1 hr. 22 min.	35,000 - 43,000 feet	Slightly dizzy at 43,000 feet.
1 hr. 22 min.	35,000 - 43,000 feet	Coming down dizziness gone (40,000).

4. Bombardier, Hughes.

1 hr. 15 min.	35,000 - 40,000 feet	Cramp pain right leg.
1 " 29 "	35,000 - 43,000 "	Cramp gone.

The other eight men had no symptoms.

Summary: No interference with mission.

MAMU FLIGHT NO. 47
Monday, October 12, 1942, from 4:36 to 6:51 p.m. (2°15')

Squadron 372, Crew 4, Flight B

			Decompression	Mask
1.	Pilot	Capt. D. B. Billings	None	Demand
2.	Pilot	1st Lt. E. E. Elliott	None	Drinker
3.	Navigator	Lt. L. T. Monogue	None	Drinker
4.	Bombardier	Lt. R. F. Wadlin	None	Demand
5.	Radio Operator & Gunner	S/Sgt. V. E. Anderson	None	A-8-B
6.	Engineer Gunner	S/Sgt. E. Hatt	None	A-8-B
7.	Engineer Gunner	S/Sgt. V. P. Hopkins	None	A-8-B
8.	Tail Gunner (Station)	Pvt. R. R. Mosier	None	A-8-B
9.	2nd Oper. Gunner	S/Sgt. B. E. Conner	None	A-8-B

Condensed Log of Flight

Highest elevation 43,000 feet

Duration Hrs.	Min.	Elevations
	38	30,000 - 34,000 feet
1	49	35,000 - 39,000 "
	3	40,000 - 41,000 "
	2	42,000 and up
2	32	over 30,000 feet

Results

2. Pilot, Elliott

1 hr. 1 min.	30-43,000 feet	At 42,000 pain in knee.
1 " 3 "	30-43,000 feet	At 33,000 pain gone.

3. Navigator, Monogue

11 min.	35,000 feet	Pain in left knee -exercised.
20 "	35,000 "	Turned up emergency O_2.
35 "	35,000 "	Pain both knees.

4. Bombardier, Wadlin

21 min.	35,000 feet	Sweating.
31 "	35,000 "	Emergency O_2 on and in air-lock.

The other six men had no symptoms.

Summary: Bombardier incapacitated but not from bends; cause unknown.

MAMU FLIGHT NO. 48

Tuesday, October 13, 1942, from 7:43 a.m. to 10:28 a.m. (2°45')

Squadron 424, Crew 2, Flight A

			Decompression	Mask
1.	Pilot	2nd Lt. W. R. Hitchcock	None	A-8-B
2.	Co-Pilot	2nd Lt. H. J. Ladd	None	A-8-B
3.	Navigator	2nd Lt. E. J. Bauman	None	A-8-B
4.	Bombardier	2nd Lt. W. D. Hughes	None	A-8-B
5.	Gunner	Cpl. J. W. Wycoff	None	Demand Rebr.
6.	Radio Operator	Cpl. B. E. Byrd	None	A-8-B
7.	Asst. Radio Opr.	S/Sgt. L. J. Chialostii	None	Drinker
8.	Engineer	S/Sgt. D. K. Long	None	Demand
9.	Asst. Engineer	Sgt. J. J. Kiback	None	Demand

Condensed Log of Flight

Highest elevation 35,000 feet

Duration Hrs.	Duration Min.	Elevations
	11	30,000 - 34,000 feet
1	53	35,000 feet
2	4	over 30,000 feet

Results

4. Bombardier, Hughes

49 min.	35,000 feet	Slight pain knee and hip.
54 "	35,000 "	Pain worse.
55 "	35,000 "	Pain very severe knee and chest. Chokes; dizzy. Went out a few seconds. Did not know it. Went down in air-lock. Weak after coming down.

7. Asst. Radio Opr., Chialostii

36 min.	35,000 feet	Emergency oxygen on.
1 hr. 30 "	35,000 "	Emergency oxygen off.
1 " 46 "	35,000 "	Did not feel good; coughing.
2 " 1 "	35,000 "	Went down in air-lock.

9. Asst. Engineer, Kiback

1 hr. 19 min.	35,000 feet	Emergency oxygen on.

The other six men had no symptoms.

Summary: Both Bombardier and Assistant Radio Operator completely incapacitated. This would seriously interfere with mission.

28

MAMU FLIGHT NO. 49

Tuesday, October 13, 1942, from 10:39 a.m. to 1:08 p.m. (2°29')

Squadron 372, Crew 4, Flight B

			Decompression	Mask
1.	Pilot	Capt. D. B. Billings	18 min. 3 m./hr.	A-8-B
2.	Pilot	1st Lt. E. E. Elliott	29 min. 3 m./hr.	A-8-B
3.	Navigator	Lt. L. T. Monogue	26 min. 3 m./hr.	A-8-B
4.	Bombardier	Lt. R. F. Wadlin	None	A-8-B
5.	Radio Operator & Gunner	S/Sgt. V. E. Anderson	None	Drinker
6.	Engineer Gunner	S/Sgt. E. Hatt	None	A-8-B
7.	Engineer Gunner	S/Sgt. V. P. Hopkins	None	Drinker
8.	Tail Gunner (Station)	Pvt. R. R. Mosier	None	A-8-B
9.	2nd Oper. Gunner	S/Sgt. B. E. Conner	None	B-Demand Rebr.

Condensed Log of Flight

Highest elevation 44,000 feet

Duration Hrs.	Min.	Elevations
	8	30,000 - 34,000 feet
1	9	35,000 - 39,000 feet
	9	40,000 - 41,000 feet
	½	42,000 feet and up
1	27	over 30,000 feet

Results

2. Pilot, Elliott

No symptoms, but came late - went up in air-lock (23 min. late).

7. Engineer Gunner, Hopkins

1 hr. 12 min.	35-44,000 feet	Pain left wrist (42,000).
1 " 14 "	35-44,000 "	Pain better (35,000).
1 " 19 "	35-44,000 "	Pain right knee - exercising (35,000).
1 " 25 "	35-44,000 "	Pain right knee better - feels stiff (35,000).
	25,000 feet	Knee all right.

9. 2nd Oper. Gunner, Conner

	20,000 feet	Discharge from ear.
20 min.	35,000 "	Ear feels better.
1 hr. 3 "	35-40,000 feet	Drainage from ear stopped

Examination after run - by Cunningham - ruptured ear drum - possibly ruptured on way up.

The other seven men had no symptoms.

Summary: No interference with mission.

29

MAMU FLIGHT NO. 50

Tuesday, October 13, 1942, from 1:48 p.m. to 3:23 p.m. (1°35')

Squadron 371, Crew 5, Flight B

		Decompression	Masks
1. Pilot	2nd Lt. G. E. Hoefler	None	B. Demand
2. Co-Pilot	2nd Lt. N. G. Guiberson	None	B. Demand Rebr.
3. Navigator	2nd Lt. A. B. Sheaffer	None	A-8-B
4. Bombardier	2nd Lt. O. A. Severson		
5. Engineer	S/Sgt. P. J. Hilgart	None	A-8-B
6.	S/Sgt. O. K. Iverson	None	B. Demand
7.	S/Sgt. W. E. Sellers	None	A-8-B
8.	S/Sgt. P. Spitaels	None	A-8-B
9.	B. Bailey	None	A-8-B

Condensed Log of Flight

Highest elevation 35,000 feet

Duration Hr.	Duration Min.	Elevations
	13	30,000 - 34,000 feet
	37	35,000 feet
	50	over 30,000 feet

Results

*2. Co-Pilot, Guiberson

14 min.	35,000 feet	Slight pain left elbow.
17 "	35,000 "	Pain severe.
	30,000 "	Came down, much better.
24 "	30,000+ "	Bad pain left arm.
44 "	30,000+ "	Came down in air-lock.

4. Bombardier, Severson - Did not make this flight.

7. Sellers

3 min.	35,000 feet	Pain right shoulder and arm.
33 "	35,000 "	Pain left knee.

8. Spitaels

7 min.	35,000 feet	Pain shoulder, arm also numb; slight cyanosis.
9 "	35,000 "	Came down in air-lock.

9. Bailey

3 min.	35,000 feet	Pain left shoulder and arm.
	30,000 "	Coming down - sinus headache. Better. Quite severe higher up.

The other four men had no symptoms.

Summary: No interference with mission.

* Bends both shoulders; transient left temporal hemianopsia. Erythema about the area of pain due to bends insertion of deltoids. Hemianopsia last one-half hour. Disappeared suddenly. Weakness in convergence. Diplopia when attempted to look at objects nearer than 5 inches. Diplopia lasted longer than hemianopsia. Erythema associated with increased warmth of skin.

MALU FLIGHT NO. 51

Wednesday, October 14, 1942, from 4:32 p.m. to 6:24 p.m. (1°52')

Squadron 370, Crew 5, Flight B

			Decompression	Mask
1.	Pilot	1st Lt. D. E. Macdonald	None	Drinker
2.	Co-Pilot	1st Lt. S. B. Bledsoe	None	Drinker
3.	Navigator	1st Lt. J. R. Wood	None	Demand Rebr.
4.	Bombardier	1st Lt. H. A. Nasburg	None	A-8-B
5.	Engineer Gunner	S/Sgt. V. Kiviat	None	A-8-B
6.	Asst. Eng. Gunner	S/Sgt. R. Flohr	None	Drinker
7.		S/Sgt. J. R. Scritchfield	None	
8.		Sgt. J. G. Jaffe	None	Demand Rebr.
9.		Sgt. E. G. Heggenbothan, Jr.	None	Demand
10.	Flight Surgeon	Major Murray	None	Demand

Condensed Log of Flight

Highest elevation 43,000 feet.

Duration Hrs.	Min.	Elevations
	36	30,000 - 34,000 feet
	27	35,000 - 39,000 "
	4	40,000 - 41,000 "
	1	42,000+ "
1	8	over 30,000 feet

Results

1. Pilot, Macdonald

23 min.	30,000 feet	Slight pain in wrist.
33 "	30,000 - 35,000	Pain wrist worse (35,000).
	38,000 feet	
36 "	30,000 - 38,000	Emergency mask on and down in air-lock (38,000).

3. Navigator, Wood

37 min.	30,000 - 43,000	Slight pain wrist, old fracture (35,000).
54 "	30,000 - 43,000	Leg feels asleep (35,000).

The other eight men had no symptoms.

Summary: Pilot had incapacitating bends thus interfering seriously with mission.

3'

MAMU FLIGHT NO. 52

Wednesday, October 14, 1942, from 7:43 a.m. to 10:29 a.m. (2°46')

Squadron 371, Crew 5, Flight B

		Decompression	Mask
1. Pilot	2nd Lt. G. E. Hoefler	None	A-8-B
2. Co-Pilot	2nd Lt. N. G. Guiberson	27 min. 3 mi./hr.	A-8-B
3. Navigator	2nd Lt. A. B. Sheaffer	None	Demand Rebr.
4. Bombardier	2nd Lt. O. Severson		
5. Engineer	S/Sgt. P. J. Hilgart	None	A-8-B
6.	S/Sgt. O. K. Iverson	None	A-8-B
7.	S/Sgt. W. E. Sellers	20 min. exercycle	A-8-B
8.	S/Sgt. P. Spitaels	27 min. 3 mi./hr.	Drinker
9.	B. Bailey		

Condensed Log of Flight

Highest elevation 40,000 feet.

Duration Hrs.	Min.	Elevations
	34	30,000-34,000 feet
1	20	35,000-39,000 feet
	1	40,000 feet
1	56	over 30,000 feet

Results

3. Navigator Sheaffer

6 min.	35,000 feet	Felt dizzy. Constant flow on; better.
30 "	35,000 "	Pain right wrist.
39 "	35,000 "	Pain worse; better, going away. Some rash.
46 "	30-35,000 feet	Much better
50 "	30-35,000 "	Pain wrist gone (30,000).
1 hr. 10 "	30-35,000 "	Went up, pain in wrist again (35,000).
1 " 13 "	30-35,000 "	Pain in wrist better (35,000).
1 " 23 "	30-35,000 "	Pain ankle (35,000); pain better when standing.
1 " 42 "	30-35,000 "	Color bad (35,000).
1 " 45 "	30-35,000 "	Pain right knee. Looks bad (35,000).
	30,000 "	Pain gone.

4. Bombardier, Severson - Did not make this flight.

7. Sellers

1 hr. 31 min.	30-40,000 feet	Pain right knee at 40,000.
1 " 33 "	30-40,000 "	Pain right elbow at 40,000.
1 " 39 "	30-40,000 "	Pain elbow gone but still in knees (35,000).
1 " 48 "	30,000 "	Pains gone.

8. Spitaels

23,000 feet	Color bad; emergency oxygen on.
25,000 "	Color better.
35,000 "	Changed to A-8-B. No further trouble.

9. Bailey - Did not make this flight.

The other four men had no symptoms.

Summary: Navigator had severe bends but not incapacitated.

32

MAMU FLIGHT NO. 53

Wednesday, October 14, 1942, from 10:55 a.m. to 1:45 p.m. (2°50')

Squadron 370, Crew 5, Flight B

			Decompression	Mask
1.	Pilot	1st Lt. D. E. Macdonald	30 min. 3 mi./hr.	A-8-B
2.	Co-Pilot	1st Lt. S. B. Bledsoe	None	A-8-B
3.	Navigator	1st Lt. J. R. Wood	30 min. 3 mi./hr.	A-8-B
4.	Bombardier	1st Lt. H. A. Nasburg	None	A-8-B
5.	Engineer Gunner	S/Sgt. V. Kiviat	None	B. Demand Rebr.
6.	Asst. Eng. Gunner	S/Sgt. R. Flohr	30 min. 3 mi./hr.	A-8-B
7.		S/Sgt. J. R. Scritchfield	None	Drinker
8.		Sgt. J. G. Jaffe	None	B. Demand
9.		Sgt. E. G. Heggenbothan, Jr.	None	B. Demand

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hr.	Min.	Elevations
	16	30,000 - 34,000 feet
2	5	35,000 - 39,000 "
	1	40,000 feet
2	22	over 30,000 feet

Results

1. Pilot, Macdonald

42 min.	35,000 feet	Pain left shoulder seems to be worse on inspiration.
57 "	35,000 "	No pain.

8. Jaffe

1 hr. 24 min.	35,000 "	Blew nose.
1 " 37 "	35-40,000 feet	At 40,000 felt faint, coughing.
1 " 39 "	30,000 feet	Feels better but severe chest pain.
1 " 42 "	30,000 "	Still feels bad (30,000).
1 " 49 "	30,000 "	Went down in air-lock.

9. Heggenbothan

46 min.	35,000 feet	Emergency oxygen on a little. No symptoms.

The other six men had no symptoms.

Summary: Sergeant had severe bends and was incapacitated and mission jeopardized.

MAMU FLIGHT NO. 54

Wednesday, October 14, 1942, from 4:17 p.m. to 5:40 p.m. (1°23')

Squadron 372, Crew 5, Flight B

			Decompression	Mask
1.	Pilot	Lt. J. R. Boyd	None	Demand
2.	Pilot	1st Lt. P. L. Veith	None	A-8-B
3.	Co-Pilot	1st Lt. I. M. Osborne	None	Demand
4.	Navigator	2nd Lt. L. A. Kozov	None	A-8-B
5.	Bombardier	2nd Lt. M. L. Cypress	None	A-8-B
6.	Tail Gunner	S/Sgt. G. Smith	None	A-8-B
7.	Radio Operator	T/Sgt. H. G. Martin	None	A-8-B
8.	Radio Operator	Pvt. W. W. Kimbel	None	A-8-B
9.	Engineer	S/Sgt. C. H. Jones	None	A-8-B
10.	Flight Engineer	1st Lt. R. M. Hoover	None	A-8-B

Condensed Log of Flight

Highest elevation 35,000 feet

Duration Hrs.	Min.	Elevations
	5	30,000 - 34,000 feet
	19	35,000 feet
	24	over 30,000 feet

Results

7. Radio Operator, Martin

18 min.	35,000 feet	Ache in thumb joint.

10. Flight Engineer, Hoover

6 min.	35,000 feet	Coughing.

The other eight men had no symptoms.

Summary: No interference with mission.

39

MAMU FLIGHT NO. 55
Wednesday, October 14, 1942, from 5:50 to 6:50 p.m. (1°)

Squadron 424, Crew 7, Flight C

			Decompression	Mask
1.	Pilot	1st. Lt. W. R. Harpster	None	Drinker
2.	Pilot	2nd Lt. R. F. Miller	None	Drinker
3.	Navigator	1st Lt. H. A. Thayer	None	B. Demand
4.	Bombardier	2nd Lt. M. G. Deer, Jr.	None	B. Demand Rebr.
5.	Tail Gunner	Sgt. J. E. Michalak	None	A-8-B
6.	Radio Opr. Gunner	Sgt. C. J. Whalen	None	A-8-B
7.	Engineer	S/Sgt. R. C. Lundy	None	A-8-B
8.	Engineer	S/Sgt. G. K. Martin	None	A-8-B
9.		Sgt. L. M. McKee	None	A-8-B
10.		S/Sgt. J. C. Gibbons	None	A-8-B
11.	Operations Off.	Capt. H. E. Jones, Jr.	None	B. Demand

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Duration Min.	Elevations
	5	30,000 - 34,000 feet
	30	35,000 - 39,000 feet
	1	40,000 feet
	36	over 30,000 feet

Results

8. Engineer, Martin

3 min.	35,000 feet	Color not good.

11. Operations Off. Jones

29 min.	35-40,000 feet	Pain right arm (40,000).
29½ "	35-40,000 "	Pain bad; color bad (35,000).
34 "	30-40,000 "	Came down (30,000). Emergency mask on.
	20,000 "	Put demand on again.
	5,000 "	Coming down, looks better.

The other nine men had no symptoms.

Summary: No interference with mission except to lower elevation by about 5,000 feet.

MAMU FLIGHT NO. 56

Thursday, October 15, 1942, from 7:40 a.m. to 10:20 a.m. (2°40')

Squadron 372, Crew 5, Flight B

			Decompression	Mask
1.	Pilot	Lt. J. R. Boyd		
2.	Pilot	1st Lt. P. L. Veith	None	B. Demand Rebr.
3.	Co-Pilot	1st Lt. I. M. Osborne	None	A-8-B
4.	Navigator	2nd Lt. L. A. Kozov	None	B. Demand Rebr.
5.	Bombardier	2nd Lt. M. L. Cypress		
6.	Tail Gunner	S/Sgt. G. Smith	None	A-8-B
7.	Radio Operator	Pvt. W. W. Kimbel	None	A-8-B
8.	Radio Operator	T/Sgt. H. G. Martin	None	A-8-B
9.	Engineer	S/Sgt. C. H. Jones	None	A-8-B
10.	Flight Engineer	1st Lt. R. M. Hoover	None	A-8-B

Condensed Log of Flight

Highest elevation 41,500 feet

Duration Hrs.	Min.	Elevations
	28	30,000 - 34,000 feet
1	31	35,000 - 39,000 feet
	2	40,000 - 41,500 feet
2	1	over 30,000 feet

Results

1. Pilot, Boyd - Did not go up.

2. Pilot, Veith

1 min.	35,000 feet	Pain left hand.

3. Co-Pilot, Osborne

22 min.	35,000 feet	Pain right ankle, rubbing it.
58 "	35,000 "	Pain right ankle and up to knee.
1 hr.	35-40,000 feet	Pain much worse knee (40,000).
1 " 1 "	35-41,500 "	Pain much worse (41,500); started down in air-lock.
	25,000 feet	Pain gone in air-lock. Went down at 9:07 and denitrogenized 9:17 to 9:32 at 4 mi./hr. Went up again and no further trouble.

4. Navigator, Kozov

29 min.	35,000 feet	Pain right arm.

5. Bombardier, Cypress - Did not go up.

8. Radio Operator, Martin

	30,000 feet	Cold sweat after holding breath a bit.
	27,000 "	Feels better.
27 min.	35,000 "	Pain right hand.
33 "	35,000 "	Emergency oxygen mask on.
34 "	35,000 "	Down in air-lock. On exercycle 30 min. and went back in chamber.
17 "	35,000 "	Bad pain in wrist.
27 "	30-35,000 feet	Wrist very bad.
	24,000 "	Pain gone.

7. Radio Operator, Kimbel

1 hr. 41 min.	35-41,500 feet	Chilly all over (35,000).

10. Flight Engineer, Hoover

1 hr. 28 min.	35-41,500 feet	Bends severe left leg (35,000).
1 hr. 30 "	35-41,500 "	Down in air-lock.

The other three men had no symptoms.

Summary: Co-Pilot, Radio Operator and Flight Engineer incapacitated. Mission undoubtedly would have to be abandoned.

36

MAMU FLIGHT NO. 57

Thursday, October 15, 1942, from 10:34 a.m. to 1:24 p.m. (2°50')

Squadron 424, Crew 7, Flight C

			Decompression	Mask
1.	Pilot	2nd Lt. R. F. Miller	None	A-8-B
2.	Navigator	1st Lt. H. A. Thayer	None	A-8-B
3.	Bombardier	2nd Lt. M. G. Deer, Jr.	None	A-8-B
4.	Tail Gunner	Sgt. J. E. Michalsk	None	Demand Rebr.
5.	Radio Opr. Gunner	Sgt. C. J. Whalen	None	Demand Rebr.
6.	Engineer	S/Sgt. R. C. Lundy	None	A-8-B
7.	Engineer	S/Sgt. G. K. Martin	None	Drinker
8.		L. M. McKee	None	A-8-B
9.		S/Sgt. J. C. Gibbons	----	-------
10.	Operations Off.	Capt. H. E. Jones, Jr.	30 min. exercycle	Demand & A-8-B

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Min.	Elevations
	35	30,000 - 34,000 feet
1	48	35,000 - 39,000 feet
	40	40,000 feet
2	24	over 30,000 feet

Results

1. Pilot, Miller

16 min.	35,000 feet	Pain right leg just below knee.
1 hr. 9 "	25-35,000 feet	Severe pain legs; very pale (30,000).
1 hr. 13 "	25-35,000 "	Does not want to go up to 40,000 so coming down in air lock.

*2. Navigator, Thayer

46 min.	35,000 feet	Coughing; chokes.
	30,000 "	In air-lock; still coughing.

3. Bombardier, Deer

1 hr. 14 min.	30-35,000 feet	At 30,000 pain right knee.

7. Engineer, Martin

34 min.	35,000 feet	Pain right knee.
	28,000 "	Pain gone.

9. Gibbons - Did not go up because of cold.

10. Operations Off., Jones

16 min.	35,000 feet	Changed to A-8-B mask.

The other four men had no symptoms.

Summary: Pilot could not go above 35,000 or even remain there. Navigator incapacitated with chokes. Mission seriously interfered with.

* His attack of chokes was quite severe but relieved as soon as he reached ground, without much after effect. In an actual flight ten days ago developed a similar cough at 32,000 feet. As the plane was then on the way down no serious symptoms continued and the coughing stopped when they reached 25,000 in about 30 minutes. This subject seems susceptible to mild chokes. Whether or not they would become severe chokes is not known.

MAMU FLIGHT NO. 58

Thursday, October 15, 1942, from 1:46 p.m. to 4:12 p.m. (2°26')

Squadron 370, Cre2 6, Flight B

			Decompression	Mask
1.	Pilot	2nd Lt. B. E. Flahauen	None	Demand
2.	Co-Pilot	2nd Lt. J. H. Ralph	None	A-8-B
3.	Bombardier	2nd Lt. M. Payton	None	A-8-B
4.	Tail Gunner	Sgt. D. J. Potter	None	A-8-B
5.	Aerial Engineer	S/Sgt. J. W. Anderson	None	A-8-B
6.	Radio Operator	S/Sgt. S. W. Naperkoski	None	Demand Rebr.
7.	Aerial Engineer	S/Sgt. J. M. Faulkenberg	None	A-8-B

Condensed Log of Flight

Highest elevation 39,000 feet

Duration Hr.	Min.	Elevations
	37	30,000 - 34,000 feet
	53	35,000 - 39,000 "
1	30	over 30,000 feet

Results

3. Bombardier, Payton

49 min.	35,000 - 37,000 feet	Pain left wrist (37,000).
51 "	35,000 - 39,000 "	Pain left wrist severe (39,000).
	34,000 feet	Pain better
	30,000 "	Pain gone.

6. Radio Operator, Naperkoski

13 min.	35,000 feet	Emergency button on.

The other five men had no symptoms.

Summary: No interference with mission.

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MAMU FLIGHT NO. 59

Thursday, October 15, 1942, from 4:24 p.m. to 7:01 p.m. (2°27')

Squadron 371, Crew 6, Flight B

			Decompression	Mask
1.	Pilot	2nd Lt. J. H. McClendon	None	Demand Rebr.
2.	Pilot	Lt. W. R. Harpster	30 min. 3 mi./hr.	A-8-B
3.	Co-Pilot	2nd Lt. C. H. Miller	None	Demand
4.	Bombardier	Lt. W. Steele		
5.	Navigator	2nd Lt. W. J. Stickle	None	
6.	Tail Gunner	S/Sgt. W. J. Pash	None	A-8-B
7.	Waist Gunner	S/Sgt. R. W. Vaughn	None	A-8-B
8.	Upper Gunner	S/Sgt. H. D. Dillon	None	A-8-B
9.	Radio Operator	S/Sgt. C. C. Hatton	None	A-8-B
10.	Asst. Radio Opr.	S/Sgt. R. L. Hopkins	None	A-8-B

Condensed Log of Flight

Highest elevation 42,000 feet

Duration Hr.	Min.	Elevations
	7	30,000 - 34,000 feet
1	44	35,000 - 39,000 "
	2	40,000 - 41,000 "
1	53	over 30,000 feet

Results

1. Pilot, McClendon

34 min.	35,000 feet	Pain right shoulder slight (35,000).
34 "	35,000 "	Emergency oxygen on.
38 "	35-42,000 feet	Pain worse (42,000).
44 "	35-42,000 "	Pain about the same (35,000).
1 hr. 24 "	35-42,000 "	Pain shoulder gone (35,000).

4. Bombardier, Steele - Did not go up because of cold.

5. Navigator, Stickle

37 min.	35-40,000 feet	Had elbow resting on knee. Knee felt tingling when took elbow off. Got worse gradually (40,000).
50 "	35-40,000 "	Pain knee very bad (35,000). Started down in air lock.

The other seven men had no symptoms.

Summary: Pilot had severe bends but stuck it out for one and a half hours. Navigator incapacitated in 50 minutes. Mission seriously handicapped.

MAMU FLIGHT NO. 60

Friday, October 16, 1942, from 7:39 a.m. to 10:09 a.m. (2°30')

Squadron 370, Crew 6, Flight B

			Decompression	Mask
1.	Pilot	2nd Lt. B. E. Flahauen	None	A-8-B
2.	Co-Pilot	2nd Lt. J. H. Ralph	28 min. 3 mi./hr.	Demand Rebr.
3.	Bombardier	2nd Lt. M. Payton	28 min. 3 mi./hr.	Drinker
4.	Tail Gunner	Sgt. D. J. Potter	20 min. exercycle	A-8-B
5.	Aerial Engineer	S/Sgt. J. W. Anderson	None	Demand
6.	Radio Operator	S/Sgt. S. W. Naperkoski	None	A-8-B
7.	Aerial Engineer	S/Sgt. J. M. Faulkenberg	None	Demand Rebr.

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Min.	Elevations
	4	30,000 - 34,000 feet
1	58	35,000 - 39,000 "
	7	40,000 feet
2	9	over 30,000 feet

Results

5. Aerial Engineer, Anderson
   1 hr. 35,000 - 40,000 feet Tremor hands

The other six men had no symptoms.

Summary: No interference with mission.

MAMU FLIGHT NO. 61

Friday, October 16, 1942, from 10:37 a.m. to 1:13 p.m. (2°36')

Squadron 371, Crew 6, Flight B

			Decompression		Mask
1.	Pilot	2nd Lt. J. H. McClendon	None		A-8-B
2.	Co-Pilot	2nd Lt. C. H. Miller	None		A-8-B
3.	Bombardier	Lt. W. Steele			
4.	Navigator	Lt. H. A. Thayer	30 min.	exercycle	Drinker Rebr.
5.	Navigator	Lt. W. J. Stickle	30 min.	3 mi./hr.	A-8-B
6.	Tail Gunner	S/Sgt. W. J. Pash	None		Drinker
7.	Waist Gunner	S/Sgt. R. W. Vaughn	None		Drinker
8.	Upper Turret	S/Sgt. H. D. Dillon	None		Drinker
9.	Radio Operator	S/Sgt. C. C. Hatton	None		Demand Rebr.
10.	Asst. Radio Operator	S/Sgt. R. L. Hopkins	None		Demand

Condensed Log of Flight

Highest elevation 35,000 feet.

Duration Hr.	Min.	Elevations
	20	30,000 - 34,000 feet
1	35	35,000 feet
1	55	over 30,000 feet

Results

3. Bombardier, Steele - Did not go up because of cold.

6. Tail Gunner, Pash

42 min.	35,000 feet	Very cyanosed; felt sleepy.

