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# GASEOUS ENVIRONMENT CONSIDERATIONS AND EVALUATION PROGRAMS LEADING TO SPACECRAFT ATMOSPHERE SELECTION

*by Edward L. Michel, George B. Smith, Jr., and Richard S. Johnston*

*Manned Spacecraft Center*
*Houston, Texas*

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# GASEOUS ENVIRONMENT CONSIDERATIONS AND EVALUATION PROGRAMS LEADING TO SPACECRAFT ATMOSPHERE SELECTION

By Edward L. Michel, George B. Smith, Jr., and Richard S. Johnston

Manned Spacecraft Center

## SUMMARY

The NASA Manned Spacecraft Center has been actively involved in the direction and support of programs leading to the selection and validations of the atmosphere for forthcoming Gemini and Apollo missions. This paper discusses the engineering and physiologic considerations involved, describes the investigations to validate spacecraft atmospheres, and discusses the implications derived from the results of these investigations.

## INTRODUCTION

The many considerations in the selection of the gaseous environment for manned spacecraft can be generally divided into two categories: engineering considerations and physiologic considerations. Ideally from a physiologic point of view, the optimum spacecraft atmosphere would be one which simulated normal or near-normal sea-level conditions. Since the present state-of-the-art has not advanced sufficiently to cope with the weight and volume penalty imposed by maintaining such an atmosphere, and since spacecraft decompressions cannot be precluded, compromises must be made which result in the selection of a spacecraft atmosphere that is not the optimum from all considerations, but which is adequate from practical considerations. The purpose of this paper is then: (1) to discuss the considerations involved in the selection of a spacecraft atmosphere, (2) to discuss the implications derived from the results of these investigations with comments as to indicated areas of future study, and (3) to describe the overall investigations that were made to validate the selected atmosphere. The results of these investigations sponsored by NASA are presented in appendixes A to D. The results are presented in this paper verbatim from final reports submitted in accordance with work conducted under NASA contracts R40, T-8630G, T-11317G, NASr-92, and T-9753-G.

## ATMOSPHERE SELECTION CONSIDERATIONS

The prime design requirements in any spacecraft system are: minimum weight and volume, minimum power usage, reliability, ease in maintenance, environmental compatibility, integration with other systems, and crew compatibility. From an engineering standpoint, necessary equipment must be provided in the minimum volume with a minimum of weight. Since power usage will affect both the volume and weight of a system, it must be maintained to a minimum. System reliability must be provided to meet the overall mission reliability factor. As the mission

time increases, the system must allow the crewman to perform inflight maintenance and repair. The systems must have the capability of withstanding both the naturally occurring and the induced environmental conditions of space flight, that is, vacuum, acceleration, heat, vibration, and such. Last, the system must integrate with other spacecraft systems to allow usage of common supplies and to serve more than one purpose.

In Project Mercury, a 100-percent oxygen, 5-psia spacecraft atmosphere was selected. Although such physiological considerations as maintaining an adequate oxygen partial pressure and protection against decompression sickness were examined, the decision to use this atmosphere was based primarily on engineering considerations similar to those previously described.

A comparison of the advantages and disadvantages of a single gas, that is, 100-percent oxygen atmosphere and a two-gas atmosphere, is shown in table I. From an engineering standpoint, the single gas, 100-percent oxygen at 5 psia, offers advantages in minimizing weight and leakage, in system simplicity and reliability, and in the extravehicular suit interface. From physiological considerations, it can be seen that the mixed gas atmosphere has advantages of offering protection against dysbarism and atelectasis, whereas the single gas atmosphere does afford greater decompression protection. Dysbarism protection afforded by the mixed gas atmosphere is a result of the 7.0-psi total operating pressure. The decompression protection afforded by the single gas atmosphere is a result of breathing 100 percent oxygen prior to any decompression.

Although ignition temperature as well as burning rates are favorably altered by a multiple gas atmosphere, the fire hazard reduction is not considered operationally significant in currently planned spacecraft. A fire in any atmosphere within a spacecraft is a very serious matter, and it is for that reason that emphasis on fire prevention has become a primary consideration in design.

TABLE I.- COMPARISON OF ARTIFICIAL ATMOSPHERES

| | Atmosphere | |
|---|---|---|
| | 5-psi oxygen | 3.5-psi oxygen, 3.5-psi nitrogen |
| Engineering considerations | | |
| Weight | X | |
| Leakage rates | X | |
| System simplicity | X | |
| Reliability | X | |
| Fire hazard | | X |
| Extravehicular suit interface | X | |
| Physiological considerations | | |
| Dysbarism protection | | X |
| Decompression protection | X | |
| Atelectasis protection | | X |

There are other considerations, both engineering and physiological, which have not been covered; only those considerations of major concern are discussed.

## PHYSIOLOGIC VALIDATION OF ATMOSPHERES

Table I shows that from a physiological standpoint the greatest unknown associated with the selection of a mixed gas, 50-percent oxygen—50-percent nitrogen, 7-psia atmosphere, was that of determining the potential decompression hazard which exists in the event of an inadvertent decompression. Accordingly, a NASA contract was awarded the U.S. Air Crew Equipment Laboratory (ACEL), Philadelphia, Pennsylvania, for the investigation of this potential decompression hazard associated in utilizing this mixed gas atmosphere. The results of this investigation are given as appendix A. Tests were conducted to determine the required time of preoxygenation at sea level to provide adequate protection against bends in the event of an early mission decompression and whether protection against bends can be achieved following a decompression after equilibration to the subject 50-percent oxygen—50-percent nitrogen, 7-psia atmosphere. The results of this investigation indicated that:

1. Three hours of preoxygenation at sea level can provide adequate protection against the onset of bends following a decompression in 40 seconds from sea level to an altitude of 35,000 feet.

2. Without any preoxygenation, 18 hours exposure to the 7-psia, 50-percent oxygen—50-percent nitrogen atmosphere is adequate to afford protection against bends following a decompression from this subject atmosphere to an altitude of 35,000 feet in 1 minute.

3. Some screening as to individual susceptibility to bends should be incorporated into the astronaut selection program.

The greatest physiological unknown associated with the 100-percent oxygen, 5-psia atmosphere was that of the potential hazard of atelectasis. That pure oxygen at low pressures (190 to 160 mm Hg) would present no pulmonary oxygen toxicity problem has been generally accepted; however, investigations were required to determine the need of an inert gas in any artificial atmosphere. Accordingly, a comprehensive atmosphere validation program was developed by the NASA Manned Spacecraft Center in cooperation with the Working Group on Gaseous Environment of the National Academy of Science. Both industrial and Department of Defense laboratories were utilized in the program. Table II summarizes the entire program. As can seen, the USAF School of Aerospace Medicine (SAM) carried out three investigations with the 100-percent oxygen, 5-psia atmosphere in which six subjects were tested. (See appendix B). Republic Aviation Corporation was awarded a contract to study four groups of six subjects each, exposed to 5-psia, 7.4-psia, and 3.8-psia pure oxygen atmospheres, as well as a control test at sea-level conditions, (appendix C). In addition, a joint project involving the U.S. Navy Air Crew Equipment Laboratory (ACEL) and the U.S. Navy Aviation Medical Acceleration Laboratory (AMAL) was established to study the combined effects on test subjects of acceleration and a 14-day exposure to a 100-percent oxygen atmosphere at 5 psia, (appendix D).

TABLE II.- ATMOSPHERE PHYSIOLOGIC VALIDATION PROGRAM

| Activity | Test Conditions | Number of Subjects |
|---|---|---|
| USAF School of Aviation Medicine (SAM) (3 Tests) | 100 percent oxygen, 5 psia, 14 days | 6 |
| Republic Aviation Corp. | 1. Control (Sea Level), 14 days | 6 |
| | 2. 100 percent oxygen, 5 psia, 14 days | 6 |
| | 3. 100 percent oxygen, 7.4 psia, 14 days | 6 |
| | 4. 100 percent oxygen, 3.8 psia, 14 days | 6 |
| U.S. Navy Air Crew Equipment Laboratory (ACEL) and U.S. Navy Aviation Medical Acceleration Laboratory (AMAL) | Launch G<br>100 percent oxygen, 5 psia<br>14 days<br>Reentry G | 6 |

In the three investigations conducted under this program, similar experimental procedure, instrumentation, and methods were utilized. In these experiments, emphasis was placed on: (1) determining whether atelectasis occurs in man during continuous exposure to pure oxygen at decreased pressure, and (2) if atelectasis does occur, to determine to what degree, its rates of development and recovery, and whether the condition can be reversed by predetermined respiratory maneuvers. Physiologic assessment of any physical alveolar collapse was obtained primarily through measurement of arterial $pO_2$ and $pCO_2$, pulmonary function testing, and chest X-ray examination. In addition to the studies described, cardiopulmonary studies, measurements relative to renal function, microbiological studies, performance studies, visual studies, and many others were performed in most, if not all, of the investigations.

The results of these investigations are presented in appendixes B to D; therefore, no attempt is made to discuss the results in detail. Briefly, however, the results of these investigations did indicate that, in general, the 100-percent oxygen, 5-psia atmosphere was well tolerated by all subjects for a 14-day period. Transient, minor difficulties similar to those expected from oxygen toxicity were evidenced in all investigations. These symptoms were restricted to eye irritation, coughing, substernal distress, and aural atelectasis. In addition, in the study made by the Republic Aviation Corporation, some unexpected urinary and hematological findings were encountered. In ACEL-AMAL investigation, alterations in the subjects' peripheral vision were evidenced during night adaption after they were returned to sea-level atmosphere from the test atmosphere. The interpretation of significance of these physiologic alterations has not been fully determined.

During the performance of this atmosphere validation program, two fires occurred: one at the SAM on the 13th day of a 14-day test, and one at the ACEL-AMAL test on the 17th day of a 20-day exposure test. The 20-day total duration of this investigation was a result of the six subjects entering the chamber on successive days. These fires demonstrated the expected hazard in using a pure oxygen atmosphere and the need for a careful screening of materials and electrical system designs and installations.

## IMPLICATIONS DERIVED FROM THE RESULTS OF THE ATMOSPHERE VALIDATION PROGRAM

A 100-percent oxygen, 5-psia atmosphere had been selected by the NASA for use in the Gemini and Apollo missions. The atmosphere validation program described in the appendixes was conducted for purposes of assessing the physiologic compatibility of this atmosphere for the anticipated mission of 14 days duration. The results of this program demonstrate that the subject atmosphere is generally well tolerated for a 14-day period. The unexpected and as yet unanswered abnormal urinary, hematological, and visual findings do not of themselves preclude the use of this atmosphere for the mission durations tested. These abnormal findings, however, may represent prohibiting factors in the use of the 100-percent oxygen, 5-psia atmosphere in missions of longer duration.

As a result of the atmosphere selection studies to date, two areas of needed research demonstrate themselves. First, an investigation should be made of the 100-percent oxygen, 5-psia atmosphere during exposure tests of longer duration (30 days) with special emphasis on those findings which appeared abnormal or questionable in the previous studies. Second, an investigation should be made of the use of other inert gases such as helium in a two-gas life-support system.

The fires that occurred during the atmosphere validation program demonstrated the known hazard of a pure oxygen atmosphere; however, it should be pointed out that the inclusion of an inert gas in any spacecraft atmosphere does not eliminate the serious problem of potential spacecraft fires. In other words, any habitable atmosphere will support combustion. Three factors are generally required to produce a fire: an oxygen-containing atmosphere, a combustible material, and an ignition source. The answer to the fire-hazard problem then appears to be one of diligent effort on the part of the spacecraft designers to be aware of the fire problems and to exercise strict control of both potential ignition sources and material selection.

## CONCLUDING REMARKS

Additional programs are currently being conducted to develop materials specifications which will provide testing procedures to determine potentially hazardous materials, to determine toxic products, and to permit a rigorous screening of materials for spacecraft applications. Exposure tests of longer than 14 days to artifical atmospheres have already been conducted. These exposure tests will extend the knowledge of the physiological effects of a 100-percent-oxygen environment as well as the comparative effects of several gas mixtures. Effects which appeared during the 14-day studies will be further elucidated and investigated during these exposure tests of longer duration.

Finally, there has been conjecture in the past that two-gas atmospheres are somehow to be preferred over pure oxygen atmospheres in spacecraft. Factual knowledge is inadequate. Within rather broad limits, either can be acceptable, but it has not been demonstrated that either is preferable. If, for long duration missions, a two-gas atmosphere were selected, it is still probable that pure oxygen would be the backup or emergency mode.

Manned Spacecraft Center,
National Aeronautics and Space Administration,
Houston, Texas, February 28, 1964

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APPENDIX A

# RAPID DECOMPRESSION HAZARDS AFTER PROLONGED EXPOSURE TO 50% OXYGEN–50% NITROGEN ATMOSPHERE

By LCDR Morris J. Damato, LCDR Francis M. Highly,
Edwin Hendler, and Edward L. Michel

Air Crew Equipment Laboratory,
Naval Air Engineering Center,
Philadelphia, Pennsylvania, and
Manned Spacecraft Center, NASA
Houston, Texas

Contract number R40

# RAPID DECOMPRESSION HAZARDS AFTER PROLONGED EXPOSURE TO 50% OXYGEN - 50% NITROGEN ATMOSPHERE

LCDR Morris J. Damato, MSC, USN, LCDR Francis M. Highly, MC, USN,

Edwin Hendler, Ph.D., and Edward L. Michel, M.S.

Air Crew Equipment Laboratory, Naval Air Engineering Center,

Philadelphia 12, Pennsylvania and

Manned Spacecraft Center, National Aeronautics and Space Administration,

Houston 1, Texas

The National Aeronautics and Space Administration (Manned Spacecraft Center) requested a study to determine the rapid decompression hazard following exposure to a proposed space capsule atmosphere. This hazard, after prolonged exposure to a 50% oxygen - 50% nitrogen atmosphere, can be minimized with adequate denitrogenation as indicated by the results of tests described in this report. Seventeen naval enlisted personnel participated in a total of 136 man ascents to simulated altitudes. Tests were conducted in the Air Crew Equipment Laboratory (ACEL) Bio-astronautical Test Facility with subjects breathing a 50% oxygen - 50% nitrogen mixture for various durations at a simulated altitude of 18,000 feet prior to rapid decompression to a simulated altitude of 35,000 feet. Results of this investigation indicate that a minimum of 18 hours under the above conditions, or three hours of pre-oxygenation at sea level, provide adequate protection against the decompression hazard of bends, with no apparent noxious or toxic effects due to exposure to the 50-50 mixture or 100% oxygen for durations tested.

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The opinions or assertions contained herein are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

## INTRODUCTION

The gaseous composition and barometric pressure of sealed space cabins utilized in flights of long duration present both mechanical and physiological problems. Among the aeromedical factors to be considered are toxicity and decompression hazards. Another consideration is the weight penalty required to replenish or refurbish these gases.

The study reported herein was designed to establish (1) the required time of pre-oxygenation for protection against a rapid decompression from sea level to 35,000 feet, (2) to establish the required time for equilibration during partial denitrogenation at a simulated altitude of 18,000 feet in a 50% oxygen - 50% nitrogen atmosphere for protection against rapid decompression, and (3) to determine the bends susceptibility of the test subjects as compared to the results presented in reference (1).

Because of the relatively small number of subjects involved in these tests, an attempt was made to avoid the possibility of misinterpretation by expressing the results as ratios rather than percentages. Thus, the ratio "2/12" is used to indicate that 2 out of a total of 12 subjects underwent some particular experience.

## METHOD

A total of 17 naval enlisted personnel attached to the ACEL served as subjects, and the tests to be described were conducted in the ACEL Bio-astronautical Test Facility. Subjects varying in age, weight, body build, and degree of previous exposure to simulated altitudes (see Table 1) were divided into three groups to effect a

similar degree of heterogeneity in each group. Each group consisted of four subjects; three of the original twelve subjects had to be replaced because of transfer or illness. An additional two subjects were utilized in the standardization tests. All subjects were examined by a physician before and after each test exposure, and a physician also served as an outside observer during each of the chamber runs.

Except for donning summer cloth helmets and the A13-A oxygen mask while breathing 100% oxygen, the subjects wore no special items of clothing or protective equipment. All or most of the subjects wore conventional summer flight coveralls or equivalent.

During periods of equilibration at 18,000 feet, except for eat, sleep, and rest periods, all subjects engaged in light exercise by playing cards between intervals of "marking time", 30 counts in 15 seconds every 15 minutes. This same exercise was continued during the period following decompression to 35,000 feet.

In standardization tests which were conducted at 33,750 feet, rate of ascent was 3,200 feet per minute, and the subjects engaged in a Masters Step Test exercise which consisted of ten step-ups on a nine-inch platform every 5 minutes. In both the standardization and experimental tests, the time of onset of bends and degree of severity were noted in each case with the subject indicating the area and describing the pain intensity. In most bends incidents, the subject continued to participate in the prescribed exercises, reporting any progression or regression. Removal of an individual from the chamber was determined by any one or a combination of factors, such as increase in intensity of pain, manifestation and progression in more than one joint or area, chokes symptoms, etc.

Reports of the subjects regarding their own conditions at altitude formed the principal basis for detecting bends. Disappearance or subsidence of symptoms upon recompression to 27,000 feet and below was interpreted as an objective indication of previously existing bends. Reports of numbness, tingling, pain, etc. which subsided or disappeared are indicated in this report as "symptoms". At least two days intervened between successive exposures of any one subject, and in most cases, a week or longer separated individual exposures.

TEST METHODS

A total of 136 man ascents were made in the Bio-astronautical Test Facility. Each of the three groups made one ascent under each set of conditions and procedures described below.

Standardization

1. Ascent to 33,750 feet at the rate of 3,200 feet per minute with the subjects donning oxygen masks at 10,000 feet to commence breathing 100% oxygen for the remainder of the test. Upon attaining a simulated altitude of 33,750 feet, the subjects engaged in a modified Masters Step Test exercise at 5 minute intervals which consisted of 10 step-ups on a 9 inch platform. (Only 16 of the 17 test subjects participated in this standardization test with 12 of the subjects repeating the same test a second time.)

Pre-oxygenation

2. Two hours pre-oxygenation at sea level, followed by a rapid decompression (40 seconds) to 35,000 feet, remaining at 35,000 feet for 3 hours.

3. Two hours pre-oxygenation at sea level, followed by a rapid decompression (80 seconds) to 35,000 feet and remaining there for 3 hours.

4. Two hours pre-oxygenation at sea level, rapid decompression to 35,000 feet (120 seconds) and remaining there for 3 hours.

5. Three hours pre-oxygenation at sea level, rapid decompression to 35,000 feet (40 seconds) and remaining there for 3 hours.

6. Two hours pre-oxygenation at sea level, decompression to 18,000 feet (60 seconds), undergoing equilibration at 18,000 feet for 12 hours in a 50-50 gas mixture (chamber purged with 50% oxygen - 50% nitrogen), followed by rapid decompression (60 seconds) to 35,000 feet and remaining there for 3 hours.

Equilibration

7. Rapid decompression to 18,000 feet (60 seconds) undergoing equilibration at 18,000 feet for 12 hours in a 50-50 gas mixture (chamber purged with 50% oxygen - 50% nitrogen), followed by rapid decompression (60 seconds) to 35,000 feet and remaining there for 3 hours.

8. Rapid decompression to 18,000 feet, undergoing equilibration at 18,000 feet for 18 hours in the 50-50 gas mixture as above, followed by a rapid decompression (60 seconds) to 35,000 feet and remaining there for 3 hours.

9. Rapid decompression to 18,000 feet (60 seconds), undergoing equilibration at 18,000 feet for 24 hours in a 50-50 gas mixture as above, followed by a rapid decompression (60 seconds) to 35,000 feet and remaining there for 3 hours.

In addition to the above tests, those four subjects determined to be most bends prone participated in the following test: Three hours pre-oxygenation at sea level, 60 second decompression to 18,000 feet,

loiter at 18,000 feet for 6 hours in a 50-50 gas mixture atmosphere, followed by a 60 second decompression to 35,000 feet and remaining there for 3 hours. All four subjects engaged in playing cards and in the marking time exercise described previously, and all four subjects completed the test without incident.

## RESULTS

### Standardization

Table 2 shows a comparison of subject characteristics and forced descents obtained by F. M. Henry (reference No. 1) for the same test conditions. In the present study, only two man-ascents (both by the same subject) did not terminate in a forced descent, indicating a comparatively high bends-prone group, despite the wide range in age and weight. Time of onset of bends ranged from 8 to 81 minutes with time of removal or forced descents ranging from 11 to 62 minutes, both times expressed as time after attaining 33,750 feet.

Table 3 presents the ratio and time range of appearance of bends and forced descents. The wide range of results are as follows:

### Pre-oxygenation

In Test 2 (2 hours of pre-oxygenation at sea level followed by a 40 second decompression to 35,000 feet), 10 of 12 subjects reported symptoms (range of onset was 13 - 119 minutes) resulting in 7 of 12 forced descents (range of time 22-126 minutes).

In Test 5 (3 hours of pre-oxygenation at sea level followed by a 40 second decompression to 35,000 feet), only 1 of 12 subjects had to be removed (132 minutes after decompression), having reported symptoms 106 minutes following the decompression.

Equilibration

In Test 7 (no pre-oxygenation, 12 hours at 18,000 feet in a 50-50 gas mixture followed by a 60 second decompression to 35,000 feet), 10 of 12 subjects reported symptoms (range of onset was 0 or during the time of decompression to 44 minutes) resulting in 3 of 12 forced descents (time ranging from 0 or immediately upon arrival at 18,000 feet to 132 minutes).

In Test 8 (no pre-oxygenation, 18 hours at 18,000 feet in a 50-50 gas mixture followed by a 60 second decompression to 35,000 feet), only 1 of 12 subjects reported symptoms (18 minutes following decompression), but no forced descents resulted.

Table 4 presents the protection or degree of symptomology in those tests other than standardization tests.

DISCUSSION

To validate the report of bends by the subjects, a "dummy" run at low level conditions (5,000 feet in a 40% oxygen - 60% nitrogen atmosphere for 12 hours followed by a decompression to 15,000 feet on 100% oxygen) was conducted. The actual conditions of the test were withheld from the subjects. The test was conducted using slower rates of ascent and simulated inlet noises. The chamber operators and observers were informed of the nature and intent of the test so as not to reveal to the test subjects the actual altitudes and rates of climb. There was no report of bends.

The results corroborate some previous observations, especially with regard to the irregular and unpredictable pattern in the manifestation of bends. The range of bends onset is extremely wide (0 - 152 minutes)

as is the pattern of progression or regression. Thus, of the seven man-ascents engendering onset of bends during the decompression to or on arrival at 35,000 feet, only one resulted in a forced descent. Yet in the one ascent where onset of bends occurred at 152 minutes following decompression, the subject requested removal two minutes following onset.

In the 96 man-ascents presented in Table 3, bends onset ranged from 99 to 152 minutes in 12 of the ascents with 7 of those 12 terminating in forced descents. In those cases where bends onset was not severe initially, the pain eventually radiated from one joint to several, lending credence to the theory of the growth of "silent" or "micro" bubbles.

In all but three cases, onset of bends occurred after subjects were decompressed to 35,000 feet. In these three cases (all three men were members of the same group on the same test), one of the subjects reported "moderate plus" pain in the shoulder after approximately 4 hours at 18,000 feet on a 50% oxygen - 50% nitrogen gas mixture; the second subject reported a throbbing pain in the knee after 7 hours at 18,000 feet; the third subject reported numbness in the knee after 5 hours at 18,000 feet. The first and second subjects mentioned above had to be removed from the chamber within 5 minutes following decompression to 35,000 feet, while the third subject was removed one hour following decompression to 35,000 feet. Questioning revealed that on the day before the test the four subjects had overextended themselves in a physical training program apparently too strenuous for their state of prior physical conditioning. The test results were negated and the test was subsequently repeated. This incident emphasized the need for proper physical conditioning as protection against the bends.

The temporal variations and the irregular and unpredictable pattern of bends (reference (2)) is indicated by the results noted in Table 5, significantly so wherein 3 of the 4 subjects reporting bends in Test 4 (24 hours at 18,000 feet on 50% oxygen - 50% nitrogen) did not experience any bends symptoms in Test 8 (18 hours at 18,000 feet on 50% oxygen - 50% nitrogen). Also notable, only Subject K (EFM) reported bends in all his 6 tests though pain never recurred in the same area. However, 9 of 13 subjects reporting bends did experience a recurrence of bends in the same area on more than one test. In addition, 4 of the 9 subjects reported pain in the same joint or area each time they experienced bends.

Chi square analyses of the various test conditions in protection against bends are reported in Tables 5, 6 and 7. As indicated in Table 5, with zero hours of equilibration and two hours of pre-oxygenation, there is no significant difference between decompression times of 40, 80 and 120 seconds with regard to bends protection.

Table 6 indicates that 18 hours or more of equilibration at 18,000 feet in a 50% oxygen - 50% nitrogen atmosphere provides significant increased bends protection.

The data (Tables 6 and 7) indicate increased pre-oxygenation may greatly reduce the required equilibration time required to give adequate bends protection. In three tests with 2 hours of pre-oxygenation and 12 hours of equilibration, only 1/12 subjects reported symptoms while again only 1/12 subjects reported symptoms after 3 hours of pre-oxygenation and no equilibration time.

Chi square analysis for pre-oxygenation time in protection against the bends is presented in Table 7, indicating a significant increase in protection after 3 hours of pre-oxygenation as compared to 2 hours

of pre-oxygenation. However, since the data presented in Table 7 involve but 24 man-ascents as compared to 36 man-ascents presented in Tables 5 and 6, the data are considered to be too limited to derive a firm conclusion.

## CONCLUSIONS

Based on the results of this investigation, the following are concluded:

a. In rapid decompression followed by prolonged exposure to altitudes of 35,000 feet, the following procedures preceding the decompression have been found to minimize the incidence of bends:

1. Breathing 100% oxygen for at least 3 hours at sea level.

2. Breathing a 50% oxygen - 50% nitrogen gas mixture for a minimum of 18 hours at an altitude equivalent of 18,000 feet.

3. Breathing 100% oxygen for two hours at sea level followed by breathing a 50% oxygen - 50% nitrogen gas mixture for 12 hours at an altitude equivalent of 18,000 feet.

b. During repeated exposures, recurrence of bends in the same area is very likely.

c. The manifestation of bends may be delayed for more than two hours following decompression.

d. Characteristic sensations of bends may be either localized in one area or may radiate eventually to involve more than one area simultaneously.

## REFERENCES

1. Henry, F. M., Cook, S. F., and Lund, D. W.: An Effective Decompression Sickness Classification Test, and a Method for Evaluating its Usefulness, Committee on Aviation Medicine Report No. 421 (1945).

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TABLE 1

CHARACTERISTICS AND PREVIOUS ALTITUDE EXPERIENCE OF INDIVIDUAL SUBJECTS

| Subject | Age | Ht. (In.) | Wt. (Lbs.) | Previous Experience: Runs at Altitude 35M-43M | Previous Experience: Bends |
|---|---|---|---|---|---|
| A (CJS) | 40 | 68 | 184 | 60 *(1) | 2 |
| B (HWD) | 33 | 71 | 185 | -- | - |
| C (VLP) | 28 | 70 | 148 | 37 *(2) | 1 |
| D (RWC) | 24 | 71 | 154 | -- | - |
| E (MEM) | 33 | 68 | 170 | 68 *(10) | 2 |
| F (KER) | 39 | 70 | 201 | -- | - |
| G (KJF) | 28 | 71 | 150 | 48 | 1 |
| $G_1$ (JWB) | 20 | 68 | 184 | -- | - |
| H (AGR) | 24 | 68 | 180 | 48 | 1 |
| $H_1$ (WCA) | 32 | 73 | 210 | -- | - |
| J (GGM) | 32 | 73 | 210 | 53 *(5) | 1 |
| K (EFM) | 23 | 70 | 160 | 25 | - |
| $K_1$ (LTL) | 19 | 70 | 160 | -- | - |
| L (WFE) | 21 | 70 | 165 | 24 | - |
| M (JVA) | 22 | 70 | 155 | 4 | - |
| N (HL) | 22 | 71 | 175 | -- | - |
| P (WFB) | 24 | 72 | 170 | -- | - |

*(x) number of exposures above 43,000 feet

Only Subject E (MEM) participated in previous low pressure chamber runs involving rapid decompression.

TABLE 2

COMPARISON OF SUBJECTS AND FORCED DESCENTS IN BENDS SUSCEPTIBILITY TEST

| | F. M. Henry, et al. (Ref.(1)) | ACEL |
|---|---|---|
| Number of subjects | 156 | 16 |
| Number of man runs | 290 | 28 |
| Age range (years) | 17 - 23 | 19 - 40 |
| Mean age (years) | 18.4 | 25.4 |
| Mean weight (lbs) | 158 | 161.8 |
| Forced descents | 33% | 26/28 |

TABLE 3

INCIDENCE AND TIME OF ONSET OF BENDS UNDER VARIOUS TEST CONDITIONS

| Tests and Conditions | Symptoms Ratio | Symptoms Range of Time of Onset (Min.) | Forced Descents Ratio | Forced Descents Time (Range) (Min.) |
|---|---|---|---|---|
| (1) Standardization | 12/12 | 8-81 | 10/12 | 11-62 |
| (2) P-2; E-0; T-40 | 10/12 | 13-119 | 7/12 | 22-126 |
| (3) P-2; E-0; T-80 | 10/12 | 40-152 | 5/12 | 65-154 |
| (4) P-2; E-0; T-120 | 10/12 | 16-134 | 6/12 | 44-158 |
| (5) P-3; E-0; T-40 | 1/12 | 106 | 1/12 | 132 |
| (6) P-2; E-12; T-60 | 1/12 | 21 | 1/12 | 86 |
| (7) P-0; E-12; T-60 | 10/12 | *0-44 | 3/12 | *0-132 |
| (8) P-0; E-18; T-60 | 1/12 | 18 | 0/12 | -- |
| (9) P-0; E-24; T-60 | 4/12 | *0-114 | 1/12 | 20 |

P - Pre-oxygenation time (sea level) in hr.

E - Equilibration time while breathing a 50% $O_2$–50% $N_2$ gas mixture, in hr.

T - Decompression time, in sec. (In runs involving equilibration, decompression time from sea level to 18,000 ft was 60 sec T, expressed in tables, is decompression time from 18,000 ft to 35,000 ft)

*0 = onset of bands symptoms and/or forced descent occurred during decompression to, or arrival at, 35,000 ft.

TABLE 4

DECOMPRESSION SICKNESS PROTECTION IN TWELVE SUBJECTS

| Pre-oxygenation | Decompression 40" | Decompression 80" | Decompression 120" | Time at 18,000 Ft 12 Hrs | Time at 18,000 Ft 18 Hrs | Time at 18,000 Ft 24 Hrs |
|---|---|---|---|---|---|---|
| 0 | -- | -- | -- | 7(1)[4] | 0(0)[1] | 1(0)[3] |
| 2 hrs | 7(0)[3] | 5(0)[5] | 6(1)[2] | 1(0)[0] | | |
| 3 hrs | 1(0)[0] | -- | -- | | | |

Key: Unenclosed number indicates forced descent.

( ) indicates moderate decompression sickness.

[ ] indicates mild decompression sickness.

TABLE 5

EFFECT OF DECOMPRESSION TIME ON BENDS

Test Conditions: 2 hr. pre-oxygenation
No. equilibration
T - Decompression time in sec. (sea level to 35,000 ft.)

| T | No. Subjs. | No. having Symptoms | No. Forced Descents |
|---|---|---|---|
| 40 | 12 | 10 | 7 |
| 80 | 12 | 10 | 5 |
| 120 | 12 | 10 | 6 |

$X^2$ for symptoms - 0

$X^2$ for forced descents - 0.8; df = $2.5 < p < .7$

TABLE 6

EFFECT OF EQUILIBRATION TIME ON BENDS

Test Conditions: No pre-oxygenation
Decompression time (sea level to 35,000 ft)
In 60 sec.
E - Equilibration time in hr at 18,000 ft in
50% $O_2$–50% $N_2$ atmosphere

| E | No. Subjs. | No. having Symptoms | No. Forced Descents |
|---|---|---|---|
| 12 | 12 | 10 | 3 |
| 18 | 12 | 1 | 0 |
| 24 | 12 | 4 | 1 |

$X^2$ for symptoms - 14.4 df = 2 $p < .001$

$X^2$ for forced descents not calc. - expected freqs. too low

TABLE 7

EFFECT OF PRE-OXYGENATION TIME ON BENDS

Test Conditions: No equilibration
Decompression time (sea level to 35,000 ft.)
In 40 sec.
P - Pre-oxygenation time at sea level in hr.

| P | No. Subjs. | No. having Symptoms | No. Forced Descents |
|---|---|---|---|
| 2 | 12 | 10 | 7 |
| 3 | 12 | 1 | 1 |

$X^2$ for symptoms - 10.2 df - 1 $p < .005$

$X^2$ for forced descents - 4.8 df - 1 $p < .05$

# APPENDIX B

## PHYSIOLOGIC STUDIES RELATED TO SPACECRAFT ATMOSPHERE SELECTION

### I. PHYSIOLOGIC EFFECTS OF EXPOSURE TO INCREASED OXYGEN TENSION AT 5 psia

By Thomas E. Morgan, Jr., M.D., Ralph G. Cutler, Capt. USAF, MC, Emil G. Shaw, Frode Ulvedal, Ph.D., John J. Hargreaves, Capt., USAF, James E. Mayer, Capt., USAF, Richard E. McKenzie, Major, USAF, and B. E. Welch, Ph.D.

### II. EFFECT OF VENTILATING AIR FLOW ON HUMAN WATER REQUIREMENTS

By B. E. Welch, Ph.D., R. G. Cutler, Capt., USAF, J. E. Herlocher, Capt., USAF, MC, J. J. Hargreaves, Capt., USAF, F. Ulvedal, Ph.D., E. G. Shaw, M.A., G. B. Smith, Major, USAF, MC, H. J. McMann, B. S., and L. Bell, B.S.

### III. BACTERIOLOGICAL STUDIES OF TWO-MAN SPACE CABIN SIMULATOR

By James E. Moyer, Capt., USAF, and Y. Z. Lewis, SSGT, USAF

USAF School of Aerospace Medicine,
Brooks Air Force Base, Texas, and
Manned Spacecraft Center, NASA,
Houston, Texas

Contract numbers T-8630G and T-11317G

# I. PHYSIOLOGIC EFFECTS OF EXPOSURE TO INCREASED OXYGEN TENSION AT 5 psia

Thomas E. Morgan, Jr., M.D.,[2] Ralph G. Cutler, Capt., USAF, MC, Emil G. Shaw, Frode Ulvedal, Ph.D., John J. Hargreaves, Capt., USAF, James E. Moyer, Capt., USAF, Richard E. McKenzie,[3] Major, USAF, MSC, B. E. Welch, Ph.D.[4]

1. This work was supported in part by the Manned Spacecraft Center, NASA, Houston, Texas.
2. Present Address: University of Washington, Seattle, Washington
3. Chief, Stress and Fatigue Section, Psychobiology Branch, Neuropsychiatry Department, USAF School of Aerospace Medicine, Brooks AFB, Texas.
4. Chief, Environmental Systems Branch, Bioastronautics Department, USAF School of Aerospace Medicine, Brooks AFB, Texas

## INTRODUCTION

The selection of the proper atmosphere for a particular spacecraft must be determined by careful consideration of both the engineering and biomedical design requirements in conjunction with the mission profile. Consideration of the mission profile might typically include duration, duties to be performed, requirement for the use of extravehicular devices, probability of decompression, etc. In order to adequately evaluate both the engineering and biomedical requirements, enough data pertinent to each must be available and must be available in such a form to allow its use for the specific questions pertinent to a given mission profile. It is for this latter area, that of obtaining biomedical data pertinent to prolonged space missions, that the experiments reported herein were conducted.

The utilization of a spacecraft of atmospheric conditions vastly different from the earth's atmosphere has required considerable knowledge of man's response to prolonged exposure to that atmosphere. Previous prolonged experiments have been conducted at various pressures and atmospheric compositions for varying lenths of time. For example, data is in the literature describing the effects of 17-day exposures to an altitude of 33,500 feet with a $pO_2$ of 174 mm Hg (1,2)*, of 17-day exposures to ground level pressure with normal atmospheric conditions (2, ), of 30-day exposure to an 18,000 foot altitude with a $pO_2$ of 150 mm Hg (1), and of 7-day exposure to an altitude of approximately 10,000 feet, $pO_2$ of 418

*Numbers in parentheses indicate references at end of paper.

mm Hg (3). A gap in knowledge has existed, however, in the area of 27,000 feet with an atmosphere consisting of primarily oxygen. The two 14-day experiments reported here form a portion of a coordinated program developed by the sponsoring agency and with close technical liaison from the Gaseous Environment Working Group, Space Science Board of the National Academy of Science to at least partially close that gap.

The objective of these studies in that program was to determine the effect on man of a 14-day exposure to a cabin altitude of 27,000 feet ($P_B$ = 258 mm Hg) with as high a $pO_2$ as possible at that altitude. Primary emphasis was given to arterial and alveolar studies, as well as to the effect of this atmosphere on psychomotor performance.

## METHODS

The two 14-day experiments were conducted in the two-man space cabin simulator described previously (4). The atmosphere was maintained by the injection of externally stored gaseous oxygen into the simulator and by the absorption of carbon dioxide by on-board stores of baralyme. Total pressure was sensed by an absolute pressure transducer; $pO_2$ by a Beckman oxygen analyzer, Model F-3; and $pCO_2$ by a Beckman carbon dioxide analyzer, Model 15-A. The $pH_2O$ was calculated from relative humidity data obtained with an El-Tronic hygrometer, Model 101C, and from temperature data obtained with a Minneapolis-Honeywell resistance bulb, Model 6630. These results were cross-checked with a modified Assman-type wet bulb-dry bulb thermometer. Nitrogen was calculated by difference, or

determined with a gas chromatograph using a molecular sieve column, with periodic checks against a Waters nitrogen analyzer, Model A-6. The ambient gaseous conditions that were maintained during these tests are shown in Table I. Mean cabin temperature was 21.6°C and mean relative humidity was 42.4 percent.

The four test subjects (all volunteers and all Air Force pilots) had the physical dimensions shown in Table II. During the experiments, the men wore loose-fitting, "hospital" greens. Prior to ascent to altitude, all subjects received a minimum of 2.5 hours of pre-oxygenation for bends protection.

The daily schedule of the subjects (Table III) was set to provide the men with a 5-hour period at night for uninterrupted sleep. The two "ground-control" periods were for collecting physiologic data, as well as providing an opportunity for the men inside the simulator to completely relax. The schedule was rotated daily in order to obtain both physiologic and performance data on both men at different times during the normal, earth-oriented, 24-hour day. Table IV shows the frequency of sampling of the various parameters measured during each of these experiments, as well as the general schedule followed during each "ground-control" period.

The parameters considered to be of primary importance in these experiments were arterial oxygen and carbon dioxide partial pressure ($P_aO_2$ and $P_aCO_2$, respectively), arterial pH, arterial saturation (calculated from the Dill, et al (5) nomogram), alveolar oxygen ($P_AO_2$) and carbon dioxide ($P_ACO_2$), hematocrit, vital capacity, posterior-anterior chest

x-ray at altitude and psychomotor performance. With the exception of pre-flight control values, all measurements or samples were obtained in the environment described in Table I. Blood and gas samples were obtained at altitude, passed through a sample lock and analyzed at ground level. Arterial blood samples were placed in an ice bath within 2-3 minutes after drawing and the blood gas tensions and pH were determined directly, using an Instrumentation Laboratory Model 113 pH and blood gas analyzer. Arterial samples were obtained by means of an in-dwelling arterial needle. Alveolar gas tensions were determined on gas samples collected by the Haldane end expiratory method (6) with subsequent analysis at ground level by the Scholander technique. Hematocrits were determined on peripheral venous blood samples by the micromethod (7). Vital capacity was determined by using a Custom Engineering Servo-Spirometer with the amplifier and readout on a Sanborn recorder located externally to the simulator. Duplicate forced vital capacity measures were made at each period indicated in Table IV and the results expressed as the average of the two, corrected to BTPS. Posterior-anterior chest x-ray films were made at altitude, using a 100 Kvp machine, shooting through a 5 mm thick aluminum port. Psychomotor performance was assessed by the operator system described previously (8,9). Programming was accomplished by punched Mylar tapes, a tape reader and a decoding device. The signal rate was held constant at 500 per hour.

When indicated by lower than expected arterial $P_{O_2}$ values (increased alveolar-arterial oxygen gradient), various techniques were performed to determine their efficacy in increasing $P_aO_2$. The first technique was

the forced vital capacity maneuver, repeated twice, followed by obtaining another arterial blood sample. If indicated or possible, this was followed by a maximum breathing capacity maneuver and another blood sample. Finally, intermittent positive pressure breathing (IPPB), using a modified Bennett valve, was used. The schedule for IPPB was five breaths at pressures of 10, 20 and 25 cm of water with the five breaths at 25 cm being followed by a final arterial sample.

In order to have a daily assessment of the test subjects, electrocardiograms, pulse rates, body temperatures, blood pressures and respiratory rates were monitored as shown in Table IV. The techniques utilized have been described previously (1).

Other parameters that were determined during these studies were considered to be of secondary importance and were added to the experimental protocol to provide additional pertinent information. These included routine hematology, blood electrolytes, urinalyses, energy and water requirements, body weight, 24-hour urinary steroid and catecholamine excretion (10) and bacteriologic studies of the test subjects and atmosphere. For the determination of the interchange of microorganisms, throat swabs and stool specimens were collected from each individual prior to, during, and following each experiment and were subjected to bacteriological analysis to determine any significant differences in microflora. Particular attention was given to the isolation of certain "marker" organisms, characteristically harbored by only one of the individuals. In addition, blood agar petri plates were exposed to the circulating

cabin atmosphere to determine if there was a cumulative increase in the number of microorganisms in the atmosphere of the simulator as the experiment progressed.

## RESULTS AND DISCUSSION

The results of the arterial studies are shown in Table V, along with the alveolar oxygen and carbon dioxide partial pressures and calculated alveolar-arterial oxygen gradients ($A_aO_2$ gradient). The $P_aO_2$ values were obtained by adherence to the schedule shown in Table IV wherever possible. In test subjects 17 and 18, arterial studies were not possible on day one of the experiment due to the occurrence of bends in subject 18 which necessitated a very slow ascent to the experimental altitude. The arterial $P_{O_2}$ values obtained during these two experiments all appear to be within normal physiologic limits for this environmental condition, although somewhat low. This is probably related to several factors, including (a) a more pronounced effect of "normal" physiologic shunt while breathing a higher $P_{O_2}$; (b) a lapse of approximately 10 minutes time between drawing the blood sample and analysis which permits oxygen consumption by the red cells; and (c) a lack of accurate body temperature at the time the blood sample was obtained. As a consequence, therefore, the alveolar-arterial oxygen gradient was apparently increased at altitude. This apparent increase was also observed, however, in the two subjects (17 and 18) at ground level while breathing a gas mixture which provided $P_AO_2$ values equivalent to those found at this experimental altitude. Periodic comparison of calculated saturation versus

determined saturation showed good agreement and in no instance was significant desaturation observed. The $P_aO_2$ levels observed were estimated to represent a venous-arterial shunt of approximately two-four percent of the cardiac output. This equals or slightly exceeds the "normal" physiologic shunt of approximately two percent, but does not represent a physiologic problem.

Several techniques were utilized to determine their effect on $P_aO_2$ or the $A_aO_2$ gradients observed in these studies. It should again be noted that the $A_aO_2$ gradients were calculated utilizing alveolar data obtained at the beginning of each series of arterial studies. A forced vital capacity or maximum breathing capacity maneuver was equally effective and each was non-additive to the other (Table VI). The use of IPPB was effective in only one instance (subject #17). This latter finding is in disagreement with data obtained with anesthetized dogs (11). The effectiveness of the forced vital capacity and maximum breathing capacity might be related to hyperventilation, an increase in blood flow as a consequence of the maneuvers or to aeration of an unaerated portion of the lung. If this latter point were true, these simple maneuvers could be of significant prophylactic use in proposed spacecraft experiments, either in preventing absorptional atelectasis or, possibly, in removing compressional atelectasis induced by a "g" forces during launch or during mid-course maneuvers.

No evidence for pulmonary atelectasis was found on the chest x-rays. The radiographs were of good to excellent quality and no technical problems associated with the experimental arrangement were encountered.

Vital capacity reduction was apparent from the outset of experimental exposure and averaged 2.9 percent less than pre-experiment levels (Table VII). The reduction was significant in three of the four test subjects, two at the 0.01 level and one at the 0.05 level. There was a prompt return of vital capacity to pre-experimental levels in all but subject 15 when the simulator pressure was returned to normal ambient laboratory pressure. This slight decrease in vital capacity following ascent to altitude has been noted during previous experiments (1,2) conducted at reduced pressures and does not appear to be indicative of atelectasis.

The effect of exposure to the 5 psi, oxygen atmosphere on hematocrit is shown in Table VIII. There appears to be a slight drop in hematocrit during the first seven days of exposure, followed by a return to pre-flight levels during the last seven days of exposure and post-flight. The meaning of this initial decline is not clear at this time and is undoubtedly complicated by repeated blood samples being obtained both during the pre-flight physical examination period and the experimental period. A comparison of the average experimental values versus the control values shows a statistically significant drop in hematocrit in three of the four subjects (subject 15, $p<0.1$; subject 16, $p<0.01$; subject 17, $p<0.05$; and subject 18, $p<0.05$). As a result of a pronounced drop in hematocrit from a pre-experiment high of 48 percent to 38 percent in the early phase of the experiment, subject 15 was given a more complete hematological examination at the termination of the study. Findings included a slight anisocytosis and hypochromia

a 0.5 to 0.9 percent reticulocyte count, normal serum iron, mild erythroid hyperplasia of the bone marrow, no occult blood and normal bilirubin. Barium enema was also normal. Conclusions were a self-limiting anemia, not secondary to a disease process. The possibility of depression of erythropoietic activity as a consequence of exposure to this environment cannot be ruled out at this time, but, as mentioned above, the effect of repeated blood sampling has undoubtedly altered the meaning of these results. We have noted, for example, a significant ($p < 0.05$) decline in the hematocrit of a subject maintained at ground level (ambient atmospheric conditions). Also, in an experiment (12) subsequent to the two being reported here in which atmospheric conditions were very similar to the studies under discussion, no significant alteration in hematocrit was observed. In that particular study, blood loss was approximately one-half (320 to 360 cc) of the blood loss in the present experiments.

Performance was evaluated in terms of mean response times in each hour at each task. Individual task means were pooled into a smaller number of similar task groups and handled in terms of a two-day (odd and even day) "package". The data for subjects 15 and 16 were quite satisfactory. For analysis, three two-day packages were selected from the early, middle, and late portions of the flight. A double classification analysis of variance with portions of the flight and five task groups as variables shows a significant difference (.01 level) for both variables with no significant interaction.

Subjects 17 and 18 presented many problems in terms of analysis due to lack of data or data falling within no systematic pattern. Much of the lack of performance data was due to technical difficulties related to the chamber or to biomedical measurements. The unsystematic data were largely due to the subjects who failed to follow the operator schedule even when this was possible. In spite of these limitations, it was possible to secure comparable data for early and late periods for three representative tasks for flights 62-3 and 62-4. The average response times for each subject on each of the three tasks for the two flights is shown in Table IX.

The tasks represented in Table IX are those involving complex discrimination (I), simple monitoring (II), and encoding - arithmetic (III). It is quite apparent that even with this limited data, one cannot find performance decrement as measured by these tasks from early in the flight to its termination. On the contrary, the increase in reaction time as an index of performance is significantly different, showing that task improvement occurred. While a portion of this improvement in performance undoubtedly is due to the learning effect, this effect would not serve to mask a significant decrement in performance ability.

## TEST SUBJECT MONITORING

At a partial pressure of oxygen of 243 mm Hg (altitude 27,000 feet), symptoms similar to those of oxygen toxicity (13) were encountered more often and were generally more severe than previously noted (14) at an

ambient $O_2$ of 174 mm Hg (altitude 33,500 feet). For example, substernal pain was seen in three of four test subjects (Table X). In one case, the pain was located beneath the sternum and was of the quality previously reported to be typical of oxygen toxicity (13). In the other two cases, sharp substernal pain which increased on deep inspiration and radiated slightly over the precordium to the left was encountered. In all three instances, however, the pain occurred within the first four days of exposure and decreased markedly within 48 hours after onset. Ear discomfort and eye irritation were encountered in all cases.

Physical examination on days 7 and 14 of the experiment revealed the previously noted (14) erythema of the posterior pharynx with mildly increased pharynegeal lymphoid tissue. Chest ausculation of three subjects (numbers 15, 16 and 17) on day 7 disclosed a few scattered fine basilar inspiratory rales which cleared with deep breathing. These were present in subject 15 on day 14 as well.

Electrocardiograms remained essentially unchanged throughout the experiment except that marked sinus arrhythmias occurred in two subjects. In one of these subjects, the arrhythmia was so marked that the subject at rest complained of forceful palpitations of the heart on normal inspiration. There was no change in blood pressure and a slight drop in pulse rate (Table XI). Body temperatures remained unchanged during the experimental period (Table XI).

## SECONDARY STUDIES

The routine hematological analyses were essentially negative throughout

the experiments, there being no alteration in the white blood count, differential count, eosinophils or sedimentation rate. Serum electrolytes were also constant, sodium averaging 147 meq/l; chloride, 104 meq/l; potassium, 4.7 meq/l; phosphate, 3.66 meq/l; and calcium, 42 mg%. Blood urea nitrogen levels were also within normal limits, averaging 14.3 mg%.

Urinalysis data were also negative, with red blood cells ranging from 0-2, no hyaline casts being present and no indications of protein in the urine. Post-flight followups 3-4 months later showed the same results. One subject (#16) showed a significant ($p<0.05$) increase in urinary specific gravity (from 1.013 to 1.024) during the study.

Body weight data, as well as a summary of energy requirements, are presented in Table XII. The pre-cooked, dehydrated foods used in this experiment were very acceptable to the test subjects and, in general, the amount consumed was adequate to maintain the body weight of the men. The energy intake is expressed both on a kilocalorie/day and kilocalorie/kilogram body weight basis. Energy requirements are based on caloric intake corrected for observed weight change, using a factor of 4 Kcal/gm of weight change. The average caloric requirement of 34.0 Kcal/kg body weight is slightly higher than we have observed in previous experiments, which averaged 30-31 Kcal/kg body weight. The distribution of the caloric intake was 54.2 percent carbohydrate, 26.8 percent fat, and 19 percent protein.

Water requirements and water use data are summarized in Table XIII. In calculating the water lost by evaporative cooling, the

assumption is made that the test subjects were in water balance, permitting the evaporative loss to be calculated by subtracting the water excreted from that water available to the body. The water available to the body averaged 2265 ml/man/day and included not only the liquid water used but also preformed water in the food and that water formed by the oxidation of foodstuffs in the body. The water lost via the kidneys and in the feces averaged 1436 ml/man/day. The average water lost by evaporative cooling (assuming water balance) was 829 ml/man/day and is in the range normally accepted for such losses.

The results of the steroid and catecholamine studies are shown in Table XIV. The data reflect the general pattern that has been observed in previous studies (10) and is characterized by higher than normal control values pre- and post-experiment with a general trend to increase during the course of the experiment. The higher than normal control values are undoubtedly related to the unfamiliar surroundings and rather extensive physical examination that each man received pre- and post-experiment. The fact that there are no overall large increments in these hormones during the experimental period is, at the present time, intepreted to mean that the exposure to the experimental environment did not constitute a particularly stressful situation. Extraordinary occurrences in the simulator during the course of the experiment (i.e., illness, anger, equipment malfunction)are, of course, correlated with increased steroid and catecholamine excretion.

The data related to the bacteriologic studies performed in these

experiments are summarized in detail in section 3. The phage lysis pattern was determined on all staphylococcal organisms isolated from throat cultures during these experiments. In addition, all staphylococcal strains, regardless of coagulase reaction, were forwarded for phage typing to prevent any weakly positive strains from being eliminated. In addition to the staphylococci present, all subjects showed the usual oral flora of alpha streptococci and neisseria species. No significant changes were noted in the normal distribution of these organisms. Beta hemolytic streptococci were not found. Escherichia coli colonies, always greatly in the predominance in the stool samples were disregarded since serological differentiation procedures were not available. No Salmonella or Shigella organisms were found.

It would appear that no demonstrable interchange of either oral or intestinal microorganisms occurred under conditions of close occupancy for these 14-day periods. This is in agreement with previously observed data (15) since, on occasion, we have noted interchange of both oral and intestinal microorganisms. Since "marker" organisms were established in both experiments, the failure to obtain evidence of any cross-transfer must be attributed to individual immunity. As regards the transmission of essentially non-infectious microorganisms such as were included in this study, evidence suggests that the ability of an organism to become established in a "foreign" host is dependent, as might be anticipated, upon the host's susceptibility to the organism.

The studies related to the bacteriologic flora of the cabin atmosphere

did not reveal a cumulative buildup with time, i.e., plates exposed at the end of the experiment did not show significantly more bacteria than plates exposed at the beginning. The predominating organism was always Staph. Epidermis, as evidenced by coagulase positivity and failure to exhibit a phage lytic pattern. No alpha streptococci were observed.

## SUMMARY

The effects of prolonged (14-day) exposure to a total pressure of 258 mm Hg and a $P_{O_2}$ of 242 mm Hg have been studied in four men. No distinct evidence of atelectasis was noted based on the following data: arterial $P_{O_2}$, alveolar $P_{O_2}$, estimated A-V shunt, chest x-ray, vital capacity and performance. No hematological disorders were noted that were directly attributable to the oxygen-rich environment. One subject did develop a self-limiting anemia of non-specific origin and possibly complicated by repeated blood samples during the course of the experiment.

Symptoms similar to those of oxygen toxicity were encountered in all subjects. These symptoms did not, in themselves, cause undue concern and were restricted to eye irritation, aural atelectasis, and erythema of the posterior pharynx. Sub-sternal pain was noted in three of the four test subjects. In only one case, however, was this of the quality previously reported to be typical of oxygen toxicity.

The data obtained indicate that this atmosphere (242 mm Hg $pO_2$) can be well-tolerated for a 14-day period. Exposure for time periods much in excess of this duration should be approached with a certain degree of caution.

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TABLE I. SUMMARY OF ENVIRONMENTAL CONDITIONS

| Parameter | mm Hg |
|---|---|
| Total pressure | 259.0 |
| Oxygen partial pressure | 243.0 |
| Carbon dioxide partial pressure | 2.8 |
| Water vapor partial pressure | 8.2 |
| Nitrogen partial pressure* | 5.0 |

*By difference - see text.

TABLE II. PHYSICAL DIMENSIONS OF TEST SUBJECTS

| | Subject Number | | | |
|---|---|---|---|---|
| | 15 | 16 | 17 | 18 |
| Height (in) | 70.0 | 69.0 | 68.5 | 71.0 |
| (cm) | 177.8 | 175.3 | 174.0 | 180.3 |
| Weight (lbs) | 154.5 | 159.5 | 147.0 | 136.0 |
| (kg) | 70.2 | 72.5 | 66.8 | 61.8 |
| Age (yrs) | 23 | 24 | 27 | 26 |
| Body surface area ($m^2$) | 1.87 | 1.88 | 1.80 | 1.79 |

TABLE III. TEST SUBJECT DAILY SCHEDULE

| Time of Day | Day 1 and all odd days | | Day 2 and all even days | |
|---|---|---|---|---|
| | On-Duty | Off-Duty | On-Duty | Off-Duty |
| 0700-0900 | Testing | Testing | Testing | Testing |
| 0900-1100 | 15, 17* | 16, 18* | 16, 18 | 15, 17 |
| 1100-1300 | 16, 18 | 15, 17 | 15, 17 | 16, 18 |
| 1300-1500 | 15, 17 | 16, 18 | 16, 18 | 15, 17 |
| 1500-1700 | 16, 18 | 15, 17 | 15, 17 | 16, 18 |
| 1700-1900 | 15, 17 | 16, 18 | 16, 18 | 15, 17 |
| 1900-2100 | Testing | Testing | Testing | Testing |
| 2100-0200 | 16, 18 | 15, 17 | 15, 17 | 16, 18 |
| 0200-0700 | 15, 17 | 16, 18 | 16, 18 | 15, 17 |

*Indicates test subject identification number.

TABLE IV. EXPERIMENTAL PROTOCOL

| Test | Pre-Experiment | Day of Experiment | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Vital capacity | A | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Alveolar $pO_2$ + $pCO_2$ | A | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Arterial $pO_2$ + $pCO_2$ | B | B | | | | | | B | | | | | | | B |
| Chest x-ray | B | B | | | | | | B | | | | | | | B |
| Blood pressure | A | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| Pulse | A | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| Body temperature | A | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| Respiratory rate | A | C | C | C | C | C | C | C | C | C | C | C | C | C | C |
| Electrocardiogram | A | C | C | C | C | C | C | C | C | C | C | C | C | C | C |

A - Six determinations made during 10-day pre-experiment period.

B - Single determination.

C - Determined once daily at 7:00 a.m. or 7:00 p.m. alternately.

X - Determined twice daily at 7:00 a.m. and 7:00 p.m.

TABLE V. RESULTS OF ARTERIAL AND ALVEOLAR STUDIES

| Subject Number | Inspired Gas | $P_B$ mm Hg | $P_AO_2$ mm Hg | $P_ACO_2$* mm Hg | $P_aO_2$ mm Hg | $P_aCO_2$ mm Hg | pH | Saturation** % | $A_aO_2$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Pre-Experiment | | | | | |
| 15 | Room air | 750 | 107 | 34 | 84 | 35 | 7.415 | 96 | 23 |
| 16 | Room air | 750 | 105 | 35 | 92 | 38 | 7.370 | 97 | 13 |
| 17 | Room air | 747 | 107 | 34 | 90 | 34 | 7.425 | 97 | 17 |
| 17 | 29.9% $O_2$ in $N_2$ | 747 | 174 | 34 | 136 | 34 | 7.420 | 100 | 38 |
| 18 | Room air | 747 | 103 | 37 | 84 | 36 | 7.440 | 96 | 19 |
| 18 | 29.9% $O_2$ in $N_2$ | 747 | 162 | 33 | 134 | 33 | 7.440 | 100 | 28 |
| | | | | Day #1 | | | | | |
| 15 | 241 mm $P_{O_2}$ | 258 | 173 | 32 | 127 | 33 | 7.440 | 100 | 46 |
| 16 | 241 mm $P_{O_2}$ | 258 | 177 | 34 | 154 | 36 | 7.420 | 100 | 23 |
| 17 | 245 mm $P_{O_2}$ | 258 | 174 | 35 | - | - | - | - | - |
| 18 | 245 mm $P_{O_2}$ | 258 | 166 | 40 | - | - | - | - | - |
| | | | | Day #7 | | | | | |
| 15 | 242 mm $P_{O_2}$ | 259 | 177 | 35 | 133 | 37 | 7.450 | 100 | 44 |
| 16 | 242 mm $P_{O_2}$ | 259 | 173 | 36 | 124 | 43 | 7.415 | 100 | 49 |
| 17 | 238 mm $P_{O_2}$ | 258 | 167 | 37 | 126 | 43 | - | 100 | 41 |
| 18 | 238 mm $P_{O_2}$ | 258 | 164 | 40 | 136 | 44 | 7.420 | 100 | 28 |
| | | | | Day #14 | | | | | |
| 15 | 243 mm $P_{O_2}$ | 258 | - | - | 131 | 39 | 7.450 | 100 | - |
| 16 | 235 mm $P_{O_2}$ | 258 | 169 | 34 | 129 | 32 | 7.460 | 100 | 40 |
| 17 | 238 mm $P_{O_2}$ | 258 | 170 | 35 | 126 | 38 | 7.415 | 100 | 44 |
| 18 | 240 mm $P_{O_2}$ | 258 | 165 | 37 | 136 | 41 | 7.450 | 100 | 29 |

* All pressures in mm Hg adjusted to BTPS.
**Percent saturation obtained from nomogram of Dill, et al (5).
\- No data available.

$P_B$ = barometric pressure; $P_AO_2$ = alveolar $P_{O_2}$; $P_ACO_2$ = alveolar $P_{CO_2}$; $P_aO_2$ = arterial $P_{O_2}$; $P_aCO_2$ = arterial $P_{CO_2}$; $A_aO_2$ = alveolar-arterial $P_{O_2}$ gradient.

TABLE VI. EFFECT OF INDICATED TECHNIQUES ON THE ALVEOLAR-ARTERIAL OXYGEN GRADIENT

| Subject Number | A - a $P_{O_2}$ Gradient (mm Hg) | | | | | |
|---|---|---|---|---|---|---|
| | Initial | Post V.C. | Post V.C. + M.B.C. | Post I.P.P.B. | Post V.C. + I.P.P.B. | Post V.C. + M.B.C. + I.P.P.B. |
| 15 | 46 | -- | -- | 40 | 40 | |
| | 44 | -- | 32 | -- | -- | |
| 16 | 49 | 32 | 52 | -- | -- | 55 |
| 17 | 41 | 25 | -- | -- | 20 | |
| | 44 | 34 | -- | -- | 38 | |
| 18 | 28 | 26 | -- | -- | 37*/31** | |
| | 29 | 29 | -- | -- | 33 | |

* $A_aO_2$ gradient immediately following I.P.P.B.

** $A_aO_2$ gradient 20 minutes after I.P.P.B.

TABLE VII. EFFECT OF 258 mm TOTAL PRESSURE, 243 mm $P_{O_2}$ ON FORCED VITAL CAPACITY (BTPS)

| Subject Number | Pre-Experiment liters | Experiment liters | Post-Experiment liters | %* Change |
|---|---|---|---|---|
| 15 | 5.44 ± 0.08 | 5.28 ± 0.14 | 5.24 ± 0.08 | - 2.9[1] |
| 16 | 5.60 ± 0.13 | 5.41 ± 0.17 | 5.75 ± 0.10 | - 2.5[2] |
| 17 | 6.15 ± 0.07 | 6.17 ± 0.07 | 6.38 ± 0.07 | + 0.3[3] |
| 18 | 4.77 ± 0.16 | 4.46 ± 0.15 | 4.75 ± 0.11 | - 6.5[1] |
| Average | 5.49 | 5.34 | 5.53 | - 2.9 |

* Pre-experiment vs experiment.
1 Significant at the 0.01 level
2 Significant at the 0.05 level
3 Not significant

TABLE VIII. SUMMARY OF HEMATOCRIT DATA

| Phase | Day of Test | Subject Number 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Pre-Experiment | | 44(4)* | 46(3) | 47(3) | 46(3) |
| Range | | 42-48 | 45-46 | 47-48 | 46-47 |
| Experiment | 3 | 38 | 42 | 45 | 44 |
| | 7 | 38 | 35? | 40 | 40 |
| | 10 | 41 | 43 | 44 | 43 |
| | 14 | 41 | 44 | 47 | 44 |
| | Mean | 40 | 43 | 44 | 43 |
| | P | <0.1 | <0.01 | <0.05 | <0.05 |
| Post-Experiment | | 40(5) | 45(1) | 45(1) | 44(1) |
| Range | | 38-41 | | | |
| Follow-Up** | | 44(2) | 48(2) | 46(2) | 47(2) |

* Number in parentheses inidcate number of samples.
**3 months later for subjects 15 & 16, 2 months for subjects 17 & 18.

TABLE IX. RESPONSE TIME IN SECONDS FOR THREE REPRESENTATIVE TASKS

| Subject Number | Period | Task I (sec.) | Task II (sec.) | Task III (sec.) |
|---|---|---|---|---|
| 15 | Early | 7.48 | 2.31 | 4.58 |
| | Late | 4.54 | 1.22 | 2.11 |
| 16 | Early | 5.17 | 1.86 | 3.51 |
| | Late | 5.06 | 2.15 | 2.85 |
| 17 | Early | 7.19 | 1.90 | 5.80 |
| | Late | 5.36 | 1.79 | 3.30 |
| 18 | Early | 6.59 | 3.22 | 6.37 |
| | Late | 5.21 | 2.54 | 4.05 |

TABLE X. SYMPTOMS OF OXYGEN TOXICITY

| Symptom | Occurrence |
|---|---|
| Substernal pain | 3 |
| Lower respiratory tract: | |
| Reduced Vital Capacity+ | 4 |
| Upper respiratory tract: | |
| Cough | 2 |
| Nasal congestion | 2 |
| Sore throat | 1 |
| Ear discomfort (aural atelectasis) | 4 |
| Fatigue | - |
| Eye irritation | 4 |
| Other: | |
| Paresthesiae | 2 |
| Dizziness | - |
| Aching teeth+ | - |
| Joint or muscle pain+ | 1 |

+Probably related to reduced barometric pressure. See Discussion.

TABLE XI. TEST SUBJECT MONITORING

| | Pre-Experiment | | | Experiment | | |
|---|---|---|---|---|---|---|
| Subject | Blood Pressure mm Hg | Pulse Beats/Min. | Temperature of | Blood Pressure mm Hg | Pulse Beats/Min | Temp. of |
| 15 | 113/67 | 66 | 98.4 | 107/66 | 56 | 97.7 |
| 16 | 102/60 | 69 | 98.3 | 106/64 | 52 | 97.9 |
| 17 | 116/65 | 69 | 98.2 | 110/68 | 59 | 98.7 |
| 18 | 104/70 | 65 | 98.2 | 100/68 | 58 | 98.3 |

TABLE XII. SUMMARY OF ENERGY REQUIREMENTS

| Subject Number | Initial Body Wt. (kg) | Caloric Intake (Kcal/day) | Caloric Intake (Kcal/kg body wt) | Wt. Change (kg) | Caloric Requirement* (Kcal/day) | Caloric Requirement* (Kcal/kg body wt) |
|---|---|---|---|---|---|---|
| 15 | 70.2 | 1975 | 28.1 | 0 | 1975 | 28.1 |
| 16 | 72.5 | 2183 | 30.1 | -1.36 | 2636 | 36.4 |
| 17 | 66.8 | 2534 | 37.9 | +0.45 | 2370 | 35.5 |
| 18 | 61.8 | 2054 | 33.2 | -0.45 | 2234 | 36.1 |
| Mean | 67.8 | 2186 | 32.3 | -0.34 | 2304 | 34.0 |

* Cabin intake data corrected for any observed weight change, using as a correction factor, 4 Kcal/gm of weight change.

TABLE XIII. SUMMARY OF WATER REQUIREMENTS

| | Subject Number | | | | |
|---|---|---|---|---|---|
| | 15 | 16 | 17 | 18 | Mean |
| Water used (ml/day) | 1526 | 1822 | 2516 | 2425 | 2072 |
| Liquids | 848 | 1021 | 1714 | 1502 | 1271 |
| Food rehydration | 552 | 724 | 752 | 694 | 681 |
| Personal hygiene | 126 | 77 | 50 | 229 | 120 |
| Available to body (ml/day) | 1682 | 2065 | 2836 | 2478 | 2265 |
| Liquids | 848 | 1021 | 1714 | 1502 | 1271 |
| Food rehydration | 552 | 724 | 752 | 694 | 681 |
| Content in food | 35 | 48 | 62 | 45 | 47 |
| Water of oxidation | 247 | 272 | 308 | 237 | 266 |
| Excreted by body (ml/day) | 1127 | 1133 | 1853 | 1631 | 1436 |
| Urine | 1068 | 1044 | 1812 | 1556 | 1370 |
| Feces | 59 | 89 | 41 | 75 | 66 |
| Evaporative water loss (ml/day) | 555 | 932 | 983 | 847 | 829 |

TABLE XIV. STEROID AND CATECHOLAMINE VALUES OBTAINED FROM URINE ANALYSIS

| Subject Number | | Epinephrine gamma/24 hrs | P-Values | Norepinephrine gamma/24 hrs. | P-Values | 17-OHCS mg/24 hrs. | P-Values | Corticosterone-like Hormones mg/24 hrs. | P-Values |
|---|---|---|---|---|---|---|---|---|---|
| 15 | Pre | 1.1 ± 0.3 | 0.2** | 49.3 ± 3.2 | 0.2 | 8.7 ± 1.4 | 0.7 | 31.7 ± 7.2 | 0.5 |
| | Exp | 1.7 ± 1.6 | | 54.3 ± 10.5 | | 9.3 ± 2.6 | | 35.7 ± 3.8 | |
| | Post | 0.9 ± 0.1 | 0.1 | 49.7 ± 5.2 | 0.4 | 11.6 ± 0.4 | -- | 29.2 ± 2.9 | -- |
| 16 | Pre | 10.6 ± 3.1 | 0.02 | 132.2 ± 23.7 | 0.02 | 10.4 ± 1.9 | 0.4 | 88.1 ± 10.4 | 0.01 |
| | Exp | 5.1 ± 3.5 | | 79.1 ± 26.7 | | 11.6 ± 2.2 | | 48.1 ± 6.9 | |
| | Post | 7.6 ± 1.9 | 0.2 | 66.7 ± 8.7 | 0.3 | 10.0 ± 2.1 | 0.4 | 47.1 ± 2.0 | 0.7 |
| 17 | Pre | 2.5 ± 0.2 | 0.01 | 65.7 ± 10.0 | -- | 15.1 ± 1.0 | 0.01 | 50.0 ± 9.9 | 0.2 |
| | Exp | 7.4 ± 3.2 | | 65.6 ± 19.5 | | 11.7 ± 2.8 | | 62.7 ± 15.8 | |
| | Post | 4.8 ± 0.0 | 0.01 | 55.8 ± 20.7 | 0.5 | 11.5 ± 1.1 | -- | 53.6 ± 10.5 | 0.4 |
| 18 | Pre | 3.1 ± 0.3 | 0.6 | 49.2 ± 24.3 | 0.7 | 6.6 ± 0.4 | 0.01 | 32.4 ± 9.0 | 0.3 |
| | Exp | 3.6 ± 1.7 | | 58.0 ± 16.9 | | 8.2 ± 2.1 | | 41.5 ± 10.3 | |
| | Post | 2.5 ± 1.3 | 0.4 | 58.6 ± 22.7 | -- | 12.4 ± 3.1 | 0.2 | 42.3 ± 10.8 | -- |

There are three samples in each of pre- and post-experiment groups; total number of control samples is six. The experimental group has fourteen samples.

* Standard Error from the Mean.

** These values show the degree of significance between Pre and Exp values and between Post and Exp values Only P-Values less than 0.05 are considered significant.

## II. EFFECT OF VENTILATING AIR FLOW ON HUMAN WATER REQUIREMENTS[1]

B. E. Welch,[2] Ph.D., R. G. Cutler, Capt., USAF, MC, J. E. Herlocher, Capt., USAF, MC, J. J. Hargreaves, Capt., USAF, F. Ulvedal, Ph.D., and E. G. Shaw, M.A., USAF School of Aerospace Medicine, and G. B. Smith[3], Maj., USAF, MC, H. J. McMann, B.S., and L. Bell, B.S., NASA Manned Spacecraft Center

1. This work was supported in part by the Manned Spacecraft Center, NASA, Houston, Texas.
2. Chief, Environmental Systems Branch, Bioastronautics Department, USAF School of Aerospace Medicine, Aerospace Medical Division (AFSC), Brooks AFB, Texas.
3. Chief, Environmental Physiology Branch, Crew Systems Division, Manned Spacecraft Center, NASA, Houston, Texas.

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## INTRODUCTION

The need for definitive information about the logistic requirements of long-duration, manned space missions must continue to receive considerable interest as mission durations lengthen and the probability of recycling techniques becomes more feasible. Data are available relating to such logistic areas as man's requirement for food, water, oxygen, etc., but frequently these data have been obtained under environmental conditions or durations sufficiently different from actual flight conditions that their use involves extensive extrapolation. For example, in the area of water requirements, there are many papers and books that explore various facets of this area, but none that provide sufficient information to allow the establishment of water requirements for conditions that vary considerably from those reported.

Hale, et al (1)* have reported that total water loss in still air from the nude body (via the lungs and skin) is dependent on barometric pressure and vapor pressure, increasing with a decrease in both of these parameters. The conditions utilized in Hale's experiments included 3-hour exposure to 14.7, 9.8, and 4.9 psi, and 6, 16, and 26 mm Hg water-vapor pressure. Water requirements have also been determined during prolonged experiments at total pressures of 3.71 psi with lightly clothed subjects in a thermally neutral environment (2).

The effect of a ventilating air flow or forced convection on evaporative cooling and water requirements further complicates the problem. The majority of the research (e.g., 3, 4, 5, 6) has been limited to the

*Numbers in parenthesis indicate references at end of paper.

investigation of the effectiveness of ventilated garments at relatively high environmental temperatures (in excess of 140°F) and for relatively short durations (approximately 3 hrs). There have been data (7,8) reported on water requirements while wearing the Navy Mark III and Mark IV pressure suits at 3.5 psi for three and five days, respectively. No data regarding flow rates, ventilating air temperatures and humidities were reported, however, that would allow one to calculate heat exchange characteristics in other environments.

In addition to a general lack of applicable data in the literature, the disagreement between various theoretical calculations used to predict evaporative cooling and water requirements (9, 10, 11) was sufficient to require experimentation under specific environmental conditions. This study was, therefore, planned to provide the following information relative to a 14-day mission involving pressure suit wear in a spacecraft atmosphere of 5 psi and essentially 100 percent oxygen:

1. Water requirements incorporating full-body ventilation approximately 40 percent of the day and torso ventilation the remainder of the time for the first ten days of the test.

2. Water requirements during full-body ventilation approximately 100 percent of the day for the last four days of the test.

3. Estimation of heat loss by evaporative cooling.

4. Determination of pressure suit habitability.

## METHODS

This study was conducted in the two-man space cabin simulator

described previously (12). The atmosphere was maintained by the injection of externally stored gaseous oxygen into the simulator on a demand basis. Total pressure was sensed by an absolute pressure transducer; $pO_2$ by a Beckman oxygen analyzer, Model F-3; and $pCO_2$ by a Beckman carbon dioxide analyzer, Model 15-A. The $pH_2O$ was calculated from relative humidity data obtained with an El-Tronic hygrometer, Model 101C, and from temperature data obtained with a Minneapolis-Honeywell resistance bulb, Model 6630 or with a gas chromatograph using a molecular sieve column. Nitrogen was determined with a Waters nitrogen analyzer, Model A-6. The ambient cabin gaseous conditions that were maintained during this test are shown in Table 1. Mean cabin temperature was 27.1°C (80.7°F), and mean relative humidity was 41.6 percent.

The two test subjects (both volunteer Air Force pilots) had the physical dimensions shown in Table 2. Both men were fitted with ventilated, full pressure garments. These garments were similar to standard full pressure garments with the exception of the arms and the legs being detachable at the middle of the upper arm and the upper leg, respectively.

The daily schedule of the subjects (Table 3) was set to provide two alternating five-hour periods per man per day in the fully donned garment with the torso portion being worn the remainder of the time. This schedule was followed until 0200 hours on day ten of the programmed 14-day test when both subjects wore the fully donned suits continuously until the unprogrammed termination on day 13. During the fully donned period, the men opened the suits only to eat, drink, void or defecate. The average time/man spent in the fully donned suit up until schedule

change was 92.5 hours out of a programmed 95 hours and out of a maximum possible 224 hours. Following the schedule change and prior to the unexpected termination of the test because of a fire, the average time/man spent in the fully donned suit was 76.5 hours out of a maximum possible of 81.6 hours.

Ventilating airflow* to the pressure suits was obtained from the ambient cabin atmosphere through the use of a high speed centrifugal compressor. The airflow (Fig. 1) was passed through a heat exchanger which utilized chilled water-glycol circulating through finned tubes. The cabin air was chilled below the dew point and the resulting condensate was collected and used as a check on flow rate. After leaving the heat exchanger (#1), the air passed into the suit. During the on-duty time, the air from the suit was passed through a heat exchanger-condenser arrangement (#2) identical with the #1 unit. Condensate was collected at this exchanger at the end of the duty periods outlined in Table 3. Glycol flow rates through both heat exchangers were adjusted to obtain outlet air temperatures as identical to each other as possible.

Temperatures were monitored at the various points indicated in Figure 1, utilizing glass bead thermistors. Flow to each suit was measured by a Hastings Raydist mass flow meter, Model SM20X.

Daily water intake was monitored by each test subject who measured all water consumed as liquid or that was added to food for rehydration purposes. Urinary output from each man was also monitored, as well as the water lost in feces. In addition to monitoring urinary output, daily samples were obtained for routine urinalysis. The

*It should be mentioned that the ventilating "air" and cabin "air" referred to throughout the report is oxygen.

water available for evaporative cooling through the lungs and skin was calculated by using the following formula and assuming body water balance:

Evaporative Water Volume = Water Intake (all sources) Minus Water Output (urine and feces)

Precooked, dehydrated food obtained from the Quartermaster Food and Container Institute, Chicago, Illinois, was used as the energy source. Energy intake was calculated from caloric data provided by the Quartermaster personnel.

Body weights were recorded daily on a calibrated Health-Meter scale with each man wearing the torso portion of the pressure suit. No weights were recorded after the scheduled change to the fully donned status.

Venous blood samples were obtained pre-test and on days 3 and 7 of the test to check for any indication of dehydration.

## RESULTS AND DISCUSSION

### General

The energy intake determined during the course of this experiment averaged 2004 Kcal/man/day (Table 4), or 27.3 Kcal/Kg body weight, based on initial body weight. The distribution of this intake was 52.4 percent carbohydrate, 27.7 percent fat, and 19.9 percent protein. The food weight averaged 1.05 lbs/day and the food, plus package weight, averaged 1.345 lbs/day. As noted in Table 4, there was a slight weight loss recorded during the first 10 days of the test. This weight loss, which averaged 0.3 Kg/man, was extrapolated out to the end of the test and an

estimated energy requirement of 2156 Kcal/man/day, or 29.3 Kcal/Kg body weight, based on initial body weights.

Routine urinalyses and blood analyses showed all values to be within normal limits. No marked fluctuations were noted nor were any specific trends observed.

Water Requirements: The effect of wearing a full pressure garment and being exposed to the ventilating airstream had a definite impact upon human water requirements under these environmental conditions. Table 5 gives a summary of the average water data for the total 13 days, combining the periods of both the partially donned and fully donned modes of pressure suit wear. In addition, similar data obtained under "shirt sleeve" conditions at 5 psi and in an essentially 100 percent oxygen environment, are presented for comparative purposes (13). These data can be considered to represent water requirements if the test subjects were maintained in water balance. There is no indication that water balance was not maintained in this experiment based on body weight measurements, urine specific gravity and osmolarity, hematocrit and blood urea nitrogen levels. Assuming body water balance, the water available to the body, including that derived from metabolism of food, was 2841 cc/man/day in this experiment. This represented a 20 percent increase over the data from subjects in the non-ventilated state (13) and was primarily obtained by increasing the liquid water consumed. Water lost by way of the urine and feces was decreased in the ventilated state by 11 percent, from 1436 to 1279 cc/man/day. The water available for evaporative loss via the lungs and skin was increased, however, from

829 to 1562 cc/man/day, a change of some 47 percent.

One factor, however, that exerts a considerable influence on the water requirement in the ventilated condition is that of suit inlet temperature. During the first six days of the experiment, the subjects commented that they felt comfortable but slightly warm. An alteration was made in the ventilation system to allow suit inlet temperatures to be lowered 4-5$^{\circ}$F to 60$^{\circ}$F during working periods (Table 6). This reduced the water requirements (Table 7) from an average of 3132 to 2590 cc/man/day, increased the combined urinary and fecal loss, and decreased the amount of water theoretically available for evaporative losses. The apparent dependence of the amount of water available for evaporative losses during body water balance is shown in Figures 2a and 2b, where daily average suit inlet temperature is plotted versus the water volume available for evaporative loss. Regression coefficients of 0.710 and 0.866 were obtained for 2a and 2b, respectively. Both are significant at the 0.01 level.

A comparison of water requirements in the fully donned versus the partially donned condition was also evaluated (Table 8). The 3-day period immediately preceding the fully donned portion of the experiment was selected for comparison since the environmental conditions were almost identical, and since the higher suit inlet temperature encountered in the early phases of the test would not provide a valid comparison. There appeared to be little difference in water requirements under these two conditions and the question must be raised of the efficiency of the torso ventilating system and the possible increased evaporative

water loss from undergarments when in the partially donned configuration following the wearing of the complete garment.

Suit Habitability. As noted in the description of the methods, the two test subjects averaged wearing the fully donned pressure suit 92.5 hours out of a programmed 95 hours during the first 224 hours of the test. The torso portion of the garment, covering approximately 60-70 percent of the body surface area was worn the remainder of the 224 hours. In general, the suits were well-tolerated by both individuals with the major difficulty centering around ventilation and, at least initially, suit inlet air temperature. Pressure points were not severe, nor were there any skin problems. An observer locked into the simulator on the seventh day noted a minimal rash on the chest of subject 19 which was due to irritations from a ventilating hose. Subject 20 was noted to have a rash between his buttocks and to have slight pressure points on the lateral aspect of his mid-thigh.

During the continuous-wear, fully donned portion of the test, both men felt somewhat more comfortable, as a whole, than when they alternated between this condition and the partially donned state. They did note, however, that their hands and feet were damp while wearing the fully donned garment continuously. Examination of both men immediately after the termination of the test and the pressurization of the cabin showed essentially nothing on subject 19. There was an area of erythema and edema on the back of the left arm with a blister-like lesion in the center of this area. Subject 20 had mild edema of the feet and slight maceration of the skin in some areas. There was a rash on the buttocks as well as on the backs of both hands. The fingers

were also involved. It would appear that although the suits were subjectively well-tolerated by the subjects, skin difficulties could have become a problem if the wearing of these suits continued indefinitely.

These findings are similar to those reported by Hall and Kelly (8) following the wearing of the Navy Mark IV full pressure suit for a five-day period at 34,000 feet. This would indicate, therefore, that two major requirements exist to permit prolonged wearing of full pressure suits. The first is the need for good ventilation down to and including the extremities, and the second is the need for good skin hygiene to preclude or, at least, minimize the occurrence of skin rashes.

Heat Exchange Analysis. Although an exact determination of the modes of metabolic heat rejection was not a primary objective of this test, an attempt was made to obtain enough data to present a general picture of the heat transfer taking place, utilizing daily averages of the measured parameters. A gross breakdown of heat rejection by subjects 19 and 20 is shown in Figures 3a and 3b, respectively. It should be mentioned again that the suit inlet temperature was lowered on the sixth day by shortening the suit inlet ventilation hoses. As a consequence, heat exchange will also be considered in two periods - first six days and last seven days.

The curve labeled Ventilating Convective Heat Loss was calculated from daily averages of oxygen flow rate and temperature rise across the suit of the subject at the duty station and then reduced to an hourly basis. The Evaporative Heat Loss curve was obtained from the evaporative water volume data calculated from measured intake and output,

utilizing a value of 0.579 Kcal/gm of water (1040 Btu/lb) as the heat of evaporation of water at 5 psi and this temperature. The area above the evaporative heat loss curve and below the raw energy intake curve represents a collective heat loss to the cabin by radiation, conduction and convection, as well as the heat equivalent of work. The heat equivalent of the food intake was not adjusted for body weight changes.

It is apparent that convective heat losses accounted for a relatively small portion of the heat rejection load, although this did increase after the inlet ventilation hoses were shortened and the flow was increased slightly. It is also of interest to note that heat loss by means other than by forced ventilation and evaporation continued to play an important role in maintaining thermal balance, even while in the fully donned condition. As discussed earlier, evaporative heat loss is apparently influenced by relatively small variations in the temperature of the ventilating air flow. In addition, it would appear that it must be significantly influenced by the environment surrounding the pressure suit-man combination. For example, in the work reported by Hall and Martin (7), where the test subject was maintained at 35,000 feet in a pressurized suit but with chamber altitudes much greater than that (up to 140,000 feet), the water available for use in evaporative cooling was approximately 4180 cc/day (2660 Kcal; 9740 Btu). By contrast, in a similar experiment (8) but with the surrounding pressure being the same as the unpressurized suit, the water available for use in evaporative cooling was approximately 760 cc/day (446 Kcal; 1768 Btu). The results obtained in the experiment reported here are similar in

magnitude to the latter.

In addition to approaching the evaporative heat loss problem by monitoring water intake and output, an attempt was made to condense all water originating with the man in the suit and compare this to the intake-output data (Fig. 4). This was generally unsuccessful during the alternating-wear phase of the experiment due to the problems of wetting the suit and undergarments and of extrapolating ten hours of data to 24 hours. During the continuous-wear phase, however, the volume of condensate collected at heat exchanger #2 from subject 20 agreed to within 2 ml with the intake-output data over a 24-hour period. Subject 20 agreed to within 531 ml/24-hour period during two one-day collection cycles. The wide divergence in this case was felt to be due primarily to a leak around the visor seal during this time period.

SUMMARY

These preliminary data indicate that the wearing of ventilated pressure garments, either partially donned or fully donned, has a marked, increasing effect on water requirements. This increase is influenced by suit inlet air temperature and by the environmental conditions surrounding the suit-man combination. Water requirements while wearing the pressure suit continuously averaged 1196 cc/man/day with an inlet air temperature of 60.6$^{\circ}$F. The partially donned type garment was reasonably well-tolerated by the test subjects as well as the fully donned mode. Prolonged (3 days) continuous wear of the suits dictates the need for good ventilation and good skin hygiene. Heat loss from the body via

evaporative cooling was greater than in the "shirt sleeve" environment but still did not assume a dominant role in maintaining thermal equilibrium.

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Table 1. Summary of Gaseous Environmental Conditions

| | mm Hg | psi |
|---|---|---|
| Total Pressure | 258 | 4.97 |
| $pO_2$ | 239 | 4.61 |
| $pCO_2$ | 2.5 | .05 |
| $pH_2O$ | 11.2 | .21 |
| $pN_2$ (by difference) | 5.3 | .10 |

Table 2. Test Subject Description

| | Subject 19 | Subject 20 |
|---|---|---|
| Age (yrs) | 29 | 32 |
| Height (cm) | 170 | 175 |
| Weight (Kg) | 67.1 | 80 |
| Body Surface Area ($m^2$) | 1.77 | 1.97 |
| Lean Body Mass (Kg)* | 56.13 | 61.2 |

* Estimated from total body water.

Table 3. Daily Crew Schedule*

| Time | On-Duty** Fully-Donned Condition | Off-Duty Partially-Donned Condition |
|---|---|---|
| 0700-0900+ | | 19, 20 |
| 0900-1400 | 20 | 19 |
| 1400-1600+ | | 19, 20 |
| 1600-2100 | 19 | 20 |
| 2100-0200 | 20 | 19 |
| 0200-0700 | 19 | 20 |

* Schedule followed for 224 hours at which time both men wore the fully-donned garments continuously

**On-Duty required performance at a group of psychomotor tasks.

+ Testing periods during which physiological data was collected, etc.

Table 4. Nutritional Summary Data

| | Body Weight - Kg | | | Measured Caloric Intake | | Corrected Caloric Intake** | |
|---|---|---|---|---|---|---|---|
| | Initial | Final* | Change | Kcal/ Day | Kcal/Kg Body Wt/Day | Kcal/ Day | Kcal/Kg Body Wt/Day |
| Subject 19 | 67.1 | 66.8 | -0.3 | 1918 | 28.5 | 2012 | 29.9 |
| Subject 20 | 80.0 | 79.3 | -0.7 | 2091 | 26.1 | 2300 | 28.7 |
| Average | 73.6 | 73.1 | -0.5 | 2004 | 27.3 | 2156 | 29.3 |

* Final body weight - see text.

**4 Kcal/Gm of weight change.

Table 5. Total Water Summary Data

| | Subj 19 ml/day | Subj 20 ml/day | Average ml/day | Average of 5 psi Data* ml/day |
|---|---|---|---|---|
| Available to Body | 2605 | 3075 | 2840 | 2265 |
| Liquid | 1609 | 2124 | 1867 | 1271 |
| Food Rehydration | 728 | 655 | 691 | 681 |
| In Food | 31 | 51 | 41 | 47 |
| Oxidation of Food | 237 | 245 | 241 | 266 |
| Excreted by Body | 1163 | 1395 | 1279 | 1436 |
| Urine | 1103 | 1318 | 1210 | 1370 |
| Feces | 60 | 77 | 69 | 66 |
| Available for Evaporative Loss** | 1442 | 1680 | 1561 | 829 |

* Date from four subjects for 14 days each.

**Assuming body water balance.

Table 6. Pressure Suit Environment

| | Air Flow | Suit Inlet Temp. On-Duty | Suit Inlet Temp. Off-Duty | Suit Outlet Temp. | Heat Exch. Outlet #1 | Heat Exch. Outlet #2 |
|---|---|---|---|---|---|---|
| | cfm @ 5 psi | °F | | °F | °F | |
| Subject 19 | | | | | | |
| Days 1-6 | 9.49 | 65.0 | 64.6 | 80.7 | 46.2 | 46.7 |
| Days 7-13 | 10.55 | 59.9 | 62.3 | 79.2 | 46.2 | 45.9 |
| Days 11-13 | 10.28 | 61.2 | 61.4 | 79.6 | 46.2 | 46.2 |
| Average | 10.25 | 61.9 | 63.3 | 79.8 | 46.2 | 46.2 |
| Subject 20 | | | | | | |
| Days 1-6 | 9.19 | 63.8 | 62.2 | 84.4 | 46.0 | 48.7 |
| Days 7-13 | 9.60 | 59.9 | 60.9 | 85.3 | 46.2 | 45.8 |
| Days 11-13 | 9.34 | 60.1 | 59.4 | 85.6 | 46.2 | 46.1 |
| Average | 9.51 | 61.6 | 61.4 | 84.9 | 46.1 | 47.1 |

Table 7. Water Summary Data - First Six vs Last Seven Days

| | Days 1-6 | | | Days 7-13 | | |
|---|---|---|---|---|---|---|
| | Subj 19 | Subj 20 | Avg. | Subj 19 | Subj 20 | Avg. |
| | Milliliters/Day | | | Milliliters/Day | | |
| Available to Body | 2807 | 3458 | 3132 | 2433 | 2747 | 2590 |
| Liquid | 1785 | 2353 | 2069 | 1458 | 1928 | 1693 |
| Food Rehydration | 757 | 807 | 782 | 704 | 524 | 614 |
| In Food | 32 | 51 | 41 | 31 | 51 | 41 |
| Oxidation of Food | 233 | 247 | 240 | 240 | 244 | 242 |
| Excreted by Body | 976 | 1226 | 1101 | 1322 | 1540 | 1431 |
| Urine | 892 | 1107 | 1000 | 1283 | 1498 | 1391 |
| Feces | 84 | 119 | 101 | 39 | 42 | 40 |
| Available for Evaporative Loss* | 1831 | 2232 | 2031 | 1111 | 1207 | 1159 |

*Assuming body water balance.

Table 8. Water Summary Data - Fully-Donned vs Partially-Donned State*

| | Partially-Donned | | | Fully-Donned | | |
|---|---|---|---|---|---|---|
| | Subj 19 | Subj 20 | Avg. | Subj 19 | Subj 20 | Avg. |
| | Milliliters/Day | | | Milliliters/Day | | |
| Available to Body | 2488 | 3194 | 2841 | 2333 | 2628 | 2480 |
| Liquid | 1547 | 2206 | 1876 | 1390 | 1826 | 1608 |
| Food Rehydration | 665 | 710 | 688 | 674 | 470 | 572 |
| In Food | 35 | 45 | 40 | 30 | 55 | 42 |
| Oxidation of Food | 241 | 233 | 237 | 239 | 277 | 258 |
| Excreted by Body | 1403 | 1547 | 1475 | 1089 | 1480 | 1284 |
| Urine | 1403 | 1498 | 1450 | 1040 | 1430 | 1234 |
| Feces | 0 | 49 | 25 | 49 | 50 | 50 |
| Available for Evaporative Loss** | 1085 | 1647 | 1366 | 1244 | 1148 | 1196 |

*Three days preceding continuous-wear utilized for comparison.