7. Waist Gunner, Vaughn

46 min.	35,000 feet	Emergency button on.

10. Asst. Radio Operator, Hopkins.

58 min.	35,000 feet	Pain left knee severe.
	35,000 "	Came down; much better.

The other six men had no symptoms.

Summary: Radio Operator severe but not incapacitating bends. Mission of about two hours not interfered with.

MAMU FLIGHT NO. 62

Friday, October 16, 1942, from 4:14 p.m. to 5:35 p.m. (1°21')

Squadron 372, Crew 6, Flight B

			Decompression	Mask
1.	Navigator	1st Lt. H. A. Thayer	None	A-8-B
2.	Pilot	2nd Lt. L. H. Scholar	None	Demand Rebr.
3.	Co-Pilot	2nd Lt. J. E. Stay	None	Drinker
4.	Navigator	2nd Lt. C. L. Seymour	None	Demand Rebr.
5.	Bombardier	2nd Lt. R. P. Ortiz	None	Demand Rebr.
6.	Radio Operator	S/Sgt. H. P. Rosenberg	None	A-8-B
7.	Tail Gunner	S/Sgt. D. F. Morgan	None	A-8-B
8.	Upper Turret Gunner	S/Sgt. P. F. Jurgensmier	None	A-8-B
9.	Bottom Turret Gunner	S/Sgt. V. R. Lehman	None	A-8-B
10.	Engineer	S/Sgt. J. F. Durden	None	A-8-B

Condensed Log of Flight

Highest elevation 35,000 feet.

Duration Hr.	Min.	Elevations
	38	30,000 - 34,000 feet
	13	35,000 feet
	51	over 30,000 feet

Results

2. Co-Pilot, Stay

8 min.	35,000 feet	Oxygen tube off, on right away.
10 "	35,000 "	Pain right shoulder, slight.
14 "	35,000 "	Pain right shoulder severe.
17 "	30-35,000 feet	Pain right fingers, wrist, elbow, shoulder, (30,000).
28 "	30-35,000 "	Down in air-lock.

3. Navigator, Seymour

1 min.	35,000 feet	Slight gas pains.
	26,500 "	Better.
41 "	26,500-35,000	Gas pains severe.
47 "	26,500-35,000	Pain left wrist, elbow and shoulder.

10. Engineer, Durden

8 min.	35,000 feet	Bad gas pains.
10 "	35,000 "	Entered air-lock.

The other seven men had no symptoms.

Summary: Co-Pilot and Engineer incapacitated and mission interfered with.

1. Navigator, Thayer - Stayed over to do another run.
    Flight 55 - No symptoms: no decompression.
    " 57 - Severe bends. Came down in air-lock. No decompression.
    " 62 - No symptoms.

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MAMU FLIGHT NO. 63

Friday, October 16, 1942 from 5:47 p.m. to 6:46 p.m. (59')

Squadron 424, Crew 4, Flight B

			Decompression	Mask
1.	Pilot	1st Lt. J. R. Boyd	21 min. 3 mi./hr.	B. Demand
2.	Pilot	1st Lt. H. L. Milledge	None	A-8-B
3.	Co-Pilot	2nd Lt. S. L. Burke	None	Drinker
4.	Navigator	2nd Lt. J. K. Woody	None	B. Demand
5.		2nd Lt. C. T. O'Neill	None	Drinker
6.	Radio Operator	S/Sgt. M. H. Smith	None	A-8-B
7.	Radio Gunner	S/Sgt. R. W. Burchette	None	A-8-B
8.	Waist Gunner	Sgt. M. E. Smith	None	A-8-B
9.	Upper Turret	S/Sgt. N. K. Bullard	None	A-8-B
10.	Extra	S/Sgt. W. M. Ward	None	A-8-B
11.	Extra	Sgt. J. V. Shaughnessy	None	A-8-B
12.	Flight Surgeon	Capt. J. R. Glasscock	None	B. Demand
*13.	Navigator	1st Lt. H. A. Thayer	None	A-8-B

Condensed Log of Flight

Highest elevation 42,000 feet

Duration	Elevations
6 min.	30,000 - 34,000 feet
20 min.	35,000 - 39,000 feet
7 min.	40,000 - 41,000 feet
33 min.	over 30,000 feet

Results

1. Pilot, Boyd

3 min.	42,000 feet	Gas pains not bad.

10. Extra, Ward

15 min.	35-42,000 feet	Cyanosis; tremor (42,000)
	35-42,000 feet	Still shaky (35,000)

The other 11 men had no symptoms.

Summary: Short mission of 33 min. above 30,000 not interfered with.

* Thayer - Flight 55, 57, 62, 63
Had trouble on flight 57 - came down in air lock.
No trouble on other 3 flights.

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MAMU FLIGHT NO. 64

Saturday, October 17, 1942 from 7:39 a.m. to 10:27 a.m. (2°48')

Squadron 372, Crew 6, Flight B

		Decompression	Mask
1. Pilot	2nd Lt. L. H. Scholar	None	A-8-B
2. Co-Pilot	2nd Lt. J. E. Stay	22 min. exercycle	A-8-B
3. Navigator	2nd Lt. C. L. Seymour	22 min. 3 mi./hr.	A-8-B
4. Bombardier	2nd Lt. R. P. Ortiz	None	A-8-B
5. Radio Operator	S/Sgt. H. P. Rosenberg	None	B.Demand Rebr.
6. Tail Gunner	S/Sgt. D. F. Morgan	None	B.Demand Rebr.
7. Upper Turret Gunner	S/Sgt. P. F. Jurgensmier	None	Drinker
8. Bottom Turret Gunner	S/Sgt. V. R. Lehman	None	B.Demand
9. Engineer	S/Sgt. J. F. Durden	22 min. 3.5 mi./hr.	A-8-B

Condensed Log of Flight

Highest elevation 44,300 feet.

Duration Hr.	Min.	Elevations
	50	30,000 - 34,000 feet
1	8	35,000 - 39,000 "
	6	40,000 - 41,000 "
	2	42,000 + feet
2	6	over 30,000 feet

Results

2. Co-Pilot, Stay

1 hr. 11 min.	30,000 - 42,000 feet	Pain right wrist (42,000).

3. Navigator, Seymour

3 min.	30,000 - 35,000 feet	Bad gas pains (35,000).
9 "	30,000 - 35,000 "	Gas pains better (30,000).

6. Tail Gunner, Morgan

1 hr. 53 min.	30,000 - 42,000 feet	Little pain left knee (35,000).
2 " 1 "	30,000 - 42,000 "	Still has pain (42,000).
	40,000 feet	Pain gone.

7. Upper Turret Gunner, Jurgensmier

	30,000 feet	Very cyanosed; flow up, better.
52 min.	30,000 - 35,000 feet	Suddenly became very cyanotic and dizzy (30,000).
1 hr. 51 "	30,000 - 42,000 "	Pain right knee (35,000).

The other five men had no symptoms.

Summary: Difficulty with oxygen apparatus but no severe bends. Mission of over two hours carried out.

MAMU FLIGHT NO. 65

Saturday, October 17, 1942 from 10:37 a.m. to 1:27 p.m. ($2^{o}50'$)

Squadron 424, Crew 4, Flight B

			Decompression	Mask
1.	Pilot	1st Lt. H. L. Milledge	None	A-8-B
2.	Co-Pilot	2nd Lt. S. L. Burke	None	A-8-B
3.	Navigator	2nd Lt. J. K. Woody	None	Demand
4.		2nd Lt. C. T. O'Neill	None	A-8-B
5.	Radio Operator	S/Sgt. M. H. Smith	None	A-8-B
6.	Radio Gunner	S/Sgt. R. W. Burchette	None	A-8-B
7.	Waist Gunner	Sgt. M. E. Smith	None	A-8-B
8.	Upper Turret	S/Sgt. N. K. Bullard	40 min. 3 m/hr.	Demand
9.	Extra	S/Sgt. W. M. Ward	40 min. 3 m/hr.	Demand
10.	Extra	Sgt. J. V. Shaughnessy	None	A-8-B
11.	Flight Surgeon	Capt. J. R. Glasscock	None	A-8-B

Condensed Log of Flight

Highest elevation 40,000 feet

Duration Hrs.	Min.	Elevations
	57	30,000 - 34,000 feet
	32	35,000 - 39,000 feet
	6	40,000 feet
1	35	over 30,000 feet

Results

1. Pilot, Milledge

55 min.	35-40,000 feet	Pain thunb (40,000).
1 hr.	35-40,000 "	Pain left shoulder (40,000).
1 " 3 "	35-40,000 "	Coughing, tickling throat (40,000).
1 " 5 "	35-40,000 "	Went down in air-lock.

2. Co-Pilot, Burke

55 min.	35-40,000 feet	Pain thumb (40,000).

3. Navigator, Woody

55 min.	35-40,000 feet	Pain thumb (40,000).
1 hr. 2 "	35-40,000 "	Pain right shoulder (40,000).
	30,000 "	On way down pain left shoulder.
	25,000 "	Pain gone.

4. O'Neill

58 min.	35-40,000 "	Pain right knee at 40,000.
	30,000 "	On way down still slight pain.
1 hr.	25,000 "	On way down pain gone.

6. Radio Gunner, Burchette

1 hr. 9 min.	35,000 feet	Pain left ankle.

11. Flight Surgeon, Glasscock

55 min.	35-40,000 feet	Pain left knee (40,000).
1 hr.	30,000 "	Still slight pain.

The other five men had no symptoms.

Summary: Pilot had chokes at 40,000 feet which were incapacitating. Mission jeopardized.

MAMU FLIGHT 66
Saturday, October 17, 1942, from 4:07 p.m. to 5:06 p.m. (59')

Squadron 371, Crew 7, Flight C

			Decompression	Mask
1.	Pilot	1st. Lt. Roland O. Lundby	None	B. Demand
2.	Co-Pilot	2nd Lt. W. C. Sharkey	None	B. Demand
3.	Navigator	2nd Lt. G. T. White	None	
4.	Bombardier	2nd Lt. I. F. Teykl	None	B. Demand
5.	Radio Operator	S/Sgt. R. D. Copeland	None	A-8-B
6.	Radio Opr.-Gunner	S/Sgt. R. A. Fale	None	A-8-B
7.	Tail Gunner	S/Sgt. A. R. Creach	None	
8.	Engineer	S/Sgt. E. W. Ericson	None	Drinker
9.	Asst. Engineer	S/Sgt. C. J. Atkinson	None	A-8-B
10.	Operations Off.	1st Lt. W. R. Harpster	None	A-8-B

Condensed Log of Flight

Highest Elevation 40,000 feet

Duration Hr.	Duration Min.	Elevations
	5	30,000 - 34,000 feet
	20	35,000 - 39,000 feet
	4	40,000 feet
	29	over 30,000 feet

Results

1. Pilot, Lundby - Did not go up.

7. Tail Gunner, Creach - Did not go up.

No member of the group had symptoms.

Summary: Mission carried out.

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL CENTER
Under Contract No. W535ac-25829

SUBJECT: Conservation of oxygen affected by the use of economizer bag, and with and without the use of the automix.

SERIAL REPORT: Series A, No. 3 DATE: November 20, 1942

A. Purposes.

1. To demonstrate that the economy of oxygen is substantial when an economizer bag is attached to the inspiratory tube. This economy is demonstrated with the automix set for either "on" or "off."

2. To confirm the economy of oxygen effected by use of the automix.

3. To demonstrate that the air-oxygen demand regulator when constructed so as to deliver the theoretically correct mixture, according to specification, functions perfectly both with and without the use of the economizer bag.

B. Factual data.

1. Method and apparatus.

a. The economizer bag made of rubber (although other materials may be used) has a maximum volume of approximately 650 cc. when fully distended. Since it usually was not fully distended the effected volume was approximately 550 cc. The bag was attached to the corrugated tubing directly below the mask. In some instances it may be advisable to attach the economizer bag directly to the demand regulator. If this is done the optimal size of the bag should be such that its maximum volume is approximately 425 cc., thus avoiding the increased CO_2 concentration which occurs with the use of a larger economizer bag attached to the regulator.

b. In the accumulation of these data Aro Products demand regulator #4902 was used.

c. During each series of observations the subject was sitting upright and remained substantially inactive. The subject wore a demand type mask (A-10 or A-14) carefully fitted and checked at each observation by the Scholander method of gas analysis. Samples were taken from both the mask and the inspiratory tube near the demand valve mask to insure against the possibility of the slightest leakage around the mask invalidating the quantitiative results obtained in regard to the value of an economizer bag.

d. At each altitude a measured amount of oxygen was used (1) without the economizer bag, automix off, (2) without the economizer bag, automix on, (3) with the economizer bag, automix off, and (4) with the economizer bag, automix on.

e. The oxygen used was measured by noting the time required for the subject to inhale from a small tank sufficient oxygen to cause a drop in pressure of 100 lbs. Our apparatus, on careful calibration at all altitudes, showed that a drop in pressure of 100 lbs. represented a volume of 4.29 liters, S.T.P.D.

f. Six subjects, (Table 1) of various statures were used in making a total of nine series of observations.

Table 1. Sex, height and weight of subjects.

Subject	Sex	Height in in.	Weight in lbs.
William Burrows	M	70	157
Rita Schmelzer	F	62	144
Eleanor Larson	F	67	141
Lucille Cronin	F	62	156
Alvin Sweeney	M	69	165
Henrietta Cranston	F	62	100

2. The data obtained in these nine series of observations, expressed as average figures, is summarized in Tables 2 and 3 where the oxygen used at various altitudes is expressed in liters per minute S.T.P.D. in Table 2, and liters per minute lung volume (ambient bar., 37° C. Sat.) in Table 3. Charts I and II graphically illustrate the same data as expressed in Tables 2 and 3 respectively.

Table 2. Oxygen used expressed in liters per minute, S.T.P.D.

	1	2	3	4
Altitude in Thousands of Feet	Without economizer bag		With economizer bag	
	Automix off	Automix on	Automix off	Automix on
15,000	3.40	1.19	2.17	.69
25,000	2.23	1.64	1.38	1.06
30,000	1.71	1.71	1.05	1.06
33,000	1.37	1.40	.91	.91

Table 3. Oxygen used expressed in liters per minute lung volume (ambient bar. 37° C. Sat.)

	1	2	3	4
Altitude in Thousands of Feet	Without economizer bag		With economizer bag	
	Automix off	Automix on	Automix off	Automix on
15,000	7.68	2.68	4.91	1.56
25,000	8.20	6.03	5.08	3.88
30,000	8.27	8.27	5.09	5.11
33,000	7.92	8.10	5.26	5.27

The great economy in the use of oxygen effected by the economizer bag may be seen in a comparison drawn between columns 1 and 3 (Tables 2 and 3). This comparison shows the oxygen waste without the economizer bag, automix off, using as our standard of efficiency the amount of oxygen used with the economizer bag attached and automix off.

In like manner a comparison may be drawn between columns 2 and 4 (Tables 2 and 3) to demonstrate the oxygen waste without the economizer bag, automix on, using as our standard of efficiency the amount of oxygen used with the economizer bag attached, automix on.

The data in Tables 2 and 3 are graphically presented in Charts 1 and 2 respectively, where it can be seen at a glance that if an economizer bag is not used one wastes a significant amount of oxygen corresponding to between 50 and 75 per cent of the oxygen used with an economizer bag as shown in Table 4.

Table 4. Percentage waste oxygen without the economizer bag as compared with oxygen used when the economizer bag is attached.

	1	2
Altitude in Thousands of Feet	Percentage with automix off	Percentage with automix on
15,000	56	75
25,000	63	57
30,000	66	67
33,000	51	54

Table 4 shows the percentage waste of oxygen runs between 51 and 75 per cent by neglecting to use an economizer bag. The percentage figures in Table 4, column 1, for automix off are obtained from either Table 2 or Table 3 as follows: $\frac{\text{Col. 1 - Col. 3}}{\text{Col. 3}}$. The percentage figures in Table 4, column 2, for automix on are obtained from either Table 2 or Table 3 as follows: $\frac{\text{Col. 2 - Col. 4}}{\text{Col. 4}}$.

Table 5. Percentage oxygen in inspired mixture coming from oxygen tank when using automix with and without economizer bag.

Altitude in Thousands of Feet	1 Percentage oxygen needed from oxygen tank in inspired mixture (B.37° C. Sat.) to maintain a strictly normal alveolar oxygen pressure	2 Percentage oxygen used from tank in inspired mixture (B.37° C.Sat.) as determined by comparison of columns 1 and 2, and columns 3 and 4, Table 3. Without economizer bag	3 With economizer bag
15,000	23.0	35.0	31.4
25,000	54.0	74.7	76.6
30,000	79.0	100.0	99.4
33,000	100.0	102.5	100.3

The data obtained, as expressed in Table 5, demonstrate two facts: (1) That at any altitude the proportion of air-oxygen furnished by use of the automix is practically identical whether the extra economy of an economizer bag is or is not taken advantage of; stated differently, the economizer bag does not disturb the relationship of the air-oxygen automix mechanism. (2) That the particular demand regulator (Aro Products #4902) used in these observations is seen to deliver roughly from 10 to 20 percentage points more oxygen than necessary for the achievement of the sea-level alveolar oxygen pressure; that is, there is a slight excess of oxygen. This discrepancy is on the safe side and, therefore, permissible; a discrepancy of similar amount, if it lowered the proportion of oxygen in the mixture, would not be permissible.

Table 6. Percentage in inspired mixture.

Altitude in Thousands of Feet	1	2	3
	Allowable percentage of nitrogen in inspired mixture so that the partial pressure of oxygen in the alveolar will be normal	Percentage nitrogen as determined by Scholander gas analysis of sample taken from tube with automix on.	
		Without economizer bag	With economizer bag
15,000	61.0	56	60
25,000	36.6	23	25
30,000	16.7	1	1
33,000	0.0	0	1

Table 6 represents a slightly different method of expressing the same data. Column 1 represents the amount of nitrogen from the addition of air which can be present in the mixture from the automix which when inspired will maintain a normal alveolar oxygen pressure. It may be seen in columns 2 and 3 (Table 6) that the percent of nitrogen delivered by the automix never exceeded the allowable amount and usually was between 5 and 15 percentage points lower than necessary to maintain a normal alveolar oxygen pressure. The use of the economizer bag does not disturb the proper functioning of the automix mechanism.

C. Conclusions.

1. Waste in the use of oxygen without the use of an economizer bag ranges from 50 to 75 per cent; thus, the use of the economizer bag materially increases oxygen economy.

2. The economy of oxygen effected by the use of the automix is confirmed. This economy is enhanced by the use of the economizer bag.

3. The use of the economizer bag does not interfere with the functioning of the air-oxygen partition mechanism of the automix demand regulator here used and this would apply to any automix regulator in good condition.

4. An important "by-product" obtained by the use of an economizer bag in conjunction with the demand system is that the recently developed demand type mask (A-10 or A-14) can be used with a constant flow regulator like the Pioneer if a simple adaptor is supplied. This interchangeability is of great advantage because the Pioneer constant flow regulator is now widely distributed all over the world,

and if the economizer bag is on the demand mask it allows the mask to be used no matter whether a constant flow regulator or a demand regulator is in any particular airplane. For most conditions it is best to have the economizer bag attached to the tubing just below the mask; however, under certain conditions it may be advisable to have the economizer bag attached to the regulator itself by a special T-tube.

5. The economizer bag need not be made of rubber as some type of pliable plastic or silk-like material may be used.

D. Recommendations.

1. That an economizer bag be used in conjunction with the autonix demand regulator:

a. to conserve oxygen over and above the conservation produced by the automix mechanism, and

b. to enable the utilization of the recently developed demand type masks (A-10 or A-14) in airplanes equipped with the present issue of Pioneer constant flow regulator as well as with the demand type regulator now being issued; therefore, a simple adaptor should be available which would render easy interchange.

Experimental work done by:

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2nd Lt. John P. Marbarger
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In cooperation with:
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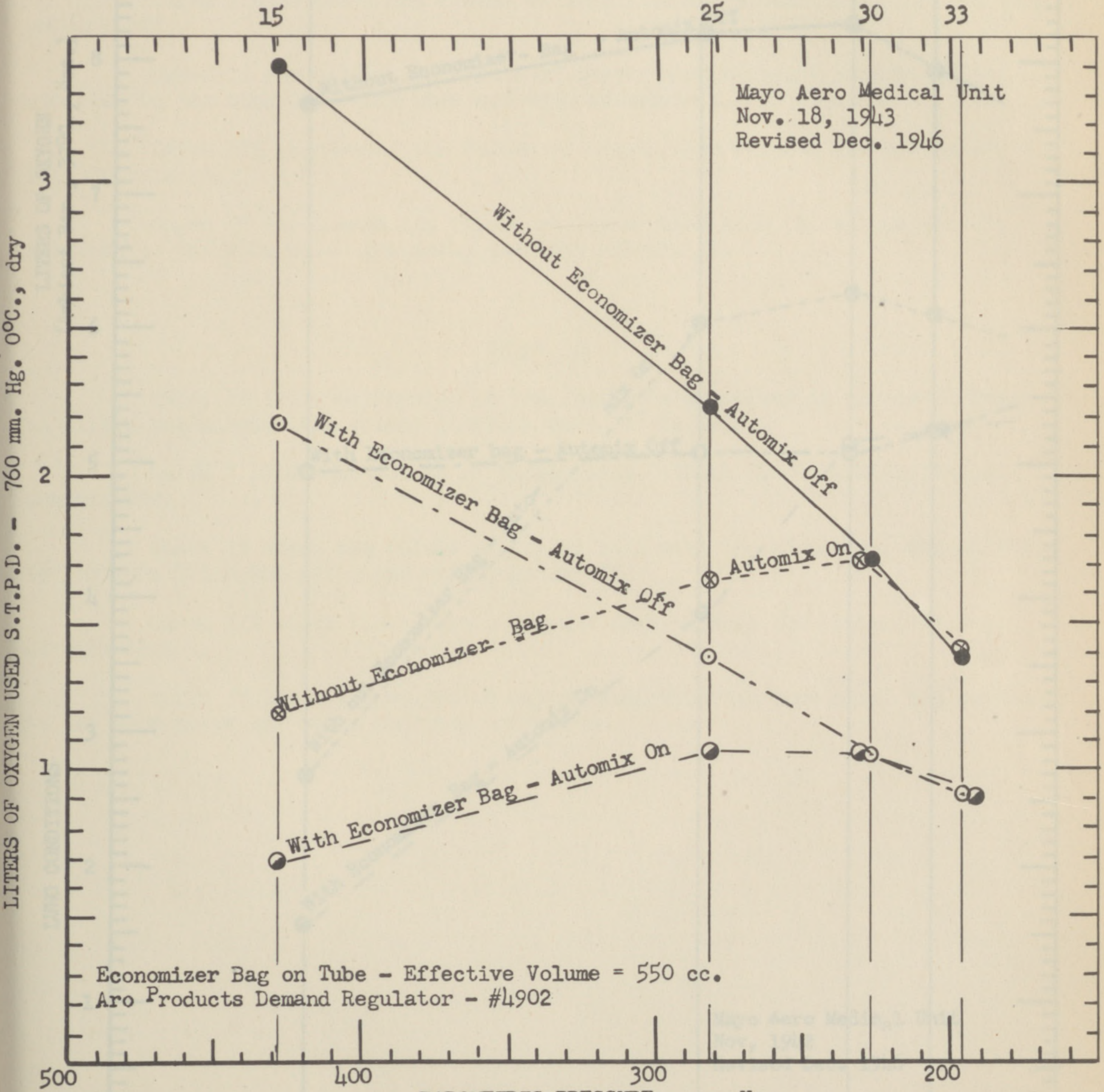
Approved by:

Walter M. Boothby, M. D.
Chairman, Mayo Aero Medical Unit

CONSERVATION OF OXYGEN

ALTITUDE IN THOUSAND FEET

Chart I



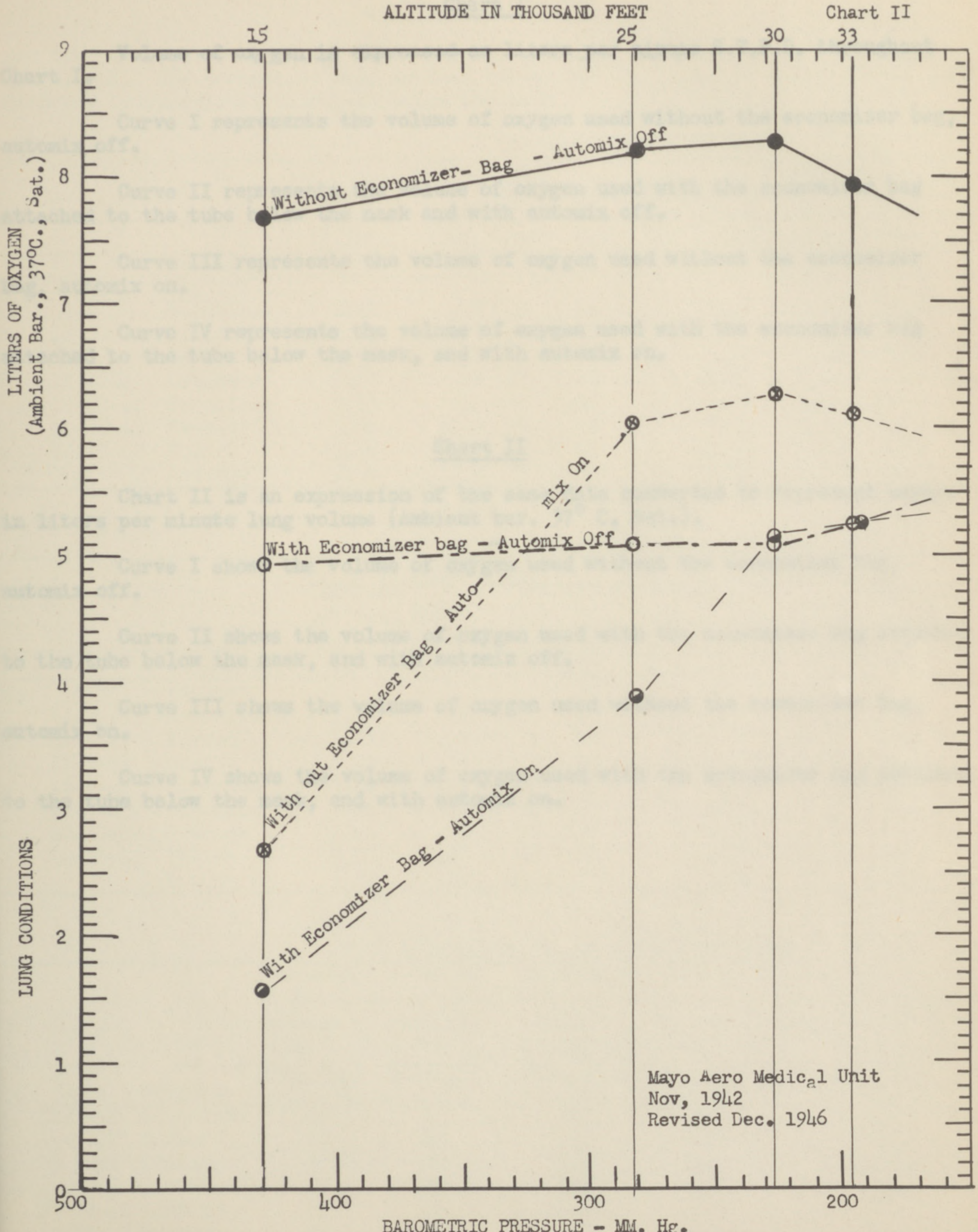
BAROMETRIC PRESSURE - mm. Hg.

Chart XVIII - 1

W.M.Boothby and B.P.Cunningham

CONSERVATION OF OXYGEN

Chart II



W.M. Boothby and B.P. Cunningham

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Chart I

Volume of oxygen is expressed as liters per minute S.T.P.D. throughout Chart I.

Curve I represents the volume of oxygen used without the economizer bag, automix off.

Curve II represents the volume of oxygen used with the economizer bag attached to the tube below the mask and with automix off.

Curve III represents the volume of oxygen used without the economizer bag, automix on.

Curve IV represents the volume of oxygen used with the economizer bag attached to the tube below the mask, and with automix on.

Chart II

Chart II is an expression of the same data converted to represent oxygen in liters per minute lung volume (Ambient bar. 37° C. Sat.).

Curve I shows the volume of oxygen used without the economizer bag, automix off.

Curve II shows the volume of oxygen used with the economizer bag attached to the tube below the mask, and with automix off.

Curve III shows the volume of oxygen used without the economizer bag, automix on.

Curve IV shows the volume of oxygen used with the economizer bag attached to the tube below the mask, and with automix on.