**Assuming body water balance.

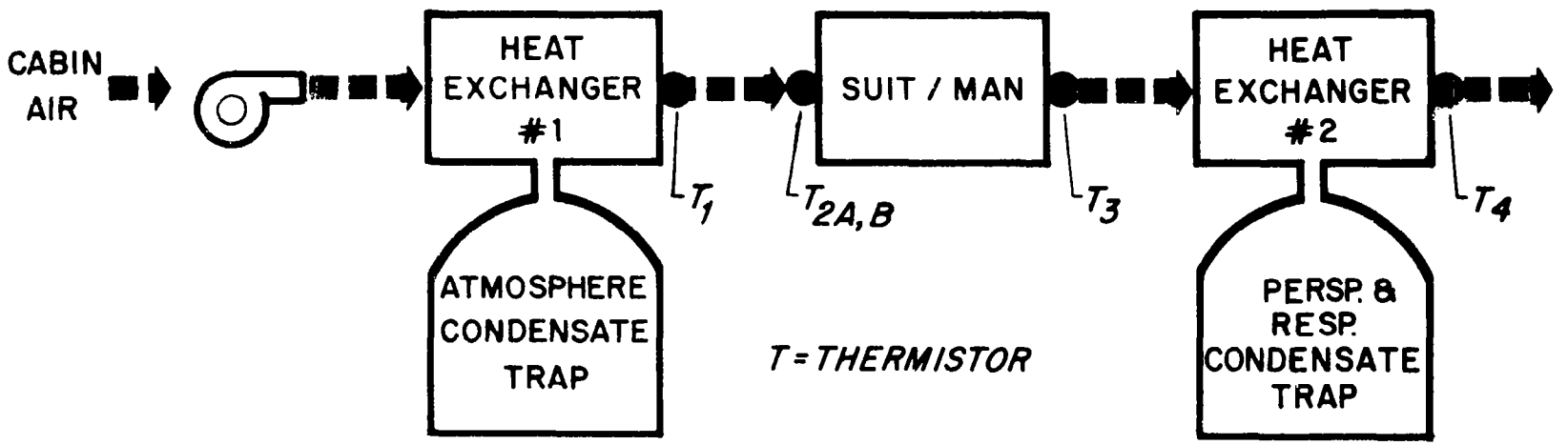



Fig.1 ***VENTILATING FLOW DIAGRAM***

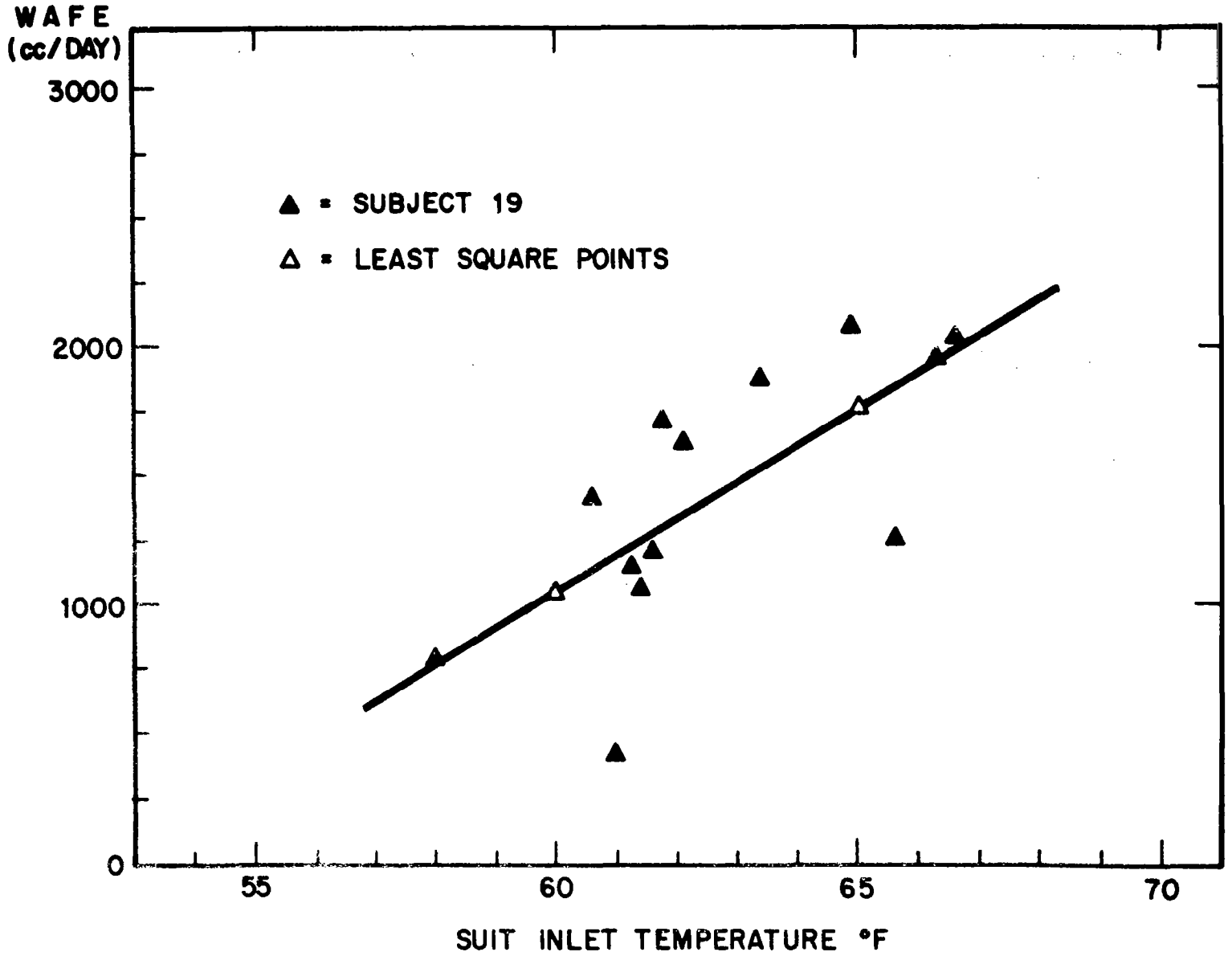



Fig. 2a WATER AVAILABLE FOR EVAPORATION vs SUIT INLET TEMPERATURE

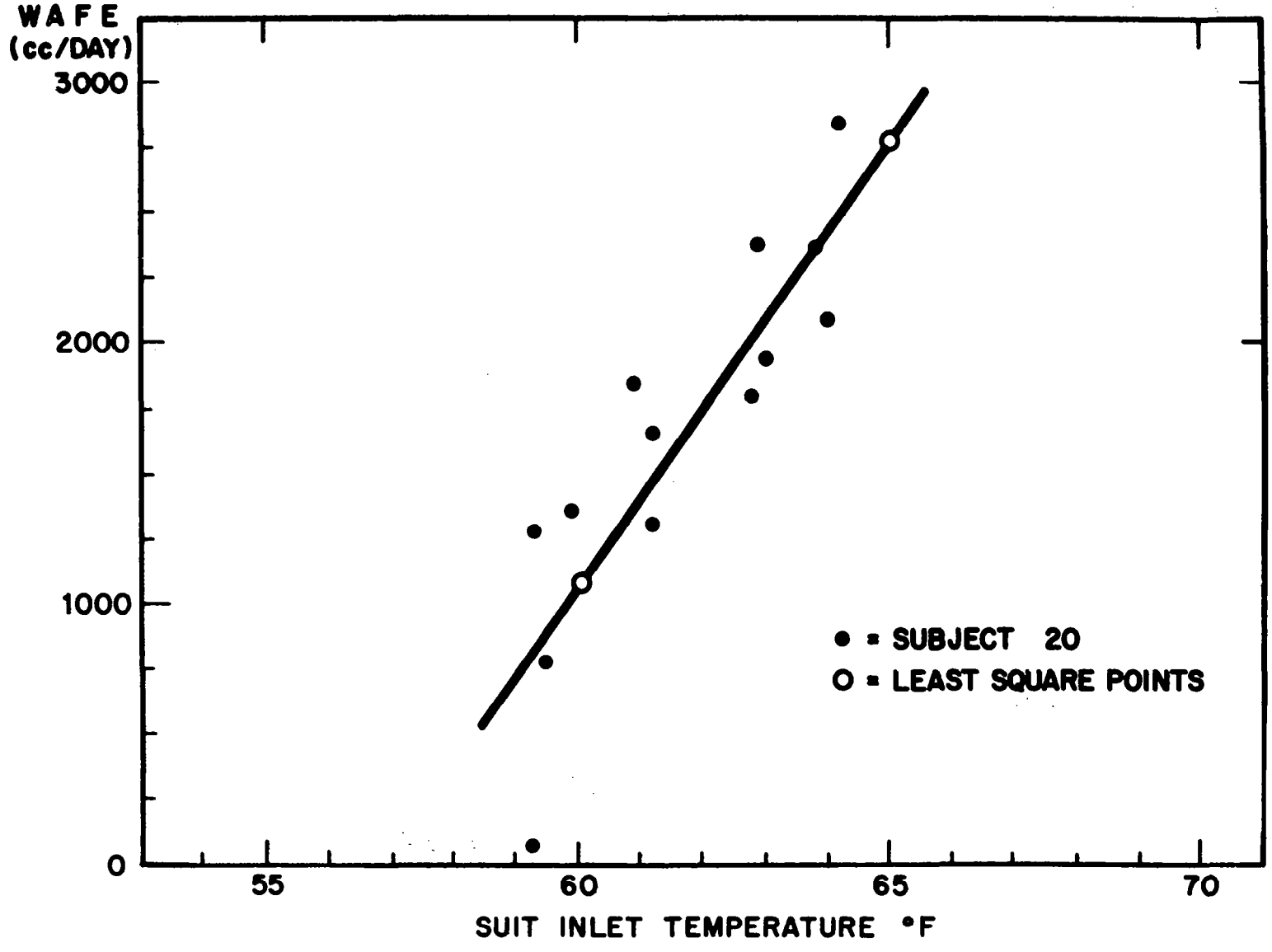



Fig. 2b. WATER AVAILABLE FOR EVAPORATION vs SUIT INLET TEMPERATURE

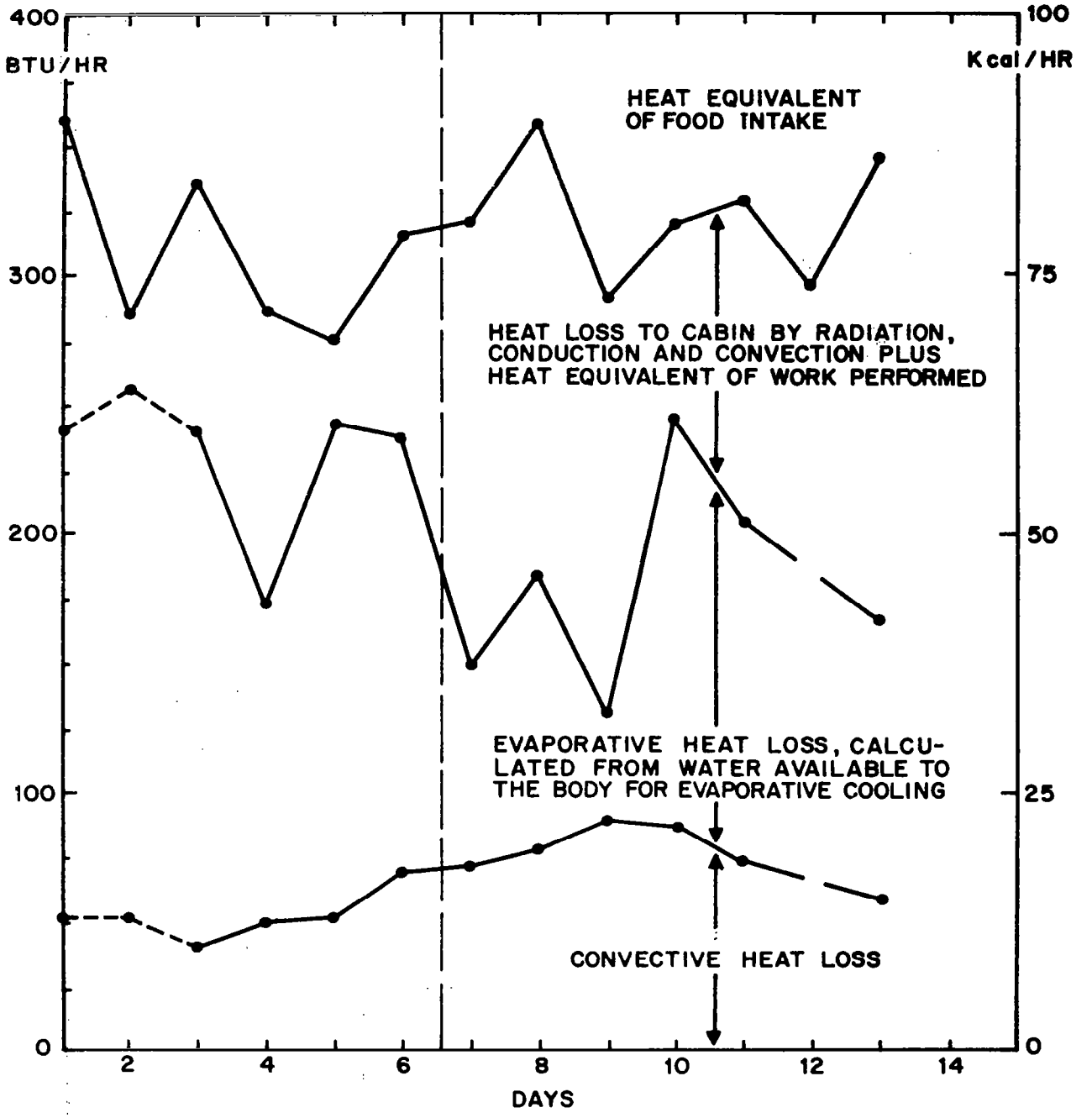



Fig.3a ESTIMATED HEAT BALANCE : SUBJECT 19

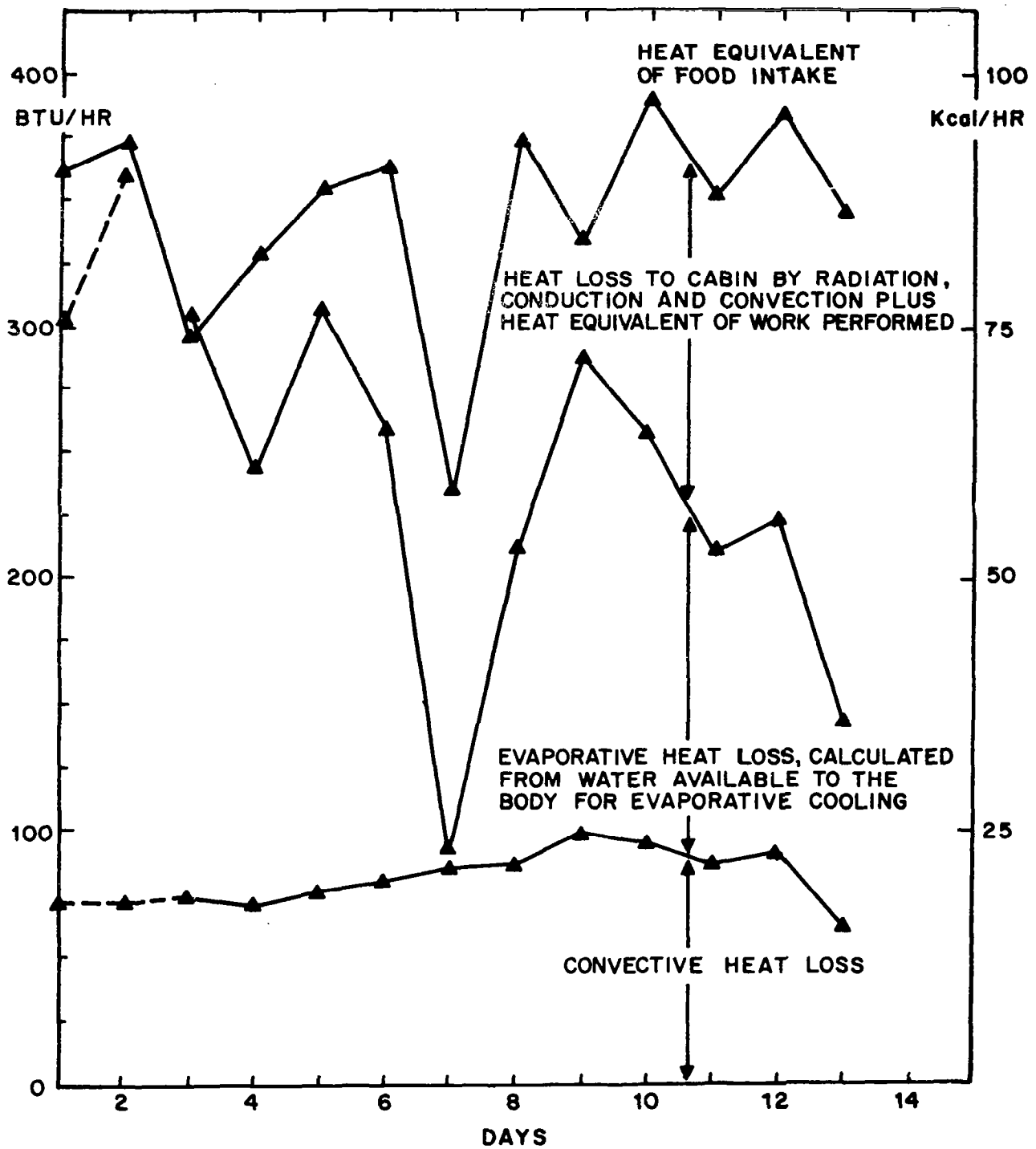
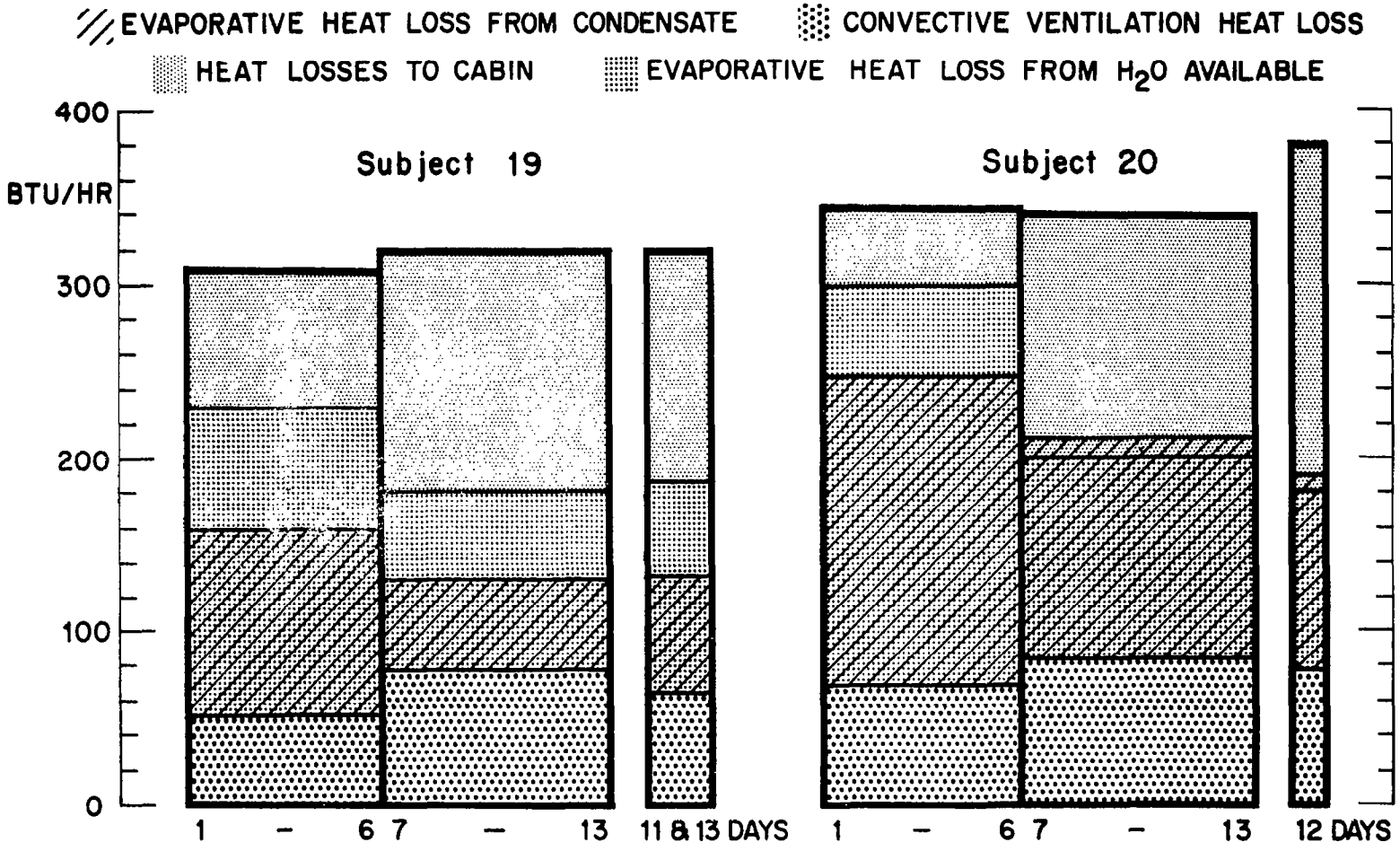



Fig. 3b ESTIMATED HEAT BALANCE : SUBJECT 20




TOP LINE IS HEAT EQUIVALENT OF FOOD
FIRST SIX DAY AND LAST SEVEN DAY MEAN HEAT LOSS FIGURES WERE USED

Fig. 4 MEAN HEAT BALANCE CHART

## III. BACTERIOLOGICAL STUDIES OF TWO-MAN SPACE CABIN SIMULATOR

James E. Moyer, Capt., USAF
Y. Z. Lewis, SSGT, USAF

### INTRODUCTION

The studies were initiated to gain some understanding of the degree of microbial interchange to be expected between individuals under conditions of close occupancy for extended periods of time as would occur during space travel. Limitations of area will necessitate close personal contact between astronauts; an environment highly favorable to the cross-transfer of microorganisms from one individual to another. Consequently, astronauts must be thoroughly screened prior to departure to determine any carriers of potentially pathogenic organisms, or cases of subclinical infection.

### METHODS

The experiments were performed on individuals confined within the two-man space cabin simulator in operation at the USAF School of Aerospace Medicine, Brooks AFB, Texas. Results presented were obtained from three experiments of 14 days duration at a simulated altitude of 27,000 feet under essentially 100 percent $O_2$. These experiments have been described in detail in Parts I and II of this report.

For the determination of the interchange of microorganisms, throat swabs and stool specimens were collected from each individual prior to, during, and following each flight, and subjected to bacteriological analysis to determine any significant differences in microflora. Particular attention was given to the isolation of certain "marker" organisms characteristically harbored by only one of the individuals. It was felt that by

establishing the identify of the so-called "marker" organisms, a basis would be available to measure the degree of microbial interchange that occurred during the experiment.

1. Throat Cultures. As many throat swabs as was conveniently possible, (never less than four) were taken prior to each experiment, 2-3 per week during the experiment, and 2-3 following the experiment. Each specimen for culture was streaked to 5 percent sheep blood agar, mannitol-salt agar, and MacConkey's differential medium, incubated at 35°C for 24 hours, and examined. Representative Staphylococcus colonies were picked to Brain Heart Infusion agar, tested for coagulase positivity, and retained for future phage typing. Phage typing of the strains was kindly performed by the 6570th Epidemiological Laboratory, Lackland AFB, Texas.

2. Stool Specimens. As many specimens as was conveniently possible were collected prior to each experiment, and 2-3 following each experiment. Since enteric organisms may be shed intermittently by the host, all stool specimens collected during the experiment were subjected to bacteriological analysis. Approximately 1 gm. of feces from each specimen was thoroughly mixed in a glycerol-saline preservative; then streaked to Eosin-Methylene Blue, MacConkeys, and Salmonella-Shigella agars, incubated for 24 hours at 35°C, and examined. Coliforms other than E. coli and all non-lactose fermenting organisms were isolated and identified by standard biochemical tests.

3. Air Exposure Samples. To determine whether a cumulative increase in the number of microorganisms present in the circulating air would occur with time, and to determine the types of organisms present in the air,

five aerosol sampling stations were established within the cabin. Blood agar petri plates were opened by the occupants and exposed to the cabin atmosphere for periods of 90 minutes. An unexposed blood agar plate served as a control. The petri dishes were removed from the cabin and incubated at 35°C until colony counts could be made.

4. Heat Exchanger Samples. During the course of experiment 62-5, water condensates from the two heat exchangers connected to the ventilating air system of the full pressure suits worn by the individuals were collected aseptically at six-hour intervals and subjected to bacteriological analysis by the Most Probable Number (MPN/100 ml) method. By this method, aliquots of the heat exchanger condensates (5-10.0 ml, 5-1.0 ml, 5-0.1 ml portions) were inoculated into 15 fermentation tubes containing 20 ml of double strength lactose broth. Following incubation for 24 hours, positive tubes were streaked to agar plates, and the predominant organisms identified by standard biochemical procedures. In addition, several of the samples were retained, and subsequently subjected to the MPN method following storage for 12 days at room temperature.

## RESULTS

Table 1 demonstrates the phage lysis pattern of staphylococcal organisms isolated from the three experiments. Also shown indirectly is the frequency of collection of throat cultures, since staphylococci were retained from each specimen. All staphylococcal strains, regardless of coagulase reaction, were forwarded for phage typing to prevent any weakly positive strains from being eliminated. In addition to the staphylococci present, all subjects showed the usual oral flora of alpha streptococci

and neisseria species. No significant changes were noted in the normal distribution of these organisms. Beta hemolytic streptococci were not found. Frequency of sampling and "marker" organisms isolated from stool cultures are shown in Table 2. Escherichia coli colonies, always greatly in the predominance, were disregarded since serological differentiation procedures were not available. No Salmonella or Shigella organisms were found.

In Table 3 may be found the average number of bacterial colonies per plate following a 90-minute exposure to the cabin atmosphere. The predominating organism observed was always Staph. epidermidis, as evidenced by coagulase negativity and failure to exhibit a phage lytic pattern. Catalose tests were performed to differentiate these organisms from the genus Aerococcus. Although specifically looked for, no alpha streptococci were observed.

In Table 4 may be found the most probable number of bacteria/100 ml. present in condensate samples for both heat exchangers. Although samples for the first five days were heavily contaminated (2400 plus per 100 ml.), a definite trend was established in later collections. Almost without exception, the number of bacteria obtained from heat exchanger No. 1 was significantly lower than the number obtained from heat exchanger No. 2. The predominating organisms isolated from the broth tubes in order of their most frequent occurrence were as follows: Bacillus subtilis (36 samples), Mima polymorpha (27), Pseudomonas sp. (10), Xanthomonas sp. (9), Escherichia coli (3), and Staphylococcus epidermidis (2). In reading these tests, each tube that showed evidence of growth was recorded as

positive, whether or not gas was observed. Several of the condensate samples collected during the latter part of the experiment were retained, stored at room temperature for 12 days, and retested by the MPN procedure to determine the ability of the condensates to serve as a bacterial growth medium. Results of the experiment may be found in Table 5. The first column shows initial counts obtained randomly from selected condensate samples (Table 4), while the second column represents counts for the same sample following 12 days storage at room temperature. Note the tremendous increase in total bacterial counts indicating that the condensates were capable of supporting good growth of microorganisms.

## DISCUSSION

Subject to the limitations of the experimental approach, it would appear that no demonstrable interchange of either oral or intestinal microorganisms occurs between individuals under conditions of close occupancy for extended periods of time. Whether the non-typable Staph. aureus strains isolated from the occupants of experiments 62-4 and 62-5 are indicative of bacterial interchange cannot be determined. In previous experiments conducted under essentially the same conditions, evidence for both a transference and a non-transference of microorganisms has been indicated. Since "marker" organisms were established in all flights, and assuming that adequate opportunity for transfer of microorganisms existed, the failure to obtain evidence of microbic interchange must be attributed to individual immunity. As regards the transmission of essentially non-infectious microorganisms such as were included in this study, evidence suggests that the ability of an

organism to become established in a "foreign" host is dependent, as might be anticipated, upon the host's susceptibility to the organism. The significance or origin of the Klebsiella sp. isolated from subjects 17 and 18 is unexplained. Sputum cultures collected at a later date were negative for the organism.

No cumulative buildup of bacteria with time was noted; i.e., plates exposed at the end of the experiment did not show significantly more bacteria than plates exposed at the beginning. Counts of individual plates varied rather widely as regards the number of organisms isolated from one sampling time to another with the exception of sampling station #1. Station #1, located on the console, consistently showed lower counts than any of the other four stations. The variance in results may be attributed to the amount of activity of the subjects within the cabin during collection of the samples.

The rather high bacterial counts (2400 plus/100 ml.) found in both exchanger condensates during the early part of experiment 62-5 may be attributed to sampling procedure and/or the necessity for the establishment of a bacterial flora within the exchangers. The finding that the total number of organisms present in the condensates from heat exchanger No. 1 was consistently lower than that of No. 2 would be expected since the No. 1 condensate reflects the presence of only the organisms of the atmosphere prior to passage through the pressure suit, while the No. 2 condensate sample represents the bacterial content of the air after contact with the suit occupant. The infrequent isolation of Staph. epidermidis, the pre-dominant organism of the air, and E. coli from condensates

is undoubtedly due to the inability of these two organisms to grow competitively with the much hardier strains of Bacillus, Mima, Pseudomonas, and Xanthomonas. All isolations were made from 24-hour lactose broth tubes in which overgrowth by these organisms could have occurred. The persistence and tremendous proliferation of these organisms after 12 days storage at room temperature would indicate that the condensates contain considerable amounts of organic material capable of serving as a substrate for microorganisms. Treatment of the water, either with chemicals or by distillation prior to its use for drinking purposes is clearly indicated.

## SUMMARY

Microbiological findings collected from three 14-day experiments conducted within the two-man space cabin simulator at the USAF School of Aerospace Medicine, Brooks AFB indicate that no significant degree of microbic interchange occurred between individuals under conditions of close occupancy for the periods studied. Bacterial aerosol counts of the cabin atmosphere revealed no cumulative buildup of microorganisms with time. Water condensates from the heat exchangers connected to the full pressure suits worn by the latter two individuals were subjected to quantitative and qualitative bacteriological analysis. Subsequent evaluation of stored condensate samples revealed tremendous preliferation of the microorganisms originally present.

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Table 1. Staphylococcal Microorganisms from Throat Cultures

| Experiment 62-3 | | | Experiment 62-4 | | | Experiment 62-5 | | |
|---|---|---|---|---|---|---|---|---|
| Day of experiment | Subject 15 Phage Pattern | Subject 16 Phage Pattern | Day of experiment | Subject 17 Phage Pattern | Subject 18 Phage Pattern | Day of experiment | Subject 19 Phage Pattern | Subject 20 Phage Pattern |
| -13 | - | - | -12 | 29/52/80 | Nontypable | -14 | - | - |
| -12 | - | 52A/79 | -11 | - | Nontypable | -12 | - | - |
| -11 | - | 52A/79 | -10 | - | 7 | -11 | - | - |
| -10 | - | - | -7 | Nontypable | Nontypable | -9 | - | - |
| -7 | - | - | -6 | - | Nontypable | -7 | - | - |
| 0 | - | - | -4 | - | Nontypable | -6 | - | - |
| 2 | - | 52A/79 | -3 | -* | - | 0 | - | - |
| 4 | - | 52A/79 | 0 | -* | Nontypable* | 2 | - | - |
| 7 | - | 52A/79 | 4 | - | - | 5 | Nontypable | Nontypable |
| 9 | - | - | 7 | - | - | 7 | - | - |
| 11 | - | - | 8 | Nontypable | Nontypable | 8 | - | Nontypable |
| +1 | - | 52A/79 | 10 | Nontypable | Nontypable | 9 | - | Nontypable |
| +2 | - | 52A/79 | 12 | - | Nontypable | | | |
| +3 | - | - | 13 | - | Nontypable | | | |
| +4 | - | 52A/79 | +3 | Nontypable | - | | | |
| | | | +4 | Nontypable | Nontypable | | | |

* - Klebsiella sp.

Table 2. Enteric Marker Organisms From Stool Cultures.

| Day of Exper. | Experiment 62-3 Subject 15 Enteric Marker | Experiment 62-3 Subject 16 Enteric Marker | Experiment 62-4 Subject 17 Enteric Marker | Experiment 62-4 Subject 18 Enteric Marker | Experiment 62-5 Subject 19 Enteric Marker | Experiment 62-5 Subject 20 Enteric Marker |
|---|---|---|---|---|---|---|
| -12 | --- | --- | --- | Providence | --- | --- |
| -11 | --- | --- | --- | | | --- |
| -10 | | --- | | | | |
| -9 | --- | | | --- | | |
| -8 | --- | --- | --- | | Arizona | |
| -7 | | --- | | | | |
| -6 | A. aerogenes | --- | --- | | | --- |
| -5 | | --- | --- | --- | | |
| -4 | --- | | --- | | Arizona | |
| -3 | | --- | --- | | | |
| -2 | --- | | | | | |
| -1 | | --- | --- | | | --- |
| 0 | | | | | Arizona | |
| 2 | A. aerogenes | --- | | Providence | Arizona | --- |
| 3 | A. aerogenes | | --- | Providence | | |
| 4 | | --- | | | | |
| 5 | | | --- | Providence | Arizona | --- |
| 6 | | | | Providence | --- | --- |
| 7 | A. aerogenes | --- | | | Pr. mirabilis | --- |
| 8 | | | | Providence | | |
| 9 | --- | --- | --- | | Pr. mirabilis | --- |
| 10 | --- | | --- | Providence | | --- |
| 11 | | --- | | | | --- |
| 12 | --- | | --- | --- | --- | --- |
| 13 | A. aerogenes | | | | | |
| 14 | --- | | | | | |
| +1 | | --- | | --- | | |
| +2 | | --- | --- | Providence | | |
| +3 | A. aerogenes | --- | --- | | | |

Table 3. Bacteriological Counts of Cabin Air

| Experiment 62-3 | | Experiment 62-4 | | Experiment 62-5 | |
|---|---|---|---|---|---|
| Day of Experiment | Average No. Colonies* | Day of Experiment | Average No. Colonies* | Day of Experiment | Average No. Colonies* |
| 0 | 33 | 1 | 32 | 1 | 31 |
| 2 | 19 | 3 | 71 | 2 | 10 |
| 4 | 19 | 5 | 78 | 5 | 66 |
| 7 | 30 | 6 | 40 | 9 | 9 |
| 11 | 29 | 7 | 93 | 12 | 33 |
| | | 10 | 82 | | |
| | | 11 | 78 | | |
| | | 13 | 95 | | |

*Average of 5 sampling stations (90-minute exposure per plate)

Table 4. Bacterial Counts of Heat Exchanger Condensates

| | | Subject 19 | | | | Subject 20 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Heat Exchanger No.1 | | Heat Exchanger No.2 | | Heat Exchanger No.1 | | Heat Exchanger No.2 | | |
| Day of Experiment | Hours of Collection | Positive Tubes | MPN/ 100 ml. | Positive Tubes | MPN/ 100 ml. | Positive Tubes | MPN/ 100 ml. | Positive Tubes | MPN/ 100 ml. | Predominant Organism(s) |
| 0 | 1600-2100 | 5/5/5 | 2400+ | 5/5/1 | 350 | | | | | B. subtilis |
| 1 | 0210-0710 | 5/5/5 | 2400+ | 5/5/5 | 2400+ | | | | | B. subtilis |
| | 2100-0200 | | | | | 5/5/3 | 920 | * | * | B. subtilis |
| | 2100-0800 | | | | | * | * | 5/5/5 | 2400+ | B. subtilis |
| 2 | 0200-0700 | 5/5/5 | 2400+ | 5/5/5 | 2400+ | | | | | B. subtilis |
| | 1620-2105 | 5/5/1 | 350 | 5/5/5 | 2400+ | | | | | B. subtilis & Pseudomonas(2) |
| | 2100-0200 | | | | | 5/5/5 | 2400+ | 5/5/5 | 2400+ | B. subtilis |
| | 1040-1607 | | | | | 5/5/1 | 350 | 5/5/5 | 2400+ | B. subtilis |
| 3 | 0200-0700 | 5/5/5 | 2400+ | 5/5/5 | 2400+ | | | | | Pseudomonas |
| | 2100-0200 | | | | | 5/5/5 | 2400+ | 5/5/5 | 2400+ | Pseudomonas |
| 4 | 0200-0700 | 5/5/5 | 2400+ | 5/5/5 | 2400+ | | | | | Pseudomonas(1) & B. subtilis(2) |
| | 1000-1400 | | | | | 5/3/0 | 79 | 5/5/5 | 2400+ | B. subtilis(1) & Pseudomonas(2) |
| | 1600-2100 | 5/5/5 | 2400+ | 5/5/5 | 2400+ | | | | | B. subtilis |
| 5 | 0900-1400 | | | | | 5/5/4 | 1600 | 5/5/5 | 2400+ | Pseudomonas |
| | 1600-2100 | 5/5/4 | 1600 | 5/5/4 | 1600 | | | | | Mima |
| | 2100-0200 | | | | | 5/5/1 | 350 | 5/5/4 | 1600 | B. subtilis |
| 6 | 0200-0700 | 5/3/0 | 79 | 5/5/3 | 920 | | | | | Mima(1) & E.coli(2) |
| | 0900-1400 | | | | | 5/5/5 | 2400+ | 5/5/2 | 540 | Mima(1) & B.subtilis (2) |
| | 1600-2100 | 5/0/0 | 23 | 5/5/3 | 920 | | | | | Mima |
| | 2100-0200 | | | | | 5/5/0 | 240 | 5/5/2 | 540 | Mima(1) & B. subtilis(2) |
| 7 | 0200-0700 | 5/5/4 | 1600 | 5/5/1 | 350 | | | | | B. subtilis |
| | 0900-1400 | | | | | 4/1/0 | 17 | 5/4/2 | 220 | Xanthomonas(1) Pseudomonas(2) |
| | 1600-2100 | 3/0/0 | 7.8 | 5/3/0 | 79 | | | | | Mima(1) & Staph epidermidis & E. coli(2) |
| | 2200-0200 | | | | | 5/1/0 | .33 | 5/5/0 | 240 | Mima(1) & B.subtilis (2) |

Table 4 (Cont'd)

| Day of Experiment | Hours of Collection | Subject 19 Heat Exchanger No.1 Positive Tubes | Subject 19 Heat Exchanger No.1 MPN/100 ml. | Subject 19 Heat Exchanger No.2 Positive Tubes | Subject 19 Heat Exchanger No.2 MPN/100 ml. | Subject 20 Heat Exchanger No.1 Positive Tubes | Subject 20 Heat Exchanger No.1 MPN/100 ml. | Subject 20 Heat Exchanger No.2 Positive Tubes | Subject 20 Heat Exchanger No.2 MPN/100 ml. | Predominant Organism(s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 0200-0700 | 5/5/0 | 240 | 5/1/1 | 46 | | | | | Mima |
| | 1100-1400 | | | | | 5/0/0 | 23 | 5/5/3 | 920 | Mima(1) & B. subtilis(2) |
| | 1600-2100 | 5/2/0 | 49 | 5/5/2 | 540 | | | | | Mima |
| | 2100-0200 | | | | | 5/0/0 | 23 | 5/3/1 | 110 | Mima |
| 9 | 0200-0700 | 3/0/0 | 7.8 | 5/4/1 | 170 | | | | | B. subtilis(1) & Mima(2) |
| | 0900-1400 | | | | | 1/0/0 | 2 | 5/1/0 | 33 | Mima |
| | 1600-2100 | 5/1/0 | 33 | 5/5/1 | 350 | | | | | B. subtilis(1) & Mima(2) |
| | 2100-0200 | | | | | 3/0/0 | 7.8 | 5/3/0 | 79 | Mima |
| 10 | 0200-0700 | 5/0/0 | 23 | 5/5/2 | 540 | | | | | Xanthomonas(1) & B. subtilis(2) |
| | 0900-1400 | | | | | 5/0/0 | 23 | 5/5/0 | 240 | Xanthomonas(1) & B. subtilis |
| | 1600-2100 | 5/5/4 | 1600 | 5/5/1 | 350 | | | | | Xanthomonas(1) & B. subtilis(2) |
| | 2100-0200 | | | | | 5/1/0 | 33 | 5/5/2 | 540 | Xanthomonas(1) & B. subtilis(2) |
| 11 | 0200-0700 | | | | | 2/0/0 | 4.5 | 5/5/0 | 240 | Mima |
| | 0700-0900 | | | | | 5/1/0 | 33 | 5/5/1 | 350 | Mima(1) & B. subtilis(2) |
| | 0900-1400 | 5/1/0 | 33 | 5/5/5 | 2400+ | | | | | Mima(1) & B. subtilis(2) |
| | 1600-2100 | 5/5/0 | 240 | 5/5/1 | 350 | | | | | Xanthomonas(1) & B. subtilis(2) |
| 12 | 0200-0700 | 5/1/0 | 33 | 5/3/1 | 110 | | | | | Mima(1) & Staph epidermidis & Xanthomonas(2) |
| | 0900-1400 | 2/0/0 | 4.5 | 5/5/0 | 240 | | | | | Xanthomonas(1) & E. coli(2) |
| | 1600-2100 | 5/0/0 | 23 | 5/4/0 | 130 | | | | | Xanthomonas(1) & B. subtilis(2) |

* - No samples received.
(1) - Refers to heat exchanger No.1.
(2) - Refers to heat exchanger No.2.
No number following predominant organism indicates identical organisms were isolated from both exchangers

Table 5. Bacterial Counts of Heat Exchanger Condensates following Storage

| Day of experiment | Hours of collection | Subject 19 Heat Exchanger No. 1 Initial MPN/100 ml. | Subject 19 Heat Exchanger No. 1 After 12 days storage MPN/100 ml. | Subject 19 Heat Exchanger No. 2 Initial MPN/100 ml. | Subject 19 Heat Exchanger No. 2 After 12 days storage MPN/100 ml. | Subject 20 Heat Exchanger No. 1 Initial MPN/100 ml. | Subject 20 Heat Exchanger No. 1 After 12 days storage MPN/100 ml. | Subject 20 Heat Exchanger No. 2 Initial MPN/100 ml. | Subject 20 Heat Exchanger No. 2 After 12 days storage MPN/100 ml. | Predominant Organism(s) after 12 days storage |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 1600-2100 | 33 | $18 \times 10^{6}$ | 350 | $240 \times 10^{7}+$ | | | | | Xanthomonas(1) & Mima(2) |
| | 2100-0200 | | | | | 7.8 | $2.4 \times 10^{10}+$ | 78 | $24 \times 10^{8}+$ | Xanthomonas(1) & B. subtilis(2) |
| 10 | 0900-1400 | | | | | 23 | $24 \times 10^{10}+$ | 240 | $240 \times 10^{9}+$ | Xanthomonas(1) & B. subtilis |
| 11 | 0200-0700 | | | | | 4.5 | $2.3 \times 10^{7}$ | 240 | $240 \times 10^{6}+$ | Xanthomonas, Mima(1) & B. subtilis(2) |
| 12 | 1600-2100 | 23 | $54 \times 10^{6}$ | 130 | $240 \times 10^{8}+$ | | | | | Xanthomonas(1) & B. subtilis(2) |

(1) Refers to heat exchanger No. 1
(2) Refers to heat exchanger No. 2

APPENDIX C

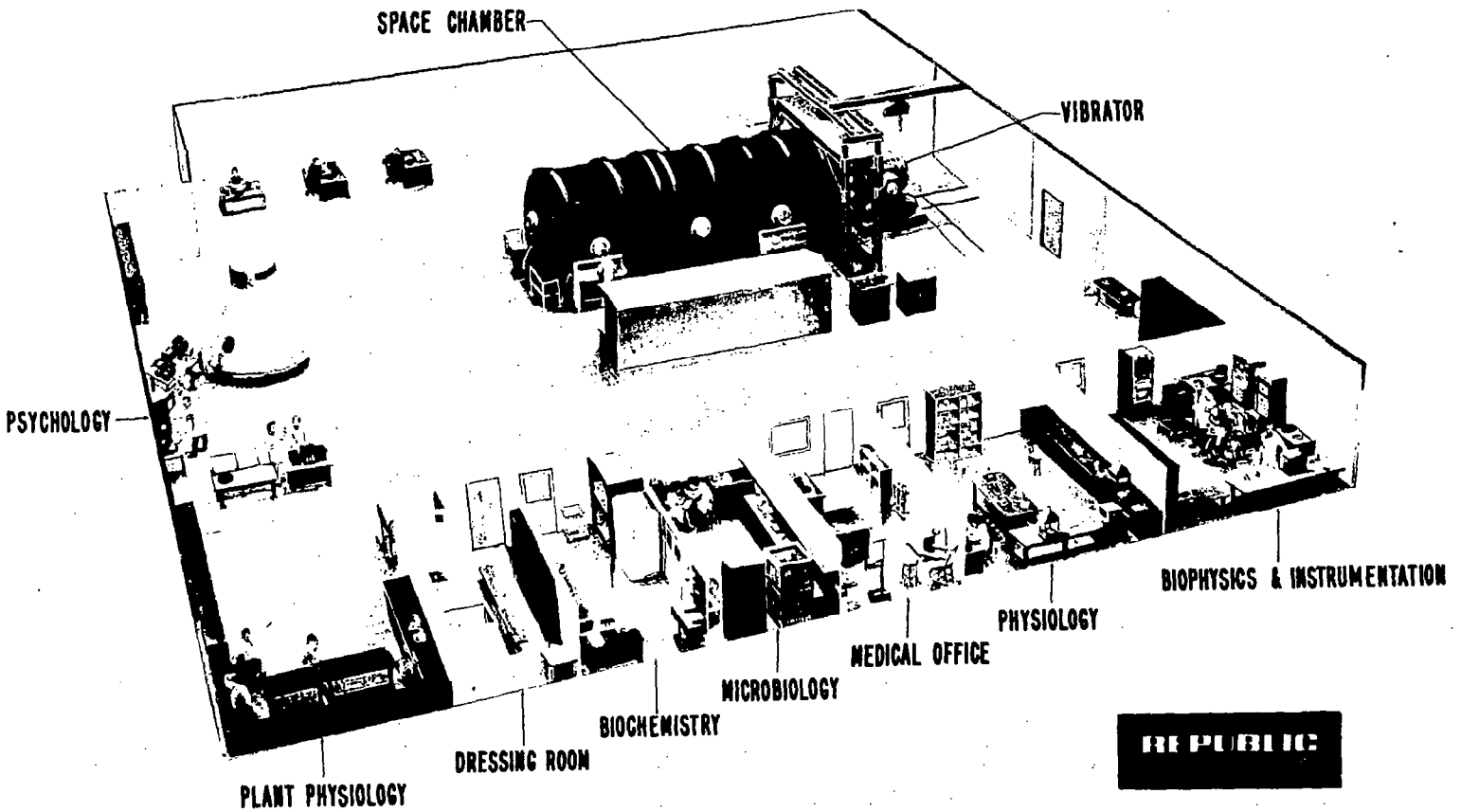
# EFFECTS OF PROLONGED EXPOSURE TO PURE OXYGEN ON HUMAN PERFORMANCE

By William M. Helvey, G. A. Albright, F. B. Benjamin,
L. S. Gall, J. M. Peters, and H. Rind

Republic Aviation Corporation
Farmingdale, L. I., N. Y.

Contract number NASr-92

# SPACE ENVIRONMENT AND LIFE SCIENCES LABORATORY




REPUBLIC

## FOREWORD

In view of the pure oxygen atmosphere selected for Project Mercury, and in anticipation of subsequent manned space missions of increasing duration, it was apparent that there was a need to obtain more extensive physiological data on the prolonged effects of pure oxygen environments on the crews.

This study, conducted by Republic Aviation Corporation under Contract NASr-92, was initiated in collaboration with General Charles Roadman, USAF (MC), Director of Aerospace Medicine (formerly the Office of Life Sciences, NASA Headquarters), and his staff in an effort to provide a greater breadth of scientific data on the prolonged effects of such an environment on human performance.

Although the 5 psi environment of Project Mercury was the focal point of the study, a broader appraisal of the effects of pure oxygen in the absence of nitrogen was attempted by including studies at 7.4 psi and 3.8 psi in addition to a control group at sea level atmospheric conditions.

After award of the contract, the technical monitoring of the study was provided by the Manned Spacecraft Center, Houston, Texas, where Mr. Edward Michel served as monitor and coordinator for these and related studies subsequently established in laboratories of the U.S. Navy and U.S. Air Force.

ACKNOWLEDGEMENTS

During the planning, performance, and analysis of these studies, the staff of the Space Environment and Life Sciences Laboratory was assisted by many persons throughout the scientific community. We wish to express our appreciation to all of those who contributed to the program. In particular, the participation of the following persons is gratefully acknowledged:

Doctors A. Schwichtenberg, U. Luft, T. Nevison, and the staff of the Lovelace Foundation, Albuquerque, New Mexico, who participated in the original planning and provided consultation throughout the study.

Doctor A. Cournand, Chief of the Cardiopulmonary Laboratories, Columbia University, Bellevue Hospital, New York City, who made arrangements to provide competent personnel and precision equipment necessary to do the arterial blood analyses.

Doctor William Briscoe, Cardiopulmonary Laboratory, Columbia University, Bellevue Hospital, who performed the arterial blood analyses and provided their interpretation. Dr. Briscoe also advised on the interpretation of all the cardiopulmonary data and consulted on many other aspects throughout the study. Dr. Briscoe was assisted by Doctors P. Caldwell, D. Rochester, and M. Ravin, who performed arterial punctures.

Doctor S. Spellman of the Cardiopulmonary Laboratory, Long Island Jewish Hospital, who collaborated with Dr. Briscoe in the arterial blood procedures and analyses.

Doctors V. Bond, E. Cronkite, T. Fliedner, J. Cuttner, and the medical staff of Brookhaven National Laboratory, who provided laboratory support and hematological consultation during the study, in addition to hospitalizing and evaluating one of the subjects.

Doctor J. Ultmann, Department of Medicine, Columbia University, who provided consultation and advised on the interpretation of the hematological data.

Doctors C. Lambertsen, A. Dubois, and members of the Working Group on Gaseous Environment in Manned Spacecraft, Space Science Board, who advised on the experimental procedures.

Doctor F. Behrendt, Radiologist, who reviewed the chest roentgenograms.

Doctor S. Natelson, Roosevelt Hospital, New York, who advised on the use of the Natelson Microgasometer for blood analyses.

Doctor B. Wagner, New York Medical College, New York City, who assisted in providing medical students to participate as subjects.

Mr. Robert Hewitt and EPSCO, Inc., who provided the electrode used for $pO_2$, $pCO_2$ and pH determinations of the blood. In addition, Mr. Hewitt assisted Doctor Briscoe on the arterial blood analyses.

Mr. D. Harrington and the Bendix Corporation, who provided a Time of Flight Mass Spectrometer to enhance the monitoring capability.

Mr. J. Mednick and Mrs. G. Soper, of the New York State Employment Service, who supplied and administered the General Aptitude Test Battery (GATB) of the U. S. Employment Service.

Doctor J. Uhlaner of the Personnel Research Office, OCRD, U.S. Army, who provided the Army Night Seeing Tester.

The Radio Corporation of America, which provided a color television for use by the subjects during recreational periods.

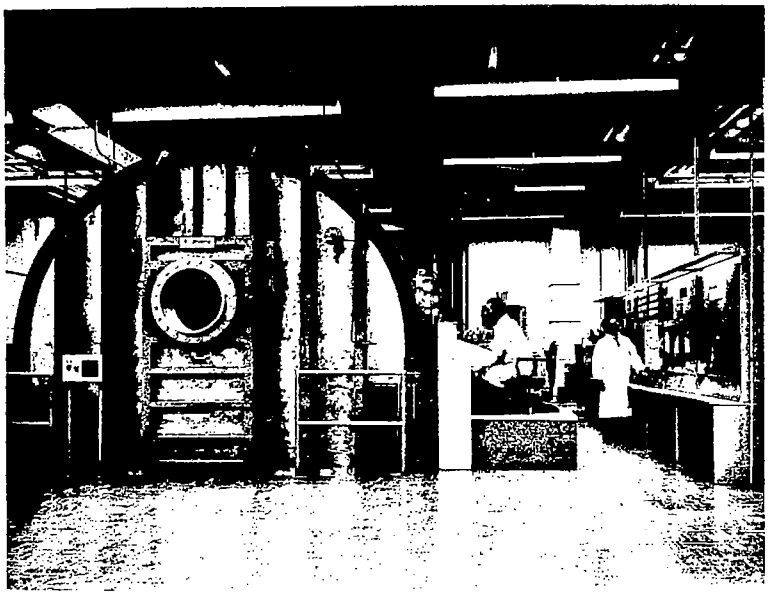
The primary responsibility for the conception, design, and implementation of the study rests with the principal authors; however, contributions of the entire staff of the Space Environment and Life Sciences Laboratory were essential for the successful completion of the experimental program as well as the Final Report.

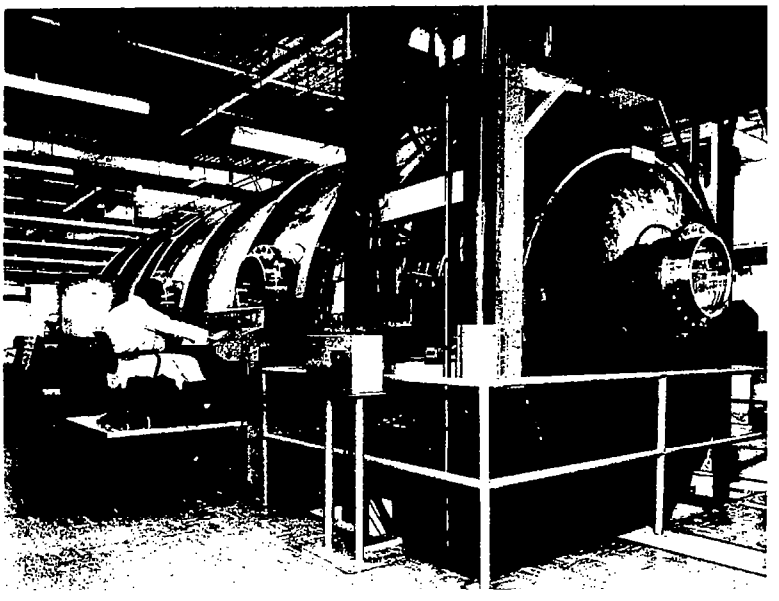
The efforts of the Life Sciences staff were coordinated by Doctor G. Albright, who shared responsibility for medical supervision during the program. Doctor J. Peters (Psychology) was assisted by J. Trump, D. Webster, and B. Keenan. Doctor L. Gall was assisted by D. Tenzer and P. Riely (Microbiology, Biochemistry, Hematology, and Nutrition). Doctor F. Benjamin (Physiology) was assisted by W. Taufman and C. Pevney. Technical assistance was provided by L. Peyser, J. Russell, G. Abaid, P. Brice, J. Benson, and L. Seykora.

The Space Environment staff, under the direction of Mr. H. Rind, was responsible for the preparation, instrumentation, and operation of the space chamber. The members of this group include: A. Beck, G. Frankel, E. Pearman, L. Baxter, and I. Axelrod. Technical assistance was provided by W. Williams, S. Bildzukewicz, H. Wajsgras, J. Doyle, S. Albert, and R. Corkery. Mr. A. Eldridge of the Materials Development Laboratory assisted in chamber monitoring with gas chromatography.

Finally, we wish to express appreciation to the twenty-four subjects, whose participation speaks for their high motivation, and whose sense of duty greatly enhanced the value of the studies.

William M. Helvey, M.D.
Chief, Space Environment and Life Sciences
Republic Aviation Corporation





## SUMMARY

The objective of this study was to determine if exposure to a pure oxygen environment, such as that currently used in the Project Mercury spacecraft, would have detrimental effects on the health or performance of astronauts. A broad approach to the problems associated with pure oxygen at various barometric pressures in the absence of an inert gas was planned. Four groups of six men each were selected to live in an altitude chamber for a two-week period. Three of the groups lived in an oxygen environment at total pressures of 3.8 psi, 5.0 psi, or 7.4 psi, and a fourth group served as a control in a sea level (14.7 psi) environment of air. Detailed medical, physiological, hematological, biochemical, microbiological, and psychological studies were conducted on all subjects.

The subjective health and morale of the groups remained high. There was no evidence of cardiopulmonary impairment. Biochemical and microbiological examinations were within normal limits, although some shift in the balance of skin and fecal microflora were observed. Aero-otitis, substernal discomfort, coughing, and eye irritation caused minor intermittent difficulties. Abnormal microscopic findings in the urinary sediments were common among the oxygen exposed subjects. All subjects after exposure to 100% oxygen atmospheres at reduced pressures exhibited hematological abnormalities, some of which have persisted. Although no deterioration of general mental, sensory, or motor performance was demonstrated during the study, these abnormal findings may represent potentially serious or disabling processes over periods of longer duration or in combination with other stresses of space flight. The causes of these findings are considered to be due to either a high level of oxygen, the absence of nitrogen, an undetected toxicant, decreased barometric pressure, or a combination of these factors.

In view of these findings, it is recommended that astronaut candidates be screened by exposure to this environment well in advance of space flight until a two-gas life support system is feasible. The etiology of these findings and the protection, if any, provided by the presence of small amounts of an inert gas require further investigation. It should also be noted that the toxicological and fire hazards associated with this closed environment merit serious consideration for safety of flight.

## INTRODUCTION

The selection of a single gas system (oxygen) for the capsule environment of Project Mercury created a requirement for obtaining more extensive knowledge of the effects of pure oxygen for prolonged periods on human health and performance. Although no serious impairment of human performance is anticipated during the relatively short flights of the Project Mercury mission (< 28 hours), the use of such an environment in Project Gemini or other forthcoming man-in-space programs requires reasonable assurance that subjecting man to such a deviation from his normal gaseous atmosphere for a period of two or more weeks will not create a serious hazard.

Since its discovery by Priestly in 1775, there has been an intense interest in the physiological effects of pure oxygen and there has also been a great deal of disagreement and disparity among the investigators, as is evident from the available experimental data concerning the effects of pure oxygen. To quote Comroe (1945),[1] "There is no agreement whatever among clinical investigators concerning the harmful effects of oxygen on man." This situation is compounded by the general lack of studies directed specifically toward determining the physiological effects of pure oxygen at reduced barometric pressures.

Studies of the effects of oxygen on man and animals can be divided generally into those which investigated: 1) pressures greater than one atmosphere, 2) pressures of one atmosphere, and 3) pressures of less than one atmosphere. The effects of oxygen under pressures greater than atmospheric were initiated by Paul Bert[2] in 1847 and have been studied by Haldane,[3] and more recently, Behnke,[4] among others. The primary effects appear to be on the central nervous system with convulsions and death occurring as a function of a sufficiently elevated partial pressure of oxygen. These studies have particular application to submarine medicine, but have only tangential pertinence to the current problem of aerospace medicine.

Many investigators have studied the effects of varying percentages of oxygen at a total pressure of one atmosphere on both animals and man. These studies generally indicated that partial pressures of oxygen over 455 to 460 mm Hg are detrimental to most organisms as a function of time. Smith,[5] in 1899, subjected birds, mice, rats, and guinea pigs to 532 to 608 mm Hg of oxygen in one atmosphere and determined that this breathing gas mixture was lethal after four days, producing hyperemia in the lungs and other organs. Stadie, Riggs, and Haugaard[6] and Bean[7] had similar results when they subjected animals to similar conditions for up to one week. Clamann,[8] and Becker-Freyseng,[9] working with an assortment of fifty mice, rats, guinea pigs, rabbits, cats, and dogs, exposed to 605 to 661 mm Hg of oxygen in one atmosphere for seven days, found severe lung edema in the sacrificed animals. Before the animals died, they appeared to show symptoms similar to those of hypoxia. Becker-Freyseng and Clamann subjected themselves to 684 mm Hg of oxygen in one atmosphere total pressure in a closed chamber with a volume of 40 cubic meters. The experiment was discontinued after 65 hours because Becker-Freyseng become ill and was vomiting and Clamann was ill. They noted paresthesia of the extremities after two days and increased feelings of fatigue as the experiment continued. A transient bronchitis which occurred in one of the experimenters disappeared within twenty-four hours after the termination of the experiment. Comroe, Dripps, Dumke, and Deming,[1] working with human subjects, provided pure oxygen by masks to groups of young men for periods of twenty-four hours. They found that 82% of the subjects experienced substernal distress, and vital capacity was usually decreased significantly. Almost half of the subjects developed nasal congestion or coryza during, or shortly after, the twenty-four hour experiment. Conjunctival irritation and ear discomfort (aero-otitis) occurred in about one-fourth of the subjects. Recognizing that the low tension of nitrogen, rather than the increased oxygen, might account for the observations, Comroe et al. placed six men in a low pressure chamber at a simulated altitude of 18,000 feet (380 mm Hg) and provided 100% oxygen by masks for twenty-four hours with no occurrence of the respiratory symptoms. Comroe thus assumed that the high $pO_2$, rather than a low $pN_2$, accounted for the symptoms. Richards and Barach[10] found no indication of pulmonary irritation when they studied the effects on two men of 343 mm Hg of oxygen in one atmosphere for seven days. There have been relatively few studies on the effects of oxygen at reduced pressures for prolonged periods. On the basis

of an analytical review, Mullinax and Beischer[11] concluded that oxygen tensions less than 425 mm Hg can be breathed indefinitely with no likelihood of physical impairment.

In addition to Comroe's study at reduced pressure, Hall and Martin[12] maintained a subject in a full pressure suit at 3.5 psi pure oxygen for seventy-two hours with no reduction in vital capacity. A pustular dermititis and irritation of the eyes, nose, and throat were noted. A similar study by Hall and Kelly[13] subjected two men, one of whom was in a pressure suit, to 3.5 psi pure oxygen for five days with no significant decrease in vital capacity, although some irritation of the conjunctivae, nose, and throat occurred.

Michel, Langevin, and Bell[14] subjected six U. S. Navy enlisted men to 418 mm Hg of oxygen in 523 mm Hg total pressure of atmosphere for 168 hours (one week). They found some decrease in vital capacity in two men and an area of probable atelectasis in one subject. Other than some substernal tightness, there were no marked symptoms noted by the subjects. Welch, Morgan, and Ulvedal[15] studied the effects on two men in a chamber of 150 mm Hg of oxygen in a total atmosphere of 380 mm Hg over a thirty-day period and 190 mm Hg of oxygen (total pressure) over a seventeen-day period. A mild reduction in vital capacity, work capacity, orthostatic tolerance and increased myocardial irritability, and weight loss occurred in both experiments. Psychological performance generally remained at a stable level.

Unfortunately, it is likely that in the great majority of the reported studies of "pure oxygen" or "100% oxygen," actual values varied from as low as 50% when oxygen tents or loose masks were used, to 90% in prolonged studies not utilizing hermetically sealed chambers. Even in conventional altitude chambers, pure oxygen levels (excluding $CO_2$ and water vapor) are rarely maintained since any leak represents an influx of nitrogen (air). In addition, Comroe points out that many of the oxygen experiments performed were without air breathing controls the number of subjects was frequently very small, and the monitoring and control of the actual gaseous environment was poor. There have apparently been no studies reported in the literature to indicate any experiments using partial pressures of oxygen exceeding 258 mm Hg in the absence of an inert gas over a prolonged period.*

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* The authors are aware of three such studies currently underway, results of which have not been published.

The study reported herein was designed to provide a broad systematic appraisal of the effects of a pure oxygen environment for two-week periods on normal adult males at a total pressure of 3.8 psi, 5.0 psi, and 7.4 psi. Identical tests were also conducted on a control group in a sea level air environment (14.7 psi). Medical, physiological, hematological, biochemical, microbiological, and psychological studies were performed on all groups, with particular emphasis on the effects of pulmonary function, since recent experience in high performance jet aircraft (Ernsting,[16] Langdon,[17] and Levy[18]) and centrifuge simulation[19] of launch and re-entry g-loads have demonstrated a significant incidence of atelectasis in pilots while breathing pure oxygen.

## RESEARCH METHOD

### A. EXPERIMENTAL DESIGN

Approximately 150 graduate and medical students were carefully screened to determine their medical and psychological suitability to live in a closed environment for 14 days in pure oxygen atmosphere at 3.8, 5.0, and 7.4 psi. From this sample group, 28 men were selected, randomly divided into four groups and assigned to the three pure oxygen atmosphere studies and to a sea level atmosphere control study. Ultimately, six men served in each group with one man per group as an alternate.

The studies were run in the Space Environment Chamber of Republic Aviation Corporation in the following order:

| Condition | Subject Numbers | Dates |
|---|---|---|
| Sea Level | 11 - 17 | May 28 - June 12 |
| 5 psi oxygen | 31 - 37 | July 9 - July 24 |
| 7.4 psi oxygen | 41 - 47 | July 30 - Aug 14 |
| 3.8 psi oxygen | 51 - 56 | Aug 20 - Sept 4 |

Medical, physiological, microbiological, and psychological data were collected in each run in accordance with the schedule in Table II-1.

### B. SUBJECT SELECTION AND ORIENTATION

#### 1. Selection

Graduate students attending Columbia and Fordham Universities and medical students attending the New York College of Medicine and Albert Einstein College of Medicine in New York City were solicited to volunteer for the artificial atmosphere studies. Thereafter, medical and psychological screening examinations were given to interested student groups at Columbia, Fordham, and the New York College of Medicine on pre-arranged dates.

TABLE II-1

SCHEDULE OF DATA COLLECTIONS DURING EXPERIMENTAL RUNS

| EVALUATION | Mon (Pre-run) | Tues 1 | Wed 2 | Thurs 3 | Fri 4 | Sat 5 | Sun 6 | Mon 7 | Tues 8 | Wed 9 | Thurs 10 | Fri 11 | Sat 12 | Sun 13 | Mon 14 | Tues (Post-run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEDICAL DATA | | | | | | | | | | | | | | | | |
| Physical Exam | * | | | | | | | | | | | | | | | * |
| Neurological Exam | * | | | | | | | | | | | | | | | * |
| Chest X-Ray (in chamber) | * | | | | | * | | | | | | | | | | * |
| EKG | * | | | | | | | | | | | | | | | * |
| Intake, Output | | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| Body Weight | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Blood Pressure | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Pulse | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Respiratory Rate | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Body Temperature | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| MENTAL PERFORMANCE | | | | | | | | | | | | | | | | |
| GATB | | | | | | | | | | | | | | | | |
| Verbal Ability | * | | | | | | | | * | | | | | | * | |
| Numerical Ability | * | | | | | | | | * | | | | | | * | |
| Space Relations | * | | | | | | | | * | | | | | | * | |
| Clerical Ability | * | | | | | | | | * | | | | | | * | |
| (PANEL PERFORMANCE) | | | | | | | | | | | | | | | | |
| Arithmetic Computation | * | * | * | * | * | * | * | * | | * | * | * | * | * | * | |
| Pattern Discrimination | * | * | * | * | * | * | * | * | | * | * | * | * | * | * | |
| Scale Position Monitoring | * | * | * | * | * | * | * | * | | * | * | * | * | * | * | |
| Tracking | * | * | * | * | * | * | * | * | | * | * | * | * | * | * | |
| SENSORY PERFORMANCE | | | | | | | | | | | | | | | | |
| Visual Acuity | * | | * | | * | | * | | * | | * | | * | | * | |
| Critical Flicker Fusion Frequency | * | | * | | * | | * | | * | | * | | * | | * | |
| Dark Adaption | * | | * | | * | | * | | * | | * | | * | | * | |
| Audiometry | * | | | | | | | | * | | | | | | | * |
| MOTOR PERFORMANCE | | | | | | | | | | | | | | | | |
| Reaction Time | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| Fine Motor Coordination | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| Gross Motor Coordination | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| † Work Performance | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| PULMONARY FUNCTION DATA | | | | | | | | | | | | | | | | |
| Tidal Volume | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Timed Vital Capacity | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Critical Flicker Fusion Frequency | * | | * | | * | | * | | * | | * | | * | | * | |
| Dark Adaption | * | | * | | * | | * | | * | | * | | * | | * | |
| Audiometry | * | | | | | | | | * | | | | | | | * |
| **MOTOR PERFORMANCE** | | | | | | | | | | | | | | | | |
| Reaction Time | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| Fine Motor Coordination | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| Gross Motor Coordination | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| † Work Performance | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | |
| **PULMONARY FUNCTION DATA** | | | | | | | | | | | | | | | | |
| Tidal Volume | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Timed Vital Capacity | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| † Max. Breathing Capacity | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Inspiratory Reserve | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Expiratory Reserve | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Alveolar Gas Analysis | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Diffusion Capacity | * | | | | | | | | | | | | | | | * |
| Total Lung Capacity | * | | | | | | | | | | | | | | | * |
| **BLOOD AND SERUM** | | | | | | | | | | | | | | | | |
| Venous | | | | | | | | | | | | | | | | |
| Plasma Volume | * | | | | | | | | | | | | | | | * |
| CBC | * | | * | | * | | | * | | * | | * | | | * | |
| Hemoglobin | * | | * | | * | | | * | | * | | * | | | * | |
| Sedimentation Rate | * | | * | | * | | | * | | * | | * | | | * | |
| Hematocrit | * | | * | | * | | | * | | * | | * | | | * | |
| Reticulocyte Count | * | | | | | | | | * | | | | | | * | |
| Urea | * | | | | | | | * | | | | | | | * | |
| Glucose | * | | | | | | | * | | | | | | | * | |
| Na, K, Cl | * | | * | | * | | | * | | * | | * | | | * | |
| Arterial | | | | | | | | | | | | | | | | |
| $p0_2$, $p\,C0_2$, pH (Electrode) | * | | | | | * | | | | | | | | | | * |
| $0_2$, $C0_2$ content and capacity | * | | | | | * | | | | | | | | | | * |
| **URINE** | | | | | | | | | | | | | | | | |
| Specific Gravity | * | | * | | * | | | * | | * | | * | | | * | |
| pH | * | | * | | * | | | * | | * | | * | | | * | |
| Protein | * | | * | | * | | | * | | * | | * | | | * | |
| Sugar | * | | * | | * | | | * | | * | | * | | | * | |
| 17 0H Corticosteroids | * | | | | | | | * | | | | | | | * | |
| **MICROBIOLOGICAL DATA** | | | | | | | | | | | | | | | | |
| Skin | * | | * | | * | | | * | | * | | * | | | * | |
| Throat | * | | * | | * | | | * | | * | | * | | | * | |
| Urine | * | | * | | * | | | * | | * | | * | | | * | |
| Feces | * | | * | | * | | | * | | * | | * | | | * | |

† Only three subjects exercise and perform MBC daily

All potential subjects who reported for the examinations were given a brief description of the projected studies. They were then administered the Cornell Index Form N2, a psychological screening instrument evolved from Form N, which was used extensively for military psychiatric screening during World War II. The Index was scored immediately and abnormal individuals were excluded from further consideration.

Subjects eligible for further consideration were given a medical examination in which a detailed history was recorded. In each history particular attention was paid to allergies, cardiac irregularity, abnormal EKG or chest X-ray, parasitic intestinal infestations, hernia, varicosities, previous pneumothorax, "bends," chronic skin infections, malaria, hepatitis, jaundice, pilonidal cysts, chronic middle ear infections, defective hearing, eye infections, allergies, smoking habits, and past feelings of claustrophobia. An impression of motivation and maturity of the subjects was obtained. Physical examination stressed verification of the history, body hygiene, general body condition, and build. Subjects who were significantly deficient on the foregoing medical criteria were excluded.

The subjects still under consideration were administered an Ischemic Contraction Test developed by the Space Environment and Life Science Laboratory to measure pain endurance in a NASA sponsored "Study of Sensory Deprivation, Pain and Personality Relationships for Space Travel." This test appeared to correlate well with endurance in general. In the test, the subject was instructed to raise his arm over his head. After 10 seconds, a sphygmomanometer cuff was applied to the upper arm and maintained above 180 mm Hg pressure. With the cuff inflated, the subject was required to contract his hand against a fixed resistance once per second, in time to a metronome, until pain and/or inability to continue forced him to stop. He was scored on the number of completed contractions.

After the administration of the Ischemic Contraction Test, the physicians and psychologists who had given the examinations made joint decisions in selecting the final group of eligible subjects. Thereafter, subjects who had previously indicated their availability for particular times when the experimental runs were scheduled were distributed across the projected runs in four groups of seven subjects. Thus, there was an available alternate in

each group from which six subjects would finally be chosen. The alternate was included in the event that one of the subjects could not participate in an experimental run due to recent illness.

2. Orientation

Six subjects and one alternate arrived at the Paul Moore Applied Research and Development Center the day before the start of the experimental run. They were conducted to the Space Environment and Life Science Laboratory, assembled, and given a general briefing. In the briefing, the subjects were told that they would:

1) Participate in a NASA-sponsored study bearing on the Gemini Project.

2) Live for 14 days in a pure oxygen atmosphere at a pre-planned altitude in the Republic Space Environment Chamber. Care was taken not to inform the subjects of the particular altitude at which they would be tested.

3) Undergo a long series of medical, physiological, and psychological tests during the pre-run day, and that most of the same tests would be administered periodically during the experimental runs.

4) Undergo the same comprehensive series of tests on the day following their release from the chamber as they had taken during the pre-run day.

5) Serve in standard fashion, without changes in procedures, in accordance with the training which they received during their pre-run testing. The importance of good motivation was stressed.

6) Have periodic veni-punctures, throat and skin cultures, and pulmonary function studies performed by the medical student subjects.

7) Eat pre-planned menus of dehydrated food, consume the food portions provided and keep an adequate calorie and fluid intake and fluid output record.

8) Wear surgical type scrub suits that would be laundered periodically during the experiment. The importance of maintaining good body hygiene was stressed.

9) Enter the chamber the following morning, at which time the final selection of six subjects would be made, based on the results of the pre-run testing.

10) Be briefed on chamber safety procedures before the start of the experimental run.

## C. CHAMBER PREPARATION, OPERATION, AND ENVIRONMENTAL MONITORING

### 1. Introduction

In order to accomplish the 100% oxygen study, it was necessary to prepare the Republic Aviation Corporation Space Environment Chamber to support human life for a 14-day period. Provisions were made to create, maintain, and monitor a 100% $O_2$ environment, to assure the safety and comfort of the subjects, and to allow for their medical, physiological, and psychological testing.

### 2. Description of Facility

The Republic Space Chamber is a stainless steel cylinder 30 feet long by 13 feet in diameter, divided into two compartments; the main chamber, and the entry lock. The main chamber is 18 feet long, and the entry lock is 8 feet long. In addition, a small transfer lock was provided for the passage into and out of the chamber of foods, waste, supplies, and physiological specimens. Each of the three compartments had separate and independent pressure controls, and could be independently flushed with oxygen (Figure 2-1).

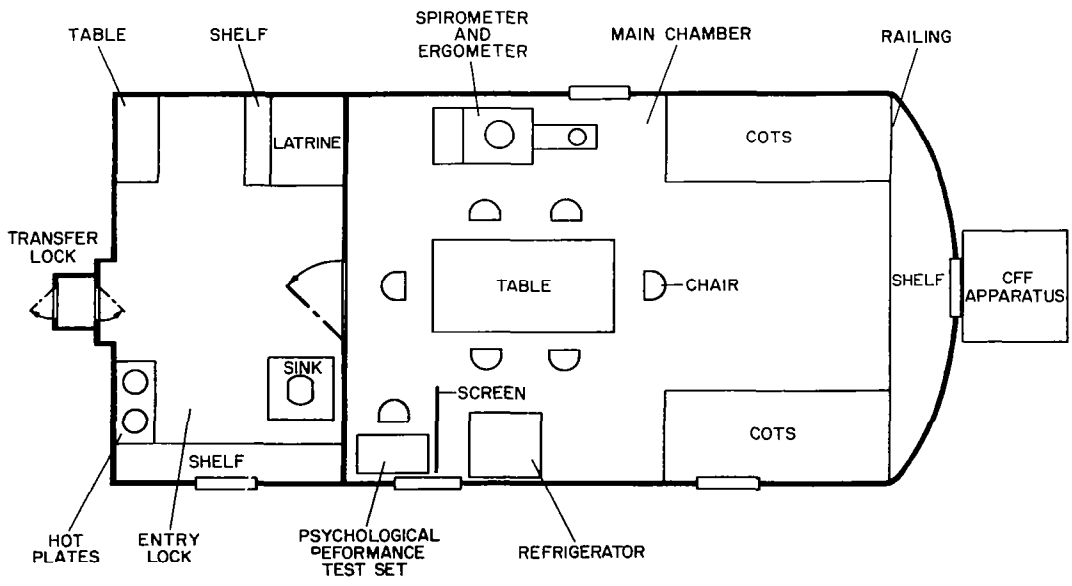



Figure 2-1 Schematic of Space Environment Chamber

The Space Chamber is designed to obtain and hold an absolute pressure below $1 \times 10^{-6}$ TORR. Consequently, the total leak rate at one micron Hg absolute is less than 0.01 cc S.T.P.D. per second into a volume of 2500 cubic feet. This made it possible, during the tests, to control the partial pressure of the $N_2$ well below the specified limit.

3. Fire Safety

The maintenance of the safety of men in an enclosed 100% $O_2$ atmosphere is fairly complex, involving such diverse elements as material combustibility, toxicity due to buildup of trace contaminants, and escape in the event of fire. The primary problem, of course, was the prevention of fire, Republic, in establishing the test program, attempted by every possible means to preclude the possibility of a fire occurring, while providing all the necessary equipment for fire fighting and means for personnel protection and escape.

Selection of fire resistant or fireproof materials involves many compromises. The food supply, for example, is inherently combustible. Such materials as napkins, facial and toilet tissue, and cotton products such as bed clothing, scrub suits, towels, and gauze pads are all combustible at sea level atmosphere and are certainly more combustible in 100% oxygen.

In view of this, the policy adopted was that the amount of combustible material permitted in the chamber at any given time would be minimized; ruled out were any materials which, in the presence of 100% oxygen at the worst altitude condition (18,000 ft) would produce, when oxidized, 1) explosions, 2) dense smoke, 3) noxious fumes, 4) large volumes of gas, 5) extremely high temperatures, or 6) flaming drops. In addition, all electrical equipment was restricted to that which would operate at 110 volts or less; moreover, the number of pieces operating at 110 volts was reduced to a minimum.

a. Material Tests

Where possible, equipment used inside the chamber at 100% oxygen was first subjected to a test in a bell jar. Initiation of combustion was provided by a high voltage arc after atmospheric conditions were established. The rise in pressure was observed on the mercury manometer; smoke was

observed visually as were most of the phenomena. After the first few tests in which pressure rise was shown to be a trivial phenomenon, testing was restricted to visual observations which were recorded after each test. Test samples were approximately 1 cc and were placed immediately adjacent to the arc. Table II-2 illustrates the variety of material tested and includes all significant observations. Based on these studies, the less flammable articles were selected for use during the tests.

TABLE II-2

PRELIMINARY SCREENING TESTS OF MATERIALS FOR POSSIBLE USE IN 100% $O_2$ ATMOSPHERE

| Test | Description | Results | Remarks |
|---|---|---|---|
| 1 | Fiberglass material coated white | Coating burned off completely | Fiberglass appeared brittle |
| 2 | Fiberglass coated green | Coating burned off completely | Fiberglass appeared brittle |
| 3 | Dynel cloth fabric | Burned completely | |
| 4 | Dynel static free | Burned completely | |
| 5 | Dacron-rayon static free | Burned completely | |
| 6 | 100% Dacron cloth fabric | Burned completely | |
| 7 | "Scotch-Shield" Type 75 (asbestos-aluminum coated) | Coating burned completely | Asbestos appeared brittle and tore readily |
| 8 | "Scotch-Shield" Type 82 (flame proof rayon-aluminum coated) | Burned completely | |
| 9 | Nylon cloth fabric | Burned completely | |
| 10. | Pluton | Burned completely | |
| 11 | Army duck | Burned completely | |
| 12 | Goose down | Burned completely | Bright flame |
| 13 | Foam rubber | Burned with bright flame | Filled bell jar with black oily smoke |
| 14 | Epoxy foam | Burned almost completely | |
| 15 | Wool rug (Harlok) | Burned completely | Bright flame |
| 16 | Wool rug (rubber coated) | Burned completely | Bright flame |

TABLE II-2 (Cont)

| Test | Description | Results | Remarks |
|---|---|---|---|
| 17 | Wash'n Dri cloths (wet) | Did not burn | |
| 18 | Wash'n Dri cloths (dry) | Burned completely | |
| 19 | Paperbound book with cover | Burned when flame applied; stopped when flame removed | |
| 20 | Hardbound book (old paper) | Burned completely | |
| 21 | Insulated wire | Largely consumed | |
| 22 | Braided insulated wire | Insulation completely burned | |
| 23 | Plastic insulated wire | Insulation almost completely burned | |
| 24 | Aluminum covered insulated wire | Insulation burned off with bright flame leaving aluminum wrapping intact | |
| 25 | Asbestos-Dynel S/1445 | Dynel consumed; but asbestos remained intact | |
| 26 | Polyurethane foam | Completely burned | |
| 27 | Styrofoam (with combustion inhibitor) | Material ignited but did not support combustion | |
| 28 | Paper towels | Burned completely | |
| 29 | Glass braided wire | Did not burn | |
| 30 | Mattress sample composite (urethane foam wrapped in aluminum foil and asbestos-Dynel) | Did not burn | |

b. Electrical Equipment Tests

Three of the critical electric items were microswitches used for vital capacity measurements, and psychomotor performance equipment containing a large number of switches, and electric hot plates used for preparing food.

The microswitches were tested by operating them in the oxygen environment for a period of over a week on a 30-second duty cycle. This was equivalent to many months use in the chamber. No malfunctions occurred.

The psychomotor performance panel was specified initially to be compatible with operation at 100% $O_2$ levels and was designed to run at 12 volts to minimize arcing. It was also sealed from chamber atmosphere to minimize the danger of combustion.

Preliminary tests of operation of the hot plates (submersible type) showed that arcing dangers existed in the temperature control circuit and that high temperatures could be reached on the surface of the hot plate itself. To prevent arcing, control of the hot plate was maintained outside the chamber by means of a voltage regulator. Preliminary tests were run in the chamber under simulated conditions, and it was determined that pieces of paper and even plastics which are highly inflammable did not burn in the presence of oxygen when exposed to hot plate temperatures less than 350°F. This limited the operation of the hot plates to approximately 70 volts but still permitted the heating of water to 212°F in pressure cookers, which were required because of the altitude.

All vacuum pumps were lubricated and sealed with tricresyl phosphate. In order to minimize the amount of combustible material such as newspapers and linen, a procedure for bookkeeping was arranged, and records were kept of all material going in and out of the chamber.

4. Preparation of Chamber

a. General Arrangements

For the 100% $O_2$ tests, it was necessary to adapt the Space Environment Chamber for habitation by 6 human subjects for two weeks. Using the materials which had been determined to be safe by the method previously described, the following preparations of the chamber were accomplished.

During the test program the main section was used as the "living quarters" in which the medical, physiological, and psychological test programs were conducted and where eating, relaxing, and sleeping took place. In order to provide adequately for the performance of these varied activities, this section of the chamber was equipped with six beds (two triple-decker arrangements), a chair for each subject, and a picnic type folding aluminum table. The urethane-foam mattresses covered with asbestos were used on the bed frames. To soften the harshness of the bare chamber walls and to cut down on glare, the walls were covered with fiberglass drapes. Further considerations for general well-being included radio and color TV, which were available at the personal discretion of each subject by means of individual headset arrangements.

The small entry lock section of the chamber became the kitchen, larder, and lavatory area. Here the subjects prepared their meals daily, accomplished transfer operations in and out, performed their daily ablutions and performed certain psychological and vision tests. Located in this area there were the following:

1) Two externally controlled hot plates for the preparation of meals.
2) Sink with hot and cold running water.
3) Toilet facilities.
4) Storage space for foods, medical supplies, linens, dishes, etc.

The external door contained the transfer lock through which transfers in and out of the chamber were accomplished. Transfer operations were kept to the absolute minimum and, except for unusual or unexpected requirements, were limited to one in-out operation each day at 0700 hours. Inasmuch as these transfer operations represented a major hazard to the maintenance of the 100% oxygen environment, they were carefully monitored and controlled. Prior to the opening of the inner door of the transfer lock, the transfer lock was evacuated to maximum vacuum and back flushed to atmospheric pressure with 100% oxygen. This procedure was repeated twice and the transfer lock was then brought to entry lock pressure.

The gas in the transfer lock was then monitored for $N_2$ by means of a nitralyzer before the inner door of the transfer lock was opened. The transfer of equipment, supplies, wastes, etc., was then accomplished.

Additional considerations included the necessity for maintaining constant intercommunications, provision of backup oxygen systems, fire extinguishers, and emergency recompression facilities.

b. Communications

The communications arrangements consisted of four private telephone lines between the interior and exterior of the chamber. Basic telephone operator headsets having carbon element microphones and magnetic earpieces were used. These were powered by 6-volt dry cell batteries. The private lines permitted the subjects to be engaged in various psychological, physical, and medical tests without interfering with each other and permitted individual communications with subjects acting as test assistant on other subjects. These private lines were arranged at the monitor consoles so that at the monitor's discretion he could interrupt any or all private conversations simultaneously to issue instructions.

Two additional private lines were installed to provide the subjects with both TV and radio sound channels, either of which was available to the individual subjects at the throw of a switch. Also, the emergency oxygen stations were equipped with telephone jacks which were connected into two of the private telephone lines, permitting communication with subjects wearing oxygen masks.

Each subject was provided with one telephone operator's headset with a plug modified to mate with a standard three-wire phone jack. In addition to the equipment described above, a P.A. system was available for one-way announcements into the chamber.

For less formal communication and general purpose activities, an intercom was provided giving the monitors constant listening to the interior of the chamber. Additional stations permitted the monitor to page the medical personnel on duty or to be alerted by them.

Among the advantages of the 6-volt telephone system, were its simplicity of operation and independence from power failure. In addition,

the use of 6-volt dry cell batteries reduced the fire hazard, since in the event of a short circuit the battery would discharge before a fire could start.

c. Backup Oxygen System

The backup supplemental oxygen system installed in the chamber consisted of the standard USAF MD-1 diluter-demand automatic pressure breathing regulator and the MS 22001 oxygen mask. The oxygen supply system was comprised of a special bank of ten high pressure (2200 psi) oxygen cylinders. System supply pressure was maintained throughout the program at 100 psi at the MD-1 regulator.

d. Life Support

Since the purpose of the test program was to study the effects of 100% oxygen on various medical aspects of human survival in test flight, the engineering function involved maintenance of the parameters as specified in the experimental design.

The Space Environment Chamber was continuously flushed with oxygen while the pumping system of the facility was used to maintain the simulated altitude. Liquid oxygen was forced through a cold panel near the ceiling of the chamber, and the oxygen, now gaseous, was introduced into the chamber. Some of the liquid oxygen was bypassed through a small refrigerator in the main chamber which was used to preserve physiological samples, etc. Before the 5.0 psi run, the liquid oxygen lines were covered with a freshly prepared polyurethane foam for insulation to prevent condensation of moisture on the lines. This was used throughout the remainder of the study.

About 600 to 700 liters of liquid oxygen per day were normally required to maintain the proper gaseous environment. Additional oxygen was required for flushing the entry lock at the beginning of the experimental run and on the fifth and fourteenth day when medical personnel were transferred into the chamber to perform arterial punctures.

In order to insure the purity of the liquid oxygen used, two samples were taken. The results, as shown in Table II-3, were well within the specified values for liquid oxygen. This analysis was performed by Air Reduction, Inc., Laboratory, Murray Hill, N.J.

TABLE II-3

INVESTIGATION OF CONTENTS OF LIQUID OXYGEN CYLINDERS

| Analysis | Quantity V/V | |
|---|---|---|
| | 1 | 2 |
| Oxygen | 99.82% | 99.82% |
| Argon | 0.1% | 0.1% |
| Nitrogen | 0.01% | 0.01% |
| Total Hydrocarbon such as $CH_4$ | 17 ppm | 16 ppm |
| Methane | 11 ppm | 10 ppm |
| Ethane | 0.03 ppm | 0.02 ppm |
| Carbone Dioxide | 0.8 ppm | 0.6 ppm |
| Krypton | 8 ppm | 9 ppm |

Other contaminants analyzed for but not detected: ethylene, acetylene, propane, propylene, i-butane and n-butane. Threshold of detection 0.01 ppm V/V

NOTES: 1. Sample for gas outlet
2. Sample from liquid outlet - vaporized through copper coil.

Actual control of the flow rate of liquid oxygen into the chamber was accomplished by manual means and in general was adjusted up or down in response to changes in nitrogen or $CO_2$ levels. Humidity was controlled by adjusting the flow through the cold panel situated close to the ceiling of the chamber. This panel, which was very close to -300°F, condensed out most of the water vapor introduced into the chamber by the men or by the cooking procedures. In order to maintain humidity within acceptable limits at night, it was necessary to evaporate water using open cooking pots placed on the hot plates.

e. Supply

The main portion of the diet was dehydrated food, provided by the Army Quartermaster Corps. It consisted of a balanced diet of three meals

of a variety of foods which yielded about 2000 calories per day. The subjects were requested to eat their basic 2000 calories and were allowed to supplement this food with candy bars and fresh bread and margarine, with the recommendation that candy consumption be limited to two bars per day. The food was prepared by the subjects according to directions provided by adding hot or cold water to the dehydrated food. A freezer in the chamber was used to keep the margarine cold and the bread frozen until ready for use.

f. Waste Disposal

Fecal waste was eliminated into a "traveling toilet" equipped with a disposable plastic bag. The bag was wadded up, placed into an ice cream carton and frozen until the next transfer out was made. The fecal matter was then weighed and disposed of. Urinals were used for urine measurements. The urine was poured down a tube connected to the sink drain which drained into a large jar below the chamber. The jar was emptied as necessary by reducing the absolute pressure in the jar to the chamber pressure with a vacuum pump, allowing the sink contents to drain into the jar by gravity, isolating the jar from the chamber by means of a valve, and then recompressing the jar to sea level.

g. Apparel and Linens

All linen used in the study, with the exception of personal linen, was supplied to the test subjects. Each subject was given a six day supply of scrub suits, face, hand, bath towels, and wash cloths. Laboratory coats and bed linens were supplied weekly. Dirty linen was transferred out, laundered, and returned to the subjects periodically during the experimental runs.

5. Chamber Procedures

a. Indoctrination of Subjects

Prior to entry into the chamber, the subjects received an intensive indoctrination in the following areas (where applicable, demonstrations were performed):

1) Basic problems of pressure differentials as they relate to dysbarism.

2) Hypoxia.

3) Oxygen requirements and the supplemental oxygen system of the chambers, MD-1 regulators, MS 22001 masks.

4) Communications network of the chamber.

5) Requirements for cleanliness and sanitation, i.e., daily housekeeping routines.

6) Meal preparation techniques.

7) Lock transfer techniques (in-out).

8) Emergency fire procedures.

b. Chamber Entry and Egress Procedures

The main chamber was prepared by first evacuating to $1 \times 10^{-4}$ mm Hg, and then back flushing with oxygen to approximately 5000 to 10,000 feet equivalent altitude. The subjects then entered the entry lock, which was at sea level conditions, and the outer door was sealed. This area was then flushed with 100% oxygen at a very high flow rate, with vent valves open, and continuous sampling was conducted until the $N_2$ was less than 0.5%. During this period and for a total period of approximately 3 hours, the subjects in the 3.8 psi run were on 100% $O_2$ discipline by way of the supplemental oxygen system. In this manner, environment conditions were achieved simultaneously with denitrogenation. When these factors had been verified, the entry lock was brought to main chamber altitude and the intervening bulkhead door opened, thereby establishing the experimental conditions.

The medical teams entered the chamber twice, once on the fifth day and again on the last day. Essentially, the procedure described above was followed. Removal of the medical team and maintenance of the experimental test conditions in the main chamber were accomplished as follows: The medical team entered the entry lock area, the bulkhead door was closed, and entry lock descent initiated. When ground level conditions were obtained, the team was removed and the entry lock was flushed with 100% oxygen until the $N_2$ was less than 0.5%. The entry lock was then brought to main chamber altitude and the bulkhead door opened.

6. Chamber Environment Monitoring

Early in the planning of the study it was recognized that the success of the experiment, as well as the safety of the subjects, would require constant and close monitoring of the chamber environment. Not only would it be necessary to maintain the parameters of the atmosphere within specified limits, but it would also be necessary to be constantly alert to the possibility of the increase of toxic contaminants beyond a safe level. It was therefore decided to monitor each parameter by as many independent sensing devices as practicable and to do so at 2-hour intervals on a 24-hour per day schedule. Parameters measured were temperature, humidity, per cent $N_2$ , per cent $CO_2$ , per cent $O_2$ , and total absolute pressure.

a. Temperature Measurement

Temperature was sensed by eight thermocouples, placed at fixed strategic points within the chamber. The output from these points was constantly read-out by an eight point strip chart recorder and a manual read-out was performed every 2 hours.

b. Humidity Measurement

Humidity was determined by dry and wet bulb temperatures, measured within the chamber by a sling psychrometer which was operated by one of the subjects. These temperatures were used in combination with a specially prepared psychrometric chart for the appropriate altitude to determine the relative humidity and also check the temperature indicated by the thermocouples.

c. Nitrogen Concentration Measurement

Nitrogen concentration was monitored by a Med-Science Electronics Inc., Nitralyzer. This instrument was connected to a gas sample manifold which could be valved to the main chamber, the entry lock, or the transfer lock. The manifold was purged to each of these test points by means of a vacuum pump. The Nitralyzer, which had been previously calibrated to chamber pressure, indicated the per cent $N_2$ in the sample being monitored. The $N_2$ content of the chamber was checked periodically with a gas chromatograph.

d. $CO_2$ Concentration Measurement

The $CO_2$ concentration was measured by means of a Kitagawa detector. In order to use this instrument, which operates properly only if the gas sample is at standard conditions, it was necessary to draw a sample of the chamber gas from the main chamber or the entry lock, trap it in a flexible rubber container, and compress it to sea level pressure. A Kitagawa volumetric pump was then used to draw a measured volume of the sample gas through a tube filled with indicator chemicals. The length of discoloration in the tube was proportional to the per cent of $CO_2$ in the sample. Gas samples were analyzed for $CO_2$ also by means of a gas chromatograph, a Harvard $CO_2$ analyzer, and a Beckman $CO_2$ sensor.

e. $O_2$ Concentration Measurement

The per cent $O_2$ was measured in the main chamber and in the entry lock by the use of two Chemtronics $O_2$ sensors. The output of the sensors was read by a sensitive vacuum tube voltmeter, and the voltage was converted to per cent $O_2$ by means of a previously determined calibration curve.

f. Total Absolute Pressure Measurement

Total absolute pressure was sensed by a Sostman pressure transducer and two Alphatron vacuum gages, each of which was read-out automatically by a Brown strip chart recorder. The altitude was visually monitored by two Wallace and Tiernan altimeters, one connected to the main chamber, the other connected to the entry lock. A mercury manometer was connected to the gas sampling manifold, and was used to check the pressure in the main chamber, the entry lock, and the transfer lock.

g. Additional Measurements

Frequently, gas samples were taken for further analysis by the Kitagawa method. These samples were analyzed for concentrations of ammonia, hydrogen, sulfide, and carbon monoxide.

During most of the three altitude experiments, a time-of-flight mass spectrometer was connected to the gas sample manifold. This instrument was used to give quantitative indications of the per cent of $N_2$ ,

$O_2$ , $CO_2$ , and $H_2O$ present in the chamber gas, as well as to scan the spectrum from Mass 0 to Mass 100 for traces of other gases. The percentages were calculated from measured mass peaks. The entire spectrum was scanned electronically, and the profile of the spectrum was recorded on a strip chart pen recorder.

7. Control of Environment

a. Ventilation at Sea Level

Chamber ventilation during the sea level run was accomplished by opening the chamber vent valves and inducing a draft by means of the vacuum pumping system. The $CO_2$ content varied from 0.08% to 0.22%, with the mean at 0.155%. The relative humidity, which depends to a great extent on the ambient, ranged from 45% to 65%, with the mean at 56%. Temperature varied from a low of 72°F to a high of 77°F, with a mean of 74.7°F.

b. Altitude Simulations

During the altitude runs, liquid oxygen was forced through a cooling panel located near the ceiling of the chamber, and the oxygen, which was then gaseous, was emptied into the chamber. The rate of flow of the LOX was controlled manually, based upon the $CO_2$ level, and the ability of the pumping system to maintain the absolute pressure requirement. It was necessary to exercise caution not to increase the rate of flow of the LOX to the point where the oxygen introduced into the chamber would still be in a liquid state.

c. $N_2$ Level Control

The $N_2$ level was controlled during the 5 psi run between 0.10% and 0.26%, with the mean at 0.13%. During the 7.4 psi run, the $N_2$ varied from 0.10% to 0.32%, with a mean of 0.13%. During the 3.8 psi run, however, the $N_2$ level varied from 0.19% to 0.55%, with the mean at 0.29%. This was due to the fact that the same partial pressure represents a greater percentage of the total pressure at the higher altitude.

d. $CO_2$ Level Control

The $CO_2$ level was controlled between 0.16% and 0.68% during the 5.0 psi run, with the mean at 0.42%. During the 7.4 psi run the

spread was 0.28% to 0.55%, with a mean of 0.42%. During the 3.8 psi run, the $CO_2$ level ranged from 0.26% to 0.45%, with a mean of 0.35%.

e. Humidity Control

The control of relative humidity during the altitude runs presented some difficulty. The cooling panel near the top of the chamber tended to condense water from the atmosphere, and it was necessary to boil water on the hot plates to maintain the relative humidity near the comfort level. During the 5.0 psi run, the humidity varied from 34% to 66%, with a mean of 51%. During the 7.4 psi run, the low was 54%, the high was 69%, and the mean was 62.5%. During the 3.8 psi run, there was greater difficulty in maintaining the relative humidity, since a constant absolute humidity and temperature results in a lower relative humidity at lower absolute pressures. The low was 30%, the high was 36%, and the mean was 33.6%.

f. Temperature Control

Temperature was a function of rate of flow of the LOX, laboratory ambient, and heat load within the chamber. During the 5.0 psi run, the temperature varied from 72° F to 76°F, with a mean of 73.7°F. During the 7.4 psi run, the temperature varied from 71°F to 74°F, while the mean remained at 73.7°F. In the final 3.8 psi run, the temperature was maintained between 70°F and 72°F, with a mean of 71°F.

8. Atmospheric Contaminants

a. Ventilation

Atmosphere contaminants were controlled by flushing the chamber with room air in the sea level run and with liquid oxygen in the altitude runs. During the control run, there was one complete turnover of the chamber atmosphere once every 20 minutes; during the altitude runs, once every 30 minutes. The flushing used in these experiments is considered more effective, as far as removal of contaminants is concerned, than the usual regeneration system.

b. Monitoring

Total pressure, oxygen, $CO_2$, nitrogen, and water vapor were monitored as described under Chamber Environmental Monitoring. The

Kitagawa gas detector was used for analysis of hydrogen sulfide, carbon monoxide, and ammonia. No measurable contamination was found at any time during these experiments.

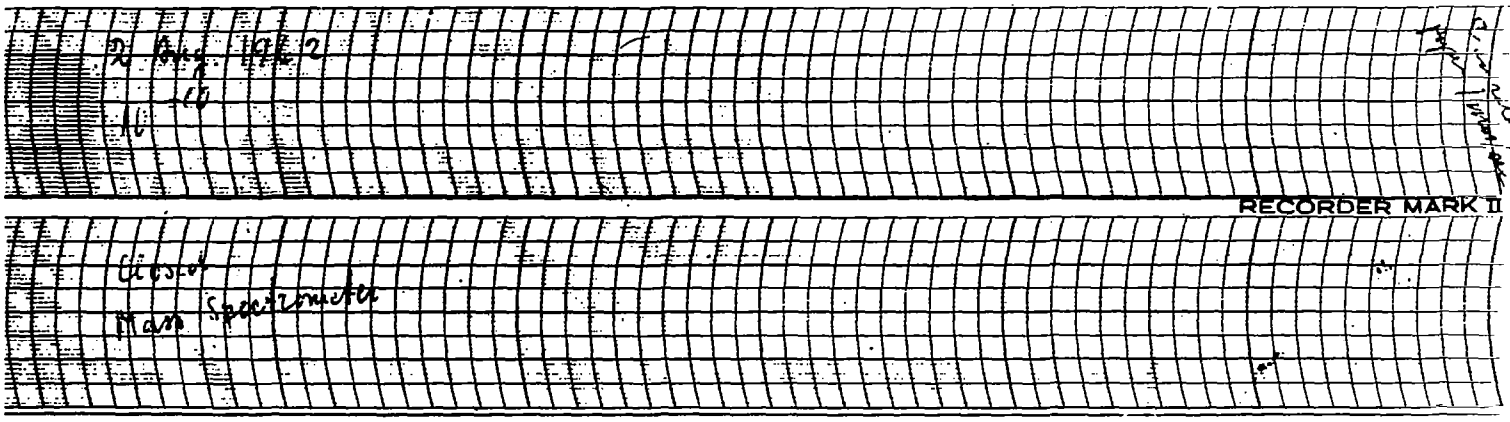
The "Time in Flight" Bendix mass spectrometer was used to monitor for possible contaminants up to Mass 100. Figure 2-2 shows a mass spectrometer analysis of; 1) environmental air, 2) breathing gas, and 3) chamber gas during the 7.4 psi oxygen experiment.

c. Post-Run Analysis

Materials used in this study were carefully selected and tested. However, at the end of the experiments, a further analysis was made of any materials that might possibly release a toxic atmospheric contaminant in a low pressure high oxygen concentration environment.

Freshly prepared lockfoams were used for insulation of the liquid-oxygen cooling pipes. The freshly synthesized type used in this study was mixed with equal parts of a polyether and a placticizer consisting of 54% toluene and 46% di-isocyanate. Therefore, the final product consisted of 27% toluene.

Backus[20] states that "Polyester, as well as polyether flexible foams may be completely déstroyed by strong oxidizing agents, but polyether foams are usually more susceptible to oxidation." The manufacturers of the lockfoams, Nopco Chemical Co., Linde Co. (Union Carbide), and Du Pont Research Division could not provide any information on the chemical stability of these foams in a low pressure, high oxygen concentration environment. Therefore, sections of these foams were placed in bell jars under a 5 psi pure oxygen atmosphere. Several days later the atmosphere was tested for toluene with the Kitagawa gas analyzer. There was a color change, but it was not the typical toluene change, making interpretation difficult. Two weeks after the start of a similar experiment, the bell jar gases were tested with the mass spectrometer. There was no peak at 78 (benzene) or 92 (toluene). However, even assuming that some breakdown products were present in the chamber, it cannot be determined whether they were in sufficient concentration to produce any significant clinical findings.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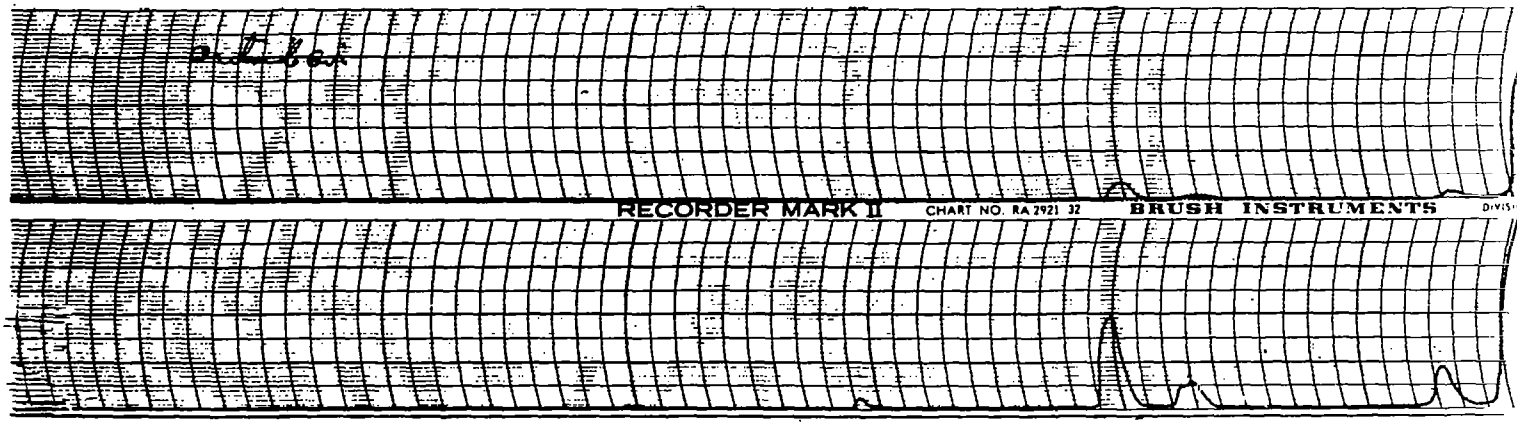
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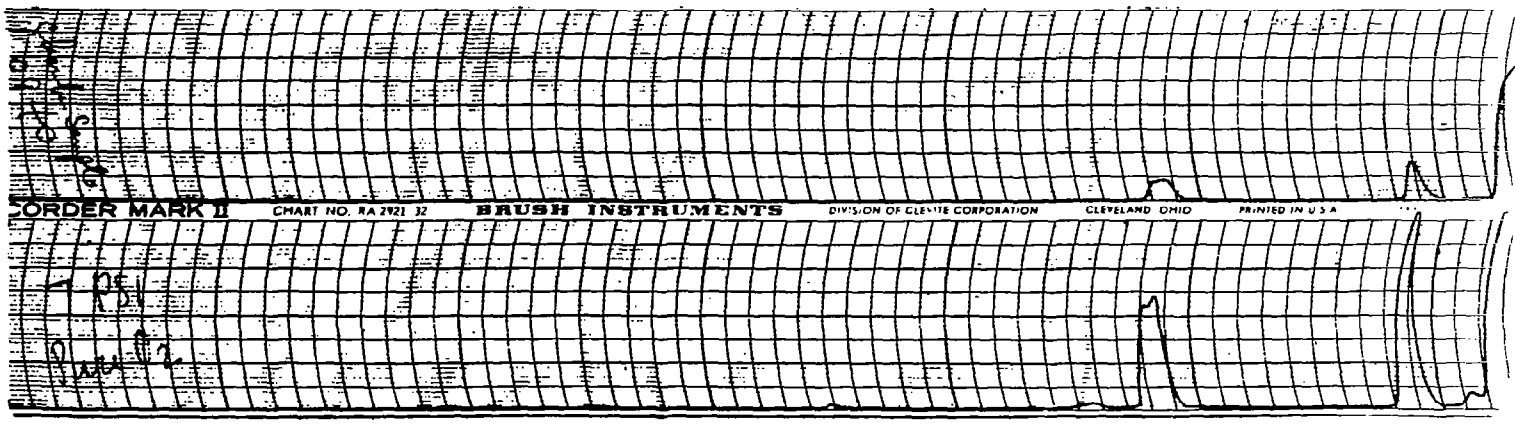
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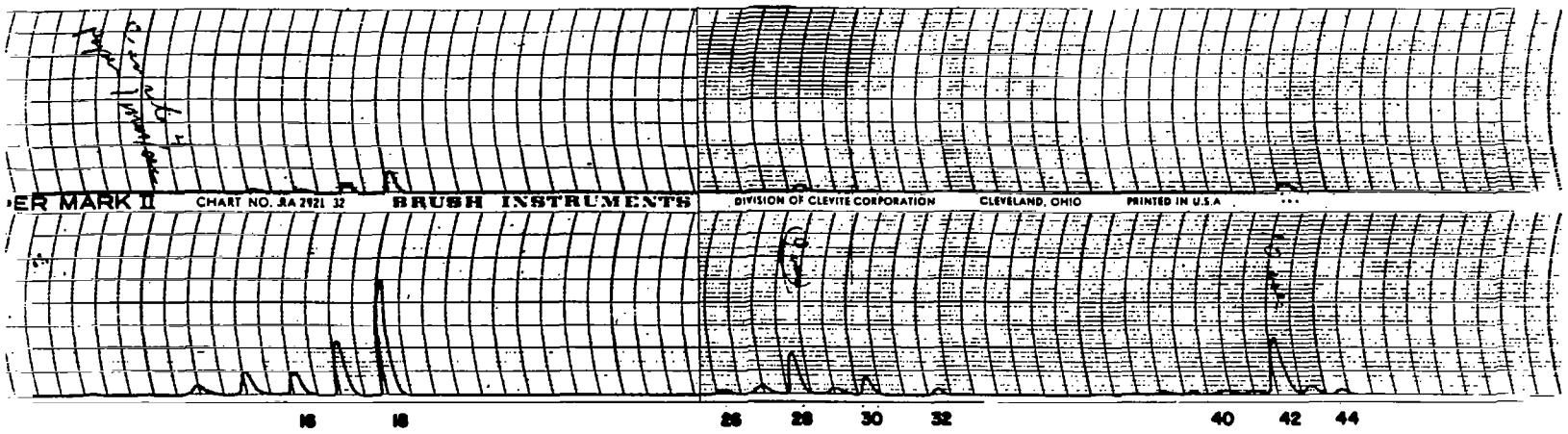
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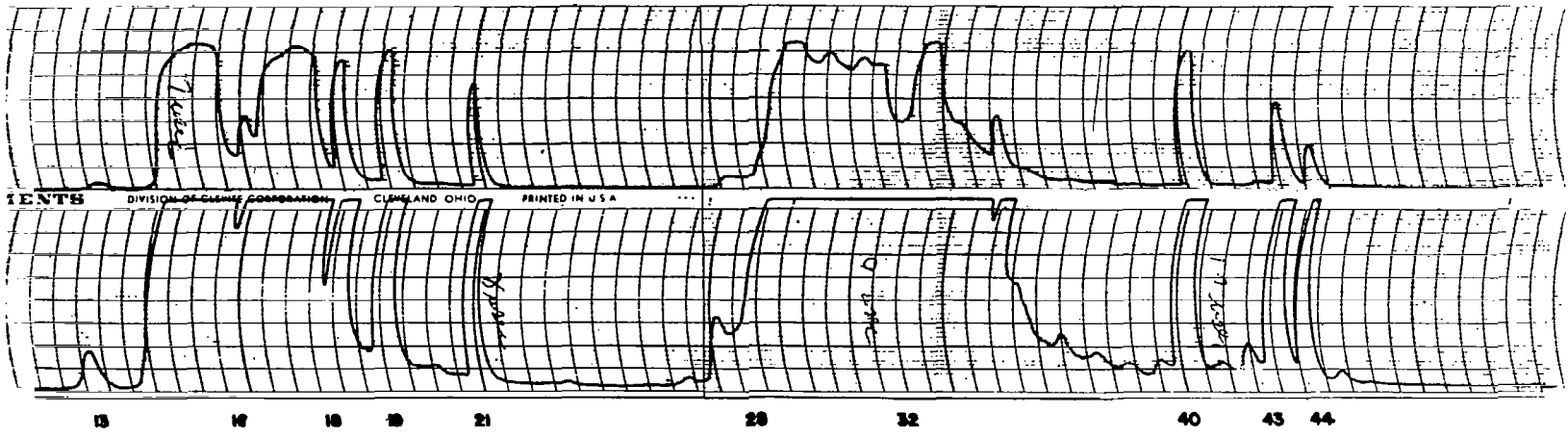
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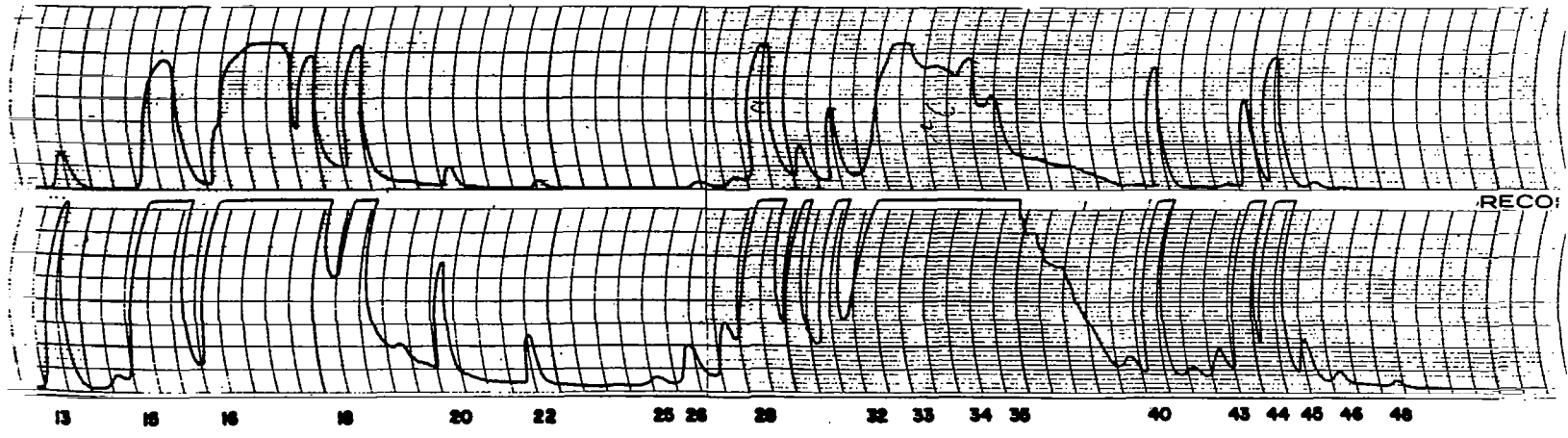
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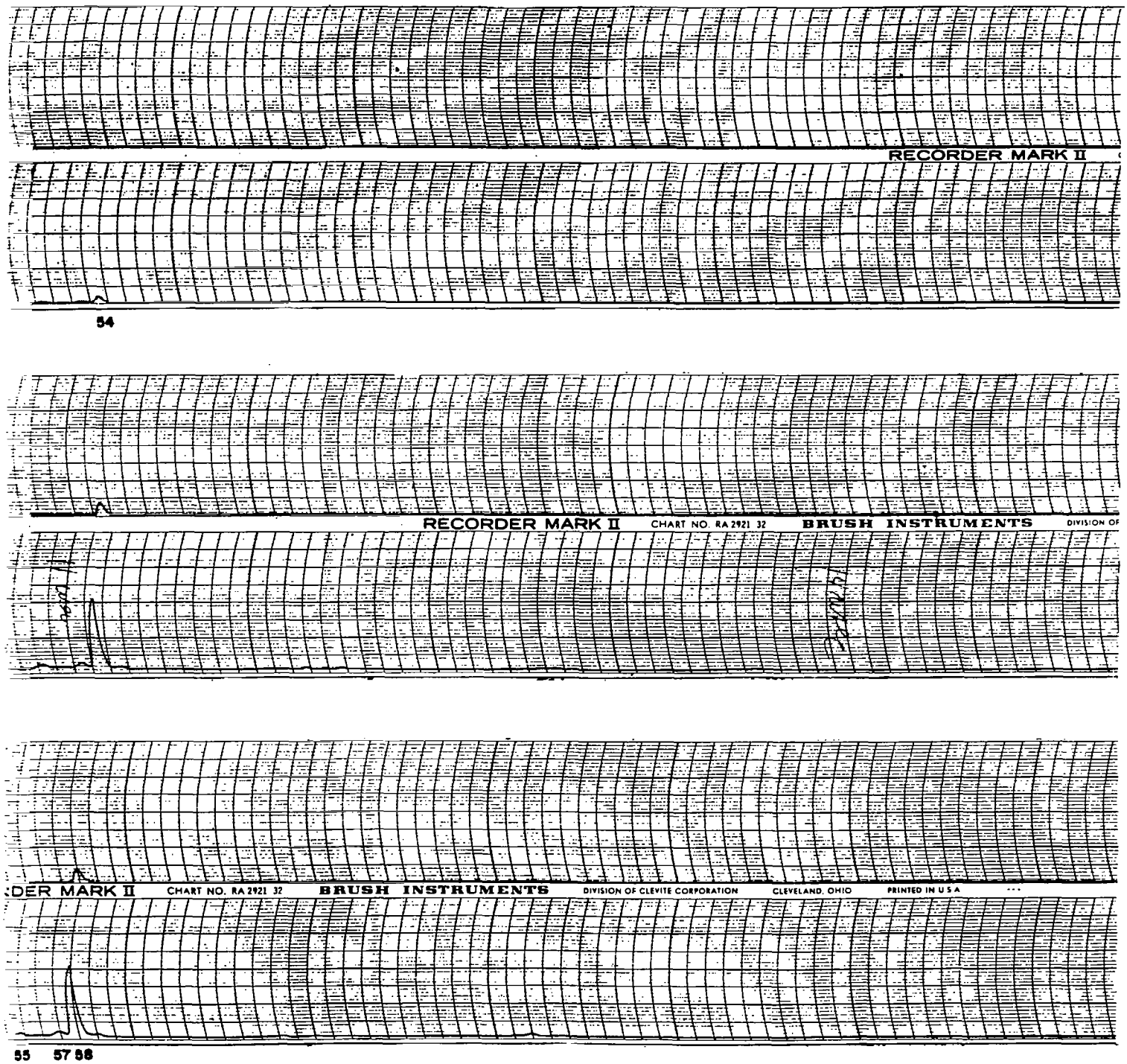



Figure 2-2 Mass Spectrometer Traces

In the course of this study, the chamber was contaminated with mercury due to the following causes:

| | | |
|---|---|---|
| 2nd day | 1st run | 4 oral thermometers broken |
| 8th day | 1st run | 1 sling psychrometer broken |
| 11th day | last run | 1 oral thermometer broken |
| 12th day | last run | 1 sling psychrometer broken |
| 14th day | last run | 1 oral thermometer broken |

Between runs, the highly polished stainless steel surfaces of the chamber were carefully cleaned, including the area beneath the floorboards. This cleaning should have removed any possible accumulation of mercury in the chamber. Additionally, the flushing system resulted in oxygen entering at shoulder height and exhausting out the bottom of the chamber below the floorboards. Since heavy mercury vapor would tend to collect below the floorboards, it would have been flushed out of the chamber instead of being inhaled by the subjects.

A number of other factors were evaluated, such as wire insulation, plastic bags, food containers, etc. They were all considered harmless. The presence of atmospheric trace contaminants must be considered in any sealed capsule experiment. The likelihood of the presence of a significant contaminant in this study is minimized by the continuous flushing of the chamber during all the experimental runs.

## RESULTS AND DISCUSSION

### A. MEDICAL DATA

A physician was present at all times during the altitude runs for continual appraisal of the health and well-being of the subjects. Vital signs were taken twice a day by the medical student subjects as described in the Appendix. They remained within the normal range (Figures 3-1, 3-2, 3-3, and 3-4). There was a slight downward trend in the average systolic and diastolic blood pressure of subjects in the 5.0 psi run and less in the 3.8 psi run. In the 7.4 psi run the blood pressure dropped initially to an average 105/75 and remained essentially unchanged throughout the experimental run. There were no significant changes in the average pulse rate, respiratory rate, and body temperatures.

Daily 12-lead electrocardiograms did not reveal any abnormalities. Chest X-rays taken before, on the fifth and on the last day of each experimental run were read by a radiologist as normal with no atelectasis detected.

The subjects were given a controlled diet of dehydrated food supplied by the Army Quartermaster Corps which supplied approximately 2000 calories, supplemented by ad lib candy bars, margarine, bread, and crackers. Measured amounts of hot or cold water were added to the individually canned dehydrated food. The food was palatable and acceptability was generally good, although many subjects complained about the monotony of the meals. Food rejects are summarized in the following table:

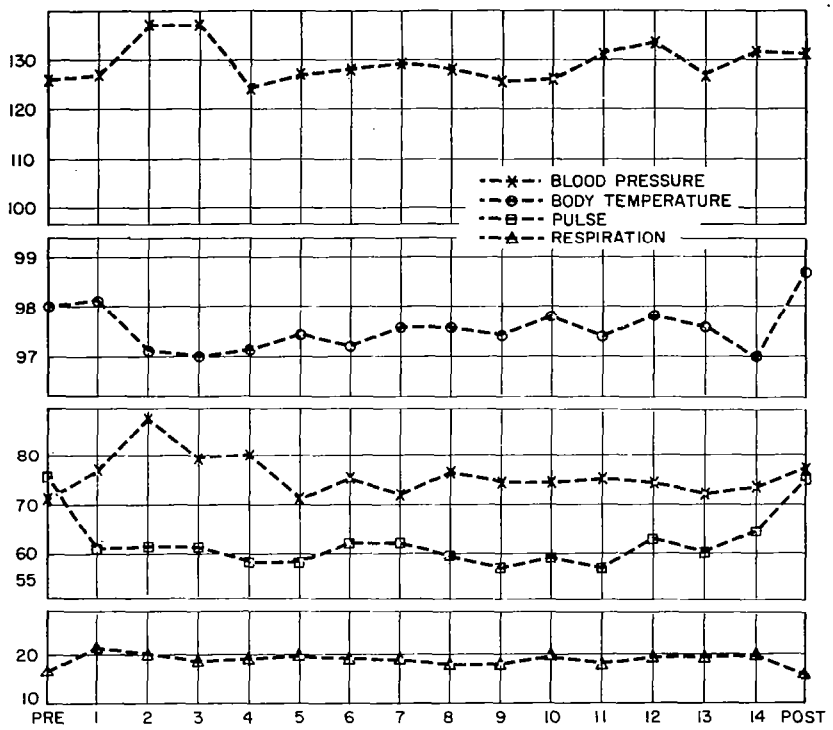



Figure 3-1 Average Vital Signs - Sea Level

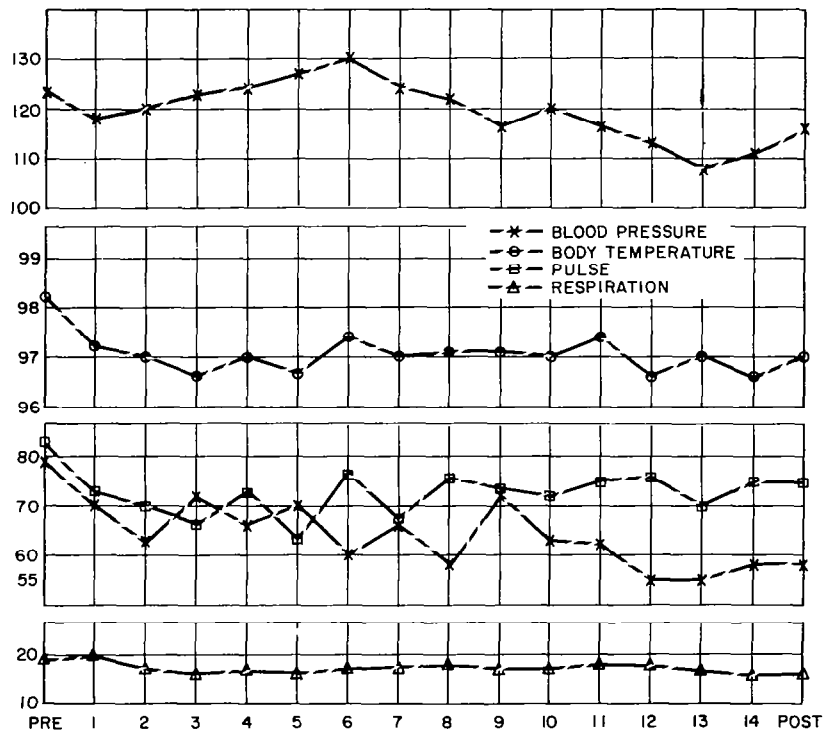



Figure 3-2 Average Vital Signs - 5.0 psi

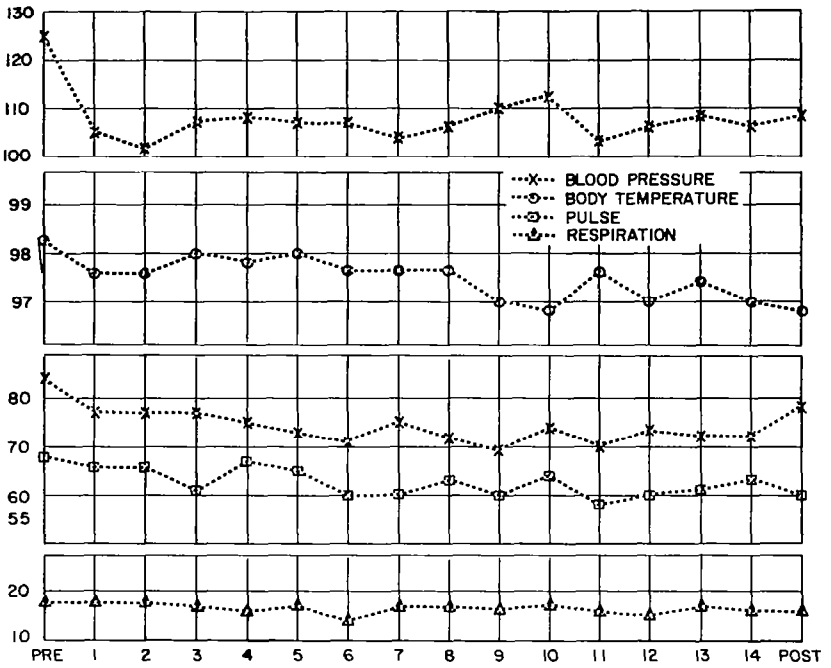



Figure 3-3 Average Vital Signs - 7.4 psi

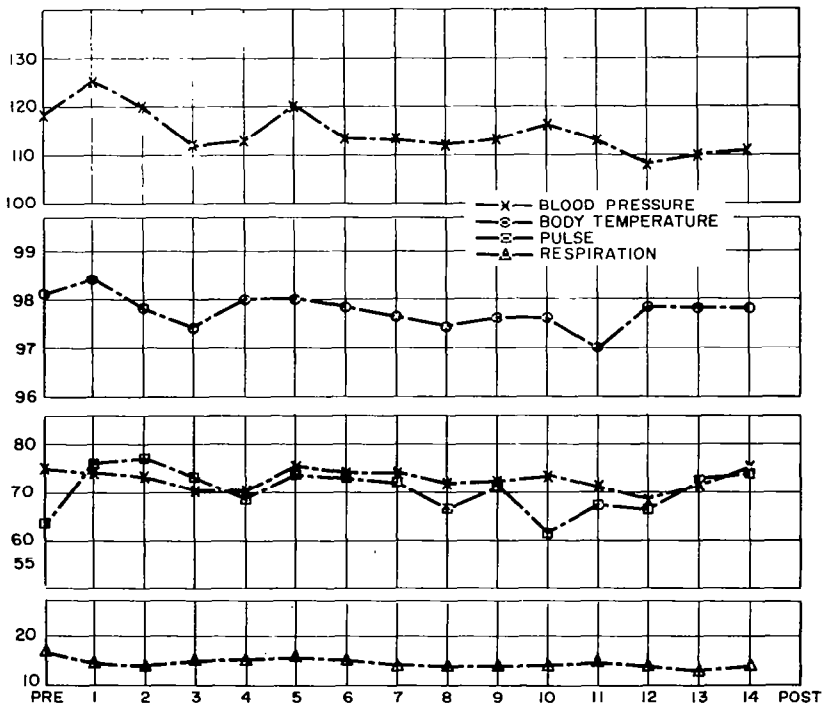



Figure 3-4 Average Vital Signs - 3.8 psi

## FOOD REJECTS

| Item | Total | Sea Level | 5 psi | 7.4 psi | 3.8 psi |
|---|---|---|---|---|---|
| Eggs | 59 | 18 | 21 | 1 | 19 |
| Bacon | 21 | 4 | 9 | 6 | 2 |
| Spanish Rice | 13 | not included | 5 | 5 | 3 |
| Sweet Potatoes | 17 | 7 | 9 | 1 | 0 |
| Lima Beans | 16 | 5 | 3 | 3 | 5 |
| Wax Beans | 13 | 0 | 3 | 0 | 10 |
| Bread Rolls | 3 | 3 | —— Discontinued —— | | |
| Hot Cereal | 10 | 0 | 2 | 0 | 8 |

Other foods rejected were:

| | | | |
|---|---|---|---|
| Apricots | 4 | Diced potatoes (too salty) | 5 |
| Chocolate pudding | 2 | Cake | 7 |
| Nut roll (defective) | 4 | Meat with vegetables | 1 |
| Rice with gravy | 2 | Crackers | (sporadically) |

Rejections varied from individuals who rejected no food to one subject (in the fourth run) who rejected 32 servings of varied foods.

Body weight was obtained in the chamber each morning after voiding and before breakfast. There was a correlation between the calorie intake and the change in body weight of the subjects, Figure 3-5. The sea level group consumed a mean 3075 calories and maintained their body weight. The 5.0 psi, 7.4 psi, and 3.8 psi group consumed progressingly less calories and had a corresponding loss of body weight. The 3.8 psi group's loss of body weight and lack of interest in ad lib food may suggest a direct effect of the low environmental pressure. Interpretation of the reduced caloric intake of the 5.0 psi and 7.4 psi group is complicated by other factors (i.e., anemia, aero-otitis) and hence not clearly related to lower environmental pressure.

Fluid intake and output were recorded daily as described in the Appendix. All groups were encouraged to increase their fluid intake even though urinary output was considered adequate.

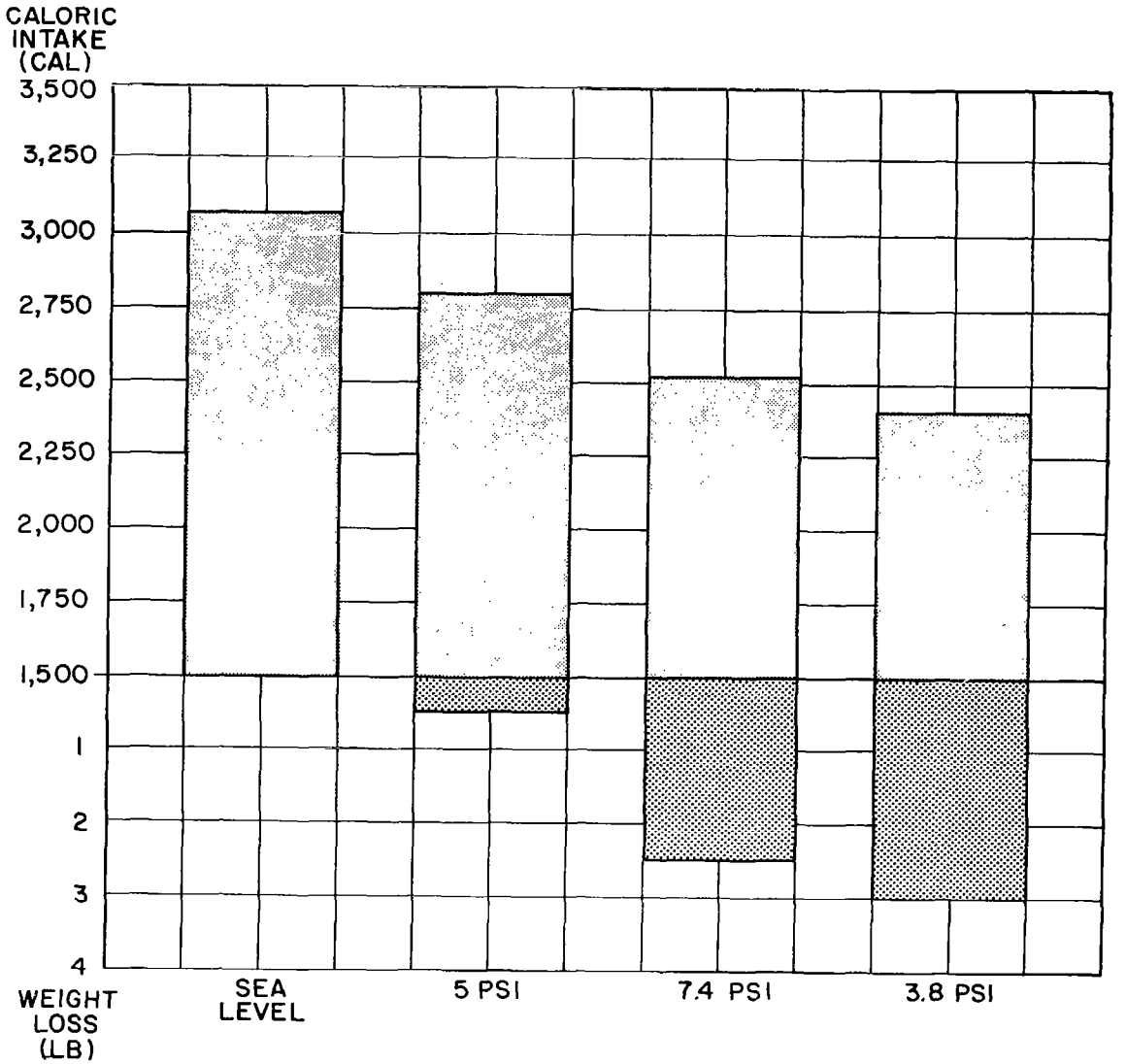



Figure 3-5 Caloric Intake and Body Weight

1. Sea Level Run

The first experimental group (sea level) exhibited some anxiety and apprehension concerning the experiment. This was not particularly lessened by their initial orientation or on learning that they would be the sea level control group. Anxiety concerning tomorrow's happenings persisted despite a repetitive testing schedule. One of the subjects almost fainted with the initial venipuncture; and after the pre-run arterial puncture, was not sure he wanted to continue. Later, during the experimental run the other subjects aggravated his intense concern over venipunctures and fears concerning arterial punctures. On the fifth day several hours prior to the scheduled arterial puncture in the chamber, another subject became ill with frontal headaches, nausea, and vomiting before breakfast.

Although the subjects were asked at the conclusion of the test not to communicate with future subjects, the "word" spread and the remaining three groups were more informed and appeared more relaxed.

Subject 14 was rejected because of a high white blood cell count and a $\beta$-hemolytic staph in his throat culture. However, he spent a night prior to the start of the experimental run sleeping in the open chamber with other subjects. Subject 12 had a small receding paranychia which later also proved to be a $\beta$-hemolytic staph infection. Subject 13 had a previous history of infectious mononucleosis. During the experimental run a $\beta$-hemolytic staph appeared at times in the throat cultures of all subjects except Subject 17. It was cultured out of four throats at the start of the second week when there was a slight rise in the white blood cell count (11,000 to 13,000). Subsequently, the number of positive throat cultures decreased and the white blood cell counts returned to normal. There was a reversal in the polymorphonuclear and lymphocytic ratio with many monocytes in all of the subjects at some time during the experimental run. The largest reversal was noted in the early part of the second week. Despite the positive throat cultures and white blood cell changes, there were no other subjective or objective clinical findings to suggest either a bacterial infection or infectious mononucleosis during the experimental run.

On the post-run physical examination, an enlarged non-tender spleen was found on Subject 17. The enlarged spleen has persisted even though the subject

has remained asymptomatic and no apparent cause for the splenomegaly has been found. The remaining subjects are well.

2. 5.0 psi Run

The 5.0 psi group was more relaxed than the sea level group. Subject 34 was eliminated because of the inability on three separate occasions to obtain a brachial arterial puncture. Subject 36 had a mild bilateral external otitis but was allowed to participate in the study. He had a flare-up of the infection during the experimental run which cleared on tetracycline 250 mg four times a day for five days in addition to local therapy to the ear canal. The offending organism was identified as a $\beta$-hemolytic rod that subsequently grew out in the throat cultures of all the subjects at some time during the experimental run. Subject 31 had a few colonies of $\beta$-hemolytic staph on his initial throat culture plate. A few colonies of $\beta$-hemolytic staph and $\beta$-hemolytic strep appeared in most of the subjects' throat culture plates early in the experimental run. There was also an increase in white blood cell count in several subjects. All throat cultures reverted to normal before the end of the experimental run. Clinically, five of the six subjects developed symptoms of a "head cold," and one subject reported a mild sore throat.

The principal medical effects of increased oxygen pressure were: 1) Eye irritation with tearing (in four subjects) beginning on the second day, clearing spontaneously by the fifth day of the experimental run, 2) A mild substernal discomfort on breathing deeply with an increased cough reflex which occurred intermittently. This was experienced by one subject. Another subject experienced a "clogged" chest feeling (similar to that incurred by too much smoking), with coughing on deep breathing, 3) Aero-otitis resulted from absorbtion of oxygen from the middle ear during the night. All subjects noted some hearing loss and five subjects had ear discomfort during the experimental run. Two subjects experienced ear discomfort from aero-otitis in the early morning hours of the second night in the chamber. This discomfort was noted by three other subjects on the following morning. "Head colds" were, at this time, prevalent among the subjects. The subjects were instructed to chew gum and use adrenalin nose drops which seemed to help.

On the sixth day Subject 37 had a marked drop in hearing acuity in the left ear which persisted until he returned to sea level conditions. On the eighth day, Subject 32 awoke with intense pain in both ears and a frontal headache. The pain was aggravated by "crackling" in his ears. The pain gradually diminished during the day in response to adrenalin nose drops and codeine. All subjects except Subject 35 continued to have ear discomfort on arising in the morning which persisted for approximately two hours.

The use of adrenalin nose drops and chewing gum was continued. The humidity in the chamber was increased during the night. All subjects were waked in the middle of the night so they could clear their ears. These measures proved effective in reducing the problem of aero-otitis during the remaining third of the experimental run. It is difficult to evaluate the effectiveness of any one of these measures, however, because the subjects' "head colds" were improving and, possibly from experience, they were becoming more adept at clearing their ears. On returning to sea level conditions hearing immediately returned to normal.

Post-run physical examinations were normal except for paleness in Subject 35. He was thoroughly studied at Brookhaven National Laboratory, Upton, New York, where a diagnosis of thalassemia trait was made. All of the subjects noted an ease of breathing at higher altitude but talking required a greater effort.

3. 7.4 psi Run

Hemolytic anemia described under hematology was the major concern in the 7.4 psi run. There was no significant eye irritation or substernal discomfort with increased cough reflex. Mild aero-otitis developed in Subjects 43 and 44 on the fourth day following mild sore throats that were noted on the third day. A $\beta$-hemolytic staph was isolated from Subject 43's throat culture on entry and persisted for the first week of the run. Subject 46 later developed mild ear discomfort which he controlled by clearing his ears during the night.

Subject 43 coughed up a teaspoonful of bright red blood on the ninth day that may have come from his posterior nasopharynx. This occurred only once. Several fecal specimens of different subjects were positive for occult blood during the experimental run.

Post-run physical examinations were negative for any signs of bleeding, jaundice, hepatosplenomegaly or cyanosis.

4. 3.8 psi Run

The 3.8 psi group denitrogenated for almost 3 hours at 100% $O_2$ by mask in the personnel entry lock of the chamber, while the nitrogen was being flushed out of the chamber with liquid oxygen. This resulted in chilling of the subjects prior to ascent to the 33,000-foot simulated altitude. Subject 55 developed symptoms of decompression illness with early neurocirculatory collapse after 15 to 30 minutes at altitude. This necessitated his removal from the chamber and terminated his participation in the experimental program. He was hospitalized for observation for 24 hours and made an uneventful recovery. Subject 52 developed mild ankle and knee pains and Subject 54 had moderate shoulder pains which gradually subsided over several hours upon lying down. Following a similar denitrogenation and chamber flushing procedure, two physicians and an assistant entered the chamber to perform arterial punctures on the fifth and last day of the experimental run. There were four cases of mild "bends," indicating the importance of low environmental temperature in increasing the incidence of "bends."

On the third day, Subject 53 developed marked coughing with deep breathing that interfered with his accurate vital capacity measurements. A chest X-ray was taken to determine if atelectasis was present, but the chest film was negative. The coughing gradually cleared and then returned in a milder form for a day or two later in the run. By the fourth day, all subjects had slight ear blocks which they cleared by swallowing or chewing gum. Throat cultures and white blood cell counts were essentially normal throughout this run. During the last part of the experimental run trace amounts of protein and hyaline cast appeared in the urine without any clinical signs of renal impairment. Post-run physical examinations were normal.

5. Summary

The medical data derived during the tests can be briefly summarized as follows:

1) Vital signs, fluid intake and output, chest X-rays, and EKG's were essentially normal during the experimental runs.

2) There was a correlation between caloric intake and change in body weight of the subjects. The 3.8 psi group on 2400 calories had a mean weight loss of 3.0 pounds.

3) The sea level control group exhibited anxiety and apprehension throughout the experimental run which was less apparent in the subsequent altitude runs.

4) Throat cultures and white blood cells changes, noted especially in the sea level and 5.0 psi runs, were not accompanied by clinical signs or symptoms of bacterial infection except for an external otitis in Subject 36.

5) Aero-otitis was a minor problem resulting in temporary impairment of hearing and slight discomfort, except for the 5.0 psi group, in which head colds were "prevalent."

6) Subjects 33, 37, and 53 experienced substernal discomfort and/or intermittent increased cough reflex with deep breathing during their experimental runs.

7) Eye irritation with increased lacrimation was bothersome for four subjects during the 2nd to 5th day of the 5.0 psi run.

8) Subject 55 was removed from the experimental program because of decompression illness with early neurocirculatory collapse.

9) Low environmental temperature during several hours of denitrogenation is an important factor in increasing the incidence of decompression illness at 3.8 psi (33,000 feet).

## B. CARDIOPULMONARY DATA

### 1. Pulmonary Function

The pulmonary function studies included static and timed vital capacities, tidal volume, inspiratory reserve, expiratory reserve, maximum breathing capacity, oxygen consumption during work performance, total lung capacity, diffusion capacity, and an end expiratory sample analysis for oxygen and carbon dioxide as described in the Appendix C-1.

#### a. Vital Capacities

Static vital capacities were determined before and after the experimental run with a Collin's Spirometer as part of the total lung capacity test. There was no significant change in the vital capacity of any group.

Mean Vital Capacities-Liters B. T. P. S.

| Group | Pre-Run | Post-Run |
|---|---|---|
| Sea Level | 5.067 | 5.111 |
| 5.0 psi | 4.838 | 4.965 |
| 7.4 psi | 5.390 | 5.240 |
| 3.8 psi | 4.968 | 4.994 |

In sequence, inspiratory, expiratory, and inspiratory static vital capacities and two inspiratory timed vital capacities were performed on a wedge (waterless spirometer) daily, before, after and during the experimental runs. There were daily variations in the measurements of several hundred cc's, both for the mean of all vital capacities and for the mean of the maximum vital capacities, Figures 3-6 and 3-7.

These variations, representing about 5% of the vital capacity in both mean values, were probably due to random changes in adjusting the calibration and, therefore, are of no biological significance.

Discrepancies between the comparison of pre- and post-run vital capacity measurements on the wedge with the Collin's Spirometer before each experimental run resulted from inexact initial calibration of the wedge with the Collins Spirometer before each experimental run.

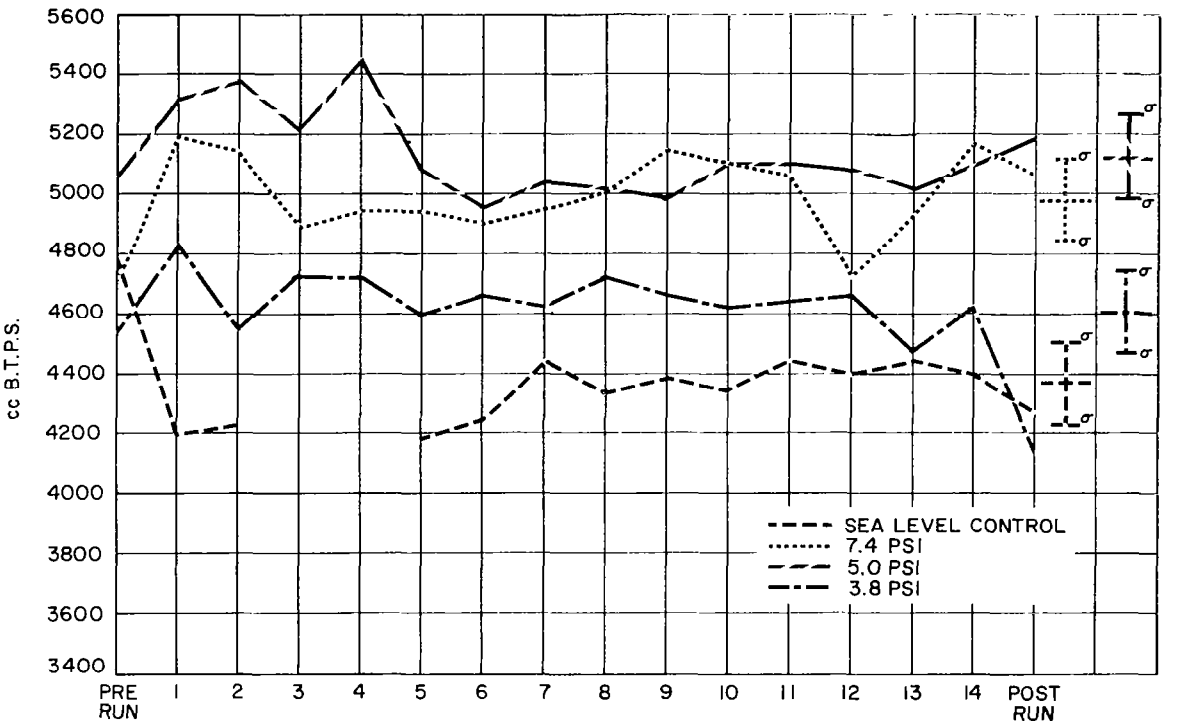



Figure 3-6 Average Maximum Vital Capacity

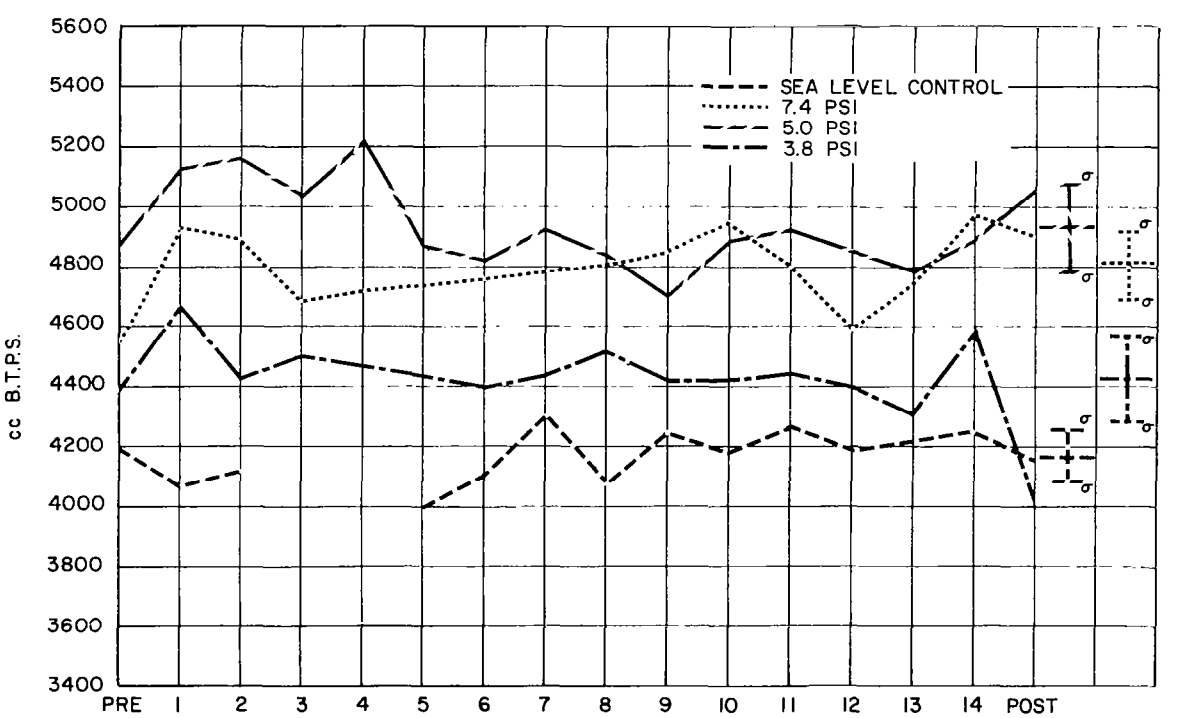



Figure 3-7 Average Mean Vital Capacity

Average per cent one-second timed vital capacities showed little change in the pre- and post-run determinations.

Timed Vital Capacity (%)

| Group | Pre-Run | Post-Run |
|---|---|---|
| Sea Level | 89 | 87 |
| 5.0 psi | 90 | 91 |
| 7.4 psi | 89 | 91 |
| 3.8 psi | 91 | 93 |

Daily variations during the experimental runs showed no significant change (Figure 3-8).

Tidal volumes average 1.0 liter B.T.P.S., with insignificant daily variations for all groups. The increase over the normal 0.5 liter tidal volume is probably the result of a non-basal state during the short time period for the determinations. Expiratory reserve volume averaged 1.55 liters B.T.P.S., and the inspiratory reserve averaged 2.2 liters B.T.P.S. A slight upward trend in the expiratory reserve volume and a downward trend in the inspiratory reserve volume were noted in all groups during the experimental runs, but these are not considered significant.

Oxygen consumption during a 5-minute 900 kpm/m work load and 15-second maximum breathing capacities were determined for half of the subjects during the experimental runs, and on all the subjects before and after the experimental runs, to determine any differences between the exercise and the non-exercise group. There was an immediate, marked, and sustained increase in maximum breathing capacity during all altitude runs over the pre- and post-run sea level values (Figure 3-9). The increase in M.B.C. at altitude is probably related to the decreased density of air. In the 3.8 psi group, there was a decrease in the M.B.C. during the last four days of the experimental run, resulting in a post-run value considerably less than the pre-run value.

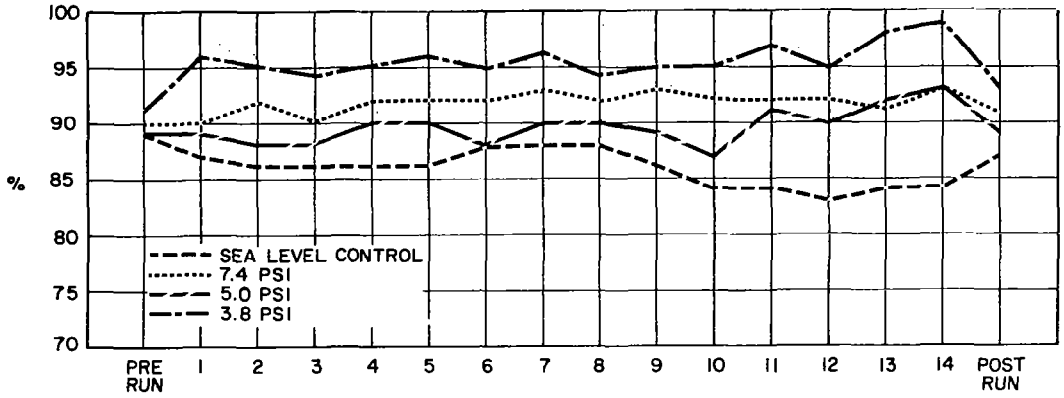



Figure 3-8 Average Timed Vital Capacity

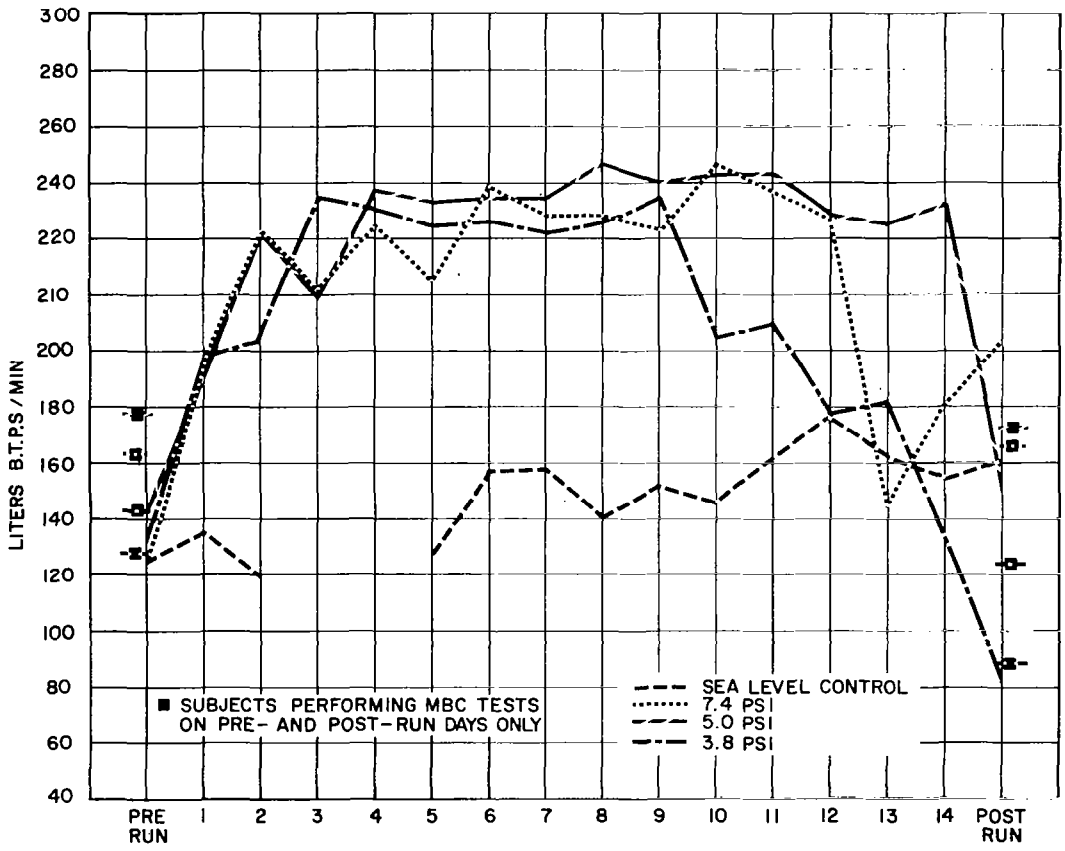



Figure 3-9 Average Maximum Breathing Capacity

There was marked coughing with many subjects during the performance of the post-run M. B. C. test which followed each altitude run. Coughing was especially noted with the 3. 8 psi group, which may have contributed to the low post-run value in the group. Normal timed vital capacities throughout the 3. 8 psi run do not support the abnormal decrease in M. B. C. toward the end of the run. Since static vital capacities as measured on the Collins Spirometer after the run did not decrease, changes in calibration could not have caused this magnitude of change in the M. B. C. This decrease in M. B. C. probably represents either an unwillingness on the subjects' part to perform maximally or an unexplained inability to do so.

A total daily average oxygen consumption and average heart rate for a 5-minute 900 kpm/m work load was determined for all altitude runs (Figure 3-10). Average heart rate alone was determined for the sea level run, as described in the Appendix. Average minute $O_2$ consumption and heart rates are shown in Figures 3-11 and 3-12. No significant changes in either oxygen consumption or heart rate were found.

Comparison between the average daily vital capacities of the exercise and non-exercise subjects in all runs showed no significant changes with time. However, the question of whether exercise or deep breathing will prevent or lessen the degree of lung atelectasis could not be answered by this experiment as no atelectasis was detected in either group.

Total lung capacities were determined before and after the experimental runs as described in the Appendix. There was no significant change in total lung capacity, residual volume, or vital capacity (Figure 3-13).

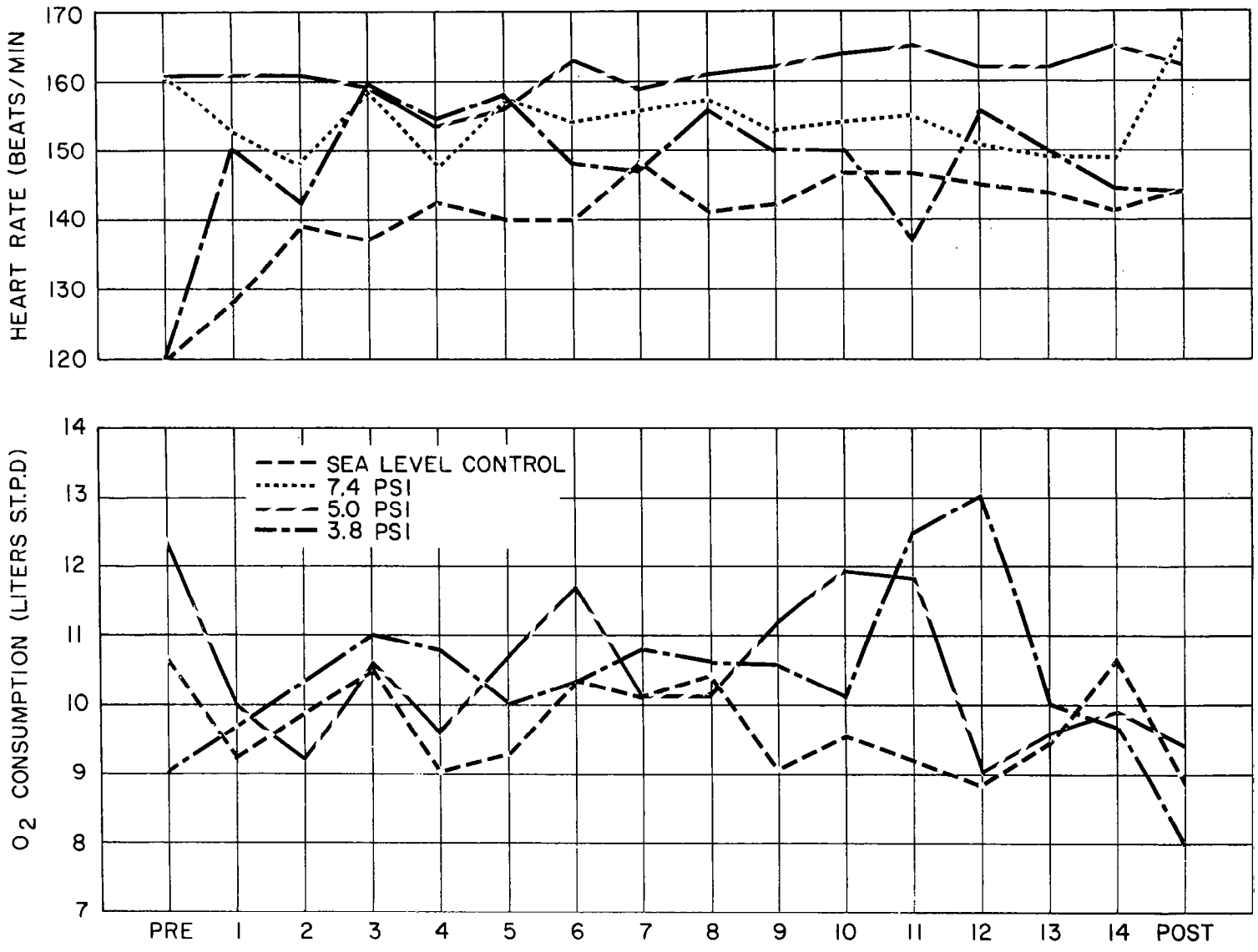



Figure 3-10 Average Heart Rate and Total $O_2$ Consumption for 5 Minute 900 kpm Work Load

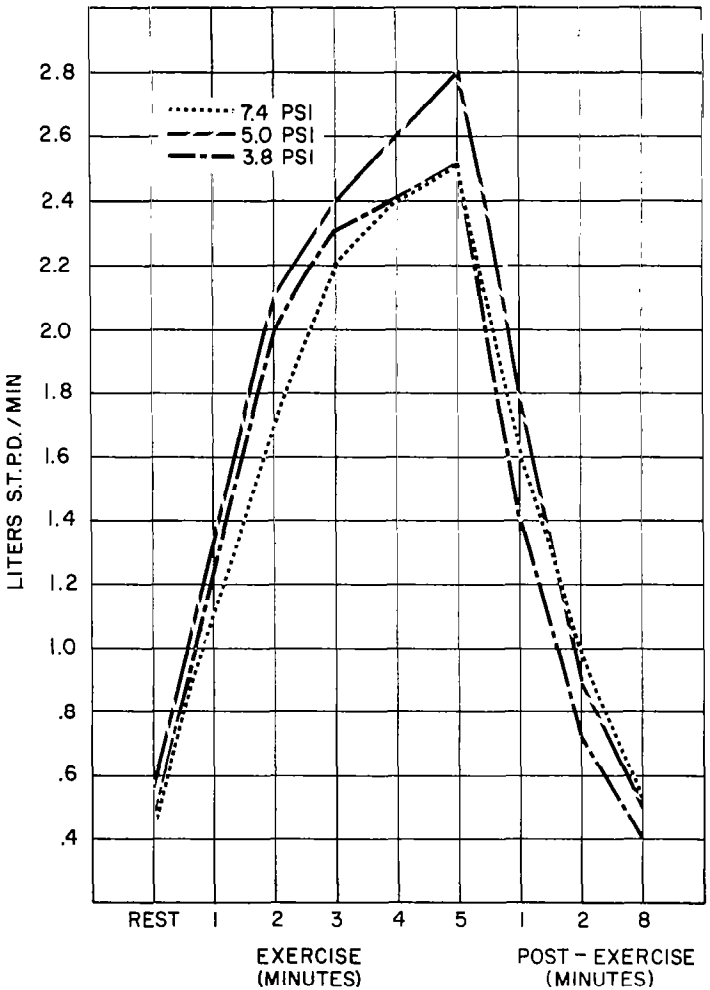



Figure 3-11 Average $O_2$ Consumption at 900 kpm Work Load

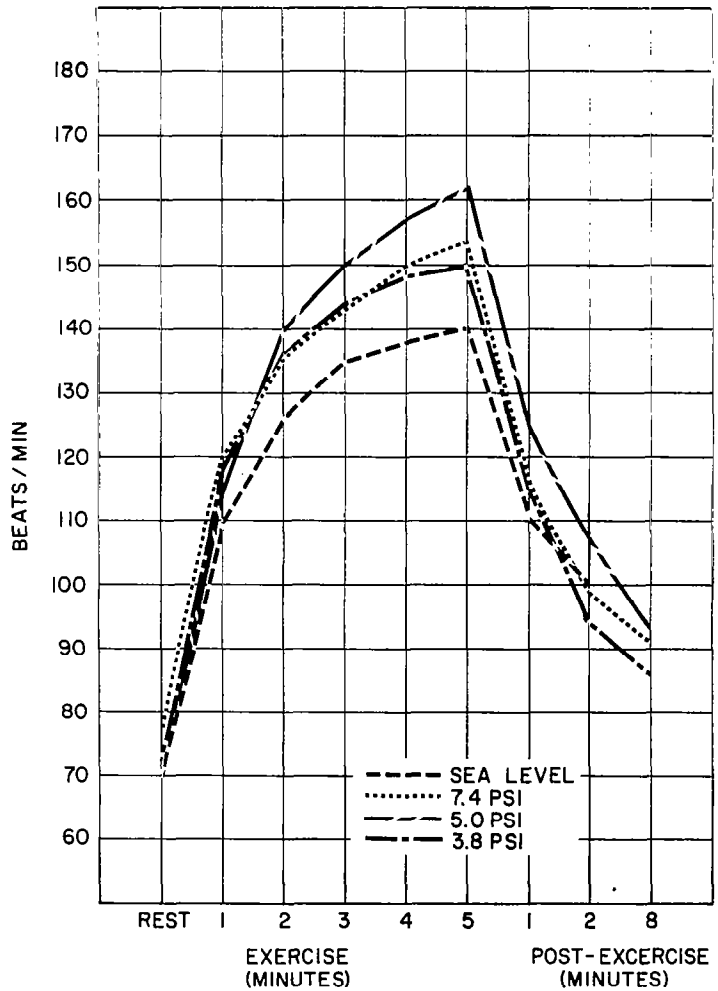



Figure 3-12 Average Heart Rate at 900 kpm Work Load

Total Lung Capacity - cc B.T.P.S.

| Group | Pre-Run | | Post-Run | |
|---|---|---|---|---|
| | M | σ | M | σ |
| Sea Level | 6103 | 338 | 6214 | 381 |
| 5.0 psi | 6603 | 741 | 6182 | 645 |
| 7.4 psi | 6638 | 790 | 6655 | 540 |
| 3.8 psi | 5989 | 480 | 6028 | 498 |

Diffusion capacities were determined before and after the experimental runs, as described in the Appendix. Except for a doubtful value obtained on the post-run determination of Subject 15, there were no significant changes in diffusion capacity (Figure 3-14).

Diffusion Capacity ml/min/mm Hg

| Group | Pre-Run | | Post-Run | |
|---|---|---|---|---|
| | M | σ | M | σ |
| Sea Level | 39.4 | 4.8 | 35.5* | 6.4* |
| 5.0 psi | 31.7 | 5.1 | 35.8 | 8.4 |
| 7.4 psi | 30.0 | 4.2 | 29.0 | 3.4 |
| 3.8 psi | 30.6 | 4.8 | 29.8 | 2.4 |

*Subject 15 not included

End expiratory samples were obtained before, during, and after the experimental runs as described in the Appendix. The consistently low $CO_2$ values obtained probably reflect the unconscious hyperventilation of the subjects prior to blowing into the balloon and/or diffusion of $CO_2$ through the ballon during transfer out of the chamber and prior to analysis.

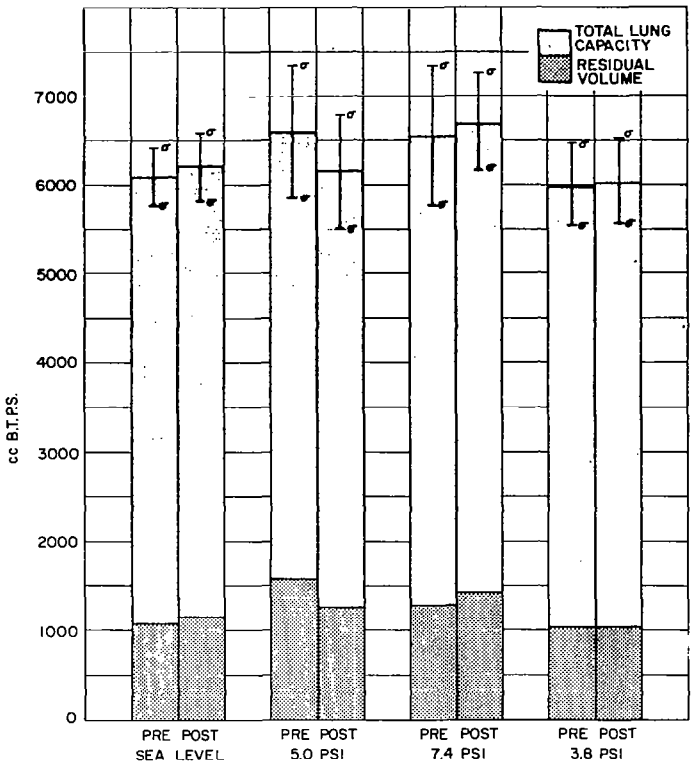



Figure 3-13 Average Total Lung Capacity and Residual Volume

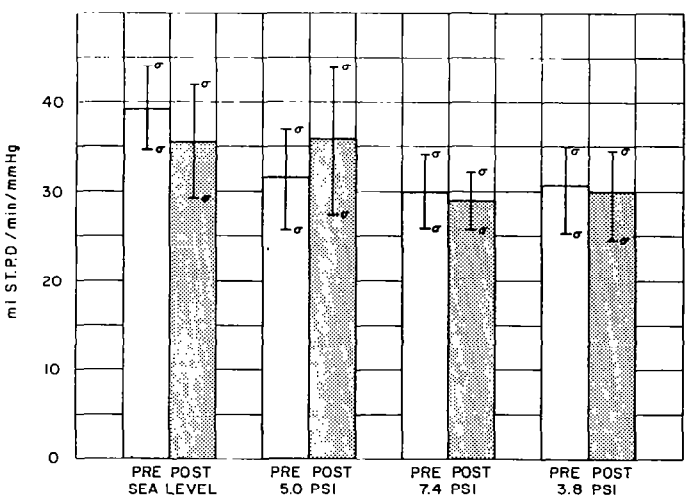



Figure 3-14 Average Diffusion Capacity

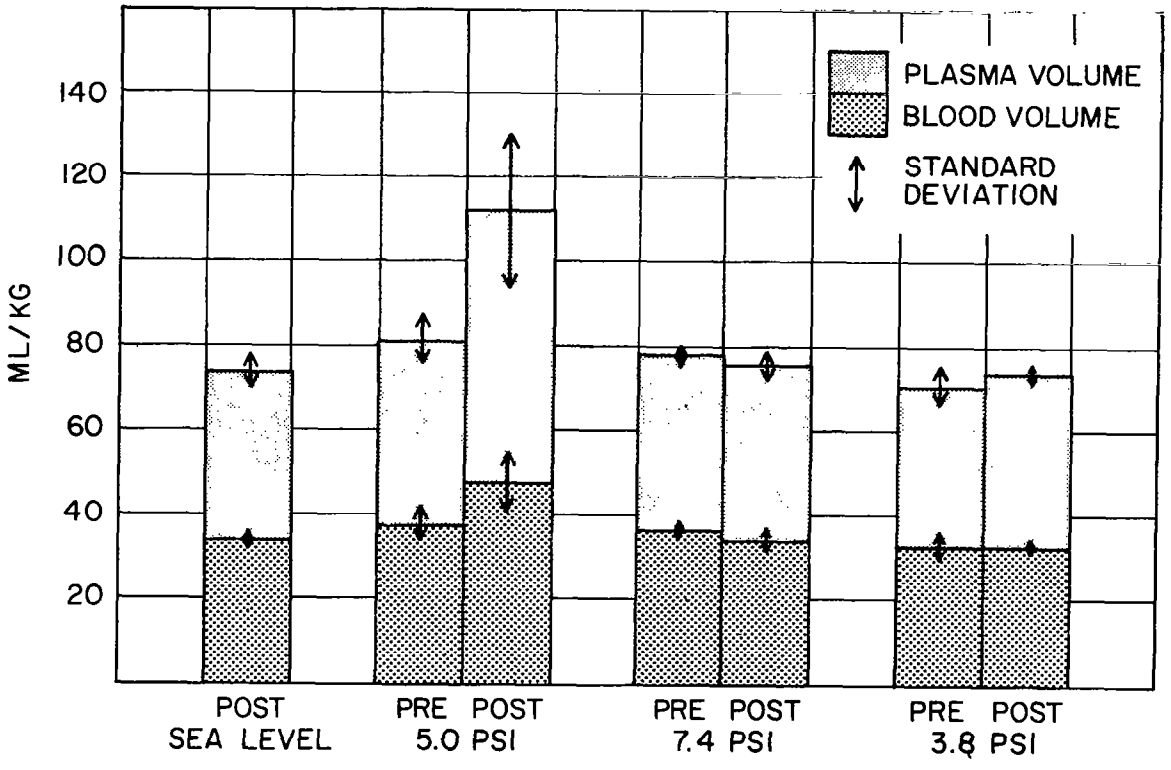



Figure 3-15 Plasma and Blood Volume

b. Plasma and Blood Volumes

Pre-run and post-run plasma and blood volumes did not show any biologically significant change (Figure 3-15). Although the post-run values on the 7.4 psi run were markedly increased over pre-run values, these were not considered true volume changes, since changes of this magnitude should have affected other physiological parameters. The high values obtained could have been due to an in vitro change in clotting mechanism or permeability of the red blood cells prior to analysis.

c. Arterials

Brachial arterial punctures were performed before, on the fifth and the last day of the experimental runs, and were analyzed with the Natelson Microgasometer and the Epsco Blood Parameter Analyzer as described in the Appendix. Table III - 1 shows the $pO_2$, pH, and $pCO_2$ values obtained using the Epsco Blood Parameter Analyzer.

TABLE III - 1

EPSCO BLOOD PARAMETER ANALYZER VALUES

| Test | Subject Number | Pre-Run | | 5th Day | Post-Run | | |
|---|---|---|---|---|---|---|---|
| | | Room Air | 100% $O_2$ (SL) | In Chamber | In Chamber | Air | 100% $O_2$ (SL) |
| | | | | Sea Level | | | |
| $pO_2$ (mm Hg) | 11 | 98 | | 94 | 98 | | 461+ |
| pH | | 7.40 | | 7.42 | 7.41 | | 7.44 |
| $pCO_2$(mmHg) | | 36 | | 38 | 41 | | 37 |
| Shunt (%) | | - | | - | - | | - |
| % Sat | | 97.0 | | 96.8 | 97.2 | | 100+ |
| $pO_2$(mm Hg) | 12 | 101 | | 94 | 111 | | 680+ |
| pH | | 7.42 | | 7.40 | 7.43 | | 7.43 |
| $pCO_2$(mmHg) | | 36 | | 37 | 37 | | 38 |
| Shunt (%) | | - | | - | - | | - |
| % Sat | | 97.4 | | 96.7 | 98.1 | | 100+ |

TABLE III - 1 (Cont)

| Sea Level | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Pre-Run | | 5th Day | Post-Run | | |
| Test | Subject Number | Room Air | 100% $O_2$ (SL) | In Chamber | In Chamber | Air | 100% $O_2$ (SL) |
| $pO_2$ (mm Hg) | 13 | 96 | | 92 | 104 | | 573+ |
| pH | | 7.40 | | 7.42 | 7.42 | | 7.42 |
| $pCO_2$ (mm Hg) | | 40 | | 40 | 39 | | 39 |
| Shunt (%) | | - | | - | - | | - |
| % Sat | | 96.8 | | 96.7 | 97.7 | | 100+ |
| $pO_2$ (mm Hg) | 14 | 95 | | - | - | | - |
| pH | | 7.41 | | - | - | | - |
| $pCO_2$ (mm Hg) | | 42 | | - | - | | - |
| Shunt (%) | | - | | - | - | | - |
| % Sat | | 96.8 | | - | - | | - |
| $pO_2$ (mm Hg) | 15 | 92 | | 96 | 103 | | 541+ |
| pH | | 7.40 | | 7.39 | 7.41 | | 7.46 |
| $pCO_2$ (mm Hg) | | 38 | | 38 | 42 | | 34 |
| Shunt (%) | | - | | - | - | | - |
| % Sat | | 96.5 | | 96.7 | 97.5 | | 100+ |
| $pO_2$ (mm Hg) | 16 | 90 | | 117 (?) | 114 | | 491+ |
| pH | | 7.41 | | 7.40 | 7.47 | | 7.48 |
| $pCO_2$ (mm Hg) | | 38 | | 38 | 33 (h) | | 30 (h) |
| Shunt (%) | | - | | - | - | | - |
| % Sat | | 96.4 | | 98.2 | 98.4 | | 100+ |
| $pO_2$ (mm Hg) | 17 | 96 | | 111 | 100 | | 570+ |
| pH | | 7.45 | | 7.40 | 7.43 | | 7.43 |
| $pCO_2$ (mm Hg) | | 37 | | 41 | 42 | | 39 |
| Shunt (%) | | - | | - | - | | - |
| % Sat | | 97.3 | | 97.9 | 97.4 | | 100+ |

TABLE III - 1 (Cont)

| Test | Subject Number | Pre-Run Room Air | Pre-Run 100% $O_2$ (SL) | 5th Day In Chamber | Post-Run In Chamber | Post-Run Air | Post-Run 100% $O_2$ (SL) |
|---|---|---|---|---|---|---|---|
| **Sea Level** | | | | | | | |
| $pO_2$ (mm Hg) | Mean | 96 | | 100 | 105 | | 552+ |
| pH | | 7.41 | | 7.40 | 7.43 | | 7.44 |
| $pCO_2$ (mm Hg) | | 38 | | 39 | 39 | | 36 |
| Shunt % | | - | | - | - | | - |
| % Sat | | 96.8 | | 97.2 | 97.8 | | 100+ |
| **5 psi** | | | | | | | |
| $pO_2$ (mm Hg) | 31 | 91 | 561+ | 147 | 149 | 103 | 449+ |
| pH | | 7.41 | 7.53 | 7.41 | 7.43 | 7.42 | 7.48 |
| $pCO_2$ (mm Hg) | | 39 | 26(h) | 41 | 48 | 39 | 31 |
| Shunt (%) | | - | - | 2.3 | 2.8 | - | - |
| % Sat | | 96 | 100+ | 99 | 99 | 97 | 100+ |
| $pO_2$ (mm Hg) | 32 | 103 | 564+ | 163 | 167 | 111 | 437+ |
| pH | | 7.42 | 7.51 | 7.42 | 7.43 | 7.43 | - |
| $pCO_2$ (mm Hg) | | 38 | 28(h) | 39 | 41 | 38 | - |
| Shunt (%) | | - | - | 0.7 | 0.3 | - | - |
| % Sat | | 97 | 100+ | 99 | 99 | 98 | 100+ |
| $pO_2$ (mm Hg) | 33 | 99 | 545+ | 168 | 153 | 99 | 541+ |
| pH | | 7.42 | 7.50 | 7.41 | 7.39 | 7.42 | - |
| $pCO_2$ (mm Hg) | | 38 | 29(h) | 42 | 42 | 37 | - |
| Shunt (%) | | - | - | 0.2 | 0.81 | - | - |
| % Sat | | 97 | 100+ | 99 | 99 | 97 | 100+ |

TABLE III - 1 (Cont)

| Test | Subject Number | Pre-Run Room Air | Pre-Run 100% $O_2$ (SL) | 5th Day In Chamber | Post-Run In Chamber | Post-Run Air | Post-Run 100% $O_2$ (SL) |
|---|---|---|---|---|---|---|---|
| **5 psi** | | | | | | | |
| $pO_2$ (mm Hg) | 35 | 103 | 515+ | 160 | 159 | 99 | 491+ |
| pH | | 7.38 | 7.41 | 7.40 | 7.45 | 7.40 | - |
| $pCO_2$ (mm Hg) | | 33 | 36 | 42 | 33 (h) | 39 | - |
| Shunt(%) | | - | - | 0.7 | 1.9 | - | - |
| % Sat | | 97 | 100+ | 99 | 99 | 17 | 100+ |
| $pO_2$ (mm Hg) | 36 | 104 | 554+ | 156 | 155 | 101 | 540+ |
| pH | | 7.43 | 7.46 | 7.40 | 7.44 | 7.43 | - |
| $pCO_2$ (mm Hg) | | 35 | 33 (h) | 40 | 39 | 36 | - |
| Shunt(%) | | - | - | 1.4 | 1.6 | - | - |
| % Sat | | 97 | 100+ | 99 | 99 | 97 | 100+ |
| $pO_2$ (mm Hg) | 37 | 93 | 483+ | 165 | 162 | 98 | 340+ |
| pH | | 7.41 | 7.42 | 7.42 | 7.40 | 7.45 | - |
| $pCO_2$ (mm Hg) | | 43 | 41 | 43 | 40 | 38 | - |
| Shunt(%) | | - | - | 0 | 0.7 | - | - |
| % Sat | | 96 | 100+ | 99 | 99 | 97 | 100+ |
| $pO_2$ (mm Hg) | Mean | 99 | 537+ | 160 | 158 | 101 | 474+ |
| pH | | 7.41 | - | 7.41 | 7.42 | 7.43 | - |
| $pCO_2$ (mm Hg) | | 38 | - | 41 | 40 | 38 | - |
| Shunt(%) | | - | - | 0.8 | 1.3 | - | - |
| % Sat | | 97 | 100 | 99 | 99 | 97 | 100+ |
| **7.4 psi** | | | | | | | |
| $pO_2$ (mm Hg) | 41 | 94 | 295+ | | | | |
| pH | | 7.43 | | 7.42 | | | |
| $pCO_2$ (mm Hg) | | 38 | | 38 | | | |
| Shunt(%) | | - | | - | | | |
| % Sat | | 97 | | 100+ | | | |

TABLE III - 1 (Cont)

| 7.4 psi | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Pre-Run | | 5th Day | Post-Run | | |
| Test | Subject Number | Room Air | 100 % $O_2$ (SL) | In Chamber | In Chamber | Air | 100% $O_2$ (SL) |
| $pO_2$ (mm Hg) | 42 | 108 | 421+ | 251 | 263 | 103 | |
| pH | | 7.43 | 7.52 | 7.42 | 7.45 | 7.41 | |
| $pCO_2$ (mm Hg) | | 35 | 34 (h) | 39 | 38 | 41 | |
| Shunt (%) | | - | | 2.51 | 1.7 | - | |
| % Sat | | 98 | 100+ | 100+ | 100+ | 97 | |
| $pO_2$ (mm Hg) | 43 | 104 | 504+ | 246 | 266 | 93 | |
| pH | | 7.42 | 7.42 | 7.42 | 7.44 | 7.43 | |
| $pCO_2$ (mm Hg) | | 36 | 41 | 43 | 42 | 41 | |
| Shunt (%) | | - | - | 2.6 | 1.2 | - | |
| % Sat | | 97 | 100+ | 100+ | 100+ | 96 | |
| $pO_2$ (mm Hg) | 44 | 104 | 523+ | 261 | 277 | 105 | |
| pH | | 7.42 | - | 7.45 | 7.46 | 7.42 | |
| $pCO_2$ (mm Hg) | | 41 | - | 36 | 37 | 37 | |
| Shunt (%) | | - | - | 2.0 | 0.8 | - | |
| % Sat | | 97 | 100+ | 100+ | 100+ | 97 | |
| $pO_2$ (mm Hg) | 45 | 97 | 526+ | 242 | 268 | 106 | |
| pH | | 7.42 | - | 7.41 | 7.44 | 7.44 | |
| $pCO_2$ (mm Hg) | | 41 | - | 42 | 43 | 40 | |
| Shunt (%) | | - | - | 2.9 | 1.0 | - | |
| % Sat | | 97 | 100+ | 100+ | 100+ | 98 | |
| $pO_2$ (mm Hg) | 46 | 1.03 | 515+ | 271 | 266 | 113 | |
| pH | | 7.40 | - | 7.42 | 7.43 | 7.43 | |
| $pCO_2$ (mm Hg) | | 38 | - | 41 | 40 | 38 | |
| Shunt (%) | | - | - | 1.0 | 1.4 | - | |
| % Sat | | 97 | 100+ | 100+ | 100+ | 98 | |

TABLE III- 1 (Cont)

| Test | Subject Number | Pre-Run Room Air | Pre-Run 100% $O_2$ (SL) | 5th Day In Chamber | Post-Run In Chamber | Post-Run Air | Post-Run 100% $O_2$ (SL) |
|---|---|---|---|---|---|---|---|
| 7.4 psi | | | | | | | |
| $pO_2$ (mm Hg) | 47 | 98 | 493+ | 258 | 257 | 111 | |
| pH | | 7.43 | - | 7.40 | 7.43 | 7.41 | |
| $pCO_2$ (mm Hg) | | 39 | - | 39 | 40 | 39 | |
| Shunt (%) | | - | - | 2.0 | 2.0 | - | |
| % Sat | | 97 | 100+ | 100+ | 100+ | 98 | |
| $pO_2$ (mm Hg) | Mean | 101 | 497+ | 254 | 266 | 105 | |
| pH | | 7.42 | - | 7.42 | 7.44 | 7.42 | |
| $pCO_2$ (mm Hg) | | 38 | - | 40 | 40 | 39 | |
| Shunt (%) | | - | - | 2.2 | 1.3 | - | |
| % Sat | | 97 | 100+ | 100+ | 100+ | 98 | |
| 3.8 psi | | | | | | | |
| $pO_2$ (mm Hg) | 51 | 94 | 295+(?) | 102 | 97 | 93 | |
| pH | | 7.43 | 7.42 | 7.43 | 7.41 | 7.41 | |
| $pCO_2$ (mm Hg) | | 38 | 38 | 39 | 43 | 41 | |
| Shunt (%) | | - | - | 2.9 | 3.3 | - | |
| % Sat | | 97.1 | 100+ | 97.6 | 97 | 96 | |
| $pO_2$ (mm Hg) | 52 | 93 | 471 | 106 | 103 | 101 | |
| pH | | 7.41 | 7.42 | 7.41 | 7.42 | 7.43 | |
| $pCO_2$ (mm Hg) | | 39 | 38 | 43 | 43 | 43 | |
| Shunt (%) | | - | - | -0.4 | 0.8 | - | |
| % Sat | | 96.6 | 100+ | 97.6 | 97.6 | 97.5 | |
| $pO_2$ (mm Hg) | 53 | 95 | 536+ | 104 | 103 | 102 | |
| pH | | 7.42 | 7.47 | 7.45 | 7.43 | 7.42 | |
| $pCO_2$ (mm Hg) | | 37 | 35 | 36 | 41 | 39 | |
| Shunt (%) | | - | - | 3.3 | 1.6 | - | |
| % Sat | | 96.9 | 100+ | 97.9 | 97.7 | 97.6 | |

TABLE III - 1 (Cont)

| 3.8 psi | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Pre-Run | | 5th Day | Post-Run | | |
| Test | Subject Number | Room Air | 100% $O_2$ (SL) | In Chamber | In Chamber | Air | 100% $O_2$ (SL) |
| $pO_2$ (mm Hg) | 54 | 90 | 485+ | 102 | 107 | 102 | |
| pH | | 7.44 | 7.45 | 7.43 | 7.44 | 7.45 | |
| $pCO_2$ (mm Hg) | | 37 | 39 | 40 | 38 | 41 | |
| Shunt (%) | | - | - | 2.5 | 1.2 | - | |
| % Sat | | 96.7 | 100 | 97.6 | 97.9 | 97.7 | |
| $pO_2$ (mm Hg) | 55 | 94 | 554+ | - | - | - | |
| pH | | 7.43 | 7.44 | - | - | - | |
| $pCO_2$ (mm Hg) | | 41 | 40 | - | - | - | |
| Shunt (%) | | - | - | - | - | - | |
| % Sat | | 97.0 | 100 | - | - | - | |
| $pO_2$ (mm Hg) | 56 | 97 | 553 | 103 | 102 | 101 | |
| pH | | 7.40 | 7.53 | 7.44 | 7.43 | 7.44 | |
| $pCO_2$ (mm Hg) | | 42 | 30 (h) | 39 | 41 | 43 | |
| Shunt (%) | | - | - | 2.5 | 2.0 | - | |
| % Sat | | 97.0 | 100+ | 97.7 | 97.6 | 97.6 | |
| $pO_2$ (mm Hg) | Mean | 93 | 482 | 103 | 102 | 100 | |
| pH | | 7.42 | 7.46 | 7.43 | 7.43 | 7.43 | |
| $pCO_2$ (mm Hg) | | 40 | 36 | 39 | 41 | 41 | |
| Shunt (%) | | - | - | 2.2 | 1.7 | - | |
| % Sat | | 96.8 | 100+ | 97.7 | 97.6 | 97.4 | |

Notes:

1. All physiological shunt estimates are overestimates, due in part to the fact that arterial $pO_2$ must have fallen between the time of collection of the sample and the time of analysis.

2. % saturation derived from $pO_2$, pH and the standard oxygen dissociation curve.

3. (h) after a $pCO_2$ figure indicates that the subject was hyperventilating as judged by $pCO_2$ and pH.

4. + after a $pO_2$ figure, breathing oxygen at sea level is a reminder that, due to analytic delay and absence of blood tonometered at this high $pO_2$, these values must actually have been considerably higher than those given here, which are therefore minimal values.

5. + after a 100% saturation figure indicates the presence of dissolved oxygen which can be computed by the formula: dissolved oxygen in volumes per cent = $pO_2$ in mm x 0.003.

6. (?) Indicates a doubtful value.

d. Calculation of % Saturation from $pO_2$

The calculation of % saturation from $pO_2$ was done using the oxygen dissociation curve of Dill [21] with extrapolation for values above 98% saturation, so that 99% saturation at pH 7.4 is deemed to exist at $pO_2$ 145 mm. Figure 3-16 illustrates this relationship. It is worth noting that at high values of saturation there is a large change in $pO_2$ for a 1% change in saturation.

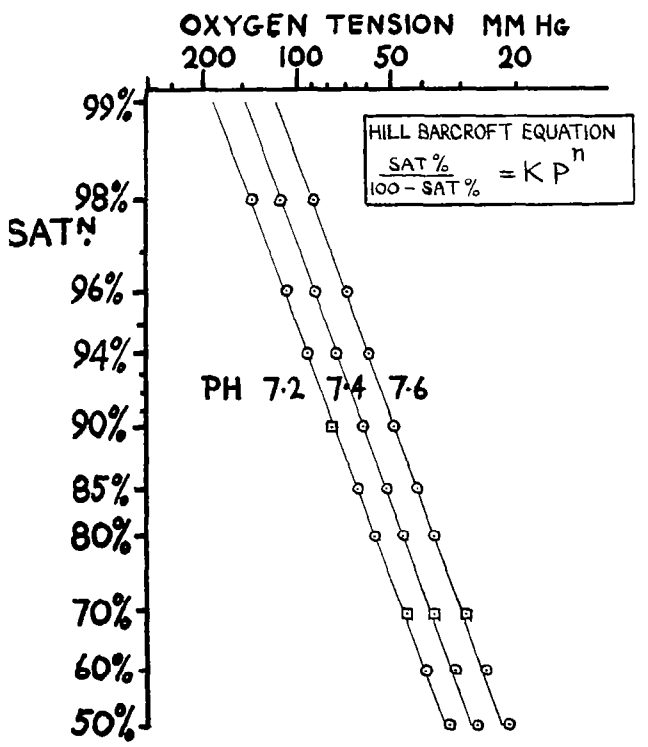



Figure 3-16 Oxygen Dissociation Curve of Dill

Between 97% and 98%, the $pO_2$ changes from 97 mm to 113 mm, a difference of 16 mm. Between 98% and 99% saturation, the $pO_2$ changes from 113 mm to 145 mm, a difference of 32 mm. Since the error of the $pO_2$ measurement is probably not more than ± 3 mm in this range (i.e., 90 to 110 mm), it seems clear that saturation derived from $pO_2$ and pH is more accurate than saturation derived from the ratio between oxygen content and oxygen capacity as measured by the Natelson Microgasometer method, in which the error of both may be about ±0.6 vols %. This greater reliability of saturation derived from $pO_2$ and pH applies only as long as saturation is high, above 90%, and as long as the individual has normal hemoglobin.

e. Calculation of Alveolar Oxygen Tension for Comparison with Arterial Oxygen Tension

There exists, in a man who has been denitrogenated by breathing almost 100% oxygen for several days, a very simple relationship, which facilitates the calibration of $p_{A_{O_2}}$. This relationship is as follows:

$$P_{A_{O_2}} = P_B - P_{A_{H_2O}} - P_{A_{CO_2}} - P_{A_{N_2}}$$

$P_B$ is the pressure of all gases including water vapor in the chamber converted to mm mercury (1 psi = 51.714 mm Hg).

$P_{A_{H_2O}}$, $P_{A_{O_2}}$, $P_{A_{CO_2}}$, and $P_{A_{N_2}}$ are, respectively, partial pressure of water vapor, oxygen, $CO_2$ and $N_2$ in the alveoli. $P_{A_{H_2O}}$ is 47 mm at 37°C. $P_{A_{CO_2}}$ is the same as arterial $CO_2$ tension in a young man with normal lungs and will not exceed this by more than 1 to 2 millimeters if the subject had developed some minor pulmonary abnormalities. $P_{A_{N_2}}$ under these conditions, breathing nearly pure oxygen is the same as the inspired nitrogen pressure.

In the runs at 5.0, 3.8 and 7.4 psi, $P_B$ was 256 mm, 196 mm, and 375 mm. $P_B - P_{H_2O}$ on the three occasions is obtained by subtracting water vapor partial pressure, which is the same (47 mm) in the inspired gas in the trachea, whether there is a high or low relative humidity in the chamber. Hence,

the total pressure of $O_2$, $CO_2$, $N_2$, $H_2O$, and not chamber relative humidity, affects these considerations. Taking inspired $N_2$ concentration as 1% of $P_B$ - $P_{H_2O}$, then $P_{N_2}$ is 2.09 mm, 1.49 mm, and 3.28 mm. These values of $P_{N_2}$ were used in the shunt calculations. Thus, when arterial oxygen tension is measured, $P_{A_{O_2}}$ can be calculated in each case.

f. Shunt Calculation

$P_{A_{O_2}}$ always exceeds arterial $O_2$ tension $\left(P_{a_{O_2}}\right)$ in a denitrogenated man breathing pure oxygen at sea level. This difference is due only to the shunt of blood from the right to the left side of the circulation through thebesian veins, bronchopulmonary venous anastomosis, etc. This shunt is normally about 1% of the cardiac output, with a scatter or an error of measurement of about ± 1%. In a denitrogenated man breathing 100% oxygen at altitudes above sea level, considerations (diffusion difficulty) other than a shunt may contribute to the alveolar-arterial oxygen difference. However, so long as the shunt (calculated as if it were the only cause of the alveolar-arterial oxygen difference) remains small, then both the shunt and diffusion difficulty are insignificantly different from normal in their contributions to this $P_{A_{O_2}} - P_{a_{O_2}}$ difference, as was found in the subjects in this study. The calculation of the physiological shunt is based on the equation given by Comroe et al:[22]

$$QS/QT = C_{c_{O_2}} - C_{a_{O_2}} / C_{c_{O_2}} - C_{v_{O_2}}$$

where QS is the shunt flow, and QT is cardiac output in liters per minute. $C_{c_{O_2}}$, $C_{a_{O_2}}$, and $C_{v_{O_2}}$ are oxygen contents of blood in cc% at the end of the pulmonary capillary, in the artery, and in the vein, respectively.

As long as the shunt is small, the denominator $C_{c_{O_2}} - C_{v_{O_2}}$ is about the same as $C_{a_{O_2}} - C_{v_{O_2}}$, which from cardiac catheterization studies is 5 ± 1 volumes %. The error in this assumption may lead to an error in the esti-

mate of about 1/5th its value, which is negligible in a shunt of 1% or 2%. Hence, the denominator presents no problem.

The numerator $C_{c_{O_2}} - C_{a_{O_2}}$ represents the sum of the differences in dissolved oxygen and oxygen combined with hemoglobin.

The difference in dissolved oxygen, calibrated from the solubility coefficient of oxygen, is 0.003 volumes % per millimeter change in $pO_2$ between alveolar and arterial blood. Thus, the difference in dissolved $O_2$ is $P_{A_{O_2}} - P_{a_{O_2}}$ x 0.003 vol %. This is the same whether $P_{A_{O_2}}$ is high or low.

The difference in combined oxygen depends on the oxygen dissociation curve. It is very small where $P_{A_{O_2}}$ is high, but becomes appreciable when $P_{A_{O_2}}$ is in the normal range. In the three studies at 5.0, 7.4, and 3.8 psi, with $P_{A_{O_2}}$ approximately 150, 250, and 100, the values for this coefficient (change in combined $O_2$ per mm difference between alveolar and arterial $pO_2$ = Capacity x d saturation/d $pO_2$) are 0.0028, 0.0005 mm and 0.0175 vols % per mm $O_2$. This supposes that hemoglobin was 15 gm % and that the deviations of hemoglobin observed in this do not significantly affect the results of the shunt calculation.

Adding the two coefficients gives the combined coefficient for dissolved and combined oxygen. The three coefficients are 0.0058, 0.0035, and 0.0205 vol % $O_2$ per mm of alveolar-arterial $pO_2$ difference. These coefficients are symbolized by the expression $\left( \frac{\alpha}{700} + \text{capacity} \frac{\text{d saturation}}{\text{d } pO_2} \right)$ where $\alpha/760$ is 0.003, capacity is 20 and the differential coefficient refers to the slope of the $O_2$ dissociation curve. Thus

$$\frac{QS}{QT} = \left( P_{A_{O_2}} - P_{a_{O_2}} \right) \left( \frac{\alpha}{700} + \text{capacity} \frac{\text{d partial saturation}}{\text{d } pO_2} \right) / 5.0$$

Insofar as the calculations of the shunt are in error, they are overestimates. This is because diffusion difficulty, which might have been important in contributing to the gradient in the run at 3.8 psi, was ignored and small delays between collection of blood and its analysis allow $P_{a_{O_2}}$ to fall due to oxygen consumption of blood.

The pH and $pCO_2$ showed no real abnormality on any occasion. (Normal ranges are 7.38 to 7.42 and 38 to 42 mm.) In some individuals, and hence in some averages of all individuals, there are minor deviations attributed to hyperventilation or hypoventilation at the time of the taking of the blood. During hyperventilation, pH rises by about 0.01 pH units for each 1 mm rise in $pCO_2$. A converse relationship occurs during hypoventilation. Considerable degrees of hyperventilation are indicated by (h) in Table III-1. On three occasions during the sea level run, individual values varied between a minimum of 90 mm up to 117 mm $pO_2$ breathing air. The highest value of 117 seems too high. The next highest value of 114 was clearly (from the $pCO_2$ and pH) associated with hyperventilation. All the other values in the sea level run fall within the normal range of about 90 to 110 mm. The same can be said of all of the 32 subsequent air breathing studies made before and after the subjects lived in the chamber for fourteen days. Moreover, after living in the chamber, in each case, the arterial $pO_2$ (as judged by the mean) tended to be higher while breathing air than it was before (99 before, 101 after; 101 before, 105 after; 93 before, 100 after). During the first 30 minutes of the re-nitrogenation process following chamber exposure to 100% oxygen, about 10 cc of nitrogen per minute would be absorbed, resulting in a relative increase in alveolar $pO_2$. However, this would have resulted in only a 0.3 to 0.5 mm Hg $pO_2$ increase, and could not explain these differences. Nevertheless, none of these differences seems significant. The subjects' lungs were as effective (in terms of oxygenation of the blood) after living in the chamber as they were before the experimental runs.

The best way to evaluate the normality of arterial oxygen tensions, at varying inspired oxygen pressures in a denitrogenated man, is by consideration of the shunt calculated by the alveolar-arterial oxygen difference. This should not be greater than about 2%. During the 3.8 psi run, two individuals (Subjects 51 and 53) had shunts apparently as high as 3.3% of the cardiac output. This probably represents experimental error. An alternative conclusion may be that about 1% of their lungs were atelectatic and still perfused with blood, or possibly these two subjects had some other abnormality in lung function. Any abnormality in function, however, would have been too small to be measured by most methods, In all other subjects, the apparent shunt was not as high as this. Hence, there was no apparent failure of the lungs to oxygenate their blood.

g. Oxygen Saturation Based on Measurements of pH and $pO_2$

The oxygen saturations were in the normal range (i.e., 96% or more) before, during, and after living in the chamber for all occasions.

h. $CO_2$ Content Determined with the Natelson Microgasometer

In the sea level and 5.0 psi runs, the average $CO_2$ content rose slightly on the fifth day, and at the end returned to its respective normal values (Table III-2). The $CO_2$ content remained essentially unchanged on the 7.4 psi run, while in the 3.8 psi run the mean values dropped slightly on the fifth day and remained at that lower level on the last day of the run. However, none of these changes are considered significant.

TABLE III-2

$CO_2$ CONTENT

(mM/L Mean Values)

| Test | Pre-Run Room Air | 5th Day In Chamber | Post-Run In Chamber | Post-Run Room Air |
|---|---|---|---|---|
| Sea Level | 25.5 | 26.6 | 25.8 | 25.7* |
| 5 psi | 23.9 | 25.5 | 24.0 | 24.0 |
| 7.4 psi | 22.5 | 23.0 | 23.0 | 22.9 |
| 3.8 psi | 25.5 | 24.1 | 24.6 | 24.5 |

* 100% $O_2$, sea level

i. Oxygen Content Determined with the Natelson Microgasometer

There was a slight increase in the mean values of blood oxygen content on the fifth day in the chamber, and a return toward initial values at the end of the sea level run (Table III-3). During the 5.0 psi run, the mean $O_2$ content increased 0.5 vol % in the chamber. These changes from expected values were of a magnitude comparable to the errors of the method, and are regarded as biologically insignificant. In the 3.8 psi run, the mean content dropped on the fifth day, but returned to its original value at the end of the run. During the 7.4 psi run, the mean oxygen content on the fifth day was 20.2 vol % with a mean hemoglobin of 14.1 gm %, as compared with 17.0 vol % and 14.3 gm % on the post-run day while at altitude. When the difference between these mean values was com-

pared by the t-test, the difference was found to be significant beyond the 0.01 level. In addition, the post-run room air oxygen content was 16.8 vol %. In view of the normal mean $pO_2$ value of 266 mm Hg and 105 mm Hg, these low blood oxygen contents could represent a qualitative change in the red blood cells, affecting their ability to transport oxygen.