ALTITUDE 15,000 FEET

Aro Products demand regulator #4902 and Bulbulian #14 demand type mask were used throughout. The economizer bag, maximum volume 650 cc., average volume 550 cc., was attached to corrugated tube just below the mask

WITHOUT ECONOMIZER BAG

			Automix on					Automix off			
			Ambient 37°Sat. L./Min.	STPD L./Min.	From tank O_2%	Scholander Tube O_2%	Scholander Mask O_2%	Ambient 37°Sat. L./Min.	STPD L./Min.	Scholander Tube O_2%	Scholander Mask O_2%
		Column No.:	1	2	3	4	5	6	7	8	9
No.	Date	Subject									
1.	11-4-42	Schmelzer	2.47	1.09	33	44		7.46	3.30	99.9	99.5
2.	11-3-42	Larson	2.33	1.03	32	45		7.19	3.18	99.4	99.0
3.	11-3-42	Cronin	2.85	1.26	42	46		6.92	3.06	99.9	99.8
4.	11-2-42	Cranston	1.97	.87	37	43		5.29	2.34	99.8	99.5
5.	10-30-42	Schmelzer	2.13	.94	27	47		7.76	3.43	100.0	98.8
6.	10-30-42	Sweeney	3.08	1.36	38	42		8.21	3.63	99.9	99.3
7.	10-28-42	Tulare	3.96	1.75	36	44		10.93	4.83	99.0	
		Average:	2.68	1.19	35	44		7.68	3.40	99.7	99.3

WITH ECONOMIZER BAG ON CORRUGATED TUBING

			Automix on					Automix off			
			Ambient 37°Sat. L./Min.	STPD L./Min.	From tank O_2%	Scholander Tube O_2%	Scholander Mask O_2%	Ambient 37°Sat. L./min.	STPD L./Min.	Scholander Tube O_2%	Scholander Mask O_2%
		Column No.:	10	11	12	13	14	15	16	17	18
No.	Date	Subject									
1.	11-4-42	Schmelzer	1.49	.66	28	43		5.27	2.33	99.9	99.2
2.	11-3-42	Larson	1.11	.49	25	42		4.39	1.94	99.5	99.0
3.	11-3-42	Cronin	1.72	.76	33	40		5.18	2.29	99.9	99.6
4.	11-2-42	Cranston	1.04	.46	28	35		3.66	1.62	99.8	99.0
5.	10-30-42	Schmelzer	1.90	.84	34	47		5.54	2.45	99.9	99.7
6.	10-30-42	Sweeney	1.63	.72	36	35		4.59	2.03	99.9	98.0
7.	10-28-42	Tulare	2.06	.91	36	36		5.75	2.54	99.9	
		Average:	1.56	.69	31.4	40		4.91	2.17	99.8	99.1

ABOVE DATA EXPRESSED AS PERCENTAGE WASTE OF OXYGEN

			Percentage waste O_2 without economizer: Automix On Col. 2-11	Percentage waste O_2 without economizer: Automix Off Col. 7-16	Percentage waste O_2 with automix off: With Economizer Col. 16-11	Percentage waste O_2 with automix off: Without Economizer Col. 7-2	Percentage waste O_2 without economizer bag, automix off Col. 7-11
No.	Date	Subject	11	16	11	2	11
1.	11-4-42	Schmelzer	66	42	254	202	400
2.	11-3-42	Larson	110	64	295	209	549
3.	11-3-42	Cronin	66	34	201	143	303
4.	11-2-42	Cranston	89	45	252	169	409
5.	10-30-42	Schmelzer	12	40	192	264	308
6.	10-30-42	Sweeney	89	79	182	167	404
7.	10-28-42	Tulare	92	90	179	176	431
		Average:	75	56	222	190	401

ALTITUDE 25,000 FEET

Aro Products demand regulator #4902 and Bulbulian #14 demand type mask were used throughout. The economizer bag, maximum volume 650 cc., average volume 550 cc., was attached to corrugated tube just below the mask

WITHOUT ECONOMIZER BAG

			Automix on					Automix off			
			Ambient 37°Sat. L./Min.	STPD L./Min.	From tank O_2%	Scholander Tube O_2%	Scholander Mask O_2%	Ambient 37°Sat. L./Min.	STPD L./Min.	Scholander Tube O_2%	Scholander Mask O_2%
		Column:	1	2	3	4	5	6	7	8	9
No.	Date	Subject									
1.	10-29-42	Burrows	6.32	1.72	73	74		8.68	2.36	99.7	99.5
2.	11-2-42	Cranston	5.33	1.45	76	74		7.02	1.91	99.5	99.2
3.	10-28-42	Tulare	8.75	2.38	67	78		13.16	3.58	99.9	
4.	10-30-42	Sweeney	4.71	1.28	54	76		8.75	2.38	99.9	99.2
5.	10-30-42	Schmelzer	5.73	1.56	78	78		7.32	1.99	99.2	97.0
6.	11-3-42	Cronin	6.43	1.75	89	81		7.20	1.96	99.9	99.4
7.	11-3-42	Larson	5.37	1.46	82	77		6.54	1.78	99.8	98.0
8.	11-4-42	Schmelzer	5.33	1.45	69	78		7.68	2.09	99.9	99.2
9.	11-2-42	Schmelzer	6.29	1.71	84	77		7.46	2.03	99.8	99.4
		Average:	6.03	1.64	74.7	77		8.20	2.23	99.7	98.9

WITH ECONOMIZER BAG ON CORRUGATED TUBING

			Automix on					Automix off			
			Ambient 37°Sat. L./Min.	STPD L./Min.	From tank O_2%	Scholander Tube O_2%	Scholander Mask O_2%	Ambient 37°Sat. L./Min.	STPD L./Min.	Scholander Tube O_2%	Scholander Mask O_2%
		Column:	10	11	12	13	14	15	16	17	18
No.	Date	Subject									
1.	10-29-42	Burrows	4.08	1.11	76	78	78	5.44	1.48	99.8	99.6
2.	11-2-42	Cranston	2.87	.78	84	73		3.42	.93	99.6	99.4
3.	10-28-42	Tulare	5.66	1.54	85	72		6.65	1.81	99.8	
4.	10-30-42	Sweeney	3.12	.85	70	73		4.48	1.22	100	99.2
5.	10-30-42	Schmelzer	3.57	.97	67	75		5.33	1.45	99.9	99.0
6.	11-3-42	Cronin	4.41	1.20	85	80		5.18	1.41	99.9	99.2
7.	11-3-42	Larson	3.71	1.01	76	75		4.89	1.33	99.5	98.5
8.	11-4-42	Schmelzer	3.46	.94	73	77		4.74	1.29	99.9	99.2
9.	11-2-42	Schmelzer	4.04	1.10	73	76		5.55	1.51	100	99.5
		Average:	3.88	1.06	76.6	75		5.08	1.38	99.8	99.2

ABOVE DATA EXPRESSED AS PERCENTAGE WASTE OF OXYGEN

			Percentage waste O_2 without economizer		Percentage waste O_2 with automix off		Percentage waste O_2 without economizer bag, automix off
			Automix On	Automix Off	With Economizer	Without Economizer	
No.	Date	Subject	Col. 2-11 / 11	Col. 7-16 / 16	Col. 16-11 / 11	Col. 7-2 / 2	Col. 7-11 / 11
1.	10-29-42	Burrows	55	60	33	37	113
2.	11-2-42	Cranston	86	105	19	32	145
3.	10-28-42	Tulare	55	98	17	50	133
4.	10-30-42	Sweeney	51	95	44	86	180
5.	10-30-42	Schmelzer	61	37	49	28	105
6.	11-3-42	Cronin	46	39	17	12	63
7.	11-3-42	Larson	45	34	32	26	76
8.	11-4-42	Schmelzer	54	62	37	44	122
9.	11-2-42	Schmelzer	56	34	37	19	85
		Average:	57	63	32	37	114

ALTITUDE 30,000 FEET

Aro Products demand regulator #4902 and Bulbulian #14 demand type mask were used throughout. The economizer bag, maximum volume 650 cc., average volume 550 cc., was attached to corrugated tube just below the mask.

WITHOUT ECONOMIZER BAG

			Automix on					Automix off			
			Ambient 37°Sat. L./Min.	STPD L./Min.	From tank O_2%	Scholander Tube O_2%	Scholander Mask O_2%	Ambient 37°Sat. L./Min.	STPD L./Min.	Scholander Tube O_2%	Scholander Mask O_2%
		Column:	1	2	3	4	5	6	7	8	9
No.	Date	Subject									
1.	11-2-42	Schmelzer	8.41	1.74	101	98.0		8.31	1.72	99.9	99.8
2.	11-2-42	Cranston	7.05	1.46	103	99.5		6.86	1.42	99.8	99.0
3.	11-4-42	Schmelzer	7.68	1.59	101	99.9		7.63	1.58	99.9	99.5
4.	11-3-42	Cronin	7.92	1.64	99	99.9		7.97	1.65	99.9	99.9
5.	10-30-42	Schmelzer	8.36	1.73	101	99.6		8.26	1.71	100.	99.9
6.	10-30-42	Sweeney	6.52	1.35	80	99.7		8.12	1.68	99.9	99.2
7.	10-28-42	Tulare	12.27	2.54	102	99.2		12.03	2.49	99.8	
8.	10-29-42	Burrows	8.70	1.80	107	99.9		8.12	1.68	99.7	99.4
9.	11-3-42	Larson	7.54	1.56	106	99.7		7.10	1.47	99.5	99.0
		Average:	8.27	1.71	100	99.5		8.27	1.71	99.8	99.5

WITH ECONOMIZER BAG ON CORRUGATED TUBING

			Automix on					Automix off			
			Ambient 37°Sat. L./Min.	STPD L./Min.	From tank O_2%	Scholander Tube O_2%	Scholander Mask O_2%	Ambient 37°Sat. L./Min.	STPD L./Min.	Scholander Tube O_2%	Scholander Mask O_2%
		Column:	10	11	12	13	14	15	16	17	18
No.	Date	Subject									
1.	11-2-42	Schmelzer	5.46	1.13	100	99.8		5.46	1.13	99.9	99.8
2.	11-2-42	Cranston	3.08	.64	99	99.8		3.11	.64	99.8	99.0
3.	11-4-42	Schmelzer	5.27	1.09	98	99.9		5.36	1.11	99.9	98.6
4.	11-3-42	Cronin	5.22	1.08	101	99.3		5.17	1.07	99.9	97.0
5.	10-30-42	Schmelzer	5.07	1.05	101	99.8		5.02	1.04	100.	99.6
6.	10-30-42	Sweeney	3.43	.71	85	99.9		4.06	.84	99.7	98.0
7.	10-28-42	Tulare	8.12	1.68	114	99.8		7.10	1.47	99.8	
8.	10-29-42	Burrows	5.60	1.16	100	99.7		5.60	1.16	98.6	99.0
9.	11-3-42	Larson	4.78	.99	97	92.8		4.93	1.02	99.7	97.8
		Average:	5.11	1.06	99.4	99.		5.09	1.05	99.7	98.6

ABOVE DATA EXPRESSED AS PERCENTAGE WASTE OF OXYGEN

			Percentage waste O_2 without economizer		Percentage waste O_2 with automix off		Percentage waste O_2 without economizer bag, automix off
			Automix On	Automix Off	With Economizer	Without Economizer	
			Col. 2-11 / 11	Col. 7-16 / 16	Col. 16-11 / 11	Col. 7-2 / 2	Col. 7-11 / 11
No.	Date	Subject					
1.	11-2-42	Schmelzer	54	52			52
2.	11-2-42	Cranston	129	121	At altitudes of 30,000		123
3.	11-4-42	Schmelzer	46	42	feet and over 100 per		45
4.	11-3-42	Cronin	52	54	cent oxygen is delivered		53
5.	10-30-42	Schmelzer	65	65	both with automix on and		63
6.	10-30-42	Sweeney	90	100	off (Aro demand regulator		137
7.	10-28-42	Tulare	51	69	#4902).		48
8.	10-29-42	Burrows	55	45			45
9.	11-3-42	Larson	58	44			49
		Average:	67	66			68

ALTITUDE 33,000 FEET

Aro Products demand regulator #4902 and Bulbulian #14 demand type mask were used throughout. The economizer bag, maximum volume 650 cc., average volume 550 cc., was attached to corrugated tube just below the mask.

WITHOUT ECONOMIZER BAG

			Automix on					Automix off			
			Ambient 37°Sat. L./Min.	STPD L./Min.	From tank O_2%	Scholander Tube O_2%	Scholander Mask O_2%	Ambient 37°Sat. L./Min.	STPD L./Min.	Scholander Tube O_2%	Scholander Mask O_2%
		Column:	1	2	3	4	5	6	7	8	9
No.	Date	Subject									
1.	10-29-42	Burrows	8.69	1.50	111	99.5		7.82	1.35	99.5	99.0
2.	11-2-42	Schmelzer	8.92	1.54	100	99.8		8.92	1.54	100	99.8
3.	11-3-42	Larson	7.42	1.28	97	99.5		7.65	1.32	99.5	99.7
4.	10-30-42	Schmelzer	8.17	1.41	99	99.8		8.29	1.43	99.4	99.9
5.	11-3-42	Cronin	8.34	1.44	102	99.9		8.17	1.41	99.3	98.0
6.	11-4-42	Schmelzer	7.94	1.37	100	99.0		7.94	1.37	99.9	98.0
7.	10-30-42	Sweeney	7.82	1.35	104	99.3		7.53	1.30	99.2	98.7
8.	11-2-42	Cranston	7.47	1.29	107	99.8		7.01	1.21	99.6	99.0
		Average	8.10	1.40	102.5	99.6		7.92	1.37	99.6	99.0

WITH ECONOMIZER BAG ON CORRUGATED TUBING

			Automix on					Automix off			
			Ambient 37°Sat. L./Min.	STPD L./Min.	From tank O_2%	Scholander Tube O_2%	Scholander Mask O_2%	Ambient 37°Sat. L./Min.	STPD L./Min.	Scholander Tube O_2%	Scholander Mask O_2%
		Column:	10	11	12	13	14	15	16	17	18
No.	Date	Subject									
1.	10-29-42	Burrows	5.62	.97	104	99.5		5.39	.93	99.0	99.0
2.	11-2-42	Schmelzer	5.97	1.03	100	99.5		5.97	1.03	99.8	99.4
3.	11-3-42	Larson	5.21	.90	100	99.8		5.21	.90	99.8	99.5
4.	10-30-42	Schmelzer	5.74	.99	101	98.3		5.68	.98	98.8	98.0
5.	11-3-42	Cronin	5.21	.90	100	99.9		5.21	.90	99.9	98.0
6.	11-4-42	Schmelzer	5.33	.92	97	99.9		5.50	.95	99.9	99.7
7.	10-30-42	Sweeney	4.69	.81	96	99.7		4.87	.84	99.3	99.0
8.	11-2-42	Cranston	4.37	.75	104	99.5		4.21	.73	99.2	99.5
		Average:	5.27	.91	100.3	99.5		5.26	.91	99.5	99.0

ABOVE DATA EXPRESSED AS PERCENTAGE WASTE OF OXYGEN

			Percentage waste O_2 without economizer		Percentage waste O_2 with automix off		Percentage waste O_2 without economizer bag, automix off
			Automix On	Automix Off	With Economizer	Without Economizer	
			Col. 2-11 / 11	Col. 7-16 / 16	Col. 16-11 / 11	Col. 7-2 / 2	Col. 7-11 / 11
No.	Date	Subject					
1.	10-29-42	Burrows	55	45			39
2.	11-2-42	Schmelzer	49	49	At altitudes of 30,000		49
3.	11-3-42	Larson	42	47	feet and over 100 per		47
4.	10-30-42	Schmelzer	42	46	cent oxygen is delivered		44
5.	11-3-42	Cronin	60	57	both with automix on and		57
6.	11-4-42	Schmelzer	49	44	off (Aro demand regulator		49
7.	10-30-42	Sweeney	67	55	#4902).		60
8.	11-2-42	Cranston	71	67			60
		Average	54	51			51

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT

to

ARMY AIR FORCES MATERIEL CENTER
Under Contract No. w535ac-25829

Subject: The Development of a Positive Pressure Jacket for Use During Positive Pressure Breathing.

SERIAL REPORT: Series A. No. 4 DATE: February 1, 1943

A. Purposes.

1. To make flying at altitudes from 43,000 feet to 48,000 feet as safe and as comfortable as at 38,000 feet or 42,000 feet.

2. To present the results of some altitude flights in the low pressure chamber in which the oxyhemoglobin saturation was studied with the use of the oximeter.

3. To present the results of a comparison between breathing in a positive pressure rebreather bag and in the positive pressure jacket. Observations were made on the blood pressure, venous pressure, pulse rate, circulation time and respiratory rate in man.

B. Factual Data.

1. The positive pressure jacket.

a. The jacket is for use during the breathing of pure oxygen under a positive pressure of 30 to 33 mm. mercury. This will raise the altitude ceiling to 48,000 feet and give a safety factor equivalent to 42,000 feet without positive pressure. An altitude of 50,000 feet can be safely reached and maintained for a short time.

b. The positive pressure jacket is designed so that it can be used below 38,000 feet as a straight constant flow system with a maximum pressure of 5 mm. mercury. In order to ascend above 38,000 feet the pressure can be raised to 30 or 35 mm. mercury or any desired pressure by simply closing a valve. It is possible to build up this positive pressure in the jacket in a few seconds, whenever the occasion demands.

c. A Bulbulian pressure mask equipped with a magnetic microphone is used with positive pressure jacket.

d. In Appendix I are attached specifications, description and a photograph to show the design and operation of our experimental positive pressure jacket.

2. Oximeter observations.

a. The oximeter records of several flights to 45,000 and 48,000 feet and one to 50,608 feet showed that the oxyhemoglobin saturation never fell below 86%. However, at 45,000 feet without positive pressure the oximeter record on the same subject showed 78% saturation and this altitude could only be tolerated for a short time without positive pressure. In Appendix II are attached curves to show the relation between the oximeter reading and the altitude.

3. The effects of positive pressure breathing on man.

a. Breathing in the positive pressure jacket increases the pulse rate, the blood pressure, the venous pressure and the circulation time. Attached in Appendix III are tables showing the magnitude of these changes.

C. Summary.

1. Subjects have continuously breathed in the positive pressure jacket for an hour and flights between 40,000 and 50,000 feet have been made in the low pressure chamber. The subjects experienced no difficulties and with the exception of minor mask leaks, were as comfortable at altitudes above 40,000 feet as at 38,000 feet.

2. We are compiling the results of some experimental work which will present a clearer picture concerning the methods by which the body compensates to positive pressure breathing.

3. Two more positive pressure jackets are under construction and will be ready for use in several days.

D. Acknowledgment.

We wish to express our appreciation to Dr. Boothby for advice and facilities of the Unit made available to us.

Prepared by 1st Lt. Charles B. Taylor, M.C.

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APPENDIX I

The construction and description of the positive pressure jacket.

1. The pressure jacket is constructed on the rebreather principle. It is a two-walled rubberized bag with a volume of approximately 6 liters. An adjustable "corset-like" outer foundation garment made of heavy canvas is used to give rigidity to the outer wall of the bag. The inner wall fits snugly to the body so that when the jacket is inflated it exerts pressure evenly on the chest cage and abdomen. Two crotch straps on the foundation garment keep the jacket from creeping up the trunk.

2. Oxygen from a high or low pressure system with a regulator set to deliver the oxygen required at 42,000 feet inactive enters the jacket through a small jet. The mask is connected to the pressure jacket by two pieces of large corrugated tubing. On inspiration oxygen passes from the jacket through one of the corrugated tubes, (A), to the mask and into the lungs. There is a one way valve (1) which closes with the cessation of inspiration and onset of expiration. Gas from the lungs is expired through corrugated tube (B) into a shell natron container and then back into the pressure jacket through a one way valve (2) which opens only on expiration and closes at the onset of inspiration. The total pressure in the system can be regulated by a spring valve (3).

3. Breathing against a positive pressure as great as 37 mm. Hg. is made relatively easy by using this sytem because on inspiration the volume of the jacket is decreased thus allowing for chest expansion. During expiration the volume of the jacket is increased as a result of gas passing from the lungs back into the jacket. This makes expiration a passive motion because the increasing volume of the jacket during expiration exerts pressure on the chest cage. However, if the flow of oxygen into the jacket is too great, e.g. 20 liters per minute, the volume of the bag is increased so rapidly that complete inspiration is hampered thus destroying the marked ease to respiration which the pressure jacket affords.

Photograph 1

APPENDIX II

Flights in a low pressure chamber and oximeter records.

1. Flights in the low pressure chamber were made to high altitudes in which the ability of the positive pressure jacket to hold the oxyhemoglobin saturation within safe limits was tested. The subject breathed pure oxygen for 15 minutes before the oximeter was set in order to insure complete hemoglobin saturation. It was then arbitrarily set at 100 per cent and the flight started. The results of these flights are shown graphically in figures 1, 2 and 3.

2. In figures 1 and 2 the [illegible] lines show the altitude and the [illegible] the oximeter readings. The altitude and oximeter readings are plotted along the ordinate and time is plotted along the abscissa.

3. Figure 1 shows the results of two flights to 45,000 feet. These results show that in flight 1, figure 1, in which 6 minutes were spent at 40,000 feet and 2 minutes at 45,000 feet, the oximeter reading remaind around 90 per cent saturation during the former period and fell to 86 per cent saturation during the latter. The positive pressure breathed was between 30 and 38 cm. water. Flight 2, figure 1, shows that 10 minutes were spent at 40,000 feet and 9 minutes at 45,000 feet and that the oximeter reading of the former period was around 93 per cent saturation and dropped to around 91 per cent during the latter. The positive pressure during this flight was held between 34 and 44 cm. water.

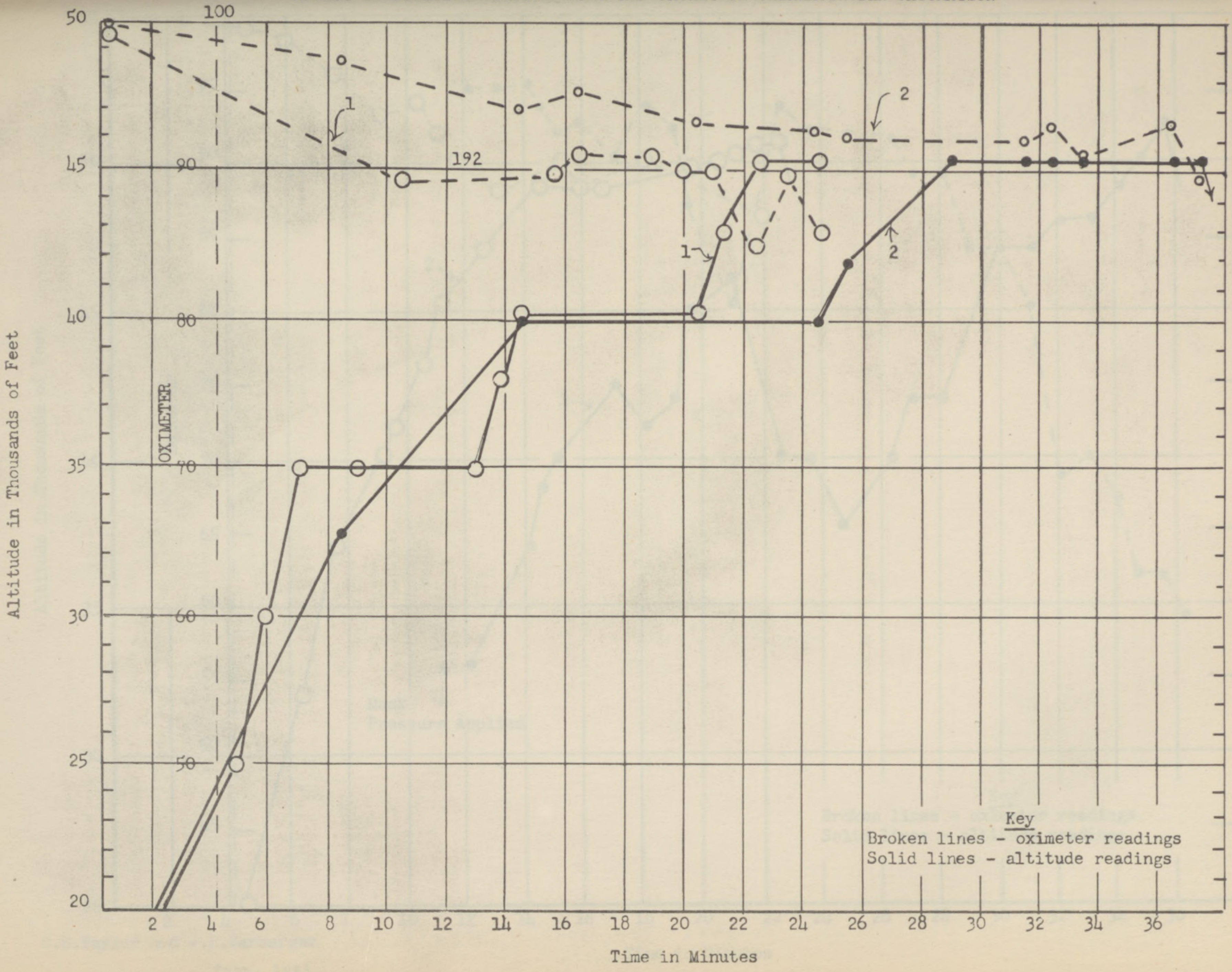
4. Figure 2 shows a flight to 51,440 feet made by Major Lovelace (flight 1) using a positive pressure mask, and a flight made by us to 50,608 feet using the positive pressure jacket (flight 2, figure 2). The figure shows that at 49,000 feet the oximeter reading on Major Lovelace was between 67 and 68 per cent and at 50,000 feet it was between 62 and 63 per cent. As far as we can determine from the records at 50,000 feet Major Lovelace was breathing against 30 cm. water. On descent at 42,000 feet the pressure was 26-33 cm. water and at 33,000 feet he was breathing against 24-34 cm. water pressure. It is interesting to note that we remained at 49,000 feet for 8 minutes and the oximeter remained at 90 per cent and only fell to 86.5 per cent when we reached 50,000 feet. The positive pressure breathed during our flight was between 45 and 50 cm. water. Our subject was alert and comfortable at 50,608 feet.

5. Figures 3 (a) and (b) show the effect on the oxyhemoglobin saturation at a given altitude when the pressure in the mask and jacket is decreased and then increased. The mask pressure and oximeter readings are plotted along the ordinate and time along the abscissa.

6. Figure 3 (a) shows that at 45,000 feet the mask pressure was dropped from 43 to 15 cm. water in a period of 1 minute and that during that time the oximeter dropped from 91 to 79 per cent. The pressure was then raised to 43 cm. water and after about ½ minute the oximeter was back to 90 per cent saturation.

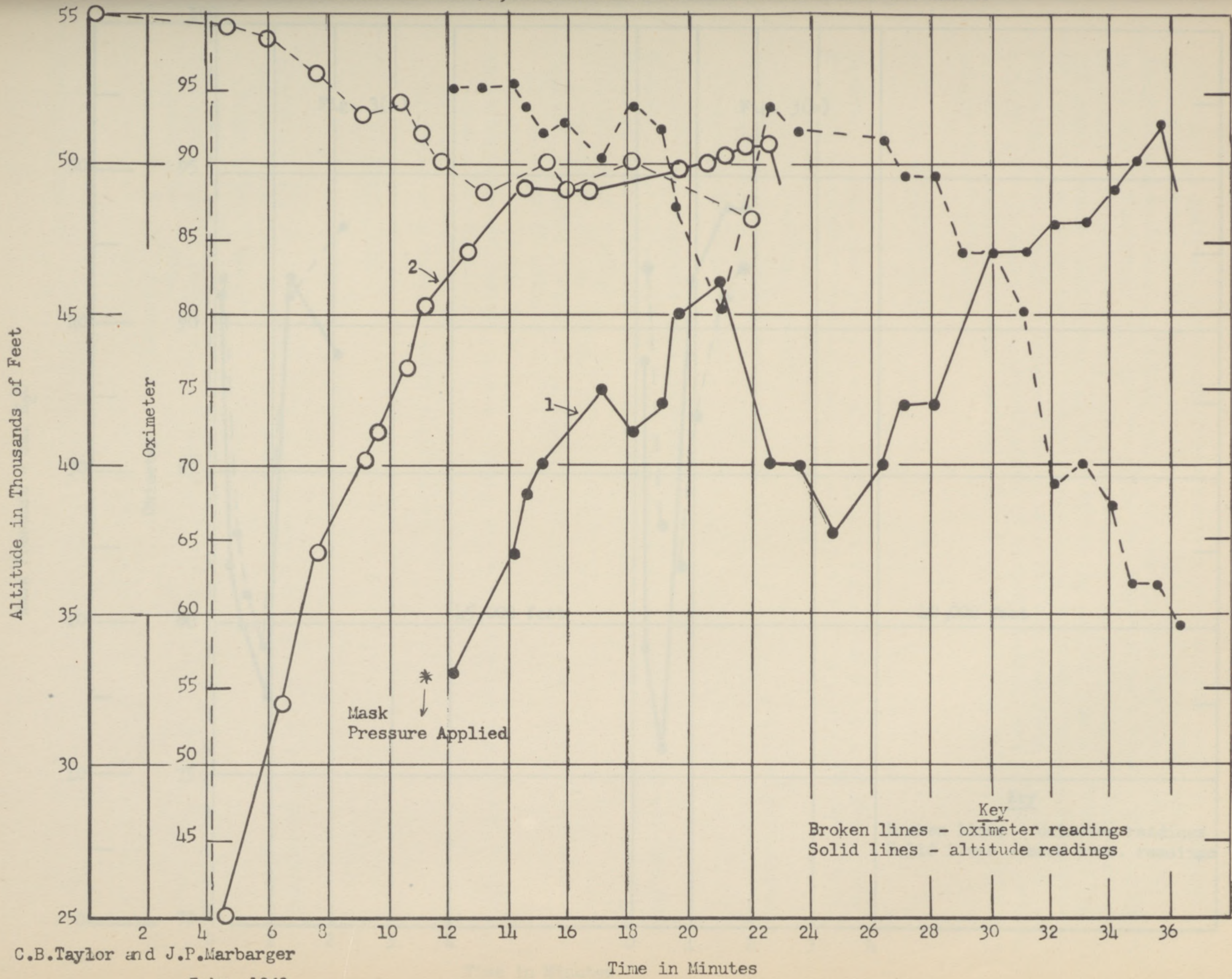
7. All altitudes above 45,000 feet have been barometrically corrected.