TABLE III-3

$O_2$ CONTENT

vol % - mean values)

| Test | Pre-Run Room Air | | 5th Day In Chamber | Post-Run In Chamber | Post-Run Room Air |
|---|---|---|---|---|---|
| Sea Level | 19.5 | | 20.6 | 19.4 | 21.4 * |
| σ ** | 1.392 | | 1.142 | 1.331 | 1.751 |
| 5 psi | 19.2 | 20.4 * | 19.7 | 19.7 | 19.5 |
| σ | 0.972 | 0.826 * | 0.599 | 0.550 | 0.446 |
| 7.4 psi | 19.2 | 19.9 * | 20.2 | 17.0 | 16.8 |
| σ | 0.743 | 1.072 * | 1.707 | 1.068 | 0.858 |
| 3.8 psi | 20.6 | | 18.6 | 20.2 | 20.8 |
| σ | 0.605 | | 0.310 | 0.665 | 0.740 |

* = 100% $O_2$, sea level

** = σ = Standard deviations

j. Oxygen Capacity Determined with the Natelson Microgasometer

The mean $O_2$ capacity is compared with the expected $O_2$ capacity as calculated ($O_2$ capacity = hemoglobin mg % x 1.34 cc $O_2$ per gm of hemoglobin). (Table III-4).

There was little change in the mean oxygen capacity with the sea level and 5 psi runs. In the 3.8 psi run, there was an unexplained low mean value of 18.3 vol % on the fifth day, as compared with an expected value of 20.0 vol %. The post-run value was normal. The mean oxygen capacities on the fifth and post-run day at altitude, during the 7.4 psi run, were 19.3 and 18.1 vol % compared with the expected oxygen capacity of 19.3 and 19.2 vol %, respectively.

TABLE III -4

$O_2$ CAPACITY AND EXPECTED $O_2$ CAPACITY (vol % - mean values)

| Test | Pre-Run Room Air | | 5th Day In Chamber | Post-Run In Chamber | |
|---|---|---|---|---|---|
| Sea Level | 20.4 | | 22.2 | 21.7 | 21.7 * |
| σ | 1.155 | | 0.762 | 1.077 | 1.097* |
| Expected | 20.1 | | 21.4 | 20.2 | |
| 5 psi | 20.0 | 19.8 * | 19.1 | 19.4 | |
| σ | 0.705 | 0.687 * | 0.428 | 0.389 | |
| Expected | 21.3 | 21.3 | 21.2 | 19.7 | |
| 7.4 psi | 19.6 | | 19.3 | 18.1 | |
| σ | 0.594 | | 1.554 | 1.319 | |
| Expected | 21.6 | | 19.3 | 19.2 | |
| 3.8 | 21.1 | | 18.3 | 19.8 | |
| σ | 1.120 | | 0.098 | 0.781 | |
| Expected | 20.5 | | 20.0 | 20.2 | |

* 100% $O_2$, sea level

The lower oxygen capacity of 18.1 vol % supports the low oxygen content of 17.0 vol % obtained on the same blood. The mean capacity was 1.1 vol % greater than the $O_2$ content, even though the mean $pO_2$ was 266 as measured by the electrode. This was the only occasion when the capacity measurement was less than the content with bloods drawn in the chamber at the increased $pO_2$ during the 5.0 and 7.4 psi runs (5.0 psi content 19.7 and 19.4 versus capacity 19.1 and 19.4; 7.4 psi run content 20.2 to 17.0 versus capacity 19.3 and 18.1). A presence of an abnormal pigment (i.e., methemoglobin), which would tend to be converted to oxyhemoglobin during equilibrium with room air, could explain why the capacity measurement was higher than the content measurement.

Oxygen saturation measurements (Table III-5) based on the ratio between content and capacity are affected by three factors which do not affect the $pO_2$ measurements and saturations derived from them.

TABLE III-5

OXYGEN % SATURATION

$$\left( \frac{O_2}{O_2} \frac{\text{Content}}{\text{Capacity}} \text{ - mean values} \right)$$

| Test | Pre-Run Room Air | | 5th Day In Chamber | Post-Run In Chamber | |
|---|---|---|---|---|---|
| Sea Level | 95 | | 93 | 90 | 99 * |
| σ | 2.708 | | 5.153 | 9.35 | 10.18 * |
| 5 psi | 96 | 100+ * | 100+ | 100+ | |
| σ | 2.930 | 2.569 * | 1.250 | 0.964 | |
| 7.4 psi | 99 | | 100+ | 94 | |
| σ | 1.708 | | 2.737 | 5.405 | |
| 3.8 psi | 98 | | 100+ | 100+ | |
| σ | 3.702 | | 1.133 | 3.229 | |

* 100% $O_2$, sea level

First, they depend not only on the ability of the lungs to oxygenate the blood, but also on the ability of the blood to take up oxygen. Saturation is the ratio between oxyhemoglobin and oxyhemoglobin plus reduced hemoglobin. If there is some third pigment present, such as carbon monoxide hemoglobin, or methemoglobin, then saturation as measured in vitro may no longer be equal to this ratio as it was in the body. The third pigment tends to be converted to oxyhemoglobin during storage of blood and/or equilibration with air, giving rise to low apparent values for saturation. Carbon monoxide hemoglobin might have been present in appreciable amounts in the blood of smokers who knew they would not be allowed to smoke for two weeks. This might have accounted for some of the Natelson Microgasometer saturations being lower than the oxygen electrode saturations before entering the chamber. And if, as seems possible when there is an unexplained anemia, the cause of the anemia may have produced methemoglobin, this would help to explain the fact that saturations measured by the Natelson Microgasometer method were lower than those measured by the oxygen electrode when the 7.4 psi run was completed.

In this group, $pO_2$ averaged 105, and pH averaged 7.42 after leaving the chamber, so 98% of their oxy plus reduced hemoglobin was in the oxy form in vivo. If about 5% of their hemoglobin, i.e., 0.65 gm, had been in the met form, and had been converted to oxyhemoglobin during the capacity measurement, this would have led to a fall in saturation of about 5% below the value determined on this run by the Natelson Microgasometer method before leaving the chamber, as opposed to the $pO_2$, pH method. This was, in fact, the magnitude of the mean discrepancy.

Second, the Natelson Microgasometer method has an inherent greater error in saturation determinations when saturation is high, because in this range, a large change in $pO_2$ corresponds to a small change in saturation, whereas error in $pO_2$ determination leads to a much smaller error in saturation derived from $pO_2$ and pH measurements.

Third, once the equipment has been carefully set up and calibrated, $pO_2$ determinations can be performed more quickly than analysis by the Natelson Microgasometer method. This leads to several times as much delay between collection of blood and its analysis by this method. During the waiting period, even when the blood is stored on ice, oxygen is consumed by cells and/or reducing substances in the blood, and leads to a lowered oxygen content and hence to a lowered saturation.

The factors to be considered are: the possibility that abnormal pigments were present, the greater error of the Natelson Microgasometer method at high saturations, and the relative slowness of the method in dealing with large numbers of blood samples. Any combination of these factors may have contributed to lower measurements of saturation by the Natelson Microgasometer method.

The first possibility, that of abnormal pigments, is most interesting in view of the anemia which developed in the 7.4 psi run and which also showed the greatest discrepancy between the two methods. If only about 5% of hemoglobin was in the met form (0.65 gm in this study) it could account for an average discrepancy of 5% in saturation, which was found.

2. Summary

The cardiopulmonary data derived from the study can be summarized as follows:

1) There was no significant change in static or timed vital capacity during the experimental runs.

2) Maximum breathing capacity showed an immediate increase during the altitude runs, probably related to the decreased density of air. Marked coughing developed during the performance of the post-run maximum breathing capacity tests following these altitude runs. There was an unexplained decrease in the maximum breathing capacity during the last four days of the 3.8 psi run.

3) No significant changes occurred in either $O_2$ consumption or heart rate during work performance in all groups.

4) Pre-run and post-run total lung capacities and diffusion capacities were essentially unchanged.

5) Arterial pH, $pCO_2$ contents showed no real abnormality on any occasion.

6) The mean $pO_2$ showed no significant change from expected values.

7) The mean $O_2$ content from the fifth to the fourteenth day in the 7.4 psi run dropped from 20.2 vol % to 17.0 vol %. This difference was found to be significant beyond the 0.01 level.

8) The mean $O_2$ capacity (18.1 vol %) was greater than the mean $O_2$ content (17.0 vol %) at the end of the 7.4 psi run in the presence of a mean blood $pO_2$ of 266 mm Hg.

9) The oxygen saturations based on measurements of pH and $pO_2$ were in the normal range (i.e., 96% or more) on all occasions.

10) Conversion of 5% of the hemoglobin to methemoglobin could account for the mean per cent saturation discrepancy noted at the end of the 7.4 psi run between the ratio of content, capacity and saturation based on pH and $pO_2$ measurements.

11) The low mean $O_2$ content coupled with the larger mean $O_2$ capacity at the end of the 7.4 psi run are compatible with the possibility that there was a qualitative change in the red blood cells or their constituents, affecting their ability to transport oxygen in vivo, possibly the formation of methemoglobin.

## C. HEMATOLOGICAL DATA

Venous blood samples were obtained at least three times weekly, with additional tests as indicated by the findings. One pre-run and one post-run evaluation served for comparative purposes. Although a longer period of observation on each individual prior to the run is desirable, the experimental design provided a parallel group at sea level for an identical two week period as the primary control for the oxygen runs.

### 1. Sea Level Run

There was little change in the red blood cell picture. The mean red blood cell count increased 280,000/mm$^3$ and the mean reticulocyte percent increased 0.6% (Figures 3-17 and 3-18). This indicated that the approximate 250 cc of blood drawn for determinations during the experimental run had little effect on the subjects' hematological status.

The white blood cell picture was complicated in all subjects by a reversal of polymorphonuclear and lymphocytic ratio with large numbers of monocytes. The sedimentation rates were normal on all subjects. The Price-Jones curves, determined from direct blood smears, were unchanged (Figure 3-19) and Table III-6)

### 2. 5.0 psi Run

Subject 35 developed a striking anemia during this experimental run. He was later shown to have thalessemia trait. Hence, he is excluded from all mean hematological values and is described separately.

The other subjects in the 5.0 psi run showed a slight progressive decrease of about 500,000 RBC/mm$^3$, a slight drop in hemoglobin, and a 1.6% increase in reticulocytes over pre-run values (Figures 3-20 and 3-21). Subject 37 showed losses of over 2.0 gm hemoglobin and 0.8 million RBC/mm$^3$ and had a 2.2% increase in reticulocytes. During the second week, there was a slight degree of anisocytosis on all subjects. Little change occurred in the red cell indices. All subjects had increased red blood cell osmotic fragilities on exit from the chamber.

The mean Price-Jones curve on Subjects 31, 32, 33 and 37 was normal on entry plus four days but on exit showed a marked flattening and a

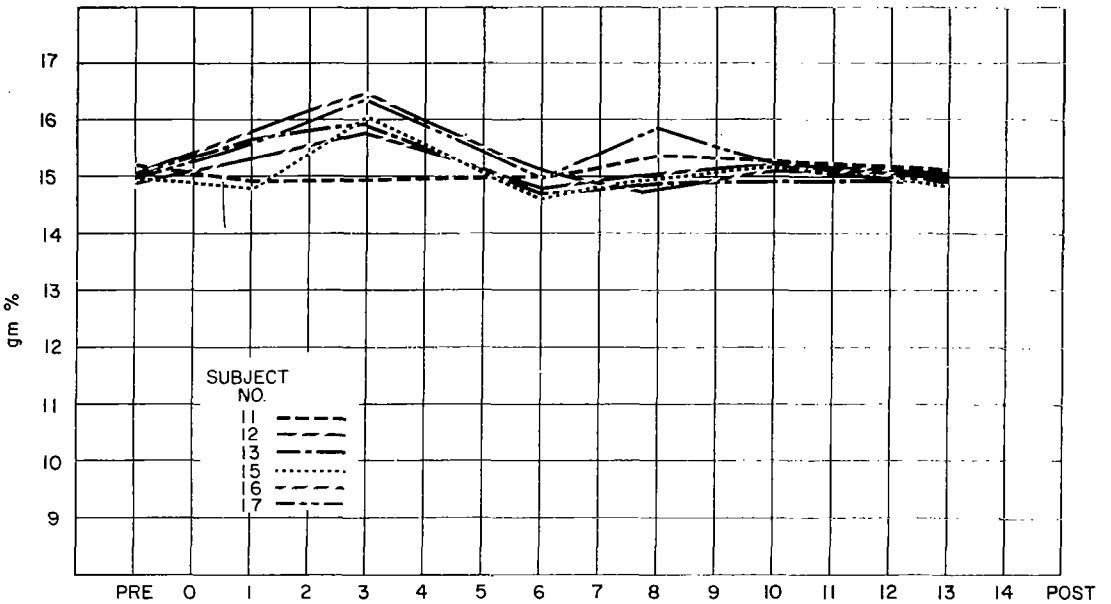



Figure 3-17 Hemoglobin Concentration at Sea Level

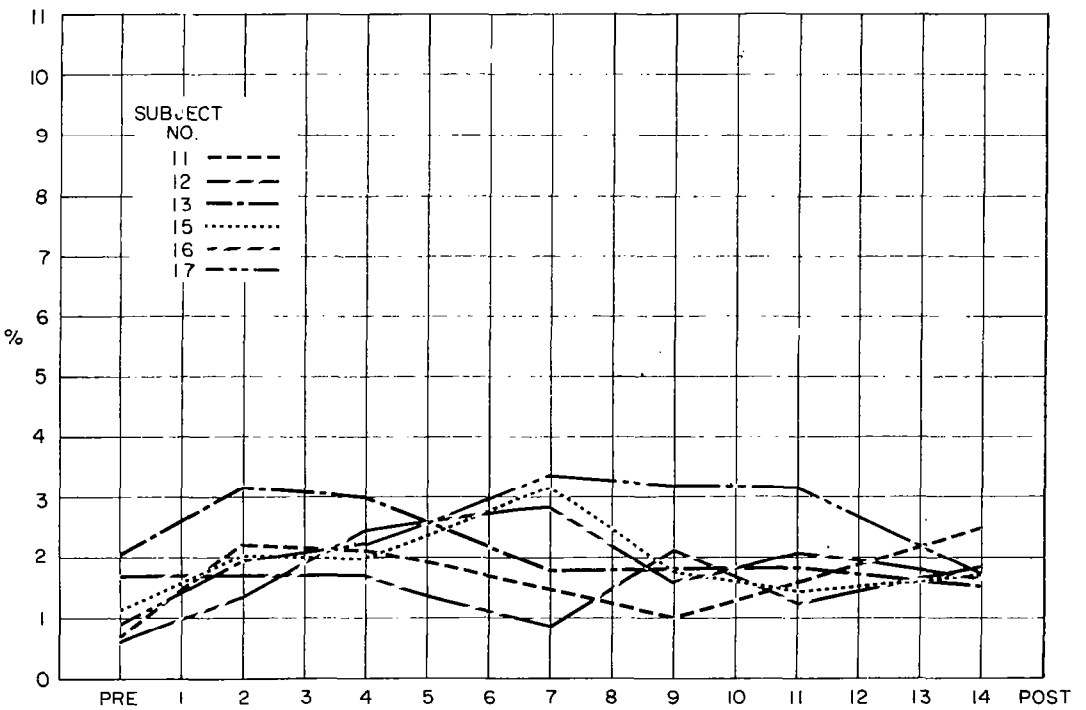



Figure 3-18 Reticulocytes at Sea Level

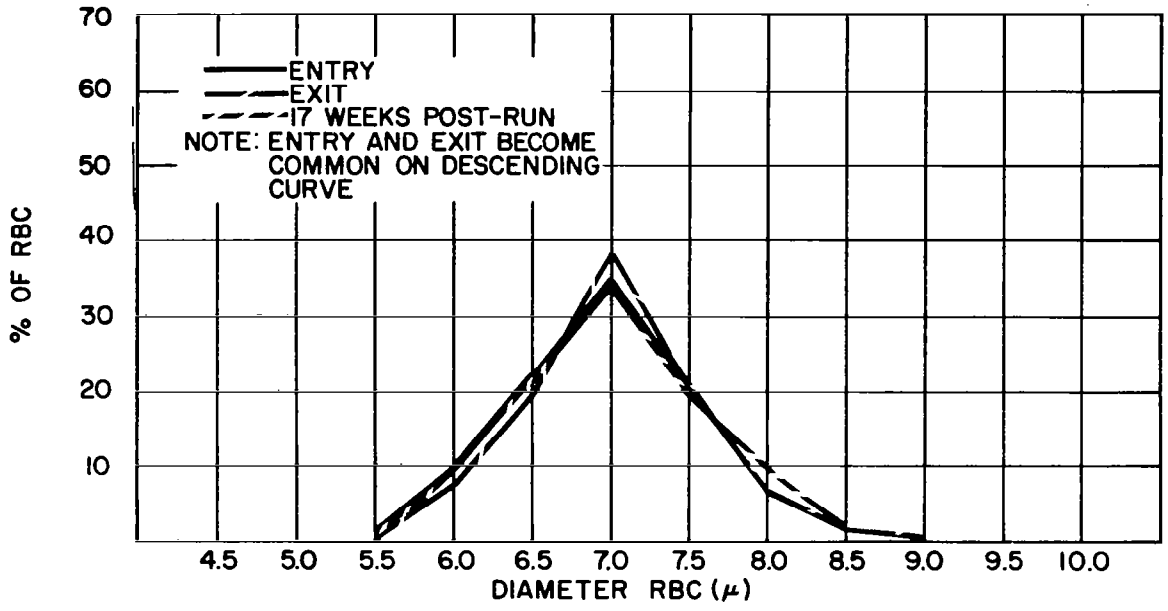



Figure 3-19 Price-Jones Curve - Sea Level Run

TABLE III-6

PRICE-JONES INDEX % RBC

Sea Level Run

| Time and Subject Number | RBC Diameter (μ) 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 |
|---|---|---|---|---|---|---|---|---|
| Entry | | | | | | | | |
| 11 | 1 | 6 | 15 | 42 | 22 | 9 | 3 | 2 |
| 12 | | 2 | 7 | 22 | 44 | 22 | 2 | 1 |
| 13 | 1 | 8 | 11 | 50 | 24 | 5 | 1 | |
| 15 | 4 | 15 | 18 | 46 | 12 | 4 | 1 | |
| 16 | 1 | 16 | 40 | 28 | 13 | 2 | | |
| 17 | 2 | 16 | 43 | 23 | 13 | 3 | | |
| Mean | 1.5 | 10 | 22 | 35 | 21 | 7 | 1 | .5 |
| Exit (SL) | | | | | | | | |
| 11 | 1 | 7 | 15 | 51 | 21 | 4 | 1 | |
| 12 | | 1 | 8 | 23 | 43 | 21 | 2 | 2 |
| 13 | | 5 | 14 | 44 | 25 | 10 | 2 | |
| 15 | 1 | 14 | 20 | 44 | 13 | 5 | 2 | 1 |
| 16 | 3 | 17 | 38 | 30 | 9 | 3 | | |
| 17 | | 5 | 19 | 45 | 26 | 4 | 1 | |
| Mean | .9 | 8 | 19 | 39 | 22 | 7 | 1 | .5 |
| 17 Weeks Post-run | | | | | | | | |
| 11 | 4 | 14 | 18 | 49 | 11 | 4 | | |
| 12 | | 1 | 8 | 24 | 42 | 20 | 4 | 1 |
| 16 | 3 | 17 | 38 | 30 | 9 | 3 | | |
| Mean | 2 | 10 | 21 | 34 | 20 | 9 | 1 | .3 |

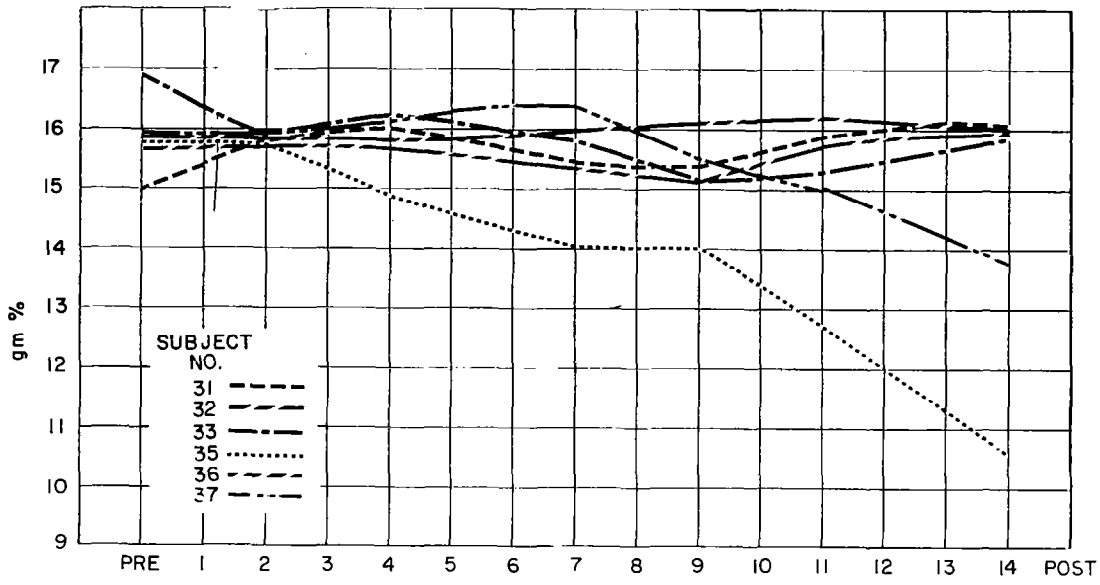



Figure 3-20 Hemoglobin Concentration at 5 psi

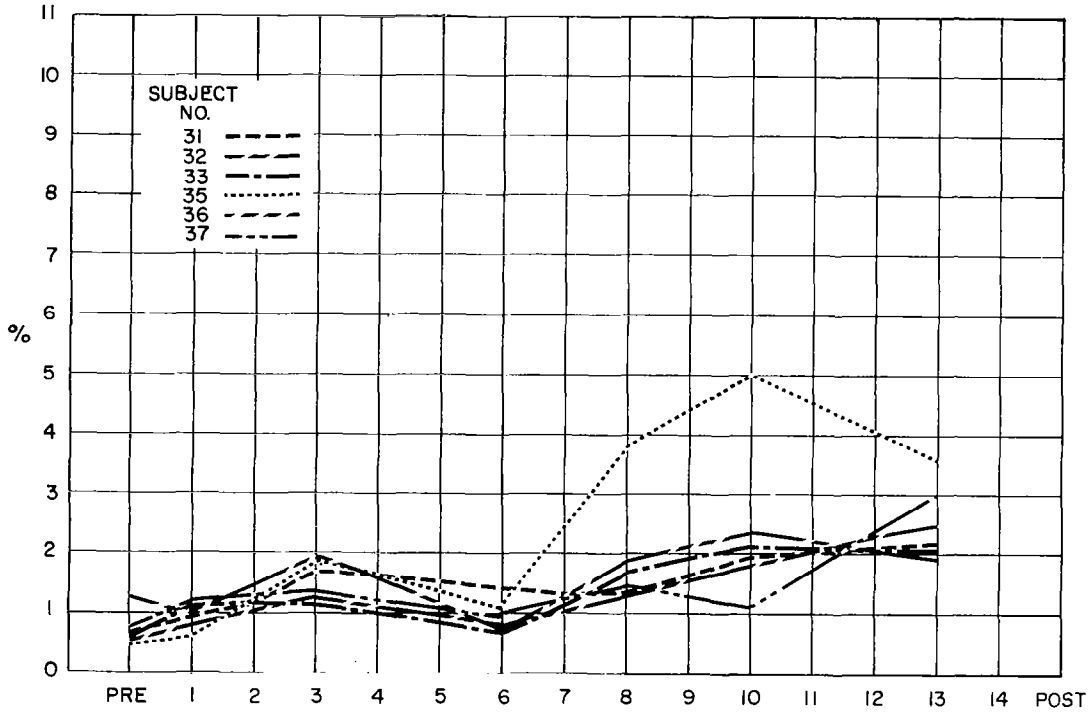



Figure 3-21 Reticulocytes at 5 psi

microcytosis (from an average of one cell of 6 $\mu$ to 24 cells of 6 $\mu$ and from 3.2 cells of 6.5 $\mu$ to 25 cells of 6.5 $\mu$) (Figure 3-22 and Table III-7). Subject No. 36 had been treated for five days on tetracyline 250 mg four times a day during the middle of the experimental run. His entry plus four days Price-Jones curve was normal and his exit curve showed only a slight flattening and broadening with a microcytosis (Figure 3-23). This variation from the other subjects may have reflected a hemopoietic response to the antibiotics he ingested during the experimental run.[23]

Subject 31 maintained a high white count throughout the run. Subjects 32 and 37 developed peak white counts of 13,000 and 12,600 by the end of the experiment and had sedimentation rates of 22 and 18 ml. The sedimentation rates of the other subjects were normal. These subjects exhibited a minimal change in hemoglobin with the exception of Subject 37 and the thalessemia trait subject. A mild increase in their reticulocyte response occurred toward the end of the experiment, suggesting minimal erythroid hyperactivity. The anisocytosis noted during the second week gives supporting evidence for increased red cell destruction. Unfortunately bilirubin determinations were not made. The major abnormality was noted on the Price-Jones curve at the end of the run; the curve demonstrated a marked flattening and a microcytosis. The Price-Jones curve is the most sensitive indication of an hematological disorder, since the degree of variability of cell sizes is more important than the mean cell diameter or the MCV.[24]

Follow-up studies at nine weeks and eleven weeks post-run more clearly demonstrated that the hematological status of the subjects had been altered as a result of the experimental conditions and had not as yet stabilized. The Price-Jones curve continued to demonstrate flattening and broadening of the base, with a microcytosis (over 50% of the cells were 6.5 $\mu$ or under). The morphology of the red blood count on both follow-up bloods on these subjects showed the following abnormalities: anisocytosis (Figure 3-24), spherocytosis (Figure 3-25), abnormal distribution of hemoglobin (Figure 3-26), stippled cells (Figure 3-27), polychromasia, normoblasts (Figure 3-28), Howell-Jolly bodies (Figure 3-29), and Cabot's ring cells (Figure 3-30).

These morphological changes, which one would expect to be associ-

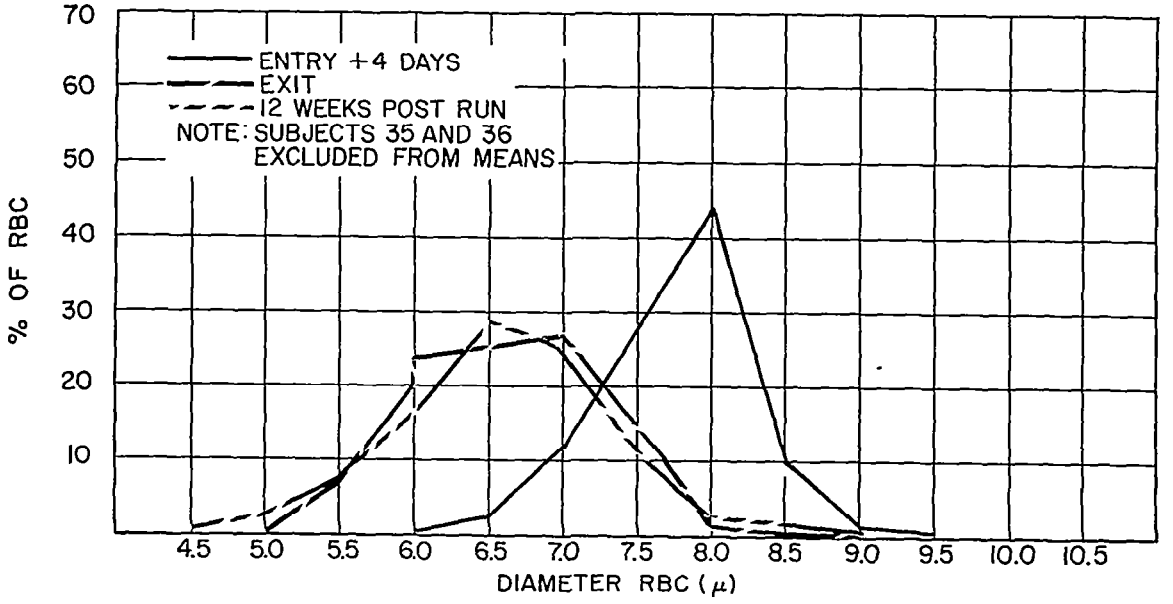



Figure 3-22 Mean Price-Jones Curve - 5.0 psi Run

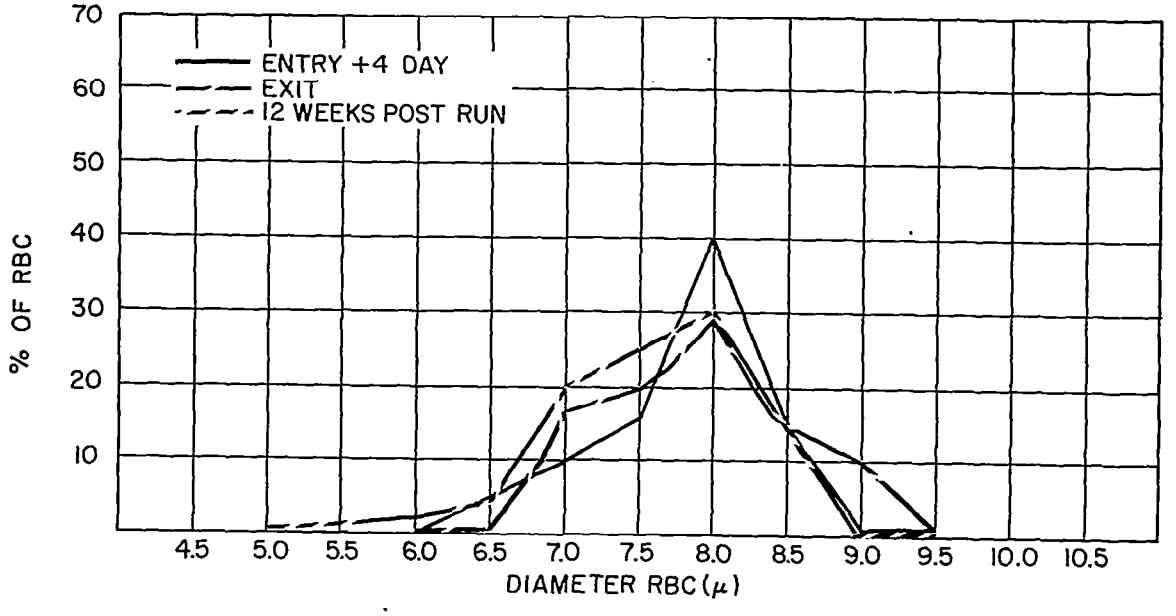



Figure 3-23 Price-Jones Curve - Subject 36

TABLE III - 7

PRICE-JONES INDEX % RBC

5 psi Run

| Time and Subject Number | RBC Diameter (μ) 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Entry +2 | | | | | | | | | | | | |
| 31 | | | | 1 | 2 | 8 | 20 | 58 | 8 | 2 | 1 | |
| Entry +4 | | | | | | | | | | | | |
| 32 | | | | 1 | 0 | 10 | 19 | 50 | 19 | 1 | | |
| Pre-run | | | | | | | | | | | | |
| 33 | | | | 1 | 4 | 16 | 50 | 25 | 2 | 1 | 1 | |
| Entry +4 | | | | | | | | | | | | |
| 35 | | | | | 1 | 15 | 18 | 56 | 8 | 2 | | |
| Pre-run | | | | | | | | | | | | |
| 36 | | | | 1 | 2 | 9 | 27 | 40 | 18 | 2 | 1 | |
| Pre-run | | | | | | | | | | | | |
| 37 | | | | 1 | 8 | 15 | 21 | 50 | 3 | 1 | 1 | |
| Mean | | | | 1 | 3.2 | 11.6 | 27.4 | 44.6 | 10 | 1.4 | .8 | |
| Exit | | | | | | | | | | | | |
| 31 | | 1 | 8 | 17 | 18 | 30 | 18 | 5 | 2 | 1 | | |
| 32 | | 1 | 9 | 26 | 32 | 26 | 3 | 2 | 1 | | | |
| 33 | | 1 | 10 | 14 | 20 | 30 | 22 | 1 | 1 | 1 | | |
| 35 | 1 | 3 | 3 | 8 | 6 | 6 | 26 | 28 | 12 | 5 | 2 | |
| 36 | | | | 1 | 1 | 17 | 18 | 30 | 19 | 12 | 1 | 1 |
| 37 | | 1 | 3 | 38 | 18 | 20 | 12 | 2 | 2 | 2 | 1 | 1 |
| Mean except Subject 35 | | .8 | 6.0 | 19.2 | 19.6 | 24.6 | 14.6 | 8 | 5 | 3.2 | .40 | .40 |
| Mean except Subjects 35 & 36 | | 1 | 7.5 | 24 | 25 | 26 | 15 | 2 | 1.4 | 1 | .5 | |

TABLE III - 7 (Cont)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 weeks Post-run | | | | | | | | | | | |
| 31 | | 1 | 9 | 25 | 30 | 20 | 9 | 3 | 2 | 1 | |
| 32 | 1 | 4 | 14 | 20 | 30 | 20 | 6 | 3 | 2 | | |
| 33 | 1 | 2 | 4 | 10 | 38 | 30 | 10 | 2 | 2 | 1 | |
| 35 | 1 | 4 | 4 | 9 | 7 | 8 | 23 | 25 | 10 | 8 | 1 |
| 36 | | 2 | 2 | 2 | 4 | 20 | 22 | 30 | 16 | 1 | 1 |
| 37 | | 1 | 3 | 10 | 20 | 30 | 25 | 4 | 4 | 2 | 1 |
| Mean except Subject 35 | .6 | 2 | 6.4 | 13.4 | 24.4 | 24 | 14.4 | 8.4 | 5.2 | 1 | .6 |
| Mean except Subjects 35 & 36 | .5 | 2 | 7 | 16 | 29 | 25 | 12 | 3 | 2.5 | 1 | .5 |

ated with a more severe form of clinical anemia, are indicative of the degree of qualitative alteration in the subjects' hematological status. The mean hemoglobin concentration decrease of 2.1 gm % nine weeks post-run with an 0.8 gm % higher level and a 3% reticulocytes, eleven weeks post-run, suggest that during the experimental run, either red blood cells were produced with abnormal survival times (60 - 80 days) or the survival times of a portion of the circulating red blood cells were shortened.

On incubation of four aseptically drawn bloods, Heinz bodies were demonstrated in the blood of Subjects 32 and 33 and not in the blood of control Subjects 11 and 16 (Figure 3-31). Heinz bodies are simply granules of precipitated hemoglobin representing the end stage of oxidative destruction of hemoglobin. Jandl [25] states, "the Heinz body anemias appear to represent an acceleration of the normal processes of red cell aging."

On the follow-up on September 26, 1962 (nine weeks post-run), the mean hemoglobin excluding Subject 35 was 13.6 gm % (entry 15.9 gm %; exit 15.5 gm %). The % reticulocytes are believed to be higher than recorded because the smears were made from warm blood 4 to 5 hours after being drawn. [26]

At the end of the first week of the experimental run, abnormal clotting was observed in the blood of Subject 32. This interfered with the performance of laboratory tests and was controlled subsequently only by greatly increasing the amount of heparin in the tubes used to obtain the blood samples. Refrigeration appeared to accentuate the clotting process. On three follow-up determinations (two weeks, nine weeks, and eleven weeks post-run), two experienced personnel were repeatedly unable to obtain accurate red blood cell counts for this subject because of red blood cell fragmentation in the counting chamber. This continued despite the use of new solutions for making the counts. Abnormal clotting was also noted while attempting to make direct smears. Similar difficulties occurred when drawing blood from Subject 31 during the eleven weeks post-run. Concurrently, the blood smears of Subjects 31 and 32 showed Rouleaux formation (Figure 3-32). These findings are suggestive of cryoglobulinemia.[27] Specific tests for this condition have not been done, hence, no conclusions can be drawn.

Subject 35, the thalassemia trait subject, exhibited a pre-run normal hemoglobin, hematocrit, red blood cell count and cellular morphology. A decrease

in hemoglobin (15.8 gm % to 10.5 gm %), red blood cell count, and hematocrit, and an increased reticulocytosis (0.6% to 3.5%) were observed during the experimental run. After the fourth day, stippled red cells appeared with hypochromasia and subsequently, many target cells, bizarre shapes, and normoblasts were seen with a more marked variation in the red blood cell size (Figure 3-33) These changes persisted throughout the remainder of the run. His Price-Jones curve was normal on entry plus four days but on exit had flattened and showed microcytosis with a broad base, indicating an abnormal distribution of cell size (Figure 3-34). His white blood cell count increased from 11,000 to 19,000. On exit, his red blood cells exhibited an increased osmotic fragility.

Subject 35 was hospitalized and followed extensively at Brookhaven National Laboratories, Upton, New York, where a diagnosis of thalassemia trait was made by electrophoretic analysis of his hemoglobin types. Although previously undiagnosed, examination of both parents demonstrated thalassemia trait in his father. His mother exhibited normal percentages of hemoglobin types. Post-run hemoglobin rose quickly to 12.0 gm % and appears to have stabilized between 12 to 13 gm % with a 3% reticulocytosis and a 5 to 6 million red blood cell count. His morphological picture, now compatible with thalassemia trait, has remained unchanged. The Price-Jones curve eleven weeks post-run showed a further and extreme broadening of the base with an increased microcytosis. His white blood cell count has returned to a high normal value and the osmotic fragility of his red blood cells is now decreased from normal which is typical of thalassemia trait.

Apparently the exposure to 100% oxygen at 5.0 psi for two weeks precipitated a hemolytic episode. The subject quickly improved on removal from the chamber, and his blood picture now appears to have stabilized showing the characteristic hematological abnormalities of thalassemia trait.

In summary, the 5.0 psi subjects exhibited only a slight anemia, except for Subject 35 (thalassemia trait) and Subject 37 (2 gm% hemoglobin decrease), during the experimental run. Nine weeks post-run there was a further mean 2.1 gm % decrease in hemoglobin with a mean 3% reticulocytosis. The Price-Jones curve done during the run showed widening and broadening of the base with a microcytosis (except Subject 36) that persisted on follow up examinations. The

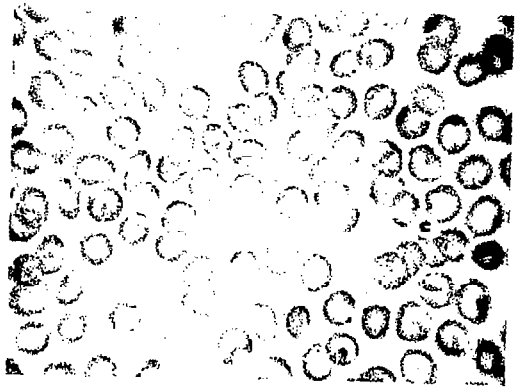


Figure 3-24 Anisocytosis

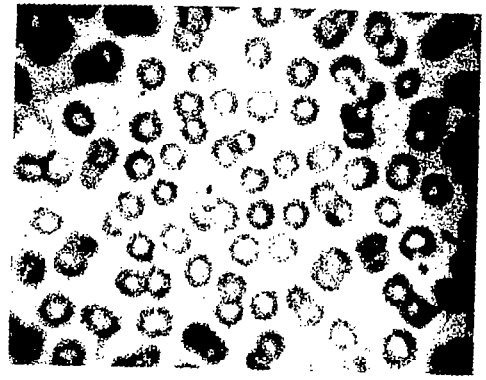


Figure 3-26 Abnormal Distribution of Hemoglobin

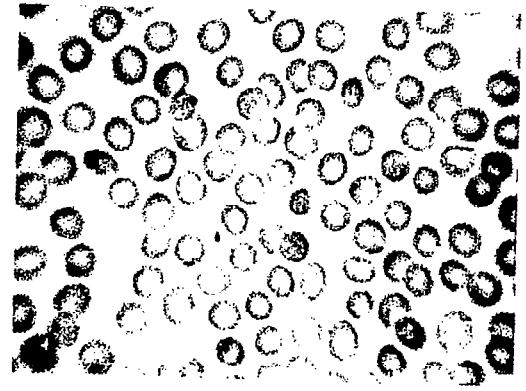
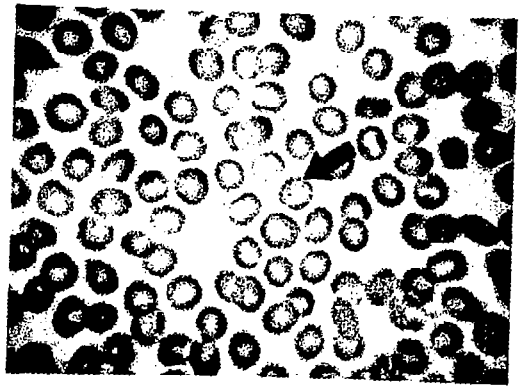


Figure 3-25 Spherocytosis



Stippled Cells

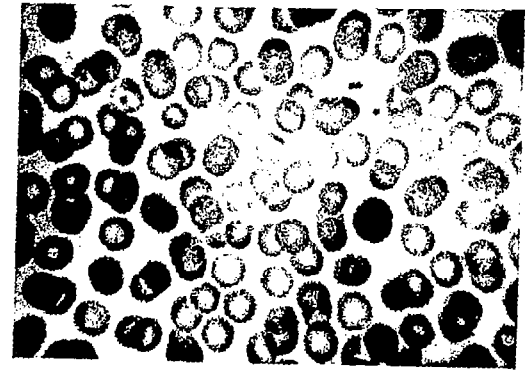


Figure 3-28 Normoblast

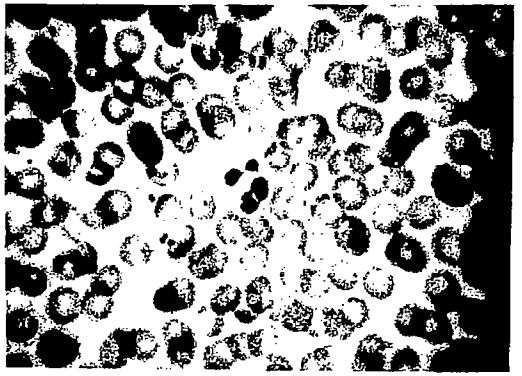


Figure 3-29 Howell-Jolly Bodies

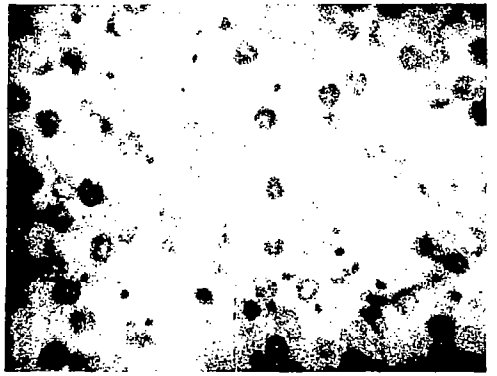


Figure 3-31 Heinz Bodies

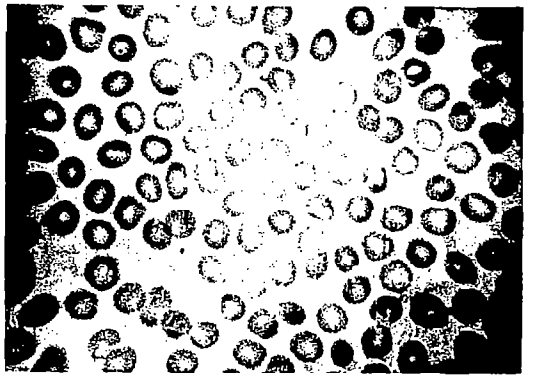


Figure 3-30 Cabot's Ring Cells

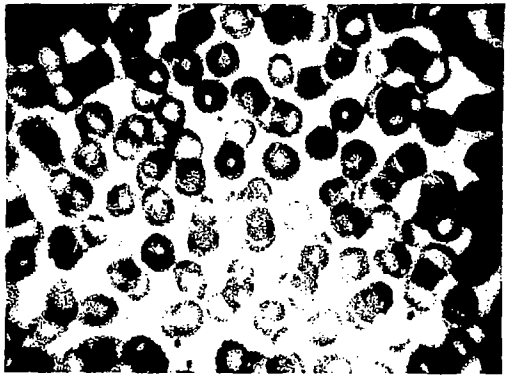


Figure 3-32 Rouleaux Formation

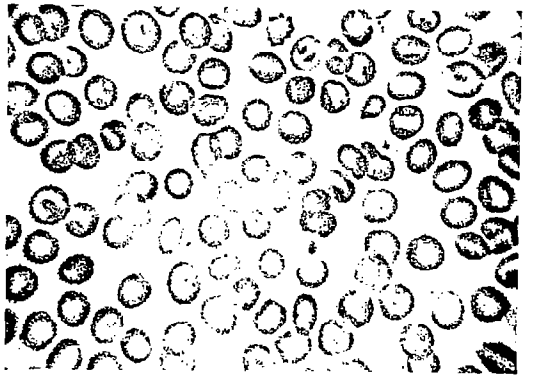


Figure 3-33 Thalassemia Trait

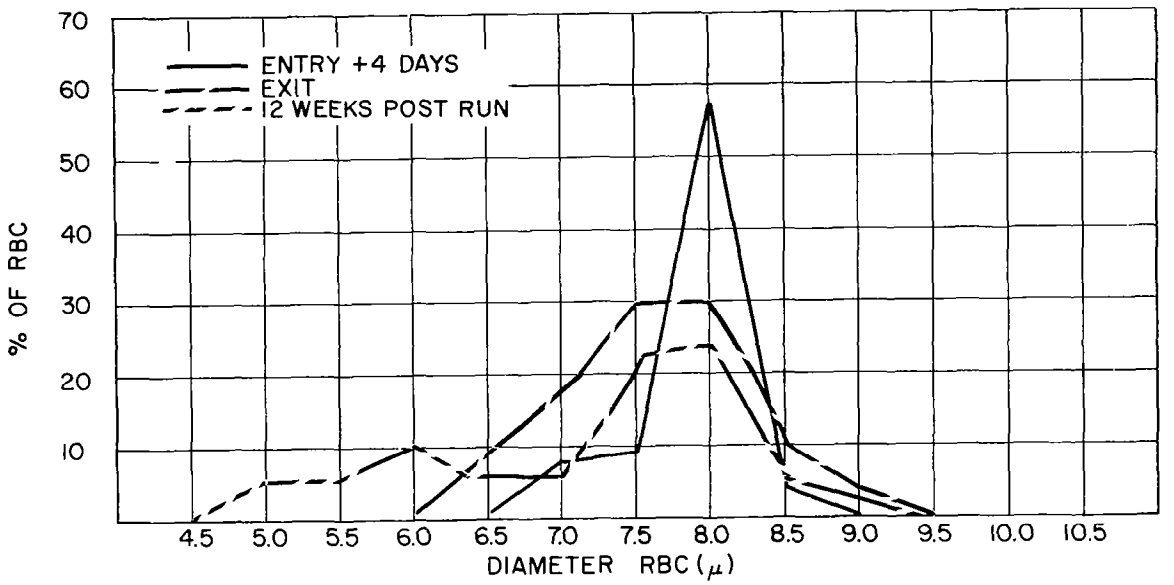



Figure 3-34 Price-Jones Curve - Subject 35

morphology of the red blood cells showed anisocytosis, spherocytosis, abnormal distribution of hemoglobin, stippled cells, polychromasia, normoblasts, Howell-Jolly bodies and Cabot's ring cells. Heinz bodies were demonstrated on incubation of blood of Subjects 32 and 33. In vitro, abnormal clotting and abnormal Rouleaux formation were noted on Subjects 32 and 33. The thalassemia trait subject had a marked hemolytic anemia which quickly improved on removal from the chamber and now appears to have stabilized at 12 to 13 gms % with a continued abnormal morphologic picture consistent with his hereditary hemoglobin defect.

3. 7.4 psi Run

Because of the hematological abnormalities noted in the 5.0 psi run, additional studies were done on the 7.4 psi run. These included bilirubin, urine urobilinogen, osmotic fragilities, and post-run bone marrow studies on all subjects. This group exhibited the most marked anemia.

The mean hemoglobin on entry was 16.1 gm %, which dropped more than 2 to 3 gm % after 48 hours in the chamber; on the fourth day there was a mean average of 13.5 gm %. A subsequent drop to 12.9 gm % occurred by the eleventh day, after which the hemoglobin rose to 14.0 gm % by the post-run day (Figure 3-35). Red blood cell counts correlated well with the hemoglobin values, decreasing from a mean of 4.916 million pre-run value to 4.488 million after 48 hours, and reaching the lowest level of 3.998 million on the eleventh day. At the end of the run the red blood cell count had returned to 4.441 million mean. Mean hemocrit values dropped from 49 mm to the lowest value of 43 mm on the tenth day and then returned to 47 mm at the end of the run. The mean reticulocyte percentage on entry was 0.9%; this rose progressively, reaching a peak of 4.9% on the tenth day and then gradually returned to 3.6% on the post-run day (Figure 3-36).

Bilirubin showed a marked increase from a mean pre-run value of 1.6 mg % to 4.4 mg % on the second day, then dropped sharply to 2.2 mg % on the third day and gradually decreased to 1.8 mg % at the end of the run. Urine urobilinogen level showed a gradual elevation, reaching a high value of 1/256 on Subjects 42 and 43, and 1/128 on the other subjects by the tenth day, decreasing to almost normal values on exit.

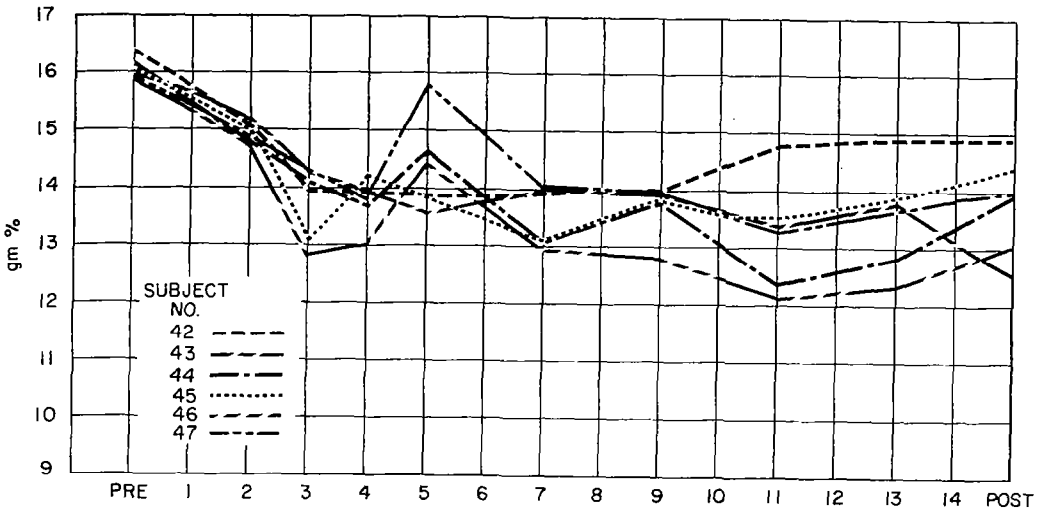



Figure 3-35 Hemoglobin Concentration at 7.4 psi

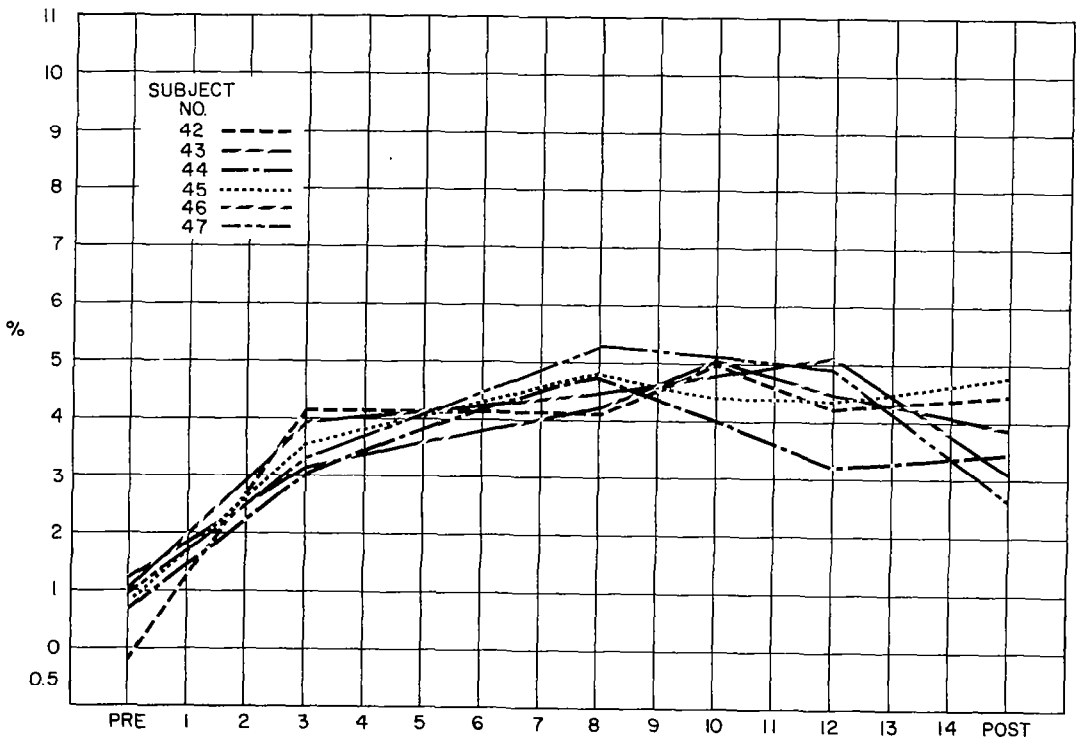



Figure 3-36 Reticulocytes at 7.4 psi

Three days after entry into the chamber, moderate anisocytosis of the red blood cells of all subjects was noted. Normoblasts were seen on the blood smears of all subjects, except Subject 42, and macronormoblasts were present on the smears of Subjects 43, 45, 46 and 47 (Figure 3-37). These morphological changes persisted throughout the remainder of the run.

A marked degree of vacuolization of the cytoplasm and nucleus of the white blood cells, a slight degree of toxic granulations, and an occasional young cell were noted on all subjects in the latter part of the second week of the experimental run (Figures 3-38 and 3-39).

The entry plus four days Price-Jones curve was normal. On exit, there was a moderate macrocytosis with over 43% of the cells having an average diameter of 8.5 $\mu$ or over (Figure 3-40 and Table III-8).

All except Subject 46 showed slightly elevated white blood cell counts at the start of the experiment. These high counts persisted with minor deviations throughout the experiment. From the end of the first week, Subjects 42, 43, and 45 showed an inversion of the poly-lymph ratio with increased monocyte counts of 11, 16, and 15%, respectively. At the end of the first week, Subject 43 had a sedimentation rate of 20 ml, which dropped to 12 ml by the end of the experiment. Subject 42 developed a high sedimentation rate at the end of the first week, with a peak of 18 ml at the end of the experiment. Subject 44 had a high sedimentation rate of 16 ml in the middle of the run which returned to normal by the end of the experiment.

Occult bloods were determined on fecal samples in the 7.4 psi run beginning on the fourth day. At least five of six samples were positive on each subject. However, no evidence of gross bleeding was detected.

Pre-run red blood cell osmotic fragilities were normal. There was a slight increase in complete hemolysis, above the normal level, in all subjects except Subject 46 at the end of the run.

Bone marrow aspirations were done on all subjects on the post-run day. All marrows except that of Subject 43 showed erythroid hyperplasia, especially marked in Subjects 45 and 46, who had between 40 and 50% red cell precursors. All of the individuals, except Subject 47, had some predominance

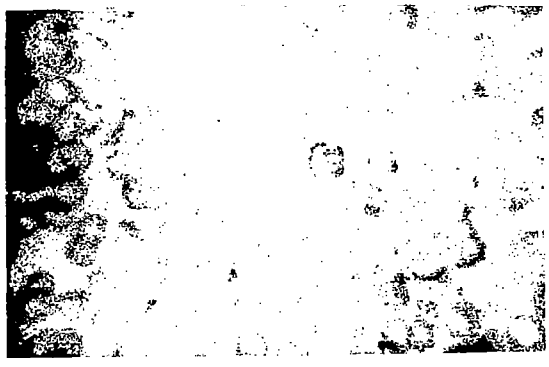
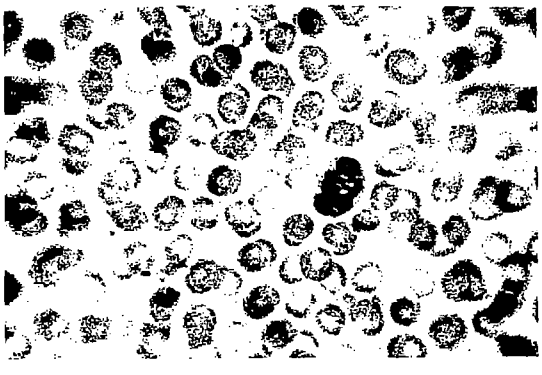


Figure 3-37 Macronormoblasts



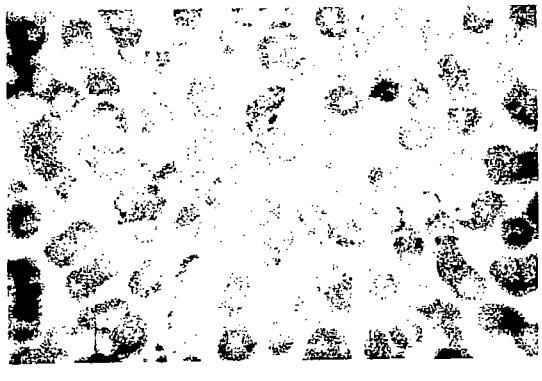


Figure 3-38 and Figure 3-39
Young White Cells

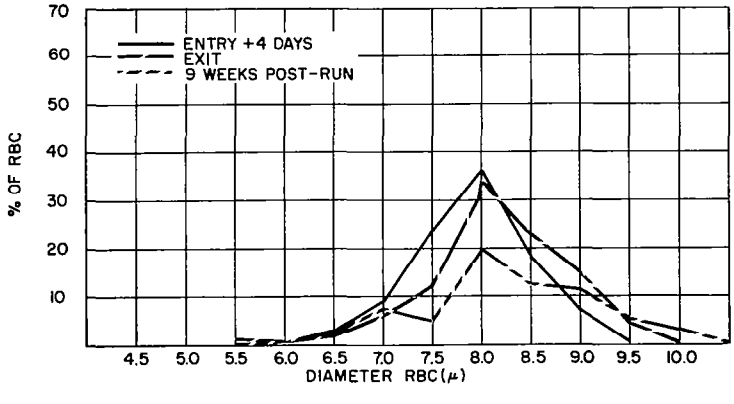



Figure 3-40 Mean Price-Jones Curve - 7.4 psi Run

TABLE III - 8

PRICE-JONES INDEX % RBC

7.4 psi Run

| Time and Subject Number | RBC Diameter (μ) 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 | 10.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Entry +4 | | | | | | | | | | | | | |
| 42 | | | | 1 | 2 | 4 | 17 | 36 | 30 | 9 | 1 | | |
| Entry +4 | | | | | | | | | | | | | |
| 43 | | | | | 1 | 12 | 30 | 38 | 18 | 1 | | | |
| Entry +4 | | | | | | | | | | | | | |
| 44 | | | | | 5 | 21 | 35 | 28 | 7 | 3 | 1 | | |
| Pre-run | | | | | | | | | | | | | |
| 45 | | | | 1 | 5 | 12 | 45 | 26 | 9 | 2 | | | |
| Pre-run | | | | | | | | | | | | | |
| 46 | | | | | 1 | 6 | 12 | 62 | 12 | 6 | 1 | | |
| Entry +4 | | | | | | | | | | | | | |
| 47 | | | | | | 2 | 8 | 28 | 36 | 24 | 2 | | |
| Mean | | | | .33 | 2.3 | 9.5 | 24.5 | 36.4 | 18.7 | 7.5 | .83 | | |
| Exit | | | | | | | | | | | | | |
| 42 | | | 1 | 3 | 5 | 18 | 21 | 40 | 10 | 2 | 1 | | |
| 43 | | | | 1 | 2 | 11 | 18 | 27 | 33 | 6 | 1 | 1 | |
| 44 | | | | | | 1 | 9 | 40 | 21 | 21 | 7 | 1 | |
| 45 | | | | | 1 | 2 | 8 | 40 | 28 | 15 | 4 | 2 | |
| 46 | | | | 1 | 2 | 2 | 10 | 30 | 28 | 18 | 8 | 1 | |
| 47 | | | | 1 | | 3 | 12 | 30 | 23 | 28 | 2 | 1 | |
| Mean | | | .2 | 1.0 | 1.6 | 6.18 | 13 | 34.5 | 23.9 | 15 | 3.8 | 1 | |
| 8 weeks Post-run | | | | | | | | | | | | | |
| 42 | | | | 1 | 5 | 22 | 16 | 40 | 6 | 10 | | | |
| 44 | | | | | 2 | 3 | 5 | 10 | 38 | 30 | 9 | 2 | 1 |
| 45 | | | | 1 | 2 | 5 | 12 | 40 | 17 | 10 | 8 | 5 | |
| 46 | | | 2 | 2 | | 11 | | 30 | 15 | 20 | 10 | 10 | |
| Mean | | | .33 | .67 | 1.5 | 6.8 | 5.5 | 20 | 12.7 | 11.6 | 4.5 | 2.8 | .16 |

of myeloid elements, in particular, promyelocytes and myeloblast cells. The erythroid hyperplasia is readily explained by the increased demand upon the bone marrow for red cell synthesis secondary to the presence of hemolysis in these subjects.[28]

In this group there was a significant fall (2 to 3 gm %) in the hemoglobin level during the first 48 hours. This was accompanied by a significant rise in the bilirubin level (4 mg %) and urine urobilinogen level, and reticulocytosis occurred on the third day and persisted at levels of 3.0 to 5.5%. This data suggests an abrupt hemolysis of a portion of the red cells during the early period of the experiment. Normoblasts and macronormoblasts appeared and macrocytosis developed, indicating increased erythropoiesis as confirmed by the post-run bone marrows. After the fourth day the hemoglobin values tended to level off. There was a drop in hemoglobin and red blood cell count, accompanied by a slight rise in the bilirubin level and reticulocytosis on the eleventh day. Thereafter, the hemoglobin level rose and the reticulocytosis decreased, suggesting that compensation for the hemolytic process was developing. Stohlman[29] believes that the reticulocytes produced in response to intensive stimulation are imperfectly formed macrocytes, whose abnormalities are probably related to the rapidity of their maturation process. These larger cells have a shorter life span than those produced later during the compensating phase.

At two weeks post-run, Subjects 42, 43, 44, and 45 showed a mean hemoglobin rise of 1.1 gm % to 15.1 gm %. The mean hemoglobin six weeks post-run was 14.9 gm %. Eight weeks post-run, the mean hemoglobin was 14.4 gm % for all six subjects. The percentage of reticulocytes was 2.8% at six weeks post-run, and 2.5% at eight weeks post-run. Subjects 42 and 46 showed stippled cells at eight weeks post-run, Subject 43 showed normoblasts and Subject 46 showed Cabot's ring cells. There was no change in the abnormal appearance of the white blood cell from that noted at the end of the run. The Price-Jones curve demonstrated a marked flattening and broadening with continued macrocytosis (30% of the cells were 8.5 $\mu$ or over and a few cells were 5.5 $\mu$). Subject 46 showed the most marked broadening with a curve from 5 $\mu$ to 10 $\mu$.

This decrease in hemoglobin and continuing reticulocytosis eight weeks post-run occurred at the same time period post-run as a similar change in the 5.0 psi group. However, there was a macrocytosis instead of a micro-

cytosis on the Price-Jones curve. This shift cannot be explained on the basis of increased reticulocytosis because of the high percentage of large cells shown on the Price-Jones curve. These cells may represent either abnormally large cells being produced by the bone marrow that persist past the reticulocyte stage, or circulating red blood cells whose size has been altered. These findings, combined with the red blood cell and white blood cell morphological changes, indicate hematological abnormalities, the nature of which is not clear.

4. 3.8 psi Run

There was a slight decrease in mean hemoglobin, during the first week, from 15.5 gm % to 14.5 gm %, which returned to 15.0 gm % by the end of the experimental run (Figure 3-41). The mean red blood cell count decreased about 0.5 million/$mm^3$. There was a profound reticulocyte response starting on the third day and peaking on the eighth day at 7.7% and then falling to 6.0% (Figure 3-42). The pre-run reticulocytes level of 2.3% is unusually high although similar values were obtained on duplicate samples at Brookhaven National Laboratories, Upton, New York. The mean bilirubin value rose from 1.4 mg % to 2.5 mg % on the eleventh day and then decreased to slightly above the pre-run value. Urine urobilinogen determinations were within normal limits at all times.

At the beginning of the second week Subject 52 (and Subject 56 to a lesser degree) had marked anisocytosis which persisted throughout the remainder of the experimental run. Normoblasts were present and persisted in all subjects starting at the end of the first week (Subject 53 had as many as 15/100 white blood cells).

Subject 53 showed marked abnormalities, at the start of the second week, of the staining mechanism of the white blood cell nucleus, in both polys and lymphs, giving the appearance of the separation and segregation of the chromatin itself (Figure 3-43). Subject 52 showed similar less marked changes on the last day of the run.[30]

On the 3.8 psi run the white counts were within the normal range throughout the experiment for all subjects except Subject 53, who had a peak count of 14,200 at the end of the first week, but which returned to normal by the end of the run. His eosinophils numbered 10% and his monocytes were 15% at

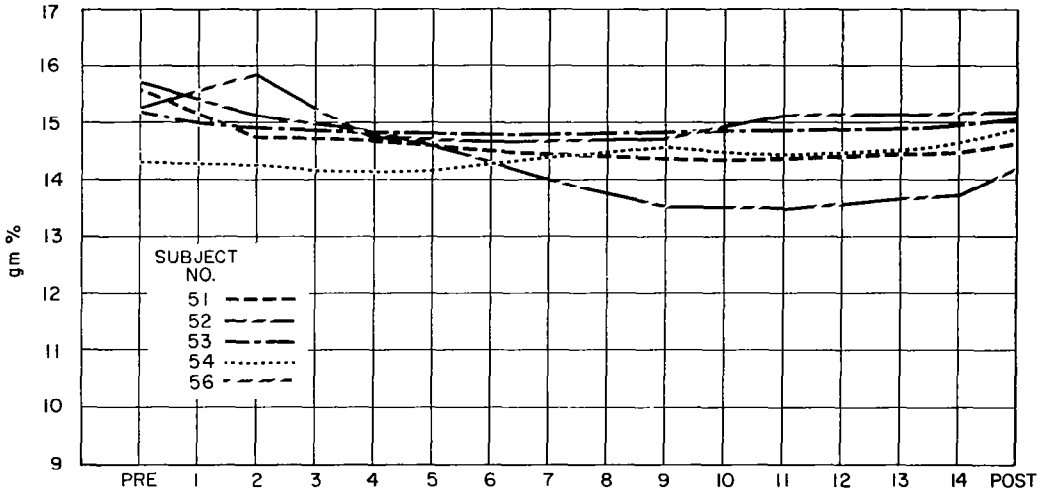



Figure 3-41 Hemoglobin Concentration at 3.8 psi

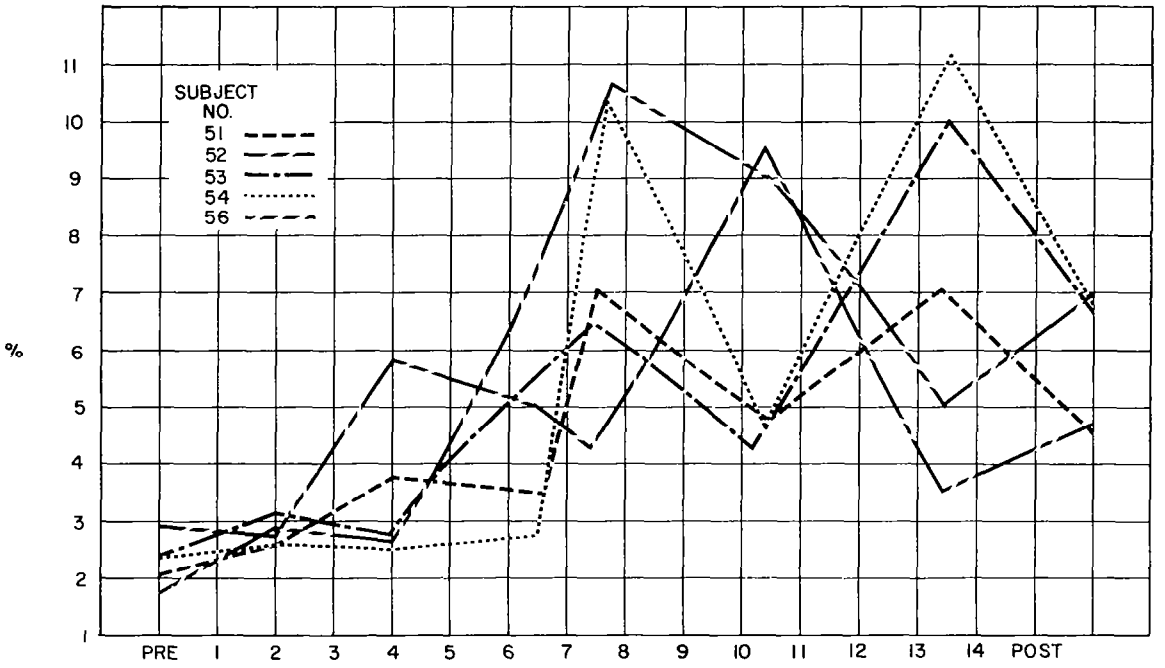
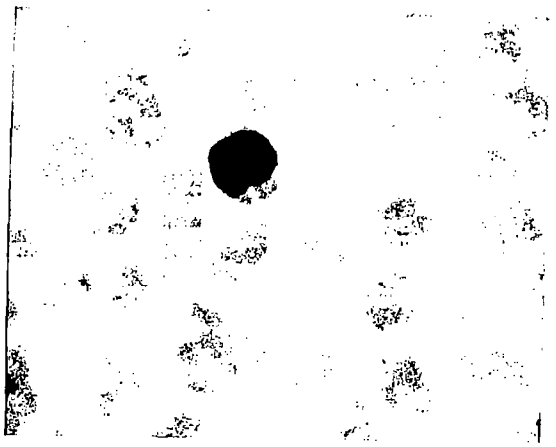
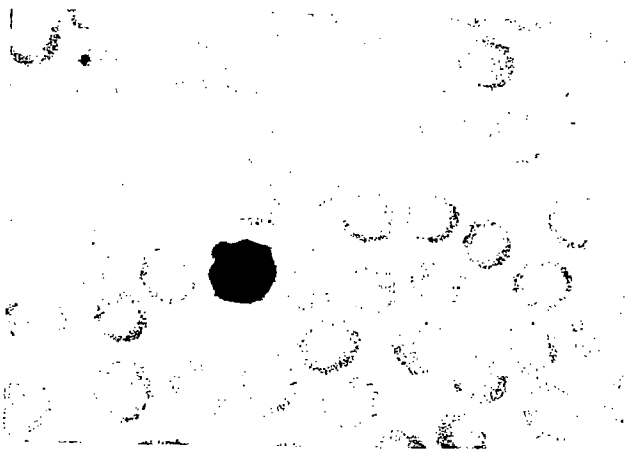



Figure 3-42 Reticulocytes at 3.8 psi





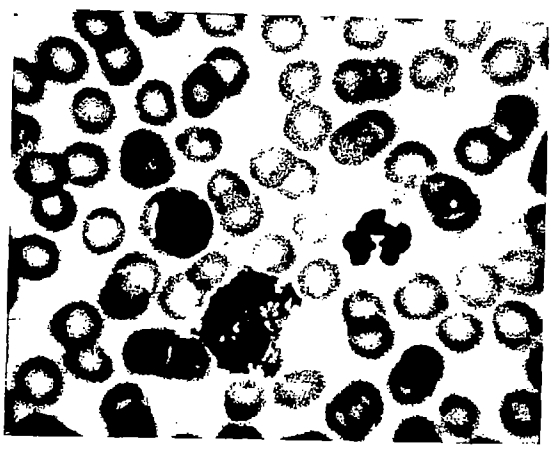


Figure 3-43 Nuclear Abnormalities of White Cells

the time of the peak count. The sedimentation rates were normal throughout.

On the 3.8 psi run, three subjects had normal osmotic fragilities at the start of the run, but at the end of the experimental run all three subjects showed moderately increased initial and complete hemolysis. The other two Subjects, 53 and 56, who started the test with increased initial hemolysis, showed a further increase in both initial and complete hemolysis at the end of the experimental run.

The Price-Jones curve on the fourth day showed normal distribution of cells. On exit there was a microcytosis with a flattening and broadening of the curve slightly more marked than in the 5.0 psi run (Figure 3-44, Table III-9).

In follow up studies, at three and five weeks post-run, Subjects 52, 54, and 56, showed no marked change in hemoglobin concentrations. Reticulocyte percentage was 5% and bilirubin was slightly above normal. There were normoblasts on the smears of Subjects 52 and 54. In addition, Subject 54 showed stippling. White blood cell nuclear changes occurred in Subjects 52 and 54 and were comparable to the changes that occurred with Subject 53 during the experimental run. The Price-Jones curve shows a more pronounced microcytosis with 47% of the cells showing diameters of 6.5 $\mu$ or less.

The hematological picture in the 3.8 psi run resembled the 5.0 psi run except for a more marked reticulocytosis (Figures 6-45 through 6-49). The Price-Jones curves showed a similar marked flattening and broadening with microcytosis. In contrast the Price-Jones curve in the 7.4 psi run demonstrated a macrocytosis. The morphological abnormalities were more marked in the 7.4 psi run and in the follow up examinations for the 5.0 psi run. The follow up examinations in the 3.8 psi run were three and five weeks post-run and were made on only three subjects. They tend to show a continuation of the hematological abnormalities present during the experimental run. Although data are not available, it is reasonable to assume that the subjects had, in the early post-run period after the 5.0 psi and 7.4 psi run, a similar continuation of their hematological abnormalities prior to their follow up examinations and that the 3.8 psi group will continue to show hematological abnormalities for at least as long as demonstrated in the 5.0 psi group.

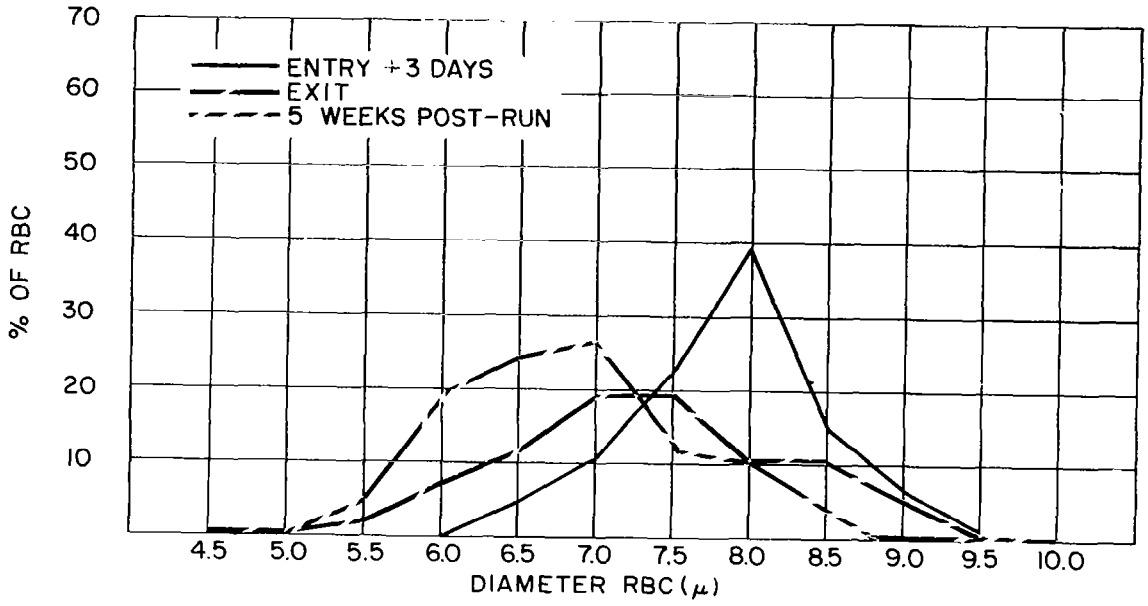



Figure 3-44 Mean Price-Jones Curve - 3.8 psi Run

TABLE III-9
PRICE-JONES INDEX % RBC

3.8 psi Run

| Time and Subject Number | RBC Diameter (μ) 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Entry +4 | | | | | | | | | | | | |
| 51 | | | | 1 | 3 | 17 | 17 | 28 | 20 | 12 | 2 | |
| Entry +4 | | | | | | | | | | | | |
| 52 | | | | 2 | 10 | 18 | 32 | 34 | 3 | 1 | | |
| Pre-run | | | | | | | | | | | | |
| 53 | | | | | 1 | 4 | 21 | 45 | 25 | 4 | | |
| Entry +4 | | | | | | | | | | | | |
| 54 | | | | 1 | 5 | 5 | 26 | 48 | 10 | 4 | 1 | |
| Entry +2 | | | | | | | | | | | | |
| 56 | | | | 1 | 3 | 10 | 18 | 42 | 16 | 9 | 1 | |
| Mean | | | | 1 | 4.4 | 10.8 | 22.8 | 39.4 | 14.8 | 6 | .8 | |
| Exit | | | | | | | | | | | | |
| 51 | | | | 1 | 3 | 18 | 18 | 28 | 20 | 11 | | |
| 52 | 1 | 7 | 10 | 32 | 24 | 17 | 5 | 3 | 1 | 1 | | |
| 53 | | | 1 | 2 | 12 | 25 | 30 | 20 | 5 | 3 | 2 | |
| 54 | | | | 1 | 3 | 10 | 19 | 35 | 18 | 12 | 1 | 1 |
| 56 | | | | 1 | 12 | 25 | 30 | 21 | 10 | 1 | | |
| Mean | .2 | 1.4 | 2.2 | 7.4 | 10.8 | 19 | 20.4 | 11.4 | 10.8 | 5.6 | .6 | .2 |
| 5 weeks Post-run | | | | | | | | | | | | |
| 52 | | 1 | 10 | 38 | 34 | 8 | 8 | 1 | | | | |
| 54 | | 1 | 5 | 10 | 20 | 37 | 16 | 10 | 1 | | | |
| 3 weeks Post-run | | | | | | | | | | | | |
| 56 | | | 1 | 8 | 15 | 33 | 10 | 20 | 10 | 1 | 1 | 1 |
| Mean | | .66 | 5.3 | 18.7 | 23 | 26 | 11.9 | 10.3 | 3.66 | .33 | .33 | .33 |

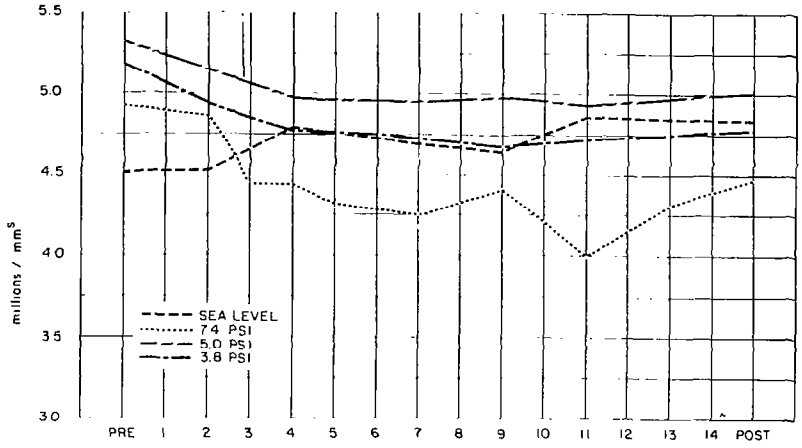



Figure 3-45 Average Red Blood Cell Count

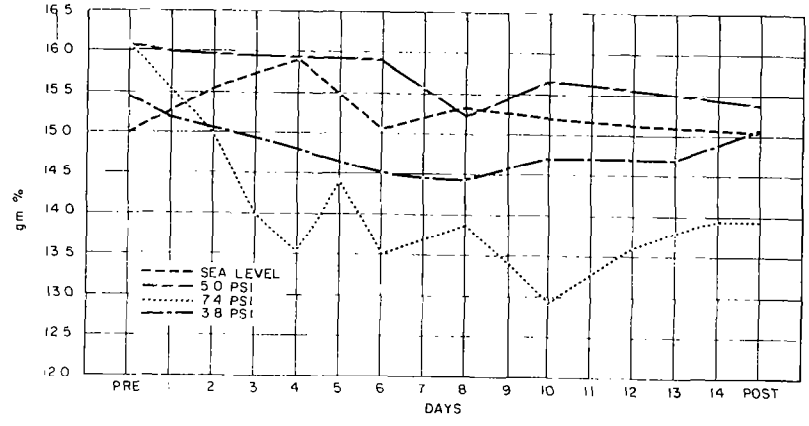



Figure 3-46 Average Hemoglobin Concentration

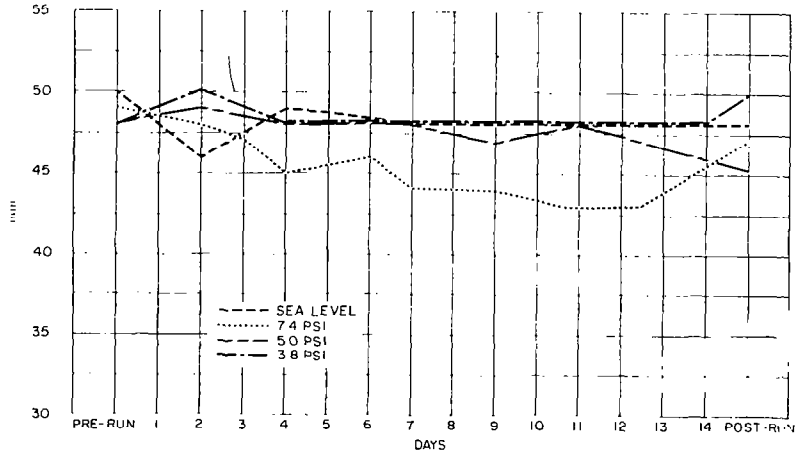



Figure 3-47 Average Hematocrit

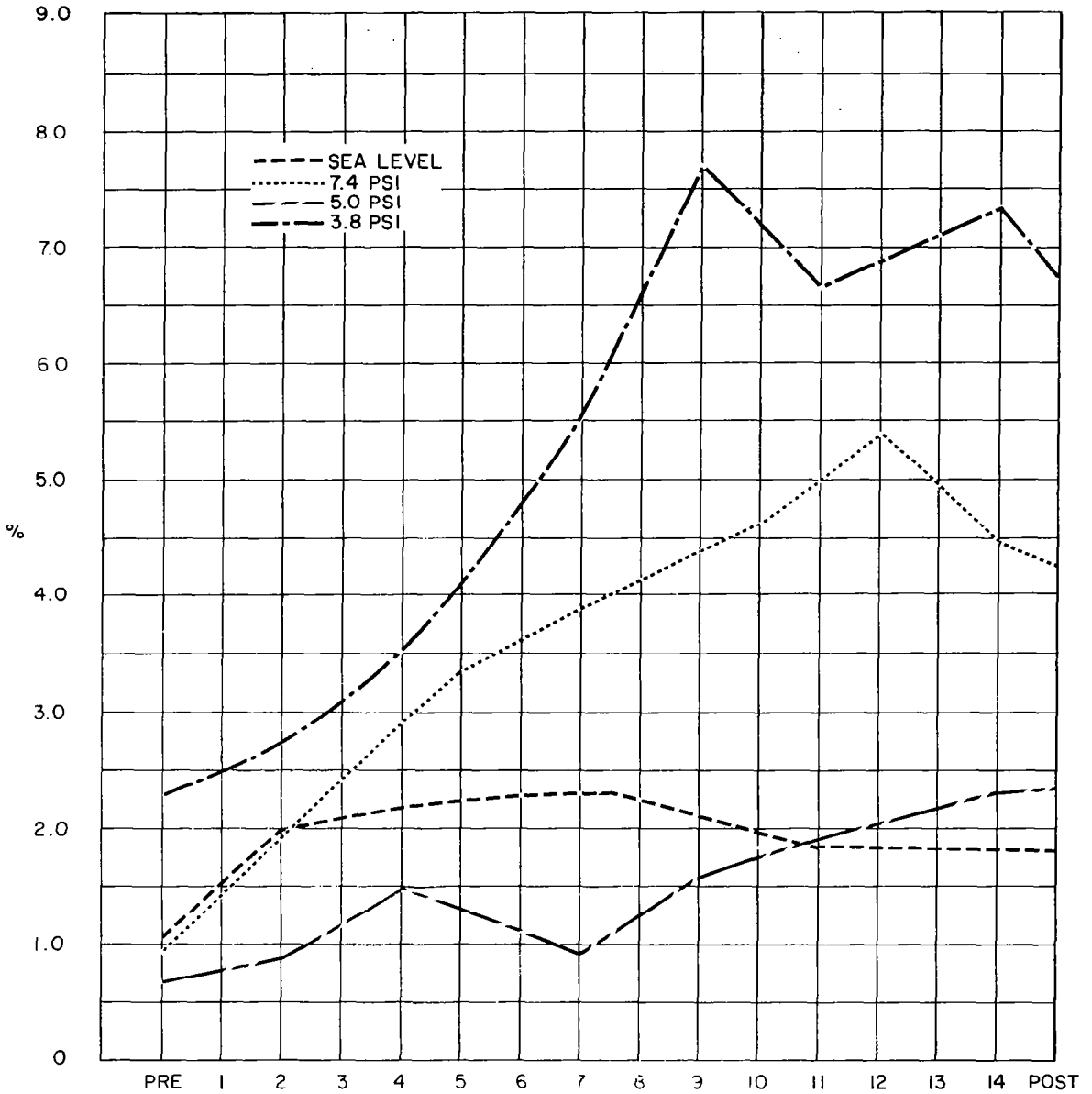



Figure 3-48 Average Reticulocytes

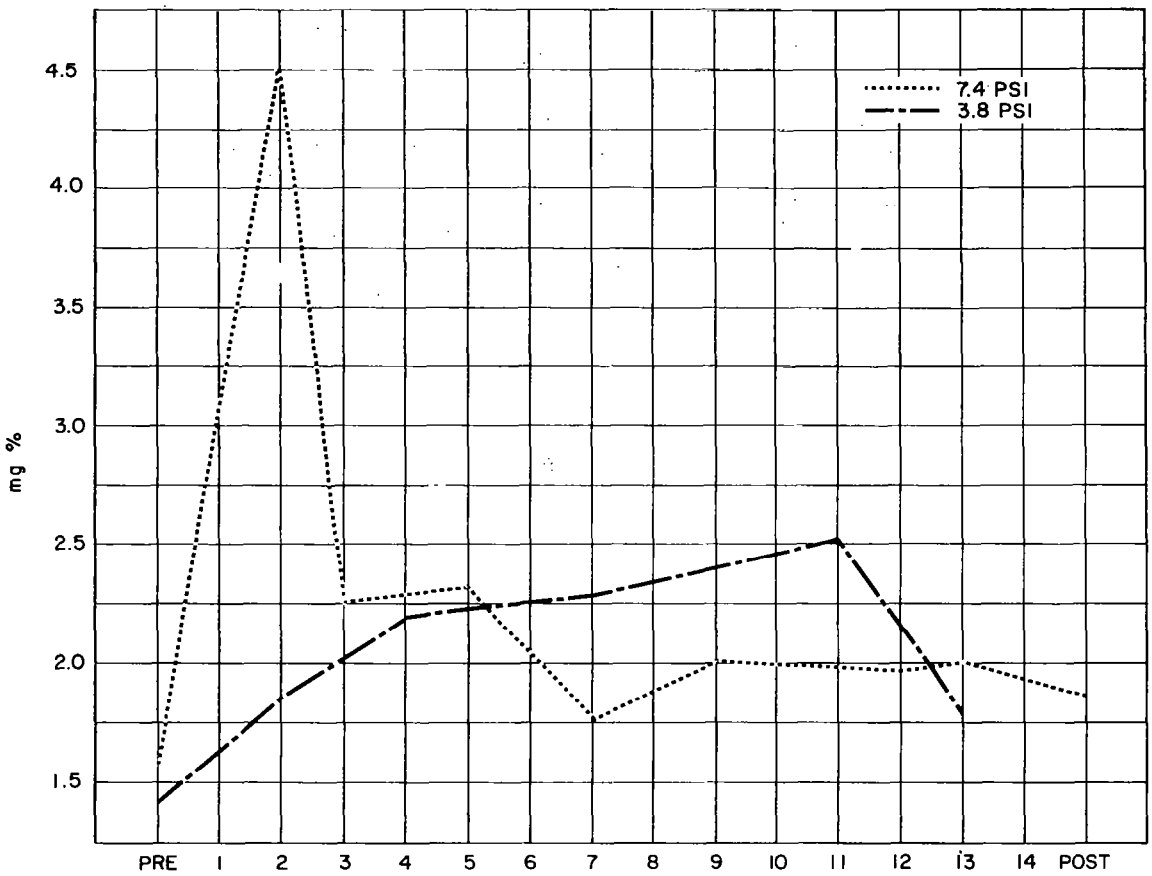



Figure 3-49 Average van den Bergh Determination

5. Summary of Data

1. The hematological system of the sea level control group showed no significant change, except a reversal of the white blood cell polymorphonuclear and lymphatic ratio.

2. The 5.0 psi group (except Subject 35) demonstrated a slight anemia, microcytosis, increased osmotic fragility, and minimal erythroid hyperactivity. Subject 37 had a loss of over 2.0 gm % hemoglobin and a 2.2% reticulocyte count. The follow up examinations nine and eleven weeks post-run more clearly demonstrated that the hematological abnormalities of the subjects had persisted. The Price-Jones curve continued to show flattening and broadening of the base with a concomitant microcytosis. The morphology of the red blood cells showed the following abnormalities: anisocytosis, spherocytosis, abnormal distribution of hemoglobin, stippled cells, polychromasia, normoblasts, Howell-Jolly bodies and Cabot's ring cells. Additionally, there was a 2.1 gm % decrease in mean hemoglobin nine weeks post-run, followed by a 0.8 gm % increase in hemoglobin concentration with a 3% reticulocyte response eleven weeks post-run. Subject 35 (later shown to have thalassemia trait) demonstrated a hemolytic anemia with a progressive decrease in hemoglobin from 15.8 to 10.5 gm %. Post-run examinations indicate that his blood picture appears to have stabilized between 12 to 13 gm % hemoglobin with a continued abnormal morphological picture consistent with his hereditary hemoglobin defect (thalassemia trait).

3. The 7.4 psi group exhibited a fall (2 to 3 gm %) in hemoglobin concentration during the first 48 hours, with a rise in bilirubin and urine urobilinogen levels. Reticulocytosis occurred on the third day and persisted at 3.0 to 5.5%. Normoblasts, macronormoblasts, and macrocytosis appeared, indicating increased erythropoiesis. The latter was also noted in the post-run bone marrow examinations. In the white blood cells of the peripheral blood there was a marked degree of vacuolization of the cytoplasm and nucleus and an occasional young white cell was seen toward the end of the experimental run. After the fourth day, the hemoglobin concentration leveled off except for a mean one gram drop on the eleventh day. Thereafter, the hemoglobin level rose and the reticulocytosis decreased. In the eight weeks post-run examination there was a slight decrease in hemoglobin and a continuing reticulocytosis, macrocytosis, and there were morphological changes in the red and white blood cells, suggesting the persistence of the hematological abnormalities.

4. The hematological picture of the 3.8 psi run subjects resembled that of the 5.0 psi run subjects, except for a more marked reticulocytosis. The Price-Jones curve showed marked flattening and broadening with microcytosis. Morphological changes

included normoblasts, spherocytes, and microcytosis, and anisocytosis of the red blood cells. Follow up examinations three and five weeks post-run on three available subjects show a continuation of the hematological abnormalities present during the experimental run. All subjects after two weeks of exposure to 100% oxygen atmospheres at reduced pressures exhibited some hematological abnormalities which have persisted. These alterations generally suggest erythroid hyperplasia secondary to hemolytic processes.

(Price-Jones curves for all the groups plotted for entry plus days, exit, and various post-run periods are shown in Figures 3-49 through 3-51.)

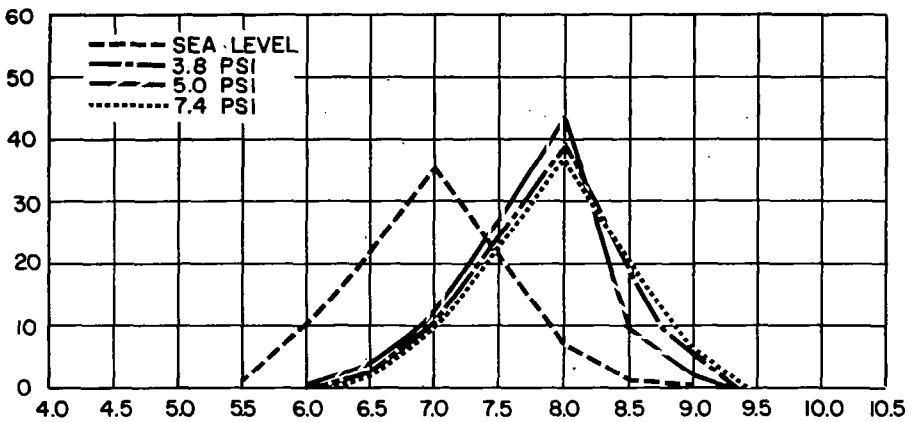



Figure 3-50 Mean Price-Jones Curves - Entry Plus Four Days Except Sea Level Group

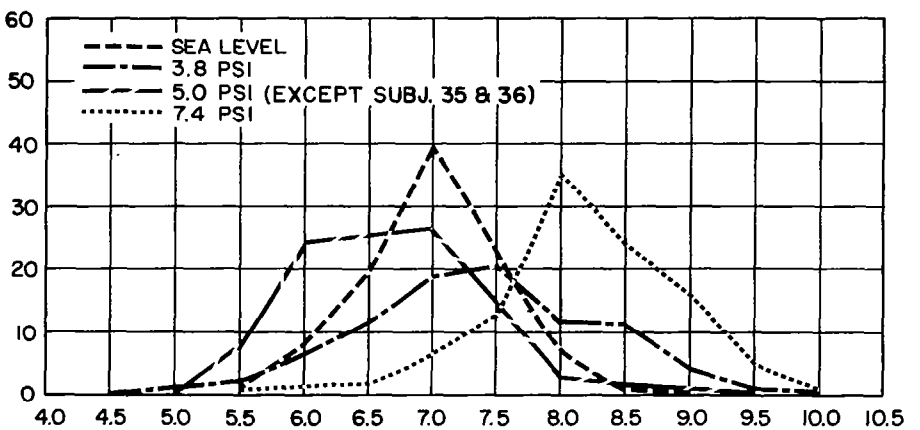



Figure 3-51 Mean Price-Jones Curves - Exit

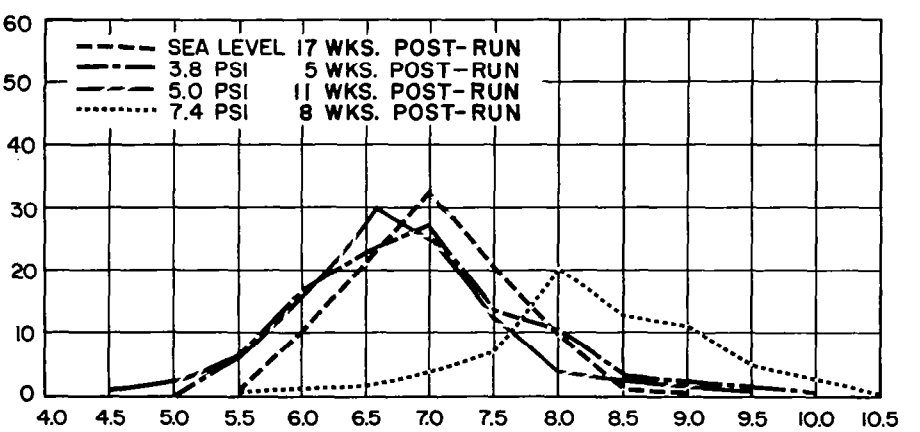



Figure 3-52 Mean Price-Jones Curves - Follow-up

6. Theoretical Discussion

The hematological changes observed in this study may be due to increased oxygen, decreased nitrogen, reduced barometric pressure, an unknown toxicant, or a combination of these factors. Consideration has been given to the possibility that increased oxygen may have precipitated a hemolytic process similar to a drug induced anemia.

Drug induced hemolytic anemias can be caused by: 1) chemicals that will affect only red cells with a defective enzyme system, 2) chemicals that will affect all red cells, and 3) chemicals that work in conjunction with abnormal serum factors (antibodies).

The factors limiting the survival of the red cell may vary with the particular challenge presented to the erythrocyte by its environment.[31] The injurious effects of hemolytic drugs in vivo and vitro are modified by the character of the red cell involved. Old red cells are more susceptible than young cells. The red cells of some individuals, particularly certain Negroes and dark-skinned Caucasians, have increased susceptibility to hemolysis.

Individual hypersusceptibility to hemolysis with primaquine-type drugs is apparently the result of a deficiency of the enzyme glucose-6-phosphate dehydrogenase. Individuals with this deficiency also have a reduced activity of catalase and glutathione. Glucose-6-phosphate dehydrogenase catalyzes the initial step in the pentose phosphate pathway of carbohydrate metabolism. It provides the mature red cell with its only oxidative apparatus and source of reduced triphosphopyridine nucleotide (TPNH). Oxidative glycolysis provides a cellular defense against primaquine-type hemolytic drugs possibly through the preservation or regeneration of reduced glutathione. TPNH, and possibly DPNH, are involved in the reduction of methemoglobin and oxidized glutathione.

Primaquine-like drugs react with molecular oxygen to form redox

intermediates between oxygen and hemoglobin and other intracellular components, thereby transmitting the high oxidation potential of oxygen to cellular components. This will result in oxidative destruction of the cellular components if the cell is unable to increase its reducing capacity. The continuous generation of reducing agents is brought about by glucose metabolism through the pentose phosphate pathway.[25]

Primaquine induced hemolysis is self-limiting. Following the initial rapid hemolyzing of the older and more susceptible red cells, there is a recovery phase with a relative resistance to hemolysis upon further exposure to potentially hemolytic agents due to the appearance in the circulation of red cells with a younger mean cell age. The hemoglobin rises and stabilizes, resulting in a diminished reticulocytosis. There is no anemia or marked hemolysis in the equilibrium phase, even though drug administration is continued. There is a shortened survival time of the red blood cells but the increased erythropoiesis compensates for the increased destruction.

The decrease in glucose-6-phosphate dehydrogenase activity in red cells of sensitive persons is associated with morphological changes in these cells characteristic of normal aged red cells. Danon, et al.[32] have found with the use of the electron microscope, that young red cells have "granular" membranes and old red cells have "smooth" membranes. The red cells of glucose-6-phosphate dehydrogenase subjects have predominantly "smooth membranes." Anderson and Turner[33] have reported that hemoglobin is an integral component of the red cell membrane. Marks[31] states "that the denaturation of hemoglobin and other protein components of the cell wall could lead to a deformation of the cell membrane and, in turn, to the sequestration and destruction of these cells."

Patients with primaquine sensitivity demonstrate a mild hemolytic state, even in the absence of exogenous drugs. They have been shown to have a 25% shortened erythrocyte survival time. Desforges[34] states that the hemolytic action of some of these primaquine-type drugs in vivo is not confined to those cases in which such a sensitivity can be demonstrated. With sulfoxane therapy, hemolysis of the aged cell is an expected phenomenon with high doses in normal individuals. Desforges has demonstrated a similar change of gluta-

thione instability in normal cells with continuous aeration depending only on the presence of oxygen. This suggests that "in the normal individual, critical levels of oxident drugs may also exist, above which biochemical trauma may be sufficient to produce hemolysis."

Chemical oxidants such as menadione, phenylhydrazine, etc., are known hemolytic agents. In discussing the action of these drugs, Jandl [25] states that "These drugs are potentially, highly reactive redox compounds whose activity in vitro tends to oxidize spontaneously under oxygen into compounds capable of oxidizing hemoglobin to methemoglobin and GSH to GSSG... It appears likely that these compounds are actual or potential intermediates between oxygen and hemoglobin and in the presence of oxygen these compounds and hemoglobin each catalyze the destruction of the other."

Brewer, et al., [35] believe that methemoglobin formation is an essential prerequisite for the irreversible denaturation of hemoglobin which precedes erythrocyte destruction by oxidant drugs of the primaquine type. Jandl, Engle, and Allen [25] (and Harley and Mauer [36]) have come to similar conclusions on the basis of in vitro studies; they have found that "oxidation of hemoglobin to methemoglobin preceded the irreversible degradation of hemoglobin and formation of Heinz bodies."

However, Beutler's [37] work did not support nor disprove conclusively that methemoglobin is the important intermediate compound in the oxidative degradation of hemoglobin. He believes, as does Heubner [38] that methemoglobin formation and oxidation degradation of hemoglobin are paralleled processes, and that methemoglobin formation is not an obligatory precursor of further hemoglobin degradation.

The greater vulnerability of primaquine-sensitive individuals to methemoglobinemia can be demonstrated during the ingestion of agents which oxidize hemoglobin, but do not produce hemolysis (i.e., sodium nitrite). However, this vulnerability is not seen during the ingestion of primaquine because it hemolyzes the older cells which are more susceptible to methemoglobin formation. Brewer [35] states that "The absence of detectable methemoglobinemia with marked hemolysis in primaquine-sensitized individuals may be explained by the speed of the destructive process with the cells containing methemoglobin

and Heinz bodies being removed from the circulation too rapidly for clinical detection."

The possibility of the presence of methemoglobin at the end of the run in the blood of the 7.4 psi subjects as a possible explanation of the discrepancy noted between the $pO_2$ and the oxygen content of the blood as described under pulmonary data would support the speculation that the high $O_2$ concentration might act as an oxidant similar to primaquine-sensitive hemolysis. However, since the older cells were presumably hemolyzed and the offending factor (high $O_2$ concentration) had been removed, the hematological abnormalities should have returned to normal.

Chemical oxidants with resonating benzene rings are capable of producing hemolysis on all red cells in vitro as well as in vivo. There is marked increase in erythrocyte osmotic fragility with many bizarre distorted red cells. These red cells are likely to have some abnormal degree of methemoglobin formed intracellularly. If all or most of the circulating red cells and the new cells formed during the altitude runs were affected, abnormal findings could be expected for up to 120 days after the exposure. It is possible that in the 7.4 psi run subjects, the increased $O_2$ affected all cells to some extent while hemolyzing the older cells, and that this occurred to a much lesser extent in the cells of the subjects in the 5.0 psi and 3.8 psi runs. The presence of the expected normal sea level blood $pO_2$ during the 3.8 psi run and the absence of confirmatory hematological abnormalities in similar studies at 5.0 and 3.5 psi pressures (but with higher contamination of nitrogen) suggest the possibility that normal and elevated blood $O_2$ adversely affected the hematological system only in the absence of nitrogen ( $<1.0$ mm Hg).

The persistence of the abnormal hematological findings many weeks post-run may be due to the development of an immunological response or to the continued presence of a toxic factor. Two of the subjects in the 5.0 psi run showed signs suggestive of cryoglobulins. Coombs' tests done post-run on the 5.0 psi group were negative. Coombs' tests have not been done on the other subjects. The abrupt early onset of anemia in the 7.4 psi run subjects does not suggest an immunologic process. Nevertheless, the possibility that immunological factors are a cause of the continuing abnormalities cannot be eliminated.

The presence of a toxic contaminant in the chamber as the etiology for the observed abnormalities cannot be entirely eliminated. However, the chamber atmosphere was controlled by flushing instead of by recirculation of a regenerated gas mixture, so that contaminants were continually being flushed out of the chamber. The different changes observed between the subjects in the 7.4 psi and the 5.0 psi and 3.8 psi runs do not suggest a single toxic factor as their etiology. Moreover, the hematological changes are not typical for any known toxicants.[28] The immediate and delayed effect on man's hematological system from long term exposure to reduced barometric pressures without concurrent hypoxia are unknown. However, more marked hematological abnormalities occurred at the highest barometric pressure (7.4 psi). Nevertheless, reduced barometric pressure may have been a contributory factor of unknown importance in the altitude runs.

7. Conclusion

It is known that oxidants (chemical) are capable of producing hemolysis in all red cells. Primaquine-like drugs induce a self-limiting hemolysis in susceptible individuals by destroying the older red cells which are deficient in glucose-6-phosphate dehydrogenase. Under these conditions methemoglobin may be produced extracellularly during the process of oxidative hemolysis. The suspected presence of methemoglobin at the end of the 7.4 psi run would support the speculation that the high $O_2$ concentration might act as an oxidant similar to drugs of the primaquine type. Since oxidative hemolysis is a self-limiting disorder, once the older, more sensitive cells have been destroyed, the continuation of hematological changes post-run cannot be explained by this mechanism alone. Hence, it is possible that the increased oxygen concentration affected all the red cells of the subjects in the 7.4 psi run, hemolyzing the older cells. Similarly, but to a lesser extent the lower oxygen concentrations affected the red cells of the subjects in the 5.0 psi and 3.8 psi runs. If all the circulating red cells were affected during the altitude runs, abnormal findings can be expected for up to 120 days post-run. The presence of normal sea level tissue oxygenation in the 3.8 psi run and the absence of confirmatory hematological abnormalities in similar studies (other laboratories) at 5.0 psi and 3.5 psi (but with slightly higher contamination of nitrogen) suggest that normal and elevated tissue oxygenation may adversely affect the hematological

system only in the absence of nitrogen ( $<1.0$ mm Hg).

The persistence of the hematological abnormalities suggest the development of an immunological response or the presence of a toxicant. However, there was little evidence to support these considerations. Reduced barometric pressure may also have been a contributory factor of unknown importance in the etiology of the observed hematological abnormalities.

## D. BIOCHEMICAL DATA

Electrolyte determinations of sodium, potassium, and chloride were made from venous drawn blood before, six times during, and after the experimental runs. There were slight daily variations but no significant changes occurred.

### 1. Determination

Average pre- and post-run values are listed below:

| Determination | | | Pre-Run | Post-Run |
|---|---|---|---|---|
| Sea Level | Na+ | (MEQ) | 146 | 141 |
| | K+ | (MEQ) | 4.55 | 4.10 |
| | Cl- | (mg %) | 470 | 454 |
| 5.0 psi | Na+ | | 142 | 141 |
| | K+ | | 4.37 | 4.32 |
| | Cl- | | 466 | 448 |
| 7.4 psi | Na+ | | 143 | 143 |
| | K+ | | 4.45 | 4.34 |
| | Cl- | | 456 | 453 |
| 3.8 psi | Na+ | | 148 | 146 |
| | K+ | | 4.54 | 4.35 |
| | Cl- | | 451 | 450 |

Blood glucose and blood urea nitrogen were determined before, during, and after the experimental runs. All the blood glucose determinations were within the normal range (88 to 111 mg %). There were no gross changes in renal functions as indicated by normal blood urea nitrogen values.

Average blood urea nitrogen values (mg %) are listed below:

| Determination | Pre-Run | Post-Run |
|---|---|---|
| Sea Level | 12.0 | 12.9 |
| 5.0 psi | 16.8 | 14.8 |
| 7.4 psi | 16.9 | 15.1 |
| 3.8 psi | 15.6 | 14.6 |

Urinary 17-hydroxycorticosteroid determinations (normal, 3 to 10 mg/24 hr) were done on 24-hour urine samples, before, in the middle, and on the last day of the experimental runs. Average mean values (mg/24 hr) are listed below:

| Determination | Pre-Run | 8th day | 14th day |
|---|---|---|---|
| Sea Level | 15.4 | 16.6 | 16.2 |
| 5.0 psi | 11.7 | 10.2 | 14.7 |
| 7.4 psi | 7.2 | 7.8 | 8.8 |
| 3.8 psi | 9.7 | 11.0 | 7.7 |

The abnormally high values obtained with the sea level control group probably indicate the anxiety and apprehension of this group throughout the experimental run. The 5.0 psi group showed a rise of 3.0 mg/24 hr over the pre-run value. The 7.4 psi and 3.8 psi group showed essentially normal values throughout the experimental runs.

2. Summary

The following conclusions may be drawn from the above data.

1) There were no significant changes in the sodium, potassium, and chloride blood electrolyte levels.

2) Blood glucose and blood urea nitrogen values were within the normal range.

3) Abnormal urinary 17-hydroxycorticosteroid levels obtained with the sea level control group may reflect the psychologic stress of being the first experimental group. The altitude groups did not demonstrate evidence of stress except at the conclusion of the 5.0 psi run (2nd experimental group).

## E. RENAL DATA

Complete urinalysis including microscopic examinations were done before, and three times weekly during the experimental runs. Follow-up examinations were made on available subjects on September 24 and October 10, 1962, These dates represent the following times in post-run weeks for each group:

| Group | Sept. 24 | Oct. 10 |
|---|---|---|
| Sea Level | 15 | 17 |
| 5.0 psi | 9 | 11 |
| 7.4 psi | 6 | 8 |
| 3.8 psi | 3 | 5 |

### 1. Results

The urinary findings are summarized in Table 3-10.

The occasional trace of protein and rare casts in the sediment during the experimental runs were not considered significant until all of the subjects in the last group (3.8 psi) developed casts and protein in their urine toward the end of the run. Thereafter, on two occasions, follow-up urines were obtained on as many subjects as possible. These urinalyses indicated a persistence of the urinary abnormalities in all altitude groups; for the 5 psi group this has persisted for more than 2-1/2 months.

If a few hyaline casts and trace amounts of protein are considered normal in view of the conscientious examinations of these urines, then it would appear that the urines tended to return to normal in approximately 3 months subsequent to experimental exposure to high-oxygen low-nitrogen environments. However, it should be noted that Subject 32 entered the experiment with a few hyaline casts on July 9, 1962, and on October 10, 1962 still had a few fine grain and rare coarse granular casts in addition to many hyaline casts present in his urine.

In the 7.4 psi run, Subject 42, eight weeks post-run, showed many tubular casts and Subject 44 showed waxy and granular casts. Neither of these subjects showed more than a plus protein during the experimental run. The few follow-up samples of the 3.8 psi group taken earlier were all abnormal.

TABLE III-10

URINARY FINDINGS

| Sea Level Run | | | | | | |
|---|---|---|---|---|---|---|
| Day | Subjects | | | | | |
| | 11 | 12 | 13 | 15 | 16 | 17 |
| Pre-run | Neg | Neg | Trace protein | Neg | Neg | Neg |
| 2 | Neg | Neg | Neg | Neg | Neg | Neg |
| 4 | Neg | Neg | Trace protein | Neg | Neg | Trace protein, rare hyl cast |
| 7 | Trace protein | Neg | Neg | Neg | Trace protein | Neg |
| 9 | Neg | Neg | Neg | Neg | Neg | Neg |
| 11 | Neg | Neg | Neg | Neg | Neg | No sample |
| 14 | Neg | Neg | Neg | Neg | Neg | Neg |
| Follow-Up | | | | | | |
| 15 wks Post-run | Trace protein | No sample | No sample | No sample | Neg | No sample |
| 17 wks Post-run | No sample | No sample | No sample | No sample | Few hyl cast | few hyl cast |

TABLE III-10 (Cont)

| Day | 31 | 32 | 33 | 35 | 36 | 37 |
|---|---|---|---|---|---|---|
| | 5 psi Run | | | | | |
| | Subjects | | | | | |
| Pre-run | + protein | + protein, few hyl cast | Neg | Neg | Neg | + protein, few hyl cast |
| 2 | Trace protein few hyl cast | Neg | Neg | Neg | Neg | Neg |
| 6 | Trace protein | Neg | Neg | Neg | Neg | Trace protein |
| 8 | Trace protein few hyl cast | Neg | Neg | Neg | Neg | Neg |
| 10 | + protein | Slight protein | No sample | + protein, few hyl cast | Neg | Trace protein few f.g. cast |
| 14 | + protein | Trace protein plus few hyl cast and rare f.g. cast | + protein, few hyl cast | No sample | Trace protein, few hyl cast | Trace protein, few hyl cast |
| | Follow-Up | | | | | |
| 9 wks Post-run | + protein, few c g. cast | Trace protein, rare hyl cast | Neg | Trace protein | Neg | Neg |
| 11 wks Post-run | Neg | few f.g. cast, rare c.g. cast, many hyl cast | Trace protein few hyl cast | Neg | Neg | Few hyl cast |

TABLE III-10 (Cont)

| Day | 7.4 psi Run | | | | | |
|---|---|---|---|---|---|---|
| | Subjects | | | | | |
| | 42 | 43 | 44 | 45 | 46 | 47 |
| Pre-run | Neg | Neg | Neg | Neg | Neg | Neg |
| 4 | Neg | Few hyl cast, rare f.g. cast, trace protein | Trace protein | Neg | Trace protein | Neg |
| 9 | Neg | Few f.g. cast, trace protein | + protein | Neg | Neg | Neg |
| 14 | +protein | + protein | Neg | Neg | Neg | Neg |
| | Follow-Up | | | | | |
| 6 wks Post- run | Few c.g. cast, + protein | Trace protein | Trace protein | Many hyl cast, rare f.g. cast, + protein | Trace protein rare f.g. cast | No sample |
| 8 wks Post-run | Many tubular cast | Neg | Waxy cast, granular cast | Neg | Neg | No sample |

TABLE III-10 (Cont)

| 3.8 psi Run | | | | | |
|---|---|---|---|---|---|
| Day | Subjects | | | | |
| | 51 | 52 | 53 | 54 | 56 |
| Pre-run | Neg | Neg | Neg | Neg | Neg |
| 3 | Neg | Many hyl cast, rare f.g. cast | Neg | Neg | Neg |
| 8 | Rare hyl cast, rare f.g. cast | Many f.g. cast, hyl cast | Rare f.g. cast | Neg | Many hyl cast, rare f.g. cast |
| 11 | Rare f.g. cast | Rare hyl cast | Few hyl cast | Many hyl cast | Many hyl cast |
| 14 | Trace protein, few f.g. cast | Trace protein, few hyl cast | Trace protein, many hyl cast, moderate f.g. cast | + protein, many f.g. cast, rare c.g. cast | Neg |
| **Follow-Up** | | | | | |
| 1-1/2 wks Post-run | No sample | Rare hyl cast, rare f.g. cast | No sample | No sample | No sample |
| 3 wks Post-run | No sample | No sample | No sample | Many hyl cast, rare f.g. cast, + protein | Trace protein, many hyl cast, rare f.g. cast |
| 5 wks Post-run | No sample | Many hyl cast | No sample | Many hyl cast, few epith cast | No sample |

There were no other abnormal signs or symptoms of renal damage during the experimental runs. Urinary output was good and blood urea nitrogen levels remained normal. There was no consistent evidence of renal infection.

The etiology of the renal changes and their significance is unknown. The persistence of the urinary findings several months post-run is disturbing, although the degree of change is not alarming. Since some mercury vapor may have been present in the chamber from broken thermometers and possible spillage during capping of the arterial blood samples, the possibility of mercury intoxication cannot be overlooked. However, the subjects did not exhibit any of other signs of chronic mercury poisoning. In addition, mercury determinations on urines obtained from Subjects 11, 16, 17, 31, 32, 33, 35, 36, 37, 42, 43, 44, 45, 46, 52, and 54 on October 10, were negative qualitatively for mercury. Mercury urinary concentrations in persons with chronic mercury poisoning generally run a mercury urinary concentration in excess of .25 milligrams per liter. Since the urinary concentration of mercury is present for months after exposure, with the average urinary concentration decreasing logarithmically with time, it is considered unlikely that the experimental subjects inhaled any significant quantities of mercury vapor. Lack of confirmation of these findings with similar studies in which the $pN_2$ was slightly higher, coupled with the lack of relationship between the urinary abnormalities and increasing $pO_2$ in this study, suggest that the absence of an inert gas (i.e., $pN_2 < 1.0$ mm Hg) during prolonged human exposure may affect renal function. It is recognized that unknown renal toxicants could account for these signs.

2. Summary

The following conclusions may be drawn from the renal data:

1) An occasional trace of protein and casts in the sediment occurred in many of the subjects during the altitude runs especially towards the end of the 3.8 psi run.
2) There has been a persistence of similar urinary abnormalities in some subjects from all the altitude groups for as long as 2-1/2 months (5 psi group).
3) The etiology of the renal changes and their significance is unknown.

## F. MICROBIOLOGICAL DATA

Prior to, and several times during all four chamber runs, microbiological studies were made on cultures taken from throat, skin swabs, specimens of urine, and specimens of feces from all the subjects. The specimens were examined to determine whether certain pathogenic bacteria were present, and whether changes in flora occurred during any of these runs.

### 1. Throat

Throat cultures were made to detect any epidemic or spread of highly infectious bacteria in the throats of the subjects during the test and to detect gross changes in throat flora during the test.

#### a. Results

The appearance of the throat cultures on all groups showed marked overall similarities, with some notable exceptions. $\alpha$-hemolytic streptococcus, other streptococci and/or a non-hemolytic staphylococci predominated in the cultures of most of the subjects throughout the test period. Gas-forming small rods were isolated commonly on the 3.8 psi run, but tended to disappear after ten days in the chamber. These organisms were isolated to a lesser extent on the 7.4 psi test and also tended to disappear after 10 days in the chamber.

The density of growth on the blood agar plates was quite uniform on three runs, but decreased markedly or disappeared on four of the subjects on the 3.8 psi run after the first week in the chamber. However, cultures taken 1 to 2 hours after release of the subjects from the chamber showed a heavy growth of $\alpha$-hemolytic strep on all five subjects. This may have been due to improper technique in swabbing too far forward in the throat, particularly since the swab from the one subject who had continued to show bacterial growth was taken by a different person. However, since the swabs, in all instances, came in contact with oral surfaces, the observation is interesting, as at least some bacterial growth should have occurred from such a sample.

All $\beta$-hemolytic colonies seen on the blood plates were examined microscopically. During the sea level run, the alternate subject was rejected because of the appearance of many $\beta$-hemolytic staph colonies. However, one subject (11) with one similar staph was accepted as a subject. The $\beta$-hemolytic

staph also occurred sporadically in three additional subjects. At the start of the second week, five of the subjects showed this infection. On the last day in the chamber, only Subject 11 still carried the $\beta$-hemolytic staph.

On the 5 psi run, one subject (36), with an ear infection from which a $\beta$-hemolytic rod of distinctive morphology had been isolated, was included in the group. After four days all the subjects had become carriers of a similar organism, but it persisted only in Subject 36 and it was virtually eliminated from the other subjects within 3 to 5 days. Only three other $\beta$-hemolytic colonies, two staph and one strep, appeared sporadically on the entire run.

On the 7.4 psi run, only eight $\beta$-hemolytic episodes occurred, of which four involving one subject (43) were caused by staph. The distinctive rod accounted for two others, occurring on the fourth day in the chamber.

On the 3.8 psi test, the distinctive $\beta$-hemolytic rod occurred on two subjects on the fourth day in the chamber and represented the only $\beta$-hemolytic isolations during the entire run.

b. Conclusions

The experimental conditions per se did not appear to influence the bacterial flora of the throat of the subjects, with the possible exceptions of the results obtained on the second week of the 3.8 psi run, when marked reduction of cultural growth from four subjects was noted on the blood agar plates, and the tendency for a gas-forming rod to disappear after 10 days on the 3.8 and 7.4 psi runs.

The progress of $\beta$-hemolytic infections among the subjects was noted in two runs - the sea level and 5.0 psi tests. It is interesting to note that these sub-clinical infections spread rapidly but were self-limiting.

2. Skin

Skin cultures were made to detect any epidemic or spread of highly infectious bacteria on the skin of the subjects during the test and to detect gross changes in skin flora during the test.

a. Results

The predominating flora of the skin of all the subjects on all runs

was quite similar overall, consisting mainly of staph, with some strep and occasional rods. The staph was of two morphological types, one being average size and the other being very large. It seemed that the large staph was more common during the later part of each run, but aside from that, no marked changes in morphological types seemed to occur. In general, few bacteria were seen on the plates.

One interesting trend in cultural growth was noted in the broth cultures incubated aerobically, compared to those incubated under partially anaerobic conditions in 10% $CO_2$. During the last week of the runs, more cultures grew better under aerobic conditions, although this was less marked on the sea level run. This may indicate an adaptation of the original flora to the high oxygen atmosphere or a shift in flora.

On the sea level run, the $\beta$-hemolytic staph (which occurred in the throats of the subjects) appeared on their skin cultures, sporadically at first, but finally, in the last four days of the run, appeared on all subjects. This coincided with an increase in general skin contamination noticed on almost all subjects. This increase in skin contamination was noted in this group of subjects only, as succeeding groups were given a mildly antiseptic soap (Dial).

There were a few $\beta$-hemolytic rods isolated from the skin of Subject 36 (who carried the rod in his ear) in the 5.0 psi run and no $\beta$-hemolytic bacteria were seen on the other two runs.

b. Conclusions

The bacteria isolated from the skin of the subjects appeared to be normal skin flora. In the sea level test, the bacterial count on the plates was very low ( 0 to 2 colonies ) at the start, but increased markedly during the last four to six days in the chamber. At that time a $\beta$-hemolytic staph, which had occurred in the throats of the subjects, appeared in the skin cultures of all subjects. The next three groups were supplied a mildly antiseptic soap, and the plate counts were uniformly low on all subjects. No $\beta$-hemolytic colonies were seen on these tests, except sporadically on the skin of a subject with an ear infection.

A possible shift in the tolerance of the skin flora to oxygen may have occurred, as the number of cultures growing densely under aerobic con-

conditions was greater at the end of the 3.8, 5.0, and 7.4 psi experimental runs than during the first week of each of these three runs.

3. Urines

Urine samples were collected and cultured to detect the development of any urinary tract infections during the experimental runs.

a. Results

In general, the subjects on all runs showed various types of bacterial contamination of the urine. The microorganisms isolated were varied in a random fashion and resembled those found on the skin or in the throats of the subjects, suggesting external urine contamination rather than infection.

Two exceptions were noted, both on the 5.0 psi run. Subject 35 had a coli-like rod in his urine samples and Subject 37 showed diplococci throughout the entire sampling period, including the initial sample taken prior to entering the chamber.

In general, the urine samples showed bacterial growth in about 70% of the culture tubes but the cultures were of varied types of bacteria and did not suggest a chronic infection. However, there were two subjects on the 5.0 psi trial who showed a consistent flora during most of the sampling period that may suggest an infection. Subject 35 carried coliforms and Subject 37 had diplococci in the last four urine samples. In addition, Subject 37 had granular casts and some protein in his urine toward the end of the run.

It is interesting to note that bacterial cultures showed that less than 20% of the urine samples were negative on the 5.0 psi run, whereas during the sea level, 7.4 psi, and 3.8 psi runs, 31%, 38%, and 40%, respectively, of the urines were negative. Also, the urines on the 5.0 psi run showed traces of protein in 78.5% of the tests, whereas on the sea level, 7.4 psi, and 3.8 psi runs, 17.5%, 38%, and 20%, respectively, showed traces of protein.

b. Conclusion

It did not appear that the experimental condition influenced the urine bacterial flora. Two subjects may have had a mild urinary tract infection.

4. Feces

The microbiology of the feces was studied to determine the character of predominating bacteria in feces, since no adequate data on this subject has been published, to determine whether the experimental conditions changed the predominating fecal flora, and also to detect an intestinal bacterial infectious disease, if any occurred.

a. Results

The results relating to the character of the predominating fecal flora will be discussed on the basis of the anaerobic versus aerobic character of flora and the occurrence of certain morphological types of bacteria.

Only organisms present in at least one billion per gram of feces were considered, and most of the observations were made on cultures representing the 100 billionth or greater dilution of feces.

(1) Anaerobic versus Aerobic Character of Flora

The plate count was designed to find the approximate aerobic bacterial content of the feces, while the anaerobic cultural series shows approximately in what numbers anaerobes are present in the feces. The figures reported in Table III-11 are not intended to represent accurate counts of the numbers of each type of bacteria present, but only to show the order of magnitude in which aerobes and anaerobic bacteria are found. The anaerobes are reported as facultative anaerobes and strict anaerobes.

The data in Tables III-11 and III-12 show that about 83% of the total subcultures made from the top dilutions of feces are anaerobes, while 17% are aerobes. Most of the aerobes are coliforms (11.3% of total subcultures), of which more than half came from three subjects. Most of the anaerobes were strict anaerobes (74% of total subcultures) while 9% of total subcultures were facultative anaerobes. Since most of the subcultures were from the $10^{-11}$ or greater dilutions of feces, anaerobes are present in most

TABLE III-11

AEROBIC VERSUS ANAEROBIC CHARACTER
OF PREDOMINATING BACTERIA AND AEROBIC PLATE COUNTS

| | Consecutive Samples | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| **Sea Level** | | | | | |
| Total subcultures ($10^{-10}$ and $10^{-11}$) | | | | | |
| (8 subcultures from $10^{-9}$ included) | 8 | 15 | 13 | 18 | 15 |
| Strict anaerobes | 8 | 10 | 6 | 16 | 14 |
| Facultative anaerobes | 0 | 3 | 2 | 1 | 0 |
| (Subject 15 | 0 | 2 | 1 | 1 | 0) |
| Aerobes | 0 | 2 | 5 | 1 | 1 |
| Coliform | 0 | 1 | 2 | 1 | 0 |
| Aerobic plate counts | | | | | |
| 15 million and below | | 5 | 5 | 5 | 5 |
| 16 million - 99 million | | 1 | 1 | 1 | 1 |
| 100 million to 1 billion | | 0 | 0 | 0 | 0 |
| **5.0 psi** | | | | | |
| Total subcultures ($10^{-11}$ to $10^{-13}$) | 18 | 15 | 14 | 15 | 15 |
| Strict anaerobes | 12 | 13 | 9 | 13 | 12 |
| Facultative anaerobes | 1 | | | | 1 |
| Aerobes | 5 | 2 | 5 | 2 | 2 |
| Coliforms | 3 | 2 | 5 | 2 | 2 |
| (Subject 36 | 3 | 2 | 2 | 2 | 2) |
| Aerobic plate counts | | | | | |
| 15 million or below | 4 | 5 | 4 | 4 | 5 |
| 16 million to 99 million | 1 | 0 | 1 | 1 | 0 |
| 100 million to 1 billion | 1 | 1 | 1 | 1 | 1 |
| **7.4 psi** | | | | | |
| Total subcultures ($10^{-11}$ to $10^{-13}$) | 12 | 19 | 16 | 17 | 15 |
| Strict anaerobes | 9 | 14 | 15 | 7 | 11 |
| Facultative anaerobes | 2 | 3 | | | 1 |
| Aerobes | 1 | 2 | 1 | 10 | 3 |
| Coliforms | 1 | 2 | 1 | 10 | 3 |
| (Subject 42 | 1 | 2 | 1 | 1 | 2) |
| Aerobic plate counts | | | | | |
| 15 million or below | 2 | 2 | 3 | 3 | 4 |
| 16 million to 99 million | 2 | 1 | 2 | 1 | 1 |
| 100 million to 1 billion | 1 | 3 | 1 | 2 | 1 |
| **3.8 psi** | | | | | |
| Total subcultures ($10^{-11}$ to $10^{-13}$) | 15 | 15 | 15 | 15 | 15 |
| Strict anaerobes | 12 | 10 | 10 | 12 | 10 |
| Facultative anaerobes | 2 | 2 | 3 | 3 | 2 |
| Subject 52 | 2 | 1 | 2 | 1 | 2 |
| Aerobes | 1 | 3 | 2 | | 2 |
| Coliforms | 1 | 1 | | | |
| Aerobic plate counts | | | | | |
| 15 million or below | 4 | 0 | 2 | 4 | 1 |
| 16 million to 99 million | 0 | 1 | 1 | 1 | 2 |
| 100 million to 1 billion | 1 | 4 | 2 | 0 | 2 |

TABLE III-12

PERCENT OF TOTAL SUBCULTURES, AEROBIC VERSUS ANAEROBIC

| | Total All Runs | Sea Level | 5 psi | 7.4 psi | 3.8 psi |
|---|---|---|---|---|---|
| Total number of subcultures | 300 | 69 | 77 | 79 | 75 |
| % Strict anaerobes | 74 | 78 | 77 | 71 | 72 |
| % Facultative anaerobes | 9 | 9 | 3 | 8 | 16 |
| % Anaerobes (total) | 83 | 87 | 80 | 79 | 88 |
| % Aerobes | 17 | 13 | 20 | 21 | 12 |
| % Subcultures (total) | 100 | 100 | 100 | 100 | 100 |
| % Of total subcultures coliforms | 11 | 6 | 16 | 21 | 3 |

subjects in numbers of at least 100 billion or greater per gram. The plate counts indicate that aerobes generally did not exceed 100M (except for those three subjects who had coliforms or a facultative coccus as the predominating flora). Thus, the strict anaerobes outnumbered the aerobes at least 1000 times for most subjects, and can be considered to be the predominating flora in 20 out of 23 subjects.

There was no significant difference in the predominance of strict anaerobes on any of the chamber runs. In general, the strict anaerobes grew rapidly within 16 to 24 hours in the highest dilution of feces cultured, which was $10^{-13}$ in all but the sea level run, where $10^{-11}$ was the top dilution.

Facultative anaerobic cultures were isolated sporadically on all tests, and consisted mainly of a gram positive coccus in chains. On the sea level run, this type of bacterium was found four times on Subject 15, while no pattern was evident on the 5.0 psi or on the 7.4 psi run. It appeared that facultative anaerobes were found most frequently on the 3.8 psi run. However, the isolations were made only from three subjects (52, 53, and 56) and occurred in every test as the predominating organism on Subject 52 and in two tests on each of the other two subjects.

Aerobes also were found sporadically in top dilutions of the cultural series of which more than half were coliforms. Two subjects on different trials, one of whom (36) was on oral antibiotic medication during much of the test, carried coliforms as the predominating organism throughout the test and accounted for half of the coliform organisms isolated. On the 7.4 psi run, 10 cultures of coliforms were isolated on one day. These samples were collected on a weekend, and seemed warm on receipt. It is possible that these samples had been improperly cooled for a period of time long enough to permit the hardy coliform to multiply and overgrow the delicate anaerobes in these samples. Other aerobic bacteria resembling E. coli, but not giving a typical test on EMB agar, appeared sporadically on all runs, although more appeared on the 3.8 psi run than on any other test.

In the cultural series, no one experimental condition seemed to favor the appearance of aerobic fecal flora as the predominating organisms, but two subjects on different runs did characteristically carry coliforms as the predominating flora, one of whom had taken antibiotics.

The aerobic plate counts are a much better index of the numbers of aerobes present than the isolations from the cultural series, since the broth used in the series was poised to favor anaerobic growth. In general, few plate counts exceeded 100M, and in all but the 3.8 psi run, most of the counts of 100M or above were accounted for by the two subjects carrying coliforms as the predominating bacteria. In the 3.8 psi run, only one plate had more than 100 M at the outset but the second set of samples showed four out of five plates with counts above 100M, and plates from two subjects were still above 100M at the end of the experiment. One of these subjects consistently showed a facultative anaerobe as the predominating flora, but only part of the numerous instances of high aerobic plate counts can be attributed to this subject.

It might appear from the data that there was some real difference in the 3.8 psi run in the numbers of bacteria capable of growing on an agar plate. This was substantiated by the fact that three out of five subjects on this run had facultative anaerobes as the predominating flora in at least two fecal samples. Thus, the plate counts tended to be characteristic of the individual from the start to the finish of the experiment, on all runs except the 3.8 psi run. Here, three out of the five subjects showed a marked increase in the plate count, which was evident throughout the experimental run.

Conclusions on aerobic versus anaerobic character of predominating flora are as follows:

1) Anaerobes outnumbered aerobes consistently by 1000 times or more on almost all subjects in all trials. Exceptions were Subjects 36 and 42, who consistently showed coliforms, and Subject 52, who carried a facultative anaerobic mixed cultures of cocci and rods. The three subjects who did not have a predominating anaerobic flora started the experiment with the peculiar flora and carried it persistently throughout. The instances when coliforms spread to subjects other than 36 and 42 occurred on one sampling date each, and suggested a failure in preservation of the sample.

2) In general, differences in predominating fecal flora seemed to stem from variations in individuals rather than in experimental conditions, except that the higher incidence of non-coliform aerobes and facultative anaerobes in the 3.8 psi run may represent a real trend in the change of flora, as it occurred mainly during the latter part of the trial and involved four out of five subjects.

(2) Occurrence of Certain Morphological Types of Bacteria

The occurrence and distribution of the non-anaerobes is discussed in the previous section. The distribution of strict anaerobes will be discussed in a very preliminary fashion, as the existing classifications of fecal anaerobes are incomplete and inaccurate, and many of the bacteria isolated in this study apparently have not been previously isolated and studied.

Two broad morphological types, a gram positive slender rod in chains, and a pointed rod, make up much of the morphologically distinguishable flora, and their characteristics and distribution are discussed below. These two rods frequently occur together, suggesting a possible symbiosis (Figures 3- 53 through 3- 55).

The slender rod is non-motile, and gram variable, usually exhibiting a gram positive character when young, and becoming gram negative when older. The morphology of this group of bacteria was extremely variable, starting out as a thin rod in chains, later developing enlarged swellings and blobs. The cultures exhibited a marked zone of inhibition of growth in agar shakes, and the colonies in the shake were of moderate size, sometimes rather diffuse in appearance. In the broth, early growth often appeared as plaques attached to the side of the test tube, which later formed balls and then became a slimy sediment. In 0.1% glucose broth, the final pH was about 6.5, sugars

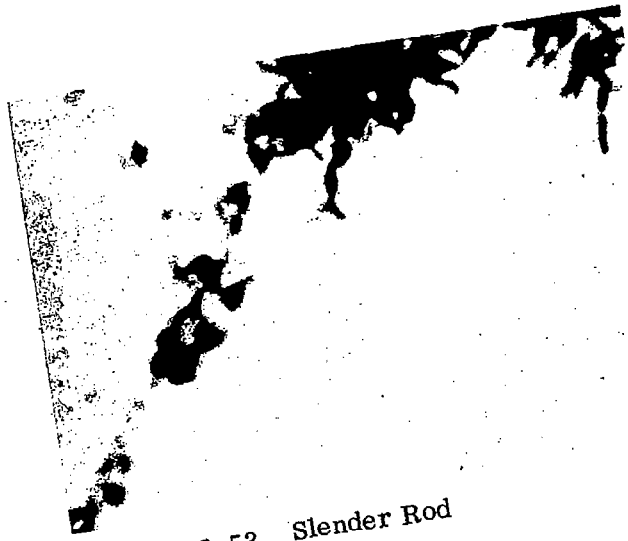


Figure 3-53 Slender Rod

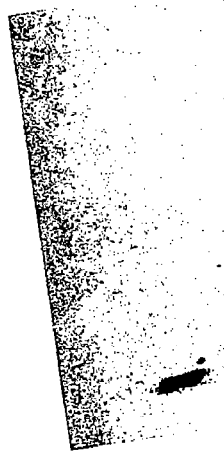


Figure 3-54 Pointed Rod

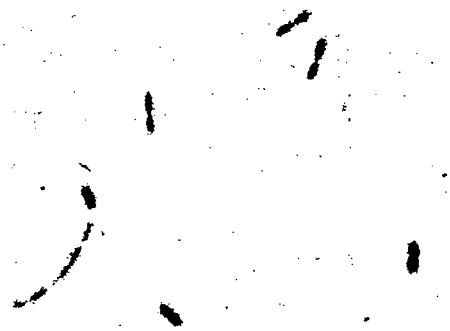


Figure 3-55 Mixed Culture of Slender Rod and Pointed Rod

incorporated in the broth at the 0.1% level were fermented, but gelatin was not attacked and litmus milk was reduced, but not curdled or acidified. This description is not incompatible with Bergey's Catenabacterium catenaforme in many respects. However, it is felt that this slender rod is not a single species, but a group of similar rods, and further studies will be needed on pure cultures to determine more accurately the characteristics of this group of bacteria.

The pointed rod group of bacteria is even less homogenous than the slender rod, but all rods in this group have pointed ends, which is a characteristic associated with a Fusobacterium. These bacteria are usually non-motile and are gram positive when young, but may become gram negative with age. Swellings sometimes occur in older cultures. This group of bacteria showed a wide zone of inhibition of growth at the top of the agar shake. Colonies were medium to small in size. Gas was produced in 0.1% carbohydrate media, and the same media without carbohydrate supported growth, but no gas was formed. A pH of 5.3 was produced in glucose broth and gelatin was not liquefied. An acid reduced curd was produced in litmus milk by some cultures, while others showed only reduction of the litmus. Further studies will be needed to separate these pointed rods into their proper categories.

Other strictly anaerobic cultures isolated as predominating bacteria showed various morphological types of bacteria. These included a long-chained pleomorphic coccus, a small rod in rafts and clusters, a gram negative bipolar staining rod, a very long slender rod occurring singly, a slender curved rod, and gram positive pleomorphic rods, resembling lactobacilli. These cultures have been preserved and will be studied further.

The slender rod and the pointed rod groups of bacteria were isolated frequently enough to show distribution. Tables III-13 and III-14 summarize these results by chamber run and sampling period.

The slender rod was a predominating organism in almost all subjects in all runs. In the sea level trial, five subjects carried this type of bacterium during the first week of sampling, while the sixth subject did not show this type of rod until the second week. In all other runs this type of rod appeared in all subjects at the start of the run and persisted throughout, with the exception of Subject 36.

TABLE III-13

OCCURRENCE OF SLENDER ROD*

| Consecutive Samples | Subject Number 11 | 12 | 13 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|
| **Sea Level** | | | | | | |
| 1st | | 4 | | 4 | | |
| 2nd | | 4 | 4 | | 4 | 3 |
| 3rd | | 4 | 4 | 2 | | 4 |
| 4th | 4 | 3 | 4 | 4 | 4 | 4 |
| 5th | 4 | 4 | 4 | 4 | 4 | 4 |
| **5.0 psi** | | | | | | |
| | Subject Number 31 | 32 | 33 | 35 | 36 | 37 |
| 1st | 3 | 2 | 2 | 2 | | 3 |
| 2nd | 2 | 3 | 4 | 2 | | 2 |
| 3rd | 2 | 4 | No sample | 4 | | 3 |
| 4th | 4 | 3 | 2 | 3 | | 4 |
| 5th | 2 | 2 | 3 | 2 | | 4 |
| **7.4 psi** | | | | | | |
| | Subject Number 42 | 43 | 44 | 45 | 46 | 47 |
| 1st | 2 | | 4 | 4 | 3 | No sample |
| 2nd | | 4 | 4 | | | 4 |
| 3rd | 4 | 4 | 4 | 4 | 4 | 4 |
| 4th | 3 | 4 | 4 | 4 | 4 | 4 |
| 5th | | 2 | 4 | 4 | 4 | 4 |
| **3.8 psi** | | | | | | |
| | Subject Number 51 | 52 | 53 | 54 | 55 | 56 |
| 1st | 2 | 3 | 4 | 4 | 4 | 3 |
| 2nd | 4 | 3 | 4 | 4 | No sample | 4 |
| 3rd | 3 | 4 | 4 | 4 | " | 4 |
| 4th | 3 | 3 | 4 | 4 | " | 4 |
| 5th | 4 | 2 | 4 | 4 | " | 4 |

*Numbers refer to predominance
4 = found in all top dilutions;
3 = found in most top dilutions;
2 = found in 100 billionth dilution, but not above.

TABLE III-14

OCCURRENCE OF POINTED ROD

| Sea Level | | | | | | |
|---|---|---|---|---|---|---|
| | Subject Number | | | | | |
| Sample | 11 | 12 | 13 | 15 | 16 | 17 |
| 1st | 4 | | | | | |
| 2nd | 3 | 3 | 3 | | | |
| 3rd | 3 | 3 | 4 | | | |
| 4th | 4 | 4 | 3 | | | 3 |
| 5th | 4 | 4 | 4 | 4 | 3 | 4 |
| 5.0 psi | | | | | | |
| | Subject Number | | | | | |
| | 31 | 32 | 33 | 35 | 36 | 37 |
| 1st | | 3 | | | | |
| 2nd | | | 2 | | | 2 |
| 3rd | | 2 | | 2 | | |
| 4th | | 3 | 3 | 3 | | 2 |
| 5th | 2 | 4 | 4 | 2 | | 2 |
| 7.4 psi | | | | | | |
| | Subject Number | | | | | |
| | 42 | 43 | 44 | 45 | 46 | 47 |
| 1st | | | | 2 | 4 | |
| 2nd | | 2 | | | 4 | 2 |
| 3rd | | | | 2 | 2 | 4 |
| 4th | | 4 | 4 | 4 | 4 | 4 |
| 5th | | 4 | 4 | | | 4 |
| 3.8 psi | | | | | | |
| | Subject Number | | | | | |
| | 51 | 52 | 53 | 54 | 55 | 56 |
| 1st | | 3 | | 4 | 3 | 3 |
| 2nd | | 3 | | 4 | No sample | 4 |
| 3rd | 3 | 2 | 2 | 4 | " | 3 |
| 4th | 4 | 4 | 4 | 4 | " | 4 |
| 5th | 3 | | 3 | 4 | " | 4 |

The pointed rod was found as a predominating organism in all subjects on all runs (with the exception of Subject 36), and was frequently found in the same culture with the slender rod. In the sea level run, three subjects started the run carrying this culture, while three other subjects did not show this type of rod in the fecal cultures until the last two samples. This was true of the other three runs as well. On the 5.0 psi run three men (with the exception of Subject 36), carried the rod at the start of the run, and two subjects picked it up later in the experiment. On the 7.4 psi run, four subjects started with the rod, and two acquired it later in the run. In the 3.8 psi run, three men started with the rod, and two subjects acquired it in the last week of the experiment.

From these findings, it would appear that the slender rod-type and the pointed rod-type were normal inhabitants of the human intestine, but that the slender rod-type was more prevalent. The pointed rod-type apparently becomes implanted rather universally under proper conditions of close contact.

The other strict anaerobes occurred sporadically on most of the subjects in all runs, and at this time in the inspection of the data, no statement can be made as to their pattern of distribution.

It may be concluded that on all runs, the fecal flora of the subjects tended to become more similar at the end of the run than in the beginning, with the exception of the three subjects who carried their own peculiar flora from start to finish. This may be due in part to the common diet eaten by all. No significant differences between runs was apparent in the distribution of the strict anaerobes on preliminary inspection.

(3) Bacterial Infectious Disease

No evidence of an infectious disease in the intestine was seen during any of the chamber runs.

b. General Conclusions

The general conclusions reached during this study are as follows:

1) The predominating fecal flora of 20 out of 23 subjects was composed of obligate anaerobes that are viable in numbers approximating a trillion or more per gram of feces.

2) The aerobes were cultured in approximately one to 500 million per gram of feces.

3) The predominating anaerobic flora consisted of bacteria of several morphological types, many of which appear to be different from any fecal flora described in the literature.

4) The fecal flora in many subjects seemed to be relatively stable, but in all runs, the flora of all subjects tended to become more similar at the end of the run than at the start, with the exception of the three subjects who carried their own peculiar flora from the start to the finish of the experiment.

5) No differences clearly attributable to experimental conditions were seen between groups, with the possible exception of the higher number of aerobic and facultative anaerobes isolated in the 3.8 psi run.

6) No evidence of bacterial infectious disease in the intestine was seen.

## G. PSYCHOLOGICAL PERFORMANCE DATA

### 1. Scope

The psychological studies reported herein concern the effects of oxygen atmospheres at pressures of 3.8, 5.0, and 7.4 psi, and a sea level atmosphere on human sensory, perceptual motor, and mental performance. This work, done in conjunction with comprehensive medical, clinical, microbiological, and physiological investigations, is especially valuable because the results obtained in each of the disciplines on the same subjects can be compared.

There are only a few psychological investigations which have been reported bearing on human behavior over long durations in artificial atmospheres. In one study by McKenzie, Hartman, and Welch[39] at the School of Aviation Medicine, Brooks AFB, a performance panel was used to present tasks requiring monitoring, vigilance, information processing, and encoding to two-man crews in 17-day and 30-day studies at 3.5 and 5.0 psi atmospheres. No significant performance changes due to the atmosphere were found. Similar findings were reported over a 7-day period for six U.S. Navy enlisted men living in a 10.1 psi atmosphere of which 8.0 psi was oxygen.[40]

In the present study, comprehensive data were collected on a large number of behavior factors, and the behavior was systematically studied in relation to the selected points on the oxygen atmosphere continuum.

### 2. Results

The psychological performance analysis will be reported under the rubrics of sensory performance, perceptual motor performance and mental performance, in the indicated order. For each particular performance within any rubric there will be a sequential presentation of figures showing tables of means and standard deviations, tables of analyses of variance, and, if pertinent, graphs.*

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*Tables referred to in this section are located in the Appendix.

a. Sensory Performance

(1) Critical Flicker Frequency

Tables 3.1.1 through 3.1.6 and Figures 3-56 through 3-58 present the analysis for the four experimental subject groups for all test days for the subjective points at which the stimulus changed respectively from discrete to coarse, coarse to fine, and fine to fusion for stimulus flash rates presented in cycles per second.

There were no significant differences between runs for any of the stimulus flash rates. Significant differences were found between days, except for the coarse to fine flash rate and for the Atmosphere by Day Interaction terms for all runs.

The graphs in Figures 3-56 through 3-58 make it clear that differences between days for the discrete flicker to coarse flicker and the fine flicker to fusion points are due to an improvement in average performance over the duration of the studies. The variability in performance in all runs, particularly evident in the coarse flicker to fine flicker point data, accounts for the significant interaction terms.

(2) Army Night Seeing Tester

Tables 3.1.7 through 3.1.10 show the means and standard deviations and analyses of variance for the Brightness Contrast Test (BCT) and the Line Resolution Test (LRT) for the experimental subject groups. Figures 3-59 and 3-60 present the test scores for the experimental runs

There was a significant difference in the BCT scores over the duration of the experiments. No other factors were significant in either the BCT or the LRT. It is worth noting that the standard deviations of the LRT in the 5.0 psi and 7.4 psi experimental runs across the testing days were often twice as large as the standard deviations for the runs at sea level and 3.8 psi. This may have made the LRT a less sensitive or less precise testing instrument than was required.

Examination of the graphs show that the 7.4 psi experimental group started at a lower performance level than the other group and remained in that relationship with respect to the others. The performance for the 7.4 psi group in relation to the other groups on the LRT was similar. The other groups, showing considerable variability, performed similarly, in general, in the BCT and the LRT.

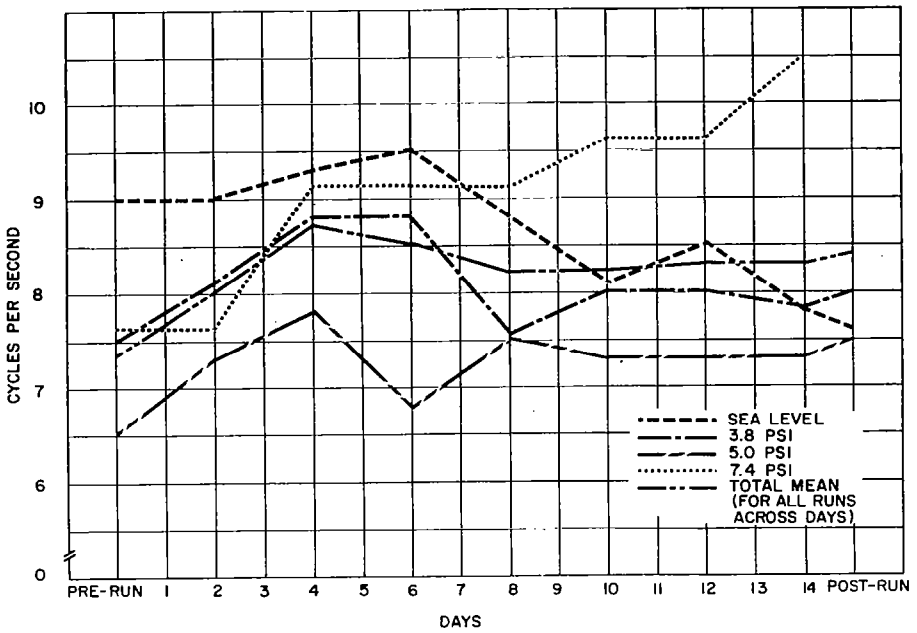


Figure 3-56 C.F.F. Discrete to Coarse

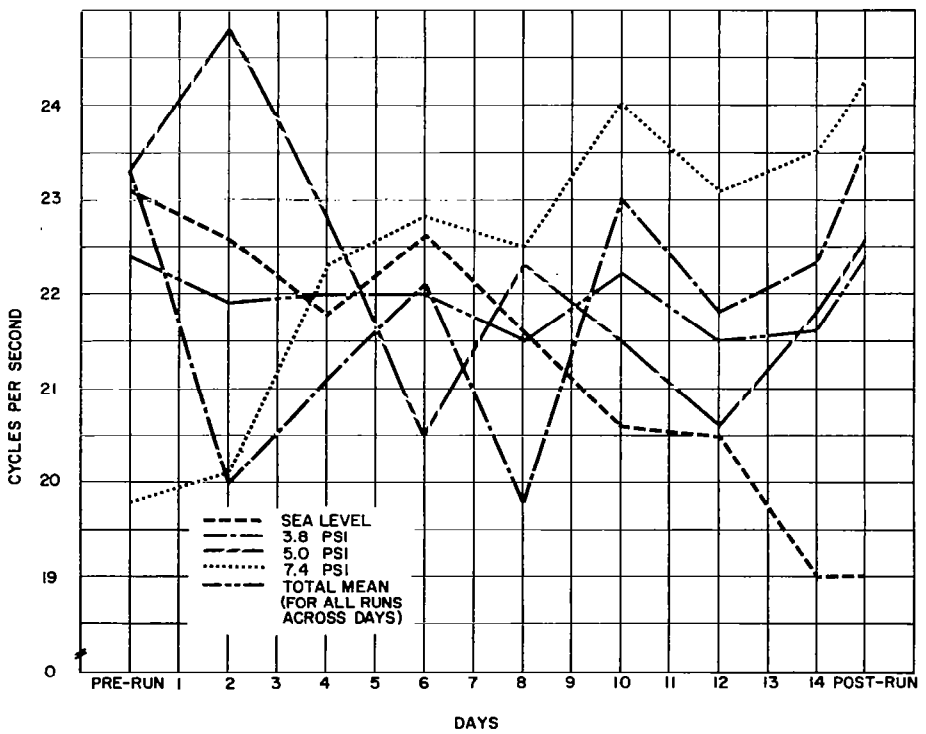


Figure 3-57 C.F.F. Coarse to Fine

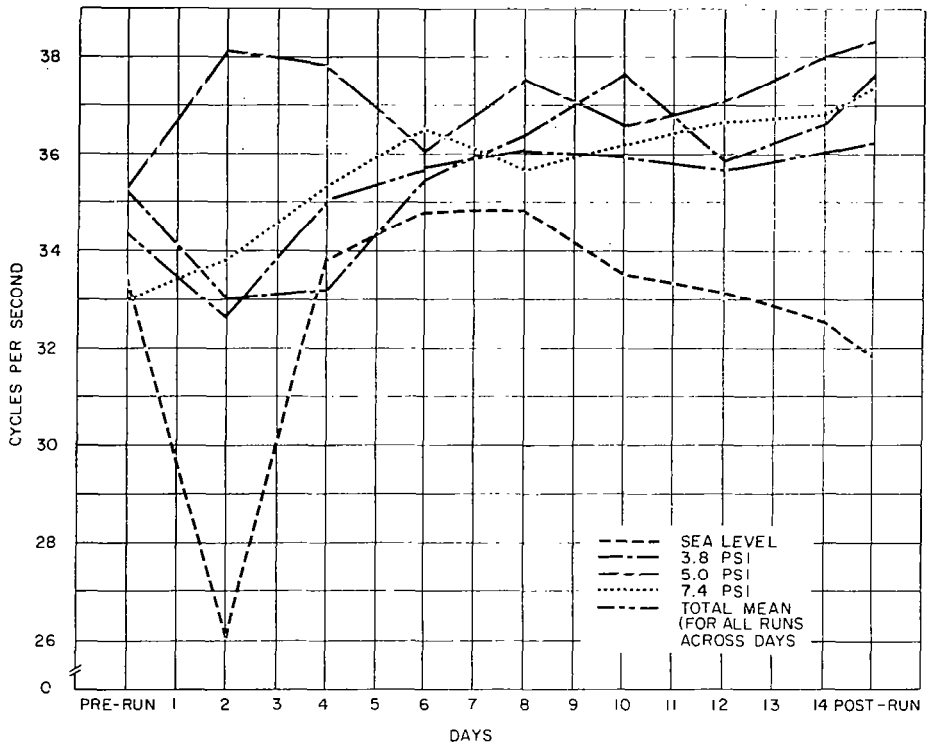


Figure 3-58 C.F.F. Fine to Fusion

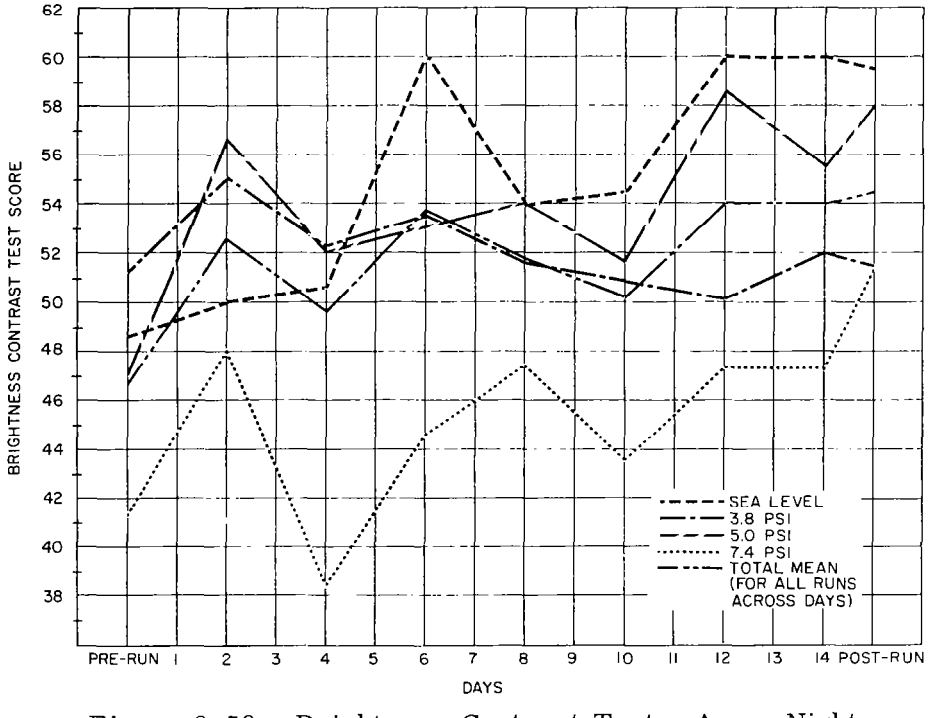


Figure 3-59 Brightness Contrast Test - Army Night Seeing Test

(3) Day Visual Performance Scores

Tables 3.1.11 through 3.1.23 and Figures 3-61 through 3-66 show the results of analysis of Esophoria, Exophoria, Binocular Acuity, Right Eye Acuity, Left Eye Acuity and Depth Perception, for the four experimental subject groups for all test days.

(a) Esophoria and Exophoria

There were no significant differences in Esophoria or Exophoria performance between the experimental groups. Also, there were no significant differences in performance over the duration of the runs for any of the groups, that is, there were no significant changes in a positive or negative direction over time.

(b) Visual Acuity

Significant differences in right eye and left eye visual acuity performance were recorded over the duration of the experiments for all groups. This reflected a slight improvement in performance, probably due to learning, over time. However, this improvement for each eye separately had little effect on binocular vision over the course of the runs. Significant Atmosphere by Day Interactions were found for the right eye and for binocular visual acuity, and these interactions must be ascribed to high variability in performance by the subjects during the experimental studies. This finding, however, is not an unusual occurrence in visual acuity performance.

(c) Depth Perception

There were no significant differences in depth perception performance of the subjects by experimental runs or duration. An F ratio of 3.09 (significant at about $P \geq 0.06$) for differences between experimental study groups is most likely ascribable to original group differences in depth perception performance.

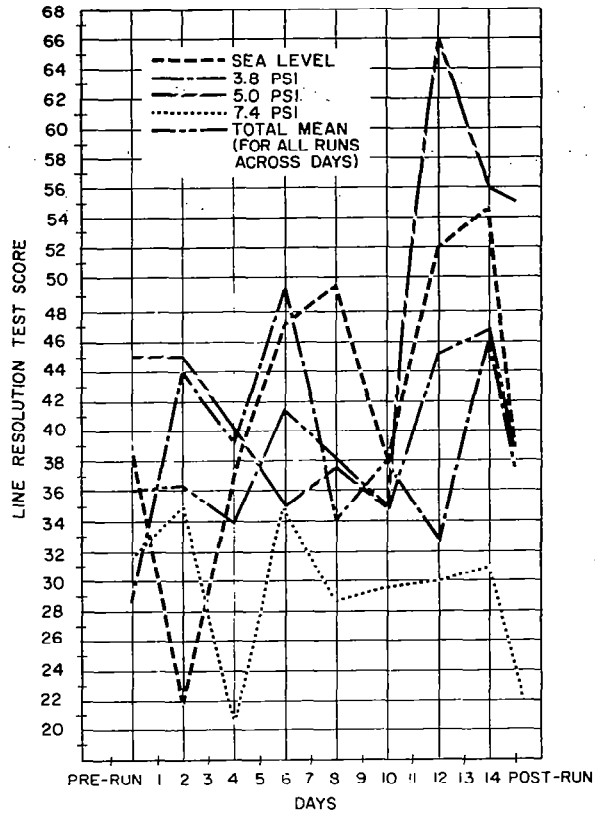


Figure 3-60 Line Resolution Test - Army Night Seeing Test

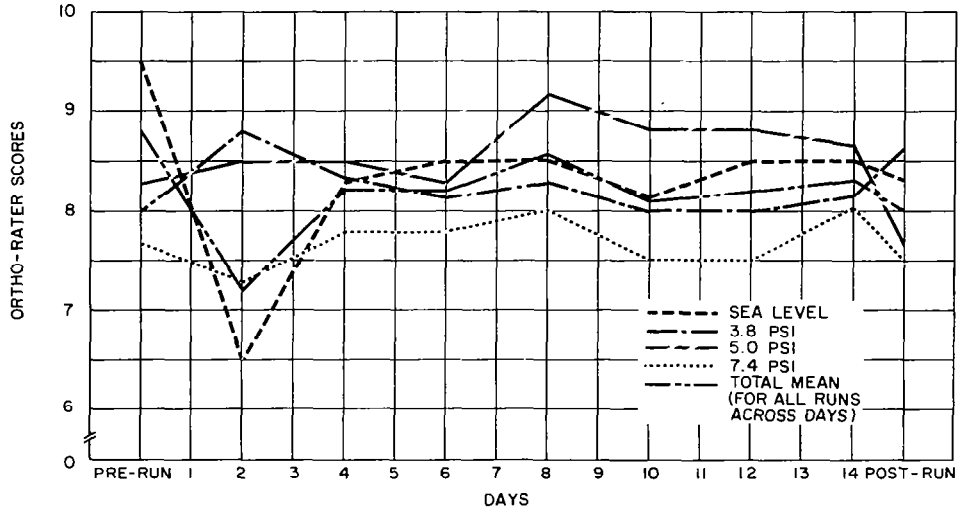


Figure 3-61 Esophoria

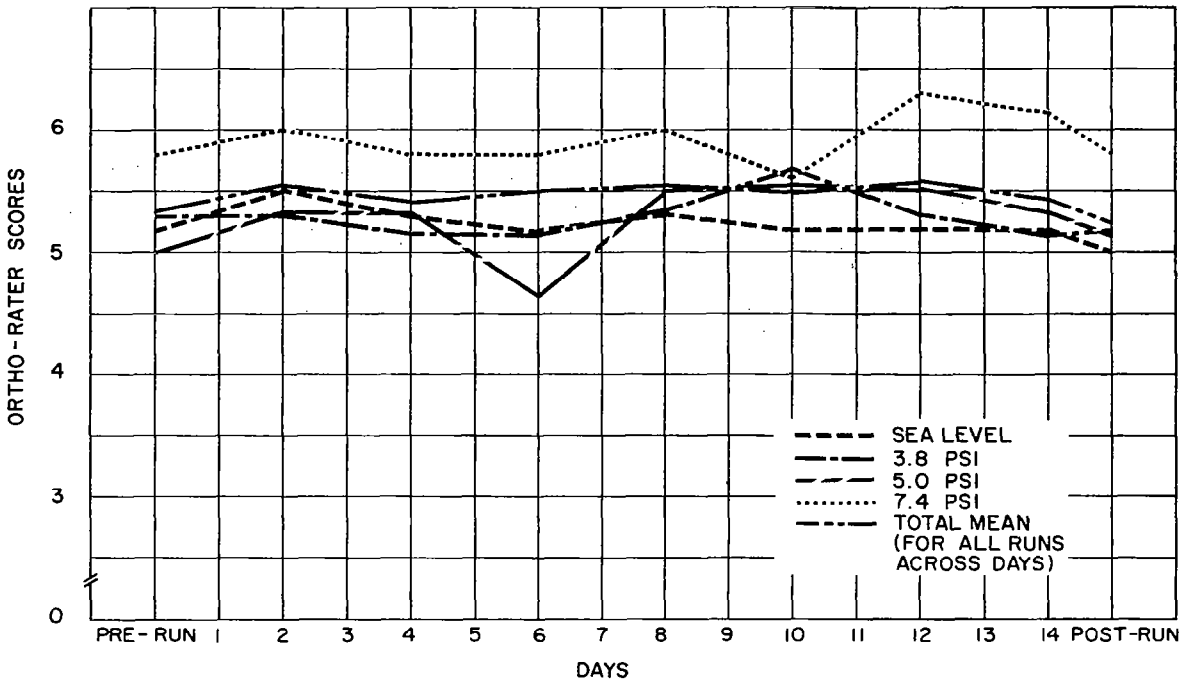


Figure 3-62 Exophoria

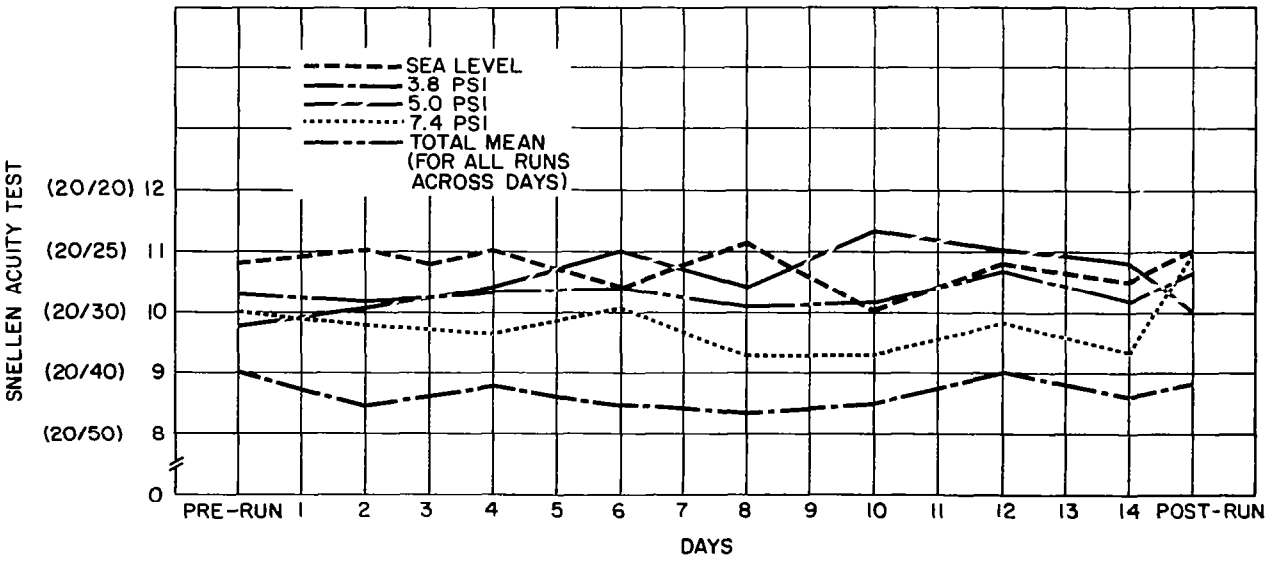


Figure 3-63 Binocular Vision

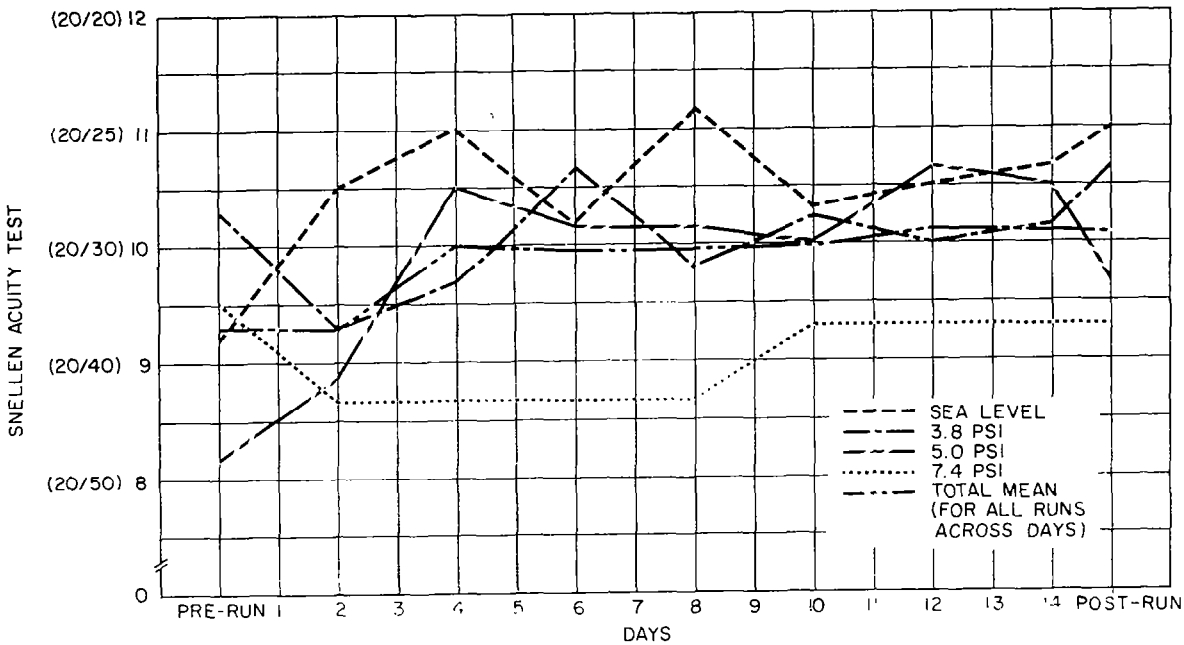


Figure 3-64 Right Eye Acuity

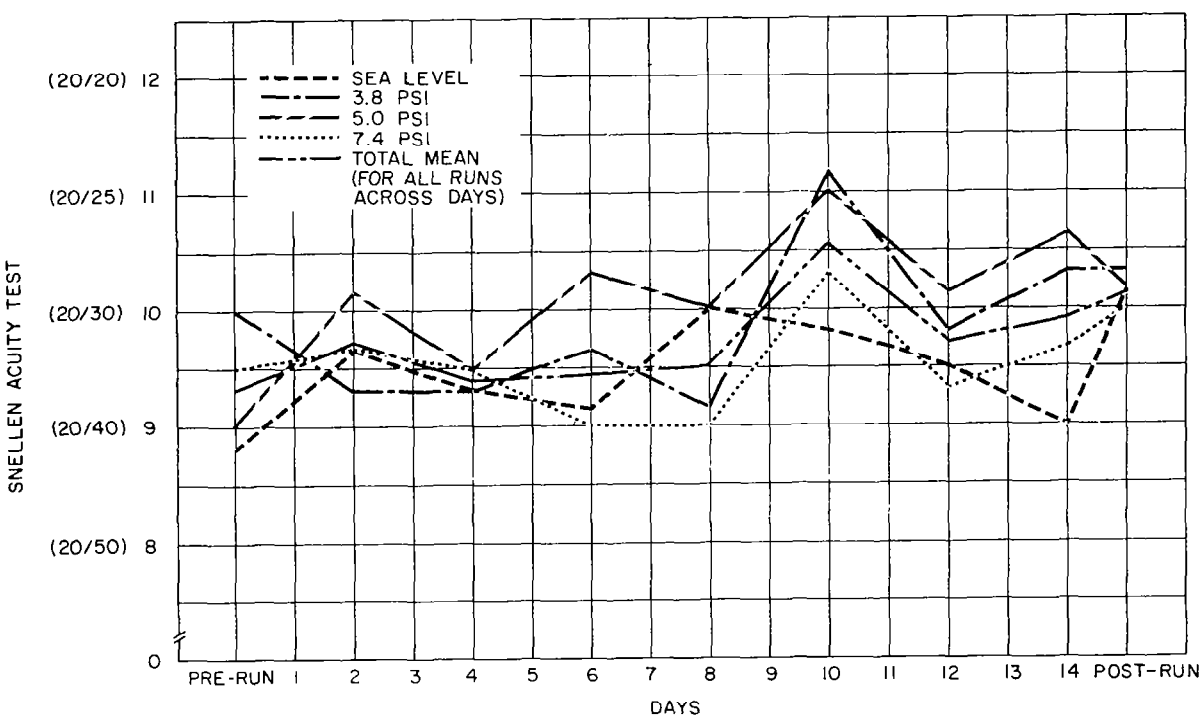


Figure 3-65 Left Eye Acuity

(d) Over-all Day Visual Performance

Examination of the graphs for all of the visual abilities which were examined clearly shows that the groups changed very little, in general, across the time of the experiments. Whatever degree of ability they had when they started, was at about the same level at the end of the runs, excepting right and left eye performance, which usually did not affect binocular seeing.

b. Perceptual Motor Performance

(1) Differential Reaction Time

Tables 3.2.1 and 3.2.2 together with Figure 3-67 present the daily means, standard deviations, analysis of variance and a graph of the means for differential reaction time performance.

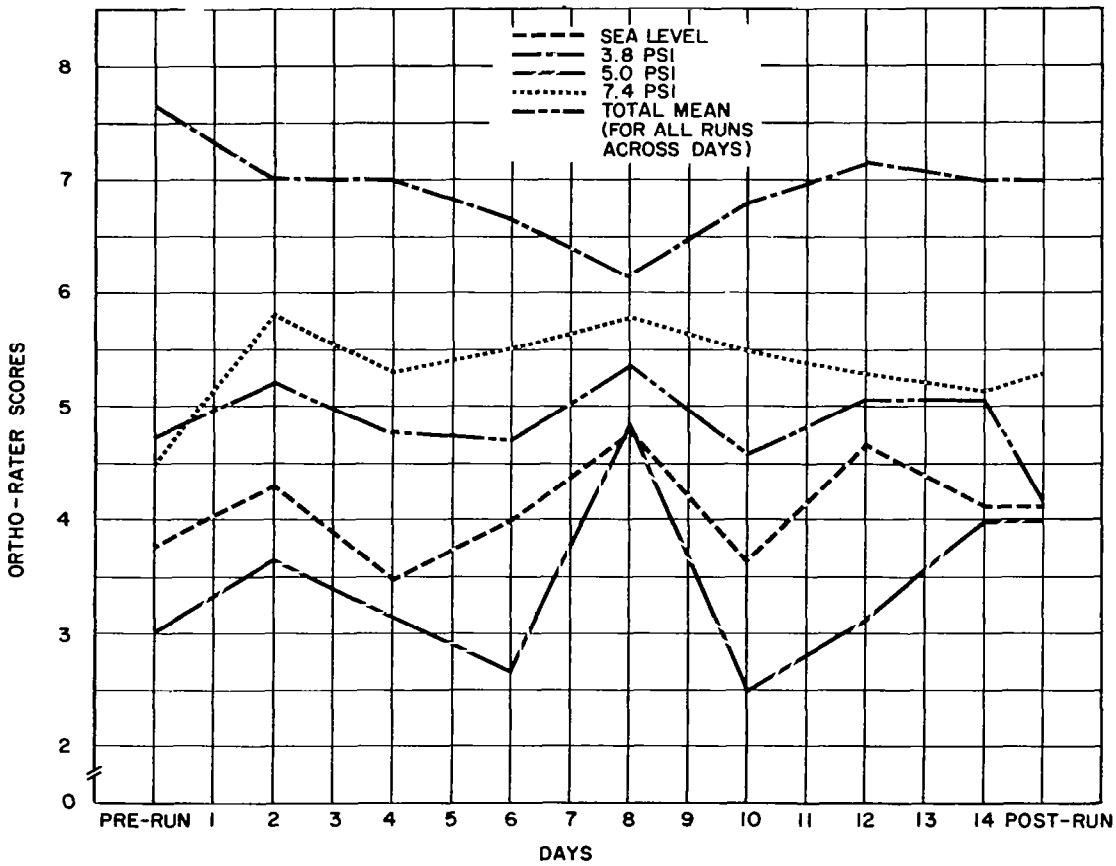


Figure 3-66 Depth Perception

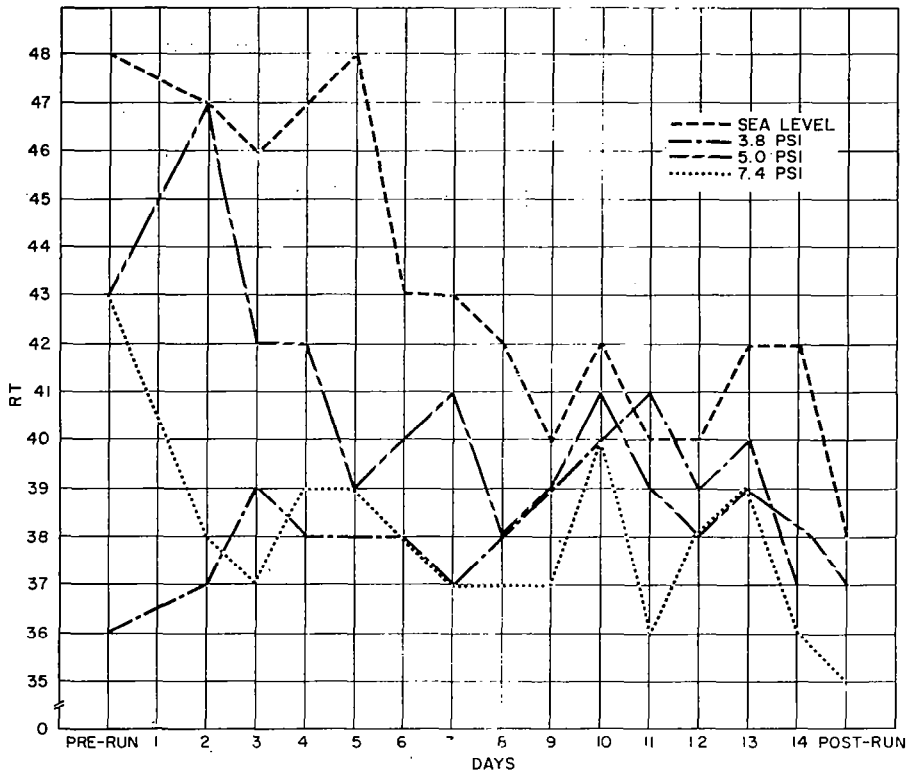


Figure 3-67 Reaction Time as a Function of Oxygen Concentration

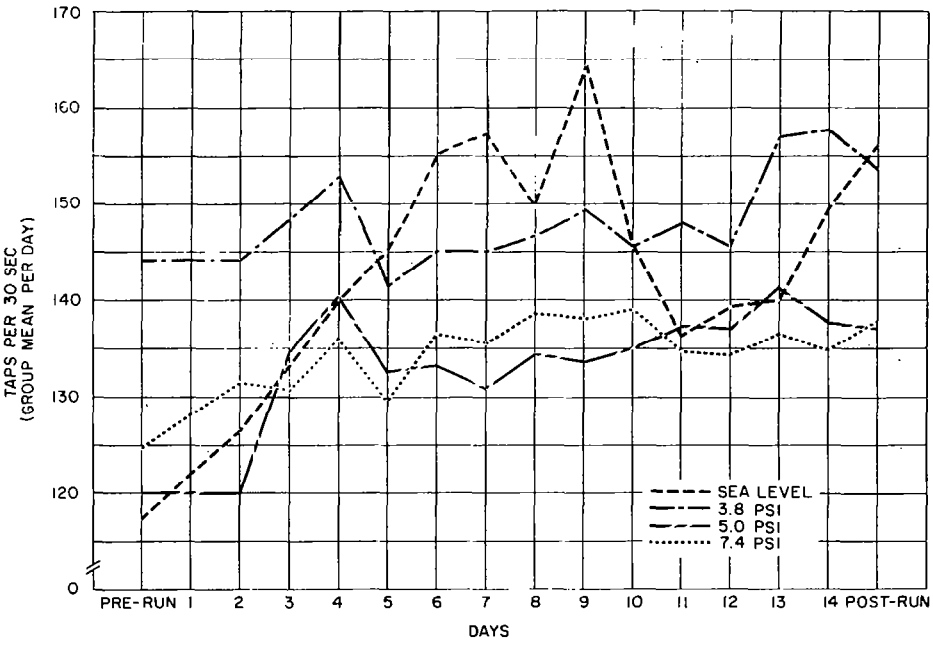


Figure 3-68 Daily Means of the Tapping Scores for the Four Experimental Groups

The tabled and graphed means and standard deviations show the trends of the data over the duration of the experimental runs. However, there were no significant differences between the experimental runs on reaction time performance. A significant day difference for the groups across time is evident and this effect, a decrease in reaction time over the duration of the experiment, is best explained as due to improvement with practice. The Atmosphere by Day Interaction is significant, probably reflecting high variability in performance across time.

(2) Tapping

Tables 3.2.3 and 3.2.4, together with Figure 3-68 present the daily means and standard deviations of the four experimental runs, an analysis of variance, and a graph of fine motor performance. The results clearly indicate that there is no significant difference between runs. However, there is a significant difference between days. This effect, an increase in tapping scores of all groups over time, can be attributed to practice. The variability in all runs, particularly evident in the sea level run, probably accounts for the significant Atmosphere by Day Interaction.

(3) Ballistic Aiming

Tables 3.2.5 and 3.2.6, together with Figure 3-69 present daily means and standard deviations for the four experimental runs, an analysis of variance, and a graph of gross motor performance. There is no significant runs difference. A significant days difference for all groups across time is evident. This increase in average performance for all groups over time is attributed to practice.

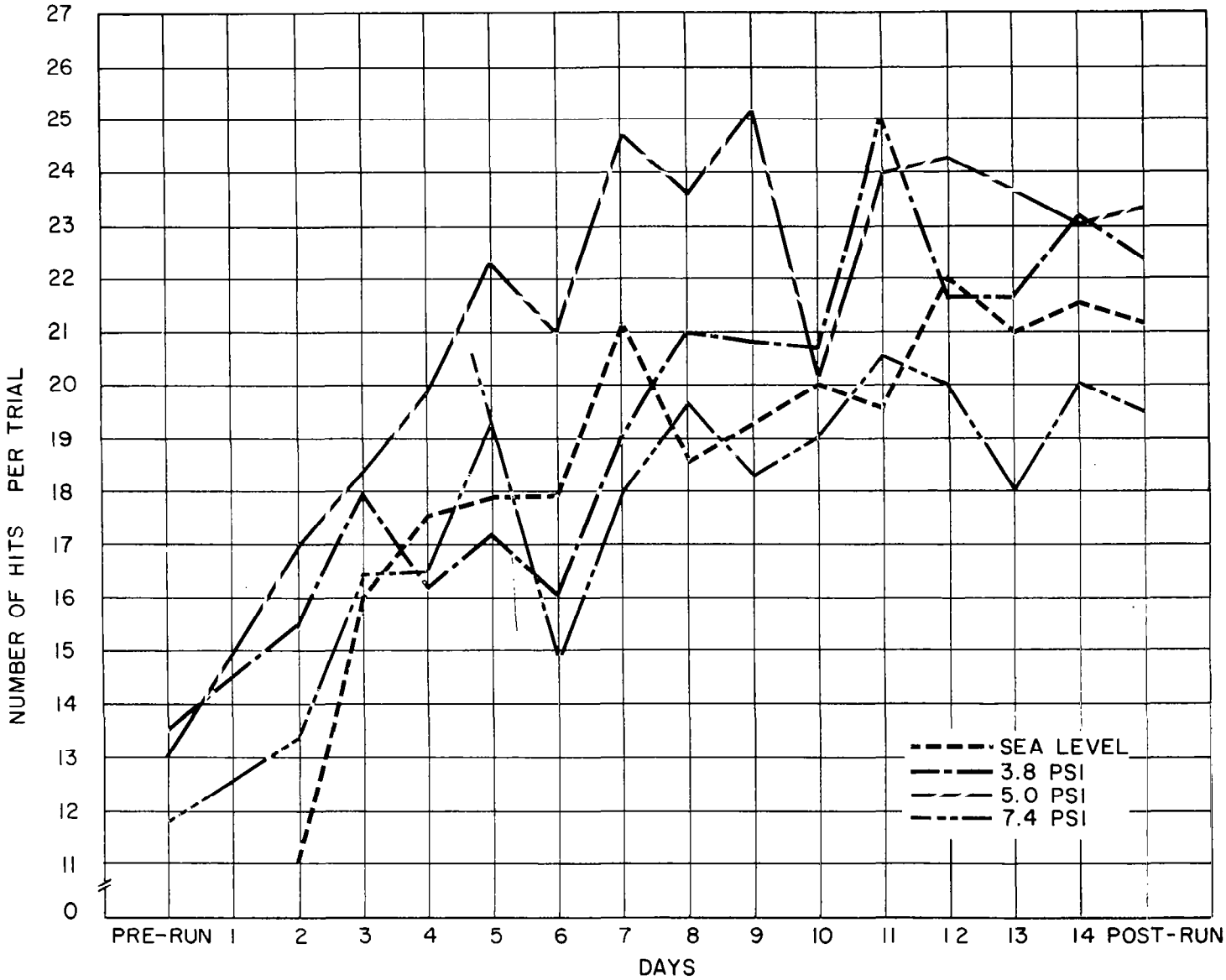


Figure 3-69 Daily Means of the Ballistic Aiming Scores for the Four Experimental Groups

c. Mental Performance

(1) Psychomotor Performance Testing System

(a) General Analysis

To eliminate tape difficulty differences and show trends over time, the means and sigmas for standardized scores ($\bar{X}$=50, $\sigma$=10) for the days in which Psychomotor Performance Testing System (PPTS) data were gathered are shown for variables in Tables 3.3.17 and 3.3.18.

Figures 3-70 and 3-71 show graphs of the standardized means for the selected variables and for the raw score means, with slight adjustments, for another variable.

Though no regression analyses were run on the standardized data, there appears to be a slight improvement in arithmetic performance, over time, in both experimental runs, little stable change in pattern discrimination performance except for an apparant decrement for the 5.0 psi experimental run.

Tables 3.3.1 through 3.3.16 show results of analysis of variance for selected data of the PPTS variables. These analyses were run on data that were comparable for the 7.4 psi and the 3.8 psi runs. No comparable data was available for the sea level and 5.0 psi runs. Comparable, in this case, means that the same program tapes were used on the corresponding days of the two runs. The need for comparability to obtain a meaningful analysis of variance restricted the data to that taken on days 1, 3, 4, 5, 6 and 8 of the two runs.

There were no significant differences between the two experimental runs. Because of the variation in number and difficulty of presentations from different tapes it was expected that the main effect for days would be significant. On all variables except one this effect was significant at the 1 per cent level.

Auditory vigilance - no response had an interaction between Runs and Days significant at the 5 per cent level. This result is probably due to variability generated by difficulties with the equipment.

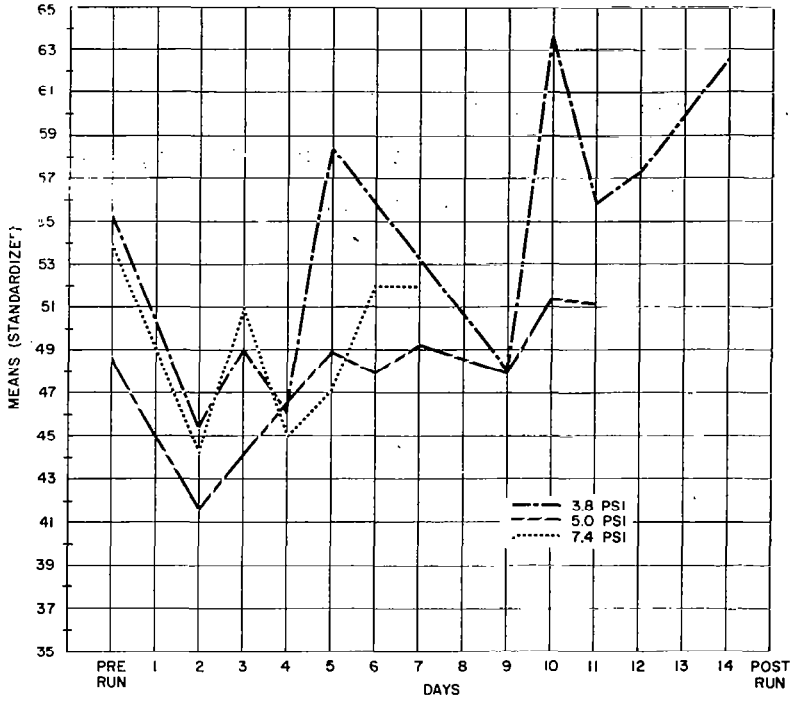


Figure 3-70 Psychomotor Performance Testing System - Arithmetic: Right

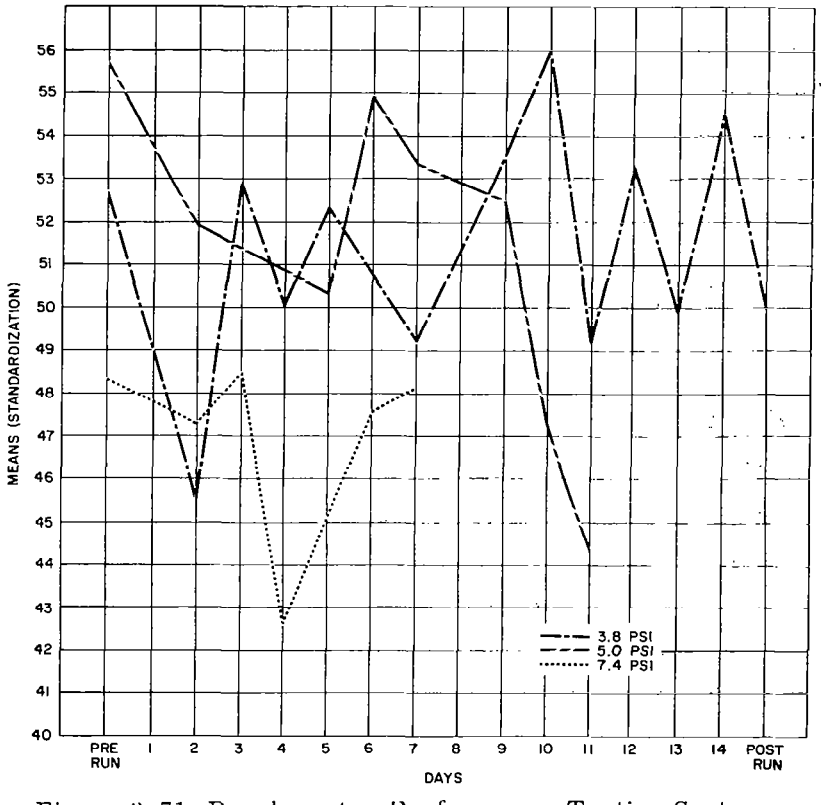


Figure 3-71 Psychomotor Performance Testing System - Pattern Discrimination: Right

The interactions were also significant at the 1 per cent level for scale position monitoring-wrong and at the 5 per cent level for scale position monitoring-extraneous responses. Since extraneous responses were obtained by subtracting the number of presentations from the sum of "right" and "wrong", and since an extraneous response was always scored as a wrong response, these two variables are of necessity correlated. Occasionally a subject would have a high number of extraneous responses and unless this happened on the same days in both runs this would tend to make the interaction significant. One interpretation of this might be that it indicates a difference in speed of response on different days of the two runs and/or differences in the interval setting in which the subjects could respond.

(b) Psychomotor Performance Testing System Correlation Matrix

Due to circumstances largely beyond our control the data gathered on the PPTS was limited to certain days and certain experimental conditions. In order to gain information about the interrelationships among the variables of the PPA, the PPTS and the GATB, the following combinations of scores were correlated: for the GATB the scores obtained on Form A on the first or pre-run day were used, for the PPTS and the PPA certain days on which the data were the most comparable between the two sets of variables were averaged for each subject for each variable. The particular days of data gathering were: days 1, 3, 4, 5, 6, 7 and 8 of the 7.4 psi run and days 1, 3, 4, 5, 6, 8, 11, 12 and 14 of the 3.8 psi run.

Certain types of information were carried along as separate variables for the correlation analysis. This was due to the fact that, for certain variables, the total right plus the total wrong did not necessarily add up to the total presented. Arithmetic Computation, Pattern Discrimination, and Auditory Vigilance omissions were not scored as wrong. Scale Position Monitoring and Auditory Vigilance response, where there was no presentation, was scored as wrong.

Using a two-tailed test at the 5 per cent level of significance for n = 11 only correlations above 0.576 in the matrix are significant. On this basis, significant correlations as shown in Table 3.3.19, among the PPTS and GATB measures were: Arithmetic Computation, Pattern Discrimination and Scale Position Monitoring correlated among themselves, the GATB variables G, V, N, S, Q, and K correlated among themselves. There were significant correlations between Arithmetic Computation and the S variable and also among the N variable, Arithmetic Computation, and Scale Position Monitoring. These measures must, therefore, have been covering the same ability area. The correlation between GATB N variable and Arithmetic-no response suggests a common speed factor in arithmetic ability.

The Auditory variables correlated among themselves and with Pattern Discrimination-wrong and GATB K variable. Auditory right and wrong probably show a correlation with "number of responses made." Experience with the equipment suggests that these correlations were artifacts of the presentations and the scoring.

The Warning Lights Monitoring variables were significantly correlated with Scale Position Monitoring and GATB Q variable.

The Red Warning Lights - Scale Position Monitoring correlations suggest a slow speed of response factor since about 2 seconds was generally allowed for response to Scale Position Monitoring, and Red Warning Lights were easily perceived so that speed of response tends to contribute more to the variance than speed of perception.

The Green Warning Lights - GATB Q (Clerical Perception) correlation is in accordance with expectation, since the absence of a green light was more difficult to perceive and required a systematic search of the console to keep the time accumulation down.

(2) Paper and Pencil Analog

(a) General

The data to be presented in this section follows the following order for each item type:

1) A table showing the mean and standard deviation for
   a) Each day under each atmosphere (columns)
   b) Each day for all atmospheres (column sub-means)
   c) All days in each atmosphere (row sub-means)
   d) All days for all atmospheres (grand means)
2) A figure (graph) showing the daily means for each atmosphere and for all atmospheres.
3) Analysis of variance.

In all cases of PPA sub-test variables, results are presented in terms of error scores. These represent either the cumulative frequency of errors within a test-form or the cumulative magnitude of errors. The only exception to this method is the total-elapsed time score. Thus for all variables a low score represents better performance, either in reduction of errors or of required time.

Two entries in these tables are marked as Synthetic Entry. During the 3.8 psi run the PPA was not administered on day 14, and no post-run administration was secured for the 5.0 psi run. For these days an arbitrary selection of performance within each run was selected for each item type to be used in lieu of missing cells. These values have been used in figuring the means and standard deviations.

In the 3.8 psi run, one of the six original subjects was eliminated for medical reasons from the study prior to data collection on day 2. The tabled values for this run are, therefore, based on five subjects rather than six. However, due to the requirements of the selected program for computation of the analysis of variance, data for six subjects was desirable. Thus, for the analysis of variance a "synthetic subject" has been added to the 3.8 psi group. The scores of the "synthetic subject" were, for each occasion, the mean score of the remaining five subjects. While this procedure reduces the overall variance, it was believed that minimum distortion of the achieved performances would be introduced

into the computations. The "synthetic subject" was required only for the analysis of variance on the PPA variables, and is not reflected in the tabled means and standard deviations.

(b) Arithmetic Computation

From Table 3.3.20 it appears that the mean errors and variability of these items decrease with increasing $O_2$ pressure, as well as decreasing across days for all atmospheres combined. Figure 3-72 shows these means more clearly. From the figure it becomes apparent that despite a sharp and progressive increase in errors of the sea level group on days 5, 6 and 7, the general trend is one of improved performance with time (reduced errors). This would appear to be ample indication of learning.

The analysis of variance in Table 3.3.21 shows, as would have been expected, significance attributable to Days when $P \leq 0.01$. In addition, an Atmosphere by Day Interaction is significant at $P \leq 0.05$. This interaction is still considered as an indication of excessive individual variation, and the probable learning demonstrated by these items could account for the significance of the Days.

(c) Pattern Discrimination

Table 3.3.22 shows the relatively low level of the error scores for these items. In fact, for the 5.0 psi group, there was an average per man of fewer than one error per day. Figure 3-73 show these means graphically, with no clear-cut trend toward either improvement or decrement throughout the study. Yet, the analysis of variance in Table 3.3.23 does show the variance associates with Days to be significant at $P \leq 0.01$. This is evidently due to the relatively large error scores on days 10 and 14.