EFFECT OF POSITIVE PRESSURE MASK AND JACKET ON OXYHEMOGLOBIN SATURATION



C. B. Taylor and J. P. Marbarger

TWO FLIGHTS OVER 50,000 FEET USING POSITIVE PRESSURE MASK AND JACKET

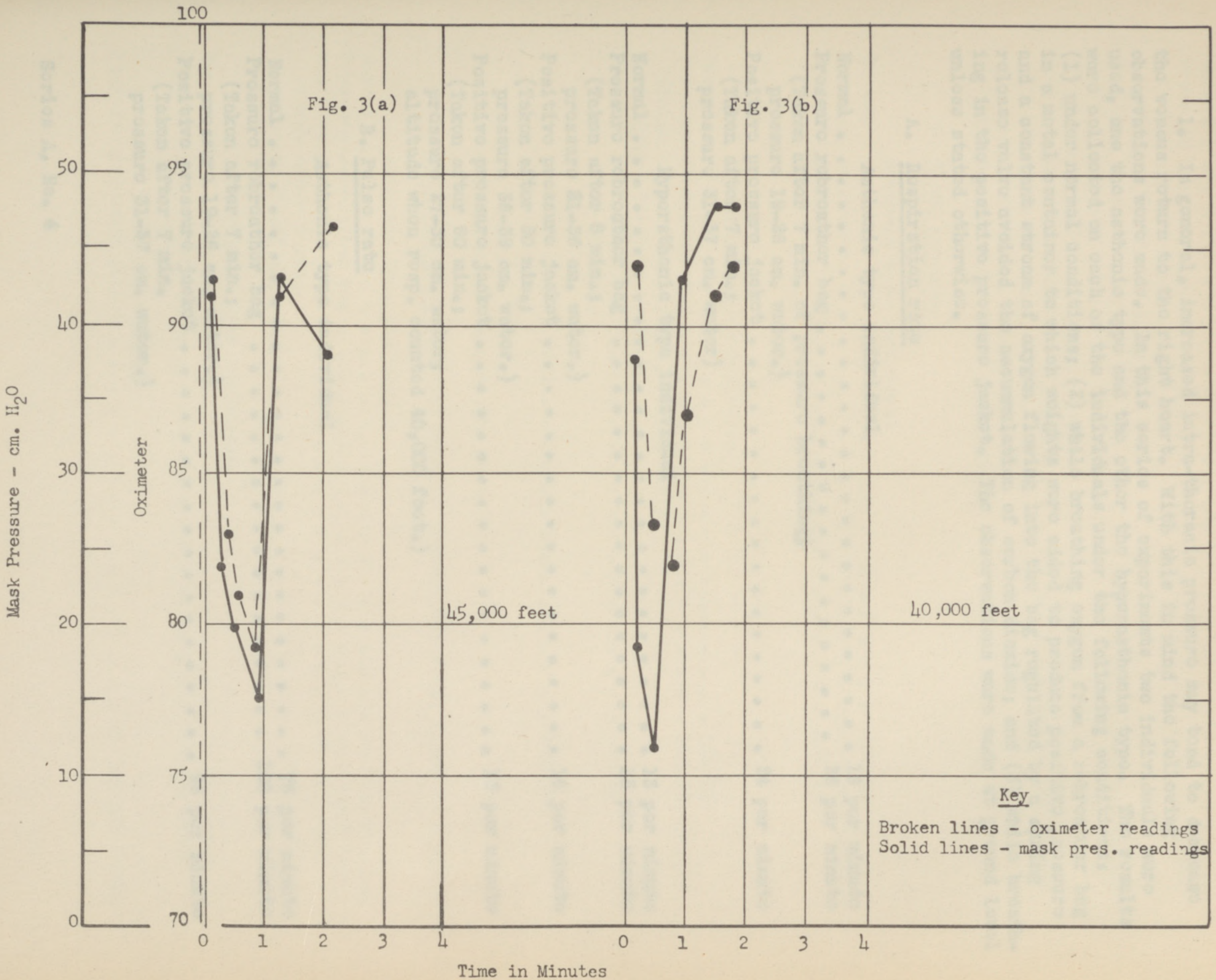


C.B.Taylor and J.P.Marbarger

Febr. 1943

XIX 5b

THE EFFECT ON THE OXYHEMOGLOBIN SATURATION AT ALTITUDE WHEN THE PRESSURE IN MASK AND JACKET IS DECREASED AND THEN INCREASED



C. B. Taylor and J. P. Marbarger

Febr. 1. 1943

Chart XIX 5c

APPENDIX III

1. In general, increased intra-thoracic pressure may tend to decrease the venous return to the right heart. With this in mind the following observations were made. In this series of experiments two individuals were used, one the asthenic type and the other the hyperasthenic type. The results were collected on each of the individuals under the following conditions: (1) under normal conditions; (2) while breathing oxygen from a rebreather bag in a metal container to which weights were added to produce positive pressure and a constant stream of oxygen flowing into the bag regulated by a spring release valve avoided the accummulation of carbon dioxide; and (3) while breathing in the positive pressure jacket. The observations were made at ground level unless stated otherwise.

A. Respiration rate

Asthenic type individual

Normal . . . . 18 per minute
Pressure rebreather bag . . . . 25 per minute
(Taken after 7 min. of pressure breathing;
pressure 19-26 cm. water.)
Positive pressure jacket . . . . 24 per minute
(Taken after 7 min.;
pressure 31-37 cm. water)

Hypersthenic type individual

Normal . . . . 13 per minute
Pressure rebreather bag . . . . 15 per minute
(Taken after 8 min.;
pressure 21-36 cm. water.)
Positive pressure jacket . . . . 14 per minute
(Taken after 30 min.;
pressure 36-39 cm. water.)
Positive pressure jacket . . . . 13 per minute
(Taken after 60 min.;
pressure 27-30 cm. water;
altitude when resp. counted 40,000 feet.)

B. Pulse rate

Asthenic type individual

Normal . . . . 76 per minute
Pressure rebreather bag . . . . 100 per minute
(Taken after 7 min.;
pressure 19-26 cm. water.)
Positive pressure jacket . . . . 96 per minute
(Taken after 7 min.
pressure 31-37 cm. water.)

Hypersthenic type individual

Normal . . . . 80 per minute
Pressure rebreather bag . . . . 94 per minute
(Taken after 8 min.;
pressure 21-36 cm. water.)
Positive pressure jacket . . . . 06 per minute
(Taken after 30 min.;
pressure 36-39 cm. water.)
Positive pressure jacket . . . . .106 per minute
(Taken after 22 min.;
pressure 37-39 cm. water;
altitude when P.R. taken 40,000 feet.)

C. <u>Blood pressure</u>

Asthenic type individual

Normal 126/88
Pressure rebreather bag . . . . record not taken
Positive pressure jacket 140/110
(Taken after 7 min.;
pressure 31-37 cm. water.)

Hypersthenic type individual

Normal 126/84
Pressure rebreather bag 116/76, 126/92
(Taken after 7 and 13 min. respectively;
pressure 25-36 cm. water.)
Positive pressure jacket 126/90
(Taken after 30 min.;
pressure 36-39 cm. water.)
Positive pressure jacket 140/108
(Taken after 28 min.;
pressure 38-40 cm. water;
altitude when B.P. taken 40,000 feet.)

D. <u>Venous pressure</u> (Direct method, antecubital vein, level r. auricle)

Asthenic type individual

Normal . . . . no record taken
Pressure rebreather bag . . . . no record taken
Positive pressure jacket . . . . 29 cm. water
(Taken after 7 min.;
pressure 32-37 cm. water.)

Hypersthenic type individual

Normal . . . . $5\frac{1}{2}$ cm. water
Pressure rebreather bag . . . . 23 cm. water
(Taken after 8 min.;
pressure 21-36 cm. water.)
Positive pressure jacket . . . . .no record taken

E. <u>Circulation time</u> (Ether, antecubital vein (arm) to lung time)

Asthenic type individual

Normal	no record taken
Pressure rebreather bag	no record taken
Positive pressure jacket	10 seconds

Hypersthenic type individual

Normal	$3\frac{1}{2}$ seconds
Pressure rebreather bag (Taken after 8 min.; pressure 21-36 cm. water.)	13 seconds
Positive pressure jacket	no record taken

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL CENTER
Under Contract No. W535ac-25829

SUBJECT: The effect of positive pressure breathing on the arterial blood pressure, venous blood pressure and the cerebro-spinal fluid pressure in the dog.

SERIAL REPORT: Series A. No. 4 a DATE: February 9, 1943

A. Purposes.

1. To answer the question, is the cerebral circulation jeopardized by the increased venous pressure caused by positive pressure breathing.

2. To present the results of some studies on the dog concerning the adjustments made by the cardiovascular and central nervous systems to positive pressure breathing.

B. Factual Data.

1. Introduction.

a. We have observed (Series A, 4, Feb. 1, 1943) that in man while breathing in the positive pressure jacket, there is a marked increase in the pulse rate, the arterial blood pressure, and the venous blood pressure. Since these physiological changes occur and since we have observed no symptoms of discomfort or cerebral disturbances (headache, loss of vision, etc.) either at ground level or at altitude after an hour or more of pressure breathing, the body must be able to adjust itself to the changes which occur while breathing a positive pressure.

2. Apparatus and method.

a. A positive pressure jacket was designed and constructed for a dog using the same plan as that described for the human (Series A, 4, Feb. 1, 1943).

b. A tracheotomy was done on an anesthetized dog and a tracheal cancula securely inserted. This was substituted for a mask.

c. Photographic records were obtained of the changes in the arterial (femoral artery), venous (external jugular vein, cannula toward heart) and cerebro-spinal (cisternal puncture) pressures with the use of spoon manometers.

d. The changes in the arterial, venous and cerebro-spinal fluid were studied while the animal was breathing in the jacket for different time periods and under the following positive pressures: 0, 10, 20, 30, 40, 50, 60 and 75 mm. Hg.

e. In Appendix I a complete description of the apparatus and method is found.

3. Results.

a. In the dog, as the tracheal oxygen pressure is increased to 30 mm. Hg the arterial pressure increased from 157 mm. to 181 mm. Hg, the venous pressure increased from 7 mm. to 35 mm. Hg, and the cerebro-spinal pressure increased from 16 mm. to 35 mm. Hg. Appendix II, Section (I).

b. The critical level was reached when the dog was breathing against a positive pressure between 30 mm. and 40 mm. Hg. Appendix II, Section (I).

c. When the tracheal pressure was raised above 40 mm. Hg the venous and spinal pressure increased directly with the increased positive tracheal pressure. The arterial pressure decreased with increased tracheal positive pressure above 40 mm. Hg. Appendix II, Section (I).

d. The effect of suddenly increasing the positive pressure against which the animal was breathing was studied by instantaneously raising the pressure from 0 mm. to 30 mm. Hg and from 0 mm. to 75 mm. Hg. Appendix II, Section (II).

e. About 80 seconds are required for the complete adjustment of the arterial, venous and cerebro-spinal pressures to changes in the positive pressure against which the animal is breathing. This depends somewhat upon the magnitude of the change. Appendix II, Section (II).

(1) Fifteen seconds after the pressure was raised from 0 mm. to 30 mm. Hg the systolic blood pressure decreased momentarily from 200 mm. to 190 mm. Hg and the diastolic increased from 130 mm. to 140 mm. Hg. After 50 seconds the average systolic pressure was 210 mm. and the average diastolic pressure was 160 mm. Hg. Ten minutes later there was no change. Appendix II, Section (II).

(2) There is always a greater increase in diastolic rather than systolic pressure. This was also observed in man.

(3) See Appendix II, Section (II) for complete details.

f. The arterial, venous and cerebro-spinal pressures are so sensitive that changes in them can be observed during the respiratory phases while the animal is breathing in the jacket against 30 mm. Hg positive pressure. See Appendix II, Section (III).

g. When the pressure against which the animal is breathing is reduced from 30 to 0 mm. Hg, about 20 seconds are required for the arterial, venous and cerebro-spinal pressure to return to normal.

(1) Four seconds are required for venous and cerebro-spinal pressures to return to normal and 18 seconds are required for the arterial pressure to return to normal.

h. See Appendix II, Section (IV).

i. Appendix III contains a discussion of the cardiovascular changes which occur during positive pressure breathing. See Appendix III and Exhibit 9.

j. After the experimental work was complete, the dog still appeared to be in good condition.

k. The ease of breathing in the jacket is well illustrated in this experiment in that the respiratory rate of the anesthetized animal (respiration under these conditions entirely involuntary) was normal.

C. Conclusions.

1. The experimental work presented in this paper suggests that positive pressure breathing in the jacket against pressures as great as 30 to 40 mm. Hg produces no harmful effects on the cerebral circulation.

2. The increase in intra-cranial pressure accompanying positive pressure breathing probably insures adequate venous return from the brain by offsetting the increase in venous pressure.

3. From experimental data already reported and found in this report, and from cardiac output and retinal vessel studies to be reported shortly, it is very probable that the cardiovascular system responds favorably to positive pressure breathing in the jacket.

Prepared by 2nd Lt. John P. Marbarger, A.C.

1st Lt. Charles B. Taylor, M.C.

Approved by E. J. Baldes, Ph.D.

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APPENDIX I

1. The dog (27.5 lbs.) used in this experiment was anesthetized by an intra-peritoneal injection of 5% pentobarbital (.3 cc. per lb.). A tracheotomy was performed and a tracheal cannula securely fastened. This cannula which replaced a mask was connected to the pressure jacket by the same tube connections used in the human jacket including a soda lime absorber can. The pressure against which the animal breathed was measured by a manometer connected to the cannula.

2. The dog was placed on its back and lashed to a board. Its head was turned to one side and the head end raised through 21° from the horizontal.

3. The arterial blood pressure was measured by connecting a spoon manometer to a cannula inserted (toward heart) into the femoral artery; the venous pressure by connecting a spoon to a cannula inserted (toward heart) into the external jugular vein; the cerebro-spinal fluid pressure by a spinal needle inserted into the cisterna magna. The arterial and venous cannulae were flushed with 3% sodium citrate solution and the cerebro-spinal cannula by saline solution. The spoon manometers in this experiment were all carefully calibrated.

APPENDIX II

1. The following experimental procedure was used: After the spoon manometers and the cannulae were carefully adjusted the camera was started and a record was taken while the dog was breathing under normal conditions; i.e., without positive pressure. In this way the normal base line for each manometer was established and any change which occurred while the animal was breathing positive pressure could be carefully calculated.

2. Section (I).

a. The animal breathed under different positive pressures and the changes were measured as follows: the pressure in the tracheal cannula was raised to 10 mm. Hg. After 3 minutes it was assumed that the animal was adapted to breathing against this pressure and a record of the changes from the normal was made. The pressure in the tracheal cannula was then raised to 20 mm. Hg and another record was taken after 5 minutes. This procedure was repeated after the tracheal cannula pressure had been raised to 30, 40, 50, 60 and 75 mm. Hg, except that the dog breathed under these pressures for the following time periods: 5, 10, 15, 15, 1 and 5 minutes respectively, before the records were made.

b. The results of this experiment are presented in tabular form in Exhibit 2. It can be seen that in the dog, as the tracheal oxygen pressure was increased to 30 mm. Hg, there was a marked increase in arterial, venous and cerebro-spinal pressure, and that the critical level was reached when the dog was breathing against a positive pressure of between 30 and 40 mm. Hg. It can be seen that after the tracheal pressure was raised above 40 mm. Hg the venous and spinal pressure increased progressively with the increased pressure, and that the blood pressure decreased with an increase in tracheal pressure above 40 mm. Hg.

EXHIBIT 2

O_2 Tracheal Pressure (mm. Hg)	Time	Spinal P (mm. Hg)	Resp. per min.	Venous Pressure (mm. Hg)	Pulse Rate	Planimeter Average B. P.	Systolic Pressure Arterial	Diastolic Pressure
0	0 min.	16	24	7	200	157	175	135
10	3 min.	20	12	7.5	200	163.5	185	150
20	5 min.	27	8.5	24	192	168.5	192.5	160
30	5 min.	35	10	35	192	181.0	195	165
30	10 min.	27	7.5	35	172	159.8	197	143
40	15 min.	38	6	45	170	172.5	204	156
50	15 min.	49		60	160	172.5	199	158
60	1 min.	57		82	170	170.5	195	160
75	5 min.	63		---	140	152	175	145

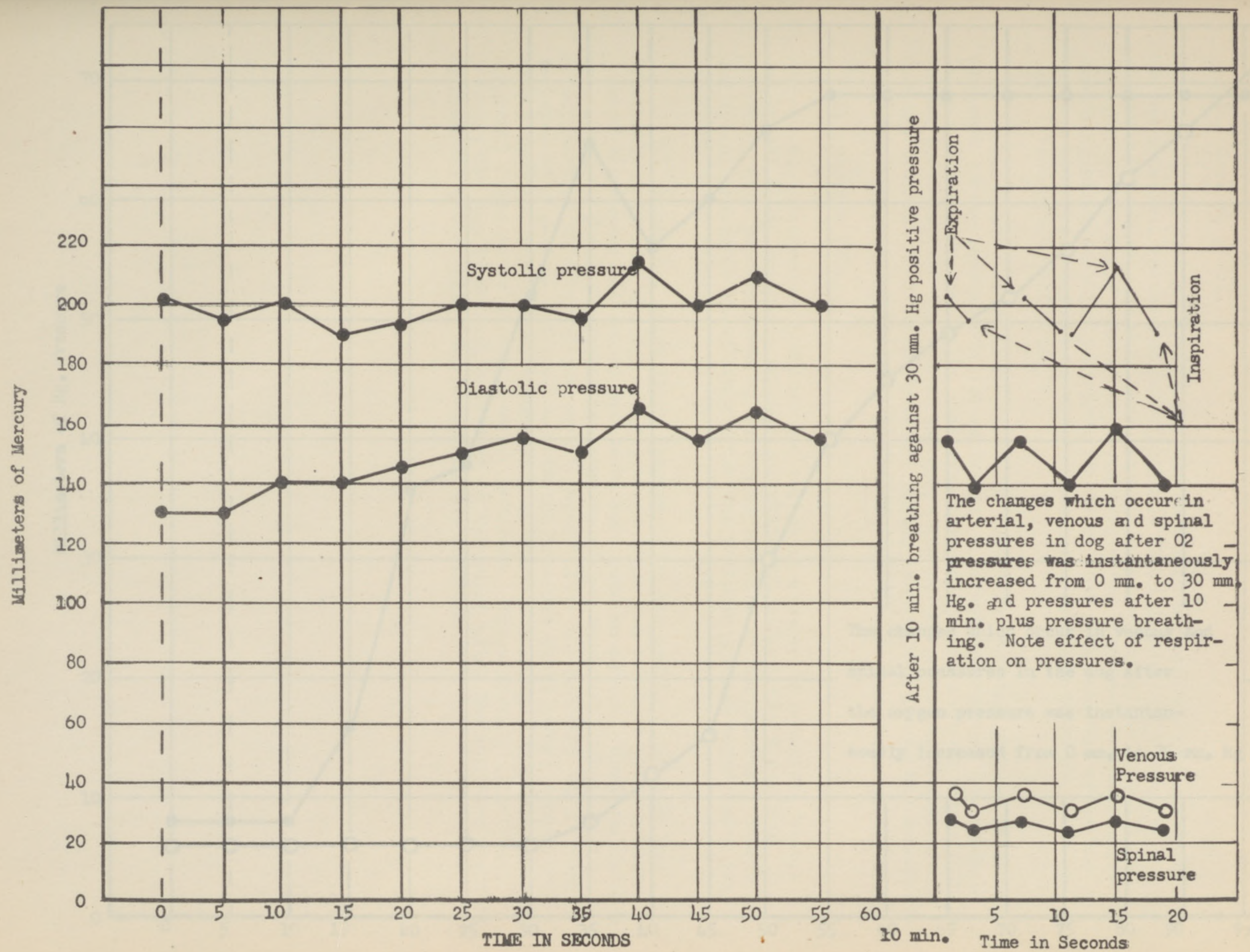
3. Section (II).

a. Section (I) shows that the arterial, venous and cerebro-spinal pressures varied with the positive pressure. The venous and spinal pressures varied directly with the increased positive pressure. The arterial pressure also varied directly with increased positive pressure but reached an optimum point between 30 and 40 mm. Hg and then varied inversely with a further increase in pressure.

b. It was observed while obtaining the record in the preceding part that the cerebro-spinal pressure was extremely sensitive to changes produced by positive pressure breathing. This point was tested as follows: the trachel oxygen pressure was instantaneously raised from 0 mm. to 30 mm. Hg and from 0 mm. to 75 mm. Hg.

c. The results of raising the pressure from 0 to 30 mm. Hg are showsn in Exhibit 5. It can be seen that 15 seconds after the pressure was applied the systolic blood pressure decreased momentarily from 200 to 190, and the diastolic increased from 130 to 140 mm. Hg. After 50 seconds the average systolic pressure was 210 mm. Hg and the diastolic was 160 mm. Hg. Ten minutes later there was no change in arterial, venous or spinal pressures. It is interesting to note that the pulse pressure in the dog decreased from 70 to 50 mm. Hg while breathing at 30 mm. Hg. We have observed a similar decrease in man (Series A, 4, Feb. 1, 1943) decreasing from 40 to 30 mm. Hg. This is due to a greater increase in diastolic rather than systolic pressure. Exhibit 5 also shows the rapid response of the spinal pressure after 30 mm. Hg is applied, increasing after 15 seconds to 25 mm. and remaining practically constant thereafter. The spinal and venous cannulae had to be readjusted before this procedure and new base lines had to be established. When this record was taken the venous cannula did not function. Proper readjustments were made and when the positive pressure was raised from 0 to 75 mm. a record of the change in venous pressure was then obtained. Exhibit 6 shows the changes which occur when the pressure is instantaneously increased from 0 to 75 mm. Hg. This curve shows that a 5 second latent period existed after the positive pressure was raised from 0 to 75 mm. before the spinal pressure changed. Then it rapidly increased and after 45 seconds had changed from 7 mm. to 68 mm. Hg. The venous pressure did not respond to increased positive pressure until 25 seconds after the pressure was applied. Sixty seconds later it increased from 5 to 68 mm. Hg.

Exhibit 5

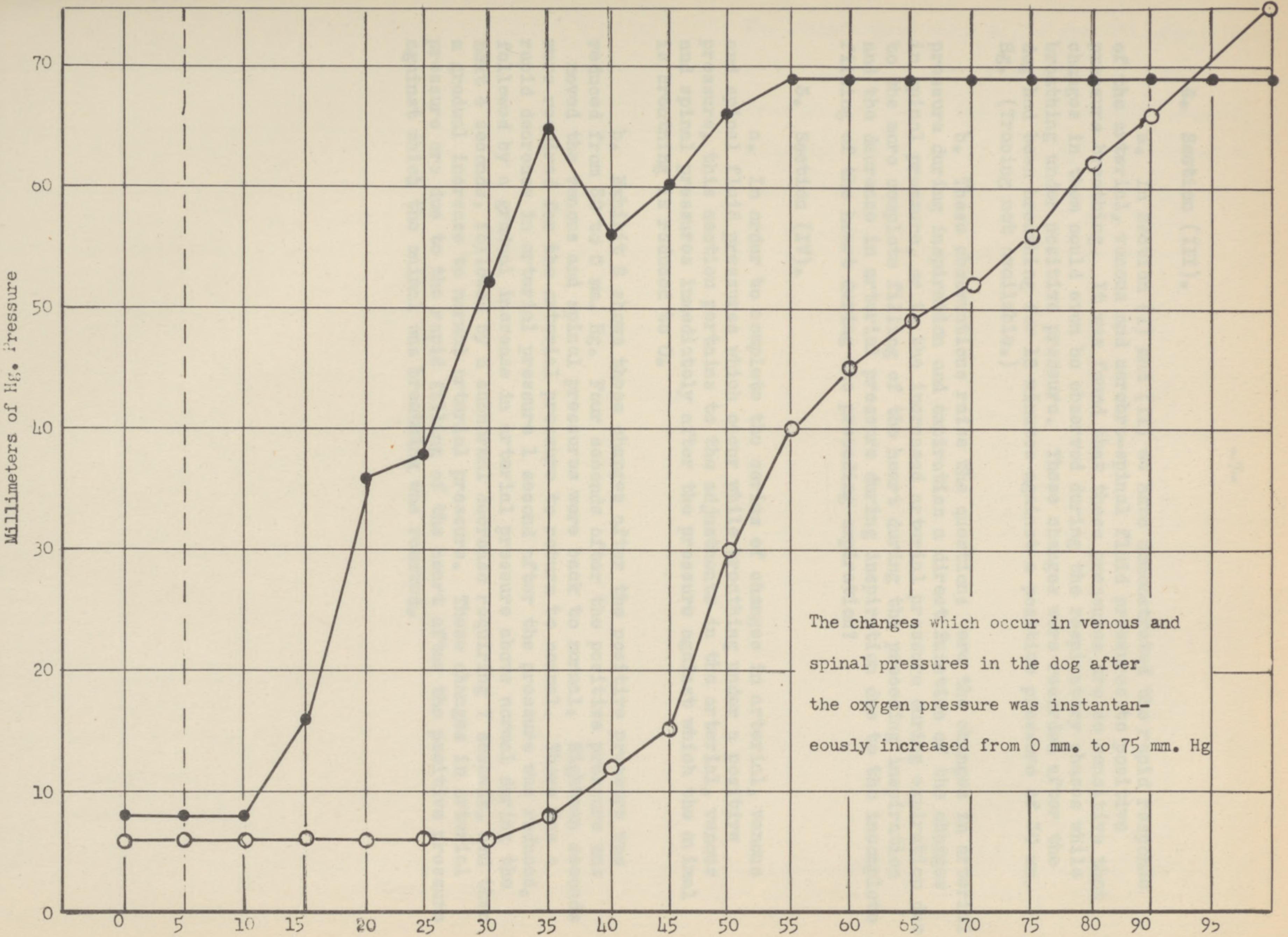


C. B. Taylor and J. P. Marbarger

Feb. 1943

Chart XIX 6a

EXHIBIT 6



C.B.Taylor and J.P. Marbarger TIME IN SECONDS Chart XIX-6b Febr. 1943

4. Section (III).

a. In Section (I) and (II) we have demonstrated the rapid response of the arterial, venous and cerebro-spinal fluid pressures to positive pressure breathing. It was found that these pressures are so sensitive that changes in them could even be observed during the respiratory phases while breathing under positive pressure. These changes were recorded after the dog had been breathing for 10 minutes against a positive pressure of 30 mm. Hg. (Tracing not available.)

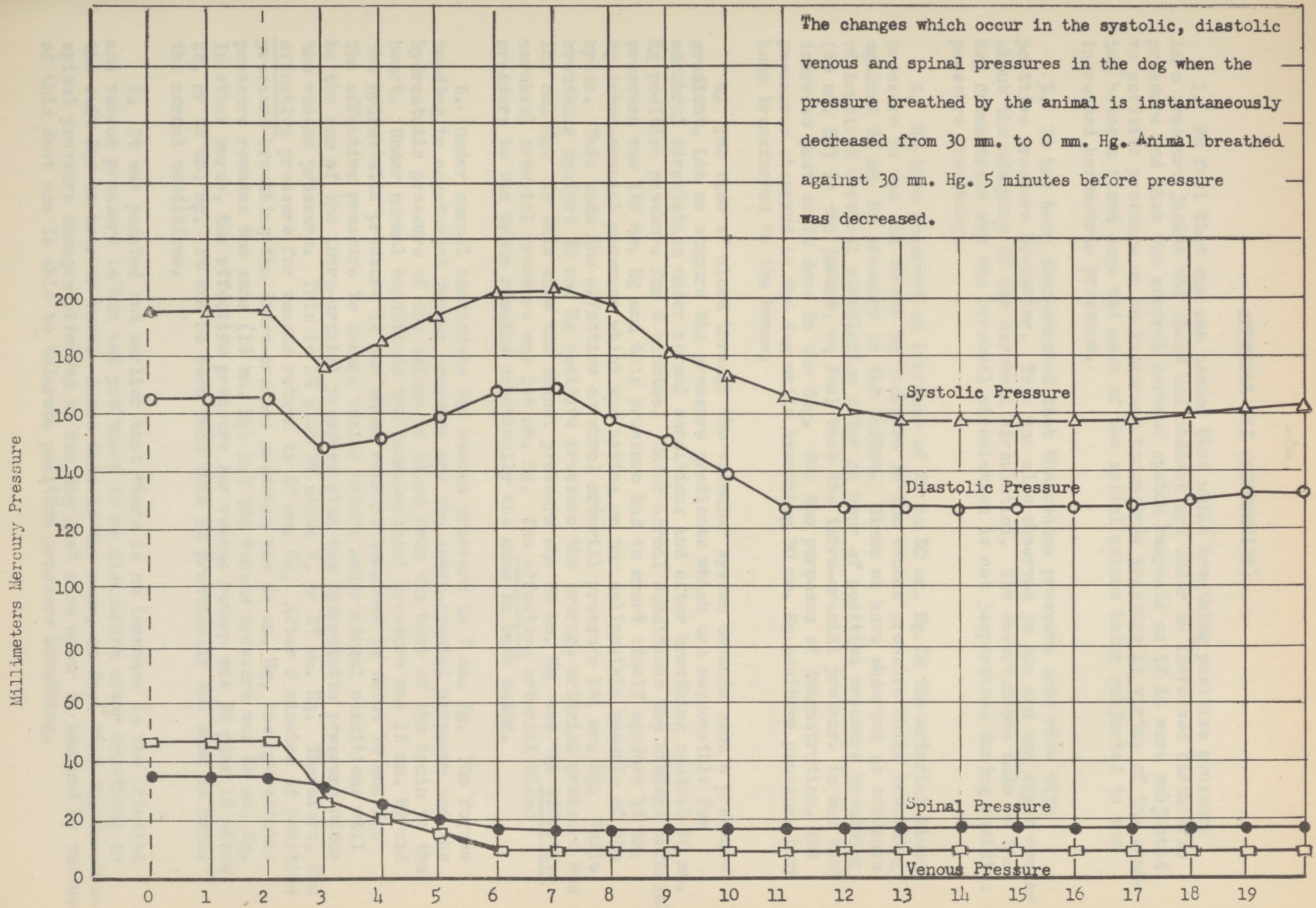
b. These observations raise the question: are the changes in arterial pressure during inspiration and expiration a direct function of the changes in spinal pressure, or is the increased arterial pressure during expiration due to the more complete filling of the heart during the preceding inspiration and the decrease in arterial pressure during inspiration due to the incomplete filling of the heart during the preceding expiration?

5. Section (IV).

a. In order to complete the series of changes in arterial, venous and spinal fluid pressures which occur while breathing under a positive pressure, this section pertains to the adjustments in the arterial, venous and spinal pressures immediately after the pressure against which the animal is breathing is reduced to 0.

b. Exhibit 8 shows these changes after the positive pressure was reduced from 30 to 0 mm. Hg. Four seconds after the positive pressure was moved the venous and spinal pressures were back to normal. Eighteen seconds were required for the arterial pressure to return to normal. There was a rapid decrease in arterial pressure 1 second after the pressure was reduced, followed by a gradual increase in arterial pressure above normal during the next 4 seconds, followed by a subnormal decrease requiring 7 seconds, and then a gradual increase to normal arterial pressure. These changes in arterial pressure are due to the rapid filling of the heart after the positive pressure against which the animal was breathing was removed.

EXHIBIT 8



The changes which occur in the systolic, diastolic venous and spinal pressures in the dog when the pressure breathed by the animal is instantaneously decreased from 30 mm. to 0 mm. Hg. Animal breathed against 30 mm. Hg. 5 minutes before pressure was decreased.

C.B.Taylor and J.P.Marbarger

Chart XIX-6c Feb. 1943

APPENDIX III (DISCUSSION)

1. We feel that one can assume that while breathing positive pressure in a pressure jacket the chest and abdomen are under an increased barometric pressure and that the central nervous system responds as if it were subjected to positive pressure or an increased barometric pressure by virtue of the cranium being a fixed cage and most of the spinal column being subjected to the increased barometric pressure.

2. It has been demonstrated that the venous pressure does rise with positive pressure breathing. This was also observed in man and one might wonder about the adequacy of the cerebral circulation. The observations made on the dog demonstrate why the cerebral circulation is not jeopardized during positive pressure breathing.

3. We have observed an increase of 25 to 30 mm. Hg in the arterial blood pressure in man and 20 mm. Hg increase in the venous pressure while breathing against 30 mm. Hg pressure in the jacket. Since we have observed no evidence of impaired cerebral circulation after an hour of positive pressure breathing (30 mm. Hg) in the jacket, we feel that the intra-cranial pressure in man must increase just as it does in the dog. For the purposes of demonstration, the pressures observed in the dog while breathing 30 mm. Hg positive pressure have been transferred to the human.

4. The flow of blood through the vascular system depends upon a pressure gradient. Let us compare the pressure gradients which are responsible for cerebral circulation under normal conditions and after breathing against 30 mm. Hg positive pressure for 5 minutes. Under normal conditions the average arterial pressure was 157 mm. Hg and this pressure had to exert itself against 16 mm. Hg intra-cranial pressure which was acting on the collapsible vessels of the brain. This made the effective cerebral arterial pressure 141 mm. Hg. While breathing against 30 mm. Hg positive pressure the average arterial pressure was 181 mm. Hg. In this case the spinal pressure was 35 mm. Hg and the effective cerebral arterial pressure was 146 mm. Hg. The effective arterial blood pressure to the brain remains practically the same in both cases.

5. Under normal conditions the venous pressure is 7 mm. Hg. The forces tending to counteract venous pressure are the intra-cranial pressure and the hydrostatic pressure of the column of blood from the base of the brain to the heart. Under normal conditions the intra-cranial pressure was 16 mm. Hg and the hydrostatic pressure in man which remains constant is about 18 mm. Hg. The effective pressure to insure venous return under normal conditions will be the sum of the intra-cranial pressure plus the hydrostatic pressure minus the venous pressure. This is 16 plus 18 minus 7, or 27 mm. Hg. Therefore, the effective pressure for venous return is 27 mm. Hg. After 5 minutes of positive pressure breathing the intra-cranial pressure was 35 mm. Hg, the hydrostatic pressure remains the same (18 mm. Hg) and the venous pressure was 28 mm. Hg. In other words, the effective pressure for venous return was 35 plus 18 minus 28, or 25 mm. Hg. It can be seen that this is practically the same as under the normal conditions.

6. It was pointed out earlier that there is an increase in the arterial and venous pressure in man and yet there is no discomfort after breathing in the suit for an hour or more. Since this is the case, we feel that the cerebrospinal pressure changes observed in the dog must also occur in man and by virtue of this fact man is able to tolerate positive pressure breathing.

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL CENTER
Under Contract No. W535ac-25829

SUBJECT: The effect of positive pressure breathing on the appearance of the retinal vessels and on the intraocular pressure in man.

SERIAL REPORT: Series A, No. 4 b   DATE: February 17, 1943

A. Purposes.

1. To study the changes, if any, in the diameter of the retinal vessels in man while breathing under positive pressure.

2. To study the changes, if any, in the intraocular pressure in man while breathing under positive pressure.

3. To investigate the possibility of the formation of papilloedema in man as the result of increased venous and intracranial pressure due to positive pressure breathing.

B. Factual Data.

1. Experiment.

Observations on the change in the diameter of the inferior temporal artery and vein were made while the subject was breathing under the following conditions: (1) breathing room air under normal conditions, (2) breathing 100 per cent oxygen without positive pressure, (3) breathing 100 per cent oxygen in a pressure rebreather bag against a positive pressure of 20-35 mm. Hg, (4) breathing 100 per cent oxygen in the pressure jacket against a positive pressure of 30-33 mm. Hg. Exhibit 1 shows the procedure and the results obtained.

a. Direct vascular measurements were made with the use of an ophthalmoscope to which was attached a specially designed metric measuring device. The vessels were continuously observed and records of the changes were periodically made. In addition to these observations, photographic records of the changes were taken. See Exhibit 1 and 2.

(1) The results show that the diameter of the inferior temporal vein was .161 mm. while breathing room air under normal conditions, and that after 5 min. breathing oxygen without positive pressure the vein was .131 mm. in diameter. Ten minutes later the diameter was .136 mm. The limit of error of the vascular measurements was .008 mm. The reduction in size when oxygen was administered is significant. There is no significant difference between the two readings recorded while breathing oxygen without positive pressure. There was no further change in size even while breathing oxygen under a positive pressure. In other words, after the initial reduction in size when oxygen was first administered without positive pressure, the size of the veins remained constant.

(2) The results (Exhibit 1) show that there was a slight reduction in the diameter of the artery after oxygen without positive pressure was administered and that no change occurred after the subject breathed against positive pressure.

(3) Therefore, when the subject breathed oxygen without positive pressure after breathing room air there was a reduction in the diameter of the inferior temporal artery and vein. After this initial reduction there was no further reduction even after positive pressure breathing was administered.

(4) A few minutes after breathing in the positive pressure jacket, the veins of the fundus appeared bright red. They approached the color of arteries.

b. Observations were made on the intraocular tension under the same conditions found in paragraph (a) above. A tonometer was used to make these observations. The results are presented in Exhibit 1.

(1) The results show that there was very little change in the intraocular tension while breathing under positive pressure. The slight changes noted are within the limits of error of the technic used.

c. Thirty-five minutes after breathing in the positive pressure jacket against a pressure of 30-33 mm. Hg there was no evidence of papillitis or early papilloedema.

d. Observations were made on the time required for the vessels to regain their normal size after 35 minutes of positive pressure breathing against 30 to 33 mm. Hg oxygen pressure in the pressure jacket. The results are presented in Exhibit 1.

(1) Exhibit 1 shows that 11 minutes after the oxygen was removed the vein and artery had returned to normal.

e. The above results indicate that the changes which occurred were the result of oxygen rather than of positive pressure. These changes which accompany oxygen breathing were more carefully studied on three subjects and the results obtained are presented in Exhibitis 3, 4 and 5. The diameters of the vessels are plotted along the ordinate and time in minutes along the abscissa. Measurements of the changes were taken frequently after the subject started to breathe oxygen without pressure, and the time required for vascular readjustment was recorded. Then oxygen was removed and the recovery period was recorded.

(1) Exhibit 3 shows that for subject 1, 6 minutes were required for arterial adjustment and 12 minutes were required for venous adjustment. Three and one-half minutes after oxygen was removed the vessels were back to normal.

(2) Exhibit 4 shows that for subject 2, 12 minutes were required for the vessels to reach minimal size. After oxygen was removed, about 4 minutes were required for the vessels to return to normal.

(3) Exhibit 5 shows that about 3 minutes were required for the vessels in subject 3 to reach minimal size. Two and one-half minutes were required for these vessels to return to normal. In each case the time rerquired for recovery was considerably less than the time required for the

vessels to reach minimal size. It is interesting to note that there was a difference of 10 years between the age of subject 3 and subjects 1 and 2.

2. Discussion.

a. For a discussion of intra-ocular pressure and the diameter of the retinal vessels consult Appendix I.

b. For a discussion of, and a consideration of papilloedema in positive pressure breathing, see Appendix II.

C. Conclusions.

1. There is a slight reduction in the size of the retinal vessels when pure oxygen without positive pressure is breathed.

2. Breathing oxygen in a pressure rebreather bag or in the positive pressure jacket does not increase the diameter of the retinal veins.

3. There is no appreciable change in the intra-ocular tension when breathing against a positive pressure as high as 33 mm. Hg.

4. From the observations mentioned in (b) and (c) above and from the literature reviewed in Appendix I, it can probably be concluded that ophthalmic and cerebral circulation are not jeopardized by positive pressure breathing.

5. The formation of papilloedema was not observed after breathing against a positive pressure of 30 to 33 mm. Hg for 35 minutes.

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Approved by E. J. Baldes, Ph.D.

Charles F. Code, M.D.

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APPENDIX I

1. It is a well known fact that in right heart failure or any condition where venous stasis is marked, the retinal veins become markedly engorged (1). Having observed an increased venous pressure in man during positive pressure breathing, we felt that a study of the appearance of the retinal vessels during positive pressure breathing might be a good index of the degree of venous stasis in the eye and possibly in the brain.

2. It can be seen from the data presented above that there was no change in the diameter of the retinal veins or arteries after 35 minutes of positive pressure breathing in the positive pressure jacket. This evidence indicates very strongly that the circulation of the ey and of the brain remains normal, (i.e. there may be pressure changes but arterial and venous flow remain constant) during positive pressure breathing of 30 to 33 mm. Hg in the jacket for periods as long as 35 minutes.

3. The fact that the intra-ocular pressure remained essentially constant during positive pressure breathing is also good evidence that the arterial and venous flow of the eye and the brain are the same as normal during positive pressure breathing. According to Duke-Elder changes in arterial pressure are reflected directly in the intra-ocular pressure when the capillary circulation remains passive but this is controlled in part by the capillary-motor nervous mechanism. Duke-Elder and Adler (3) also state that if the venous pressure is altered, other things being equal, the intra-ocular pressure varies very intimately with it. They point out various methods used in producing venous stasis such as tying the vortex veins as they issue from the eye (causing a rise in intra-ocular pressure to 80-90 mm. Hg). A similar rise in intra-ocular pressure occurs on ligating the veins at the back of the orbit or obstructing venous return by retro-bulbar injections or retro-bulbar haematomata, or in exophthalmic conditions. These conditions are out and out venous stasis conditions and are very similar to other experiments mentioned by Duke-Elder where all the channels of venous return are simultaneously impeded, such as passing a ligature around the neck compressing the thorax, or abdomen, or obstructing the superior vena cava. Here one also has a marked increase in intra-ocular pressure.

4. It was pointed out in Serial Report (Series A, No. 4 a) that the intracranial pressure rises as the venous pressure rises. This probably insures adequate cerebral venous return. It is true that most of the arterial venous supply of the eye comes through the cranium and if the cerebral venous return is impaired as in right heart failure or obstruction of the superior vena cava, etc. as mentioned above, there would be an increase in the size of the retinal veins and an increase in intra-ocular pressure. Neither an increase in the diameter of the retinal veins nor an increase in intra-ocular pressure occurred during positive pressure breathing. This indicates (1) that the circulation of the eye, both arterial and venous, maintained normal proportions and was not impaired and (2) that probably the cerebral blood flow (both arterial and venous) was not impaired.

(1) Cameron, 1933, Vol. 17, pp. 167, Brit. J.O.
(2) Duke-Elder, Text Book of Ophthalmology, 1933. Vol. 1, pp.502-505,C.V.Mosby Co.
(3) Adler, F. H.,"Clinical Physiology of the Eye" McMillan Co.,N.Y.1933,p.369.

APPENDIX II

1. Another question which arises and deserves further investigation is the probability of the formation of papilloedema due to the increased intra-cranial pressure associated with positive pressure breathing. Duke-Elder (3) stated "It has been demonstrated and it is an obvious logical proposition, that in general terms there is a fairly close relationship between the venous pressure at the disc and the intra-cranial pressure; the former keeps from 2 to 4 mm. Hg above the latter in order to allow the circulation to be maintained, rising with it step by step until the cerebro-spinal pressure. reaches the intra-ocular arterial pressure at which point the circulation ceases. It was found by (Sobanski A. F. O. 137, 84, 1937) that if the normal relationship between the pressure in the central vein and artery (usually 1:3) was seriously disturbed so that the two approximated, then papilloedema was prone to develop; if the arterial pressure rose with the intra-cranial pressure (that is, with the venous pressure), no oedema followed, but if it did not and the relation between the venous and arterial pressure approximated 1:1.5 papilloedema invariably resulted."

2. We found that in the dog breathing against positive pressure (Series A, No. 4 a) the arterial pressure rose with the intra-cranial pressure up to 30 mm. Hg of positive pressure breathing, at which time the intra-cranial pressure was 35 mm. Hg, and that as the intra-cranial pressure was increased above that point by greater positive pressure breathing, the arterial pressure decreased. In our experiment the intra-cranial pressure increase was the result of increased venous pressure and increased intra-thoracic and intra-abdominal pressure.

3. In the dog it appears that in positive pressure breathing in the jacket up to 30 mm. Hg positive pressure, the arterial pressure responds to increased intra-cranial and venous pressure by increasing proportionately, thus maintaining the normal relationship between the pressure in the central retinal vein and artery (usually 1:3); but as the amount of positive pressure breathed against is increased above 30 mm. Hg the arterial pressure begins to decrease, thus upsetting the 1:3 central retinal vein and artery ratio. As Duke-Elder stated above, as the ratio approached 1:1.5 papilloedema invariably results; therefore papilloedema may possibly develop if the amount of positive pressure in the pressure jacket is greater than 30 mm. Hg.

4. In man after 35 minutes of positive pressure breathing in the jacket against 30 - 33 mm. Hg there was no evidence of early papilloedema. We realize that this is not a long enough time interval and that if greater pressures had been used, we might have noted papilloedema. It seems that further investigation of this problem should be carried out such as 1) breathing against positive pressures greater than 30 mm. Hg for fairly long periods of time and observing the optic disc for papilloedema, and 2) measuring the retinal arterial and venous pressure with an ophthalmic dynamometer.

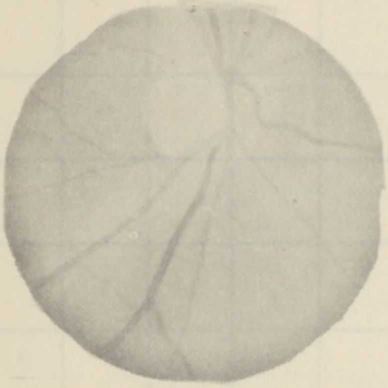
(1) Duke-Elder, ibid Vol. III, pp. 2959-2960.

Series A, No. 4 b.

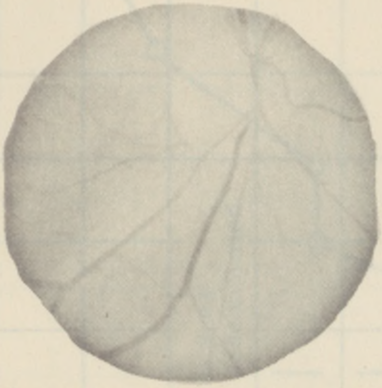
EXHIBIT 1

Subject: C. B. Taylor. The change in the venous, arterial ratio in the retinal vessels of the right eye (size) and the change in the intra-ocular tension (left eye) under the following conditions: normal (control), oxygen without pressure, oxygen with positive pressure rebreather bag and oxygen in positive pressure jacket.

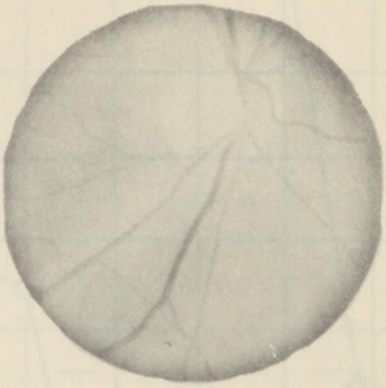
Conditions	Inferior vein	Time after exp. conditions established	Inferior temporal artery	Time after exp. conditions established	Pressure breathed against	Intra-ocular tension Tonometer	Photographs Time	Remarks
1. Control-breathing room air under normal conditions	Diameter .161 mm.		Diameter .106 mm.			15 mm. Hg	3 normals taken	Optic disc including temporal crescent was 2.2 mm.
2. Oxygen without positive pressure	.131 mm. .136 mm.	after 5 min. after 15 min.	.102 mm. .097 mm.	after 6 min. after 17 min.		15 mm. Hg after 19 min.	2 pht. after 20 min. 21 min.	
3. Positive pressure rebreather bag.	.131 mm. .142 mm.	after 4 min. after 10 min.	.110 mm. .106 mm.	after 5 min. after 11 min.	25 - 35 20 - 35 mm. Hg	13 mm. Hg after 15 min.	2 pht. after 7 min. 12 min.	
4. Positive pressure jacket	.144 mm. .136 mm. .136 mm. .136 mm.	after 2 min. after 7 min. after 16 min. after 24 min.	.102 mm. .102 mm. .102 mm. .102 mm.	after 3 min. after 8 min. after 17 min. after 25 min.	30 - 33	17 mm. Hg after 35 min.	4 pht. after 9 min. 11 min. 30 min. 32 min. (Kodachrome)	After 25 min. fundus bright red (all vessels). Veins smaller than normal but not changed since O_2 originally administered. Veins approach color of arteries
5. Oxygen and pressure removed.	.165 mm.	after 10 min.	.106 mm.	after 11 min.		Time after p.p. remv. / Tension mm. 2 min. 15 4 min. 13 6 min. 13 8 min. 13		10 min. after O_2 and pressure removed. Fundus in general is deeper red. The veins are darker red.
								Limit of error of vascular measurements is .008 mm.



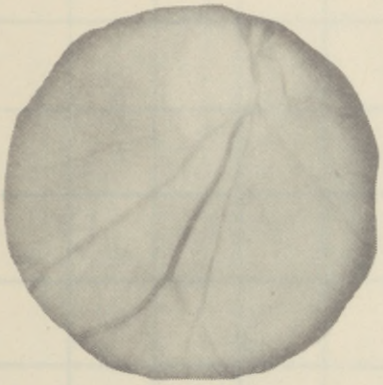
1. Control; breathing room air under normal conditions.



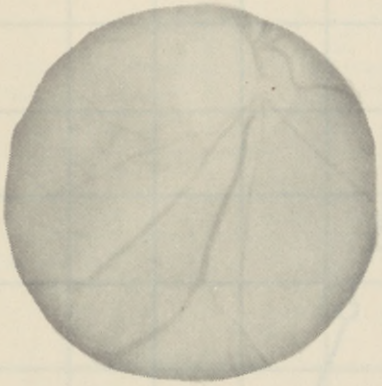
2. After 20 min. of breathing oxygen <u>without</u> positive pressure.



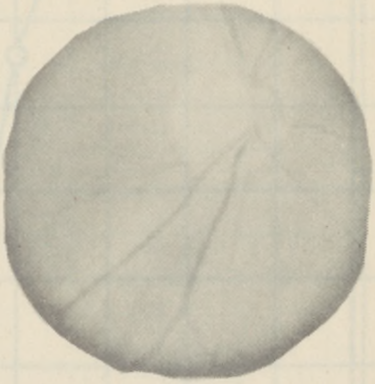
3. After 7 min. of breathing against 25-35 mm. Hg. oxygen in the positive pressure rebreather bag.



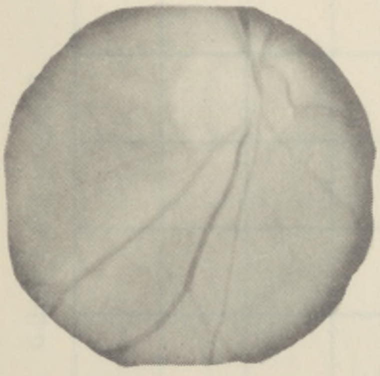
4. After 12 min. of breathing against 25-35 mm. Hg. oxygen in the positive pressure rebreather bag.



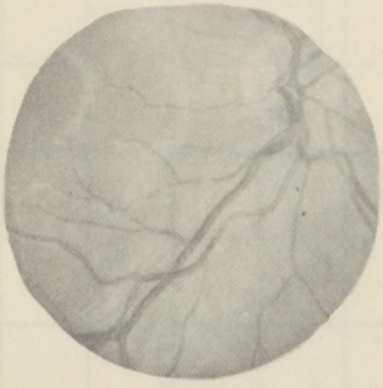
5. After 9 min. of breathing against 30-33 mm. Hg. oxygen in the positive pressure jacket.



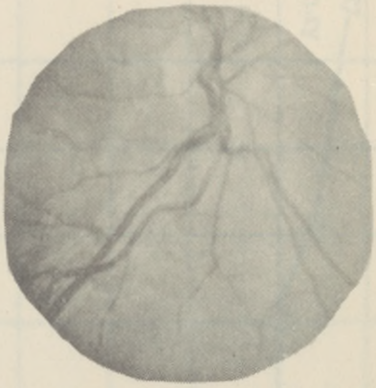
6. After 11 min. of breathing against 30-33 mm. Hg. oxygen in the positive pressure jacket.



7. After 30 min. of breathing against 30-33 mm. Hg. oxygen in the positive pressure jacket.



8. Control; breathing room air under normal conditions.

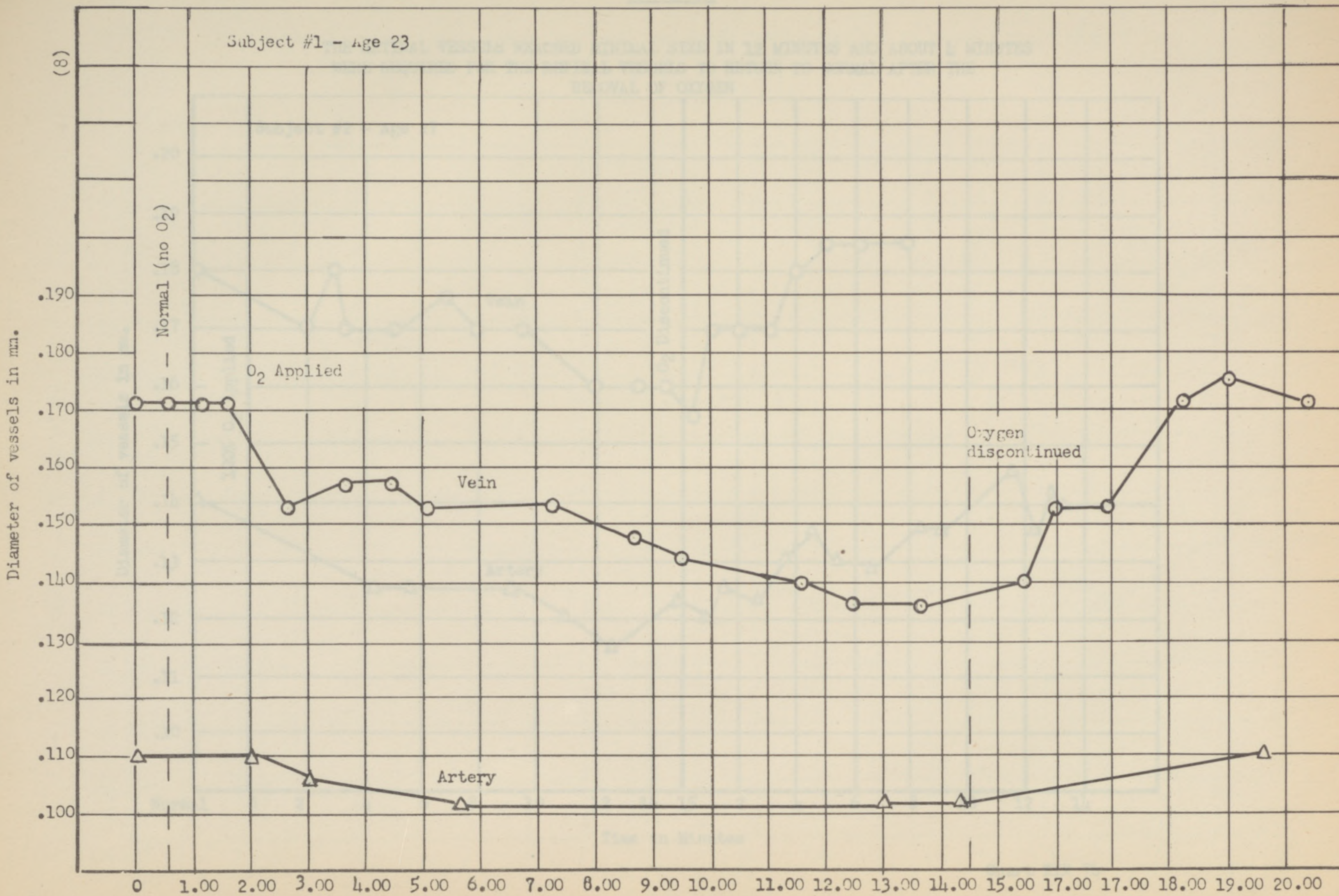


9. After 20 min. of breathing against 30 mm. Hg. (20 per cent oxygen, 80 per cent helium mixture) in positive pressure jacket.

Exhibit 2.

EXHIBIT 3

Six minutes required for arterial adjustment and 12 minutes required for venous adjustment. One and one-half minutes after O_2 removed the vessels were back to normal.