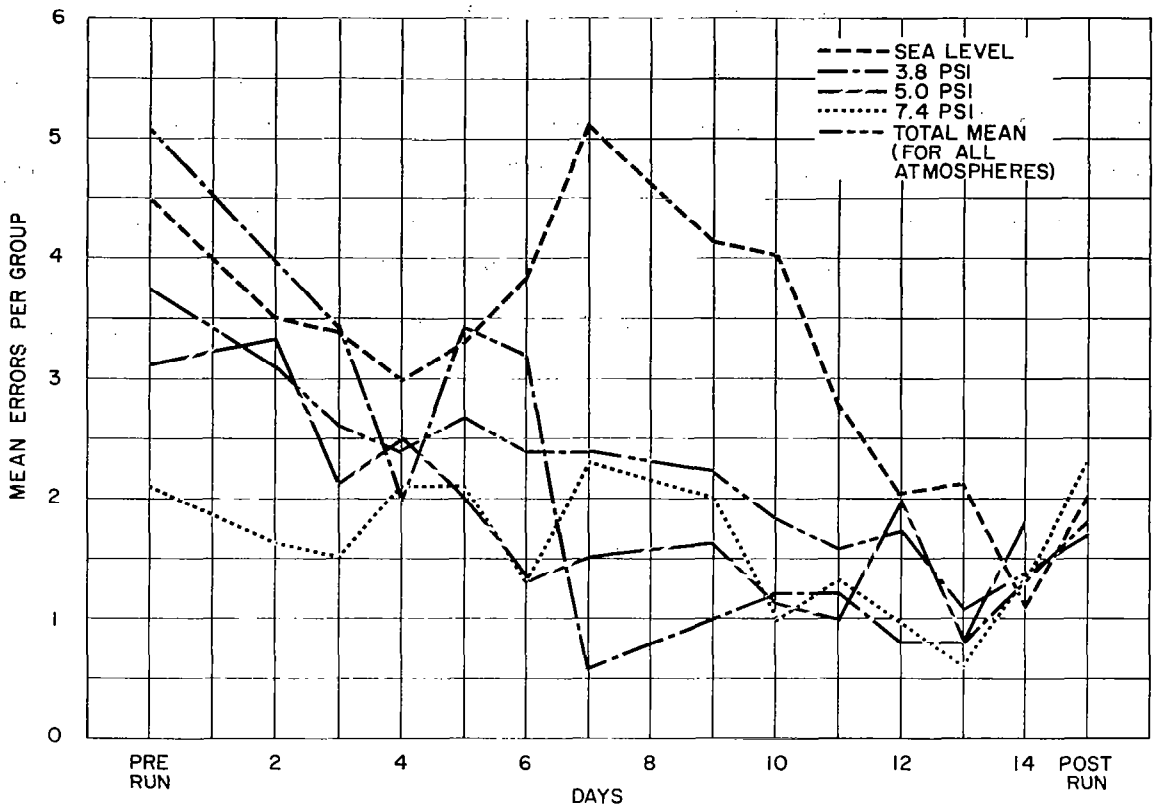


Figure 3-72 Group Mean Daily Performance for Each Atmosphere and for All Atmospheres on P. P. A. Arithmetic Computation Items

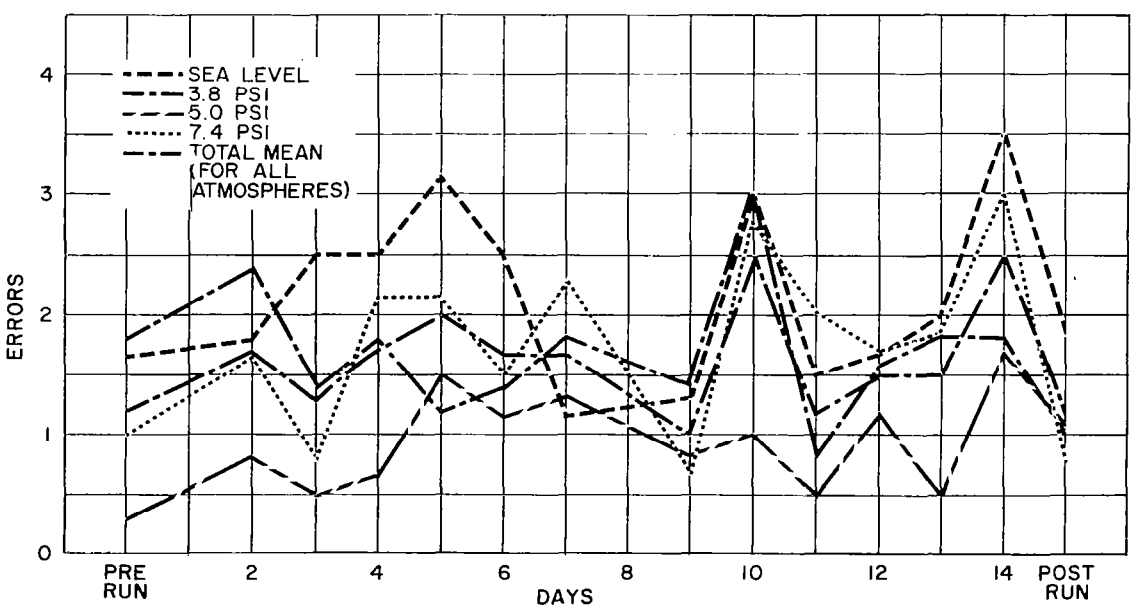


Figure 3-73 Group Mean Daily Performance for Each Atmosphere and for All Atmospheres on P. P. A. Pattern Discrimination Items

(d) Scale Position Monitoring

Table 3.3.24 shows the relevant means and standard deviations for the scale position monitoring. The sea level run shows the largest mean-error as well as the largest variance across days. These means are graphed in Figure 3-74 where the higher error score for the sea level run is more apparent, as well as the relatively low level of all of the error scores.

The analysis of variance in Table 3.3.25 supports this observation of consistency of performance, for neither of the main effects nor the interaction is significant.

(e) Incomplete Matrices

Table 3.3.26 shows little difference between the mean performances under each of the atmospheres, whereas across all atmospheres, days 4 through 7 show rather large mean-error scores. Figure 3-75 shows these scores as a general hump, which seems to be repeated at a lower level from about day 12 on. Since six of these test forms were administered twice, Figure 3-76 presents a comparison of the incomplete matrices scores, across all atmospheres, for the initial administrations and re-administrations. From this figure it seems that there is an inherent problem-difficulty factor unique to at least five of these six forms. While the second administration results, in all cases, in a lower mean-error score, the difference between these means is surprisingly constant, suggesting a familiarity factor, but not showing any clear-cut evidence of generalized learning.

The analysis of variance in Table 3.3.27, shows significant variance associated only with Days. As shown above, this is probably a reflection of difficulty with a differing form.

(f) Profile Discrimination

The means and standard deviations are presented in Table 3.3.28. While variance within each atmospheric condition is high, there appears a reduction of mean-error associated with $O_2$ pressure until the 7.4 psi condition, where the mean-error doubles the mean of the three lower pressure atmospheres. A check of the pre-run scores, however, shows the group under the 7.4 psi condition started off with about this error ratio to the other groups.

The analysis of variance in Table 3.3.29, however, shows no significance due to atmospheres. It also shows a main effect, Days and Atmosphere by Day Interaction, both significant at $P \geq 0.01$. The possible source of the Days significance is shown by a check of the daily means for all atmospheres where an apparent increase in error during the second week over the first week's performance appears. Figure 3-77 shows these changes graphically. The Atmosphere by Day Interaction can only be interpreted as demonstrating a large variation of individual scores in these studies.

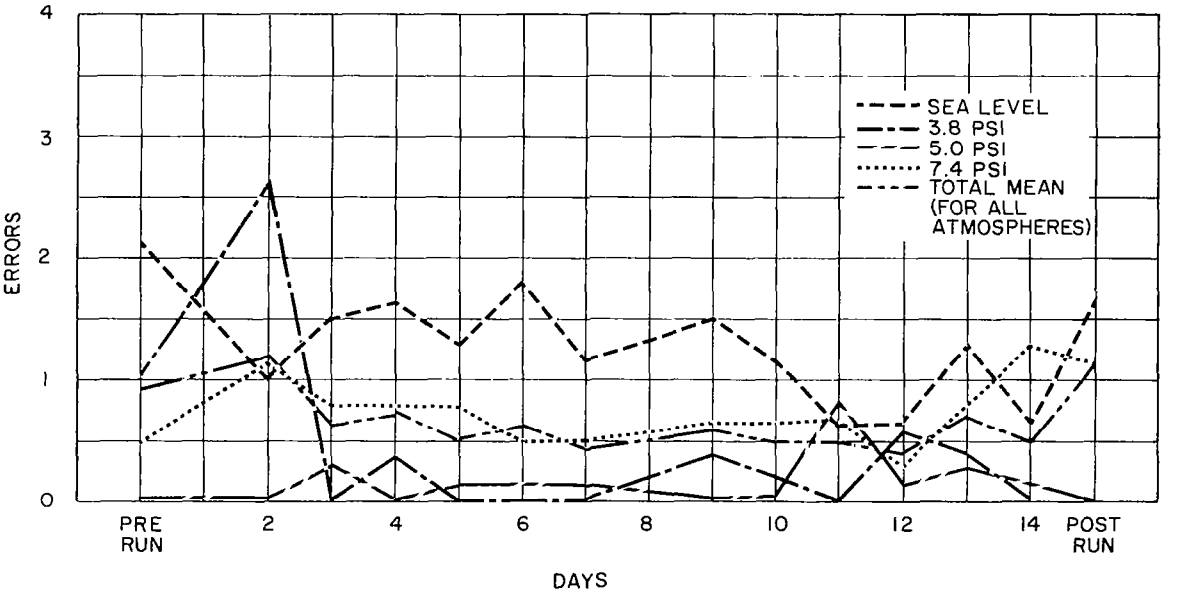


Figure 3-74 Group Mean Daily Performance for Each Atmosphere and for All Atmospheres on P. P. A. Scale Position Monitoring Items

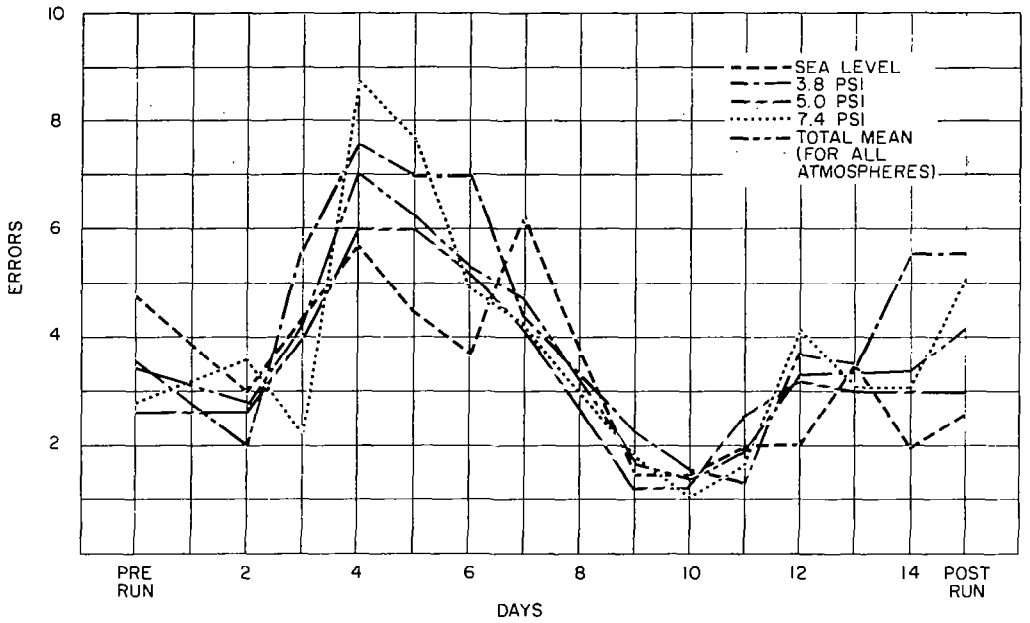


Figure 3-75 Group Mean Daily Performance for Each Atmosphere and for All Atmospheres on P. P. A. Incomplete Matrices Items

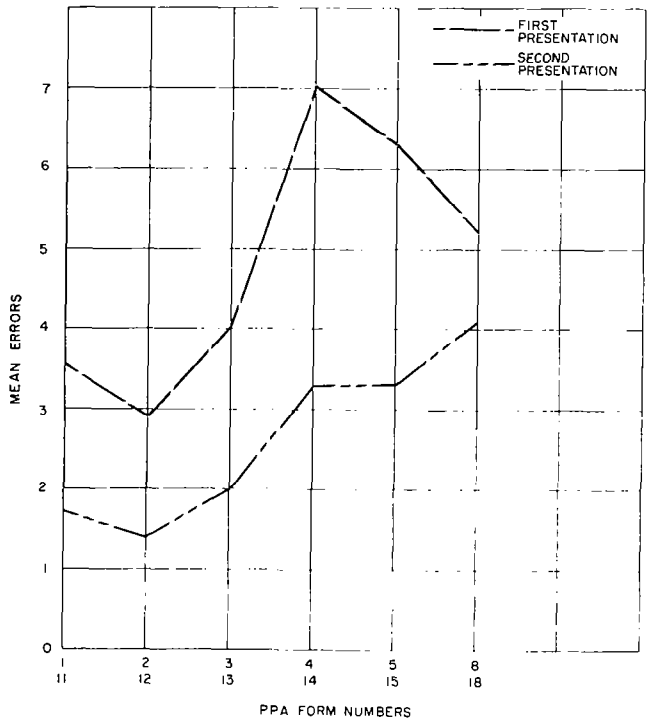


Figure 3-76 Comparison of Group Daily Performance for All Atmospheres Combined on First and Second Administration of P. P. A. Incomplete Matrices Items

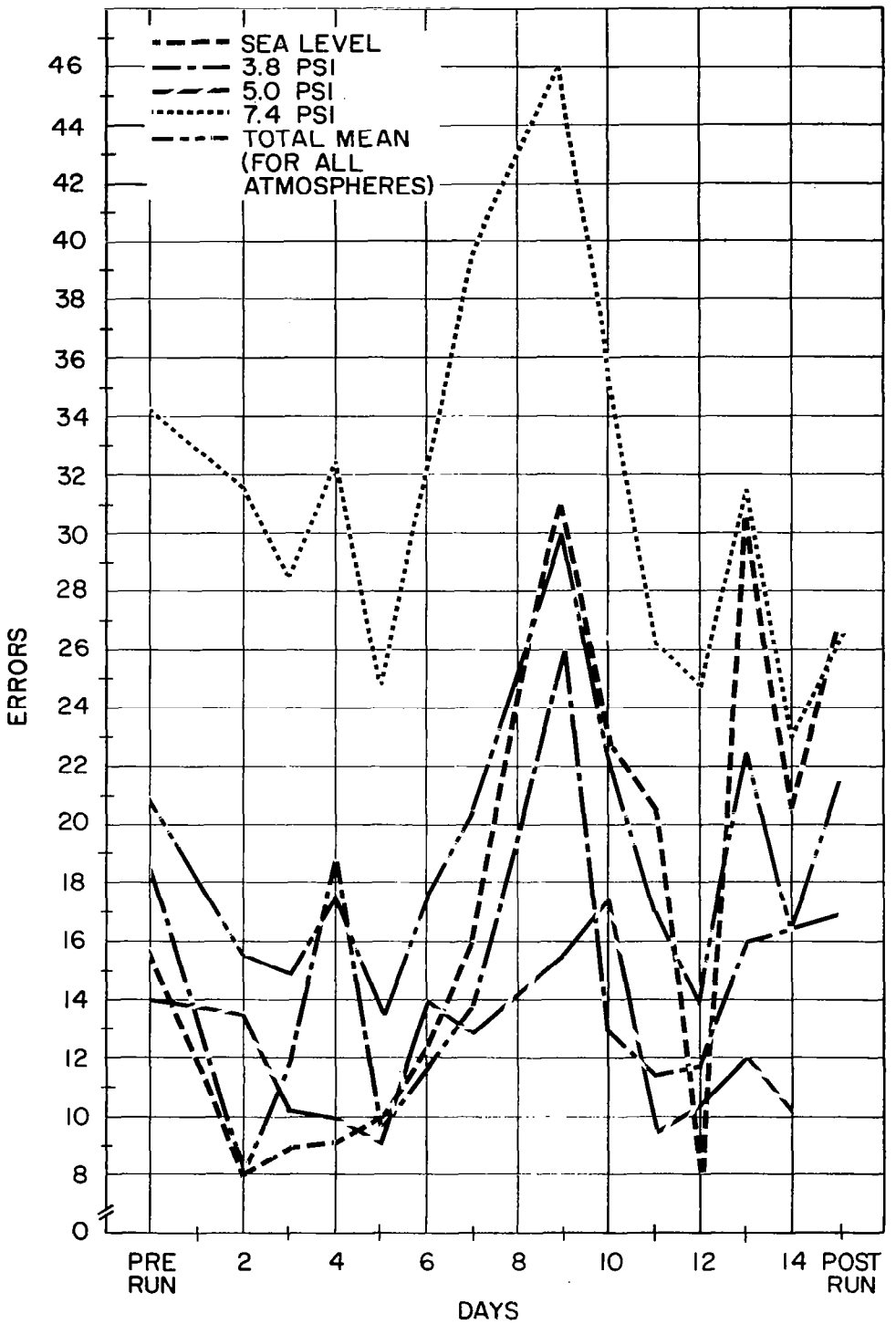


Figure 3-77 Group Mean Daily Performance for Each Atmosphere and for All Atmospheres on P. P. A. Profile Discrimination Items

(g) Vector Construction

From Table 3.3.30 it appears that the sea level group was more inaccurate on these problems, and more variable, than the other groups. The separate day means appear to show a general reduction during the first week and a fairly stable level during the second week. Figure 3-78 shows this more clearly, with the sea level group showing sizeable fluctuations in mean-error score (magnitude), with an apparent leveling out of performance for the experimental groups after about the 6th day. This may be indicative of learning, but it is not sufficiently clear to be firm in so labeling this trend.

In fact, the analysis of variance in Table 3.3.31 does show significance for both Days and an Atmosphere by Day Interaction at $P \geq 0.05$, with no significance associated with atmospheres.

(h) Axis Intersection

Table 3.3.32 shows the means across days of the 3.8 psi and 5.0 psi groups are almost identical, while the remaining two means are considerably higher. The analysis of variance in Table 3.3.33 supports this observation by showing a significant contribution to the total variance attributable to Atmospheres. There is also a significant contribution attributed to Days. A review of the day means across atmospheres reveals a slightly higher mean-error score during the second week and a slightly lower standard deviation. The relationship of the means is shown in Figure 3-79. In this figure, the similarity of daily error scores for the sea level and 7.4 psi groups is clearly shown, as well as the similarity, but at a lower mean-error score level, of the 5.0 and 3.8 psi groups. In addition, the generally increasing mean-error score across all atmospheres is shown.

(i) Elapsed Time

Two items emerge from an examination of Table 3.3.34. First, the sea level group was consistently slower than the experimental groups on this test, and second, for all groups there was a sharp decrease in required time for the second week in comparison with the first week. These are shown graphically in Figure 3-80. While the slower performance of the sea level group is evidently a characteristic of the working habits of those

subjects, the uniformly sharp break between the first and second weeks corresponds with the start of a series of re-administrations of these forms, so there is quite obviously a familiarity factor operating. The analysis of variance in Table 3.3.35 shows both main effects and their interaction significant at $P \geq 0.01$. Again, the Atmosphere significance is apparently due to the sea level group, while the Days significance seems to reflect form familiarity on a second administration. As before, the interaction term is believed indicative only of the level of variation within the groups.

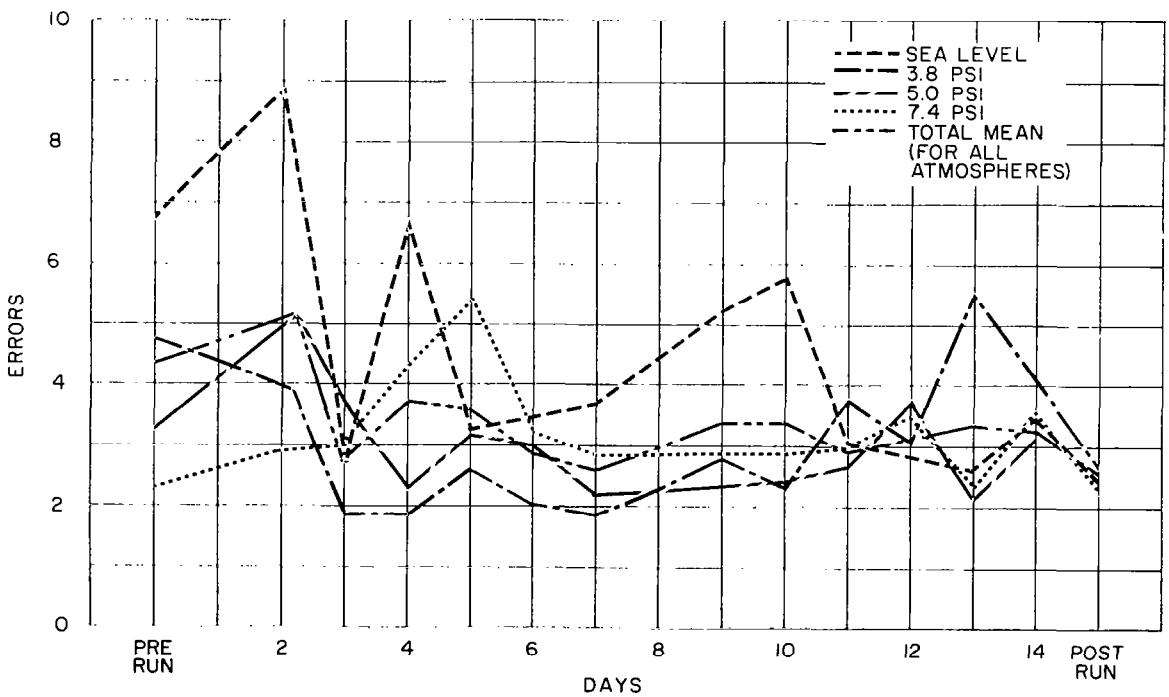


Figure 3-78 Group Mean Daily Performance for Each Atmosphere and for All Atmospheres on P. P. A. Vector Construction Items

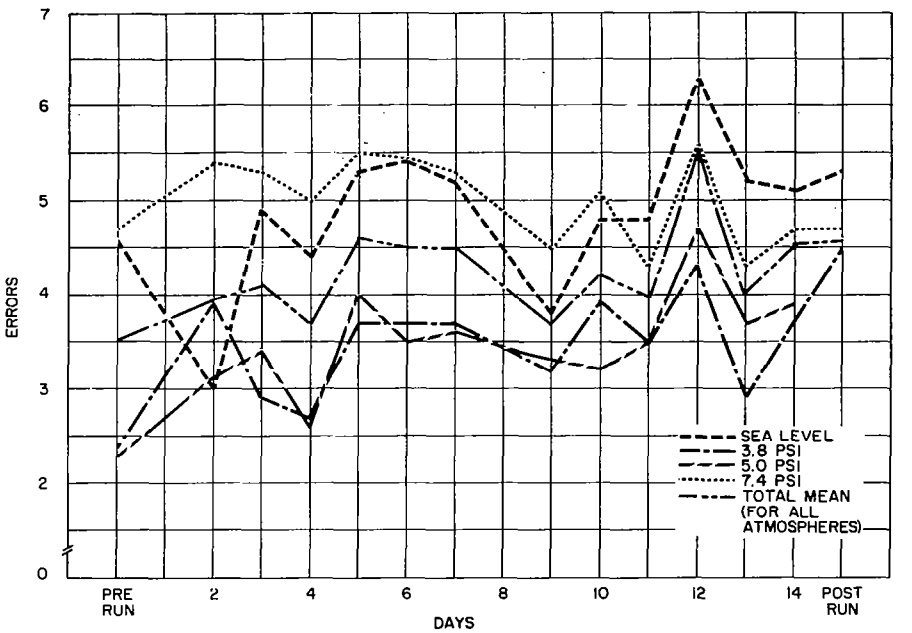


Figure 3-79 Group Mean Daily Performance for Each Atmosphere and for All Atmospheres on P. P. A. Axis Intersection Items

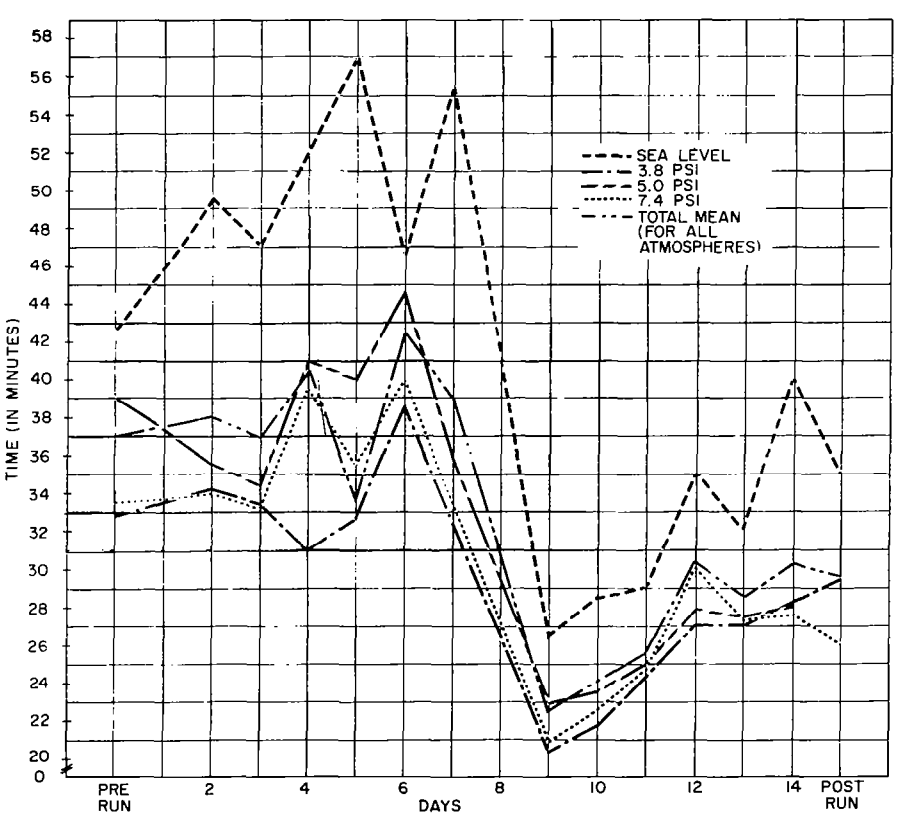


Figure 3-80 Group Mean Daily Performance for Each Atmosphere and for All Atmospheres on P. P. A. Elapsed Time

(j) Analysis of Variance Summary for Paper and Pencil Analog Variables

Table 3.3.36 summarizes the patterns of significance for the PPA variables. Only two variables show significance attributable to atmospheres (both at $P \geq 0.01$). These were the Axis Intersection problems (error score), and the total Elapsed Time scores. It was suggested that the significance of the Elapsed Time scores was related to the consistently slower work rate of the sea level group. Significance of the Axis Intersection problems may have been due to a difference between the sea level and 7.4 psi groups on one hand, and the 5.0 and 3.8 psi groups on the other.

While the variance of all but the Scale Position Monitoring scores showed significance attributable to Days, there has been no consistent pattern over item-types to account for this significance. This is shown in Figure 3-81, in which daily mean scores across all atmospheres are presented for each item type. In this table all ordinates are error scores except for Elapsed Time.

Four of the eight PPA variables showed a significant Atmosphere x Day interaction. This is interpreted as merely indicative of a larger subject variance than would be desired.

Thus, on this instrument, there has been no demonstration of change in performance, clearly due to prolonged exposure to specific oxygen atmosphere.

(k) Correlational Study

In an effort to gain more understanding of the relationship between the scores on the Psychomotor Performance Testing System (PPTS) and its Paper and Pencil Analog (PPA), performances on these measures on selected days from the 7.4 psi and 3.8 psi runs were averaged for each of the eleven subjects. Then the mean performance scores were intercorrelated together with the GATB-A-1 series. The correlations are shown in Table 3.3.19, and are of interest here for any information they can offer about the PPA; the

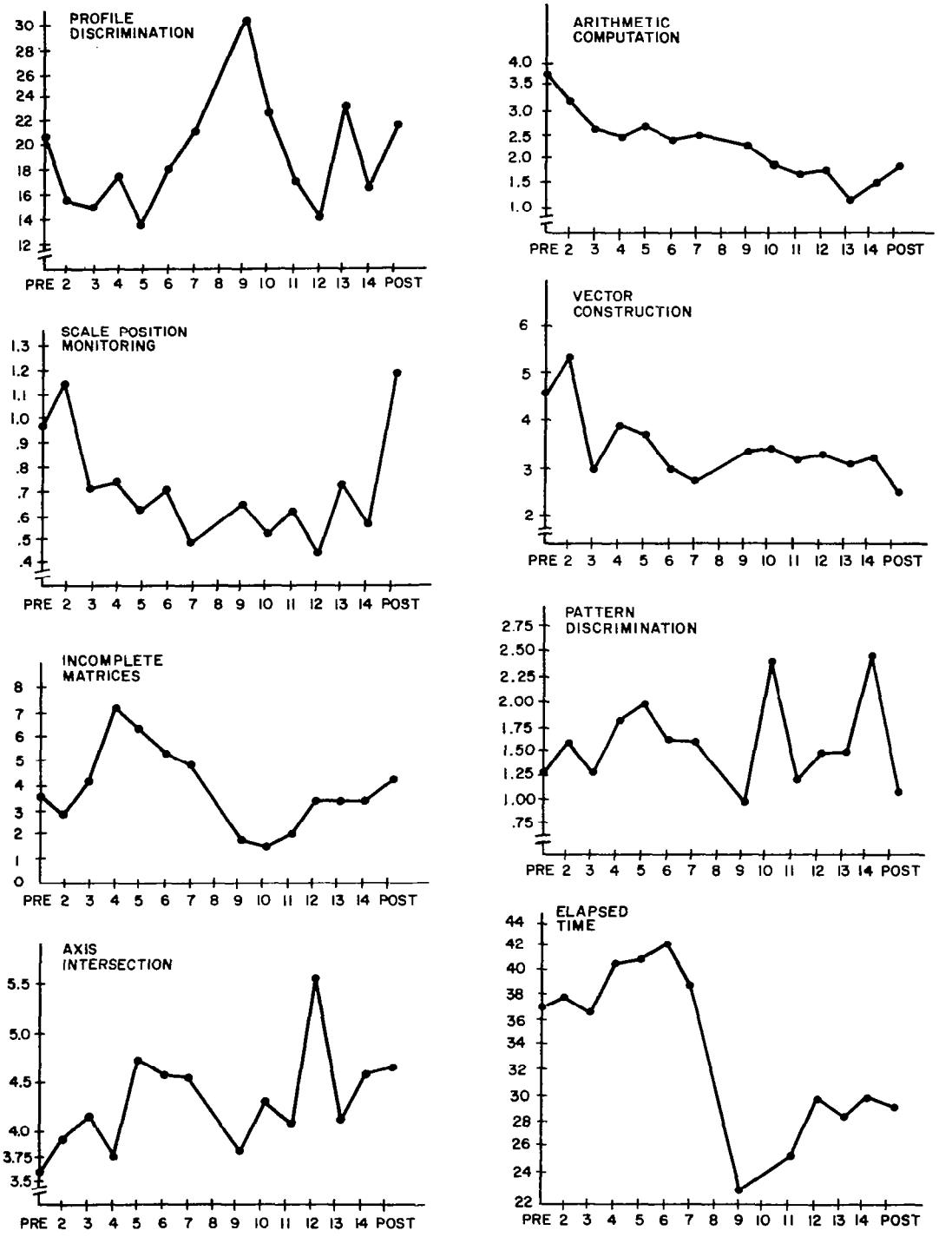


Figure 3-81 Summary of Daily Means by Item Type

relationships of the PPTS scores are presented in paragraph (ℓ) below.

Since among the PPA variables all scores are error scores, except for total time, it is expected that all significant correlations will be positive, except those involving total time. Therefore, a one-tailed test of significance will be used for the specific test components, and a two-tailed test for correlations involving total time. For convenience those correlations have been abstracted from the larger table and are presented separately in Table 3.3.37. Values significant at $P \geq 0.05$ are marked with an asterisk.

This table shows, primarily, that the scores on Pattern Discrimination and Total Time have failed to demonstrate any significant relationships with the other measures on the PPA. The highest value in the table ($r = 0.898$; $P > 0.005$) is the correlation between Profile Discrimination and Axis Intersection. A correlation of this magnitude, if substantiated in further studies, is practically a reliability coefficient, and is quite a respectable measure of similarity for "alternate forms." It is not too surprising, therefore, to find that both tests exhibit almost the same pattern of correlations with the remaining measures. Neither, however, is related significantly with any of the GATB variables.

Vector Construction shows the largest remaining correlations (both at $P \geq 0.005$) with Arithmetic Computation ($r = 0.789$) and with Scale Position Monitoring ($r = 0.712$). Thus each are sharing about half of the total variance of the Vector Construction problems. That it is not entirely the same half is shown by their correlation, $r = 0.547$. About 30 per cent of the variance of the Vector Construction test may be, as a maximum, in common with both Arithmetic Computation and Scale Position Monitoring. This leaves with each variable separately, about 30 per cent related to Arithmetic Computation and about 20 per cent in common with Scale Position Monitoring. But, in the absence of relationships with known and calibrated reference variables, such knowledge gives little practical information. Vector Construction, it will be noted, does not have any significant correlation with the GATB variables in this sample.

Incomplete Matrices, a problem type postulated to measure general reasoning and number facility, shows a surprising spread of

relationships. It correlates ($P \geq .05$) with Profile Discrimination, Scale Position Monitoring, Axis Intersection, and Vector Construction. The original General Reasoning and Incomplete Matrices hypothesis is supported by Incomplete Matrices correlation with the GATB G score ( $r = -0.813$, $P \geq 0.005$), but it also correlates with S ($r = -.734$, $P \geq 0.005$), with V ($r = -0.661$, $P \geq 0.01$). The correlation with the GATB clerical score Q ($r = 0.509$), is not in the expected direction, and hence is not accepted as a significant relationship. Using a two-tailed hypothesis, this value would have been rejected at $P \geq 0.10$.

Scale Position Monitoring is shown to be less independent within the predictor space of the PPA than had been anticipated, with correlations with Incomplete Matrices ($r = 0.535$, $P \geq 0.05$), Axis Intersection ($r = 0.497$, $P \geq 0.05$), Arithmetic Computation ($r = 0.547$, $P \geq 0.05$) and with Vector Construction ($r = 0.712$, $P \geq 0.005$). This measure has no significant correlations with the GATB variables.

($\ell$) Relationship of Paper and Pencil Analog with Psychomotor Performance Testing System

Three of the PPA tests are theoretically face valid counterparts of their PPTS measures, Scale Position Monitoring, Arithmetic Computation and Pattern Discrimination. None of the three in this sample has demonstrated any relationship to their counterparts, and in fact only the Pattern Discrimination test shows a relationship to any PPTS variable (Arithmetic Computation omit score, $r = 0.70$). Thus, increased error in Pattern Discrimination of the PPA is related to increased omissions on the Arithmetic Computation of the PPTS.

Three of the PPA tests do correlate with the PPTS Arithmetic - Rights score - Incomplete Matrices ($r = -0.57$), Axis Intersection ($r = -0.57$) and Total Time ($r = -0.74$). The latter relationship seems to reflect a speed factor in the Arithmetic Computation (PPTS) problem programming. A similar speed factor is shown in the correlation of PPTS - Time with PPTS - Scale Position Monitoring, Rights ($r = -0.60$).

Two PPA variables show relationship with the PPTS Auditory Vigilance - Units score: Profile Discrimination ($r = 0.69$) and Axis Intersection ($r = 0.61$). In view of the intercorrelation of these two tests, it is

not surprising to find both related to a common variable on the PPTS. In addition, the PPA-Profile Discrimination test correlates ($r = -0.57$) with PPTS-Auditory Vigilance - Rights.

d. General Aptitude Test Battery

Table 3.3.38 presents the means and standard deviations for each of the aptitude scores as measured in pre-run, mid-run, and last day of chamber occupation for each of the four atmosphere conditions. The first and last administrations of Form A are differentiated as A-1 and A-2. This table shows, in all cases, an improvement in achieved score on the second administration of the test, and, in a majority of the cases, a reduction in the variance. Form B, used at the mid-point of each run, generally shows a higher performance than A-1, but lower than A-2. For the number score (N) this is true of only the 7.4 psi groups, and there is a reversal for the sea level group on the Form Perception (P) score, although the difference is probably not significant.

It is also of interest to note the generally high score levels of these subjects, as compared with a population mean of 100 and standard deviation of 20. It is obvious on most aptitudes that these subjects represented a select population, at least on the non-manipulatory scores. On measures of dexterity (F and M) the superiority vanished.

The analysis of variance in Tables 3.3.39 through 3.3.47 shows for all variables (aptitude scores) significant variance associated with first, second and last administration. This is related to the score improvement on the second administration of Form A. In addition, two variables show significance associated with atmospheres, for N at $P \geq 0.01$, and for Spatial (S), at $P \geq 0.05$. For N, the significance seems to be due to the original level of aptitude of the subjects in the 7.4 psi group relative to the other groups. Similarly, for S the 3.8 psi group appears to have an initial advantage.

e. General Aptitude Test Battery Intercorrelations

For this discussion the intercorrelations of the GATB variables have been abstracted from Table 3.3.19 and are presented here as Table 3.3.48. As with the correlations of the PPA, those elements significant at $P \geq 0.05$ are indicated by an asterisk.

In this sample, Form Perception (P) failed to yield any significant correlation with the other aptitude scores, and the two measures of Dexterity (F and M), are correlated only with themselves. The measure of General Intelligence (G) shows the highest correlation with Verbal (V) ($r = 0.954$), then with Motor Coordination (K) ($r = -0.702$), with Clerical Perception (Q) ($r = 0.662$), with Spatial (S) ($r = 0.603$) and with Number (N) ($r = 0.583$). The correlation with V is of a magnitude much sought after for reliability coefficients, and obviously, the correlations of V with the other tests closely parallels that of G. Specifically it correlates with K ($r = -0.741$), with Q ($r = 0.677$), with S ($r = 0.422$, but not significant at $P \geq 0.05$) and with N ($r = 0.632$).

For scores G and V, it is not surprising to find this degree of intercorrelation with other measures in the battery, but it is surprising to find the moderately large negative correlation with K. In fact, the only remaining significant correlation is that of Q with K ($r = -0.563$). Thus, those of the class of measures which might be termed intellective, which correlate with the motor aptitude measures, all show a negative relationship. This is probably indicative of a characteristic of the 11 S's whose test performance were correlated. These men show a consistent superiority over the normative population in all of the intellective measures, but show only minimal superiority, if any, on the motor tests.

3. Analysis of Results

a. Sensory Performance

(1) Critical Flicker Frequency

According to Bartley[41] residual flicker, which occurs at about 20 flashes per second is indicative of the normal inherent discharge rate of the retinal ganglion cells. The fine flicker point in the present inves igation is probably similar to Bartley's residual flicker. Since the flashes per second for fine flicker are quite comparable with the described residual flicker in cycles per second, it is likely that the peripheral retinal ganglion processes were not affected by the experimental oxygen environments.

Baker[42] used orange-red critical flicker frequency flashes and no artificial pupil to present right and left monocular images to show binocular synthesis. He concluded that binocular flicker fusion was in part, at least, a central process. On the basis of this conclusion and the fact that the critical flicker frequency fusion point in the present studies did not decline between pre-run and experimental run conditions, it is probable that the central nervous system was not adversely affected.

The critical flicker frequency (CFF) point rose a little, but not significantly, between the pre- and post-run examinations on all runs, except the control (sea level) run. The anomalous results evident for the control group were most likely due to trouble with the counting apparatus. A similar rise in CFF, probably due to learning, was obtained by Grandjean and Perret[43] when they re-administered CFF tests using similar red light flashes.

The evidence provided by the critical flicker frequency test data results appear to support the hypothesis that the peripheral retinal ganglion processes and the optic cortex of the central nervous system were not adversely affected by the experimental atmospheres.

(2) Brightness Contrast Test of the Army Night Seeing Test

The scores on the Brightness Contrast Test (BCT) of the Army Night Seeing Test showed no decline over time. In fact, they increased a little due to learning. Thus, it is clear that the experimental run atmospheres did not negatively affect the nervous pathways involved in brightness discrimi-

nation. Since the BCT scores did not decline, hypoxia probably did not occur. Such negative effects have been reported[44] as a function of altitude. Hypoxia and decline in brightness contrast ability is clearly due to a lack of sufficient partial pressures of oxygen at altitude. This was not the condition at any time in the present studies.

(3) Day Visual Performance

The day visual performance score results are consistent with the data on CFF and brightness contrast ability.

(4) Overall Sensory Performance

On an overall basis, it is clear that the experimental atmospheres did not degrade visual performance which may be taken as an index to sensory performance. It is not likely that sensory performance was negatively affected by the experimental atmospheres.

b. Perceptual Motor Performance

(1) General

The results from perceptual motor performance tests seem to indicate that the artificial oxygen atmospheres of the present studies have little detrimental effect. There are no significant differences between the scores of the treatment groups and the control group on the differential reaction time, tapping, or ballistic aiming tests. All of the results are comparable to similar data reported in the literature for experiments done under sea-level atmosphere conditions.

There have been many research studies reported which demonstrate that various agents and environmental conditions which are known to affect the central nervous system also affect reaction-time performance. If such negative effects had occurred, it is probable that performance would have been degraded on one or more of the perceptual motor tests. It is not likely that the oxygen atmospheres of the present study had any negative effects on the central nervous system.

(2) Differential Reaction Time

The analysis of variance presented in the results shows that the artificial atmospheres had little effect on differential reaction time.

It follows that the differential reaction time results of the present study should compare favorably with similar studies reported in the literature. In general, this is found to be the case. For example, the mean reaction time for all experimental groups is about 0.40 seconds. Considering that seven stimuli were used, this can probably be considered a very short reaction time However, it may be that four of these stimuli were probably placed in a similar response category by the subject and envisioned as being quite different from the stimulus to which the subject was required to respond. On the basis that there were subjectively fewer than seven stimuli presented, it is quite probable that the seven stimuli had less than the expected effect in lengthening reaction time Hence, one should probably expect differential reaction times only slightly higher than 0.37 seconds.[45] Similarly the standard deviations reported in this study are not unreasonable when one considers the number of stimuli and the length of the variable foreperiod.[47,48]

The significant increase in reaction time performance over days attributed to practice is also well documented.[49] It is also well known that reaction time exhibits considerable variability among individuals.[50] Hence, it is not unusual to find, as this study has, different treatment effects over time that were not attributable to the independent variables reflected in the interaction term.

Since differential reaction times are composed of sensory, central and motor components, they would be easily influenced by elements which affect the central nervous system. Malmo[51] and McFarland[44] showed that slight hypoxia decreases reaction time. Mackworth[52] showed that benzedrine offset performance decrements attributed to fatigue. Forbes[53] showed that small amounts of carbon monoxide poisoning decreases reaction time, while Miles[54] showed that alcohol increased reaction time. Fuster[55] shows that stimulation of the reticular formation decreases reaction time. Since the artificial oxygen environments of the present study had little affect on the differential reaction times, it is not likely that the central nervous system was affected by the oxygen environment.

(3) Tapping

The tapping data is in close agreement with the differential reaction time data in that the analysis of variance also shows that the artificial

oxygen environment has no affect on tapping performance and also that the results of the tapping data were not found to be inconsistent from those of other investigators. The tapping means of this study are about 140 taps per 30 second period with standard deviations of about 12 taps. Wells [56], Bryan [57], and King [58] show that one can expect mean values from 120 to 210 taps per 30 second period with standard deviations from 5 to 15 taps.

In the present study a significant increase in performance over time was attributed to practice. Wells [56] showed that each 30 seconds of tapping practice raised the subjects score about one tap per each 30 second period, and that this increase in tapping as a result of practice continued over a twenty day period. Similarly, as was the case with reaction time, there is considerable variability among subjects [58,59] which probably accounts for the significant Days x Runs interaction term in the analysis of variance.

Forefinger tapping, one of the best simple measures of fine motor control, has long been used as a standard test for drug effects.[58,60] Both Malmo [51] and McFarland [44] found this test to be one of the more sensitive indices of hypoxia. Turner [61] showed that benzedrine increases tapping rate, while Macht [62] showed that most known analgesics reduce tapping rate. No decrements in tapping performances were noted in the present study and it appears that the central processes, which regulate fine motor control, are not affected by 3.8 to 7.4 psi oxygen atmospheres.

(4) Ballistic Aiming

As is the case with differential reaction time and tapping the analysis of variance demonstrates that the artificial oxygen environments have no effect on ballistic aiming performance. In fact, the only significant finding was a practice effect. The practice curve shown in Figure 3.2.3 appears to be typical of ballistic aiming practice curves. [63]

Although the ballistic rotary aiming test is probably not as sensitive as the differential reaction time and tapping tests; it was included because gross motor tests of this sort very often reflect the effects of toxic agents on the corticospinal system. [64,65] However, Payne [66] showed that SCOPOLAMINE-diphenhydramine, which is known to affect the central processes, produced a marked degradation on rotary tracking performance. Whipple [67]

and Carver[68] showed that forced breathing and smoking produced decrements in performance on ballistic aiming tasks. The treatments in the present study had no effect on ballistic aiming performance and it appears that the process, which governs the accuracy of gross motor movements, is not affected by 3.8 to 7.4 psi oxygen atmospheres.

c. Psychomotor Performance Testing System

Delays in the production and check-out of the Psychomotor Performance Testing System prevented gathering enough data of the type needed to answer questions about the effects of artificial atmosphere on performance on the Psychomotor Performance Testing System. The data obtained, however, has been and will be of value in further development of the system, and will be valuable in the refinement of parameters for the program tapes.

d. Paper and Pencil Analog

This test was developed to provide a backstop for the Psychomotor Performance Testing System (PPTS). As circumstances actually occurred, the PPTS provided useful data only for the 7.4 psi and 3.8 psi experimental runs. Thus there were about half of the number of subjects in all studies (n = 11) for which there was data common to both the Paper and Pencil Analog (PPA) and PPTS and thus available for a correlation study. Nevertheless, it is disappointing to find insufficient correspondence, as shown by the present small-sample correlation study, between the two testing systems. Where significant relationships exist, the causes are obscure. In general, judgments as to whether the two systems have significant communalitus, must be held in abeyance despite some apparent measurement similarities.

The degree of correlation of the PPA variables with some of the General Aptitude Test Battery (GATB) tests are also unexpected. It was anticipated that the score on PPA Arithmetic Computation would be related to GATB "Number," for example, but not to Finger Dexterity. These apparent differences might be a reflection of the difference in the population sampled for this study, and the population against which the GATB has been standardized. Effective difficulty differences can definitely change the factorial structure of a test battery, and such changes may have occurred in this study. Further work would be required to demonstrate that such a factor was operating in the present instance.

Despite an inability to establish firmly the factorial structure of the PPA in this study, the results of these "mental-performance" measures support a general conclusion that there was no practical difference in mental performance over a two-week period due to the atmospheres. In the two item-types where a significant difference between atmospheres was identified, it appeared to be due more to original differences between the particular groups as shown by pre-run scores, than the subsequent atmospheric conditions to which they were exposed. Analogously, there was no significant evidence of a progressive deterioration of mental performance, as would be expected if specific oxygen atmospheres adversely affected mental performance.

4. Conclusions

1) The subjects of all of the experimental groups were superior to the normative population in all aptitude measures and did not show any loss in performance over the duration of any of the experiments.

2) There was no significant evidence of a progressive deterioration of general mental performance, as would be expected if prolonged exposure to specific oxygen atmospheres had adversely affected it.

3) The experimental atmospheres did not degrade visual performance which may be taken as an index to sensory performance. It is not likely that sensory performance was negatively affected by the experimental atmospheres.

4) The artificial oxygen atmospheres were not detrimental to perceptual motor performance.

## CONCLUSIONS

### A. MEDICAL

The medical observations during this study indicate no apparent abnormalities in vital signs, fluid balance, chest X-rays, electrocardiograms, or in the general well-being of the subjects. Aero-otitis, substernal discomfort, coughing, and eye irritation caused intermittent distress of varying severity during the altitude runs apparently without the development of complications such as infection or disability.

### B. CARDIOPULMONARY

The most significant cardiopulmonary findings were the normal pulmonary function studies and arterial $pO_2$, $pCO_2$, and pH determinations on all subjects throughout each experimental run. A discrepancy between the blood $pO_2$ values and the low $O_2$ content and capacity measurements during the 7.4 psi run suggests that there may have been a qualitative change in the red blood cell or its constituents (possibly the formation of methemoglobin) affecting the cell's ability to transport oxygen in vivo.

### C. HEMATOLOGY

The hematological system of the sea level control group showed no significant change. All subjects, after two weeks exposure to 100% oxygen atmospheres at reduced pressures, exhibited, and have continued to exhibit, hematological abnormalities. The 5.0 psi group demonstrated a slight decrease in hemoglobin concentration, anisocytosis, microcytosis, increased osmotic fragility, and minimal erythroid hyperactivity. The 7.4 psi group exhibited a fall (2 to 3 gm %) in hemoglobin concentration during the first 48 hours with a rise in bilirubin and urine urobilinogen. Reticulocytosis developed on the third day and persisted at 3.0 to 5.5%. Price-Jones curves demonstrated macrocytosis.

Post-run bone marrow examinations revealed increased erythropoiesis. The hematological picture of the 3.8 psi group resembled that of the 5.0 psi group, except for a more marked reticulocytosis. Their mean Price-Jones curves showed a similar microcytosis with great variability in cell size. Varying degrees of anemia, reticulocytosis, high degree of variability in red cell size, and morphological changes in both red and white cells have persisted in all altitude groups. Some of these alterations may represent a compensatory erythroid hyperplasia in response to hemolytic processes.

## D. BIOCHEMISTRY

Biochemical determinations on the blood for electrolytes, glucose, and urea nitrogen were within normal values on all subjects. Urinary 17-hydroxycorticosteroid levels were persistently elevated with the sea level control group, reflecting the clinically apparent stress of being the first experimental group. The subsequent altitude groups did not exhibit evidence of stress except at the end of the 5.0 psi run (second experimental group).

## E. RENAL

Urinary microscopic abnormalities occurred in many of the subjects during the altitude runs, especially toward the end of the 3.8 psi run, and have persisted in some subjects. The etiology of these changes and their significance is undetermined.

## F. MICROBIOLOGY

The experimental conditions did not appear to influence the bacterial flora of the throats of the subjects. However, a possible shift in the tolerance of the normal skin flora to oxygen may have occurred during the altitude runs. The balance of the fecal flora in each group changed, tending to become similar by the end of each run. The predominantly anaerobic flora consisted of bacteria of several morphological types, many of which appear to be different from any fecal flora described in the literature.

## G. PSYCHOLOGY

The subjects in each experimental group demonstrated no deterioration of general mental performance, sensory performance, or (perceptual) motor performance during the experimental runs.

## H. ETIOLOGY

The etiology of the abnormalities observed in this study may be related to increased oxygen concentration, decreased nitrogen concentration, reduced barometric pressure, and/or the presence of an unknown toxicant.

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## APPENDIX C-1

### A. TEST PROCEDURES

The procedures used in the collection of the experimental data are described under the same headings used in Section III, Results and Discussion.

#### 1. Medical Data

Vital signs were taken and recorded twice a day by the medical students in the chamber using oral mercury thermometers and a mercury sphygmomanometer in the usual manner. Body weight was determined immediately after voiding on arising in the morning, using a medical scale. Urinary output was measured in graduated urinals, and fluid intake and calorie intake calculations were simplified by the use of dehydrated foods. Tympanic membranes were visualized using an otoscope, and a stethoscope was used for auscultation of the chest. Heart rates were monitored at night using plastic cup, wire mesh, floating electrodes as sensors, with an eight-channel Sanborn Visoscope mounted outside the chamber providing the monitoring screen.

PA chest films (14 x 17) were taken through the chamber wall with a portable G.E. dental X-ray unit before the experimental run, and on the fifth and the last day at altitude. The transfer lock was modified for the X-ray work by installing a 2-inch diameter aluminum filter port in its center. The subjects were positioned with their backs to the aluminum port window, holding a high speed cassette in front of their chest. Fifteen milliampere, 90 kilovolt, 1/6 - 2/15 second exposures were made on royal blue Kodak high speed film. The X-ray film was about 52 inches, rather than the customary 60 inches from the X-ray source, resulting in slightly larger heart shadows. This technique resulted in good technical X-ray films, making for ease of interpretation.

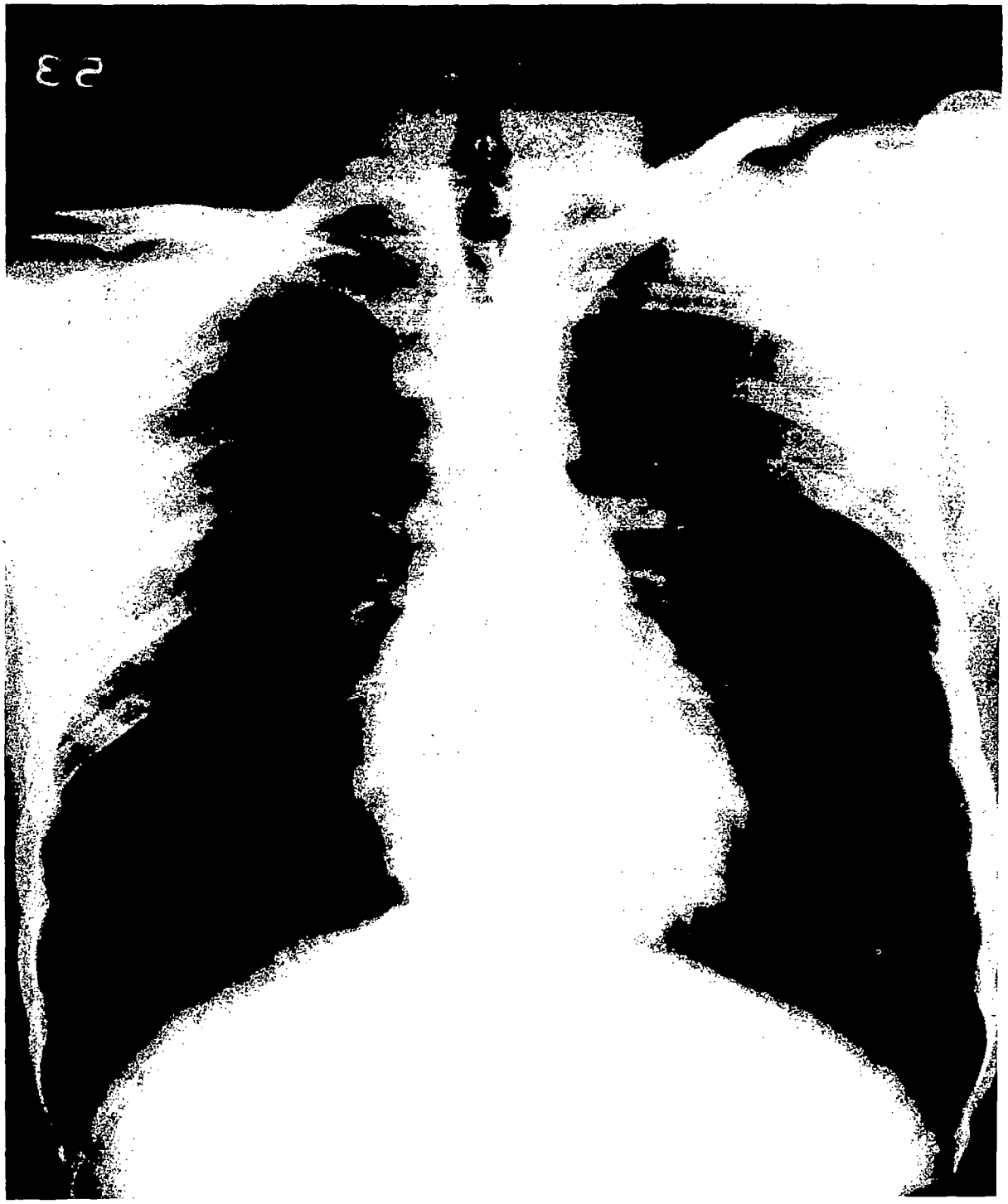
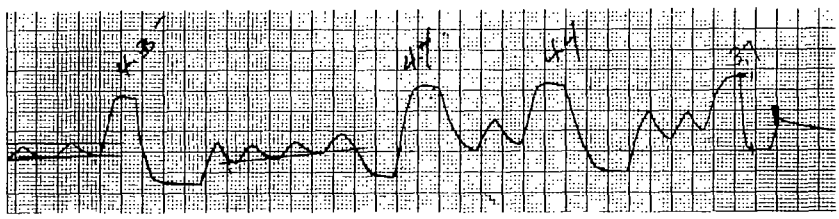


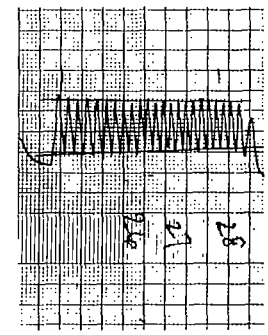
Figure A-1 Chest X-ray of Subject in Chamber at 3.8 psi

2. Cardiopulmonary Data

a. Pulmonary Function

Pulmonary function studies within the chamber were conducted using a wedge waterless spirometer. This instrument provides electrical signals proportional to volumes and flows which were recorded outside the chamber on a six-channel Sanborn recorder. Using a plastic bellows and large tubing, the 10-liter capacity wedge offers almost no resistance to breathing. The standard wedge was modified by including a thermometer just ahead of the bellows in the inlet and outlet stream and placing a humidifier with a water trap on the oxygen source. Vital capacity, total volume, inspiratory resource, expiratory resource, timed vital capacity, and MBC were determined in a rebreathing system without any $CO_2$ absorber. The wedge was calibrated against a constant voltage before and at the end of a series of daily tests. Because of the small range available on the Sanborn recording paper, in the last three experimental runs the accuracy of the calibration from one day to the next was improved by increasing the gain five times in adjusting the 1-liter calibration signal and then rechecking at normal gain. Each subject would breathe in and out of the wedge until a stable rising baseline was established. A static inspiratory vital capacity, static expiratory capacity, static cuspiratory vital capacity, and two timed inspiratory vital capacity were performed in the same sequence daily. Centigrade degree temperature changes were read and recorded. The wedge was flushed with 100% $O_2$ three to four times to remove the $CO_2$ and then a 15-second MBC was performed on the subjects selected to do exercise. The following is a typical record obtained with this method.





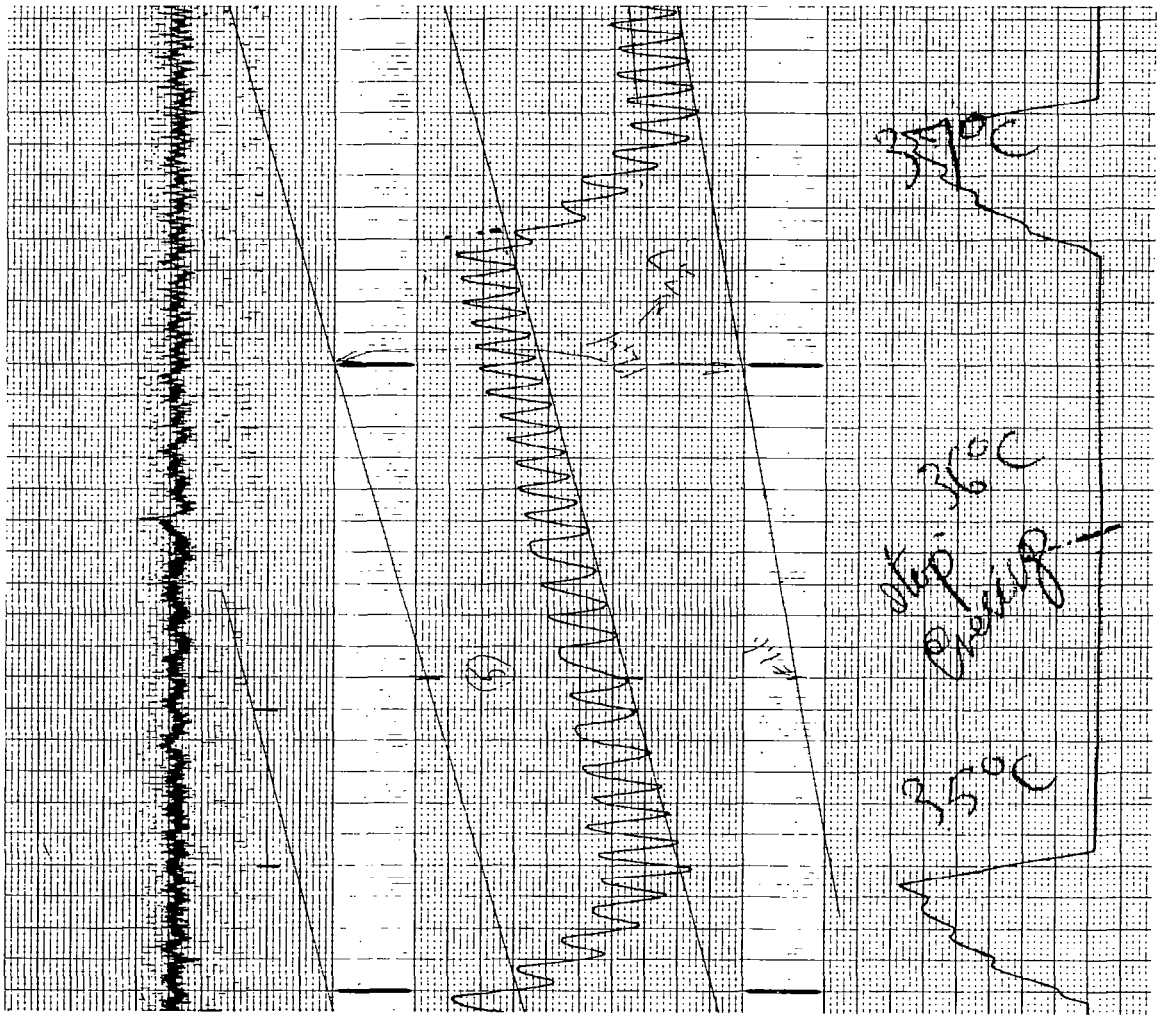
The measured volumes were corrected for temperature and pressure changes to B.T.P.S. according to the following table:

| Temp. °C | Sea Level | 5 psi | 7.4 psi | 3.8 psi |
|---|---|---|---|---|
| 20 | 1.102 | 1.206 | 1.152 | 1.269 |
| 21 | 1.096 | 1.195 | 1.144 | 1.256 |
| 22 | 1.091 | 1.187 | 1.137 | 1.244 |
| 23 | 1.085 | 1.176 | 1.129 | 1.231 |
| 24 | 1.080 | 1.166 | 1.121 | 1.217 |
| 25 | 1.075 | 1.154 | 1.113 | 1.203 |
| 26 | 1.068 | 1.144 | 1.104 | 1.190 |
| 27 | 1.063 | 1.132 | 1.096 | 1.175 |
| 28 | 1.057 | 1.122 | 1.086 | 1.160 |
| 29 | 1.051 | 1.109 | 1.078 | 1.144 |
| 30 | 1.045 | 1.097 | 1.070 | 1.128 |
| 31 | 1.039 | 1.084 | 1.061 | 1.111 |
| 32 | 1.032 | 1.071 | 1.051 | 1.094 |
| 33 | 1.026 | 1.058 | 1.041 | 1.077 |
| 34 | 1.020 | 1.044 | 1.031 | 1.058 |
| 35 | 1.014 | 1.029 | 1.021 | 1.039 |
| 36 | 1.007 | 1.014 | 1.010 | 1.020 |
| 37 | 1.000 | 1.000 | 1.000 | 1.000 |

Work performance was evaluated by measuring $O_2$ consumption and recording heart rate obtained from an electrocardiogram while performing a steady 5-minute work load of 900 kpm/minute meters on a Monarch bicycle ergometer (kpm = kilopod meter; 1 kp is the force acting on the mass of 1 kg at normal acceleration of gravity). Because at the highest altitude over 75 liters (A.T.P.S.) of oxygen would be required, standard spirometers were not suitable for this determination. Instead of using a large gasometer, two wedges were interconnected, with one acting as a replenishable reservoir, so that unlimited volumes of oxygen would be available.

In performing the tests, the subject, with chest EKG leads attached, would sit on the ergometer rebreathing into a pulmonary function

system (see below) consisting of two wedges, a Collins Triple "J" high velocity valve (P-338), a 4-liter baralyme $CO_2$ absorber with large (1-1/4-inch I.D.) connecting hoses and two electrically operated valves. These valves direct $O_2$ from the reservoir wedge to the rebreathing wedge in response to signals from microswitches attached to the wedges that indicate loss of volume from the rebreathing wedge as the subject consumes $O_2$. The following instrument trace is a typical record obtained by this method.



After a resting $O_2$ consumption was recorded, the subject would pedal 50 times per minute for 5 minutes at a 3 kp load in time to a metronome, and then rest in the sitting position for 8 minutes. Volume changes in the two wedges and an EKG were recorded continuously. Degree centigrade temperature changes were noted and recorded.

The volumes (A. T. P. S.) were corrected for temperature and pressure in conversion to S. T. P. D. according to the following table:

| Temp. °C | Sea Level | 5 psi | 7.4 psi | 3.8 psi |
|---|---|---|---|---|
| 18 | | | .4690 | .2406 |
| 19 | | | .4674 | .2398 |
| 20 | .907 | .3162 | .4658 | .2390 |
| 21 | .902 | .3152 | .4642 | .2382 |
| 22 | .898 | .3141 | .4627 | .2374 |
| 23 | .893 | .3130 | .4611 | .2365 |
| 24 | .888 | .3120 | .4595 | .2357 |
| 25 | .883 | .3109 | .4580 | .2350 |
| 26 | .879 | .3099 | .4565 | .2342 |
| 27 | .874 | .3089 | .4550 | .2334 |
| 28 | .869 | .3078 | .4534 | .2326 |
| 29 | .864 | .3068 | .4519 | .2319 |
| 30 | .859 | .3058 | .4504 | .2311 |
| 31 | .854 | .3048 | .4490 | .2303 |
| 32 | .848 | .3038 | .4475 | .2296 |
| 33 | .843 | .3028 | .4460 | .2288 |
| 34 | .839 | .3018 | .4446 | .2281 |
| 35 | .834 | .3008 | .4431 | .2273 |
| 36 | .829 | .2999 | .4417 | .2266 |
| 37 | | .2989 | .4403 | .2259 |
| 38 | | .2979 | .4389 | .2252 |
| 39 | | .2970 | .4375 | .2244 |
| 40 | | .2960 | .4361 | .2237 |

In order to establish the total oxygen cost of the work load, the resting $O_2$ consumption level times total time of the test was subtracted from the

total oxygen consumption. The total oxygen consumption minus the resting oxygen consumption represents the oxygen consumption during the work load and the oxygen debt incurred, as shown by the increase over the resting state in the post-work-load period. Ten-second heart rates and oxygen consumptions were calculated at rest, at 1, 2, 3, 4, and 5 minutes during work load and at 1, 2, and 8 minutes post-work load. Because of instrumentation malfunction during the sea level run, oxygen consumption could not be determined.

The functional residual capacity and the vital capacity were determined and the total lung capacity and residual volume calculated before and after the experimental run by the closed circuit helium dilution method.

In this method, 3 liters of air and 1 liter of 100% helium are introduced into the spirometer and an He concentration is read on the Catharometer. A liter of 100% $O_2$ is added and the subject, in the supine position, is connected to the spirometer at the end of a normal expiration. The subject rebreathes until his breathing base line crosses the He-in air base line. The helium concentration is read on the Catharometer. The subject is then instructed to do an inspiratory vital capacity and expiratory vital capacity, from which the expiratory reserve is measured.

$$\text{Instrument dead space} = \frac{\text{vol of He added}}{\text{final He concentration}} - \text{vol of He added}$$

$$FRC_{A.T.P.S.} = \frac{\text{vol of He added}}{\text{final He concentration}} - \text{vol of He added,}$$

$-$instrument dead space, $-$ 200 (standard correction factor), minus

base line correction

The standard correction factor represents an overestimation of the functional residual capacity because of some He absorption in the blood and tissue unaccounted for by instrument dead space (100-110 cc), the mouthpiece and valve (10-15 cc) and variation in He concentration as measured by thermal conductivity, since the Catharometer is affected by variation in nitrogen concentration (75 ml), and a dubious correction for R.Q. that is all rounded out to 200 ml. A base line correction is made from the spirographic tracing when the subject is not connected to the spirometer at his resting expiratory level so that

only the functional residual capacity is measured. The following data was recorded or subsequently determined from the spirographic tracing as shown in the sample calculations:

| | |
|---|---|
| Dead Space Instrument He Reading | 11.67% |
| Final He Concentration | 9.24 |
| Temperature | 23.0°C |
| He Added | 1000 cc |
| Expiratory Reserve (ER) A.T.P.S. | 1140 |
| Expiratory Reserve (ER) S.T.P.D. | 929 |
| Vital Capacity (VC) A.T.P.S. | 5120 |
| Vital Capacity (VC) S.T.P.D. | 4572 |
| Baseline Correction Factor | 0 |
| Residual Volume (RV) S.T.P.D. | 905 |
| Total Lung Capacity (TLC) S.T.P.D. | 5477 |

$$\text{Instrument Dead Space} = \frac{1000}{.1167} - 1000$$

$$FRC_{A.T.P.S.} = \frac{1000}{10,924} - 1000 - \left(\frac{1000}{.1167} - 1000\right) - 200 - 0 = 2053$$

$$FRC_{S.T.P.D.} = 2053 \times .893 = 1834 \text{ (S.T.P.D. correction factor)}$$

$$ER_{S.T.P.D.} = 1140 \times .893 = 929$$

$$VC_{S.T.P.D.} = 5120 \times .893 = 4572$$

$$RV_{S.T.P.D.} = FRC - ER = 1834 - 929 = 905$$

$$TLC_{S.T.P.D.} = RV + VC = 905 + 4572 = 5477$$

Diffusion capacity was determined before and after the experimental run by the Forster modification of the Krogh single breath-holding method for diffusion capacity.

A rapid maximal inspiration after a forced expiration of a mixture of 10.0% He, .1% CO, 21% $O_2$, and remainder $N_2$ is held for 10 seconds. An aveolar sample obtained from the expirate is analyzed for He and CO concentration. From the fractional dilution of inspired helium by the residual gas in the lung, the initial alveolar CO concentration is calculated:

$$\text{Initial alveolar } P_{CO} = \text{inspired } P_{CO} \times \frac{\%\text{ expired He}}{\%\text{ inspired He}}$$

$$D_{L_{CO}} = \text{time in seconds} \times (\text{barometric pressure} - 47)$$

$$\times \text{ natural logarithm } \frac{\text{initial CO concentration}}{\text{expired CO concentration}}$$

The helium concentration was measured by a Collins Catharometer (P-490) and the CO concentration with a Beckman Infrared Analyzer Model 15A.

The subject was placed in supine position, nose clip positioned and the mouthpiece of the Collins spirometer adjusted. An initial dry run was performed with the subject instructed to blow out all of his breath; take as deep and fast breath as he could and hold it for 10 seconds, then to blow out rapidly. An alveolar sample was collected in a rubber bag for analysis. The following data was recorded, or subsequently determined, from the spirographic tracing as shown in the sample calculations:

| | |
|---|---|
| Temperature | 22°C |
| Tank CO | .085% |
| Tank He | 10.38% |
| Final He | 7.17% |
| Final CO | .0268% |
| Time | 11.3 sec |
| $VC_{S.T.P.D.}$ | 4436 |
| $RV_{S.T.P.D.}$ | 905 |
| $TLC_{S.T.P.D.}$ | 5341 |
| DC | 31.2 |

$$Alv_{CO} = .085 \times \frac{7.17}{10.38} = .0587$$

$$DC = \frac{5341 \times 60}{713 \times 11.3} \ln \left(\frac{.0587}{.0268}\right) = 31.2$$

End expiratory samples were collected daily during the experimental run before breakfast. They were transferred out of the chamber, brought to atmospheric pressure and analyzed for $CO_2$ with the Harvard continuous $CO_2$ analyzer. The pre- and post-run samples were also analyzed for oxygen with the Beckman D II oxygen analyzer. The subjects were instructed to suck the air out of the balloon and clamp off the collapsed balloon until the end expiratory sample was exhaled into the balloon. The balloon was clamped off again and transferred out. The partial pressure of $CO_2$ was determined by deducting 47 mm Hg for water vapor from the total experimental pressure in mm Hg and then multiplying

by the experimentally determined percentage. The partial pressure of oxygen was determined by deducting $pH_2O$ and $pCO_2$ from the experimental pressure.

Due to the low environmental pressure, the $CO_2$ concentration in the expiratory sample was higher than at sea level. The Harvard instrument turned out to be unreliable for these higher concentrations, and a number of samples were lost until suitable adjustments to the method could be made. Hence, these values are not included in this Appendix.

b. Plasma Volume

Plasma volumes were determined using the Evans Blue (T-1824) procedure before and after the experimental runs, except that only the post-run determinations were made on the sea level control group. The subjects were fasting for 3 to 4 hours and resting in the supine position for several minutes. A 16 cc venous sample (Blood Sample I) was drawn and heparinized followed by the injection of 5 cc of 0.5% (25 mg) aqueous solution of Evans Blue (T-1824). The syringe was back filled with 1 cc of the subject's blood and reinjected to flush out the syringe. After 10 minutes by stop watch with the subject remaining in the supine position, 10 cc of venous blood (Blood Sample II) was drawn from the opposite arm and placed in a heparinized test tube. The subjects were probably not in a basal resting state for the blood volume determinations because an arterial puncture had to be performed prior to this procedure.

The blood samples were prepared and analyzed as follows:

A standard dye solution was prepared by diluting one vial (5 cc) T-1824 to 1 liter of distilled water.

| | |
|---|---|
| Blank | X ml of plasma from Blood Sample I - dilute to 5 cc with water. |
| Standard I (Individual) | To X ml of plasma (Blood Sample I) add one ml standard dye solution and dilute to 5 cc in the water. |
| Sample | Take X ml of plasma from Blood Sample II and dilute to 5 cc with water. |

All samples are read at 620 $\mu$ on the Bausch and Lomb Spectronic "20" colorimeter, in optically clear test tubes. The calculations for plasma volume were made as follows:

$$\text{Pl Vol} = \frac{\text{Standard I (reading)}}{\text{(number ml plasma) sample (reading)} \times 1000}$$

c. Arterials

Arterial punctures were performed before, and on the fifth and the last day of the experimental runs while still at altitude. An indwelling Cournand needle was inserted in the brachial artery under local anesthetic by experienced physicians. Two arterial samples were drawn and maintained anaerobically in mercury capped, heparinized syringes from each subject, 15 cc for analysis of $pO_2$, $pCO_2$, pH and 10 cc for $O_2$ content, $O_2$ capacity, and $CO_2$ content. After obtaining the initial room air arterial samples, the subject was given 100% $O_2$ by aviator's mask for 10 minutes and additional blood samples were drawn. The Cournand needle was left in place during the descent to sea level at the conclusion of the experimental run so that additional samples could be taken after breathing room air for 10+ minutes; with the 5 psi group, a third sample on 100% $O_2$ was drawn before the needle was removed.

In the case of the $pO_2$ measurements, blood was usually analyzed between 2 and 15 minutes after collection. It is desirable to keep this interval as short as possible, since $pO_2$ falls in stored blood, even on ice, due to the "oxygen consumption" of blood.

Measurements of $pO_2$, $pCO_2$, and pH were carried out on an Epsco Blood Parameter Analyzer with a tonometer. The $pO_2$ electrode, which depends on the polarigraph principle, was a Clark electrode and the blood in contact with it was kept stirred by a small paddle, and maintained at a temperature of 37°C. The pH and $pCO_2$ electrodes were carefully checked initially with known pH buffers and $CO_2$ gas mixtures. They were then rechecked with a known pH buffer (pH 7.38) and with a known $CO_2$ gas mixture ($pCO_2$ 28 mm) before each analysis. The $pO_2$ oxygen electrode measurements are subject to error unless the greatest care is taken. The polarigraphic principle is applied only with difficulty to whole blood.

The oxygen electrode was calibrated not only with a gas of known $pO_2$, but also with a blood of known $pO_2$. This known $pO_2$ must be close to the $pO_2$ of the arterial blood being analyzed. Three tanks containing 11.81%, 18.64%, and 32.47% oxygen in nitrogen were used. (These concentrations are the result of analysis, differing somewhat from specification.)

When saturated with water vapor at 37°C, the $pO_2$'s of these three gas mixtures are, respectively, 84 mm, 133 mm, and 232 mm. These

gas mixtures were selected to approximately match the arterial $pO_2$'s expected with normal lung function in the control sea level run, in the 100% oxygen at 3.8 psi run, in the 100% oxygen at 5 psi run, and in the 100% oxygen at 7.4 psi run.

Initially, 10 ml of venous blood was put into the tonometer situated next to the oxygen electrode in the water bath maintained at 37°C in the Epsco Blood Parameter Analyzer and equilibrated with the appropriate gas for 2 hours before the first arterial blood was collected. During this time, the tonometer blood, which could easily and simply be transferred to and from the oxygen electrode, was repeatedly transferred to the oxygen electrode and used to calibrate it, by noting when there was no further rise in blood $pO_2$ toward the value found with gas leaving the tonometer at the same $pO_2$. Thereafter, before each arterial blood was analyzed, the tonometer blood containing oxygen at a known $pO_2$ was first checked in the oxygen electrode. Thus, at all times when unknown blood was analyzed, the reading given by the electrode with blood of a known $pO_2$ was known. The reading in blood was less than that in gas with the same $pO_2$ and this difference was not constant from day to day. The difference ranged between 2% and 10% of the $pO_2$ reading in blood. In no case would the saturation derived from the $pO_2$ and pH measurements have been more than a 1% difference from the values obtained without using the blood tonometric correction factor. This is a sign of the insensitivity of saturations derived from $pO_2$ and pH measurements to errors in $pO_2$ where the saturation is high, as with this experiment. Since the electrode, when uncalibrated with tonometered blood, gives low values for $pO_2$, and since blood tonometered to a $pO_2$ of approximately 600 mm was not available, all the values while breathing 100% $O_2$ at sea level are underestimated. This is indicated by the symbol + following these values in the tables.

Oxygen content, oxygen capacity, and $CO_2$ content were analyzed with the Natelson Microgasometer. A 0.03 ml aliquot of anaerobically-maintained arterial blood is drawn into the microgasometer. This followed by drawing in caprylic alcohol, a saponinferricyanide mixture, and a mercury seal. This is shaken for 3 minutes until the brown precipitate of methemoglobin is formed. A reading is then taken on the manometer, and two successive readings are taken after shaking for an additional 2 minutes until two consecutive readings within 1 mm are obtained, indicating that the liberation of gases is complete. The last reading is $P_1$.

Following this, 0.03 ml of 3N NaOH is introduced into the microgasometer, followed by a mercury seal. This is shaken for 3 minutes and a manometer reading is taken. The reagents are shaken for another minute; an initial reading is taken and then successive readings are taken until two consecutive manometer readings are the same or within 1 mm. The brown precipitate has now dissolved into the olive-green solution of alkaline methemoglobin and the absorption of $CO_2$ is complete. The final reading is $P_2$.

Next, 0.03 ml of sodium hydrosulfite reagent is introduced into the microgasometer and shaken for 3 minutes and the pressure read on the manometer. Two successive readings are taken after the reagents have been shaken an additional 1 minute each, or until two consecutive readings are the same, or have increased 1 mm, indicating that the absorption is complete. The final reading is $P_3$. The olive-green solution of alkaline methemoglobin has now changed to the red of hemoglobin.

To analyze the arterial bloods for $O_2$ capacity, the bloods were taken from the anaerobically-maintained syringes, expelled into 10 ml Erlenmeyer flasks, which remain unstoppered, leaving the bloods exposed to room air while placed on a rotator for 25 minutes at about 60 rpm, so that the blood becomes thoroughly saturated. The flasks were then stoppered to prevent evaporation and were replaced on the rotator to insure even mixing of the samples, until the bloods were analyzed with the microgasometer using the same procedure described above for the $O_2$ content.

The samplings of the bloods were done a few at a time so that the bloods could be kept on ice until just prior to testing. All reagents used in the determinations were deaerated immediately before analysis. Sample calculations are as follows:

$O_2$ Content (vol %) = $P_2 - P_3$ x Temp Correction Factor (vol %) + 0.6

$O_2$ Capacity (vol %) = $P_2 - P_3$ x Temp Correction Factor (vol %) + 0.3

$$\% \, O_2 \text{ Saturation} = \frac{\text{Oxygen Cont}}{\text{Oxygen Cap.}}$$

Arterial whole bloods were collected and immediately introduced under a thick layer of mineral oil contained in small test tubes. The bloods were centrifuged, and an aliquot of 0.03 ml of plasma from each sample was drawn into the microgasometer, followed by lactic acid, mercury, anti-foam reagent, mercury,

low-form detergent, mercury, and then shaken for 1 minute and a manometer reading taken ($P_1$). Sodium hydroxide was added along with a mercury seal, mixed with the other reagents and a second reading taken ($P_2$). $CO_2$ content is calculated as follows:

$CO_2$ Content (mM/l) = $P_1 - P_2$ x Temp Correction Factor (mM/l).

3. Hematological Data

Hematology studies were initially scheduled to be done before, three times a week, and after the experimental run. Because of unexpected changes in the hematological status of the subjects, the frequency of some of the determinations was increased as necessary and additional studies were added where indicated. Except for the pre- and post-run examinations, the venous blood specimens were drawn by the medical student subjects in the morning before breakfast and were immediately transferred out of the chamber for analysis.

The following methods were used:

Red blood cells were counted as described in the War Department Technical Manual TM 8-227, Methods for Laboratory Technicians, 1941.

Hemoglobin was determined as cyanmethemoglobin using acuglobin standard and read on the Bausch and Lomb Spectronic colorimeter: Ortho Pharmaceutical Corp., Raritan, New Jersey.

Hematocrits in duplicate were done by the microhematocrit tube method and read on the Spiracrit chart: G. Guest and V. Silber, Journal of Laboratory and Chemical Medicine, Vol. 19, No. 7, April, 1934.

Reticulocytes were determined by counting 1000 red blood cells in various portions of a slide stained by the Brecher method using New Methylene Blue: American Journal of Clinical Pathology, Vol. 19, No. 9, September, 1949.

The mean corpuscular volume, mean corpuscular hemoglobin and mean corpuscular hemoglobin concentration were derived from the hemoglobin, red blood cell count, and hematocrit values using tables in the Manual for Clinical Laboratory Methods, by O. E. Hepler, Charles C. Thomas, Springfield, Ill., 1960.

The white blood cells were counted in accordance with procedures set forth in the War Department Technical Manual TM 8-227, Methods for Laboratory Technicians, 1941. The differentials were counted and recorded using a Marbel blood cell calculator.

Erythrocyte sedimentation rates were determined on heparinized blood in Cutler

tubes in accordance with the procedure described in the War Department Technical Manual TM 8-227, Methods for Laboratory Technicians, 1941.
van den Berghs were determined using Evelyn and Malloy's method where diazolized sulfanilic acid is coupled with bilirubin in methyl alcohol to produce a pink dye, the color of which is read with a green filter, 540$\mu$wavelength: Kolmer Applied Laboratory Technique, Appleton-Century Crafts Inc., New York, N.Y., 1951.
Icteric index was determined by dilution of sera and compared with a postasium dichromate standard, both being read in the Bausch and Lomb colorimeter: Clinical Diagnosis by Laboratory Methods, Todd-Sanford, W.B. Saunders and Co., Philadelphia, Pa., 1953.
Urinary urobilinogen was determined with Erlich's test: Kolmer, Spaulding and Robinson, Appleton-Century Crafts, Inc., New York, N.Y., 1951.
Fragility tests employing 20 tubes were done in the manner set forth in Manual for Clinical Laboratory Methods by O.E. Hepler, Charles C. Thomas, Springfield, Ill., 1960.
Fecal bloods were determined by Guaiac Test, Manual for Clinical Laboratory Methods, by O. E. Hepler, Charles C. Thomas, Springfield, Ill., 1960 and by the Hematest tablet method - a commercial preparation and method.

The routine hematological data determined by Republic were verified by Brookhaven National Laboratory, Upton, New York and the South Shore Analytical and Research Laboratory, Islip, New York on several occasions as shown in Table 1.1.1.

The average hemoglobin difference between Republic and Brookhaven was .47%; between Republic and South Shore Analytical Lab, .40%, and between Brookhaven and South Shore Analytical Lab, .47%. The smaller percentage of reticulocytes noted at Brookhaven National Lab may have been due to the length of time that the blood was at room temperature while being transported.

The hemoglobin concentrations determined at Republic were generally in good agreement with derived hemoglobin values from the experimentally determined oxygen carrying capacity of the blood.

TABLE 1.1.1

COMPARISON OF HEMATOLOGICAL DATA

| Subject Number | Lab | Rbc | Hbg | Hemat | Ret | Wbc |
|---|---|---|---|---|---|---|
| | | | Date 8/14/62 | | | |
| 42 | Republic | 5010 | 14.8 | 49 | 4.5 | 9400 |
| | Brookhaven | 5300 | 16 | 45 | 1 | 7300 |
| 43 | Republic | 4230 | 12 | 47 | 3.8 | 9450 |
| | Brookhaven | 4990 | 15.6 | 45.3 | 0.6 | 6400 |
| 44 | Republic | 4530 | 14.8 | 47 | 3.4 | 11,300 |
| | Rrookhaven | 4530 | 14.5 | 43.2 | 0.7 | 8100 |
| 45 | Republic | 4720 | 14.8 | 49 | 4.8 | 10,200 |
| | Brookhaven | 5050 | 15.1 | 46 | 0.6 | 8700 |
| 46 | Republic | 4150 | 13.47 | 44 | 3.0 | 9350 |
| | Brookhaven | 4100 | 13.1 | 38.2 | 1.1 | 5300 |
| 47 | Republic | 4120 | 14.0 | 45 | 2.6 | 7450 |
| | Brookhaven | 4660 | 13.5 | 41.4 | 0.6 | 4600 |
| | | | Date 8/20/62 | | | |
| 51 | Republic | 5510 | 15.6 | 50 | 2.1 | |
| | Brookhaven | 5140 | 15.2 | 45 | 1.6 | |
| | S. Shore | | 15.9 | 46 | | |
| 52 | Republic | 5200 | 15.6 | 51 | 2.9 | |
| | Brookhaven | 5500 | 15.9 | 46.5 | 3.0 | |
| | S. Shore | | 16.4 | 45 | | |
| 53 | Republic | 4930 | 15.2 | 46 | 2.4 | |
| | Brookhaven | 5120 | 15.3 | 45.5 | 2.3 | |
| | S. Shore | | 15.9 | 45 | | |
| 54 | Republic | 4650 | 14.3 | 47 | 2.5 | |
| | Brookhaven | 4930 | 13.5 | 43 | 1.6 | |
| | S. Shore | | 14.0 | 47 | | |
| 55 | Republic | 5100 | 14.8 | 48 | 2.3 | |
| | Brookhaven | 5010 | 14.6 | 43.5 | 2.8 | |
| | S. Shore | | 14.8 | 44 | | |
| 56 | Republic | 5500 | 15.6 | 50 | 1.9 | |
| | Brookhaven | 6040 | 16.2 | 46.0 | 2.7 | |
| | S. Shore | | 16.4 | 50 | | |

4. Biochemical Data

Sodium, potassium, and chloride electrolyte determinations were made from venous blood drawn before, six times during, and after the experimental run. During the chamber run, the medical student subjects performed the venipunctures in the morning before breakfast and prepared the specimens for transferring out.

The sodium and potassium concentrations were determined in the sera of clotted bloods with the Baird-Atomic Flamephotometer. In the indirect method, lithium is used as internal standard. To one ml of serums, 10 ml of lithium (500 ppm) were added and then diluted to 200 ml with a volumetric flask. Simultaneous readings of sodium and potassium can be read directly in meg/liter using calibration standards (Na 120, K 1; Na 140, K 5; Na 160, and K 9). Chlorides were determined by the Whitehorn's method as found in the War Department Technical Manual TM 8-227, Methods for Laboratory Technicians, 1941.

Blood sugar and blood ureas nitrogen were determined before, during, and after the experimental run. Blood sugars were done by Hadin's Modification of the Folin-Wu method as found in Clinical Diagnosis by Laboratory Methods, Todd-Sanford-Wells, W. B. Saunders and Co., Philadelphia, Pa., 1953. Blood ureas were determined by direct Nesslerization using the method of Karr (Approved Laboratory Technique by Kolmer-Spaulding-Robinson, Appleton-Century Crafts, Inc., New York, N. Y., 1961).

Urinary 17-hydroxycorticosteroids determinations were done by the South Shore Analytical and Research Laboratory, Inc., Islip, New York, an independent laboratory, on 24-hour samples collected before, in the middle, and on the last day of the experimental run using the method described by Silber-Porter in the Journal of Biological Chemistry, 1954.

5. Renal Data

Routine urinalysis including microscopic examination were done before, after, and three times weekly during the experimental run. Protein and sugar were determined using Uristik Reagent Strips supplied by Ames Company, Elkhart, Indiana. When indicated by positive microscopic findings, Heller's and Purdy's Tests for albumin were made as found in Kolmer, Spaulding, and Robinson's Approved Laboratory Technique, Appleton-Century Crafts, Inc., New York, N. Y., 1951. Additional renal studies included determinations for urinary urobilinogen and 17-hydroxycorticosteroids and blood urea nitrogen as previously described.

6. Microbiological Data

Throat and volar forearm skin swabs were taken seven times during the experimental run, once prior to entering the chamber and three times weekly thereafter. The specimens were obtained in the chamber in the morning after the subjects had arisen and before they had eaten breakfast,and were transferred out of the camber for innoculation. Morning mid-stream urine specimens were also obtained in sterile containers and transferred out. Fecal specimens were examined from each subject at the start of the experimental run and twice weekly thereafter. A walnut size specimen was placed immediately into a sterile buffered solution with a sterile applicator and kept cold but not frozen until the morning transfer procedure.

a. Procedure for Culturing Throat and Skin Swabs

The throat and skin swabs were each used to innoculate two broth tubes with media of the composition noted below (Gall's media), but without the addition of cysteine or bicarbonate. In addition, each of these swabs were smeared on two blood agar plates composed of 5% sterile blood added to Gall's agar medium without added cysteine or bicarbonate.

One set of broths and blood agar plates was incubated at 38°C aerobically, while the other set was incubated in an anaerobic jar with added $CO_2$ as described under fecal culturing procedure. Observations were made after 24 hours by making a Gram stain of each broth showing growth and each B-hemolytic colony on the blood plates.

Gall's media consists of:

1% Peptone (Difco)
1% Tryptone (Difco)
1% Beef Extract (Difco)
1% Yeast Extract (Difco)
0.1% $K_2HPO_4$
0.1%$KH_2PO_4$
0.1% Glucose

Make up to 100 ml with distilled water. Immediately before use, add aseptically 2 drops of sterile 10% sodium bicarbonate and 1 drop of 10%

cysteine-bicarbonate solution. This gives a pH of approximately 6.8 and an Eh of approximately -200 mv. Add 1.5% agar to the above when agar is needed for shakes and plates.

b. Procedure for Culturing Urine

One broth tube as described above was innoculated with urine and incubated aerobically. All tubes showing growth were examined by Gram stain.

c. Procedure for Culturing Feces (Figure A-2)

Fecal samples were taken at the start of the experiment, and twice weekly thereafter. The samples were analyzed according to the following procedure.

1) With a sterile applicator stick place a freshly eliminated fecal sample, weighing about 10 gm into 90 ml of the sterile buffered glycerol water (containing 4 drops of cysteine-$NaHCO_3$ solution placed in immediately before addition of feces) contained in a tightly sealed plastic box. Refrigerate if necessary until cultured.
2) Thoroughly mix the feces with the buffer.
3) This gives approximately a $10^{-1}$ dilution. The sample is then weighed in the tarred plastic box and a $10^{-3}$ dilution is made by aseptically placing the appropriate amount of the first dilution into 99 ml diluting fluid, which has just been gassed and had 2 drops of cysteine solution added to it.
4) Shake vigorously and mix.
5) Aseptically transfer 1 ml from the $10^{-3}$ dilution into the next dilution blank (also gassed and with cysteine solution added to it). Shake and mix thoroughly. This becomes $10^{-5}$ dilution.
6) Aseptically take 1 ml from the $10^{-5}$ dilution blank and place into a test tube containing 9 ml of Gall's media which contains 1 drop of sterile cysteine solution and 2 drops of sterile 10% sodium bicarbonate (placed aseptically in all of broth series just prior to addition of fecal samples). Mix the fecal sample with the broth by successively drawing the solution up in the pipette and gently expelling it back into the broth. This becomes the $10^{-6}$ dilution blank.
7) Aseptically take 1 ml out of the $10^{-6}$ dilution blank (broth tube) and add it to the next broth tube containing 9 ml. This becomes the $10^{-6}$ culture and is the first tube incubated. One ml is removed from that tube and placed into the next broth tube to make serial-dilutions until the $10^{-13}$ dilution is reached.
8) Place tubes in anaerobic jar which has been evacuated and filled with 10% $CO_2$ and incubate at 38°C. Observe at 16, 20,

24 hours, 48 hours and daily thereafter for growth for one week or until growth occurs.

9) Subcultures were made from top dilutions $10^{-11}$ to $10^{-13}$ of broth series into agar shakes.

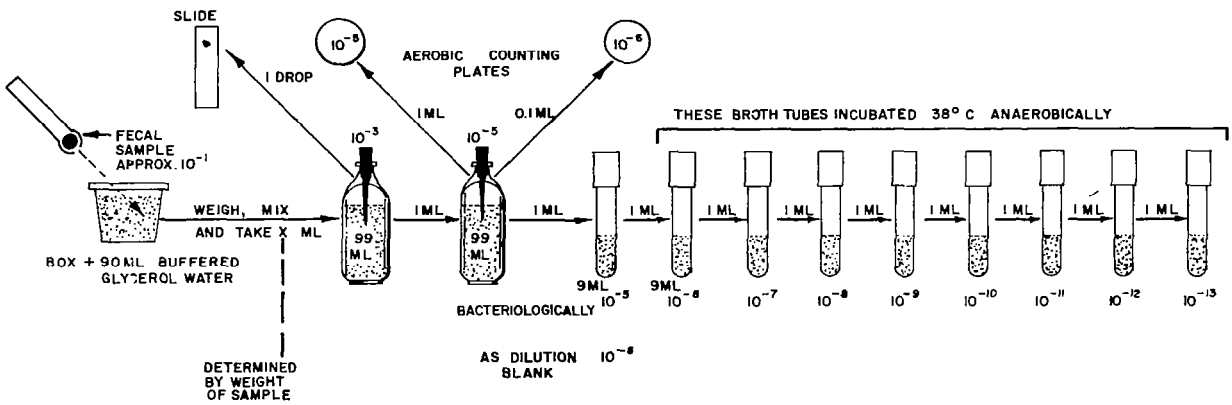



Figure A-2 Schematic Representation of Isolation Technique for Fecal Bacteria

7. Psychological Performance Data

a. Psychological Research Plan

Psychological performance data were collected according to original plans which required testing of sensory, perceptual motor, and mental performance the data before, at scheduled times during, and the day after the experimental runs. Times of administration are specified on the description for each test. All data was analyzed by means of a nested analysis of variance model[69] and, in addition, tables of intercorrelation were prepared for the mental performance data.

b. Tests

(1) Sensory Performance

A number of visual abilities, including day visual ability, night visual ability and the ability to discriminate critical flicker flash

rates, were selected to provide information on sensory performance. All sensory tests were administered, pre- and post-run, and every other day during the experimental runs.

(a) Critical Flicker Frequency Test

A square rolling table was constructed to permit testing equipment to be placed window height at the ports of the environmental chamber. On this table, a black cloth covered enclosure, 3 feet high by 3 feet square, and open at the front, was constructed.

An episcotister, with an 8 inch disc, divided into equal black and white sectors which were employed to produce stimulus flash rates in cycles per second, was placed on the table to be viewed by subjects through a chamber port. Disc rotation rate was controlled by a Variac which received 110-volt constant voltage. Speed of rotation was measured by a photoelectric system in which amplified impulses from a sensing unit were fed into a Hewlett-Packard decade counter.

Illumination was provided by eight 60-watt red-orange frosted lamps which were evenly spaced around the front perimeter of the enclosure. When the table and its enclosure was rolled up to a port of the environmental chamber it fitted against an aluminum reflector designed to exclude external illumination and reflect the light of the eight lamps (16 foot-candles total illumination) to the episcotister discs.

The test was administered to individual subjects. The subjects viewed the rotating disks at a distance of 3 feet; all subjects standing in approximately the same place. A black cloth arranged over and behind the subject excluded direct fluorescent light. Each subject was instructed to watch the 12 o'clock position on the rotating wheel and to report when he saw the stimulus flash rate change from (a) discrete to coarse, (b) coarse to fine and (c) fine to fusion, in an ascending series of stimuli presentations. A similar series was presented in the reverse order on descending presentations. Three ascending and three descending series of stimuli were presented. All subjects were trained to understand the testing procedure and requirements before actual test data was collected. Standard instructions were given the subjects each time

the test was administered. Figures A-3 and A-4 show the critical flicker frequency equipment before emplacement and in position as the subject viewed it from the chamber.

(b) Night Vision Test

The Army Night Seeing Tests (ANST) were used to collect data on night visual ability,[70, 71, 72]. The ANST-I and mesopic Brightness Contrast Test (BCT) and Line Resolution Test (LRT) plates, in cassettes adapted for use with the device, were loaned by the Personnel Research Office, OCRD, U.S. Army, for use in the experiment. Test procedure for collecting the data was in accordance with recommended procedure [73], except that when the subjects were in the chamber they were trained to place the test target plates in the cassettes provided for the ANST. However, actual administration and scoring of the test was conducted from outside the chamber. All subjects were allowed 10 minutes to dark-adapt before the tests were administered. BCT and LRT scores were recorded separately for the purposes of the present study.

(c) Day Visual Ability Test

The Bausch and Lomb Ortho-Rater and the test plates provided by the manufacturer were used to test visual performance in accordance with the recommended standard procedure [74], except that scoring of the visual acuity tests was modified. In the modified scoring, the score for the subject was the number correct minus the number wrong, the subject having been asked to read all the checkerboards, guessing if necessary. The Ortho-Rater provided test data on visual performance for the left eye, the right eye, both eyes, exophoria, esophoria, and depth perception.