C. B. Taylor and J. P. Marbarger

Feb. 1943
Chart XIX 7a

Exhibit 4

THE RETINAL VESSELS REACHED MINIMAL SIZE IN 12 MINUTES AND ABOUT 4 MINUTES WERE REQUIRED FOR THE RETINAL VESSELS TO RETURN TO NORMAL AFTER THE REMOVAL OF OXYGEN

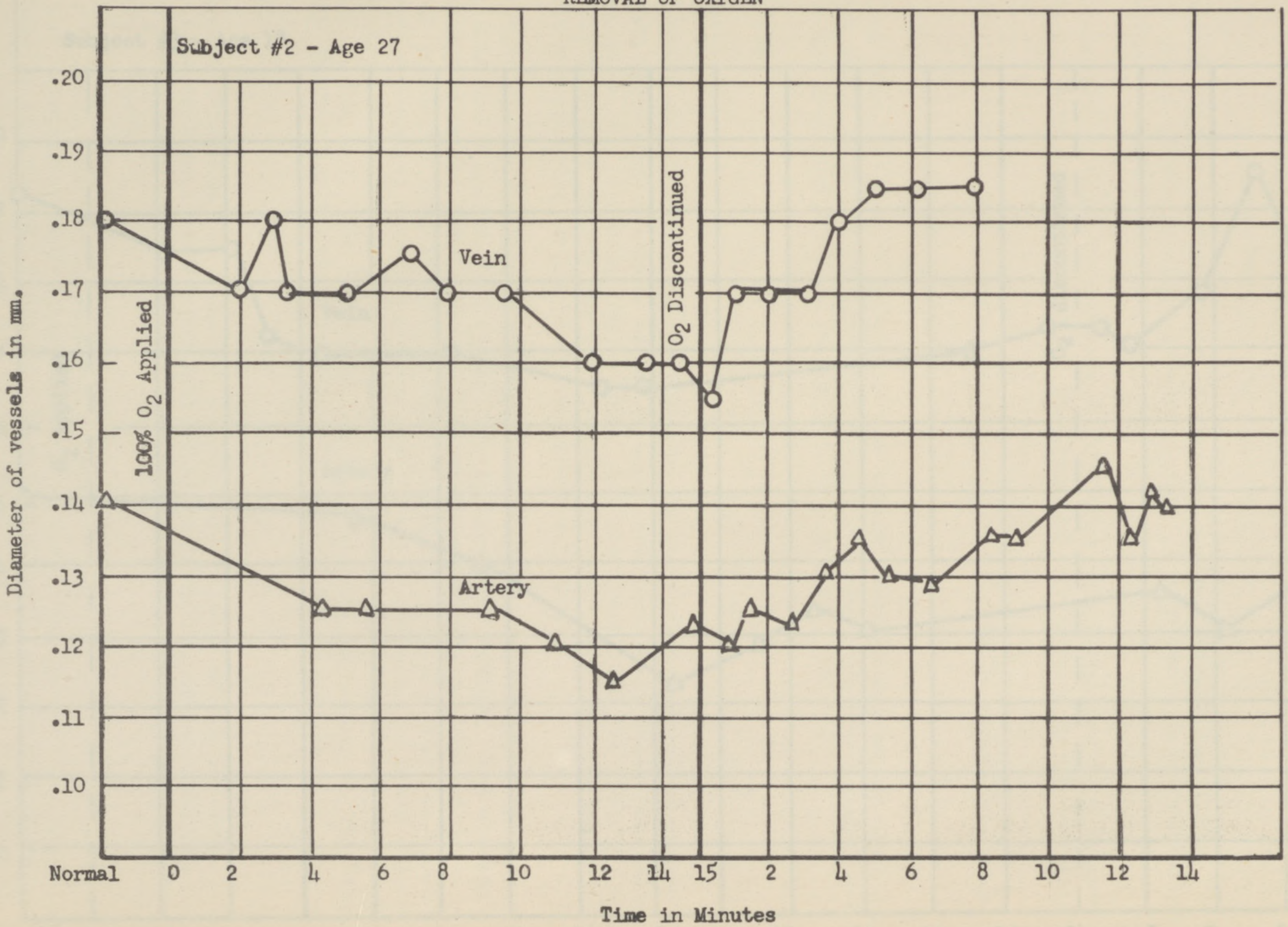


Chart XIX 7b

EXHIBIT 5

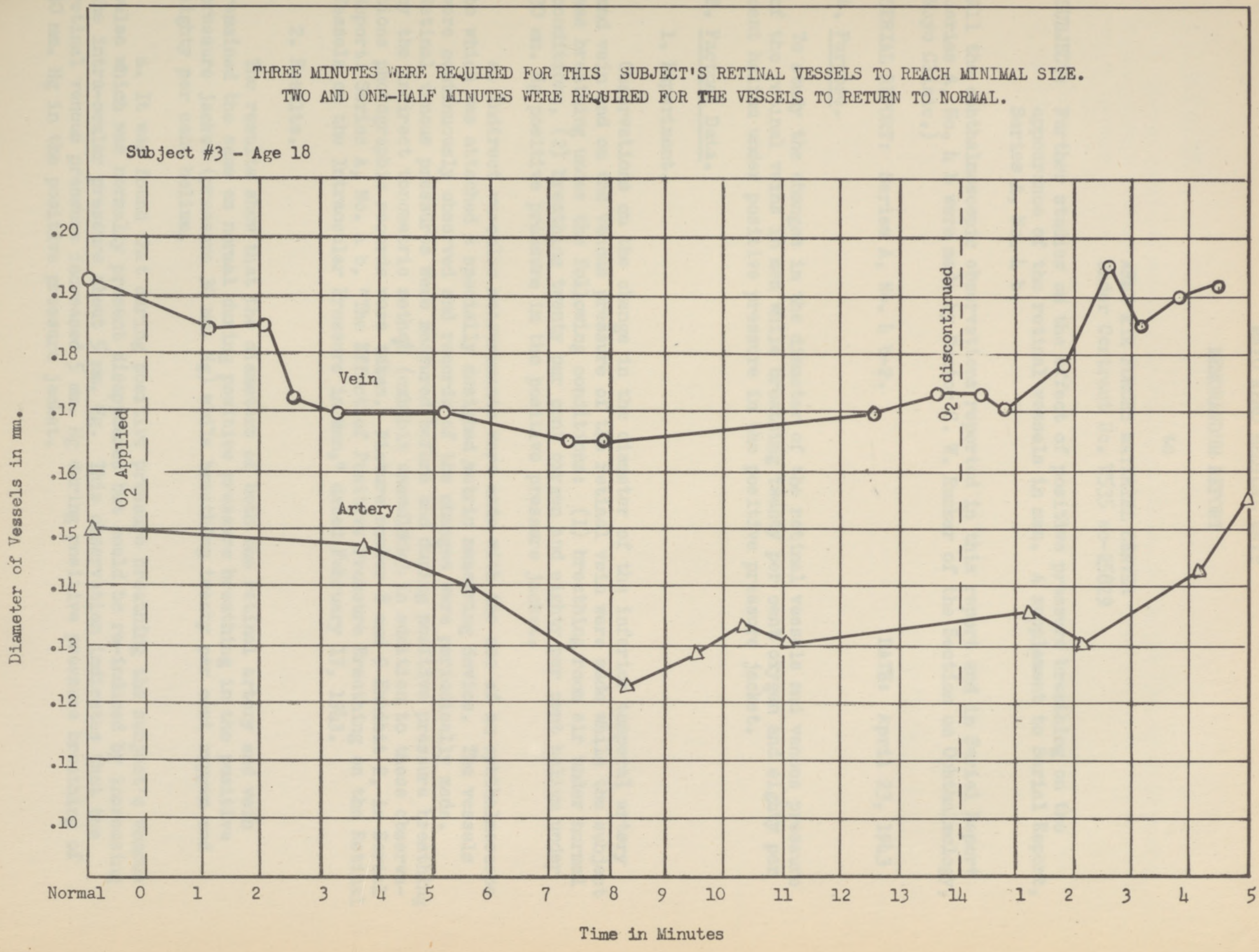


Chart XIX 7c

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT

to

ARMY AIR FORCES MATERIEL CENTER
Under Contract No. W535 ac-25829

SUBJECT: Further studies on the effect of positive pressure breathing on the appearance of the retinal vessels in man. A supplement to Serial Report, Series A, No. 4 b.

(All the ophthalmoscopic observations reported in this report and in Serial Report Series A, No. 4 b were made by Doctor C. W. Rucker of the Section on Ophthalmology, Mayo Clinic.)

SERIAL REPORT: Series A, No. 4 b-2. DATE: April 23, 1943

A. Purpose.

To study the changes in the diameter of the retinal vessels and venous pressure of the retinal veins in men while breathing twenty per cent oxygen and eighty per cent helium under positive pressure in the positive pressure jacket.

B. Factual Data.

1. Experiment.

Observations on the change in the diameter of the inferior temporal artery and vein and on the venous pressure of the retinal vein were made while the subject was breathing under the following conditions: (1) breathing room air under normal conditions, (2) breathing twenty per cent oxygen and eighty per cent helium under 30 mm. Hg positive pressure in the positive pressure jacket.

a. Indirect vascular measurements were made with the use of an ophthalmoscope to which was attached a specially designed metric measuring device. The vessels were continuously observed and records of the changes were periodically made. Retinal venous pressures were measured before and during positive pressure breathing by the indirect tonometric method (exhibit unavailable). In addition to these observations photographic records were taken. Picture number 8 and 9 Exhibit 2, in Serial Report: Series A, No. 4 b, "The Effect of Positive Pressure Breathing on the Retinal Vessels on the Intraocular Pressure in Man," dated February 17, 1943.

2. Results.

The results show that the diameters of both the retinal artery and vein remained the same as normal during positive pressure breathing in the positive pressure jacket (pressure 30 mm. Hg) while breathing twenty per cent oxygen and eighty per cent helium.

a. It was found that during positive pressure breathing the subject's venous pulse which was normally present disappeared but could be re-induced by increasing the intra-ocular pressure about 5 mm. Hg. This observation indicates that the retinal venous pressure increased 5 mm. Hg during positive pressure breathing of 30 mm. Hg in the positive pressure jacket.

C. Conclusions.

1. During positive pressure breathing of 30 mm. Hg in the positive pressure jacket using a mixture of twenty per cent oxygen and eighty per cent helium there are no changes in the diameter of the retinal veins.

2. Under the same conditions as mentioned in (1) above there is about a 5 mm. of Hg increase in retinal venous pressure.

Prepared by C. B. Taylor, 1st Lt. M. C.

J. P. Marbarger, 2nd Lt. AAF

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL CENTER
Under Contract No. W535ac-25829

SUBJECT: The effect of breathing against 30-35 mm. Hg on the cardiac output.

SERIAL REPORT: Series A, No. 4 c. DATE: February 24, 1943

A. Purpose.

To observe the effect of positive pressure breathing in the pressure jacket on the cardiac output in man by means of the roentgen kymograph.

B. Factual Data.

This weekly report and Serial Report Series A, No. 4 a (on the dog) were detailed investigations on but one subject and one animal. We regret that this is the case, but the experimental work reported was very carefully carried out. Both of these experiments were carried out by us and at our own personal expense; lack of subjects, time, money and permission made it impossible for us to further investigate these problems. We feel that the results presented are pertinent to the problem of positive pressure breathing and should stimulate further investigation.

1. Introduction and method.

Observations on the cardiac output and changes in heart volume during positive pressure breathing were made on one individual on three separate days with the use of the roentgen kymograph. Two of the determinations were made with the subject in the sitting position and the other in the erect position. With each of the determinations the roentgen kymogram was taken before the onset of positive pressure breathing against 30 - 35 mm. Hg in the jacket, and at varying time intervals during positive pressure breathing. The diastolic and systolic heart volume, the stroke output and the minute output were calculated from the roentgen kymogram and changes in these heart functions were compared in a relative way. In studies of this nature the direction and magnitude of changes in heart functions with positive pressure breathing can be accurately ascertained by comparing them in a relative way with values obtained immediately before positive pressure breathing. Therefore, it is not essential to question as to whether the values obtained represent the absolute values for the heart functions in this individual. Neither is it necessary to make the determinations under basal conditions.

This subject was selected for these observations because he has been exposed to altitudes as high as 50,000 feet and to altitudes from 45,000 to 48,000 feet for as long as 40 minutes at a time in the positive pressure jacket. He has also been able to move around in the chamber with ease and do femoral arterial punctures at 46,000 feet. The other subject who has also had considerable experience in the positive pressure jacket was not satisfactory because dense hilar markings obliterated the details of the cardiac silhouette.

a. The following method was used. The diastolic outline of the cardiac contour was drawn on the x-ray film selecting a reference diastolic "peak" in one of the exposed strips. The remaining diastolic peaks occurring at the same moment of time in the other exposed strips were then joined to complete the lateral contours of the heart. The same procedure was used to determine the systolic outline, the systolic reference always being the systolic "valley" immediately following the reference diastolic peak in each of the exposed strips. The systolic and diastolic outlines were joined asymptotically to the point of fusion in the uncertain regions of the base and apex of the heart. In any series of tracings the vertical height of the heart was kept constant because the horizontal grid of the kymograph does not reflect changes in the cardiac contours in this sagittal direction.

b. The systolic and diastolic area of the heart was then determined by planimetry and corrected for distortion by the equation:

$$A = A^1 \frac{(Y - C)}{Y^2}$$

where A = true area, A^1 = observed area, Y = distance x-ray tube to the film which was 36" in our determinations, and C = distance from the outer margin of the heart to the film which is approximately one-third the anterior-posterior diameter of the chest, plus 4 cm. which represents the average distance from chest wall to the film when the suit is on.

c. The volume of the heart and stroke output of the left ventricle were determined from the formula of Keys and Friedell (1) in which

$$\text{Volume} = 0.64 \times \text{area}^{1.45} \text{ and}$$

Stroke output = diastolic - systolic volume.

d. Since the systolic and diastolic outlines of the heart are joined in the sagittal direction, the difference between the diastolic volume and the modified systolic volume is approximately half as great as the actual total change between these volumes so that their difference gives the output of one ventricle rather than two. Keys and Friedell (1) have found a close correlation between the stroke output as determined by the roentgen kymogram and the Grollman acetylene method of determining stroke output when normal subjects are used.

e. The pulse rates were calculated from the x-ray film by counting the number of contractions occurring in a unit time. The time was recorded by the oscillations of an electric timer superimposed on the x-ray film. The minute output was then determined by multiplying the stroke output by the pulse rate.

f. Exhibit 2 shows a table of the results obtained.

2. Results.

a. Exhibit 2 shows that the results obtained on the three determinations while breathing against 30 - 35 mm. Hg in the positive pressure jacket were all uniform in that they showed a marked decrease from the normal in the diastolic and systolic heart volume and the stroke output. However, the decrease in the stroke output was compensated for by a marked increase in the subject's pulse rate so that the minute output while breathing against positive pressure was essentially the same as under normal conditions, i.e., without positive pressure.

(1) Keys, A., Friedell, H.L., Garland, L.H., Madrazo, M.F. and Rigler, L.G., 1940. The American Journal of Roentgenology and Radium Therapy, Vol. 44, p. 805.

(1) The results show that in the first determination with the subject seated there was a decrease in the diastolic and systolic volume from normal of 14% and 12% respectively after 2 minutes of breathing against a positive pressure of 30 - 35 mm. Hg and that after 25 minutes the decrease was essentially the same. At this time the diastolic volume was 16% and the systolic volume was 14% below the normal. The stroke output decreased 27% and 26% respectively after 2 minutes and 25 minutes of breathing against this positive pressure. On the other hand, the pulse rate increased from 100 to 140 and remained constant at 140 so that the minute output was not changed from normal while breathing against 30 - 35 mm. Hg positive pressure.

(2) The results show that in the second determination with the subject seated, the roentgen kymogram taken 27 minutes after breathing against 30 - 35 mm. Hg showed changes essentially the same as in the first determination. It can be seen that the diastolic volume decreased 18% and systolic 17% from normal. The stroke output showed 30% decrease from normal but again the minute output remained practically the same as the normal.

(3) The third determination taken in the erect position showed more marked decrease in diastolic and systolic volume and stroke output, but again an increase in the pulse rate compensated for the decreased stroke output so that the minute output remained essentially the same.

b. Exhibit 3 shows two superimposed heart tracings. The tracing in solid line shows the normal heart silhouette and the dotted line shows the heart silhouette 25 minutes after onset of positive pressure breathing.

C. Conclusion.

The observations made at different times on a single subject breathing against 30 - 35 mm. Hg in the positive pressure jacket for as long as 27 minutes show, at least in this individual, that although there is a marked decrease in diastolic and systolic volume and the stroke output of the heart, the increase in the pulse rate compensates for the reduced stroke output so that the minute output remains the same while breathing against positive pressure as that obtained under normal conditions.

Prepared by Eldon W. Erickson, M.D.

J. P. Marbarger, 2nd Lt. A.A.F.

C. B. Taylor, 1st Lt. M.C.

Approved by E. J. Baldes, Ph.D.

Charles F. Code, M.D.

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Aero Medical Research Laboratory
Wright Field, Dayton, Ohio

Office of the Air Surgeon
Attention Col. Loyd E. Griffis
Washington, D.C.

Series A, No. 4 c.

Exhibit 2

Subject: J. P. Marbarger Age 26
Surface area - 2.2 square meters
Anterior-posterior diameter of chest - 24 centimeters
Correction for each x-ray distortion - .7545

DETERMINATION # 1. Subject sitting, in the positive pressure jacket. The positive pressure used was 30 - 35 mm. Hg and the exposures were made under the following conditions:	Diastolic area (sq.cm.)	Systolic area (sq. cm.)	Diastolic volume (cc.)	Systolic volume (cc.)	Stroke output (cc.)	Pulse rate	Minute output (L./min.)
A. Control. No positive pressure, subject seated.	112.6	101.4	603.7	518.8	84.9	100	8.49
B. After 2 minutes breathing against 30 - 35 mm.Hg	101.5	93.0	519.5 (-14%)	457.7 (-12%)	61.8 (-27%)	140	8.65 (+2%)
C. After 25 minutes breathing against 30 - 35 mm.Hg	100.0	91.3	508.4 (-16%)	445.5 (-14%)	62.9 (-26%)	140	8.81 (+4%)
DETERMINATION # 2.							
A. Control. No positive pressure, subject seated.	114.7	104.9	620.2	544.9	75.3	100	7.53
B. After 27 minutes breathing against 30 - 35 mm.Hg	99.6	92.4	505.2 (-18%)	453.3 (-17%)	51.9 (-30%)	150	7.79 (+3%)
DETERMINATION # 3.							
A. Control. Subject standing, in positive pressure jacket.	114.2	102.9	616.4	530.2	86.2	100	8.62
B. After 2 minutes breathing against 30 - 35 mm. Hg	92.8	86.2	462.2 (-25%)	410.0 (-23%)	52.2 (-40%)	170	8.77 (+2%)

The percentages indicate the changes from the normal.

Series A, No. 4 c.

MAYO AERO MEDICAL UNIT

ROCHESTER, MINNESOTA

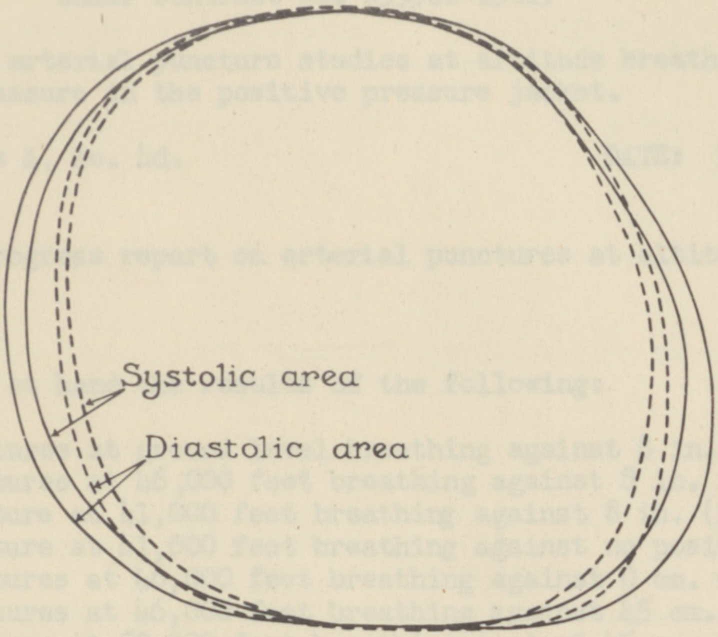

Exhibit 3. Two superimposed heart tracings
The tracing in solid line shows the normal
heart silouette and the dotted line shows th
the heart silhouette 25 minutes after onset
of positive pressure breathing.

C.B.Tayler and J.P.Marbarger March, 1943
Chart XIX-7d

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL CENTER
Under Contract No. w535ac-25829

SUBJECT: Progress on arterial puncture studies at altitude breathing against positive pressure in the positive pressure jacket.

SERIAL REPORT: Series A, No. 4d. DATE: March 3, 1943

A. Purpose. Weekly progress report on arterial punctures at altitude.

B. Factual Data.

1. To date we have at hand the results of the following:

2 arterial punctures at ground level breathing against 8 in. (21 cm. water).
5 arterial punctures at 46,000 feet breathing against 8 in. (21 cm. water).
1 arterial puncture at 41,000 feet breathing against 8 in. (21 cm. water).
1 arterial puncture at 41,000 feet breathing against no positive pressure.
3 arterial punctures at 46,000 feet breathing against 0 cm. water.
2 arterial punctures at 46,000 feet breathing against 45 cm. water.
1 arterial puncture at 50,000 feet breathing against 45 cm. water.
4 venapunctures at 46,000 feet breathing against 8 in. (21 cm. water).
1 venapuncture at 46,000 feet breathing against 45 cm. water.

Six subjects were used in these experiments.

We expect to complete this work by Monday, March 8, 1943, and to submit a complete report of our findings very soon thereafter.

2. We are obtaining some electrocardiographic and electroencephalographic studies with the positive pressure jacket at ground level and at altitude breathing against 20, 30 and 40 cm. of water.

3. We are deeply indebted to Dr. M. H. Power without whose willing cooperation in making the chemical analyses, etc. this investigation would have been impossible.

Distribution:
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Attention Col. O. O. Benson, Jr.
Aero Medical Research Laboratory
Wright Field, Dayton, Ohio

Office of the Air Surgeon
Attention Col. Loyd E. Griffis
Washington, D. C.

Prepared by: Charles B. Taylor, 1st Lt. M.C.

John P. Marbarger, 2nd Lt. A.A.F.

Approved by: E. J. Baldes, Ph.D.

C. F. Code, M.D.

No. 11

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL CENTER
Under Contract No. w535ac-25829

SUBJECT: Arterial blood studies at altitudes up to 50,000 feet, breathing under positive pressure in the positive pressure jacket.

SERIAL REPORT: Series A, No. 4 e DATE: March 11, 1943

A. Purpose.

1. To report on the determinations of arterial oxygen saturation made under the following conditions:

a. Breathing under 20 cm. (8") water positive pressure in the positive pressure jacket at ground level, 41,000 and 46,000 feet.

b. Breathing under no positive pressure at 41,000 and 46,000 feet.

c. Breathing under an average of 44 cm. water positive pressure in the positive pressure jacket at 46,000 and 50,000 feet.

2. To report on the pH and carbon dioxide content of arterial blood under the above mentioned conditions.

3. To report the correlation between the arterial oxygen saturation and the oximeter readings (Coleman model 17, no. 5769) under the conditions mentioned above.

4. To submit a report of the chamber flights made to obtain the arterial samples needed for this investigation.

B. Factual data.

1. Apparatus and method.

a. Ten cubic centimeter samples of arterial blood were taken from the femoral artery under oil in a syringe containing a bead for mixing, and a little heparin as an anticoagulant. As soon as the sample was collected the needle (20 gage) was inserted into a rubber cork. The sample was mixed 2 or 3 times and then put into ice water. Then it was immediately put into the air lock, dropped to ground level and pH and gas determinations were made as soon as possible. Determinations of pH were made at 38° by means of a jacketed capillary glass electrode as described by Dill, Daly and Forbes[1] in conjunction with a Coleman Model 4 pH meter the scale of which read to 0.1 millivolts. The glass electrode was calibrated with suitable phosphate buffers before and after each blood pH determination. Although some slight decrease of pH may have occurred in the time interval between the collection of sample and the determinations of pH. This is believed to have been very small and the pH values are presented as obtained without corrections. The Van Slyke and Neill manometric method was used for gas analysis. While each sample of blood was drawn, oximeter readings were taken simultaneously with the use of a Coleman oximeter set at 100 per cent while breathing oxygen under 20 cm. (8") water pressure.

1. J.B.C., Vol. 117: 569, 1937.

In most of the chamber runs the subjects breathed against 10 to 20 cm. water pressure from ground up. The samples obtained while breathing against no positive pressure and an average of 44 cm. positive pressure were collected after the pressure had been regulated at altitude. Appendix I shows a complete description of the log of each trip. Different periods of time at altitude were allowed before the arterial punctures were made. These data are found in Exhibit 1.

2. Results.

a. The results of the arterial blood oxygen are presented in tabular form in Exhibit 1. The results of 10 punctures at 46,000 feet and breathing against 20 cm. (8") water positive pressure show that the range in arterial oxygen saturation (by chemical analysis) was from 87.4 per cent to 69.1 per cent, the average being 77.6 per cent. At 41,000 feet and breathing against the same pressure the arterial oxygen saturation (1 case) was 90.3 per cent and when the pressure was reduced to 0 the saturation was 89.9 per cent. The table shows that at 46,000 feet when the pressure under which the subjects were breathing was reduced from 20 cm. (8") water to no pressure, the arterial oxygen saturation (3 cases) ranged from 71.9 per cent to 58.3 per cent, the average being 67.1 per cent. Exhibit 1 shows that at 46,000 feet when the pressure against which the subject (4 cases) was breathing was increased from 20 cm. to an average of 44 cm. water, the arterial oxygen saturation ranged from 95.6 per cent to 88.0 per cent, the average being 93.9 per cent. At 50,000 feet the table shows that the arterial oxygen saturation ranged (4 cases) from 92.0 per cent to 75.7 per cent, the average being 80.3 per cent.

b. Exhibit 2 shows a curve for arterial blood oxygen saturation at altitudes up to 44,000 feet breathing pure oxygen without pressure. This was taken from PHYSIOLOGY OF FLIGHT, fig. 8, p. 13, 1940-42, Wright Field, Dayton, Ohio. The data for arterial blood oxygen saturation found in Exhibit 1 was then added to this graph. See Exhibit 2 and legend for further description.

c. Positive pressures of 15 mm. Hg (20 cm. water) and 32.5 mm. Hg. (44 cm. water) actually increases the effective alveolar oxygen tension. Hence under these conditions one would expect an arterial oxygen saturation equivalent to the saturation found in fig. 8, p. 13, of PHYSIOLOGY OF FLIGHT, at altitudes with a barometric pressure 15 mm. Hg and 32.5 mm. Hg lower. With this in mind in Exhibit 3 we shifted the curve found in PHYSIOLOGY OF FLIGHT, 15 mm. Hg and 32.5 mm. Hg to the right. This curve shows that the results we obtained at 46,000 and 50,000 feet lie within the anticipated range. See Exhibit 3.

d. Exhibit 1 shows the pH determinations and the carbon dioxide content in volumes per cent for each sample. It can be seen that at 46,000 feet and breathing under 20 cm. (8") water positive pressure the pH values (10 cases) and carbon dioxide contents ranged from pH 7.42, 43.10 vol. % to pH 7.49, 48.65 vol. %. The average pH and carbon dioxide content values were 7.46 and 46.14 respectively. At 41,000 feet with and without positive pressure the pH values were the same, 7.41, and the carbon dioxide contents were 46.70 and 45.70 vol. % respectively. At 46,000 feet with no positive pressure (3 cases) the ranges of the pH values and carbon dioxide contents were pH 7.46, 42.07 vol. % and pH 7.48, 48.20 vol. % respectively. The averages were pH 7.473 and 44.18 vol. %. At 46,000 feet with an average of 44 cm. water positive pressure the ranges were (4 cases) pH 7.45, 38.87 vol. % and pH 7.52, 47.05 vol. %. The averages were pH 7.487 and 42.48 vol. % respectively. At 50,000 feet with 44 cm. water positive pressure the ranges (4 cases) were from pH 7.46, 39.38 vol. % to pH 7.55, 44.51 vol. %. The averages were pH 7.482 and 42.39 vol. % to pH 7.55, 44.51 vol. %. The averages were pH 7.482 and 42.39 vol. %, respectively.

According to Gibbs et al., (J.B.C. Vol. 144, No. 2, 1942, p. 325) in the study of 50 normal males in resting condition the range for arterial pH was from 7.374 to pH 7.455. The carbon dioxide contents ranged from 45.6 vol. % to 50.4 vol. %. The averages were pH 7.424 and 48.2 vol. % respectively. Our results show that in positive pressure breathing there is a tendency towards an increased pH and a decrease in carbon dioxide content compared with the work of Gibbs et al mentioned above. Peters and Van Slyke (Quant. Clin. Chem. Vol. 1, Williams and Wilkens Co., 1931, p. 942) content that tetany is not likely to occur until there has been a rise of at least 0.2 pH units. It has been our experience that during the first 5 minutes after pressure is instituted one tends to hyperventilate in the positive pressure jacket. This also occurs if the pressure is increased from 20 cm. to 44 cm. water. Sample 5, subject H. Haglund, 3/5/43 (Exhibit 1) demonstrates this temporary rise in pH and fall in carbon dioxide content at the beginning of positive pressure breathing. Sample 8, subject H. Haglund, 3/5/43, taken on the same day breathing against the same pressure but 17 minutes later shows a rise in carbon dioixide and a decrease in pH to an essentially normal level. This is more strikingly shown in samples 5, 6, 7 and 8 (Exhibit 1) subject C. B. Taylor, 3/3/43 and 3/6/43. This work shows that there is a temporary alkalosis during positive pressure breathing which is probably not dangero us and which disappears after a few minutes of adaptation to positive pressure breathing.

e. Oximeter readings were carefully taken simultaneously with arterial punctures. Except for a possible slight venous stasis of the ear (necessary because the mask had to be firmly fixed to the face) conditions f or accurate oximeter readings were ideal. In Exhibit 4 oximeter readings are plotted against arterial blood oxygen saturations determined by chemical analysis. Exhibit 4 also contains a table of points plotted and of the error of the oximeter for each of the 23 samples. Except for 5 oximeter readings which proved to be very inaccurate, the oximiter checked quite well with the arterial blood oxygen saturations. Exhibit 4 also suggests that the oximeter used (Coleman Model 17, No. 5769) is fairly accurate for arterial blood saturations above 75 to 80 per cent but is quite inaccurate when the arterial saturation falls below this level.

f. The logs of the 12 flights made in obtaining the arterial punctures may be found in chronological order in Appendix I. The first page of each log contains the oximeter readings made during the flight, the second a record of denitrogenization and all pages after that a running record of the flight. A few interesting points of the flights might be made: 1) an altitude of 46,000 feet was easily tolerated by the subject (H.R.) and observer (J.P.M.) for 22½ min.; 2) an altitude of 50,000 feet was easily tolerated by subject (C.B.T.) and observer (J.P.M.) for almost 18 minutes; 3) the observer during all flights to both 46,000 and 50,000 feet walked around in the chamber and moved all body parts as freely and with as much ease as if at ground level; 4) the observer (J.P.M.) of all the flights (9 flights to 46,000 and 2 flights to 50,000 feet in this series) only once experienced very mild bends in his right hand after ½ hour at 46,000 feet. He had been holding his hand over the femoral artery of the subject most of the time at altitude and had been compressing the artery and moving his hand considerably, while obtaining the sample. 5) It can be noted from the logs of the flights that a number of subjects had trouble keeping their ears open on descent. This was due to the fact that the subjects were lying on their backs and in all cases the difficulty was corrected when they sat up. 6) One subject (C.B.T.) who has very frequently developed severe gas pains during many flights to 35,000 feet to 42,000 feet while wearing a constant flow or demand mask has experienced no gas pains during one flight to 41,000, 3 flights to 46,000 and 2 flights to 50,000 feet in the positive pressure jacket. The pressure of the jacket around the abdomen seems to prevent the distention of the intestines which occurs as the gas in the intestine expands on ascent, and instead forces it into the sigmoid colon where it is easily expelled.

C. Summary.

1. The average arterial blood oxygen saturation (by chemical analysis) of 10 blood samples taken at 46,000 feet while breathing 20 cm. (8") water positive pressure in the positive pressure jacket was 77.6 per cent, while breathing against 44 cm. of water, 93.3 per cent and while breathing against 44 cm. water in the positive pressure jacket at 50,000 feet the average arterial oxygen saturation was 80.3 per cent.

2. During the first 4 or 5 minutes of positive pressure breathing or during the first 4 or 5 minutes after positive pressure is increased from 20 to 44 cm. water, the subjects, in becoming adjusted to the pressure, show a tendency towards a mild alkalosis (indicated by blood pH and carbon dioxide content studies). This is due to temporary hyperventilation. The degree of alkalinity does not approach those levels of tetany. Arterial blood chemistry studies after 5, 10, 15 and 20 minutes of positive pressure breathing at altitude show that after 5 minutes of positive pressure breathing the blood pH and carbon dioxide content almost approach normal.

3. It was found that oximeter readings check quite well with the arterial oxygen per cent saturation (23 samples) chemically analyzed to a saturation of 75 to 80 per cent. They do not check very well below this level.

D. Recommendations.

1. The results of arterial blood oxygen saturations, pH determinations and carbon dioxide content determinations done on blood samples collected at 46,000 and 50,000 feet while breathing in the positive pressure jacket show that the jacket is a very definite improvement over present oxygen equipment for altitudes above 40,000 feet. An exhaustive study of its possibilities and further investigations as to its application for military flying personnel sh ould be seriously considered.

2. It is recommended that positive pressures of 30 cm. of water be used in preference to 20 cm. of water because an altitude of 46,000 feet can be maintained more comfortably and for a longer period of time. The pilot will also be more efficient. We do not believe that positive pressures up to 45 cm. of water are harmful to the pilot but the difficulty of keeping the mask to the face makes it somewhat uncomfortable.

Distribution:
Commanding Officer
Attention Col. O.O.Benson, Jr.
Aero Medical Research Laboratory
Wright Field, Dayton, Ohio

Office of the Air Surgeon
Attention Col. Loyd E. Griffis
Washington, D. C.

Prepared by M. H. Power, Ph.D.

C. B. Taylor, 1st Lt., M.C.

J. P. Marbarger, 2nd Lt., AAF
Not present when report submitted

Approved by E. J. Baldes, Ph.D.

C. F. Code, M.D.

pH DETERMINATIONS AND THE CARBON DIOXIDE CONTENT IN VOLUMES PER CENT

Sample No.	Subj.	Date	Altitude in feet	Pos. press. cm. H_2O	Time at alt. breathing agnst. pres. before puncture started	* Arterial blood					
						O_2 content Vol. % (Note)	O_2 capacity Vol. %	O_2 sat. % (chemical analysis)	O_2 sat. % (oximeter)	CO_2 content Vol.%	pH
1	CBT	2/16/43	41,000	20	9.58	17.93	19.85	90.3	97	46.70	7.41
2	CBT	2/23/43	46,000	20	1.67	17.89	20.46	87.4	89	43.10	7.46
3	CBT	2/26/43	46,000	20	3.25	16.84	20.40	82.5	84	44.18	7.47
4	WLB	2/22/43	46,000	20	0.42	16.87	20.64	81.7	83	46.70	7.47
5	HH	3/5/43	46,000	20	3.58	15.42	19.73	78.1	79	43.87	4.47
6	HH	3/2/43	46,000	20	6.33	16.12	20.89	77.2	83	44.56	7.44
7	RE	3/2/43	46,000	20	2.75	14.83	19.33	76.7	89	47.64	7.44
8	HH	3/5/43	46,000	20	21.08	15.18	20.17	75.3	74	46.10	7.44
9	RE	3/5/43	46,000	20	1.08	14.24	19.20	74.2	89	48.44	7.46
10	WLB	3/3/43	46,000	20	7.08	14.87	20.25	73.4	74	48.14	7.49
11	RE	3/5/43	46,000	20	1.08	13.31	19.25	69.1	89	48.65	7.42
1	CBT	2/16/43	41,000	0	1.97	17.46	19.43	89.9	90	45.70	7.41
2	CBT	2/23/43	46,000	0	1.08	14.83	20.63	71.9	76	42.07	7.48
3	CBT	2/26/43	46,000	0	2.17	14.65	20.61	71.1	76	42.26	7.46
4	WLB	2/22/43	46,000	0	1.75	12.45	21.37	58.3	69	48.20	7.46
1	WLB	3/3/43	46,000	44	1.92	19.69	20.60	95.6	93	43.59	7.49
2	CBT	2/26/43	46,000	46	4.00	19.34	20.33	95.1	95	38.87	7.52
3	CBT	2/23/43	46,000	43	1.00	19.40	20.51	94.6	98	40.36	7.49
4	RE	3/5/43	46,000	40	0.50	16.92	19.22	88.0	98	47.05	7.45
5	CBT	3/3/43	50,000	45	0.33	17.74	19.29	92.0	93	39.38	7.55
6	CBT	3/6/43	50,000	45	5.17	15.78	20.57	76.7	77	44.51	7.46
7	CBT	3/6/43	50,000	43	10.50	15.75	20.50	76.8	76	42.93	7.46
8	CBT	3/6/43	50,000	43	15.33	15.69	20.72	75.7	77	42.74	7.46
1	CBT	2/8/43	Ground	20	10.00	20.80	20.00	104.0	--	46.30	7.41
2	JM	2/8/43	Ground	20	15.00	22.70	21.00	108.1	--	44.20	7.40

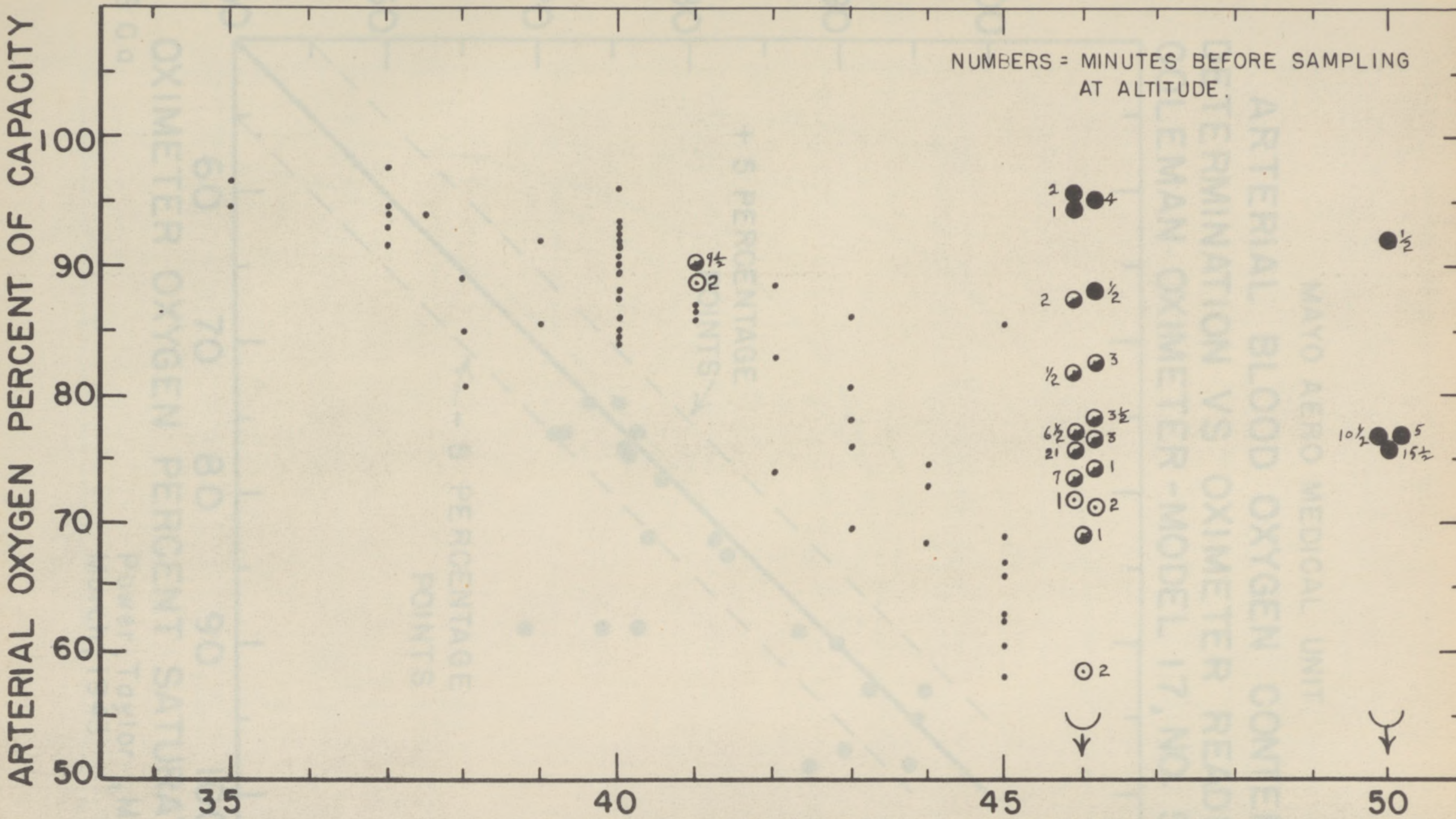
* The samples were taken from the femoral artery by J. P. Marbarger, 2nd Lt., A.A.F.

Note: All but the two samples taken at ground level were corrected for dissolved oxygen.

Exhibit 1.

MAYO AERO MEDICAL UNIT

ARTERIAL BLOOD OXYGEN CONTENT BREATHING OXYGEN WITH AND WITHOUT PRESSURE



• No pressure - Physiology of Flight Wright Field, 1940-42, Fig. 8

○ No pressure

◐ 20 cm. water pressure

● 40-46 cm. water pressure

III-8-C

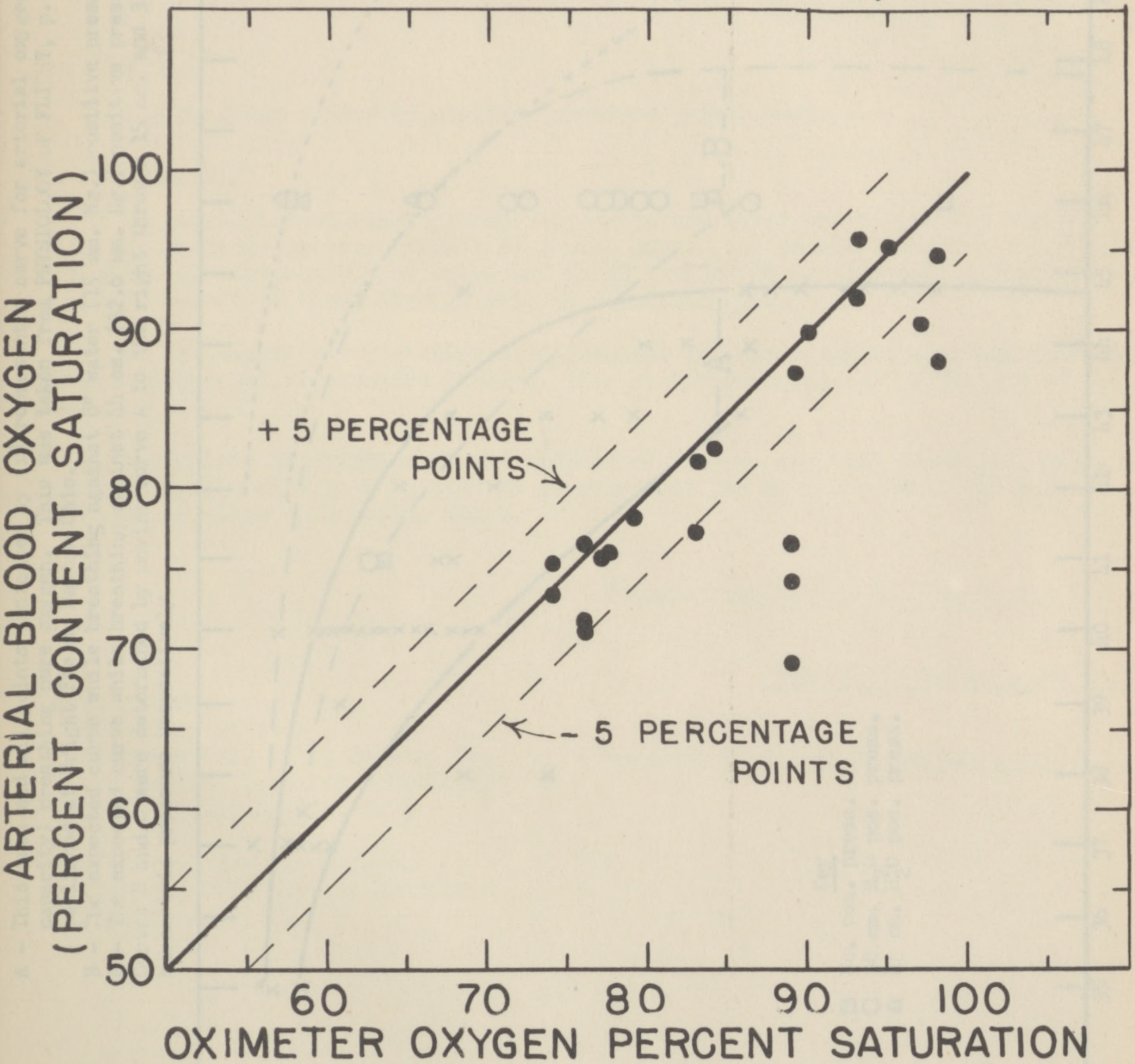
POWER, TAYLOR AND MARBARGER

MARCH, 1943

6

MAYO AERO MEDICAL UNIT

ARTERIAL BLOOD OXYGEN CONTENT DETERMINATION VS OXIMETER READINGS COLEMAN OXIMETER-MODEL 17, NO. 5769



III - 8 Ca

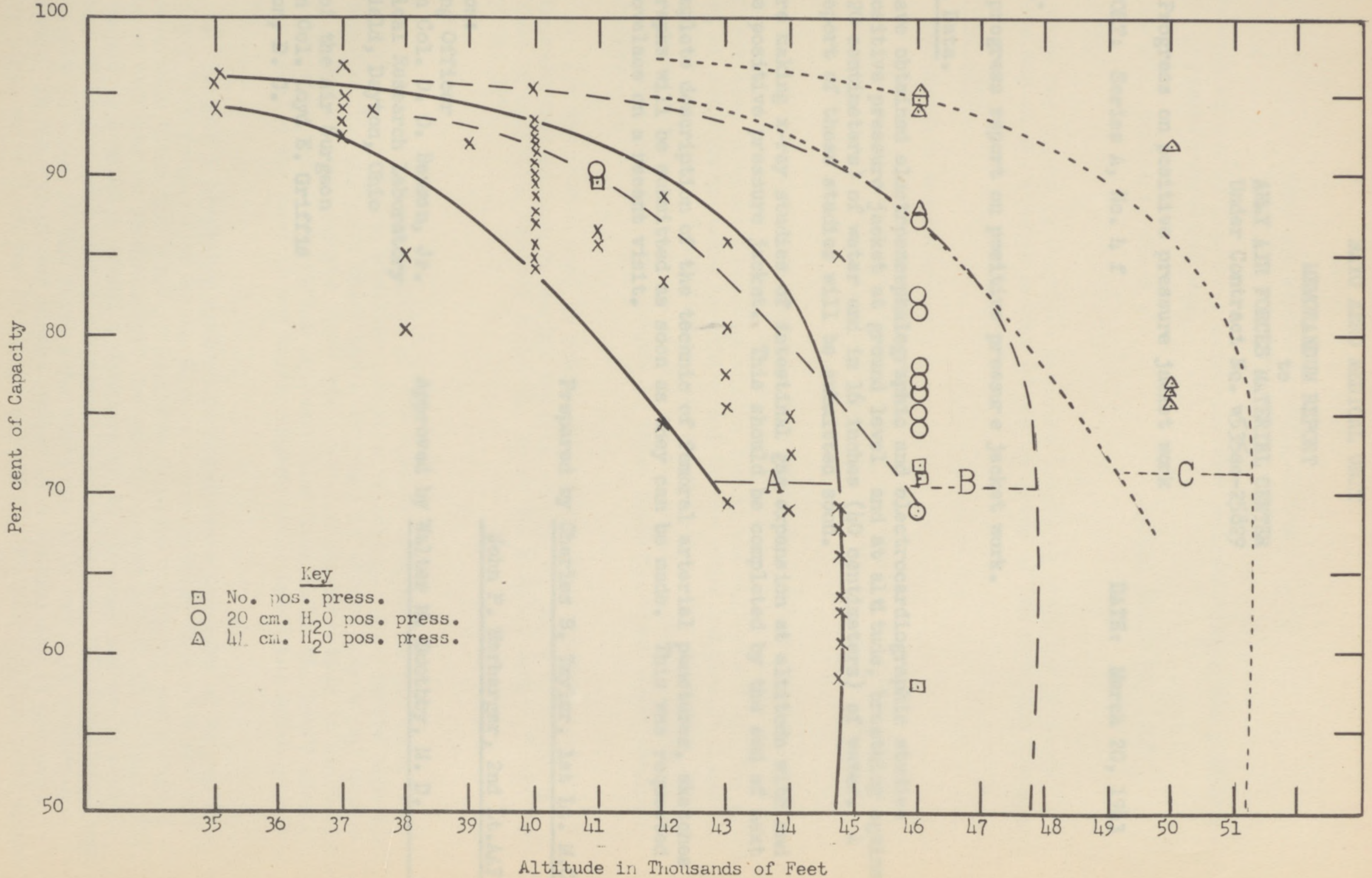
Power, Taylor, Marbarger
March, 1943

A - This area and all points indicated by (x) represent a curve for arterial oxygen (per cent of capacity) breathing pure oxygen. This was taken from PHYSIOLOGY OF FLIGHT, p. 13, 1940-42, published at Wright Field, Dayton, Ohio.

B - The expected curve while breathing against 8" water (15 mm. Hg.) positive pressure.

C - The expected curve while breathing against 44 cm. (32.6 mm. Hg.) positive pressure.

Curves B and C were determined by moving curve A to the right through 15 mm. and 32.5 mm. Hg. barometric pressure respectively.



C. B. Taylor and J. P. Marbarger

March 1943
Chart III 8d

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL CENTER
Under Contract No. w535ac-25829

SUBJECT: Progress on positive pressure jacket work

SERIAL REPORT: Series A, No. 4 f DATE: March 20, 1943

A. Purpose.

Weekly progress report on positive pressure jacket work.

B. Factual Data.

1. We have obtained electroencephalographic and electrocardiographic studies with the positive pressure jacket at ground level and at altitude, breathing against 8 inches (20 centimeters) of water and in 16 inches (40 centimeters) of water. A complete report of these studies will be submitted soon.

2. We are making x-ray studies of intestinal gas expansion at altitude with and without the positive pressure jacket. This should be completed by the end of next week.

3. A complete description of the technic of femoral arterial punctures, sketches and photographs will be submitted as soon as they can be made. This was requested by Major Lovelace on a recent visit.

Prepared by Charles B. Taylor, 1st Lt. M.C.

John P. Marbarger, 2nd Lt. AAF

Approved by Walter M. Boothby, M. D.

Distribution:
Commanding Officer
Attention Col. O. O. Benson, Jr.
Aero Medical Research Laboratory
Wright Field, Dayton, Ohio

Officer of the Air Surgeon
Attention Col. Loyd E. Griffis
Washington, D. C.

MAYO AERO MEDICAL UNIT

MEMORANDUM REPORT
to
ARMY AIR FORCES MATERIEL CENTER
Under Contract No. W535ac-25829

SUBJECT: The effect of breathing under positive pressure using the positive pressure rebreather bag.

SERIAL REPORT: Series A, No. 4 g DATE: March 30, 1943

A. Purpose.

To study the effect of positive pressure breathing with the pressure rebreather bag on the cardiac output in man by means of the roentgen kymograph.

B. Factual Data.

1. Introduction and method.

a. Observations on the cardiac output and changes in heart volume during positive pressure breathing were made on 3 individuals with the use of the roentgen kymograph.

b. The determinations were all made with the subjects in the sitting position. With each determination the roentgen kymograph was taken before the onset of positive pressure breathing and in two of the subjects 5 minutes after the onset of positive pressure breathing and in the other subject at 5 and 10 minutes after the onset of positive pressure breathing. The diastolic and systolic heart volume, the stroke output and the minute output were calculated from the roentgen kymogram and changes in these heart functions were compared in a relative way.

c. For the method used in making the calculations for the various functions reference is made to Serial Report: Series A, No. 4 c, Subject: "The effect of breathing against 30-35 mm. Hg on the cardiac output," February 24, 1943.

2. Results.

a. Exhibit 1 shows a table of the results obtained on the three individuals before and during positive pressure breathing. The results show that in all three of the subjects there was a decrease in stroke output and minute output. In two of the subjects there was also a marked reduction in diastolic and systolic volumes during positive pressure breathing while the heart size remained essentially the same in the third subject while breathing under positive pressure.

b. Subject 1 breathing against an inspiratory pressure of 22 mm. Hg and an expiratory pressure of 30 mm. Hg had determinations made at 5 and 10 minute intervals after the onset of positive pressure breathing and showed a progressive decrease in stroke output and minute output during this time. The stroke output at 5 minutes showed a decrease of 20 per cent and at 10 minutes a decrease of 34 per cent from the original (normal) value. Although there was a progressive increase in the pulse rate there was a 13 per cent reduction (from normal) in the calculated minute output at 5 minutes and 19 per cent reduction (from normal) at the 10 minute exposure. The heart volume also showed a progressive decrease from the original over this period of positive pressure breathing. Subjectively this individual was unable to maintain positive pressure breathing of 22 to 30 mm. Hg for more than 10 minutes.

c. Subject 2, breathing against an inspiratory pressure of 22 mm. Hg and an expiratory pressure of 28 mm. Hg, showed similar changes but of greater magnitude. In this subject only one determination was made 5 min. after the onset of positive pressure breathing. At this time the stroke output was reduced 44 per cent from normal and although there was an increase in pulse rate, the calculated minute output was reduced 30 per cent from the normal. There was also a reduction in this subject's heart volume.

d. Subject 3, breathing against an inspiratory pressure of 20 mm. Hg to 25 mm. Hg, had a decrease in stroke output and minute output of 17 per cent. This subject's pulse rate remained constant and there were only slight changes in the heart volume. During the inspiratory phase while breathing against positive pressure the radial pulse was obliterated but was easily palpated during expiration.

e. A fourth subject was studied but we were unable to secure satisfactory roentgen kymograms during positive pressure breathing. At 4.5 minutes of breathing against a positive pressure from 22 to 28 mm. Hg this subject showed signs and symptoms of circulatory collapse. He became cold and clammy and subjectively felt faint. The positive pressure was immediately discontinued and the subject's pulse rate decreased from 100 to 48 with gradual return to 80, the original resting pulse rate, at the end of 5 minutes.

3. Discussion.

a. The roentgen kymograms were all made during the mid-phase of inspiration. In view of the fact that the pulse was obliterated during inspiration in one case one wonders if there would be a difference in stroke output during inspiration and expiration while breathing against positive pressure. Roentgen kymograms should probably be made during the phase of mid-expiration before final conclusions are drawn concerning the heart output under positive pressure breathing.

C. Summary.

The observations on the three subjects breathing against positive pressure from 20 to 30 mm. Hg in the positive pressure rebreather bag indicate that there is a reduction in both stroke output and minute output while breathing against these pressures at ground level. Although there is an increase in pulse rate during positive pressure breathing under these conditions, this increase fails to compensate for the decrease in stroke output.

Distribution:
Commanding Officer
Attention Col. O. O. Benson, Jr.
Aero Medical Research Laboratory
Wright Field, Dayton, Ohio

Office of the Air Surgeon
Attention Col. Loyd E. Griffis
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Presspared by Elmon W. Erickson, M.D.
C. B. Taylor, 1st. Lt., M.C.
J. P. Marbarger, 2nd Lt., A.A.F.

Approved by Walter M. Boothby, M.D.

EXHIBIT 1

RESULTS OF CARDIAC OUTPUT STUDIES USING THE POSITIVE PRESSURE REBREATHER BAG

Conditions	Diastolic area (sq. cm.)	Systolic area (sq. cm.)	Diastolic volume (cc.)	Systolic volume (cc.)	Stroke output (cc.)	Pulse rate	Minute output (L./min.)
Subject #1. Control. No positive pressure. Subject seated.	105.1	95.5	546.2	475.5	70.7	110	7.78
Subject #1. After 5 minutes. Inspiratory pressure = 22 mm. Hg. Expiratory pressure = 30 mm. Hg.	99.5	91.7	504.5 (-7.6%)	448.3 (-5.7%)	56.2 (-20.5%)	120	6.74 (-13.3%)
Subject #1. After 10 minutes. Pressures same as above.	95.1	88.5	472.5 (-13.5%)	426.1 (-10.4%)	46.4 (-34.4%)	136	6.31 (-18.9%)
Subject #2. Control No positive pressure. Subject seated.	125.0	109.9	702.6	582.9	119.7	80	9.58
Subject #2. After 5 minutes. Inspiratory pressure = 22 mm. Hg. Expiratory pressure = 28 mm. Hg.	111.0	102.1	591.4 (-15.8%)	524.1 (-10.1%)	67.3 (-43.8%)	100	6.73 (-29.7%)
Subject #3. Control. No positive pressure. Subject seated.	115.7	104.4	628.1	541.0	87.1	100	8.71
Subject #3. After 5 minutes. Inspiratory pressure = 20 mm. Hg. Expiratory pressure = 25 mm. Hg.	115.3	106.0	624.9 (-0.5%)	553.0 (+2.2%)	71.9 (-17.5%)	100	7.19 (-17.5%)

The percentages indicate the changes from the normal.

MAYO AERO MEDICAL UNIT
Rochester, Minnesota

LIAISON REPORT NO. 4 h.
May 6, 1943

SUBJECT: Report of Liaison Officers, 1st Lt. C. B. Taylor, M.C., and 2nd Lt. J. P. Marbarger, A.A.F., attached to the Mayo Aero Medical Unit for activities from April 19 to May 5, 1943.

TO: Office of the Air Surgeon, Washington, D.C., and Chief, Aero Medical Research Laboratory, Wright Field, Dayton, Ohio.