(2) Perceptual Motor Performance

Three tests were used to assess the motor performance of the subjects, a differential reaction time test for measuring of decision-type reaction time, a forefinger tapping test (used as an index of fine motor control), and a ballistic aiming test measuring the accuracy and coordination of gross motor movements. The tests were administered on the day before the experiment began, during every successive day of the experiment (day number two excepted), and after the experiment.

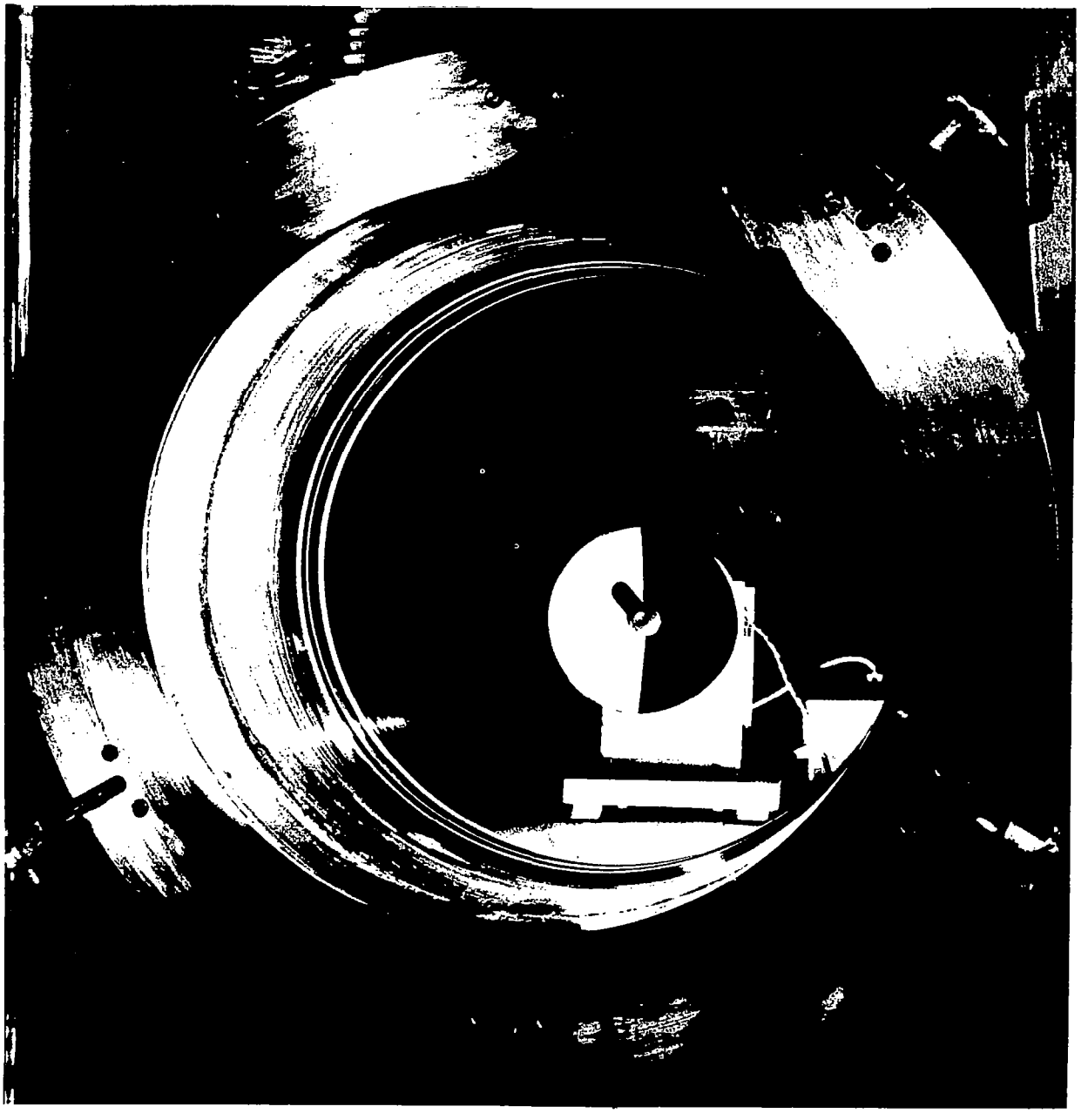


Figure A-3 Critical Flicker Frequency Equipment as Seen from Chamber

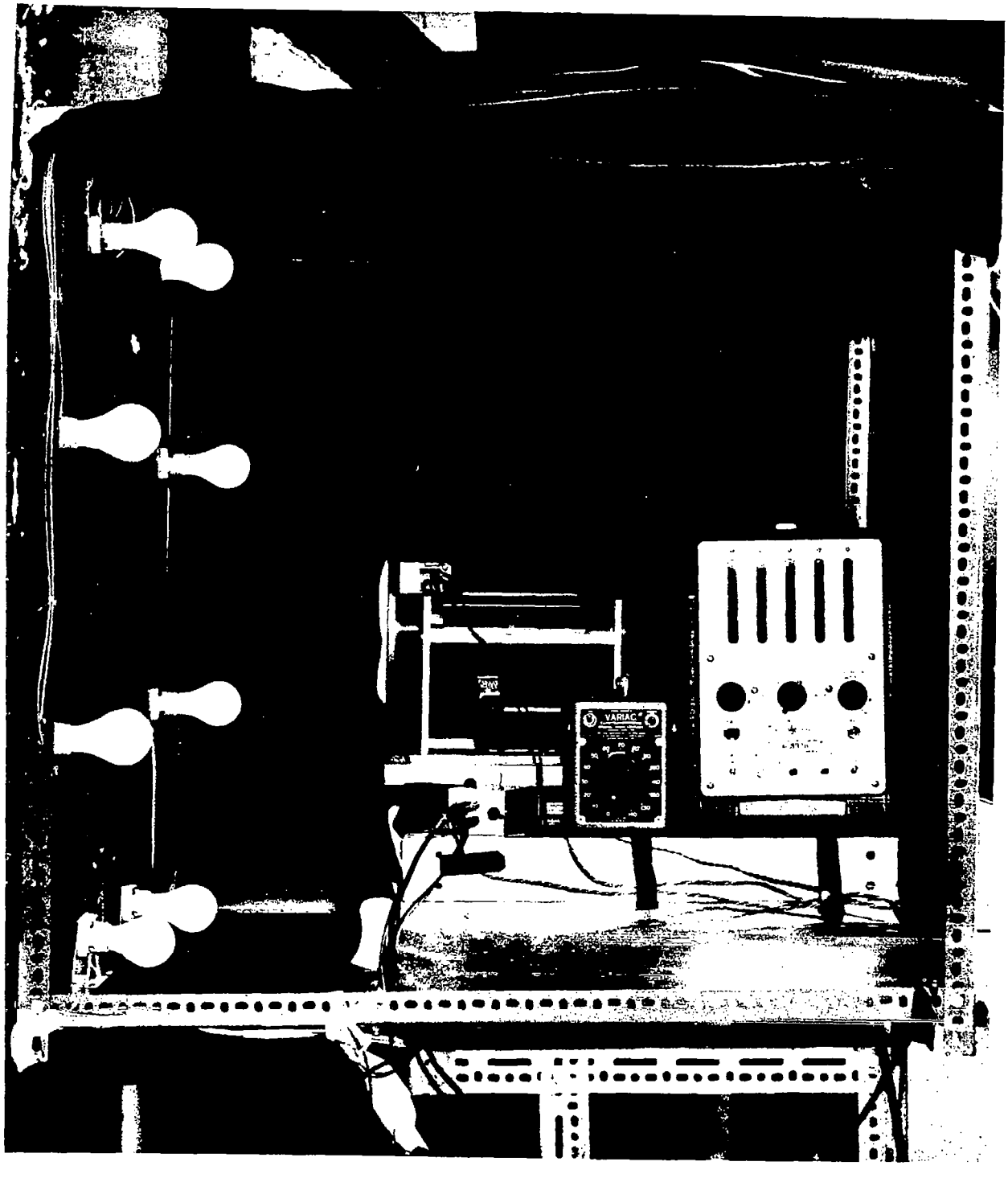



Figure A-4 Critical Flicker Frequency Equipment before Emplacement

(a) Differential Reaction Time

In this test the subject stood in front of a panel containing three stimulus lights (red, green, and white) and one response button. The subject was instructed to rest his forefinger on the response button and press it as quickly as possible when the appropriate stimulus was presented. Even though the stimulus can be a red, green or white light, or any combination of two of these, or all three of them together, the subject was instructed to respond to only the presentation of the single green light (Donder's "type C" reaction time). The stimuli were presented in random order.

Each experimental session consisted of ten trials. The experimenter signaled the subject at the onset of the trial and presented the stimuli at 1-second intervals during the trial. The trial was terminated when the subject responded to the first single green light. The presentation of the first green light was coincident with the start of a clock. The clock was stopped by the subject's response (button press). The resulting reaction time was recorded in hundredths of a second. Since the number of stimuli presented during each trial varied from one to ten, it follows that the foreperiod also varied from one to ten seconds.

(b) Tapping Test

The tapping test was the standard Whipple telegraph-key tapping test, frequently used in drug and clinical research. The subject stood with his hand resting flat on a table. He tapped a telegraph key by raising and lowering his extended index finger, while the palm, heel of the hand, and remaining extended fingers remained firmly pressed against the surface of the table. During the tapping test, flexion was permitted only at the metacarpo-phalangeal joint of the index finger. The subject was instructed to maintain the above position while tapping as rapidly as possible. The tapping of the telegraph key energizes a 12-volt General Control counter. The subject's score is the number of counts per 30-second period.

(c) Ballistic Aiming Test

To test visual tracking, accuracy of gross ballistic arm movements, and forearm-eye coordination, the classic Whipple aiming test was adapted for use with a rotary pursuit meter. The subject stood about 12 inches away from a Kornith type pursuit meter. The height of the meter

was adjusted so as to be about 8 to 12 inches below the subject's elbow. The subject's task was to hit the horizontally rotating target with a rigid metal stylus, using only a gross ballistic vertical forearm motion, with the elbow as a pivot. The subject was given the following information:

1) Grasp the wooden handle of the stylus by wrapping the fingers around the handle in a fist-like fashion.
2) Flex the forearm to its maximum vertical position so that the stylus and hand are even with the shoulder, taking care to keep the elbow and upper arm close to the body.
3) Strike at the rotating target as it comes towards you, using only vertical forearm extension.
4) Count out loud each target hit.
5) Return to the original position after each strike.

If the subject follows these instructions the vertical forearm flexion-extension angle is about 145° with a possible medial lateral rotation about the forearm joint of about 90°.

The target was a brass disc three-quarters of an inch in diameter mounted on the horizontal surface of a 12-inch diameter, 60-rpm turntable (Rek-O-Kut), at a distance of about 11 inches from the center of the turntable. Hence, the target traced a circular path, 11 inches in diameter, at a rate of one cycle per second. The subject was required to make one and only one strike during each successive cycle. The number of hits for 30 successive cycles was the subject's score.

(3) Mental Performance

The General Aptitude Test Battery of the U. S. Employment Service, The Psychomotor Performance Testing System developed by the Republic Aviation Corp., and its analog, the Paper and Pencil Analog, were used to collect information on mental performance. Data on the administration schedule are detailed in relation to the test descriptions.

(a) General Aptitude Test Battery

The General Aptitude Test Battery B-1002, Forms A and B were administered as mental test reference measures by a representative of the New York State Employment Service. Form A was used as a pre-test and on the last specific atmosphere day of each study. Form B was administered at the mid-point of each study. This battery was selected for the reference battery on the basis of the overall quality of its development and the scope of its occupational norms [75].

(b) Psychomotor Performance Testing System

1. General Description

The Republic Aviation Corporation Psychomotor Performance Testing System (PPTS) was designed to be an automated system for presenting seven tasks to a subject seated before a display panel and scoring his responses. A system built by the Lockheed Aircraft Corporation [76] provided a starting point for construction of the present system. The PPTS features improvements in display and response equipment, and highly sophisticated and integrated input of problem and output of scored responses. The input and output is entirely digital, the output is binary digital on punched paper tape, and the output is decimal digital printed on 3-inch wide paper, in most cases.

2. Tasks

Although seven tasks were to have been in operation during the experimental runs, only five actually had been constructed up to that time and not all of them had been checked out in the first two experimental runs. The five tasks used were as follows:

a. Arithmetic Computation

A display was presented consisting of nine decimal digits grouped by threes, and aligned in a row. Plus, minus and equal signs indicated that the subject was required to add the first group to the second group, subtract the third group and indicate the result on a four digit set of thumb wheels to the right of the display. The subject was scored right or wrong when he indicated completion of the problem by pressing a button below the thumbwheels. A blue light above the button flashed if the answer was correct.

b. Pattern Discrimination

Two random patterns were presented successively on a six by six matrix of yellow lights. The subject responded by moving a spring loaded switch in the direction marked "SAME" if the second pattern was the same as the first, or in the direction marked "DIFF" if the second pattern was different from the first by having one light added or subtracted. The second pattern may have been rotated 0, 90, 180, or 270 degrees with respect to the first so that the subject had first to determine the rotation before making the comparison. A blue light flashed if the response was correct. The response was scored right or wrong.

c. Scale Position Monitoring

The display included four vertically oriented scales with different units on each scale. Tolerances for each scale were displayed under the scale. Only one pointer moved at one time. If a pointer moved out of tolerance at any time the subject was scored one right if he responded, within a time interval selected by the experimenter, by moving the corresponding spring loaded switch to its out of tolerance position and then releasing it, but otherwise, was scored one wrong. If a pointer moved within tolerance and a blue light went on the score was one right for pressing a button under the light, again within the time interval, but otherwise one wrong. Finally, if a pointer moved within tolerance and there was no blue light the score was one wrong for any response and one right otherwise.

d. Auditory Vigilance

The subject was presented with a tone of approximately 1200 cps through a single headphone. The tone was normally repeated every 500 milliseconds for about 100 milliseconds. The critical signal was a delay in the onset of the tone, ranging from 100 milliseconds up to about 7 seconds. A response within 30 seconds after a critical signal was scored one right and a response at any other time was scored as one wrong. Delays of about 3 to 7 seconds occurred approximately every 5 minutes and a delay of from 100 to 1600 milliseconds occurred at a random time within the 5-minute interval.

e. Warning Lights

The display consisted of five pairs of red and green lights. The subject had to turn on any green light that went off and had to turn off any red light that went on by pressing a button under the light. The total amount of time that green lights were off or red lights were on was accumulated separately.

3. Input Program Tapes

Problem input was via an eight channel punched tape. Since the final system will have seven tasks, each task was assigned to a channel and the eighth channel was used essentially for "housekeeping."

It was possible to write a Fortran program for the RAC IBM 7090 computer system which was used to generate program tapes. The program uses a pseudo-random number technique combined with a set of parameters to produce a tape with desired characteristics. The parameters contain the desired number of presentations of each selected task, the amount of time to be allowed to solve the given type of task before another task is presented, and sets of numbers which can be used to vary the uncertainty and hence the difficulty of the tasks. The tape can be divided into segments with different parameters in each segment. Within each segment the program generates bit patterns according to the difficulty parameters, arranges the tasks in a random sequence, and places them randomly in time, subject to the restriction that they be at least the minimum specified times between presentations.

Difficulty of Arithmetic Computation can be varied by varying the probabilities that any three digit number will fall in any one of three ranges from zero to any of three different parameter numbers.

Difficulty of Pattern Discriminations can be varied by varying the probability of "SAME" or "DIFF" and by varying the probabilities of the four possible rotations.

Difficulty of Scale Position Monitoring can be varied by varying the probabilities of the following events: a blue light, a particular scale being selected, a particular combination of up or down and in or out of tolerance pointer movement.

Difficulty of Auditory Vigilance can be varied by varying the difference between the normal and the critical signal interval.

Difficulty of Warning Lights Monitoring can be varied by varying probability of a red or green light and by varying the probability of the selection of a particular pair of lights.

4. Description of Individual Tapes

A total of eight tapes was used in the experiments. Each tape was made up of eight segments of approximately 5-minute duration. At times, for various reasons, fewer than eight segments were used from some tapes. Table 3.4.1 shows the total number of presentations of each type of task and the trend across segments in difficulty and number of presentations or speed. Some tapes alternated direction of bias in the probabilities of various events as well as the uncertainty among them. Table 3.4.2 shows which tapes or tape segments were used on specific days during the experiments.

TABLE 3.4.1

PSYCHOMOTOR PERFORMANCE TESTING SYSTEM PROGRAM TAPE DIFFICULTY AND SPEED CHARACTERISTICS BY TASK PRESENTATIONS

| Tape No. and Segments (in parentheses) | TASKS: Arithmetic | Pattern Discrimination | Scale Position Monitoring | Auditory Vigilance | Warning Lights Monitoring: Red | Warning Lights Monitoring: Green |
|---|---|---|---|---|---|---|
| Tape 1 | (Increasing Difficulty and Speed) | | | | | |
| (4-7) | 21 | 16 | 22 | 8 | 12 | 17 |
| Tape 2 | (Decreasing Difficulty but Increasing Speed) | | | | | |
| (1-5) | 14 | 21 | 30 | 10 | 28 | 19 |
| (1-8) | 34 | 43 | 58 | 16 | 104 | 30 |
| Tape 3 | (Increasing Difficulty and Speed) | | | | | |
| (1-8) | 41 | 22 | 84 | 16 | 30 | 39 |
| Tape 4 | (Increasing Difficulty and Speed) | | | | | |
| (1-8) | 42 | 22 | 84 | 16 | 41 | 39 |
| Tape 5 | (Low Constant Difficulty but Increasing Speed) | | | | | |
| (1-8) | 64 | 39 | 82 | 16 | 120 | 13 |
| Tape 6 | (High Constant Difficulty but Increasing Speed) | | | | | |
| (1-8) | 40 | 30 | 72 | 16 | 15 | 95 |
| (4, 5, 7, 8) | 25 | 20 | 38 | 8 | 8 | 57 |
| Tape 7 | (Increasing difficulty, alternating bias, but very high constant speed) | | | | | |
| (1-8) | 78 | 56 | 112 | 16 | 148 | 92 |
| Tape 8 | (Increasing difficulty, alternating bias, but fairly high constant speed) | | | | | |
| (1-8) | 72 | 48 | 64 | 16 | 58 | 46 |

TABLE 3.4.2

PSYCHOMOTOR PERFORMANCE TESTING SYSTEM DAILY SCHEDULE FOR THE EXPERIMENTAL GROUPS

| Experimental Condition | Pre-Run | Days in Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sea Level | | | | | | | | | | | | | | | | |
| 3.8 psi | 2 (1-5) | | 4 | 7 | 8 | 5 | | 3 | | 2 | 4 | 7 | 3 | 8 | 5 | 6 (4,5,7,8) |
| 5.0 psi | 1 (4-7) | 2(1-5) | | | | 3 | 4 | 5 | | 6 | 2 | 1(4-7) | | | | |
| 7.4 psi | 2 (1-5) | | 4 | 7 | 8 | 5 | 1 | 3 | | | | | | | | |

Note: Numbers in parentheses are tape segment numbers when only part of the tape was presented.

(c) Paper and Pencil Analog of the Psychomotor Performance Testing System Tasks

1. General

During the planning stages for this study, a contract was let for the development and construction of a psychomotor performance testing panel. When it appeared probable that the panel would not be ready in time for this study, a paper and pencil analog was prepared incorporating the following seven item-types:

1) Arithmetic Computation
2) Pattern Comprehension
3) Scale Position Monitoring
4) Incomplete Matrices
5) Profile Discrimination
6) Vector Construction
7) Axis Intersection

2. Description of Item Types

a. Arithmetic Computation

The arithmetic computation items were direct analogs of the computational task used in the Psychomotor Performance Testing System, and hence, they were designed to provide a measure of simple computational ability.

The items were constructed by selection of digits from a table of random numbers with the restriction that no negative sums were permitted.

b. Pattern Discrimination

The proposed Psychomotor Performance Testing System was to have a six by six matrix of lights to present visual patterns for temporally successive comparison, therefore a six by six format was chosen for the analog. While successive comparison was physically possible in a paper-pencil measure, it becomes awkward to present and dubious to analyze. Therefore, simultaneous comparisons were selected. However, with simultaneous presentations, and with no precise control of viewing time per pattern, the use of simple geometric patterns would have been difficult to control. Therefore, random arrangements were chosen, both for the determination of the standard patterns and for the location of discrepancies in the comparison patterns.

As actually used, the pattern discrimination items were, essentially, a test-difficulty control. They added to total task complexity.

c. Scale Position Monitoring

The scale position monitoring item presented rectangular scales with numerical positions from 1 through 9. Each scale was divided into three sections labelled "LOW," "NORMAL" and "HIGH." A clearly identified pointer was present in each problem. The width of the three zones and the assigned position of the scale pointer were varied randomly.

The subject was instructed that when the pointer was in the "LOW" range he was to record the clock time, in hours and minutes, and record the scale position of the pointer. When the pointer was in the "NORMAL" range he was to record clock-time only. With the pointer in the "HIGH" range position he was to record clock time, and the displacement of the pointer, in scale-units, from the mid-point of the "NORMAL" range.

d. Incomplete Matrices

In the incomplete matrices problems, two by four and three by four matrices were presented with one matrix element omitted in each case. In most instances the problems required the development of a concept and some computation before solution, but in some of the simpler examples the pattern, and hence the missing element, were easily seen.

To provide a source from which many problems could be constructed systematically nine 10 by 10 master matrices were constructed. Each of the nine master matrices was generated by a different relationship between the marginal values. An equal number of 2-row and 3-row problem matrices were constructed using the following procedure: First, the order in which the master matrices were to be sampled was determined by references to tables of random numbers. Then, again by random numbers, the rows in the chosen master matrix to be sampled were chosen, and finally, the columns were similarly determined. There was one restraint applied to both row and column selection; they were selected in order of increasing magnitude.

e. Profile Discrimination

The item consisted of a rectangular field of F's, 51 characters per row, 26 rows, single spaced, with one E in each row. The subject was required to circle the E in the first row and draw a continuous line from that circle to the E in the second row, from the second to the third, etc. This item type is viewed as a discrimination-tracking task, i.e., an eye-hand coordination problem in which the target location must be discriminated in a relatively homogeneous field, and a trace must be made from the last target position to the new target location.

f. Vector Construction

Vector construction items were developed to measure alertness, and to a lesser degree, both eye-hand coordination and visualization. Each item was composed of a 4-inch square with scale notations on two axes. The scale notations were varied from problem to problem by systematic variations in the marginal scales. These variations could be achieved through reversal of one or both scales in successive problems and/or change of scale origin or units. Two sets of point-coordinates were provided for each problem and the subject was required to construct a free-hand vector from the first defined point to the second. An error score was obtained by summing the measured discrepancy of each constructed point from the specified point location. Errors for each point were measured separately for the horizontal and vertical dimensions, rather than rms, and summed for the error score.

g. Axis Intersection

A rectangular typed field provided the row material for the axis intersection problem type. A field* of lower-case O's was displayed in which two sets of three lower-case e's were embedded. Each set of e's was arranged in a straight line. The two lines of e's intersected within the field, but no other restraint was imposed on them, that is, neither line was required to maintain any particular relationship either to a side of the field or to the other line. The subject was required to VISUALIZE the two lines and their point of intersection, then to draw a vector with its origin at the point of intersection of the two defined lines and its termination at the midpoint of the field. No supporting "construction" lines were permitted.

The axis intersection problem was designed to be a complex visualization-coordination problem. In constructing the specific items two requirements had to be met; an equal number of line intersections were to appear in each quadrant; each line had to be so located that three typed characters fell along a straight line.

h. Total Time

These tests were administered under the personal supervision of a test administrator who recorded the total time required. Time was measured to the nearest quarter of a minute. In addition, a total-time measure was built into the test as the difference between starting time, and the time recorded for the last item, a scale-position monitoring item, but the externally observed and recorded score was found to be the more accurate of the two measures.

i. Alternate Test Forms

Nine forms of the paper and pencil analog were prepared to permit enough different presentations of the same type of material without giving training on specific item content. To minimize inadvertent bias on the part of the test constructor, heavy reliance was placed on tables of random numbers throughout the construction of the nine forms as a means for generating item characteristics.

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* The initial field was a square of 51 characters wide by 26 characters high. Use of other typewriters on later forms introduced some variation from the initial square field.

Organization of the items was a joint function of the number of items of various types which could be combined and typed on one page and the desire to maintain a balanced presentation of items. Each form, as finally constructed, had approximately eight cycles of item-types, and a total of 78 items.

j. Order of Presentation

Table 3.4.3 shows the order in which the alternate forms which had been prepared for the PPA were administered. It is to be noted that the 10 series forms were identical with their unit-series numbered counterparts except for the cover sheet. Thus in the administration of the test, no attempt was made to conceal that these (10 series) were re-administrations, but no particular attention was brought to the fact. The table also shows the order in which the GATB forms were administered.

TABLE 3.4.3

PAPER AND PENCIL ANALOG AND GENERAL APTITUDE TEST BATTERY DATA COLLECTION SCHEDULE

| Day of Week | Day in Chamber | Mental Test Form No. |
|---|---|---|
| Monday | Pre-Run | PPA-1 |
| Tuesday | 1 | GATB (A-1) |
| Wednesday | 2 | PPA-2 |
| Thursday | 3 | PPA-3 |
| Friday | 4 | PPA-4 |
| Saturday | 5 | PPA-5 |
| Sunday | 6 | PPA-8 |
| Monday | 7 | PPA-9 |
| Tuesday | 8 | GATB (B) |
| Wednesday | 9 | PPA-11 |
| Thursday | 10 | PPA-12 |
| Friday | 11 | PPA-13 |
| Saturday | 12 | PPA-6 |
| Sunday | 13 | PPA-14 |
| Monday | 14 | PPA-15/GATB (A-2) |
| Tuesday | Post-run | PPA-18 |

## B. TABULAR DATA

### 1. Medical Data

TABLE 1.1.2

VITAL SIGNS

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sea Level | | | | | | | | | | | | | | | | | | |
| Temp | AM | 11 | 98.0 | | 97.6 | 97.2 | 97.4 | 96.6 | 98.0 | 97.6 | 98.4 | 96.8 | 97.8 | 96.8 | 96.8 | 97.2 | 96.8 | 98.6 |
| | PM | | | 98.6 | 98.6 | 98.4 | 98.2 | 97.8 | 97.8 | 97.6 | 97.8 | 97.8 | 98.6 | 98.2 | 98.4 | 98.2 | 97.8 | |
| Pulse | AM | | 78 | | 56 | 72 | 68 | 52 | 68 | 56 | 68 | 64 | 52 | 60 | 60 | 68 | 72 | 64 |
| | PM | | | 60 | 68 | 68 | 72 | 80 | 72 | 68 | 72 | 72 | 64 | 80 | 72 | 72 | 76 | |
| Resp. | AM | | 16 | | 20 | 20 | 20 | 24 | 24 | 20 | 20 | 20 | 18 | 18 | 18 | 20 | 20 | 16 |
| | PM | | | 16 | 20 | 20 | 24 | 24 | 24 | 20 | 20 | 20 | 20 | 24 | 18 | 18 | 18 | |
| B.P. | AM | | 135/68 | | 135/85 | 135/75 | 128/68 | 128/68 | 125/90 | 120/60 | 135/70 | 130/70 | 126/78 | 130/70 | 130/75 | 125/75 | 140/60 | 150/80 |
| | PM | | | 140/85 | 130/55 | 130/65 | 126/60 | 125/65 | 135/70 | 130/70 | 120/60 | 125/70 | 130/60 | 115/55 | 120/75 | 125/65 | 130/70 | |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 12 | 98.6 | | 97.2 | 97.2 | 97.2 | 97.0 | 97.0 | 96.8 | 97.0 | 97.0 | 96.8 | 96.8 | 97.8 | 97.4 | 97.0 | |
| | PM | | | 98.6 | 98.4 | 98.8 | 97.2 | 97.0 | 97.2 | 98.2 | 98.0 | 98.0 | 98.8 | 98.4 | 98.0 | 98.8 | 98.8 | |
| Pulse | AM | | 64 | | 80 | 68 | 72 | 68 | 80 | 78 | 76 | 64 | 72 | 72 | 72 | 60 | 80 | |
| | PM | | | 64 | 60 | 76 | 80 | 88 | 72 | 80 | 76 | 88 | 92 | 88 | 80 | 80 | 84 | |
| Resp. | AM | | 16 | | 20 | 16 | 16 | 20 | 16 | 20 | 16 | 16 | 20 | 18 | 16 | 20 | 20 | |
| | PM | | | 16 | 16 | 20 | 20 | 16 | 16 | 20 | 20 | 20 | 16 | 16 | 18 | 20 | 16 | |
| B.P. | AM | | 140/85 | | 145/85 | 148/70 | 148/78 | 130/86 | 134/94 | 132/90 | 134/90 | 130/76 | 128/68 | 146/86 | 178/72 | 134/74 | 144/84 | |
| | PM | | | 140/100 | 144/80 | 134/78 | 154/72 | 160/98 | 138/78 | 142/74 | 132/80 | 130/78 | 144/74 | 138/80 | 144/74 | 145/85 | 134/70 | |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 13 | 98.6 | | 96.2 | 97.2 | 96.8 | 98.0 | 97.0 | 96.8 | 97.0 | 97.4 | 98.0 | 97.4 | 98.2 | 99.4 | 97.0 | 98.6 |
| | PM | | | 97.4 | 98.2 | 98.8 | | 97.8 | 98.0 | 97.8 | 98.0 | 98.8 | 98.2 | 98.0 | 97.8 | 97.6 | 97.6 | |
| Pulse | AM | | 98 | | 64 | 64 | 60 | 60 | 52 | 56 | 60 | 60 | 64 | 60 | 60 | 60 | 60 | 84 |
| | PM | | | 68 | 72 | 68 | 80 | 56 | 80 | 72 | 76 | 80 | 76 | 60 | 64 | 68 | 68 | |
| Resp. | AM | | 16 | | 20 | 18 | 18 | 18 | 20 | 20 | 20 | 20 | 16 | 20 | 18 | 20 | 20 | 16 |
| | PM | | | 27 | 20 | 20 | 24 | 22 | 20 | 22 | 16 | 20 | 20 | 18 | 20 | 16 | 20 | |
| B.P. | AM | | 110/70 | | 120/90 | 128/74 | 156/76 | 130/72 | 120/60 | 120/66 | 120/64 | 114/70 | 120/70 | 116/64 | 115/74 | 126/76 | 126/84 | 112/70 |
| | PM | | | 110/60 | 115/65 | 120/70 | 132/68 | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 15 | 97.6 | | 97.0 | 96.4 | 97.4 | 97.4 | 97.2 | 97.4 | 97.4 | 98.2 | 97.8 | 97.8 | 98.4 | 97.2 | 98 | 99.4 |
| | PM | | | 97.5 | 98.0 | 98.2 | 98.0 | 98.4 | 97.8 | 98.4 | 98.4 | 98.4 | 98.4 | 98.4 | 98.4 | 98.4 | | |
| Pulse | AM | | 52 | | 48 | 44 | 44 | 44 | 48 | 48 | 44 | 44 | 44 | 44 | 80 | 56 | 44 | 76 |
| | PM | | | 56 | 52 | 60 | 56 | 60 | 52 | 64 | 60 | 60 | 60 | 56 | 60 | 52 | 56 | |
| Resp. | AM | | 18 | | 20 | 24 | 20 | 20 | 20 | 18 | 18 | 18 | 18 | 16 | 20 | 16 | 18 | 16 |
| | PM | | | 25 | 24 | 20 | 25 | 20 | 18 | 20 | 20 | 20 | 16 | 20 | 16 | 16 | 16 | |
| B.P. | AM | | 126/65 | | 138/76 | 138/78 | 148/80 | 130/56 | 126/58 | 124/60 | 110/60 | 112/58 | 116/60 | 110/64 | 105/60 | 110/55 | 115/58 | 130/78 |
| | PM | | | 105/50 | 132/54 | 110/55 | 122/56 | 125/65 | 125/55 | 136/78 | 126/68 | 110/55 | 115/55 | 110/55 | 112/60 | 126/60 | 115/56 | |

TABLE 1.1.2 (Cont)

VITAL SIGNS

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp | AM | 16 | 97 | | 97.6 | 96.8 | 97.0 | 97.6 | 97.8 | 96.8 | 97.0 | 97.0 | 96.2 | 96.4 | 98.4 | 97.6 | 97.0 | |
| | PM | | | 98.6 | 98.0 | 98.4 | 98.0 | 97.0 | 97.4 | 97.2 | 98 | 98.4 | 98.8 | 96.6 | 97.4 | 98.2 | 99.2 | |
| Pulse | AM | | 76 | | 60 | 56 | 52 | 64 | 64 | 60 | 64 | 64 | 60 | 60 | 48 | 60 | 68 | 84 |
| | PM | | | 60 | 68 | 72 | 76 | 80 | 80 | 68 | 80 | 64 | 68 | 72 | 76 | 72 | 84 | |
| Resp. | AM | | 16 | | 20 | 20 | 20 | 20 | 16 | 16 | 16 | 16 | 25 | 16 | 20 | 16 | 16 | 16 |
| | PM | | | 15 | 20 | 20 | 18 | 20 | 20 | 20 | 20 | 16 | 16 | 16 | 18 | 20 | 16 | |
| B.P. | AM | | 124/70 | | 158/104 | 145/105 | 150/100 | 124/75 | 140/75 | 148/80 | 148/98 | 146/96 | 140/80 | 164/96 | 144/88 | 145/80 | 138/76 | 138/80 |
| | PM | | | 142/92 | 158/94 | 166/76 | 162/82 | 145/80 | 140/70 | 138/76 | 140/85 | 138/80 | 160/86 | 140/75 | 135/70 | 160/80 | 165/90 | |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 17 | 98.4 | | 96.8 | 97.6 | 97.0 | 97.8 | 97.6 | 97.4 | 96.6 | 97.6 | 97.2 | 96.4 | 97.6 | 97.8 | 96.6 | 98.2 |
| | PM | | | 97.9 | 98.2 | 98.4 | 98.2 | 98.2 | 98.6 | 98.4 | 98.6 | 98.2 | 98.2 | 98.6 | 98.2 | 98.4 | 98.2 | |
| Pulse | AM | | 88 | | 60 | 60 | 56 | 60 | 60 | 72 | 52 | 48 | 64 | 48 | 60 | 56 | 60 | 68 |
| | PM | | | 60 | 60 | 76 | 80 | 68 | 68 | 68 | 68 | 60 | 72 | 68 | 64 | 68 | 68 | |
| Resp. | AM | | 16 | | 16 | 16 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 24 | 20 | 24 | 16 |
| | PM | | | 28 | 20 | 16 | 24 | 20 | 20 | 20 | 24 | 24 | 24 | 24 | 24 | 20 | 24 | |
| B.P. | AM | | 122/70 | | 130/80 | 132/72 | 142/78 | 118/68 | 120/74 | 130/78 | 124/74 | 118/72 | 125/80 | 122/72 | 124/73 | 120/70 | 125/75 | 125/80 |
| | PM | | | 126/74 | 136/76 | 116/60 | 170/66 | 115/65 | 120/70 | 130/72 | 126/74 | 130/72 | 130/70 | 130/70 | 120/70 | 138/88 | 118/66 | |
| 5 psi | | | | | | | | | | | | | | | | | | |
| Temp | AM | 31 | 98 | 96.2 | 97 | 95.8 | 97.0 | 97.0 | 97.6 | 96.4 | 96.6 | 97.2 | 97.2 | 97.4 | 96.6 | 97.2 | 96.8 | 97.2 |
| | PM | | | | | 97.0 | 97.0 | 96.6 | 97.8 | 97.2 | 97.2 | 97.2 | 97.4 | 97.2 | 97.8 | 97 | 97 | 98.8 |
| Pulse | AM | | 96 | 68 | 78 | 62 | 68 | 60 | 75 | 64 | 69 | 68 | 68 | 68 | 90 | 68 | 76 | 68 |
| | PM | | | | | 64 | 70 | 64 | 84 | 75 | 78 | 72 | 74 | 68 | 88 | 78 | 80 | 64 |
| Resp. | AM | | 18 | 18 | 16 | 16 | 18 | 16 | 14 | 16 | 16 | 16 | 16 | 16 | 18 | 16 | 16 | 16 |
| | PM | | | | | 16 | 18 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 18 |
| B.P. | AM | | 128/90 | 126/73 | 130/77 | 120/80 | 122/67 | 118/76 | 132/64 | 128/74 | 118/55 | 124/80 | 122/66 | 124/68 | 108/56 | 122/66 | 114/58 | 115/78 |
| | PM | | | | | 118/62 | 130/72 | 134/86 | 136/72 | 124/72 | 124/66 | 118/64 | 130/66 | 120/50 | 116/65 | 130/60 | 116/58 | 130/85 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 32 | 98.4 | 97.4 | 96.9 | 96.6 | 97.2 | 96.4 | 97.0 | 97.2 | 97.0 | 98.0 | 96.6 | 97.6 | 96.6 | 96.6 | 96.4 | 96.6 |
| | PM | | | | | 98.4 | 97.8 | 97.8 | 98.2 | 98.4 | 97.6 | 98.0 | 98.0 | 97.6 | 97.6 | 98.6 | 98.0 | 98.6 |
| Pulse | AM | | 100 | 80 | 84 | 68 | 84 | 64 | 72 | 72 | 80 | 68 | 76 | 84 | 80 | 74 | 84 | 84 |
| | PM | | | | | 80 | 84 | 80 | 88 | 80 | 86 | 64 | 80 | 80 | 76 | 80 | 88 | 76 |
| Resp. | AM | | 20 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 18 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | PM | | | | | 16 | 16 | 16 | 17 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 20 |
| B.P. | AM | | 112/80 | 118/72 | 108/70 | 118/78 | 122/70 | 124/74 | 120/62 | 116/72 | 118/60 | 112/66 | 118/60 | 116/56 | 110/58 | 104/54 | 112/56 | 116/62 |
| | PM | | | | | 118/62 | 120/64 | 128/68 | 108/62 | 106/60 | 126/68 | 118/64 | 118/64 | 114/62 | 114/64 | 100/50 | 118/56 | 110/75 |

TABLE 1.1.2 (Cont)

VITAL SIGNS

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp | AM | 33 | 98.0 | 97.6 | 96.9 | 96.0 | 97.0 | 96.0 | 97.4 | 96.2 | 97.2 | 97.4 | 97.6 | 97.8 | 97.0 | 97.2 | 96.6 | 97.0 |
| | PM | | | | | 98.3 | 97.0 | 97.8 | 97.4 | 97.4 | 98.2 | 98.2 | 97.6 | 97.6 | 97.4 | 98.6 | 98 | 97.6 |
| Pulse | AM | | 72 | 60 | 56 | 80 | 64 | 64 | 72 | 60 | 62 | 68 | 80 | 80 | 68 | 64 | 80 | 60 |
| | PM | | | | | 88 | 68 | 68 | 72 | 58 | 76 | 76 | 72 | 80 | 78 | 68 | 80 | 68 |
| Resp. | AM | | 18 | 24 | 24 | 19 | 18 | 14 | 20 | 20 | 20 | 16 | 20 | 20 | 20 | 16 | 16 | 16 |
| | PM | | | | | 24 | 20 | 20 | 20 | 20 | 20 | 16 | 20 | 20 | 20 | 20 | 16 | 18 |
| B.P. | AM | | 128/75 | 120/73 | 126/76 | 124/68 | 120/67 | 132/62 | 128/57 | 124/60 | 124/62 | 127/80 | 126/56 | 112/58 | 114/52 | 102/52 | 108/55 | 120/54 |
| | PM | | | | | 128/56 | 118/68 | 126/64 | 128/52 | 186/58 | 124/57 | 122/56 | 115/57 | 122/54 | 118/56 | 108/58 | 120/52 | 125/75 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 35 | 98.2 | 97.6 | 98.2 | 97.2 | 97.8 | 97.0 | 96.4 | 97 | 97.4 | 97 | 96.5 | 97.4 | 97.0 | 98.0 | 96.8 | 97.4 |
| | PM | | | | | 97.8 | 98.0 | 98.4 | 97.8 | 98.5 | 98.2 | 97.8 | 97.6 | 98 | 97.6 | 98.2 | 97.8 | |
| Pulse | AM | | 80 | 76 | 64 | 64 | 64 | 52 | 76 | 80 | 68 | 80 | 72 | 68 | 78 | 72 | 72 | 84 |
| | PM | | | | | 80 | 80 | 78 | 80 | 77 | 64 | 80 | 62 | 64 | 72 | 72 | 84 | |
| Resp. | AM | | 18 | 18 | 16 | 14 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 20 | 16 | 20 | 16 | 16 |
| | PM | | | | | 16 | 16 | 16 | 18 | 16 | 16 | 18 | 14 | 16 | 16 | 16 | 16 | |
| B.P. | AM | | 120/75 | 113/68 | 104/65 | 116/62 | 110/64 | 122/62 | 132/53 | 118/60 | 108/57 | 100/60 | 104/52 | 108/58 | 108/58 | 103/50 | 103/60 | 112/52 |
| | PM | | | | | 112/62 | 118/52 | 132/58 | 118/52 | 110/54 | 128/50 | 110/62 | 116/55 | 104/47 | 112/62 | 108/40 | 118/48 | |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 36 | 97.8 | 97 | 97.4 | 97.4 | 97.4 | 96.8 | 98.2 | 97.0 | 97.4 | 96.8 | 97.8 | 97.0 | 96.6 | 96.4 | 96.2 | 96.8 |
| | PM | | | | | 96.8 | 96.0 | 98.2 | 98.0 | 98.2 | 98.2 | 98.0 | 98.2 | 98.0 | 97.6 | 96.4 | 97.4 | 97.2 |
| Pulse | AM | | 80 | 84 | 72 | 68 | 80 | 76 | 76 | 66 | 84 | 76 | 72 | 76 | 76 | 76 | 80 | 84 |
| | PM | | | | | 80 | 72 | 78 | 72 | 72 | 60 | 76 | 76 | 80 | 80 | 76 | 88 | 72 |
| Resp. | AM | | 20 | 27 | 16 | 14 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | PM | | | | | 20 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 20 | 18 |
| B.P. | AM | | 120/75 | 112/68 | 128/78 | 144/78 | 148/60 | 150/75 | 150/60 | 130/64 | 143/57 | 122/78 | 118/54 | 118/76 | 124/54 | 118/52 | 118/64 | 122/53 |
| | PM | | | | | 136/76 | 122/66 | 162/70 | 118/58 | 128/62 | 132/43 | 120/60 | 112/58 | 130/50 | 126/60 | 122/57 | 128/42 | 130/90 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 37 | 98.6 | 97.2 | 97.2 | 97.0 | 97.0 | 95.8 | 98 | 98 | 97.6 | 97.1 | 98.4 | 97.0 | 97.0 | 97.0 | 97.0 | 97 |
| | PM | | | | | 97.8 | 97.2 | 97.6 | 98.2 | 98 | 97.6 | 98.2 | 98.4 | 98.2 | 97.4 | 98.6 | 97.8 | 97.2 |
| Pulse | AM | | 72 | 70 | 64 | 58 | 80 | 60 | 88 | 60 | 92 | 80 | 76 | 76 | 62 | 68 | 60 | 72 |
| | PM | | | | | 72 | 80 | 76 | 84 | 80 | 88 | 88 | 78 | 76 | 72 | 60 | 84 | 60 |
| Resp. | AM | | 20 | 14 | 20 | 16 | 18 | 18 | 18 | 16 | 22 | 20 | 18 | 18 | 20 | 18 | 18 | 18 |
| | PM | | | | | 20 | 18 | 18 | 18 | 18 | 22 | 20 | 18 | 18 | 16 | 18 | 20 | 18 |
| B.P. | AM | | 130/80 | 116/68 | 122/68 | 116/68 | 120/68 | 118/68 | 118/64 | 128/67 | 118/60 | 108/66 | 110/62 | 122/64 | 122/52 | 100/58 | 112/52 | 112/50 |
| | PM | | | | | 122/54 | 126/68 | 118/60 | 162/62 | 124/64 | 124/66 | 108/62 | 118/60 | 120/54 | 120/55 | 112/50 | 118/48 | 126/76 |
| | | | | | | | | | | | | | | | | | | |

TABLE 1.1.2 (Cont)

VITAL SIGNS

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.4 psi | | | | | | | | | | | | | | | | | | |
| Temp | AM | 42 | 98.2 | 98 | 98.0 | 98.2 | 97.8 | 97.8 | 97.0 | 97.0 | 97.8 | 97.8 | 97.4 | 97.4 | 97.0 | 98.2 | 97.8 | 97.8 |
| | PM | | | | 98.4 | 97.4 | 97.8 | 98.4 | 98 | 97.2 | 97.4 | 98.4 | 98.4 | 98.2 | 98.8 | 97.8 | 98.0 | 97.8 |
| Pulse | AM | | 64 | 74 | 74 | 64 | 72 | 58 | 62 | 62 | 64 | 62 | 64 | 50 | 58 | 66 | 66 | 62 |
| | PM | | | | 70 | 66 | 66 | 64 | 62 | 52 | 58 | 64 | 58 | 60 | 58 | 62 | 68 | 80 |
| Resp | AM | | 18 | 16 | 16 | 16 | 15 | 16 | 14 | 16 | 16 | 14 | 16 | 14 | 14 | 14 | 16 | 14 |
| | PM | | | | 18 | 16 | 18 | 16 | 16 | 20 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 18 |
| B.P. | AM | | 122/82 | 104/89 | 104/89 | 115/80 | 112/78 | 108/74 | 104/70 | 106/80 | 112/72 | 120/72 | 116/80 | 100/70 | 106/68 | 114/84 | 116/84 | 114/80 |
| | PM | | | | 98/88 | 112/74 | 106/70 | 110/66 | 112/80 | 120/74 | 104/66 | 120/72 | 108/78 | 116/76 | 108/80 | 114/78 | 118/82 | 135/85 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 43 | 98.4 | 97.4 | 97.4 | 98.0 | 98.8 | 97.6 | 98.6 | 97.0 | 98.0 | 97 | 97.4 | 97.4 | 97.0 | 97.6 | 97.0 | 96.8 |
| | PM | | | | 98.6 | 99.0 | 99.6 | 98.0 | 98.0 | 98.0 | 97.8 | 97.4 | 98.2 | 98.0 | 98.0 | 98.0 | 98.0 | 98.6 |
| Pulse | AM | | 64 | 64 | 64 | 62 | 70 | 78 | 56 | 54 | 60 | 54 | 62 | 52 | 56 | 56 | 58 | 54 |
| | PM | | | | 62 | 64 | 54 | 62 | 62 | 64 | 62 | 64 | 58 | 56 | 50 | 58 | 62 | 96 |
| Resp | AM | | 18 | 22 | 22 | 16 | 20 | 21 | 16 | 22 | 21 | 22 | 22 | 22 | 19 | 26 | 22 | 22 |
| | PM | | | | 24 | 20 | 12 | 18 | 18 | 22 | 26 | 22 | 22 | 20 | 24 | 20 | 14 | 20 |
| B.P. | AM | | 130/80 | 118/72 | 98/72 | 110/74 | 118/72 | 110/70 | 120/60 | 106/76 | 102/76 | 106/60 | 112/68 | 108/76 | 104/66 | 110/62 | 100/68 | 112/76 |
| | PM | | | | 100/89 | 112/76 | 142/80 | 102/60 | 110/70 | 118/70 | 110/82 | 108/76 | 110/66 | 104/66 | 104/64 | 98/62 | 105/68 | 130/85 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 44 | 98.4 | 97.3 | 97.4 | 97.2 | 97.4 | 98.8 | 97.4 | 97.2 | 97.6 | 97.0 | 97.2 | 97.6 | 96.8 | 97.4 | 96.8 | 96.8 |
| | PM | | | | 98.2 | 98.8 | 98.8 | 98.6 | 97.6 | 99.0 | 98.6 | 98.4 | 98.4 | 97.8 | 98.6 | 98.6 | 97.8 | 97.4 |
| Pulse | AM | | 68 | 54 | 54 | 60 | 74 | 50 | 60 | 58 | 60 | 60 | 56 | 52 | 52 | 54 | 54 | 56 |
| | PM | | | | 54 | 64 | 60 | 72 | 72 | 68 | 72 | 52 | 58 | 60 | 58 | 50 | 48 | 84 |
| Resp | AM | | 18 | 18 | 18 | 20 | 16 | 16 | 14 | 18 | 16 | 16 | 18 | 16 | 18 | 16 | 16 | 16 |
| | PM | | | | 22 | 20 | 18 | 22 | 20 | 22 | 22 | 18 | 22 | 22 | 20 | 24 | 20 | 18 |
| B.P. | AM | | 112/78 | 100/80 | 100/80 | 100/80 | 100/70 | 104/80 | 98/70 | 100/74 | 104/76 | 106/70 | 98/78 | 94/70 | 100/70 | 96/72 | 96/76 | 96/74 |
| | PM | | | | 105/84 | 104/82 | 110/70 | 108/75 | 100/72 | 105/68 | 100/70 | 102/70 | 100/74 | 102/72 | 98/66 | 96/70 | 96/60 | 130/95 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 45 | 98.4 | 97.6 | 97.6 | 98.0 | 97.2 | 97.4 | 97.4 | 98 | 97.8 | 96.8 | 97.4 | 98.0 | 97 | 97.6 | 97.4 | 97.4 |
| | PM | | | | 99.0 | 98.8 | 98.8 | 98.0 | 98.2 | 98.2 | 97.6 | 98.4 | 98.6 | 98.0 | 98.8 | 97.6 | 98.6 | 98.6 |
| Pulse | AM | | 60 | 62 | 62 | 46 | 62 | 72 | 60 | 58 | 70 | 54 | 66 | 64 | 60 | 62 | 68 | 60 |
| | PM | | | | 64 | 64 | 52 | 64 | 62 | 64 | 62 | 62 | 64 | 60 | 72 | 60 | 64 | 68 |
| Resp | AM | | 18 | 14 | 14 | 16 | 14 | 18 | 14 | 19 | 16 | 18 | 16 | 15 | 14 | 16 | 17 | 22 |
| | PM | | | | 20 | 20 | 18 | 16 | 18 | 20 | 16 | 16 | 16 | 20 | 16 | 19 | 20 | 20 |
| B.P. | AM | | 125/88 | 100/80 | 100/80 | 104/84 | 112/80 | 110/80 | 116/78 | 106/74 | 104/66 | 108/70 | 116/78 | 104/64 | 106/78 | 110/76 | 110/70 | 108/82 |
| | PM | | | | 100/65 | 120/78 | 104/60 | 120/80 | 116/72 | 112/88 | 120/80 | 120/80 | 110/74 | 102/68 | 120/76 | 116/76 | 118/78 | 122/88 |

TABLE 1.1.2 (Cont)

VITAL SIGNS

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp | AM | 46 | 99.2 | 97.8 | 97.8 | 97.6 | 97.6 | 98.6 | 98.4 | 97.6 | 97.8 | 97.0 | 97.2 | 97.6 | 97.0 | 96.8 | 97.4 | 96.4 |
| | PM | | | | 98.6 | 98.0 | 98.6 | 98.0 | 98.0 | 98 | 98.6 | 98.4 | 98.6 | 98.0 | 98.4 | 97.6 | 98.0 | 98.0 |
| Pulse | AM | | 92 | 76 | 74 | 72 | 62 | 66 | 60 | 62 | 58 | 70 | 82 | 64 | 76 | 66 | 72 | 60 |
| | PM | | | | 76 | 80 | 70 | 72 | 80 | 72 | 86 | 78 | 81 | 76 | 78 | 78 | 76 | 92 |
| Resp | AM | | 18 | 18 | 18 | 18 | 20 | 17 | 16 | 12 | 16 | 18 | 14 | 16 | 16 | 16 | 16 | 16 |
| | PM | | | | 16 | 21 | 16 | 16 | 16 | 14 | 21 | 18 | 16 | 20 | 20 | 21 | 20 | 18 |
| B.P. | AM | | 150/95 | 98/68 | 98/68 | 102/72 | 100/80 | 100/68 | 102/78 | 104/76 | 102/70 | 106/70 | 112/74 | 102/74 | 102/80 | 106/66 | 106/68 | 112/82 |
| | PM | | | | 95/75 | 110/78 | 100/70 | 115/72 | 108/78 | 106/76 | 116/78 | 116/78 | 110/66 | 110/68 | 102/70 | 102/70 | 106/86 | 140/90 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 47 | 97.2 | 97.6 | 97.6 | 98.4 | 97.4 | 97.4 | 96.6 | 98.0 | 97.0 | 96.8 | 95.6 | 97.0 | 96.8 | 97.4 | 96.8 | 95.6 |
| | PM | | | | 97.4 | 97.4 | 97.8 | 97.8 | 97.6 | 97.8 | 97.4 | 98.0 | 98.2 | 98.0 | 98.4 | 96.8 | 97.8 | 97.4 |
| Pulse | AM | | 60 | 66 | 66 | 60 | 74 | 68 | 64 | 66 | 64 | 60 | 54 | 64 | 58 | 64 | 58 | 64 |
| | PM | | | | 68 | 68 | 58 | 60 | 60 | 64 | 66 | 66 | 68 | 66 | 62 | 64 | 66 | 80 |
| Resp | AM | | 18 | 18 | 18 | 16 | 14 | 16 | 13 | 16 | 16 | 10 | 16 | 12 | 10 | 16 | 12 | 9 |
| | PM | | | | 18 | 12 | 18 | 19 | 18 | 14 | 12 | 14 | 18 | 9 | 10 | 11 | 16 | 16 |
| B.P. | AM | | 120/80 | 110/74 | 110/74 | 110/72 | 108/68 | 110/68 | 104/70 | 104/72 | 110/70 | 112/70 | 108/68 | 108/68 | 118/78 | 110/70 | 110/66 | 108/76 |
| | PM | | | | 108/78 | 104/70 | 106/68 | 104/66 | 104/70 | 100/66 | 106/70 | 108/66 | 102/70 | | 105/80 | 112/68 | 105/68 | 128/85 |
| 3.8 psi | | | | | | | | | | | | | | | | | | |
| Temp | AM | 51 | 98.0 | 98.5 | 97.4 | 97.4 | 98.4 | 97.8 | 98.0 | 97.6 | 97.6 | 97.2 | 97.4 | | 98.0 | 98.6 | 98.2 | |
| | PM | | | | 97.4 | 97.8 | 98.4 | 98.0 | 97.6 | 98.0 | 98.2 | 97.6 | 97.8 | | 98.0 | 98.6 | | 99.0 |
| Pulse | AM | | 72 | 84 | 74 | 90 | 88 | 66 | 74 | 82 | 74 | 64 | 64 | 68 | 64 | 84 | 80 | |
| | PM | | | | 90 | 62 | 84 | 80 | 78 | 86 | 84 | 72 | 64 | 88 | 80 | 96 | 72 | 100 |
| Resp | AM | | 18 | 16 | 16 | 20 | 16 | 14 | 14 | 14 | 14 | 12 | 12 | 14 | 14 | 14 | 18 | |
| | PM | | | | 18 | 18 | 16 | 16 | 14 | 14 | 18 | 12 | 12 | 14 | 20 | 16 | 14 | 18 |
| B.P. | AM | | 120/70 | 126/78 | 124/78 | 118/76 | 108/70 | 118/80 | 110/68 | 108/74 | 114/68 | 110/68 | 114/68 | 110/64 | 108/68 | 108/74 | 122/82 | |
| | PM | | | | 128/76 | 112/72 | 118/68 | 130/90 | 110/74 | 116/64 | 108/64 | 110/80 | 108/76 | 110/64 | 116/74 | | 118/74 | 115/55 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 52 | 98.4 | 98.2 | 97.8 | 97.2 | 97.8 | 97.2 | 97.8 | 97.8 | 97.2 | 97.6 | 97.6 | | 97.4 | 97.6 | 97.4 | |
| | PM | | | | 98.2 | 98.2 | 97.6 | 98 | 97.6 | 97.4 | 97 | 98 | 97.6 | | 98.6 | 98.4 | | 98.0 |
| Pulse | AM | | 70 | 76 | 84 | 78 | 80 | 84 | 84 | 98 | 86 | 90 | 64 | 70 | 70 | 74 | 70 | |
| | PM | | | | 90 | 70 | 86 | 88 | 92 | 82 | 74 | 66 | 64 | 70 | 78 | 70 | 70 | 72 |
| Resp | AM | | 14 | 14 | 12 | 12 | 14 | 14 | 16 | 14 | 14 | 14 | 14 | 14 | 14 | 12 | 14 | |
| | PM | | | | 14 | 14 | 14 | 14 | 16 | 14 | 14 | 14 | 14 | 16 | 14 | 14 | 16 | 18 |
| B.P. | AM | | 113/70 | 126/76 | 122/74 | 110/76 | 110/68 | 110/70 | 112/76 | 108/68 | 108/72 | 108/68 | 110/72 | 116/61 | 106/68 | 112/72 | 108/68 | |
| | PM | | | | 116/50 | 120/74 | 112/68 | 112/74 | 118/72 | 108/72 | 108/68 | 118/68 | 110/72 | 120/76 | 110/72 | 100/62 | 104/66 | 115/70 |

TABLE 1.1.2 (Cont)

VITAL SIGNS

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp | AM | 53 | 97.8 | 98.6 | 97.6 | 97.4 | 97.8 | 97.4 | 97.6 | 97.6 | 97.4 | 98.4 | 97.6 | 97 2 | 98.0 | 97.4 | 97.8 | |
| | PM | | | | 98.2 | 98.0 | 98.2 | 98.2 | 98 | 98.6 | 98.2 | 98.4 | 98.4 | | 98.4 | 98.0 | | 98.7 |
| Pulse | AM | | 56 | 72 | 74 | 50 | 50 | 52 | 60 | 56 | 50 | 69 | 44 | 52 | 48 | 70 | 70 | |
| | PM | | | | 84 | 48 | 44 | 44 | 52 | 64 | 60 | 64 | 58 | 52 | 48 | 60 | 62 | 84 |
| Resp | AM | | 18 | 18 | 14 | 12 | 14 | 16 | 12 | 12 | 12 | 16 | 16 | 16 | 14 | 12 | 11 | |
| | PM | | | | 14 | 19 | 14 | 16 | 14 | 14 | 14 | 16 | 16 | 16 | 14 | 14 | 14 | 18 |
| B.P. | AM | | 120/75 | 128/64 | 120/72 | 110/56 | 122/70 | 130/76 | 108/76 | 116/84 | 112/70 | 114/70 | 116/74 | 112/72 | 108/68 | 122/70 | 112/78 | |
| | PM | | | | 120/80 | 112/72 | 116/72 | 132/78 | 122/76 | 116/72 | 126/80 | 122/72 | 112/72 | 112/74 | 112/76 | 110/78 | 108/76 | 128/85 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 54 | 97.8 | 98.6 | 98.0 | 97.2 | 97.8 | 98.6 | 97.8 | 97.6 | 97.4 | 97.4 | 97.4 | 97.1 | 97.8 | 97.2 | 97.8 | |
| | PM | | | | 98.2 | 98.0 | 98.6 | 98.4 | 98.8 | 98.4 | 97.8 | 98.4 | 97.6 | | 97.6 | 98.6 | | 98.6 |
| Pulse | AM | | 52 | 78 | 72 | 66 | 58 | 76 | 60 | 62 | 58 | 64 | 54 | 64 | 67 | 74 | 70 | |
| | PM | | | | 70 | 58 | 66 | 76 | 70 | 58 | 63 | 72 | 66 | 56 | 58 | 76 | 54 | 88 |
| Resp | AM | | 16 | 14 | 14 | 12 | 12 | 22 | 14 | 12 | 11 | 12 | 11 | 12 | 13 | 12 | 12 | |
| | PM | | | | 16 | 18 | 14 | 14 | 14 | 13 | 14 | 14 | 13 | 13 | 12 | 13 | 13 | 16 |
| B.P. | AM | | 110/74 | 115/76 | 114/72 | 110/66 | 114/70 | 118/74 | 120/80 | 108/72 | 112/70 | 110/76 | 110/74 | 108/74 | 104/64 | 108/74 | 104/70 | |
| | PM | | | | 120/70 | 110/70 | 116/76 | 118/74 | 118/22 | 110/62 | 116/72 | 112/72 | 106/68 | 118/78 | 104/66 | 106/72 | 114/74 | 138/75 |
| | | | | | | | | | | | | | | | | | | |
| Temp | AM | 56 | 98.6 | 98.4 | 98.6 | 97.8 | 98.0 | 98.6 | 97.8 | 97.6 | 97.6 | 97.4 | 98.0 | | 98.0 | 97.6 | 98.0 | |
| | PM | | | | 98.4 | 98.2 | 98.2 | 98.4 | 98.3 | 98.4 | 97.6 | 98.0 | 98.2 | | 98.4 | 98.6 | 98.0 | 98.4 |
| Pulse | AM | | 64 | 68 | 80 | 80 | 62 | 94 | 88 | 64 | 60 | 72 | 80 | 80 | 80 | 60 | 80 | |
| | PM | | | | 88 | 62 | 62 | 72 | 78 | 64 | 62 | 62 | 70 | 80 | 64 | 68 | 76 | 72 |
| Resp | AM | | 18 | 12 | 16 | 18 | 20 | | 18 | 18 | 17 | 18 | 18 | 17 | 17 | 15 | 16 | |
| | PM | | | | 16 | 18 | 16 | 20 | 16 | 16 | 16 | | 18 | 19 | 16 | 15 | 17 | 18 |
| B.P. | AM | | 128/85 | 132/76 | 122/70 | 112/76 | 110/72 | 118/74 | 116/70 | 126/70 | 112/82 | 122/76 | 128/78 | 120/82 | 116/70 | 100/64 | 108/78 | |
| | PM | | | | 138/74 | 114/70 | 110/74 | 130/82 | 128/74 | 132/76 | 130/80 | 120/76 | 114/72 | 112/66 | 110/68 | 122/76 | 112/70 | 135/98 |

TABLE 1.1.3

FLUID INTAKE - OUTPUT (oz)

CALORIC INTAKE AND BODY WEIGHT (lb)

| Test | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intake | 11 | | 70 | 55 | 79 | 57 | 70 | 76 | 97 1/2 | 75 1/2 | 51 1/2 | 59 | 74 | 81 | 53 | | |
| Output | | | 15 | 67 | 60 | 53 | 82 | 45 | 77 | 51 | 43 | 71 | 115 | 51 | 70 | 32 | |
| Caloric | | | 2334 | 2674 | 3045 | 2519 | 2765 | 2588 | 2140 | 2462 | 2106 | 1913 | 1990 | 2705 | 2126 | 2102 | |
| Weight | | 166 1/2 | 175 | 176 | 176 1/2 | 176 1/2 | 176 1/2 | 176 | 178 | 177 | 176 | 177 | 176 1/2 | 176 | 176 | 175 1/2 | 175 |
| Intake | 12 | | 44 | 54 | 71 | 50 | 52 1/2 | 54 | 81 1/2 | 86 1/2 | 77 1/2 | 70 | 69 | 85 | 56 | 51 | |
| Output | | | 21 | 54 | 69 | 52 | 61 | 30 | 43 | 101 | 48 | 41 | 68 | 42 | 57 | 52 | |
| Caloric | | | 2000 | 1976 | 1943 | 1934 | 2064 | 1510 | 1915 | 2021 | 1708 | 2066 | 1555 | 1568 | 1524 | 1925 | |
| Weight | | 179 | 184 3/4 | 184 1/4 | 183 1/4 | 182 1/2 | 181 1/2 | 182 | 181 3/4 | 182 3/4 | 181 | 180 1/4 | 181 | 180 | 179 3/4 | 179 1/2 | |
| Intake | 13 | | 52 | 89 | 93 | 58 1/2 | 67 | 74 1/2 | 89 1/2 | 86 1/2 | 54 1/2 | 80 | 77 | 88 | 72 | 59 | |
| Output | | | 46 1/4 | 87 | 74 | 85 | 81 | 58 | 59 | 90 | 36 1/2 | 104 | 54 1/2 | 82 1/2 | 40 1/2 | 93 | |
| Caloric | | | 3144 | 3541 | 4130 | 3374 | 2457 | 2848 | 3522 | 2799 | 2350 | 3093 | 2643 | 3976 | 3000 | 2784 | |
| Weight | | 167 | 167 | 167 1/2 | 168 1/2 | 168 1/2 | 167 | 166 | 167 | 165 1/2 | 166 | 164 1/2 | 164 1/2 | 164 1/2 | 166 1/2 | 165 | 166 |
| Intake | 15 | | 62 | 81 | 64 | 50 1/2 | 62 | 66 1/2 | 73 1/2 | 62 1/2 | 72 1/2 | 54 1/2 | 69 | 80 | 54 | 43 | |
| Output | | | 18 | 48 1/2 | 61 | 55 1/2 | 56 | 37 | 48 | 68 1/2 | 28 1/2 | 69 | 50 | 37 | 51 | 69 | |
| Caloric | | | 2770 | 3303 | 3172 | 3652 | 3279 | 3124 | 2843 | 3006 | 2973 | 3190 | 2654 | 2973 | 2626 | 2917 | |
| Weight | | 183 1/4 | 179 | 179 1/2 | 180 1/2 | 180 1/2 | 179 | 178 1/2 | 179 1/4 | 180 1/2 | 179 | 179 | 177 3/4 | 178 | 179 1/4 | 179 | 178 1/4 |
| Intake | 16 | | 78 | 70 | 87 | 57 1/2 | 70 | 70 1/2 | 85 1/2 | 86 1/2 | 72 1/2 | 86 | 59 | 80 | 64 | 67 | |
| Output | | | 31 1/4 | 66 | 71 | 61 3/4 | 44 1/2 | 47 | 49 | 50 | 72 | 89 1/2 | 53 1/2 | 60 1/2 | 39 1/2 | 55 1/2 | |
| Caloric | | | 2533 | 2379 | 2494 | 2922 | 2397 | 2791 | 2646 | 2720 | 2635 | 3002 | 2792 | 2898 | 3001 | 2297 | |
| Weight | | 209 | 206 | 206 | 204 1/4 | 203 1/2 | 203 1/2 | 202 3/4 | 201 1/2 | 203 3/4 | 202 1/4 | 202 1/4 | 201 | 200 3/4 | 201 | 202 | 202 3/4 |
| Intake | 17 | | 48 | 60 | 92 | 60 1/2 | 54 | 58 1/2 | 73 1/2 | 94 1/2 | 64 1/2 | 70 | 59 | 80 | 54 | 48 | |
| Output | | | 36 | 76 | 60 | 66 | 57 | 39 | 53 | 80 | 77 | 75 | 65 | 66 | 60 | 68 1/2 | |
| Caloric | | | 2096 | 2060 | 2043 | 2456 | 2279 | 2323 | 2525 | 2919 | 2548 | 2704 | 2344 | 2737 | 2651 | 2262 | |
| Weight | | 152 | 152 1/2 | 153 | 152 | 153 | 151 1/2 | 151 1/2 | 152 1/4 | 152 1/4 | 153 1/4 | 152 1/2 | 152 1/2 | 152 1/2 | 152 1/2 | 154 1/4 | 152 1/6 |
| Intake | 31 | | 63 1/2 | 89 | 57 1/2 | 73 1/2 | 87 1/2 | 50 1/2 | 88 1/2 | 93 | 62 | 87 | 63 | 70 | 54 1/2 | 60 1/2 | |
| Output | | | 22 | 22 1/2 | 56 | 32 | 43 | 33 | 46 | 28 3/4 | 31 | 34 1/2 | 45 | 48 | 43 3/4 | 39 | |
| Caloric | | | 2707 | 3272 | 3240 | 3622 | 2645 | 2989 | 3065 | 3369 | 2247 | 3011 | 2629 | 2725 | 2474 | 2608 | |
| Weight | | 149 1/2 | 150 | 150 | 150 1/2 | 150 3/4 | 150 3/4 | 151 3/4 | 152 | 151 3/4 | 153 1/4 | 153 1/4 | 153 | 153 1/4 | 153 1/2 | 152 1/2 | 152 1/2 |

TABLE 1.1.3 (Cont)

FLUID INTAKE - OUTPUT (oz)

CALORIC INTAKE AND BODY WEIGHT (lb)

| Test | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intake | 32 | | 55 1/2 | 70 | 57 1/2 | 72 1/2 | 56 | 85 | 83 | 100 1/2 | 89 | 54 | 53 1/2 | 67 | 78 1/2 | 97 1/2 | |
| Output | | | 32 | 40 1/2 | 38 | 40 | 37 | 47 | 33 | 19 | 36 1/2 | 50 | 32 | 32 | 29 | 23 | |
| Caloric | | | 2383 | 2286 | 2704 | 2073 | 2898 | 2416 | 2443 | 2105 | 2419 | 1939 | 1781 | 1877 | 2555 | 2276 | |
| Weight | | 147 1/4 | 146 | 146 3/4 | 145 3/4 | 145 1/2 | 145 1/4 | 145 1/2 | 144 3/4 | 144 1/4 | 144 1/2 | 145 1/2 | 143 1/2 | 142 1/2 | 142 | 142 1/2 | 142 1/2 |
| Intake | 33 | | 52 1/2 | 105 | 81 1/2 | 99 | 89 | 74 | 90 | 81 | 67 | 76 | 77 1/2 | 62 | 78 1/2 | 81 1/2 | |
| Output | | | 32 1/2 | 43 1/2 | 45 1/2 | 50 | 41 | 35 | 39 1/2 | 39 1/2 | 36 | 46 1/2 | 43 1/2 | 39 | 41 | 46 | |
| Caloric | | | 2702 | 3199 | 3304 | 2850 | 2932 | 2829 | 2948 | 2431 | 2481 | 2645 | 2296 | 2487 | 3065 | 3086 | |
| Weight | | 189 | 187 | 186 1/4 | 185 1/2 | 185 | 185 1/4 | 185 1/4 | 184 1/4 | 185 1/2 | 184 3/4 | 185 1/2 | 183 1/4 | 184 1/4 | 182 3/4 | 183 1/2 | 182 1/2 |
| Intake | 35 | | 67 1/2 | 93 | 65 1/2 | 111 | 89 | 77 | 123 1/2 | 135 | 81 | 60 | 104 1/2 | 95 1/2 | 105 1/2 | 119 1/2 | |
| Output | | | 29 | 50 | 43 1/2 | 46 | 37 | 41 | 41 | 31 1/2 | 27 | 55 1/2 | 42 | 41 | 41 1/2 | 49 | |
| Caloric | | | 2767 | 3118 | 3475 | 2855 | 2613 | 3231 | 4014 | 3775 | 3649 | 3378 | 3580 | 3406 | 3300 | 3749 | |
| Weight | | 156 | 157 1/4 | 156 1/2 | 155 1/2 | 155 1/4 | 155 3/4 | 156 | 156 | 158 1/4 | 158 3/4 | 161 | 159 1/2 | 158 3/4 | 158 3/4 | 159 1/2 | 158 3/4 |
| Intake | 36 | | 47 1/2 | 72 | 73 1/2 | 67 | 71 1/2 | 50 | 82 | 70 | 81 | 84 | 77 1/2 | 64 | 67 1/2 | 79 1/2 | |
| Output | | | 27 | 57 | 34 1/4 | 32 | 36 | 38 | 47 | 31 1/2 | 30 | 44 | 29 | 33 | 38 | 38 | |
| Caloric | | | 3146 | 3468 | 3282 | 2297 | 2392 | 2553 | 2814 | 2492 | 2946 | 3151 | 2513 | 2752 | 2846 | 3465 | |
| Weight | | 182 1/4 | 181 | 182 | 179 3/4 | 180 1/2 | 180 1/4 | 181 1/2 | 179 | 179 1/2 | 179 1/2 | 180 1/4 | 179 3/4 | 179 1/4 | 177 3/4 | 179 1/4 | 181 1/4 |
| Intake | 37 | | 56 1/2 | 102 | 65 1/2 | 79 | 54 1/2 | 71 | 72 1/2 | 62 | 73 | 66 1/2 | 61 1/2 | 67 | 78 1/2 | 73 1/2 | |
| Output | | | 28 1/2 | 55 1/2 | 38 | 27 | 49 | 38 | 32 | 27 1/2 | 39 | 47 | 37 | 27 | 18 1/2 | 37 1/2 | |
| Caloric | | | 3133 | 2970 | 3249 | 2550 | 2529 | 2264 | 2755 | 2061 | 2536 | 2670 | 2969 | 2344 | 2722 | 2680 | |
| Weight | | 158 1/4 | 160 | 161 1/2 | 160 1/2 | 161 1/2 | 161 1/2 | 161 1/4 | 162 1/4 | 161 1/4 | 163 | 163 | 162 1/4 | 162 1/4 | 161 | 162 1/4 | 161 3/4 |
| Intake | 42 | | 95 1/2 | 113 | 99 1/2 | 92 | 70 1/2 | 74 | 96 1/2 | 81 | 105 | 89 | 82 1/2 | 85 | 90 1/2 | 88 | |
| Output | | | 46 3/4 | 62 | 47 | 28 | 36 | 44 | 41 1/2 | 36 | 46 | 42 | 32 | 18 | 45 | 37 | |
| Caloric | | | 2672 | 1776 | 2820 | 3456 | 2983 | 2646 | 2408 | 1844 | 2204 | 2513 | 2500 | 2864 | 3029 | 2749 | |
| Weight | | 169 | 168 | 168 | 168 | 167 | 168 | 168 | 168 | 168 | 167 | 166 | 165 | 166 | 166 | 167 | |
| Intake | 43 | | 79 1/2 | 129 | 99 1/2 | 135 | 128 1/2 | 114 | 99 1/2 | 89 | 97 | 71 | 96 1/2 | 98 | 90 1/2 | 88 | |
| Output | | | 36 3/4 | 60 | 45 1/4 | 70 | 44 | 38 | 44 1/2 | 41 | 36 | 42 1/2 | 48 | 48 | 53 3/4 | 43 | |
| Caloric | | | 3156 | 3133 | 2772 | 2201 | 2875 | 3248 | 3080 | 3066 | 3154 | 3089 | 3405 | 3184 | 3451 | 3455 | |
| Weight | | 178 | 178 | 179 | 177 | 177 | 176 | 177 | 177 | 176 | 175 | 175 | 174 | 175 | 175 | 175 | |
| Intake | 44 | | 98 | 102 | 131 1/2 | 100 | 120 1/2 | 80 | 91 1/2 | 89 | 105 | 123 | 88 1/2 | 98 | 101 1/2 | 80 | |
| Output | | | 40 1/2 | 46 | 39 3/4 | 59 | 61 | 43 | 50 | 48 1/3 | 57 | 52 1/2 | 33 | 52 | 48 | 51 | |
| Caloric | | | 2571 | 2574 | 3398 | 3578 | 3713 | 3536 | 2898 | 2993 | 3348 | 3690 | 3616 | 4145 | 3250 | 2234 | |
| Weight | | 169 | 168 | 168 | 167 | 168 | 166 | 169 | 169 | 169 | 167 | 167 | 168 | 169 | 169 | 170 | |

TABLE 1.1.3 (Cont)

FLUID INTAKE - OUTPUT (oz)

CALORIC INTAKE AND BODY WEIGHT (lb)

| Test | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intake | 45 | | 103 1/2 | 89 | 104 1/2 | 101 1/2 | 80 1/2 | 88 1/2 | 104 1/2 | 78 | 97 | 97 | 104 1/2 | 80 1/2 | 90 1/2 | | |
| Output | | | 39 | 56 | 44 | 40 | 43 | 56 | 39 | 30 | 40 | 44 | 46 | 48 | 58 | 35 | |
| Caloric | | | 3277 | 4098 | 3941 | 4175 | 3703 | 3220 | 3838 | 3354 | 3375 | 3568 | 3395 | 3268 | 3449 | | |
| Weight | | 180 1/4 | 183 | 183 | 172 | 172 | 172 | 174 | 173 | 174 | 173 | 173 | 173 | 172 | 174 | 151 | |
| Intake | 46 | | 87 1/2 | 81 | 91 1/2 | 102 | 103 | 82 | 82 | 89 | 97 | 100 | 88 1/2 | 87 | 95 1/2 | 96 | |
| Output | | | 37 | 48 | 63 | 57 | 63 | 55 | 43 | 56 | 49 | 62 | 59 | 56 | 59 | 55 | |
| Caloric | | | 2931 | 3346 | 3264 | 3968 | 3276 | 2941 | 2712 | 3275 | 3434 | 3465 | 3119 | 3479 | 3091 | 3355 | |
| Weight | | 151 1/4 | 152 | 152 | 152 | 151 | 152 | 152 | 152 | 152 | 151 | 151 | 152 | 152 | 151 | 174 | |
| Intake | 47 | | 76 1/2 | 97 | 71 1/2 | 87 | 72 1/2 | 79 | 83 1/2 | 81 | 81 | 100 | 88 1/2 | 93 | 90 1/2 | 72 | |
| Output | | | 37 | 52 | 53 | 40 | 36 | 50 | 44 1/2 | 54 1/2 | 51 | 44 | 44 | 49 | 48 | 46 | |
| Caloric | | | 2390 | 2441 | 2165 | 2904 | 2440 | 2385 | 2588 | 2616 | 2694 | 2815 | 2843 | 2848 | 2796 | 2888 | |
| Weight | | 164 | 163 | 163 | 163 | 163 | 163 | 165 | 163 | 162 | 164 | 162 | 162 | 162 | 163 | 163 | |
| Intake | 51 | | 73 1/2 | 89 | 91 | 70 | 92 | 84 | 92 | 79 | 75 | 70 1/2 | 78 | 76 | 74 | 64 | |
| Output | | | 82 | 41 1/2 | 27 | 26 | 40 | 53 | 39 | 27 | 13 | 28 | 61 | 22 | 36 | 25 | |
| Caloric | | | 2041 | 2173 | 2000 | 2552 | 3000 | 3044 | 3238 | 2437 | 2465 | 2513 | 2549 | 2823 | 2179 | 2430 | |
| Weight | | | 171 1/2 | 169 | 162 1/2 | 157 1/2 | 170 | 168 | 170 | 170 | 170 | 168 1/2 | 170 | 168 | 168 | 168 1/2 | 170 |
| Intake | 52 | | 64 1/2 | 95 | 93 | 70 | 76 | 66 | 73 | 71 | 94 | 70 1/2 | 64 | 57 | 69 | 73 | |
| Output | | | 37 | 39 | 47 | 35 | 21 | 49 | 36 | 39 1/2 | 25 | 43 | 46 | 39 | 37 | 24 | |
| Caloric | | | 2233 | 1873 | 2263 | 2282 | 2247 | 1995 | 2253 | 1919 | 2000 | 2100 | 1831 | 1866 | 1947 | 2086 | |
| Weight | | | 186 | 183 | 183 | 182 1/2 | 181 3/4 | 181 1/2 | 181 1/2 | 180 1/4 | 179 1/2 | 181 | 180 1/2 | 179 3/4 | 179 1/2 | 179 1/4 | 178 3/4 |
| Intake | 53 | | 80 | 97 | 94 | 98 | 104 | 118 | 83 | 94 | 101 | 98 1/2 | 93 | 118 | 94 | 104 | |
| Output | | | 77 | 51 1/2 | 60 | 61 | 57 | 66 | 72 | 58 | 65 | 73 | 43 | 65 | 66 | 65 | |
| Caloric | | | 2892 | 2834 | 3212 | 2345 | 2599 | 2488 | 2641 | 2573 | 3082 | 3143 | 3055 | 3251 | 2784 | 2681 | |
| Weight | | | 160 1/2 | 160 3/4 | 157 1/2 | 157 | 155 3/4 | 155 1/2 | 155 3/4 | 154 3/4 | 154 3/4 | 155 1/2 | 155 | 154 1/2 | 154 1/2 | 155 | 155 1/2 |
| Intake | 54 | | 75 | 71 | 99 | 77 | 76 | 76 | 84 | 79 | 83 | 60 | 62 | 83 | 61 | 82 | |
| Output | | | 59 | 45 | 44 | 35 | 43 | 51 | 55 | 36 | 32 | 51 | 36 | 30 | 39 | 33 | |
| Caloric | | | 2527 | 2339 | 2746 | 2262 | 2312 | 1942 | 2384 | 2216 | 2279 | 2506 | 2240 | 2184 | 2070 | 2324 | |
| Weight | | | 142 1/4 | 139 3/4 | 139 | 139 1/2 | 140 | 140 1/2 | 141 | 140 1/4 | 139 3/4 | 139 3/4 | 139 3/4 | 139 1/2 | 138 3/4 | 139 1/4 | 140 1/2 |
| Intake | 56 | | 84 1/2 | 87 | 83 | 84 | 84 | 80 | 84 | 91 | 91 | 83 | 78 | 94 | 81 | 93 | |
| Output | | | 31 1/2 | 37 1/2 | 41 | 38 | 34 | 21 | 34 | 33 | 32 | 41 | 41 | 36 | 41 | 40 | |
| Caloric | | | 2615 | 2323 | 2630 | 2505 | 2318 | 2492 | 2657 | 2314 | 2840 | 3122 | 2649 | 2743 | 2481 | 3144 | |
| Weight | | | 158 3/4 | 158 1/4 | 154 1/2 | 154 | 154 | 154 | 153 1/2 | 154 | 153 1/2 | 154 | 154 1/2 | 153 1/2 | 154 | 155 | 153 1/2 |

2. Cardiopulmonary Data

TABLE 1.2.1

VITAL CAPACITIES (liters B.T.P.S.) AND % TIMED VITAL CAPACITY

| Test | Subject Number | Pre-Run | Days in Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V.C. 1 | 11 | 4.1 | 4.0 | 4.3 | | | 3.8 | 3.6 | 4.0 | 3.0 | 3.1 | 3.2 | 3.4 | 3.0 | 3.4 | 3.6 | 3.3 |
| V.C. 2 | | 4.1 | 3.7 | 4.2 | | | 3.4 | 3.8 | 3.9 | 3.4 | 3.4 | 3.7 | 3.5 | 2.8 | 3.4 | 3.6 | 3.3 |
| V.C. 3 | | 4.0 | 3.5 | 4.0 | | | 3.5 | 3.7 | 3.8 | 3.6 | 3.4 | 3.2 | 3.0 | 2.9 | 3.2 | 3.5 | 3.5 |
| V.C. 4 | | 4.0 | 3.8 | 4.2 | | | 4.0 | 3.9 | 4.0 | 3.7 | 3.5 | 3.7 | 3.8 | 3.7 | 3.9 | 3.6 | 3.6 |
| V.C. 5 | | 4.0 | 3.8 | 4.0 | | | 4.0 | 3.7 | 4.0 | 3.8 | 3.7 | 3.7 | 3.9 | 3.5 | 3.8 | 3.6 | 3.6 |
| % T.V.C. | | 92 | 94 | 84 | | | 80 | 77 | 92 | 77 | 96 | 86 | 84 | 79 | 82 | 81 | 86 |
| V.C. 1 | 12 | 5.0 | 4.7 | 4.6 | | | 3.[illegible] | 4.6 | 4.9 | 4.8 | 5.1 | 4.8 | 5.1 | 5.1 | 5.0 | 5.0 | 4.8 |
| V.C. 2 | | 4.9 | 4.7 | 4.6 | | | 3.4 | 4.7 | 5.1 | 4.8 | 5.2 | 5.1 | 5.2 | 5.2 | 5.1 | 5.1 | 5.0 |
| V.C. 3 | | 6.9 | 4.7 | 4.7 | | | 3.5 | 4.4 | 5.1 | 4.7 | 5.1 | 5.0 | 5.1 | 5.1 | 3.7 | 5.0 | 4.9 |
| V.C. 4 | | 4.6 | 4.5 | 4.5 | | | 3.8 | 4.2 | 4.7 | 4.5 | 4.9 | 4.7 | 4.8 | 4.6 | 4.7 | 4.6 | 4.6 |
| V.C. 5 | | 4.6 | 4.3 | 4.4 | | | 3.8 | 4.1 | 4.7 | 4.5 | 4.6 | 4.6 | 4.8 | 4.7 | 4.9 | 4.8 | 4.6 |
| % T.V.C. | | 87 | 84 | 85 | | | 84 | 82 | 84 | 83 | 87 | 81 | 83 | 85 | 81 | 80 | 80 |
| V.C. 1 | 13 | 4.4 | 4.3 | 4.4 | | | 4.7 | 4.2 | 4.9 | 4.8 | 4.6 | 4.8 | 4.8 | 4.4 | 4.8 | 4.8 | 4.8 |
| V.C. 2 | | 4.3 | 4.3 | 4.4 | | | 4.6 | 4.4 | 4.8 | 4.7 | 4.6 | 4.8 | 4.7 | 4.6 | 4.7 | 4.7 | 4.8 |
| V.C. 3 | | 4.4 | 4.4 | 4.4 | | | 4.4 | | 4.8 | 4.6 | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 | 4.7 | 4.8 |
| V.C. 4 | | 4.1 | 3.8 | 4.3 | | | 4.3 | | 4.1 | 3.5 | 4.5 | 4.4 | 4.3 | 4.3 | 4.4 | 4.3 | 4.4 |
| V.C. 5 | | 4.2 | 4.0 | 4.2 | | | 4.1 | 4.3 | 4.2 | 4.2 | 4.6 | 4.2 | 4.5 | 4.5 | 4.4 | 4.4 | 4.1 |
| % T.V.C. | | 86 | 90 | 86 | | | 92 | 91 | 96 | 100 | 81 | 84 | 88 | 89 | 88 | 89 | 92 |
| V.C. 1 | 15 | 4.5 | 4.6 | 4.1 | | | 4.4 | 4.5 | 4.5 | 4.5 | 4.7 | 4.6 | 4.6 | 4.8 | 4.8 | 4.6 | 4.5 |
| V.C. 2 | | 5.2 | 4.3 | 4.2 | | | 4.6 | 4.3 | 4.7 | 4.8 | 4.8 | 4.6 | 4.7 | 4.9 | 4.8 | 4.5 | 4.5 |
| V.C. 3 | | 4.4 | 4.6 | 4.2 | | | 4.4 | 4.4 | 4.8 | 4.7 | 4.8 | 4.6 | 4.7 | 4.8 | 4.8 | 4.8 | 4.5 |
| V.C. 4 | | 3.9 | 4.3 | 4.0 | | | 4.4 | 4.3 | 4.6 | 4.4 | 4.3 | 4.3 | 4.4 | 4.5 | 4.4 | 4.6 | 4.3 |
| V.C. 5 | | 3.5 | 4.4 | 4.1 | | | 4.4 | 4.4 | 4.6 | 4.0 | 4.4 | 4.4 | 4.5 | 4.6 | 4.5 | 4.6 | 4.4 |
| % T.V.C. | | 91 | 78 | 80 | | | 75 | 78 | 82 | 85 | 81 | 77 | 76 | 77 | 81 | 80 | 88 |
| V.C. 1 | 16 | 4.4 | 4.1 | 4.2 | | | 4.4 | 4.2 | 4.4 | 4.4 | 4.4 | 3.9 | 4.5 | 4.2 | 4.5 | 4.2 | 4.2 |
| V.C. 2 | | 4.4 | 4.2 | 4.2 | | | 4.4 | 4.4 | 4.4 | 4.2 | 4.4 | 4.4 | 4.5 | 4.3 | 4.5 | 4.4 | 4.2 |
| V.C. 3 | | 4.4 | 4.1 | 4.2 | | | 4.5 | 4.4 | 4.2 | 4.2 | 4.5 | 4.4 | 4.5 | 4.4 | 4.3 | 4.7 | 4.3 |
| V.C. 4 | | 4.2 | 4.1 | 4.2 | | | 4.2 | 4.3 | 4.4 | 3.9 | 4.4 | 4.3 | 4.5 | 4.4 | 4.3 | 4.3 | 4.2 |
| V.C. 5 | | 4.2 | 4.1 | 4.2 | | | 4.2 | 4.3 | 4.5 | 4.2 | 4.3 | 4.4 | 4.6 | 4.4 | 4.5 | 4.5 | 4.4 |
| % T.V.C. | | 90 | 85 | 82 | | | 86 | 96 | 82 | 85 | 81 | 80 | 81 | 84 | 83 | 81 | 91 |
| V.C. 1 | 17 | 3.6 | 3.9 | 3.7 | | | 3.5 | 3.9 | 3.6 | 3.6 | 3.6 | 3.7 | 3.6 | 3.6 | 3.5 | 3.5 | 3.5 |
| V.C. 2 | | 3.8 | 3.8 | 3.7 | | | 3.6 | 3.6 | 3.7 | 3.6 | 3.7 | 3.8 | 3.7 | 3.8 | 3.6 | 3.5 | 3.6 |
| V.C. 3 | | 3.8 | 3.8 | 3.7 | | | 3.6 | 3.7 | 3.6 | 3.6 | 3.7 | 3.8 | 3.6 | 3.6 | 3.6 | 3.3 | 3.5 |
| V.C. 4 | | 3.7 | 3.7 | 3.5 | | | 3.5 | 3.9 | 3.5 | 3.6 | 3.6 | 3.8 | 3.7 | 3.6 | 3.6 | 3.5 | 3.6 |
| V.C. 5 | | 3.9 | 3.5 | 3.5 | | | 3.7 | 3.8 | 3.7 | 3.5 | 3.6 | 3.6 | 3.8 | 3.6 | 3.6 | 3.7 | 3.6 |
| % T.V.C. | | 90 | 96 | 98 | | | 96 | 98 | 96 | 96 | 93 | 93 | 94 | 86 | 92 | 95 | 94 |

TABLE 1.2.1 (Cont)

VITAL CAPACITIES (liters B.T.P.S.) AND % TIMED VITAL CAPACITY

| Test | Subject Number | Pre-Run | Days in Chamber | | | | | | | | | | | | | | Post Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| V.C. 1 | 31 | 5.3 | 5.4 | 5.4 | 5.2 | 5.4 | 5.1 | 4.8 | 5.1 | 4.8 | 5.0 | 5.0 | 4.9 | 4.8 | 4.8 | 4.9 | 5.0 |
| V.C. 2 | | 5.3 | 5.6 | 5.5 | 5.3 | 5.7 | 5.2 | 5.1 | 5.1 | 5.0 | 5.0 | 5.2 | 4.9 | 5.0 | 4.9 | 5.3 | 5.1 |
| V.C. 3 | | 5.2 | 5.6 | 5.1 | 5.2 | 5.7 | 5.1 | 4.8 | 5.0 | 4.8 | 5.0 | 5.1 | 5.0 | 4.9 | 4.8 | 5.1 | 5.2 |
| V.C. 4 | | 4.9 | 5.4 | 5.2 | 4.8 | 4.9 | 4.7 | 4.5 | 4.9 | 3.8 | 4.2 | 4.5 | 3.4 | 4.5 | 4.4 | 4.6 | 4.4 |
| V.C. 5 | | 5.3 | 5.0 | 5.4 | 5.0 | 5.0 | 5.0 | 4.4 | 4.9 | 4.7 | 5.0 | 4.8 | 4.6 | 4.6 | 4.3 | 4.7 | 4.9 |
| % T.V.C. | | 98 | 98 | 96 | 98 | 100 | 93 | 98 | 98 | 100 | 91 | 98 | 100 | 98 | 100 | 98 | 96 |
| V.C. 1 | 32 | 5.3 | 5.3 | 5.2 | 5.0 | 5.3 | 4.8 | 4.8 | 5.1 | 5.1 | 4.9 | 5.1 | 5.0 | 5.0 | 5.0 | 5.1 | 5.0 |
| V.C. 2 | | 5.2 | 5.3 | 5.1 | 5.0 | 5.3 | 4.8 | 4.9 | 5.1 | 5.1 | 4.9 | 5.1 | 5.2 | 5.0 | 4.9 | 5.1 | 5.0 |
| V.C. 3 | | 5.3 | 5.3 | 5.1 | 5.1 | 5.3 | 4.6 | 4.9 | 5.1 | 5.0 | 4.9 | 5.1 | 5.0 | 4.9 | 4.9 | 4.9 | 5.0 |
| V.C. 4 | | 5.2 | 5.1 | 4.9 | 4.8 | 5.1 | 4.5 | 4.9 | 4.8 | 4.9 | 4.9 | 4.9 | 4.7 | 4.9 | 4.8 | 4.6 | 4.9 |
| V.C. 5 | | 5.4 | 5.3 | 5.2 | 5.0 | 5.0 | 4.6 | 4.9 | 5.0 | 4.9 | 4.7 | 4.7 | 4.8 | 4.8 | 4.9 | 4.8 | 4.9 |
| % T.V.C. | | 86 | 85 | 83 | 82 | 86 | 86 | 80 | 83 | 81 | 86 | 84 | 86 | 86 | 88 | 88 | 89 |
| V.C. 1 | 33 | 4.5 | 4.7 | 4.9 | 4.8 | 4.3 | 4.6 | 4.4 | 4.6 | 4.6 | 4.3 | 4.5 | 4.5 | 4.0 | 4.0 | 4.5 | [illegible] |
| V.C. 2 | | 4.6 | 4.6 | 5.2 | 4.8 | 4.5 | 4.7 | 4.2 | 4.6 | 4.5 | 4.4 | 4.5 | 4.5 | 4.5 | 4.6 | 4.6 | [illegible] |
| V.C. 3 | | 4.6 | 4.1 | 4.8 | 5.0 | 4.6 | 4.6 | 4.4 | 4.4 | 4.6 | 4.4 | 4.5 | 4.5 | 4.4 | 4.6 | 4.4 | [illegible] |
| V.C. 4 | | 4.5 | 4.5 | 3.9 | 4.3 | 4.8 | 4.5 | 4.1 | 4.3 | 4.1 | 4.2 | 4.0 | 4.2 | 4.0 | 4.0 | 4.3 | [illegible] |
| V.C. 5 | | 4.1 | 4.1 | 4.9 | 4.6 | 4.7 | 3.9 | 4.4 | 4.4 | 4.2 | 4.0 | 4.2 | 4.4 | 4.2 | 4.4 | 4.3 | 4.2 |
| % T.V.C. | | 97 | 84 | 91 | 90 | 88 | 91 | 91 | 89 | 89 | 89 | 91 | 92 | 94 | 97 | 95 | 93 |
| V.C. 1 | 35 | 4.0 | 5.0 | 5.6 | 5.4 | 5.7 | 5.2 | 5.2 | 5.3 | 5.4 | 5.2 | 5.4 | 5.5 | 5.5 | 5.4 | 5.5 | |
| V.C. 2 | | 4.0 | 5.3 | 5.7 | 5.6 | 5.8 | 5.4 | 5.2 | 5.5 | 5.4 | 5.3 | 5.6 | 5.5 | 5.5 | 5.4 | 5.5 | |
| V.C. 3 | | 4.3 | 5.4 | 5.6 | 5.6 | 5.7 | 5.3 | 5.3 | 5.4 | 5.2 | 5.2 | 5.6 | 5.5 | 5.8 | 5.5 | 5.5 | |
| V.C. 4 | | 4.4 | 5.3 | 5.5 | 5.4 | 5.7 | 5.0 | 5.2 | 5.2 | 5.3 | 4.6 | 5.3 | 5.3 | 5.4 | 5.0 | 5.0 | |
| V.C. 5 | | 4.4 | 5.3 | 5.7 | 5.3 | 5.6 | 5.0 | 5.1 | 5.2 | 5.2 | 4.4 | 5.1 | 5.1 | 5.2 | 5.0 | 4.7 | |
| % T.V.C. | | 95 | 93 | 87 | 91 | 92 | 91 | 89 | 93 | 93 | 92 | 91 | 90 | 89 | 93 | 98 | |
| V.C. 1 | 36 | 5.4 | 5.8 | 4.8 | 5.4 | 5.4 | 4.9 | 5.2 | 5.5 | 5.4 | 5.5 | 5.7 | 5.8 | 5.4 | 5.3 | 5.6 | 5.9 |
| V.C. 2 | | 4.9 | 6.0 | 5.2 | 5.6 | 5.7 | 5.4 | 5.5 | 5.5 | 5.5 | 5.3 | 5.7 | 5.7 | 5.6 | 5.5 | 5.6 | 5.7 |
| V.C. 3 | | 5.1 | 6.1 | 5.4 | 5.6 | 5.8 | 5.4 | 5.6 | 5.4 | 5.2 | 5.3 | 5.4 | 5.8 | 5.5 | 5.2 | 5.5 | 5.9 |
| V.C. 4 | | 5.8 | 6.3 | 5.7 | 5.3 | 5.7 | 5.5 | 5.4 | 5.4 | 5.4 | 4.8 | 5.4 | 5.6 | 5.5 | 5.0 | 5.4 | 5.7 |
| V.C. 5 | | 5.8 | 6.2 | 5.7 | 5.4 | 5.9 | 5.7 | 5.4 | 5.4 | 5.3 | 4.3 | 5.3 | 5.5 | 5.5 | 4.9 | 5.4 | 5.7 |
| % T.V.C. | | 70 | 78 | 78 | 81 | 82 | 80 | 81 | 77 | 79 | 79 | 77 | 80 | 77 | 80 | 83 | 74 |
| V.C. 1 | 37 | 4.8 | 4.5 | 4.8 | 4.6 | 4.8 | 4.6 | 4.4 | 4.4 | 4.5 | 4.1 | 4.3 | 4.6 | 4.2 | 4.2 | 4.4 | 4.6 |
| V.C. 2 | | 4.8 | 4.7 | 4.9 | 4.6 | 5.0 | 4.6 | 4.5 | 4.4 | 4.4 | 4.5 | 4.3 | 4.6 | 4.6 | 4.6 | 4.4 | 4.8 |
| V.C. 3 | | 4.6 | 4.5 | 4.9 | 4.6 | 5.1 | 4.5 | 4.5 | 4.5 | 4.5 | 4.8 | 4.2 | 4.6 | 4.3 | 4.4 | 4.5 | 4.8 |
| V.C. 4 | | 4.4 | 4.2 | 4.5 | 4.3 | 4.5 | 4.0 | 4.3 | 4.2 | 4.0 | 3.8 | 4.5 | 4.2 | 4.1 | 4.1 | 4.1 | 4.6 |
| V.C. 5 | | 4.2 | 4.1 | 4.9 | 4.6 | 4.6 | 4.5 | 4.5 | 4.0 | 4.3 | 4.1 | 3.5 | 4.5 | 3.9 | 4.2 | 4.2 | 4.5 |
| % T.V.C. | | 90 | 97 | 92 | 90 | 95 | 97 | 92 | 97 | 100 | 97 | 80 | 100 | 94 | 90 | 97 | 95 |