FACTUAL DATA:

1. After returning from Wright Field several arterial punctures were tried during the week of April 19 with the new Bendix #17 pressure regulator. In all of the runs electrocardiograms were obtained on the subjects which will be evaluated in a subsequent report. During two of the runs the subjects got into difficulty at altitude and had to come down and in one the operator missed the puncture. Consequently no blood samples were obtained during that week.

2. It was observed that the Bendix #17 regulator did not function quite properly. The disc covering the exhaust valve did not seat properly with the result that it was impossible to hold pressure at altitude. This was overcome for a time by reseating the disc manually. With continued use, however, the disc again became displaced and had to be reset. It was thought best to return it to Wright Field and if possible exchange it for another regulator.

3. A series of arterial blood gas analyses were made at ground level. These results will be presented in a subsequent report.

4. During the week of April 25 Dr. Clark, flight surgeon, Willow Run Bomber Plant, brought test pilot, Murray Hawley, here for high altitude indoctrination. They were preparing to take the Thunderbolt to ceiling and therefore they were interested in positive pressure breathing. Pilot Hawley was indoctrinated in pressure breathing and made several flights to 46,000 feet, using the positive pressure vest and the Emerson regulator; he made one flight to 50,000 feet with positive pressure vest.

5. A series of arterial punctures were performed on Pilot Hawley at 46,000 and 44,000 feet using 8 inches water positive pressure as delivered by the Emerson regulator. Electrocardiograms were also obtained on him. These results will be presented in a subsequent report. It was observed that there was extreme fluctuation in pressure using this regulator and the subject's respiratory rate was only nine times per minute. Blood gas analysis after seven and seventeen minutes showed a rather high pH and corresponding high oxygen saturation and low carbon dioxide content. It was thought that this was due to the extreme pressure fluctuations and since subjects are limited no further blood work was deemed advisable until the regulators come from Wright Field.

6. A pneumograph was constructed to continuously record the respiratory rate of the subject. In order to record the respiratory rate simultaneously with electrocardiogram records and oximeter readings, an improved set-up with pneumograph was arranged which will be used as soon as the positive pressure regulator arrives from Wright Field.

Addendum: This afternoon with the use of Professor Akerman's pressure suit with 2½ lbs. pressure plus the Emerson positive pressure regulator delivering oxygen under a differential pressure of 7 inches of water J. P. Marbarger went to a pressure elevation equivalent of 56,964 feet corrected and remained above 50,000 feet for 15 minutes.

MAYO AERO MEDICAL UNIT
Walter M. Boothby, M.D., Responsible Investigator

Memorandum Report
to
Army Air Forces Materiel Center
Under Contract No. W535-ac-25329

SUBJECT: Arterial blood studies at altitudes of 44,000 and 46,000 feet, breathing under positive pressure with the Wright Field positive pressure mask and regulator developed by Major A. P. Gagge, A.C., and his group.

Serial Report: 4 j Date: May 1943

A. Purpose

1. To report on the arterial blood oxygen and carbon dioxide contents and partial pressures of arterial blood taken at 44,000 and 46,000 feet while the subject was breathing under eight inches of water or 15 mm. Hg positive pressure with the Wright Field pressure mask and regulator.

a. To report the pH's of arterial bloods taken under the conditions mentioned above.

2. To report on three cases of circulatory collapse during positive pressure breathing with a mask only.

B. Factual Data

1. Apparatus.

a. For details of technique and chemical procedures used see Serial Report, Series A, No. 4 c on arterial blood studies at altitudes to 50,000 feet, breathing under positive pressure in the positive pressure jacket, March 11, 1943.

b. For details on determinations of the partial pressure of oxygen and carbon dioxide see under (2) Factual Data of the preceding report.

2. Results.

a. In Table I the results of the chemical analyses of the (13) blood samples taken at 46,000 and 44,000 feet and the condition of the experiments are listed in tabular form.

b. The average arterial oxygen saturation of the twelve samples taken at 46,000 feet while the subject was breathing under eight inches of water or 15 mm. Hg positive pressure, was 78.0% and ranged from 68.9% to 84.7% saturation. The average arterial oxygen saturation of five of the samples taken after five minutes at 46,000 feet was 77.1% and ranged from 68.9% to 84.7% saturation. One sample at 44,000 feet with the subject breathing under 13 mm. Hg positive pressure showed an arterial saturation of 88.5%.

c. The pH's and CO_2 contents were slightly toward the side of alkalosis but a long way from the danger level. For a more detailed discussion of the dangers of tetany of alkalosis see paragraph (d) under Results (2 of Factual Data) in Serial Report, Series A, No. 4 c, March 11, 1943.

d. In Table II can be found the partial pressures of O_2 and CO_2. The pO_2, PCO_2, and water vapor tension have been totaled and can be compared with the barometric pressure at the time the sample was taken plus the positive pressure under which the subject was breathing. It will be noted that here too the two totals approximate each other very well.

e. It is of interest that one of our subjects, age 18, who had participated in all athletics in high school and college and had been accepted as a Navy Aviation Cadet and who, as far as physical examination revealed, was a healthy young male, developed a severe bradycardia after not more than one-half hour of positive pressure breathing of eight inches of water or 15 mm. Hg with a mask only. Electrocardiograms were being taken incidental to the arterial punctures; the subject's pulse rate, immediately after positive pressure breathing was started, rose to 96, but while at 46,000 feet not more than one-half hour after pressure breathing was started it slowed to 45 per minute and collapse became imminent; he was immediately brought to ground level and the positive pressure breathing was discontinued. Electrocardiogram tracings showed marked bradycardia with no evidence of heart block.

We have observed this reaction twice previously while subjects were breathing under twleve inches of water or 22½ mm. Hg at ground level.

One of these two subjects approached collapse in less than five minutes. His pulse rate normally 70, was 42 per minute and did not return to normal until five minutes after pressure breathing with mask only had to be discontinued. The other subject came near collapse after ten minutes of positive pressure of 22½ mm. Hg. His pulse was not observed. Both of these subjects were apparently normal healthy males on physical examination.

Conclusions

1. Subjects breathing under eight inches of water or 15 mm. Hg positive pressure at 46,000 feet have an average arterial oxygen saturation of 77.0% to 78.0% (by chemical analysis).

2. The CO_2 contents and pH's suggest that alkalosis from hyperventilation while breathing under positive pressure is not a serious problem. It can be noted (Table I) that after periods of as long as 23½ minutes at 46,000 feet the pH and CO_2 contents remained very near the normal levels.

3. It might be assumed from the totals of partial pressure of O_2, CO_2, and water vapor, compared with the barometric pressure plus the positive pressure that the partial pressures of O_2 and CO_2 reported in Table II are good approximations of the partial pressures of those gases that existed in the lungs at these altitudes of 44,000 and 46,000 feet.

4. Observations reported in Serial Report, Series A, No. 4 g to Army Air Forces Materiel Center, and from the observations reported in paragraph (e) under Results in this report, suggest that circulatory collapse may be a serious hazard in the use of the positive pressure mask and regulator with eight inches of water or 15 mm. Hg positive pressure without the support of a

pneumatic vest of some sort over the chest and abdomen.

Recommendations

1. Paragraph 4 under Conclusions above suggests that more extensive studies of the cardiovascular response to positive pressure breathing without a positive pressure vest should be carried out. A maximum level of positive pressure without counter pressure chest support which normal individuals could tolerate for long periods of exposure should be determined. It is our impression that eight inches or 15 mm. Hg positive pressure in a mask without chest and abdominal support will cause an appreciable number of cases of circulatory collapse in relatively short periods of time (½ to 1 hour).

Prepared by M. H. Power, Ph.D.

C. B. Taylor, 1st Lt., M.C.

J. P. Marbarger, 2nd Lt. A.A.F.

TABLE II A

ARTERIAL BLOOD OXYGEN STUDIES USING THE WRIGHT FIELD POSITIVE PRESSURE REGULATOR AND MASK

Subject	Altitude in 1000 of feet	Pos. pres. against which subj. breathed in mm. Hg	Time after attaining alt. before puncture was done	Arterial Blood: O_2 content Vol. % (Note)	Arterial Blood: O_2 capacity Vol.%	Arterial Blood: O_2 saturation %(chemical analysis)	Arterial Blood: O_2 saturation % oximeter	Arterial Blood: CO_2 content Vol.%	pH
C.B.T.	46	15	20 sec.	16.4	19.6	83.6	85	43.7	7.52
C.B.T.	46	15	15 min.	14.9	19.5	76.6	81	45.0	7.46
D.B.	46	15	2 min. 45 sec.	15.0	18.8	79.7	78	47.3	7.48
S.A.	46	15	3 min.	15.4	19.0	80.9	79	42.9	7.44
D.D.	46	15	2 min. 30 sec.	14.3	18.7	76.3	78	49.7	7.43
D.D.	46	15	19 min.	13.2	19.1	68.9	73	49.2	7.40
J.M.	46	15	3 min.	16.5	20.6	80.0	83	46.0	7.46
J.M.	46	15	22 min.	17.0	20.6	82.2	77	45.0	7.44
H.H.	46	15	3 min. 35 sec.	14.7	19.4	75.8	77	45.1	7.44
R.E.	46	15	3 min. 40 sec.	13.4	17.8	75.0	77	46.5	7.43
R.E.	46	15	23 min. 35 sec.	12.7	17.3	73.0	78	46.8	7.44
M.H.	46	15	7 min. 45 sec.	17.6	20.7	84.7	86	44.8	7.51
M.H.	44	13	4 min. 23 sec.	18.6	21.0	88.4	91	44.5	7.49

TABLE II B

Gaseous pressures of arterial blood using Wright Field positive pressure regulator and mask.

Total of partial pressures of oxygen, carbon dioxide, and water vapor compared with the barometric pressure plus positive pressure.

			Calculated partial pressure of gases in whole arterial blood (mm.Hg)				
Subject	Altitude in 1000s of ft. & barometric pressure	Positive pressure in mm. Hg	Total Bar. p. + pos. p. mm. Hg	pCO_2	pO_2	pH_2O	Total of pCO_2, pO_2, & pH_2O
C.B.T.	46 (106)	15	121	28	44	47	119
C.B.T.	46 (106)	15	121	31	40	47	118
D.B.	46 (106)	15	121	33	42	47	122
S.A.	46 (106)	15	121	32	45	47	124
D.D.	46 (106)	15	121	38	41	47	126
D.D.	46 (106)	15	121	41	36	47	124
J.M.	46 (106)	15	121	34	43	47	124
J.M.	46 (106)	15	121	34	46	47	127
H.H.	46 (106)	15	121	34	40	47	121
R.E.	46 (106)	15	121	36	40	47	123
R.E.	46 (106)	15	121	35	38	47	120
M.H.	46 (106)	15	121	30	46	47	123
M.H.	44 (115)	13	128	31	52	47	130

Mayo Aero Medical Unit
Walter M. Boothby, M.D., Responsible Investigator

Memorandum Report

to

Army Air Forces Materiel Center

Under Contract No. W535 ac-25829

SUBJECT: 1. Some preliminary observations on the partition of the total respiratory volume during positive pressure breathing with and without the counter-support of a pressure jacket.

2. Some preliminary observations on the effect of pressure breathing on the oxygen saturation of arterial blood.

Serial Report: 4 k — Date: May 1943

A. Purpose

1. To report the effect of positive pressure breathing with and without a positive pressure vest on the partition of the total respiratory volume. A study of three cases at ground level.

2. To report preliminary studies on the effect of positive pressure breathing (without a positive pressure vest for counter support) on the per cent of oxygen saturation of arterial blood.

B. Factual Data

1. Apparatus and Methods

a. To study the partition of the total respiratory volume during positive pressure breathing without the counter support of a pressure vest a recording spirometer was placed inside a compression chamber. The outlet of the spirometer was brought outside the chamber and connected with the Wright Field Pressure Mask. The recording spirometer was filled with oxygen; there was no CO_2 absorbing cannister in the system. The subject stood outside the chamber and respired into and out of the spirometer inside the chamber at 0, 10, 20, 30 and 40 cm. of water compression of the chamber; records of tidal air and the vital capacity were obtained. The partitions of the total respiratory volumes were calculated from the tracings obtained as described above; they were obtained within the first minute of positive pressure breathing at each level of positive pressure. Rest periods of from three to give minutes were allowed between each level of positive pressure breathing.

To study the partition of the total respiratory volume during positive pressure breathing with the counter support of a pressure vest the same procedure and equipment as above was used with the following addition: a pneumatic vest which covered the entire chest cage including the apices and the entire abdomen and back was connected to the compression chamber by means of two corrugated rubber tubes (inside diameter $1\frac{1}{4}$ in.) with one way flutter valves operating in opposite directions. The pneumatic vest, therefore, exerted the same pressure on the chest and abdomen as that exerted on the lungs via the spirometer.

b. To study the effect, if any, of positive pressure breathing without the counter support of a pressure vest on the per cent O_2 saturation of arterial blood the following procedure and techniques were used: A large gasometer was placed beside the decompression chamber; it was connected by a large rubber tube diameter 1¼ in, to a positive pressure mask inside the chamber which the subject wore. There was also an expiratory tube on the mask which led to the outside of the chamber. Each of these two tubes had appropriate one way flutter valves to control flow of inspiratory and expiratory air. The gasometer was kept at a constant level of fullness by flow from a cylinder of 13% oxygen. With equal barometric pressures inside and outside the chamber the subject breathed the gas mixture for seventeen minutes before the first sample was taken and thirty-four minutes before the second sample was taken.

Next the chamber was decompressed to approximately 15 mm. Hg lower barometric pressure than that on the outside (see Table 1 for exact differences of pressures). The subject was still breathing from the gasometer on the outside of the chamber which was subjected to exactly the same barometric pressure as it had been when the first two samples were taken without pressure breathing. Two blood samples were taken each at least fifteen minutes after the subject had been breathing this gas mixture under a positive pressure of 15 mm. Hg.

See Serial Report: Series A, No. 4E for details of collecting arterial samples and methods of chemical analysis.

2. Results

a. The results of the studies of the partition of the total respiratory volume during positive pressure breathing with and without counter support of a positive pressure vest have been shown in graphic form (exhibits not available). It should be pointed out that all three of these subjects had been doing positive pressure breathing for several months at the time these studies were made. It should also be pointed out that each of the partitions of total respiratory volumes were determined from tidal airs and vital capacities taken before one minute of positive pressure breathing had elapsed at each level of positive pressure. You will note (see graphs) the marked and progressive increase with increased pressure in supplemental air that developed in these short periods of time.

It is demonstrated in the graphs that with counter support of a positive pressure vest these changes are much less marked.

b. Chemical analysis of blood samples taken while a subject was breathing a 13% oxygen mixture with and without positive pressure but with the same total barometric pressure in the lungs (see Table 1) showed no increase in the per cent O_2 saturation of the arterial blood during positive pressure breathing.

Conclusions

1. Pressure breathing against 20, 30, and 40 cm. of water positive pressure with a mask only for periods as short as one minute produces definite changes in the supplemental air volume in subjects well trained in pressure breathing. This change is definitely improved by a positive pressure vest for counter support.

2. Positive pressure breathing in this one case did not increase the per cent O_2 saturation of arterial blood. Apparently in this one case the distention of the lungs to avoid shunting of blood through partially filled or collapsed alveoli which might result in incomplete aeration of the blood in the alveoli did not increase the per cent O_2 saturation of arterial blood.

Recommendations

1. Since the partition of the total respiratory volume is markedly changed during positive pressure breathing with a mask only it seems logical that studies should be carried out on animals to investigate the possibility of the development of emphysema after repeated and fairly lengthy exposures to these conditions.

2. Counter support of the chest and abdomen should be seriously considered if positive pressure breathing is to be used extensively.

3. The possibility of the marked increase in supplemental air (which would produce marked distention of the lungs) producing mechanical obstruction of the great veins in the chest and interfering with right heart filling should be investigated.

Prepared by C. B. Taylor, 1st Lt., M.C.

M. H. Power, Ph. D.

J. P. Marbarger, 2nd Lt.,AAF

Table 1

The following four samples were taken from the same subject during the same experiment in the order they are listed and under the conditions listed. Subject C.B.T. Date of experiment 4/27/43.

The subject was breathing 12.93% O_2 at ground level - with positive pressure during the 1st two samples and during the last two.

Bar. Press. mm.Hg	Pos. Press. mm.Hg	Bar.P. plus Pos.P.	Time breathing mixture before sample taken	O_2 content	O_2 capacity	O_2 saturation %(chemical analysis)	O_2 saturation % (oximeter).	CO_2 content	pH	pCO_2	PO_2	PCO_2	Bar.P.-pH_2O times O_2% mm.Hg
725	0	725	17 min. 40 sec.	16.7	20.1	82.7	87	44.9	7.37	40.0	50.3	90.3	86.7
725	0	725	34 min. 25 sec.	17.0	20.2	84.0	87	44.7	7.38	39.1	51.2	90.5	86.7
709.3	15.7	725	16 min. 5 sec.	17.3	20.3	85.5	84	43.2	7.40	36.3	53.0	89.3	86.7
710.4	14.6	725	16 min. 35 sec.	17.0	20.2	83.9	82	43.0	7.39	36.8	51.0	87.8	86.7

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Mayo Aero Medical Unit
Walter M. Boothby, M. D., Responsible Investigator

Memorandum Report
to
Army Air Forces Materiel Center
Under Contract No. W535ac-25829

SUBJECT: Partial pressures of oxygen and carbon dioxide of blood samples taken at simulated altitudes up to 50,000 feet, breathing under positive pressure in the positive pressure jacket.

SERIAL REPORT: 4 1 DATE: May 30, 1943

A. Purpose

1. To report the partial pressures of oxygen and carbon dioxide of blood samples taken at altitudes up to 50,000 feet.

2. To report a comparison of the total of (1) partial pressure of oxygen, (2) partial pressure of carbon dioxide, and (3) partial pressure of water vapor to the total of (a) the barometric pressure at the time the sample was taken, and (b) the amount of positive pressure under which the subject was breathing.

B. Factual Data

1. Apparatus and Method.

a. For details of experimental conditions and techniques used in collecting samples and blood gas analyses see Serial Report: Series A, No. 4c to Army Air ForcesMateriel Center, Under Contract No. W 535ac-25829.

2. The arterial blood O_2 and CO_2 partial pressures were calculated as follows:

a. Partial pressures of oxygen were taken from: Oxygen Dissociation Curves for Human Blood, Curves based on data of Major Dill, Wright Field, Aero-Medical Unit, by Lt. Mason Guest, A.C., Mayo Aero Medical Unit, June 9, 1942 (III-5A).

b. Partial pressure of carbon dioxide: The serum carbon dioxide tension of blood was calculated from the carbon dioxide content of whole blood using the procedure shown in figure 96, page 907, of Vol. 1 in Peters and Van Slyke Quantitative Clinical Chemistry. This calculation is based on mean values; the factors necessary to make these calculations are the carbon dioxide content of whole blood, pH, oxygen capacity and per cent oxygen saturation.

The pH scale is the ordinary pH scale. From the calculated serum carbon dioxide content and the pH of whole blood the carbon dioxide tensions of blood were calculated from the following equation, Peters and Van Slyke, Vol. 1.

$$CO_2 \text{ tension} = \frac{CO_2 \text{ content (Millimols)}}{0.0591\sigma \left(\frac{K'}{[H^+]} + 1\right)}$$

$$= \frac{CO_2 \text{ content (millimols)}}{0.0591\alpha(10^{pH} - 6.10) + 1}$$

1 millimol CO_2 = 2.226 volumes per cent

3. Results.

a. The results of the partial pressures of oxygen and carbon dioxide are shown in tabular form in Table 1; they are listed in the same order and are a supplementary report on the samples reported in Exhibit 1, Serial Report: Series A, No. 4 e to Army Air Forces Materiel Center on March 11, 1943.

1. In table 1 you will note the total of the partial pressures of CO_2, O_2 and water vapor in the arterial blood; you will also note the total of the barometric pressure at the time the sample was taken and the positive pressure under which the subject was breathing.

2. It is evident from the data in Table 1 that in most cases the total of the pO_2, pCO_2 and water vapor tension very closely approximates the total effective alveolar tension (barometric pressure plus posi tive pressure).

Conclusions.

Since (2) immediately above is the case it might be assumed that the partial pressures of O_2 and CO_2 reported in Table 1 are good approximations of the partial pressures of those gases in the lungs at these simulated altitudes of 41,000, 46,000 and 50,000 feet.

Prepared by M. H. Power, Ph. D.

C. B. Taylor, 1st. Lt., M. C.

J. P. Marbarger, 2nd Lt. AAF

Table 1

Total of Partial Pressures of Oxygen, Carbon Dioxide, and Water Vapor Compared with the Barometric Pressure plus Positive Pressure.

No.	Subject	Date	Altitude in thousands of ft. and B.P.	Positive press in mm. Hg	Total of B.P. + Pos. P.	P-CO_2 in.	P-O_2 mm.	P-H_2O Hg	Total pCO_2, pO_2 & pH_2O mm. Hg
1	C.B.T.	2/16/43	41 (134.2)	15	149.2	38.2	62	47	147.2
2	C.B.T.	2/23/43	46 (105.7)	15	120.7	32.0	52	47	131.5
3	C.B.T.	2/26/43	46 (105.7)	15	120.7	32.2	45	47	124.2
4	W.L.B.	2/22/43	46 (105.7)	15	120.7	34.1	44	47	125.1
5	H.H.	3/5/43	46 (105.7)	15	120.7	31.8	41	47	119.8
6	H.H.	3/2/43	46 (105.7)	15	120.7	34.8	41	47	122.8
7	R.E.	3/2/43	46 (105.7)	15	120.7	36.6	41	47	124.6
8	H.H.	3/5/43	46 (105.7)	15	120.7	35.7	39	47	121.7
9	R.E.	3/5/43	46 (105.7)	15	120.7	35.7	38	47	120.7
10	W.L.B.	3/3/43	46 (105.7)	15	120.7	33.6	36	47	116.6
11	R.E.	3/5/43	46 (105.7)	15	120.7	39.0	36	47	122.0
1	C.B.T.	2/16/43	41 (134.2)	0	134.2	37.1	60	47	144.1
2	C.B.T.	2/23/43	46 (105.7)	0	105.7	30.2	35	47	112.2
3	C.B.T.	2/26/43	46 (105.7)	0	105.7	31.6	35	47	113.6
4	W.L.B.	2/22/43	46 (105.7)	0	105.7	36.3	28	47	111.3
1	W.L.B.	3/3/43	46 (105.7)	32.6	138.3	30.3	76	47	153.3
2	C.B.T.	2/26/43	46 (105.7)	34.1	139.8	25.4	70	47	142.4
3	C.B.T.	2/23/43	46 (105.7)	31.9	137.6	28.1	69	47	144.1
4	R.E.	3/5/43	46 (105.7)	30.0	135.7	35.2	54	47	136.2
5	C.B.T.	3/3/43	50 (87.3)	33.3	120.6	23.9	56	47	126.9
6	C.B.T.	3/6/43	50 (87.3)	33.3	120.6	33.2	40	47	120.2
7	C.B.T.	3/6/43	50 (87.3)	31.9	119.2	32.0	40	47	119.0
8	C.B.T.	3/6/43	50 (87.3)	31.9	119.2	32.0	39	47	118.0
1	C.B.T.	2/8/43	Ground	15	—	38.0			
2	J.P.M.	2/8/43	Ground	15	—	37.0			

Mayo Aero Medical Unit
Walter M. Boothby, M.D., Responsible Investigator

Memorandum Report
to
Army Air Forces Materiel Center
Under Contract No. W535 ac-25829

SUBJECT: A comparison of per cent saturation of arterial blood by chemical determination, to per cent saturation of arterial blood as determined by the oximeter.

SERIAL REPORT: 4 m DATE: June 1943

A. Purpose

1. To report the correlation between per cent saturation of arterial blood (as determined by chemical analysis) and oximeter readings (Coleman Model 17, No. 5769) under the following conditions:

a. Breathing under positive pressure at altitude (32 arterial blood samples and oximeter readings).
b. Breathing gas mixtures low in O_2 under positive pressure at ground level (two samples).
c. At altitude breathing 100% O_2 with no positive pressure (four samples).
d. Breathing gas mixtures low in O_2 at ground level with no positive pressure (two samples).

B. Factual Data

1. These 40 arterial samples and oximeter readings were taken while studying arterial blood O_2 saturations during different types of pressure breathing. For details of technique and chemical methods, see Serial Report, Series A, No. 4c under Factual Data.

Results and Conclusions

1. The results are reported in graphic form (exhibit unavailable).

2. It can be noted (1) that 33 of the oximeter readings correlated + or - 5% with arterial blood O_2 saturation per cent determined by chemical analysis, (2) five of the oximeter readings were very different from arterial blood O_2 saturation per cent determined by chemical analysis, (3) that the oximeter had a tendency to give a higher arterial blood O_2 saturation per cent than the saturation per cents determined by chemical analysis.

Prepared by F. J. Robinson, M. D.
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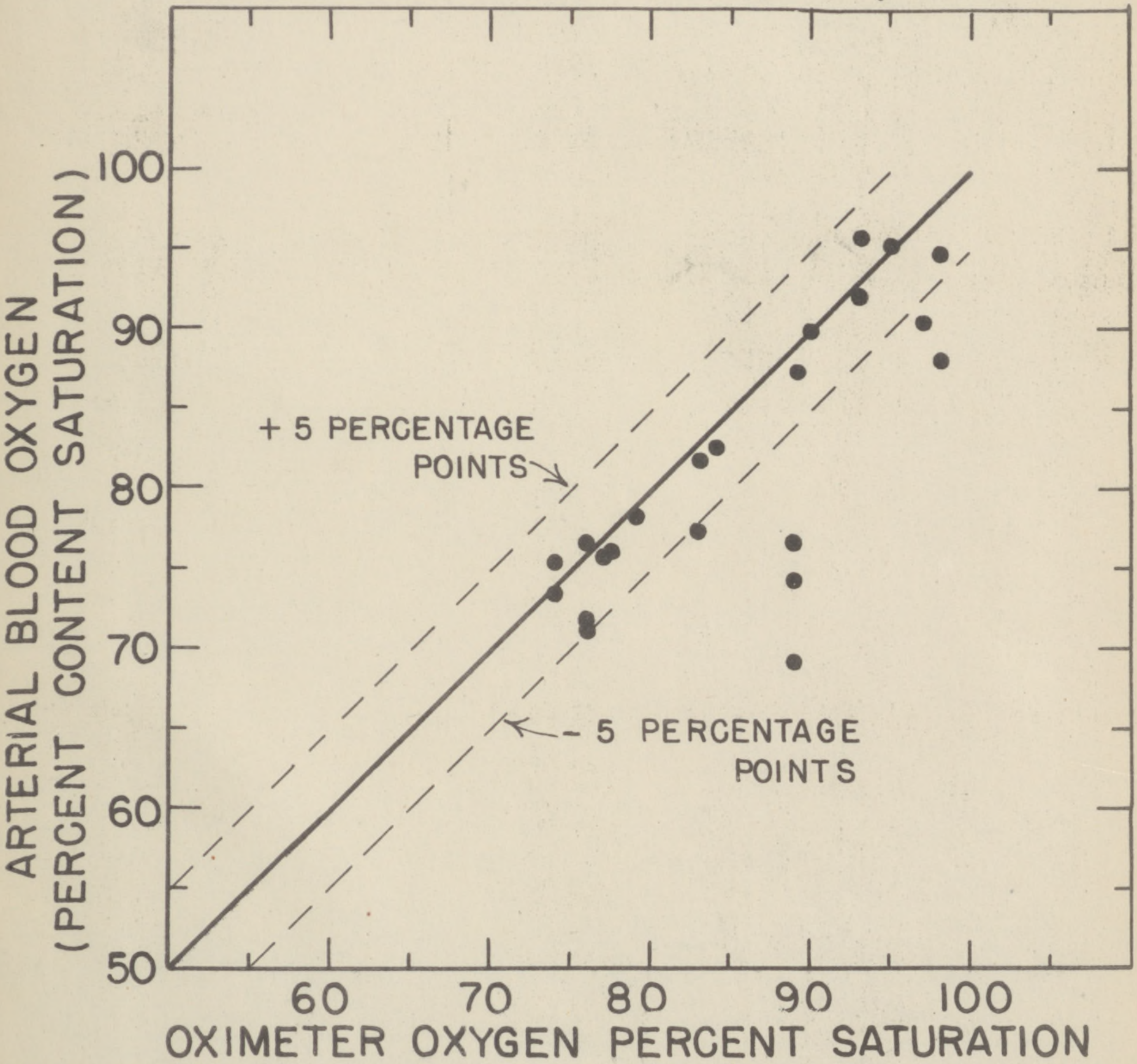
M. H. Power, Ph. D.
J. P. Marbarger, Ph. D.

MAYO AERO MEDICAL UNIT

ARTERIAL BLOOD OXYGEN CONTENT DETERMINATION VS OXIMETER READINGS COLEMAN OXIMETER - MODEL 17, NO. 5769



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Power, Taylor, Marbarger
March, 1943