TABLE 1.2.1 (Cont)

VITAL CAPACITIES (liters B.T.P.S.) AND % TIMED VITAL CAPACITY

| Test | Subject Number | Pre-Run | Days in Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V.C. 1 | 42 | 4.4 | 4.5 | 4.2 | 4.0 | 4.0 | 3.8 | 3.8 | 4.1 | 4.0 | 4.0 | 3.9 | 3.9 | 3.9 | 3.4 | 4.1 | 4.6 |
| V.C. 2 | | 4.5 | 4.7 | 4.0 | 4.0 | 4.2 | 4.1 | 4.0 | 4.1 | 4.2 | 4.4 | 4.4 | 4.2 | 4.0 | 3.6 | 4.4 | 4.7 |
| V.C. 3 | | 4.5 | 4.4 | 4.0 | 4.2 | 3.8 | 4.0 | 4.0 | 3.9 | 4.2 | 4.2 | 4.4 | 4.1 | 3.8 | 3.5 | 4.0 | 4.6 |
| V.C. 4 | | 4.4 | 4.2 | 3.7 | 3.7 | 3.6 | 3.7 | 3.9 | 3.6 | 3.7 | 4.2 | 3.9 | 4.1 | 3.9 | 3.5 | 4.0 | 4.4 |
| V.C. 5 | | 4.5 | 4.0 | 3.9 | 3.9 | 3.9 | 3.4 | 3.8 | 3.6 | 3.5 | 4.1 | 3.9 | 4.0 | 4.2 | 3.6 | 3.8 | 4.4 |
| % T.V.C. | | 93 | 97 | 97 | 100 | 100 | 94 | 100 | 100 | 97 | 95 | 100 | 95 | 94 | 97 | 97 | 94 |
| V.C. 1 | 43 | 3.8 | 5.3 | 5.3 | 5.0 | 5.2 | 5.2 | 4.8 | 5.2 | 5.6 | 5.6 | 5.6 | 5.5 | 5.5 | 5.9 | 5.8 | 6.0 |
| V.C. 2 | | 4.2 | 5.3 | 5.3 | 5.6 | 5.5 | 5.5 | 5.5 | 5.3 | 5.7 | 5.8 | 5.7 | 5.7 | 5.4 | 6.0 | 6.1 | 5.9 |
| V.C. 3 | | 4.2 | 5.3 | 5.3 | 5.2 | 5.5 | 5.5 | 5.3 | 5.4 | 5.7 | 5.8 | 5.7 | 5.7 | 5.6 | 6.0 | 6.0 | 6.0 |
| V.C. 4 | | 4.4 | 5.7 | 5.6 | 5.4 | 5.5 | 5.1 | 5.4 | 5.1 | 5.5 | 5.5 | 5.6 | 5.4 | 5.3 | 5.5 | 5.6 | 5.7 |
| V.C. 5 | | 4.5 | 5.7 | 5.5 | 5.3 | 5.3 | 5.5 | 5.0 | 5.3 | 5.4 | 5.5 | 5.5 | 5.5 | 5.2 | 5.7 | 5.5 | 5.7 |
| % T.V.C. | | 90 | 86 | 90 | 84 | 88 | 91 | 92 | 91 | 86 | 90 | 88 | 88 | 89 | 83 | 86 | 87 |
| V.C. 1 | 44 | 3.5 | 5.0 | 5.2 | 4.8 | 4.9 | 4.8 | 5.0 | 5.0 | 5.0 | 4.8 | 4.7 | 4.7 | 3.7 | 4.1 | 4.9 | 4.5 |
| V.C. 2 | | 3.7 | 4.9 | 5.2 | 5.0 | 4.8 | 4.7 | 5.0 | 5.2 | 5.1 | 5.2 | 5.1 | 5.0 | 4.2 | 4.9 | 5.2 | 4.6 |
| V.C. 3 | | 3.6 | 4.7 | 5.1 | 4.9 | 4.6 | 4.5 | 5.1 | 5.0 | 4.9 | 4.9 | 5.0 | 4.8 | 4.2 | 4.9 | 5.0 | 4.6 |
| V.C. 4 | | 3.5 | 4.5 | 4.4 | 4.7 | 4.6 | 4.5 | 5.0 | 4.8 | 3.9 | 4.8 | 5.0 | 4.7 | 4.0 | 4.6 | 4.8 | 4.6 |
| V.C. 5 | | 3.5 | 4.5 | 4.4 | 4.9 | 4.6 | 4.4 | 4.8 | 4.8 | 4.8 | 4.9 | 4.9 | 4.8 | 4.2 | 4.8 | 4.8 | 4.6 |
| % T.V.C. | | 91 | 85 | 88 | 86 | 79 | 86 | 80 | 80 | 86 | 84 | 80 | 86 | 86 | 84 | 89 | 82 |
| V.C. 1 | 45 | 5.1 | 4.6 | 4.9 | 4.4 | 4.8 | 4.7 | 4.7 | 4.5 | 4.5 | 4.4 | 4.7 | 4.6 | 4.6 | 4.6 | 4.5 | 4.6 |
| V.C. 2 | | 4.9 | 4.6 | 5.0 | 4.7 | 4.8 | 4.8 | 4.8 | 4.8 | 4.7 | 4.9 | 4.8 | 4.8 | 4.7 | 4.9 | 4.8 | 4.5 |
| V.C. 3 | | 4.9 | 4.6 | 5.0 | 4.6 | 4.6 | 4.7 | 4.6 | 4.7 | 4.5 | 4.8 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.4 |
| V.C. 4 | | 4.8 | 4.2 | 4.4 | 4.4 | 4.1 | 4.4 | 4.5 | 4.4 | 4.5 | 4.3 | 4.6 | 4.3 | 4.6 | 4.8 | 4.6 | 4.5 |
| V.C. 5 | | 4.8 | 4.4 | 4.1 | 4.3 | 4.0 | 4.5 | 4.6 | 4.7 | 4.6 | 4.6 | 4.6 | 4.5 | 4.7 | 4.7 | 4.7 | 4.5 |
| % T.V.C. | | 84 | 88 | 85 | 85 | 86 | 88 | 88 | 93 | 85 | 92 | 86 | 90 | 88 | 82 | 86 | 88 |
| V.C. 1 | 46 | 4.7 | 5.6 | 5.2 | 4.3 | 5.0 | 5.0 | 4.9 | 5.0 | 4.9 | 5.2 | 5.2 | 4.9 | 4.9 | 4.7 | 5.2 | 4.6 |
| V.C. 2 | | 4.8 | 5.3 | 5.3 | 4.5 | 5.1 | 5.0 | 5.1 | 5.0 | 5.3 | 5.3 | 5.1 | 5.0 | 4.7 | 4.8 | 5.3 | 4.8 |
| V.C. 3 | | 4.8 | 5.3 | 5.2 | 4.5 | 5.1 | 5.0 | 5.1 | 5.0 | 5.3 | 5.3 | 5.2 | 5.1 | 4.9 | 4.8 | 5.3 | 4.5 |
| V.C. 4 | | 5.0 | 5.7 | 5.4 | 4.8 | 5.2 | 5.2 | 5.0 | 5.0 | 5.2 | 5.3 | 5.3 | 5.0 | 4.9 | 5.0 | 5.2 | 4.7 |
| V.C. 5 | | 5.1 | 5.7 | 5.5 | 4.8 | 5.1 | 5.0 | 4.8 | 5.0 | 5.0 | 5.3 | 5.2 | 5.0 | 5.2 | 5.1 | 5.3 | 4.9 |
| % T.V.C. | | 92 | 98 | 98 | 95 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| V.C. 1 | 47 | 5.2 | 4.9 | 5.0 | 4.8 | 4.9 | 5.2 | 5.0 | 5.0 | 4.9 | 5.1 | 5.2 | 4.9 | 4.4 | 4.2 | 5.3 | 5.3 |
| V.C. 2 | | 5.2 | 5.4 | 5.3 | 5.0 | 5.0 | 5.2 | 5.0 | 5.3 | 5.0 | 5.1 | 5.3 | 5.0 | 4.7 | 5.3 | 5.3 | 5.6 |
| V.C. 3 | | 5.2 | 5.2 | 5.2 | 5.0 | 5.0 | 5.0 | 5.0 | 5.3 | 5.0 | 5.3 | 5.2 | 5.0 | 4.7 | 5.3 | 5.3 | 5.6 |
| V.C. 4 | | 5.1 | 5.0 | 5.2 | 5.0 | 4.8 | 5.0 | 4.6 | 4.8 | 4.6 | 4.8 | 4.6 | 4.6 | 4.4 | 4.8 | 5.0 | 5.1 |
| V.C. 5 | | 5.3 | 5.0 | 5.3 | 4.9 | 4.4 | 4.7 | 4.9 | 4.6 | 4.7 | 4.6 | 5.1 | 4.7 | 4.4 | 4.7 | 4.4 | 5.4 |
| % T.V.C. | | 90 | 89 | 91 | 93 | 100 | 95 | 93 | 95 | 98 | 98 | 98 | 95 | 95 | 98 | 100 | 95 |

TABLE 1.2.1 (Cont)

VITAL CAPACITIES (liters B.T.P.S.) AND % TIMED VITAL CAPACITY

| Test | Subject Number | Pre-Run | Days in Chamber | | | | | | | | | | | | | | Post Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| V.C. 1 | 51 | 3.8 | 5.2 | 5.0 | 4.8 | 4.6 | 4.9 | 5.0 | 4.9 | 4.6 | 4.3 | 4.3 | 4.5 | 4.7 | 4.3 | 4.6 | 5.0 |
| V.C. 2 | | 3.3 | 5.2 | 5.1 | 5.0 | 4.9 | 4.8 | 5.0 | 5.1 | 4.9 | 4.9 | 4.9 | 4.8 | 4.9 | 4.9 | 5.0 | 5.0 |
| V.C. 3 | | 3.4 | 5.1 | 5.1 | 4.9 | 4.6 | 4.8 | 4.9 | 5.0 | 4.8 | 4.8 | 4.7 | 4.9 | 4.8 | 4.8 | 5.1 | 5.1 |
| V.C. 4 | | 3.4 | 4.6 | 4.8 | 4.8 | 4.9 | 4.5 | 4.4 | 4.6 | 4.6 | 4.3 | 4.2 | 4.4 | 4.3 | 4.7 | 4.3 | 4.1 |
| V.C. 5 | | 3.6 | 4.8 | 4.6 | 4.8 | 4.7 | 4.5 | 4.7 | 4.8 | 4.6 | 4.5 | 4.4 | 4.5 | 4.5 | 4.5 | 4.4 | 4.3 |
| % T.V.C. | | 94 | 97 | 95 | 88 | 85 | 92 | 89 | 97 | 95 | 90 | 91 | 97 | 95 | 100 | 100 | 90 |
| V.C. 1 | 52 | 5.6 | 5.5 | 5.2 | 5.2 | 4.9 | 4.9 | 4.9 | 4.8 | 5.0 | 5.1 | 4.9 | 5.0 | 4.5 | 4.6 | 4.7 | 3.4 |
| V.C. 2 | | 5.5 | 5.6 | 5.2 | 5.4 | 5.3 | 5.3 | 5.4 | 5.2 | 5.2 | 5.4 | 5.1 | 5.1 | 5.1 | 4.9 | 5.0 | 3.5 |
| V.C. 3 | | 5.5 | 5.4 | 5.4 | 5.3 | 5.2 | 5.0 | 4.8 | 5.1 | 5.0 | 5.2 | 5.0 | 4.8 | 4.8 | 4.8 | 4.9 | 3.5 |
| V.C. 4 | | 5.4 | 5.3 | 5.1 | 5.0 | 5.0 | 4.9 | 4.8 | 5.0 | 4.9 | 5.2 | 4.9 | 5.0 | 4.8 | 4.7 | 4.8 | 3.3 |
| V.C. 5 | | 5.4 | 5.4 | 5.2 | 5.0 | 5.0 | 4.8 | 4.6 | 4.8 | 5.0 | 5.1 | 5.0 | 4.9 | 4.8 | 5.0 | 4.9 | 3.5 |
| % T.V.C. | | 90 | 93 | 95 | 98 | 93 | 98 | 98 | 98 | 95 | 98 | 98 | 100 | 97 | 100 | 98 | 94 |
| V.C. 1 | 53 | 4.8 | 4.2 | 3.7 | 3.7 | 4.4 | 4.4 | 4.0 | 4.2 | 4.3 | 3.9 | 4.0 | 4.7 | 4.2 | 3.5 | 4.2 | 4.0 |
| V.C. 2 | | 5.0 | 4.5 | 3.8 | 4.6 | 4.6 | 4.7 | 4.4 | 3.5 | 4.7 | 4.2 | 4.4 | 4.8 | 4.8 | 4.5 | 4.6 | 4.4 |
| V.C. 3 | | 4.8 | 4.4 | 3.8 | 4.2 | 4.5 | 4.3 | 4.3 | 4.4 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.4 |
| V.C. 4 | | 4.9 | 4.5 | 3.7 | 3.9 | 4.1 | 4.4 | 4.3 | 4.2 | 4.1 | 4.0 | 4.2 | 4.5 | 4.2 | 4.2 | 4.2 | 4.3 |
| V.C. 5 | | 4.9 | 4.4 | 3.8 | 4.0 | 4.1 | 4.3 | 4.3 | 4.2 | 4.2 | 4.2 | 4.5 | 4.2 | 4.4 | 4.5 | 4.2 | 4.3 |
| % T.V.C. | | 87 | 94 | 91 | 94 | 100 | 94 | 92 | 94 | 94 | 97 | 92 | 92 | 92 | 95 | 96 | 92 |
| V.C. 1 | 54 | 3.6 | 4.5 | 4.2 | 4.2 | 4.0 | 3.8 | 4.2 | 3.8 | 4.4 | 4.1 | 4.0 | 3.8 | 3.7 | 3.6 | 4.2 | 3.6 |
| V.C. 2 | | 3.7 | 4.4 | 4.2 | 4.3 | 4.4 | 4.2 | 4.2 | 4.2 | 4.4 | 4.3 | 4.4 | 4.1 | 4.2 | 3.9 | 4.3 | 3.7 |
| V.C. 3 | | 3.8 | 4.3 | 4.0 | 4.3 | 4.2 | 4.0 | 4.2 | 4.2 | 4.4 | 4.2 | 4.2 | 4.1 | 4.2 | 3.8 | 4.3 | 3.7 |
| V.C. 4 | | 3.8 | 4.3 | 4.0 | 4.3 | 4.0 | 3.9 | 3.9 | 4.1 | 4.4 | 4.1 | 4.1 | 4.1 | 3.8 | 3.9 | 3.7 | 3.4 |
| V.C. 5 | | 3.7 | 4.0 | 4.0 | 4.1 | 4.2 | 3.8 | 4.0 | 4.2 | 4.5 | 4.2 | 4.3 | 4.1 | 4.0 | 3.9 | 4.0 | 3.6 |
| % T.V.C. | | 86 | 97 | 94 | 91 | 97 | 94 | 94 | 91 | 87 | 91 | 94 | 94 | 91 | 94 | 100 | 91 |
| V.C. 1 | 56 | 4.3 | 4.3 | 4.0 | 4.1 | 3.9 | 4.2 | 3.7 | 4.3 | 3.8 | 3.8 | 3.8 | 3.7 | 4.1 | 3.9 | 4.0 | 3.6 |
| V.C. 2 | | 4.4 | 4.3 | 4.4 | 4.3 | 4.1 | 4.1 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 3.9 | 4.3 | 4.0 | 4.2 | 4.0 |
| V.C. 3 | | 4.0 | 4.2 | 4.0 | 4.1 | 4.0 | 4.1 | 4.1 | 4.2 | 4.0 | 3.9 | 4.2 | 3.9 | 4.0 | 3.9 | 4.0 | 4.0 |
| V.C. 4 | | 4.1 | 4.2 | 4.3 | 4.2 | 4.2 | 4.2 | 4.3 | 4.2 | 4.3 | 4.0 | 4.1 | 4.3 | 4.1 | 4.2 | 4.2 | 4.0 |
| V.C. 5 | | 4.3 | 4.3 | 4.3 | 4.2 | 4.4 | 4.1 | 4.3 | 4.2 | 4.3 | 4.0 | 4.2 | 4.3 | 4.2 | 4.2 | 4.0 | 4.0 |
| % T.V.C. | | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 97 |

TABLE 1.2.2

TIDAL VOLUME (liters B.T.P.S.)

| Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| 11 | 1.5 | .6 | .9 | | | .4 | .7 | .4 | .4 | .4 | .4 | .4 | .5 | .4 | .4 | .5 |
| 12 | 1.2 | .9 | 1.0 | | | .4 | .8 | .7 | .5 | .4 | .6 | .7 | .7 | .9 | .6 | .9 |
| 13 | .9 | .9 | .8 | | | .7 | 1.0 | .7 | 1.1 | 1.3 | .9 | 1.2 | .7 | .9 | .7 | .7 |
| 15 | .7 | .7 | .5 | | | .7 | .9 | .7 | .8 | .6 | .7 | 1.0 | .7 | .7 | .6 | .7 |
| 16 | 1.0 | 1.0 | 1.0 | | | 1.2 | .9 | .7 | 1.0 | 1.0 | .9 | 1.2 | 1.2 | 1.0 | 1.3 | 1.4 |
| 17 | .9 | 1.5 | 1.1 | | | .9 | 1.1 | .9 | .7 | .8 | 1.3 | .7 | .8 | .7 | .7 | .7 |
| 31 | .9 | .8 | .8 | .9 | .9 | 1.0 | 1.0 | .9 | 1.1 | .9 | .8 | .7 | .9 | 1.1 | 1.0 | .7 |
| 32 | 1.2 | .9 | 1.1 | 1.2 | 1.0 | 1.1 | 1.4 | 1.0 | 1.1 | 1.0 | .9 | 1.1 | 1.0 | 1.1 | .9 | 1.0 |
| 33 | .6 | 1.0 | 1.0 | .9 | .9 | .9 | 1.2 | 1.0 | 1.1 | 1.1 | 1.1 | .9 | .9 | 1.1 | 1.1 | 1.2 |
| 35 | 1.0 | 1.3 | 1.6 | 1.5 | 1.0 | 1.0 | 1.2 | 1.0 | 1.0 | 1.2 | .9 | 1.2 | 1.2 | 1.2 | 1.5 | |
| 36 | 1.0 | 1.5 | .9 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.0 | .9 | .9 | 1.4 | 1.0 | 1.1 | 1.4 | 1.0 |
| 37 | 1.2 | 1.2 | 1.5 | 1.0 | 1.9 | 1.1 | 1.2 | 1.0 | .9 | .8 | 1.2 | 1.5 | .9 | 1.1 | 1.1 | 1.3 |
| 42 | .9 | .9 | .6 | 1.2 | .6 | 1.4 | 1.3 | .6 | .8 | 1.1 | 1.7 | 1.2 | 1.1 | .9 | 1.6 | 1.2 |
| 43 | 1.1 | 1.1 | 1.6 | 1.2 | .9 | .9 | 1.4 | 1.1 | 1.0 | 1.1 | 1.4 | .9 | .6 | 1.0 | .6 | 1.0 |
| 44 | 1.0 | 1.0 | 1.3 | 1.4 | 1.5 | 1.2 | 1.2 | 1.3 | 1.3 | 1.2 | 1.3 | 1.5 | 1.5 | 1.0 | 1.8 | 1.4 |
| 45 | .9 | 1.2 | .9 | 1.0 | 1.0 | 1.0 | 1.0 | .9 | 1.0 | 1.0 | 1.2 | 1.1 | 1.1 | .8 | 1.3 | 1.2 |
| 46 | .6 | .6 | .7 | .4 | .9 | .7 | 1.6 | .9 | .9 | .7 | .9 | .8 | 1.5 | 1.0 | .8 | .6 |
| 47 | 1.0 | 1.4 | 1.3 | 1.2 | 1.5 | 1.2 | 1.1 | 1.0 | .9 | 1.3 | 1.4 | 1.1 | 1.1 | .9 | 1.3 | 1.4 |
| 51 | .4 | .6 | 1.1 | .6 | .7 | 1.0 | .7 | .8 | .7 | .5 | .7 | .7 | .7 | .7 | .7 | .4 |
| 52 | .8 | 1.0 | 1.2 | 1.2 | 1.1 | 1.6 | 1.1 | 1.4 | 1.3 | 1.2 | 1.2 | 1.5 | 1.1 | 1.3 | 1.4 | .6 |
| 53 | .8 | .7 | 1.3 | 1.1 | 1.7 | 1.2 | 1.3 | 1.1 | .9 | 1.1 | .8 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 |
| 54 | .7 | .8 | 1.9 | 1.2 | 1.1 | 1.2 | .8 | .7 | 1.4 | 1.1 | .7 | 1.0 | 1.0 | 1.0 | 1.0 | .8 |
| 56 | 1.3 | 1.4 | 1.2 | 1.0 | 1.0 | 1.1 | .8 | .7 | 1.0 | 1.2 | 1.1 | 1.1 | 1.3 | 1.0 | 1.0 | .8 |

TABLE 1.2.3

INSPIRATORY RESERVE (liters B.T.P.S.)

| Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| 11 | 2.1 | 1.8 | 1.3 | | | 1.4 | 2.0 | 1.8 | 1.3 | 1.2 | 1.2 | 1.5 | 1.0 | 1.2 | 1.5 | 1.4 |
| 12 | 3.6 | 3.1 | 2.0 | | | 1.4 | 2.1 | 2.6 | 2.9 | 3.2 | 2.6 | 3.0 | 3.0 | 2.1 | 3.0 | 2.4 |
| 13 | 2.8 | 2.6 | 1.1 | | | 2.0 | 1.7 | 1.7 | 1.5 | 1.7 | 2.2 | 1.2 | 2.3 | 1.7 | 2.0 | 2.0 |
| 15 | 2.5 | 2.9 | 2.4 | | | 2.2 | 1.7 | 2.0 | 1.8 | 1.9 | 2.1 | 1.6 | 1.7 | 2.0 | 2.1 | 1.7 |
| 16 | 3.0 | 2.2 | 2.0 | | | 1.8 | 1.9 | 1.9 | 1.3 | 1.6 | 1.7 | 1.0 | 1.4 | 1.4 | 2.8 | 1.4 |
| 17 | 2.4 | 2.9 | 1.1 | | | 1.5 | 1.7 | 1.7 | 1.5 | 1.6 | 1.1 | 1.5 | 1.5 | 1.5 | 1.7 | 1.5 |
| 31 | 2.8 | 3.3 | 3.0 | 2.5 | 2.0 | 2.5 | 2.2 | 2.7 | 2.3 | 2.6 | 2.7 | 2.7 | 2.6 | 2.2 | 2.5 | 2.6 |
| 32 | 2.0 | 2.5 | 2.0 | 1.6 | 2.2 | 2.0 | 2.2 | 2.4 | 2.2 | 2.2 | 2.7 | 2.2 | 2.3 | 1.9 | 1.8 | 2.2 |
| 33 | 2.7 | 2.1 | 2.4 | 2.4 | 1.2 | 2.5 | 2.1 | 2.2 | 2.5 | 2.0 | 2.5 | 2.4 | 2.0 | 1.6 | 1.9 | 2.3 |
| 35 | 1.9 | 1.3 | 2.6 | 2.1 | 2.7 | 2.4 | 2.6 | 2.4 | 2.4 | 1.8 | 2.9 | 2.8 | 2.8 | 2.8 | 2.2 | |
| 36 | 2.8 | 2.5 | 3.2 | 2.6 | 2.6 | 2.3 | 2.4 | 2.5 | 2.5 | 2.9 | 2.7 | 2.9 | 2.5 | 2.7 | 2.0 | 2.6 |
| 37 | 2.5 | 2.4 | 2.0 | 1.9 | 2.4 | 2.3 | 1.9 | 2.2 | 2.0 | 2.3 | 2.0 | 1.9 | 2.2 | 2.2 | 1.7 | 1.9 |
| 42 | 2.5 | 2.3 | 2.1 | 1.8 | 2.4 | 1.1 | 1.6 | 1.9 | 1.9 | 1.9 | 1.4 | 1.7 | 1.8 | 1.7 | 2.0 | 1.9 |
| 43 | 1.9 | 2.9 | 2.7 | 2.7 | 3.3 | 2.8 | 2.3 | 3.2 | 3.0 | 3.2 | 2.8 | 3.0 | 3.4 | 3.3 | 3.4 | 3.0 |
| 44 | 1.3 | 2.1 | 2.1 | 2.0 | 2.4 | 1.9 | 2.0 | 2.3 | 2.3 | 2.5 | 2.2 | 2.3 | 1.4 | 2.1 | 1.7 | 2.0 |
| 45 | 2.5 | 3.2 | 2.4 | 2.3 | 2.5 | 2.3 | 2.4 | 2.4 | 2.3 | 2.1 | 2.1 | 2.4 | 2.4 | 2.4 | 2.5 | 2.1 |
| 46 | 2.3 | 2.9 | 2.9 | 2.5 | 2.6 | 2.4 | 1.7 | 2.4 | 2.4 | 3.1 | 2.7 | 2.3 | 2.0 | 2.6 | 2.4 | 2.7 |
| 47 | 2.2 | 2.0 | 2.8 | 2.4 | 2.2 | 2.7 | 2.4 | 2.5 | 2.7 | 2.4 | 2.4 | 2.4 | 2.2 | 2.6 | 1.9 | 2.7 |
| 51 | 2.4 | 3.0 | 2.4 | 2.9 | 2.8 | 2.0 | 2.9 | 2.6 | 2.7 | 2.5 | 2.5 | 2.4 | 2.4 | 2.6 | 2.2 | 3.0 |
| 52 | 3.3 | 3.1 | 2.4 | 2.5 | 2.8 | 1.4 | 2.4 | 2.3 | 2.3 | 1.9 | 2.6 | 2.4 | 1.9 | 2.0 | 1.4 | 1.8 |
| 53 | 2.4 | 2.5 | 1.4 | 1.3 | 1.3 | 1.8 | 1.8 | 1.8 | 2.4 | 1.8 | 1.7 | 2.1 | 1.7 | 1.6 | 2.1 | 2.0 |
| 54 | 2.2 | 2.8 | 1.3 | 2.1 | 2.2 | 1.4 | 2.2 | 1.9 | 1.5 | 2.2 | 2.0 | 2.4 | 2.0 | 1.9 | 1.5 | 2.0 |
| 56 | 1.5 | 2.0 | 1.5 | 2.2 | 2.0 | 1.8 | 2.2 | 2.1 | 1.9 | 1.8 | 2.0 | 1.9 | 1.8 | 1.9 | 1.9 | 1.5 |

TABLE 1.2.4

EXPIRATORY RESERVE (liters B.T.P.S.)

| Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| 11 | 1.7 | 1.8 | 2.2 | | | 1.8 | 1.1 | 1.8 | 1.4 | 1.5 | 1.8 | 1.6 | 1.0 | 1.4 | 1.6 | 1.4 |
| 12 | 1.8 | 1.5 | 1.2 | | | 1.8 | 1.6 | 1.6 | 1.4 | 1.5 | 1.6 | 1.6 | 1.4 | 1.7 | 1.6 | 2.0 |
| 13 | 1.6 | 1.2 | 1.9 | | | 2.0 | | 2.3 | 2.1 | 2.0 | 2.0 | 2.0 | 1.7 | 2.0 | 2.2 | 2.0 |
| 15 | 1.7 | 1.3 | 1.1 | | | 1.7 | 1.7 | 1.8 | 2.1 | 2.1 | 1.8 | 2.1 | 2.0 | 2.1 | 1.9 | 1.8 |
| 16 | 1.1 | 1.2 | 1.2 | | | 1.3 | 1.6 | 1.8 | 1.5 | 1.8 | 1.7 | 2.2 | 1.7 | 2.3 | 2.1 | 1.4 |
| 17 | 1.3 | .9 | 1.2 | | | 1.3 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 | 1.2 | 1.2 |
| 31 | 1.7 | 1.6 | 1.8 | 1.9 | 1.5 | 1.5 | 1.7 | 1.3 | 1.6 | 1.5 | 1.6 | 1.7 | 1.5 | 1.6 | 1.5 | 1.7 |
| 32 | 2.3 | 1.8 | 2.2 | 2.2 | 2.3 | 1.9 | 2.0 | 1.6 | 1.6 | 1.9 | 1.8 | 1.9 | 1.9 | 1.8 | 2.2 | 1.6 |
| 33 | 1.4 | 1.8 | 1.9 | 1.9 | 1.4 | 1.1 | 1.5 | 1.3 | 1.2 | 1.2 | 1.5 | 1.8 | 1.6 | 1.6 | 1.2 | 1.7 |
| 35 | .6 | 2.2 | 1.7 | 2.1 | 2.0 | 2.0 | 2.0 | 2.0 | 1.7 | 1.7 | 1.6 | 1.8 | 1.6 | 1.6 | 1.6 | |
| 36 | 1.3 | 1.7 | 1.6 | 2.0 | 2.1 | 1.9 | 1.7 | 1.7 | 1.8 | 1.5 | 1.9 | 1.8 | 1.7 | 1.8 | 1.7 | 1.8 |
| 37 | 1.3 | 1.2 | 1.1 | 1.5 | 1.1 | 1.5 | 1.4 | 1.4 | 1.4 | 1.1 | 1.1 | 1.1 | 1.0 | 1.4 | 1.4 | 1.5 |
| 42 | .8 | 1.3 | 1.3 | .9 | 1.2 | 1.4 | 1.0 | 1.0 | 1.1 | 1.1 | 1.2 | 1.1 | .8 | 1.0 | 1.0 | 1.8 |
| 43 | 1.1 | 1.6 | 1.6 | 1.7 | 1.5 | 2.0 | 1.6 | 1.2 | 1.9 | 1.6 | 1.9 | 1.6 | 1.5 | 2.1 | 1.9 | 1.5 |
| 44 | 1.0 | 1.3 | 1.5 | 1.4 | 1.5 | 1.8 | 1.5 | 1.5 | 1.6 | 1.5 | 1.1 | 1.2 | 1.0 | 1.1 | 1.2 | 1.0 |
| 45 | 1.4 | 1.1 | 1.4 | 1.3 | 1.5 | 1.6 | 1.5 | 1.2 | 1.5 | 1.3 | 1.4 | 1.5 | 1.3 | 1.4 | 1.2 | 1.3 |
| 46 | 1.7 | 2.0 | 1.6 | 1.4 | 2.0 | 2.0 | 1.6 | 1.7 | 2.0 | 1.6 | 1.8 | 1.5 | 1.5 | 1.4 | 2.0 | 1.3 |
| 47 | 1.7 | 1.4 | 1.9 | 1.7 | 1.3 | 1.5 | 1.8 | 1.9 | 1.5 | 1.7 | 1.9 | 1.5 | 1.3 | 1.5 | 1.7 | 1.8 |
| 51 | 1.1 | 1.8 | 1.2 | 1.3 | 1.1 | 1.2 | 1.2 | 1.3 | 1.5 | 1.2 | 1.2 | 1.2 | 1.2 | .9 | 1.0 | 1.7 |
| 52 | 1.5 | 2.0 | 1.3 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 1.9 | 1.9 | 1.4 | 2.0 | 1.7 | 1.5 | 1.6 | 1.0 |
| 53 | 1.9 | 1.0 | 1.4 | 1.3 | 1.5 | 1.7 | 1.2 | 1.6 | 1.5 | 1.0 | 1.5 | 1.3 | 1.3 | 1.2 | 1.4 | 1.1 |
| 54 | .6 | .9 | 1.2 | 1.2 | 1.1 | 1.2 | .8 | 1.1 | 1.3 | 1.1 | .8 | 1.2 | 1.2 | 1.0 | 1.2 | .9 |
| 56 | 2.2 | 1.3 | 1.4 | 1.2 | 1.1 | 1.4 | 1.2 | 1.4 | 1.2 | 1.2 | 1.2 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 |

TABLE 1.2.5

MAXIMUM BREATHING CAPACITY (liters B. T. P. S.)

| Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| 11 | 151.0 | | | | | | | | | | | | | | | 134.8 |
| 12 | 113.3 | | | | | | | | | | | | | | | 110.9 |
| 13 | 126.7 | 151.2 | 131.4 | | | | 172.9 | 175.8 | 142.7 | 161.6 | 152.0 | 181.2 | 189.5 | 188.0 | 182.2 | 173.4 |
| 15 | 102.9 | 123.3 | 90.0 | | | | 162.2 | 165.1 | 135.1 | 163.5 | 155.5 | 147.0 | 163.7 | 148.9 | 159.3 | 165.8 |
| 16 | 162.6 | | | | | | | | | | | | | | | 124.8 |
| 17 | 144.1 | 131.5 | 133.8 | | | 125.3 | 135.9 | 131.8 | 138.6 | 130.8 | 127.2 | 151.4 | 179.1 | 150.7 | 123.3 | 143.1 |
| 31 | 196.5 | | | | | | | | | | | | | | | 168.4 |
| 32 | 186.0 | | | | | | | | | | | | | | | 172.6 |
| 33 | 155.6 | | | | | | | | | | | | | | | 178.6 |
| 35 | 159.8 | 224.5 | 210.6 | 230.4 | 259.9 | 248.1 | 256.9 | 259.4 | 263.2 | 265.0 | 270.9 | 274.2 | 296.5 | 260.2 | 259.2 | |
| 36 | 111.1 | 167.6 | 220.8 | 175.5 | 207.9 | 205.7 | 202.2 | 222.4 | 217.4 | 219.4 | 212.6 | 210.6 | 205.1 | 178.2 | 186.0 | 151.3 |
| 37 | 152.2 | 188.6 | 235.4 | 224.4 | 248.0 | 247.1 | 246.6 | 217.4 | 261.3 | 232.9 | 248.1 | 240.4 | 180.2 | 230.9 | 244.9 | 154.5 |
| 42 | 185.0 | | | | | | | | | | | | | | | 163.0 |
| 43 | 65.5 | 158.5 | 208.9 | 177.8 | 205.6 | 190.2 | 227.4 | 207.6 | 219.2 | 185.9 | 222.8 | 220.9 | 213.0 | 115.7 | 170.6 | 172.5 |
| 44 | 138.4 | 178.9 | 162.6 | 181.0 | 184.1 | 162.9 | 185.0 | 181.9 | 174.9 | 173.6 | 210.6 | 190.2 | 191.5 | 110.1 | 138.6 | 168.9 |
| 45 | 159.8 | | | | | | | | | | | | | | | 171.2 |
| 46 | 165.3 | 254.2 | 292.4 | 276.8 | 283.3 | 287.2 | 298.8 | 292.0 | 292.4 | 310.0 | 308.3 | 304.6 | 281.2 | 202.4 | 232.8 | |
| 47 | 136.6 | | | | | | | | | | | | | | | 153.5 |
| 51 | 79.1 | | | | | | | | | | | | | | | 86.1 |
| 52 | 136.1 | | | | | | | | | | | | | | | 57.6 |
| 53 | 98.1 | 211.3 | 229.9 | 256.5 | 265.1 | 233.9 | 238.0 | 277.5 | 245.6 | 246.8 | 234.6 | 253.6 | 199.9 | 229.4 | 270.7 | 90.0 |
| 54 | 163.8 | 182.9 | 179.0 | 212.2 | 196.3 | 214.4 | 215.6 | 166.0 | 206.8 | 220.9 | 178.5 | 165.0 | 153.3 | 133.3 | 194.6 | 78.2 |
| 56 | 170.3 | | | | | | | | | | | | | | | 119.1 |

TABLE 1.2.6

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 11 | 2.6 | | | | | | | | | | | | | | | .8 |
| | HR | | 78 | | | | | | | | | | | | | | | 75 |
| Exercise 1 min | $O_2$ | | 1.4 | | | | | | | | | | | | | | | 4.1 |
| | HR | | 108 | | | | | | | | | | | | | | | 120 |
| 2 min | $O_2$ | | 5.2 | | | | | | | | | | | | | | | 6.6 |
| | HR | | 126 | | | | | | | | | | | | | | | 141 |
| 3 min | $O_2$ | | 6.0 | | | | | | | | | | | | | | | 8.0 |
| | HR | | 129 | | | | | | | | | | | | | | | 138 |
| 4 min | $O_2$ | | 5.8 | | | | | | | | | | | | | | | 7.4 |
| | HR | | 132 | | | | | | | | | | | | | | | 138 |
| 5 min | $O_2$ | | 5.8 | | | | | | | | | | | | | | | 8.7 |
| | HR | | 129 | | | | | | | | | | | | | | | 141 |
| Post Exercise 1 min | $O_2$ | | 5.0 | | | | | | | | | | | | | | | 4.6 |
| | HR | | 114 | | | | | | | | | | | | | | | 117 |
| 2 min | $O_2$ | | 4.7 | | | | | | | | | | | | | | | 3.0 |
| | HR | | 102 | | | | | | | | | | | | | | | 111 |
| 8 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | | | | | | | | | | | | | | | | |
| Rest | $O_2$ | 12 | 2.5 | | | | | | | | | | | | | | | 2.1 |
| | HR | | 66 | | | | | | | | | | | | | | | 87 |
| Exercise 1 min | $O_2$ | | 4.6 | | | | | | | | | | | | | | | 1.2 |
| | HR | | 102 | | | | | | | | | | | | | | | 129 |
| 2 min | $O_2$ | | 5.7 | | | | | | | | | | | | | | | 7.7 |
| | HR | | 129 | | | | | | | | | | | | | | | 147 |
| 3 min | $O_2$ | | 6.6 | | | | | | | | | | | | | | | 8.5 |
| | HR | | 138 | | | | | | | | | | | | | | | 156 |
| 4 min | $O_2$ | | 7.2 | | | | | | | | | | | | | | | 9.4 |
| | HR | | 144 | | | | | | | | | | | | | | | 159 |
| 5 min | $O_2$ | | 10.1 | | | | | | | | | | | | | | | 10.2 |
| | HR | | 144 | | | | | | | | | | | | | | | 168 |
| Post Exercise 1 min | $O_2$ | | 5.7 | | | | | | | | | | | | | | | 4.8 |
| | HR | | 108 | | | | | | | | | | | | | | | 135 |
| 2 min | $O_2$ | | 4.4 | | | | | | | | | | | | | | | 4.7 |
| | HR | | 102 | | | | | | | | | | | | | | | 123 |
| 8 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | | | | | | | | | | | | | | | | |

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 16 | 3.6 | | | | | | | | | | | | | | | 2.0 |
| | HR | | 69 | | | | | | | | | | | | | | | 102 |
| Exercise 1 min | $O_2$ | | 3.2 | | | | | | | | | | | | | | | 5.4 |
| | HR | | 102 | | | | | | | | | | | | | | | 126 |
| 2 min | $O_2$ | | 5.4 | | | | | | | | | | | | | | | 6.5 |
| | HR | | 123 | | | | | | | | | | | | | | | 141 |
| 3 min | $O_2$ | | 5.2 | | | | | | | | | | | | | | | 5.4 |
| | HR | | 132 | | | | | | | | | | | | | | | 144 |
| 4 min | $O_2$ | | 7.4 | | | | | | | | | | | | | | | 6.7 |
| | HR | | 138 | | | | | | | | | | | | | | | 147 |
| 5 min | $O_2$ | | 5.7 | | | | | | | | | | | | | | | 7.1 |
| | HR | | 138 | | | | | | | | | | | | | | | 144 |
| Post Exercise 1 min | $O_2$ | | 5.4 | | | | | | | | | | | | | | | 4.9 |
| | HR | | 114 | | | | | | | | | | | | | | | 123 |
| 2 min | $O_2$ | | 3.4 | | | | | | | | | | | | | | | 3.7 |
| | HR | | 108 | | | | | | | | | | | | | | | 114 |
| 8 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | | | | | | | | | | | | | | | | |
| Rest | $O_2$ | 31 | .6 | | | | | | | | | | | | | | | .7 |
| | HR | | 96 | | | | | | | | | | | | | | | 84 |
| Exercise 1 min | $O_2$ | | 2.4 | | | | | | | | | | | | | | | 1.0 |
| | HR | | 126 | | | | | | | | | | | | | | | 132 |
| 2 min | $O_2$ | | 2.5 | | | | | | | | | | | | | | | 2.1 |
| | HR | | 138 | | | | | | | | | | | | | | | 147 |
| 3 min | $O_2$ | | 2.5 | | | | | | | | | | | | | | | 2.0 |
| | HR | | 144 | | | | | | | | | | | | | | | 150 |
| 4 min | $O_2$ | | 2.5 | | | | | | | | | | | | | | | 2.0 |
| | HR | | 150 | | | | | | | | | | | | | | | 159 |
| 5 min | $O_2$ | | 2.4 | | | | | | | | | | | | | | | 2.0 |
| | HR | | 147 | | | | | | | | | | | | | | | 162 |
| Post Exercise 1 min | $O_2$ | | 2.4 | | | | | | | | | | | | | | | 1.8 |
| | HR | | 132 | | | | | | | | | | | | | | | 123 |
| 2 min | $O_2$ | | .8 | | | | | | | | | | | | | | | .4 |
| | HR | | 117 | | | | | | | | | | | | | | | 108 |
| 8 min | $O_2$ | | .5 | | | | | | | | | | | | | | | .4 |
| | HR | | | | | | | | | | | | | | | | | 102 |

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 32 | .4 | | | | | | | | | | | | | | | .6 |
| | HR | | 81 | | | | | | | | | | | | | | | 76 |
| Exercise 1 min | $O_2$ | | .4 | | | | | | | | | | | | | | | 1.6 |
| | HR | | 123 | | | | | | | | | | | | | | | 115 |
| 2 min | $O_2$ | | 1.6 | | | | | | | | | | | | | | | 1.8 |
| | HR | | 138 | | | | | | | | | | | | | | | 137 |
| 3 min | $O_2$ | | 1.6 | | | | | | | | | | | | | | | 1.7 |
| | HR | | 156 | | | | | | | | | | | | | | | 147 |
| 4 min | $O_2$ | | 1.6 | | | | | | | | | | | | | | | 1.5 |
| | HR | | 168 | | | | | | | | | | | | | | | 154 |
| 5 min | $O_2$ | | 2.0 | | | | | | | | | | | | | | | 1.5 |
| | HR | | 177 | | | | | | | | | | | | | | | 158 |
| Post Exercise 1 min | $O_2$ | | 2.0 | | | | | | | | | | | | | | | 1.1 |
| | HR | | 159 | | | | | | | | | | | | | | | 122 |
| 2 min | $O_2$ | | .8 | | | | | | | | | | | | | | | .9 |
| | HR | | 144 | | | | | | | | | | | | | | | 109 |
| 8 min | $O_2$ | | .4 | | | | | | | | | | | | | | | .6 |
| | HR | | | | | | | | | | | | | | | | | |
| Rest | $O_2$ | 33 | .6 | | | | | | | | | | | | | | | .6 |
| | HR | | 60 | | | | | | | | | | | | | | | 78 |
| Exercise 1 min | $O_2$ | | 1.1 | | | | | | | | | | | | | | | 1.2 |
| | HR | | 99 | | | | | | | | | | | | | | | 108 |
| 2 min | $O_2$ | | 2.0 | | | | | | | | | | | | | | | 2.2 |
| | HR | | 111 | | | | | | | | | | | | | | | 120 |
| 3 min | $O_2$ | | 2.2 | | | | | | | | | | | | | | | 2.1 |
| | HR | | 117 | | | | | | | | | | | | | | | 132 |
| 4 min | $O_2$ | | 2.3 | | | | | | | | | | | | | | | 2.0 |
| | HR | | 120 | | | | | | | | | | | | | | | 135 |
| 5 min | $O_2$ | | 2.2 | | | | | | | | | | | | | | | 1.5 |
| | HR | | 117 | | | | | | | | | | | | | | | 141 |
| Post Exercise 1 min | $O_2$ | | 1.4 | | | | | | | | | | | | | | | 1.5 |
| | HR | | 84 | | | | | | | | | | | | | | | 114 |
| 2 min | $O_2$ | | 1.0 | | | | | | | | | | | | | | | 1.0 |
| | HR | | 78 | | | | | | | | | | | | | | | 102 |
| 8 min | $O_2$ | | .4 | | | | | | | | | | | | | | | .8 |
| | HR | | 75 | | | | | | | | | | | | | | | 99 |

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 42 | .4 | | | | | | | | | | | | | | | .6 |
| | HR | | 81 | | | | | | | | | | | | | | | 99 |
| Exercise 1 min | $O_2$ | | 1.0 | | | | | | | | | | | | | | | 1.6 |
| | HR | | 120 | | | | | | | | | | | | | | | 138 |
| 2 min | $O_2$ | | 2.0 | | | | | | | | | | | | | | | 1.6 |
| | HR | | 150 | | | | | | | | | | | | | | | 165 |
| 3 min | $O_2$ | | 2.0 | | | | | | | | | | | | | | | 2.2 |
| | HR | | 159 | | | | | | | | | | | | | | | 171 |
| 4 min | $O_2$ | | 2.1 | | | | | | | | | | | | | | | 2.1 |
| | HR | | 165 | | | | | | | | | | | | | | | 180 |
| 5 min | $O_2$ | | 2.1 | | | | | | | | | | | | | | | 1.8 |
| | HR | | 168 | | | | | | | | | | | | | | | 180 |
| Post Exercise 1 min | $O_2$ | | 1.5 | | | | | | | | | | | | | | | 1.3 |
| | HR | | 147 | | | | | | | | | | | | | | | 153 |
| 2 min | $O_2$ | | 1.0 | | | | | | | | | | | | | | | .6 |
| | HR | | 123 | | | | | | | | | | | | | | | 129 |
| 8 min | $O_2$ | | .5 | | | | | | | | | | | | | | | .5 |
| | HR | | 105 | | | | | | | | | | | | | | | 114 |
| Rest | $O_2$ | 45 | .4 | | | | | | | | | | | | | | | .5 |
| | HR | | 84 | | | | | | | | | | | | | | | 99 |
| Exercise 1 min | $O_2$ | | 1.2 | | | | | | | | | | | | | | | 1.6 |
| | HR | | | | | | | | | | | | | | | | | 144 |
| 2 min | $O_2$ | | 1.8 | | | | | | | | | | | | | | | 1.6 |
| | HR | | | | | | | | | | | | | | | | | 168 |
| 3 min | $O_2$ | | 2.3 | | | | | | | | | | | | | | | 2.0 |
| | HR | | | | | | | | | | | | | | | | | 174 |
| 4 min | $O_2$ | | 2.3 | | | | | | | | | | | | | | | 2.0 |
| | HR | | | | | | | | | | | | | | | | | 180 |
| 5 min | $O_2$ | | 2.2 | | | | | | | | | | | | | | | 2.4 |
| | HR | | | | | | | | | | | | | | | | | 183 |
| Post Exercise 1 min | $O_2$ | | 1.0 | | | | | | | | | | | | | | | 1.6 |
| | HR | | | | | | | | | | | | | | | | | 144 |
| 2 min | $O_2$ | | .9 | | | | | | | | | | | | | | | .8 |
| | HR | | | | | | | | | | | | | | | | | 120 |
| 8 min | $O_2$ | | .5 | | | | | | | | | | | | | | | .5 |
| | HR | | | | | | | | | | | | | | | | | 105 |

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 47 | .6 | | | | | | | | | | | | | | | .5 |
| | HR | | 66 | | | | | | | | | | | | | | | 78 |
| Exercise 1 min | $O_2$ | | 1.6 | | | | | | | | | | | | | | | 2.3 |
| | HR | | 105 | | | | | | | | | | | | | | | 114 |
| 2 min | $O_2$ | | 1.6 | | | | | | | | | | | | | | | 2.4 |
| | HR | | 123 | | | | | | | | | | | | | | | 138 |
| 3 min | $O_2$ | | 1.5 | | | | | | | | | | | | | | | 2.8 |
| | HR | | 132 | | | | | | | | | | | | | | | 150 |
| 4 min | $O_2$ | | 2.1 | | | | | | | | | | | | | | | 2.8 |
| | HR | | 135 | | | | | | | | | | | | | | | 159 |
| 5 min | $O_2$ | | 2.1 | | | | | | | | | | | | | | | 1.5 |
| | HR | | 138 | | | | | | | | | | | | | | | 165 |
| Post Exercise 1 min | $O_2$ | | .8 | | | | | | | | | | | | | | | 1.1 |
| | HR | | 93 | | | | | | | | | | | | | | | 123 |
| 2 min | $O_2$ | | .8 | | | | | | | | | | | | | | | 1.1 |
| | HR | | 87 | | | | | | | | | | | | | | | 108 |
| 8 min | $O_2$ | | .5 | | | | | | | | | | | | | | | .5 |
| | HR | | 90 | | | | | | | | | | | | | | | 102 |
| Rest | $O_2$ | 51 | .5 | | | | | | | | | | | | | | | .4 |
| | HR | | 75 | | | | | | | | | | | | | | | 84 |
| Exercise 1 min | $O_2$ | | 1.2 | | | | | | | | | | | | | | | 1.1 |
| | HR | | 120 | | | | | | | | | | | | | | | 126 |
| 2 min | $O_2$ | | 1.9 | | | | | | | | | | | | | | | 1.8 |
| | HR | | 135 | | | | | | | | | | | | | | | 114 |
| 3 min | $O_2$ | | 1.8 | | | | | | | | | | | | | | | 2.0 |
| | HR | | 141 | | | | | | | | | | | | | | | 120 |
| 4 min | $O_2$ | | 2.1 | | | | | | | | | | | | | | | 2.4 |
| | HR | | 147 | | | | | | | | | | | | | | | 142 |
| 5 min | $O_2$ | | 2.4 | | | | | | | | | | | | | | | 2.4 |
| | HR | | 150 | | | | | | | | | | | | | | | 142 |
| Post Exercise 1 min | $O_2$ | | 1.1 | | | | | | | | | | | | | | | 1.9 |
| | HR | | 126 | | | | | | | | | | | | | | | 138 |
| 2 min | $O_2$ | | .9 | | | | | | | | | | | | | | | 1.2 |
| | HR | | 105 | | | | | | | | | | | | | | | 126 |
| 8 min | $O_2$ | | .4 | | | | | | | | | | | | | | | .5 |
| | HR | | 99 | | | | | | | | | | | | | | | 84 |

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 52 | .5 | | | | | | | | | | | | | | | .3 |
| | HR | | 78 | | | | | | | | | | | | | | | 84 |
| Exercise 1 min | $O_2$ | | 1.3 | | | | | | | | | | | | | | | 1.2 |
| | HR | | 129 | | | | | | | | | | | | | | | 108 |
| 2 min | $O_2$ | | 2.1 | | | | | | | | | | | | | | | 1.4 |
| | HR | | 153 | | | | | | | | | | | | | | | 132 |
| 3 min | $O_2$ | | 2.2 | | | | | | | | | | | | | | | 1.7 |
| | HR | | 162 | | | | | | | | | | | | | | | 138 |
| 4 min | $O_2$ | | 2.1 | | | | | | | | | | | | | | | 1.7 |
| | HR | | 165 | | | | | | | | | | | | | | | 138 |
| 5 min | $O_2$ | | 2.4 | | | | | | | | | | | | | | | 2.3 |
| | HR | | 174 | | | | | | | | | | | | | | | 146 |
| Post Exercise 1 min | $O_2$ | | 2.0 | | | | | | | | | | | | | | | 1.8 |
| | HR | | 144 | | | | | | | | | | | | | | | 132 |
| 2 min | $O_2$ | | 1.1 | | | | | | | | | | | | | | | .9 |
| | HR | | 132 | | | | | | | | | | | | | | | 117 |
| 8 min | $O_2$ | | .8 | | | | | | | | | | | | | | | .3 |
| | HR | | 102 | | | | | | | | | | | | | | | 92 |
| Rest | $O_2$ | 56 | .3 | | | | | | | | | | | | | | | .5 |
| | HR | | 69 | | | | | | | | | | | | | | | 102 |
| Exercise 1 min | $O_2$ | | .9 | | | | | | | | | | | | | | | 1.2 |
| | HR | | 120 | | | | | | | | | | | | | | | 126 |
| 2 min | $O_2$ | | 1.9 | | | | | | | | | | | | | | | 1.5 |
| | HR | | 135 | | | | | | | | | | | | | | | 144 |
| 3 min | $O_2$ | | 1.9 | | | | | | | | | | | | | | | 1.6 |
| | HR | | 142 | | | | | | | | | | | | | | | 156 |
| 4 min | $O_2$ | | 1.9 | | | | | | | | | | | | | | | 1.6 |
| | HR | | 143 | | | | | | | | | | | | | | | 156 |
| 5 min | $O_2$ | | 1.8 | | | | | | | | | | | | | | | 1.6 |
| | HR | | 144 | | | | | | | | | | | | | | | 156 |
| Post Exercise 1 min | $O_2$ | | 1.4 | | | | | | | | | | | | | | | 1.2 |
| | HR | | 110 | | | | | | | | | | | | | | | 120 |
| 2 min | $O_2$ | | .7 | | | | | | | | | | | | | | | .5 |
| | HR | | 108 | | | | | | | | | | | | | | | 108 |
| 8 min | $O_2$ | | .3 | | | | | | | | | | | | | | | .4 |
| | HR | | 93 | | | | | | | | | | | | | | | 96 |

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 13 | * | | | | | | | | | | | | | | | |
| | HR | | 69 | 69 | 69 | | | | | 72 | 75 | 69 | 75 | 78 | 72 | 78 | 72 | |
| Exercise 1 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 96 | 102 | 104 | | | | | 111 | 114 | 108 | 117 | 117 | 102 | 114 | 108 | |
| 2 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 111 | 108 | 129 | | | | | 129 | 126 | 123 | 132 | 129 | 126 | 129 | 120 | |
| 3 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 117 | 120 | 132 | | | | | 138 | 135 | 135 | 138 | 132 | 132 | 138 | 126 | |
| 4 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 126 | 132 | 132 | | | | | 135 | 144 | 135 | 138 | 141 | 138 | 135 | 135 | |
| 5 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 129 | 135 | 141 | | | | | 144 | 147 | 138 | 144 | 138 | 144 | 138 | 141 | |
| Post Exercise 1 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 114 | 117 | 120 | | | | | 120 | 114 | 111 | 117 | 126 | 120 | 126 | 114 | |
| 2 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 108 | 111 | 111 | | | | | 111 | 108 | 99 | 111 | 114 | 108 | 117 | 105 | |
| 8 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | | | | | | | | | | | | | | | | |
| Rest | $O_2$ | 15 | | | | | | | | | | | | | | | | |
| | HR | | 60 | 57 | 69 | | | | | 72 | 66 | 60 | 84 | 75 | | 78 | 72 | 84 |
| Exercise 1 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 96 | 99 | 108 | | | | | 114 | 111 | 108 | 120 | 105 | | 114 | 108 | 129 |
| 2 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 112 | 105 | 123 | | | | | 141 | 123 | 132 | 132 | 117 | | 129 | 117 | 141 |
| 3 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 117 | 108 | 132 | | | | | 147 | 126 | 129 | 138 | 129 | 132 | 138 | 132 | 147 |
| 4 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 123 | 108 | 129 | | | | | 141 | 129 | 129 | 138 | 135 | 141 | 135 | 135 | 147 |
| 5 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 120 | 114 | 132 | | | | | 144 | 126 | 129 | 141 | 144 | 141 | 135 | 132 | 147 |
| Post Exercise 1 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 102 | 102 | 99 | | | | | 111 | 90 | 81 | 105 | 114 | 96 | 102 | 87 | 105 |
| 2 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 90 | 87 | 81 | | | | | 93 | 90 | 78 | 96 | 90 | 84 | 84 | 78 | 102 |
| 8 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | | | | | | | | | | | | | | | | |

* Oxygen consumption value for subjects No. 11-17 not recorded due to instrument malfunction.

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 17 | | | | | | | | | | | | | | | | |
| | HR | | 63 | 63 | 66 | | | | | | 63 | 69 | 63 | 63 | | 72 | 66 | |
| Exercise 1 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 93 | 99 | 102 | | | | | | 105 | 114 | 111 | 108 | | 108 | 108 | |
| 2 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 111 | 123 | 129 | | | | | 132 | 135 | 144 | 141 | 141 | | 144 | 135 | |
| 3 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 123 | 135 | 135 | | | | | 147 | 144 | 153 | 147 | 144 | | 150 | 138 | |
| 4 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 123 | 138 | 141 | | | | | 153 | 144 | 156 | 153 | 153 | | 153 | 144 | |
| 5 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 126 | 144 | 144 | | | | | 156 | 150 | 159 | 156 | 159 | 150 | 159 | 150 | |
| Post Exercise 1 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 93 | 120 | 111 | | | | | 114 | 117 | 120 | 120 | 123 | 114 | 120 | 108 | |
| 2 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | 84 | 112 | 93 | | | | | 102 | 99 | 108 | 105 | 105 | 99 | 108 | 96 | |
| 8 min | $O_2$ | | | | | | | | | | | | | | | | | |
| | HR | | | | | | | | | | | | | | | | | |
| Rest | $O_2$ | 35 | .4 | .3 | .5 | .6 | .6 | .6 | .6 | .6 | .6 | .4 | .5 | .4 | .5 | .7 | | |
| | HR | | 69 | 78 | 90 | 71 | 69 | 69 | 66 | 69 | 60 | 66 | 69 | 81 | 66 | 66 | | |
| Exercise 1 min | $O_2$ | | 1.1 | 1.2 | 1.4 | 1.6 | 1.2 | 1.1 | 1.2 | .9 | 1.2 | 1.0 | .8 | .9 | .8 | 1.1 | | |
| | HR | | 132 | 141 | 135 | 123 | 102 | 99 | 120 | 117 | 129 | 120 | 126 | 132 | 126 | 120 | | |
| 2 min | $O_2$ | | 2.3 | 1.8 | 1.9 | 1.6 | 2.0 | 2.2 | 2.1 | 1.9 | 1.9 | 2.0 | 1.7 | 1.6 | 1.9 | 2.0 | | |
| | HR | | 150 | 153 | 150 | 149 | 150 | 144 | 153 | 144 | 150 | 153 | 147 | 153 | 150 | 141 | | |
| 3 min | $O_2$ | | 2.0 | 2.1 | 2.3 | 2.5 | 2.5 | 2.7 | 2.5 | 2.3 | 2.4 | 2.4 | 2.3 | 1.9 | 2.2 | 2.4 | | |
| | HR | | 168 | 168 | 165 | 159 | 156 | 147 | 162 | 156 | 159 | 162 | 156 | 162 | 162 | 150 | | |
| 4 min | $O_2$ | | 1.9 | 2.4 | 2.4 | 2.7 | 2.5 | 2.8 | 2.6 | 2.4 | 2.7 | 2.5 | 2.2 | 2.2 | 2.6 | 2.6 | | |
| | HR | | 177 | 180 | 171 | 168 | 165 | 165 | 165 | 162 | 168 | 165 | 159 | 171 | 165 | 165 | | |
| 5 min | $O_2$ | | 2.7 | 2.9 | 2.6 | 2.9 | 2.8 | 2.9 | 2.5 | 2.9 | 2.4 | 3.0 | 2.8 | 2.2 | 2.6 | 3.4 | | |
| | HR | | 183 | 183 | 177 | 174 | 162 | 168 | 168 | 171 | 174 | 171 | 168 | 177 | 168 | 174 | | |
| Post Exercise 1 min | $O_2$ | | 2.2 | 1.4 | 1.5 | 2.4 | 1.9 | 2.8 | 1.9 | 2.6 | 1.7 | 2.1 | 1.7 | 1.9 | 1.5 | 2.2 | | |
| | HR | | 180 | 150 | 144 | 144 | 132 | 135 | 138 | 141 | 138 | 147 | 129 | 156 | 132 | 132 | | |
| 2 min | $O_2$ | | .8 | .7 | .9 | 1.0 | 1.1 | 1.1 | 1.0 | 1.1 | 1.1 | 1.3 | 1.0 | 1.3 | .8 | 1.2 | | |
| | HR | | 153 | 117 | 123 | 120 | 108 | 105 | 114 | 114 | 117 | 120 | 111 | 147 | 111 | 111 | | |
| 8 min | $O_2$ | | .7 | .5 | .5 | .5 | .4 | .6 | .5 | .6 | .7 | .6 | .6 | .6 | .6 | .6 | | |
| | HR | | 117 | 96 | 102 | 99 | 93 | 78 | 81 | 96 | 90 | 99 | 93 | 94 | 90 | 93 | | |

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 36 | .5 | .5 | .6 | .5 | .6 | .5 | .5 | .5 | .5 | .4 | .5 | .5 | .4 | .7 | .5 | .6 |
| | HR | | 66 | 72 | 75 | 69 | 69 | 75 | 69 | 63 | 72 | 69 | 96 | 63 | 67 | 72 | 75 | 67 |
| Exercise 1 min | $O_2$ | | 1.1 | 1.3 | 1.9 | 1.4 | 1.3 | 1.1 | 1.7 | 1.4 | 1.8 | 1.2 | 1.9 | .7 | 1.2 | 1.9 | 1.3 | 2.1 |
| | HR | | 117 | 117 | 120 | 117 | 123 | 105 | 126 | 90 | 114 | 120 | 129 | 117 | 109 | 126 | 126 | 111 |
| 2 min | $O_2$ | | 2.0 | 2.2 | 2.4 | 2.2 | 2.2 | 2.5 | 2.5 | 2.0 | 2.4 | 2.0 | 2.3 | 1.7 | 2.0 | 2.4 | 2.2 | 2.1 |
| | HR | | 135 | 123 | 135 | 138 | 132 | 135 | 138 | 126 | 135 | 132 | 138 | 138 | 132 | 135 | 138 | 144 |
| 3 min | $O_2$ | | 2.9 | 2.5 | 3.0 | 2.7 | 2.8 | 2.7 | 2.8 | 2.7 | 2.4 | 2.7 | 2.6 | 2.3 | 2.3 | 2.5 | 2.5 | 2.3 |
| | HR | | 141 | 147 | 153 | 141 | 141 | 144 | 150 | 138 | 141 | 138 | 141 | 138 | 144 | 144 | 144 | 153 |
| 4 min | $O_2$ | | 2.8 | 2.7 | 3.1 | 2.7 | 3.2 | 2.8 | 2.9 | 2.9 | 2.8 | 2.7 | 3.3 | 2.4 | 2.5 | 2.9 | 2.7 | 2.3 |
| | HR | | 141 | 150 | 150 | 153 | 147 | 144 | 156 | 141 | 144 | 144 | 150 | 144 | 147 | 150 | 144 | 159 |
| 5 min | $O_2$ | | 4.8 | 2.7 | 3.2 | 3.1 | 3.5 | 2.7 | 3.1 | 3.2 | 2.6 | 2.7 | 3.3 | 2.8 | 2.6 | 3.2 | 3.0 | 2.2 |
| | HR | | 135 | 150 | 153 | 153 | 150 | 150 | 156 | 150 | 150 | 147 | 153 | 153 | 150 | 156 | 153 | 162 |
| Post Exercise 1 min | $O_2$ | | 1.4 | 2.0 | 1.3 | 1.4 | 1.3 | 2.0 | 1.4 | 3.0 | 2.2 | 1.6 | 1.8 | 1.5 | 1.4 | 1.7 | 1.8 | 1.3 |
| | HR | | 108 | 108 | 105 | 105 | 96 | 99 | 99 | 108 | 96 | 102 | 102 | 105 | 104 | 99 | 104 | 120 |
| 2 min | $O_2$ | | 1.4 | .7 | .7 | 1.2 | .7 | .9 | .8 | 1.1 | .8 | .8 | 1.1 | 1.3 | .7 | .9 | .9 | .9 |
| | HR | | 84 | 90 | 93 | 87 | 84 | 93 | 93 | 90 | 87 | 84 | 90 | 87 | 90 | 84 | 90 | 108 |
| 8 min | $O_2$ | | .4 | .4 | .5 | .5 | .5 | .6 | .5 | .6 | .4 | .5 | .5 | .5 | .5 | .4 | .5 | .4 |
| | HR | | 78 | 81 | 87 | 90 | 81 | 90 | 90 | 81 | 84 | 81 | 84 | 87 | 85 | 84 | 85 | 96 |
| Rest | $O_2$ | 37 | .4 | .5 | .4 | .2 | .4 | .4 | .4 | .3 | .4 | .5 | .4 | .3 | .5 | .5 | .5 | .4 |
| | HR | | 66 | 60 | 72 | 60 | 72 | 60 | 81 | 69 | 70 | 84 | 66 | 72 | 72 | 69 | 75 | 66 |
| Exercise 1 min | $O_2$ | | .8 | 1.0 | .8 | 1.0 | 1.0 | 1.5 | 1.4 | 1.0 | 1.2 | .9 | 1.8 | 1.0 | 1.3 | .9 | 1.8 | 1.4 |
| | HR | | 120 | 93 | 102 | 108 | 114 | 105 | 120 | 108 | 111 | 126 | 117 | 126 | 120 | 117 | 123 | 108 |
| 2 min | $O_2$ | | 1.6 | 1.5 | 2.0 | 2.6 | 1.9 | 2.1 | 2.5 | 2.0 | 2.0 | 2.2 | 2.4 | 2.0 | 2.2 | 1.8 | 2.4 | 1.7 |
| | HR | | 135 | 120 | 132 | 129 | 135 | 132 | 141 | 132 | 135 | 147 | 141 | 144 | 141 | 144 | 150 | 138 |
| 3 min | $O_2$ | | 1.9 | 1.9 | 2.1 | 2.2 | 2.3 | 2.3 | 2.6 | 2.3 | 2.0 | 2.4 | 2.5 | 2.1 | 2.3 | 2.3 | 2.7 | 1.8 |
| | HR | | 147 | 132 | 141 | 138 | 141 | 144 | 150 | 147 | 141 | 159 | 159 | 147 | 150 | 153 | 156 | 153 |
| 4 min | $O_2$ | | 1.9 | 2.5 | 2.4 | 2.4 | 2.2 | 2.5 | 2.7 | 2.5 | 2.3 | 2.6 | 3.2 | 2.3 | 2.4 | 2.2 | 2.9 | 2.3 |
| | HR | | 153 | 141 | 147 | 147 | 144 | 147 | 159 | 153 | 153 | 165 | 171 | 159 | 156 | 156 | 162 | 162 |
| 5 min | $O_2$ | | 2.0 | 2.4 | 2.5 | 2.4 | 2.3 | 2.7 | 2.8 | 2.6 | 2.5 | 3.1 | 3.5 | 2.3 | 2.5 | 2.4 | 2.9 | 2.4 |
| | HR | | 165 | 150 | 153 | 150 | 147 | 150 | 165 | 153 | 159 | 168 | 171 | 165 | 168 | 156 | 171 | 168 |
| Post Exercise 1 min | $O_2$ | | 1.4 | 1.4 | 1.2 | 1.4 | 1.6 | 2.2 | 2.1 | 1.6 | 1.5 | 1.9 | 2.3 | 1.4 | 2.0 | 1.2 | 1.5 | 1.4 |
| | HR | | 132 | 108 | 111 | 105 | 123 | 114 | 126 | 120 | 126 | 126 | 156 | 135 | 132 | 123 | 129 | 132 |
| 2 min | $O_2$ | | .6 | .4 | .8 | .6 | .8 | .8 | 1.1 | .7 | 1.0 | 1.0 | 1.7 | 1.0 | .9 | .7 | .9 | .9 |
| | HR | | 123 | 102 | 99 | 105 | 102 | 105 | 114 | 111 | 111 | 117 | 132 | 117 | 120 | 111 | 120 | 117 |
| 8 min | $O_2$ | | .3 | .4 | .4 | .4 | .4 | .4 | .6 | .5 | .5 | .5 | .6 | .3 | .6 | .6 | .6 | .5 |
| | HR | | 105 | 93 | 99 | 96 | 102 | 99 | 105 | 102 | 96 | 108 | 111 | 102 | 102 | 99 | 102 | 102 |

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 43 | .4 | .6 | .6 | .6 | .4 | .2 | .4 | .5 | .5 | .3 | | .5 | .2 | .4 | .3 | .7 |
| | HR | | 72 | 66 | 66 | 70 | 87 | 69 | 70 | 72 | 69 | 72 | | 69 | 57 | 63 | 60 | 96 |
| Exercise 1 min | $O_2$ | | 1.0 | 1.0 | 1.8 | 1.1 | 1.5 | .3 | .4 | 1.2 | .8 | 1.6 | | 2.0 | .9 | 1.0 | 2.1 | 1.5 |
| | HR | | 117 | 114 | 117 | 126 | 114 | 120 | 118 | 120 | 120 | 114 | | 117 | 114 | 114 | 108 | 138 |
| 2 min | $O_2$ | | 2.5 | 2.2 | 2.2 | 2.0 | 2.4 | 1.3 | 1.8 | 1.9 | 2.3 | 1.9 | | 2.1 | 2.0 | 2.0 | 2.3 | 1.4 |
| | HR | | 138 | 132 | 129 | 141 | 138 | 132 | 134 | 132 | 135 | 126 | | 132 | 129 | 126 | 129 | 162 |
| 3 min | $O_2$ | | 2.5 | 2.6 | 2.4 | 2.0 | 2.5 | 1.8 | 2.3 | 2.3 | 2.6 | 2.1 | | 2.6 | 2.2 | 1.9 | 2.5 | 2.3 |
| | HR | | 144 | 138 | 144 | 150 | 144 | 138 | 140 | 141 | 138 | 135 | | 138 | 135 | 132 | 132 | 156 |
| 4 min | $O_2$ | | 2.1 | 2.6 | 2.4 | 2.4 | 2.6 | 2.3 | 2.0 | 2.9 | 2.9 | 2.0 | | 2.3 | 2.1 | 2.5 | 3.1 | 2.3 |
| | HR | | 144 | 144 | 141 | 150 | 144 | 144 | 144 | 144 | 144 | 141 | | 141 | 141 | 138 | 138 | 159 |
| 5 min | $O_2$ | | 1.8 | 2.7 | 2.5 | 2.6 | 2.6 | 2.4 | 2.5 | 2.3 | 3.2 | 2.6 | | 2.3 | 2.6 | 2.6 | 2.5 | 2.7 |
| | HR | | 141 | 145 | 144 | 150 | 147 | 147 | 145 | 150 | 144 | 144 | | 141 | 141 | 138 | 141 | 162 |
| Post Exercise 1 min | $O_2$ | | 1.3 | 2.3 | 2.5 | 1.5 | 1.3 | .9 | 2.4 | 1.6 | 1.6 | 1.6 | | 1.1 | 1.4 | 1.3 | 1.8 | 1.9 |
| | HR | | 108 | 102 | 96 | 111 | 117 | 102 | 105 | 99 | 108 | 96 | | 105 | 96 | 102 | 99 | 132 |
| 2 min | $O_2$ | | .9 | .9 | .9 | .7 | 1.0 | .9 | 1.0 | 1.1 | 1.1 | .9 | | 1.1 | .8 | .9 | .4 | 1.0 |
| | HR | | 93 | 81 | 93 | 102 | 111 | 93 | 93 | 96 | 93 | 90 | | 87 | 87 | 84 | 75 | 114 |
| 8 min | $O_2$ | | .5 | .5 | .5 | .5 | .6 | .5 | .5 | .5 | .4 | .4 | | .4 | .4 | .4 | .4 | .4 |
| | HR | | 93 | 81 | 78 | 105 | 102 | 90 | 86 | 84 | 81 | 78 | | 84 | 78 | 81 | 78 | 102 |
| Rest | $O_2$ | 44 | .4 | .7 | .6 | .4 | .3 | .7 | .3 | .5 | .6 | .5 | | .5 | .5 | .5 | .4 | .4 |
| | HR | | 57 | 63 | 72 | 66 | 69 | 63 | 65 | 69 | 63 | 57 | | 60 | 66 | 54 | 54 | 102 |
| Exercise 1 min | $O_2$ | | 1.2 | .7 | .9 | 1.7 | .3 | 1.2 | .5 | .6 | .7 | .9 | | 1.4 | .9 | 1.7 | .5 | 1.0 |
| | HR | | 102 | 105 | 96 | 102 | 96 | 108 | 105 | 105 | 111 | 96 | | 102 | 102 | 108 | 99 | 132 |
| 2 min | $O_2$ | | 2.4 | 1.7 | 2.2 | 1.9 | .3 | 1.6 | 1.4 | 1.5 | 1.1 | 1.6 | | 1.4 | 1.9 | 1.8 | 1.6 | 1.8 |
| | HR | | 120 | 117 | 111 | 123 | 111 | 120 | 121 | 120 | 129 | 114 | | 126 | 123 | 123 | 111 | 144 |
| 3 min | $O_2$ | | 2.9 | 2.1 | 2.3 | 2.4 | 2.1 | 2.2 | 2.0 | 2.0 | 1.6 | 2.0 | | 2.1 | 2.4 | 2.1 | 1.9 | 2.4 |
| | HR | | 129 | 123 | 120 | 132 | 126 | 129 | 129 | 132 | 135 | 120 | | 135 | 126 | 129 | 120 | 153 |
| 4 min | $O_2$ | | 3.0 | 2.2 | 2.3 | 2.8 | 2.2 | 2.6 | 2.0 | 2.2 | 2.4 | 2.0 | | 2.7 | 2.3 | 2.3 | 2.0 | 2.3 |
| | HR | | 138 | 132 | 126 | 141 | 132 | 141 | 136 | 138 | 141 | 123 | | 144 | 132 | 132 | 123 | 159 |
| 5 min | $O_2$ | | 2.9 | 1.8 | 2.4 | 2.8 | 2.8 | 2.8 | 2.6 | 2.9 | 2.2 | 2.4 | | 2.5 | 2.5 | 2.6 | 2.4 | 2.2 |
| | HR | | 159 | 141 | 135 | 150 | 135 | 147 | 143 | 144 | 150 | 135 | | 150 | 138 | 135 | 126 | 159 |
| Post Exercise 1 min | $O_2$ | | 1.4 | 1.7 | 1.9 | 2.7 | 1.4 | 2.8 | 1.3 | 1.2 | 1.1 | 1.8 | | .8 | 1.6 | .7 | 1.1 | 1.4 |
| | HR | | 96 | 87 | 81 | 105 | 84 | 90 | 91 | 84 | 87 | 87 | | 99 | 90 | 84 | 78 | 120 |
| 2 min | $O_2$ | | 1.4 | 1.1 | .8 | 1.0 | .7 | 1.6 | .8 | 1.2 | 1.1 | .9 | | .8 | .8 | .8 | .5 | 1.1 |
| | HR | | 78 | 72 | 78 | 78 | 72 | 72 | 76 | 78 | 75 | 72 | | 78 | 75 | 69 | 66 | 105 |
| 8 min | $O_2$ | | .7 | .6 | .6 | .9 | .5 | .5 | .5 | .7 | .5 | .6 | | .5 | .5 | .4 | .4 | .5 |
| | HR | | 81 | 78 | 78 | 87 | 87 | 81 | 79 | 75 | 72 | 72 | | 81 | 75 | 72 | 60 | 102 |

TABLE 1.2.6 (Cont)

$O_2$ CONSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 46 | .5 | .5 | .5 | .3 | .4 | .2 | .4 | .3 | .2 | .4 | | .2 | .6 | .3 | .3 | .5 |
| | HR | | 108 | 84 | 99 | 90 | 81 | 78 | 89 | 84 | 81 | 87 | | 89 | 87 | 84 | 84 | 108 |
| Exercise 1 min | $O_2$ | | 1.9 | .9 | .8 | 1.0 | .7 | 1.0 | .9 | 1.5 | .8 | 1.0 | | 1.2 | 1.6 | .9 | 1.2 | 1.8 |
| | HR | | 135 | 129 | 141 | 141 | 135 | 126 | 136 | 138 | 132 | 129 | | 136 | 144 | 138 | 135 | 147 |
| 2 min | $O_2$ | | 2.0 | 1.9 | 1.7 | 1.5 | 1.8 | 1.9 | 1.9 | 1.6 | 1.9 | 1.8 | | 2.1 | 1.8 | 2.1 | 2.3 | 1.8 |
| | HR | | 165 | 144 | 144 | 156 | 153 | 150 | 152 | 147 | 147 | 156 | | 153 | 162 | 156 | 159 | 162 |
| 3 min | $O_2$ | | 1.9 | 1.9 | 2.2 | 2.1 | 2.2 | 2.0 | 2.2 | 2.0 | 2.2 | 2.1 | | 2.0 | 2.2 | 2.3 | 2.1 | 2.0 |
| | HR | | 180 | 156 | 159 | 165 | 162 | 162 | 164 | 165 | 159 | 165 | | 162 | 165 | 159 | 168 | 171 |
| 4 min | $O_2$ | | 1.9 | 2.2 | 2.3 | 2.2 | 2.1 | 2.3 | 2.7 | 2.0 | 2.4 | 2.3 | | 2.8 | 2.4 | 2.3 | 2.9 | 2.0 |
| | HR | | 180 | 165 | 168 | 168 | 168 | 171 | 170 | 168 | 168 | 171 | | 168 | 168 | 165 | 174 | 177 |
| 5 min | $O_2$ | | 2.2 | 2.4 | 2.6 | 2.3 | 2.4 | 2.2 | 2.5 | 2.1 | 2.7 | 2.5 | | 2.6 | 2.4 | 2.6 | 2.0 | 1.9 |
| | HR | | 183 | 174 | 165 | 174 | 171 | 177 | 175 | 174 | 177 | 177 | | 174 | 174 | 174 | 180 | 180 |
| Post Exercise 1 min | $O_2$ | | 1.4 | 2.2 | 2.4 | 1.1 | 1.6 | 1.5 | 1.9 | 1.6 | 1.6 | 1.9 | | 1.2 | 1.5 | 1.5 | 1.8 | 1.5 |
| | HR | | 153 | 132 | 135 | 138 | 138 | 141 | 140 | 141 | 138 | 147 | | 138 | 141 | 135 | 141 | 150 |
| 2 min | $O_2$ | | 1.4 | 1.0 | 1.0 | 1.1 | 1.2 | .8 | .7 | 1.0 | .9 | .9 | | 1.2 | .7 | .8 | 1.0 | .9 |
| | HR | | 141 | 117 | 120 | 120 | 123 | 129 | 124 | 126 | 120 | 123 | | 120 | 123 | 120 | 123 | 135 |
| 8 min | $O_2$ | | .5 | .5 | .5 | .5 | .5 | .5 | .4 | .5 | .5 | .5 | | .4 | .5 | .4 | .4 | .5 |
| | HR | | 117 | 102 | 108 | 105 | | 108 | 109 | 114 | 114 | 102 | | 108 | 108 | 105 | 108 | 120 |
| Rest | $O_2$ | 53 | .5 | | .4 | .6 | .5 | .4 | .3 | .4 | .4 | .5 | .4 | .4 | .5 | .4 | .3 | .7 |
| | HR | | 63 | | 57 | 63 | 54 | 60 | 69 | 60 | 57 | 66 | 69 | 62 | 60 | 66 | 60 | 78 |
| Exercise 1 min | $O_2$ | | 1.0 | | 1.0 | 1.1 | 1.0 | 1.2 | .4 | 2.0 | 1.4 | 1.2 | 1.9 | 1.2 | 1.0 | 1.1 | 1.2 | 1.2 |
| | HR | | 111 | | 105 | 114 | 120 | 117 | 120 | 120 | 120 | 120 | 114 | 113 | 114 | 96 | 96 | 114 |
| 2 min | $O_2$ | | 1.9 | | 2.1 | 2.2 | 2.1 | 2.1 | 1.8 | 2.2 | 2.4 | 2.0 | 2.0 | 2.2 | 2.1 | 2.1 | 2.2 | 2.0 |
| | HR | | 120 | | 120 | 132 | 129 | 129 | 126 | 132 | 135 | 138 | 135 | 132 | 132 | 138 | 138 | 138 |
| 3 min | $O_2$ | | 2.0 | | 2.3 | 2.4 | 2.5 | 2.2 | 2.5 | 2.7 | 2.8 | 2.4 | 2.4 | 2.3 | 2.4 | 2.3 | 2.4 | 2.3 |
| | HR | | 123 | | 126 | 138 | 141 | 141 | 135 | 135 | 144 | 150 | 141 | 140 | 144 | 150 | 138 | 150 |
| 4 min | $O_2$ | | 1.7 | | 2.3 | 2.7 | 2.6 | 2.4 | 2.9 | 2.2 | 2.8 | 2.8 | 2.5 | 2.7 | 2.2 | 3.4 | 2.4 | 2.2 |
| | HR | | 126 | | 132 | 150 | 138 | 144 | 132 | 138 | 144 | 150 | 147 | 144 | 150 | 156 | 156 | 156 |
| 5 min | $O_2$ | | 1.6 | | 2.4 | 2.7 | 2.5 | 2.4 | 2.5 | 2.6 | 2.9 | 2.5 | 2.7 | 2.6 | 2.6 | 2.4 | 2.5 | 2.1 |
| | HR | | 120 | | 135 | 150 | 141 | 144 | 138 | 141 | 150 | 150 | 153 | 144 | 156 | 150 | 120 | 150 |
| Post Exercise 1 min | $O_2$ | | 1.1 | | 1.4 | 1.4 | 1.7 | 1.3 | 1.1 | 1.2 | 1.6 | 1.4 | 2.1 | 1.6 | 1.4 | 1.6 | 1.6 | 1.5 |
| | HR | | 75 | | 99 | 117 | 114 | 111 | 96 | 120 | 114 | 114 | 120 | 116 | 120 | 132 | 132 | 144 |
| 2 min | $O_2$ | | .8 | | .5 | .6 | .8 | .7 | .5 | .7 | .7 | .8 | .9 | .7 | .8 | .6 | .6 | .4 |
| | HR | | 66 | | 81 | 102 | 93 | 90 | 72 | 75 | 93 | 90 | 102 | 91 | 114 | 108 | 72 | 126 |
| 5 min | $O_2$ | | .3 | | .3 | .4 | .4 | .4 | .3 | .4 | .5 | .4 | .5 | .4 | .6 | .3 | .4 | .4 |
| | HR | | 60 | | 75 | 84 | 87 | 84 | 72 | 78 | 87 | 78 | 90 | 84 | 90 | 84 | 72 | 90 |

TABLE 1.2.6 (Cont)

$O_2$ COMSUMPTION (liters/min. S.T.P.D.) AND HEART RATE WITH EXERCISE (900 kpm/min.)

| Test | | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rest | $O_2$ | 54 | .3 | | .5 | .3 | .2 | .3 | .7 | .4 | .8 | .3 | .4 | .4 | .7 | .3 | .5 | .3 |
| | HR | | 60 | | 75 | 72 | 78 | 84 | 78 | 72 | 74 | 69 | 78 | 62 | 84 | 72 | 72 | 87 |
| Exercise 1 min | $O_2$ | | 1.1 | | 1.8 | 1.2 | 1.7 | .8 | .7 | 1.7 | 2.0 | 1.2 | .9 | 1.5 | 1.3 | 1.2 | 1.4 | .8 |
| | HR | | 120 | | 111 | 126 | 132 | 126 | 132 | 129 | 135 | 129 | 126 | 115 | 124 | 108 | 114 | 118 |
| 2 min | $O_2$ | | 1.9 | | 2.0 | 1.6 | 2.2 | 1.8 | 1.9 | 2.2 | 2.2 | 2.2 | 2.1 | 2.8 | 2.0 | 1.8 | 1.9 | 1.4 |
| | HR | | 132 | | 129 | 141 | 150 | 147 | 147 | 144 | 150 | 138 | 144 | 125 | 141 | 138 | 138 | 114 |
| 3 min | $O_2$ | | 1.7 | | 1.8 | 2.4 | 2.4 | 2.3 | 2.1 | 2.3 | 2.5 | 2.1 | 2.0 | 2.4 | 2.1 | 2.0 | 2.0 | 1.8 |
| | HR | | 141 | | 132 | 150 | 156 | 159 | 150 | 150 | 162 | 147 | 147 | 133 | 148 | 138 | 150 | 120 |
| 4 min | $O_2$ | | 1.6 | | 1.8 | 2.7 | 2.4 | 2.4 | 2.0 | 2.4 | 2.4 | 2.2 | 2.1 | 2.7 | 2.4 | 1.8 | 2.3 | 1.8 |
| | HR | | 135 | | 144 | 159 | 162 | 168 | 156 | 150 | 162 | 150 | 147 | 135 | 153 | 144 | 162 | 150 |
| 5 min | $O_2$ | | 1.7 | | 2.0 | 2.6 | 2.6 | 2.5 | 2.4 | 2.6 | 2.6 | 2.3 | 2.2 | 2.6 | 2.4 | 1.9 | 2.3 | 1.6 |
| | HR | | 132 | | 150 | 168 | 168 | 171 | 159 | 153 | 162 | 150 | 144 | 130 | 156 | 150 | 168 | 138 |
| Post Exercise 1 min | $O_2$ | | 1.1 | | .7 | 1.0 | 1.4 | 1.1 | .8 | .8 | 1.5 | 1.4 | 1.0 | 1.3 | 1.5 | 1.3 | 1.4 | 1.2 |
| | HR | | 93 | | 102 | 128 | 132 | 117 | 111 | 108 | 126 | 102 | 108 | 100 | 112 | 102 | 114 | 126 |
| 2 min | $O_2$ | | .7 | | .5 | .7 | .8 | .7 | .5 | .8 | .6 | .7 | .7 | .8 | .7 | .5 | .6 | .8 |
| | HR | | 75 | | 84 | 108 | 111 | 105 | 93 | 96 | 102 | 90 | 93 | 90 | 97 | 90 | 102 | 108 |
| 8 min | $O_2$ | | .3 | | .4 | .4 | .4 | .4 | .3 | .3 | .4 | .4 | .3 | .4 | .4 | .2 | .3 | .3 |
| | HR | | 78 | | 87 | 99 | 105 | 96 | 90 | 90 | 90 | 87 | 87 | 80 | 90 | 78 | 90 | 96 |

TABLE 1.2.7

TOTAL LUNG CAPACITY (liters B.T.P.S.) AND DIFFUSION CAPACITY

(ml S.T.P.D./min/mm Hg)

| Test | Subject Number | Pre-Run | Post-Run | Test | Subject Number | Pre-Run | Post-Run |
|---|---|---|---|---|---|---|---|
| T.L.C. | 11 | 6.108 | 5.544 | T.L.C. | 42 | 5.507 | 6.194 |
| D.C. | 11 | 41.9 | 36.5 | D.C. | 42 | 25.7 | 23.3 |
| T.L.C. | 12 | 6.567 | 6.776 | T.L.C. | 43 | 7.578 | 6.797 |
| D.C. | 12 | 38.8 | 31.8 | D.C. | 43 | 34.1 | 34.3 |
| T.L.C. | 13 | 6.493 | 6.279 | T.L.C. | 44 | 6.527 | 6.963 |
| D.C. | 13 | 42.6 | 11.7 | D.C. | 44 | 30.0 | 30.6 |
| T.L.C. | 15 | 5.975 | 6.425 | T.L.C. | 45 | 5.806 | 6.208 |
| D.C. | 15 | 40.5 | 43.8 | D.C. | 45 | 26.9 | 29.0 |
| T.L.C. | 16 | 5.872 | 6.279 | T.L.C. | 46 | 7.546 | 7.131 |
| D.C. | 16 | 29.2 | 25.5 | D.C. | 46 | 26.4 | 26.6 |
| T.L.C. | 17 | 5.604 | 5.982 | T.L.C. | 47 | 6.867 | 6.900 |
| D.C. | 17 | 43.4 | 39.8 | D.C. | 47 | 37.1 | 30.2 |
| T.L.C. | 31 | 5.984 | 5.958 | T.L.C. | 51 | 6.423 | 6.629 |
| D.C. | 31 | 41.6 | 46.0 | D.C. | 51 | 31.4 | 31.2 |
| T.L.C. | 32 | 5.724 | 6.151 | T.L.C. | 52 | 6.704 | 6.605 |
| D.C. | 32 | 33.1 | 35.8 | D.C. | 52 | 34.3 | 33.3 |
| T.L.C. | 33 | 6.475 | 5.848 | T.L.C. | 53 | 5.520 | 5.742 |
| D.C. | 33 | 25.5 | 27.5 | D.C. | 53 | 21.9 | 26.6 |
| T.L.C. | 35 | 7.729 | 6.893 | T.L.C. | 54 | 5.664 | 5.768 |
| D.C. | 35 | 27.6 | 27.5 | D.C. | 54 | 30.0 | 27.7 |
| T.L.C. | 36 | 7.458 | 7.075 | T.L.C. | 56 | 5.635 | 5.399 |
| D.C. | 36 | 30.2 | 47.9 | D.C. | 56 | 35.4 | 30.6 |
| T.L.C. | 37 | 6.248 | 5.168 | | | | |
| D.C. | 37 | 32.2 | 29.8 | | | | |

TABLE 1.2.8

END EXPIRATORY $O_2$ AND $CO_2$ CONCENTRATIONS (mm Hg)

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| $O_2$ | 11 | | | | | | | | | | | 115.51 | 118.36 | | 119.78 | 104.10 | |
| $CO_2$ | | | 32.80 | | | | | | | | | 26.74 | 38.50 | | 34.94 | 30.66 | |
| $O_2$ | 12 | | | | | | | | | | | 129.05 | 121.21 | | 123.35 | 121.21 | |
| $CO_2$ | | | | | | | | | | | | 14.97 | 36.36 | | 32.09 | 24.96 | |
| $O_2$ | 13 | | | | | | | | | | | 127.63 | 118.36 | | 119.07 | 122.64 | |
| $CO_2$ | | | 19.96 | | | | | | | | | 19.25E | 37.08 | | 35.65 | 27.09 | |
| $O_2$ | 15 | | | | | | | | | | | 119.07 | 116.93 | | 115.51 | 109.10 | |
| $CO_2$ | | | | | | | | | | | | 27.09 | 46.35 | | 37.43 | 34.22 | |
| $O_2$ | 16 | | | | | | | | | | | 127.63 | 126.91 | | 121.92 | 122.64 | |
| $CO_2$ | | | | | | | | | | | | 24.24 | 29.95 | | 31.73 | 19.96 | |
| $O_2$ | 17 | | | | | | | | | | | 127.63 | 120.50 | | 116.26 | 121.21 | |
| $CO_2$ | | | | | | | | | | | | 19.25 | 35.65 | | 39.93 | 14.97 | |
| $O_2$ | 31 | 128.34 | | | | | | | | 176.92 | 184.62 | 173.46 | 179.73 | 175.11 | | | |
| $CO_2$ | | | | | | | | | | 34.60 | 26.38 | 32.54 | 31.27 | 35.89 | | | |
| $O_2$ | 32 | 109.80 | | | | | | | | 181.16 | 176.40 | 170.17 | 181.67 | 175.74 | | | |
| $CO_2$ | | | | | | | | | | 29.84 | 34.60 | 40.83 | 29.33 | 35.26 | | | |
| $O_2$ | 33 | 129.77 | | | | | | | | 187.73 | 190.81 | 186.29 | 189.25 | 187.35 | | | |
| $CO_2$ | | | | | | | | | | 23.27 | 20.19 | 24.71 | 21.75 | 23.65 | | | |
| $O_2$ | 34 | 121.92 | | | | | | | | 184.75 | 183.89 | 186.55 | 185.91 | 178.06 | | | |
| $CO_2$ | | | | | | | | | | 26.25 | 27.11 | 24.45 | 25.09 | 32.94 | | | |
| $O_2$ | 36 | 126.91 | | | | | | | | 188.11 | 183.38 | 186.69 | 185.11 | 190.41 | | | |
| $CO_2$ | | | | | | | | | | 22.89 | 22.62 | 24.31 | 25.89 | 20.59 | | | |
| $O_2$ | 37 | 126.20 | | | | | | | | 176.92 | 187.20 | 182.07 | 185.03 | 182.16 | | | |
| $CO_2$ | | | | | | | | | | 34.08 | 23.30 | 28.93 | 25.97 | 28.84 | | | |
| $O_2$ | 42 | 120.50 | | 300.07 | 304.76 | 302.53 | 305.79 | 304.36 | 307.36 | 306.63 | 304.76 | 305.79 | 309.66 | 306.63 | 308.26 | 311.49 | 129.77 |
| $CO_2$ | | 32.44 | | 32.93 | 28.24 | 30.47 | 27.21 | 28.64 | 25.64 | 26.37 | 28.24 | 27.21 | 22.34 | 26.37 | 24.74 | 21.51 | 20.68 |
| $O_2$ | 43 | 114.08 | | 292.77 | 297.07 | 292.77 | 300.70 | 299.30 | 302.53 | 302.53 | 302.16 | 305.19 | 300.50 | 303.80 | 306.19 | 307.83 | 131.19 |
| $CO_2$ | | 33.51 | | 40.23 | 35.93 | 40.23 | 32.30 | 33.70 | 30.47 | 30.47 | 30.84 | 26.81 | 32.50 | 29.20 | 26.81 | 25.17 | 23.53 |
| $O_2$ | 44 | 117.65 | | 306.19 | 300.49 | 300.73 | 301.76 | 303.56 | 306.09 | 307.23 | 313.12 | 307.63 | 307.26 | 307.39 | 307.83 | 305.63 | 128.34 |
| $CO_2$ | | 33.15 | | 26.81 | 32.51 | 32.27 | 31.24 | 29.44 | 26.91 | 25.77 | 19.88 | 25.37 | 25.74 | 25.61 | 25.17 | 27.37 | 21.75 |
| $O_2$ | 45 | 120.50 | | 299.90 | 304.16 | 303.76 | 297.97 | 305.19 | 297.70 | 304.16 | 301.93 | 302.73 | 307.43 | 295.67 | 305.79 | 308.02 | 122.64 |
| $CO_2$ | | 29.59 | | 33.10 | 28.34 | 29.24 | 35.03 | 27.81 | 35.30 | 28.84 | 31.07 | 30.27 | 25.57 | 37.33 | 27.21 | 24.98 | 24.24 |
| $O_2$ | 46 | 112.65 | | 306.63 | 304.99 | 307.39 | 305.79 | 303.76 | 308.36 | 306.43 | 310.46 | 303.96 | 308.42 | 309.86 | 309.46 | 304.76 | 126.20 |
| $CO_2$ | | 32.09 | | 26.37 | 28.01 | 25.61 | 27.21 | 29.24 | 24.64 | 26.57 | 22.54 | 29.04 | 24.58 | 23.14 | 23.54 | 28.24 | 27.45 |

TABLE 1.2.8 (Cont)

END EXPIRATORY $O_2$ AND $CO_2$ CONCENTRATIONS (mm Hg)

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| $O_2$ | 47 | 123.35 | | 307.03 | 306.59 | 303.36 | 304.63 | 305.79 | | 304.76 | 306.43 | 307.43 | 304.79 | 302.96 | 308.66 | 312.89 | 119.07 |
| $CO_2$ | | 25.10 | | 25.97 | 26.41 | 29.64 | 28.37 | 27.21 | | 28.24 | 26.57 | 25.57 | 23.21 | 30.04 | 24.34 | 20.11 | 22.16 |
| $O_2$ | 51 | 111.23 | | | 108.63 | 110.74 | | 117.32 | 110.17 | 110.46 | 116.45 | 115.61 | 115.42 | | 108.99 | 113.37 | 124.06 |
| $CO_2$ | | 31.66 | | | 31.37 | 22.26 | | 22.68 | 22.83 | 22.54 | 23.55 | 24.39 | 24.58 | | 31.01 | 26.63 | 28.56 |
| $O_2$ | 52 | 121.21 | | | 111.87 | 105.70 | 109.76 | 104.16 | 113.37 | 110.46 | 113.27 | 107.27 | 103.35 | | 105.59 | 106.85 | 116.23 |
| $CO_2$ | | 26.21 | | | 28.23 | 31.31 | 30.24 | 35.84 | 26.63 | 29.51 | 26.73 | 32.73 | 36.15 | | 34.41 | 33.15 | 33.30 |
| $O_2$ | 53 | 123.35 | | | 104.16 | 93.30 | 103.88 | 98.14 | 106.19 | 100.76 | 101.78 | 117.57 | 97.16 | | 95.91 | 107.13 | 125.49 |
| $CO_2$ | | 27.21 | | | 35.94 | 46.20 | 36.12 | 41.86 | 33.51 | 30.24 | 38.22 | 22.43 | 42.84 | | 44.09 | 32.37 | 30.45 |
| $O_2$ | 54 | 110.52 | | | 113.19 | 108.37 | 168.84 | 105.00 | 111.23 | 102.34 | 107.53 | 111.79 | 100.56 | | 112.00 | 107.38 | 111.94 |
| $CO_2$ | | 33.51 | | | 26.81 | 31.63 | 28.84 | 35.00 | 28.77 | 37.66 | 32.47 | 28.21 | 39.34 | | 28.0 | 32.62 | 34.72 |
| $O_2$ | 56 | 112.65 | | | 113.19 | 108.37 | 114.38 | 108.64 | 108.29 | 104.65 | 101.65 | 105.91 | 106.12 | | 110.31 | 104.39 | 126.20 |
| $CO_2$ | | 27.31 | | | 26.81 | 31.63 | 25.62 | 31.36 | 31.71 | 35.35 | 38.35 | 34.00 | 33.88 | | 29.69 | 34.61 | 31.23 |

TABLE 1.3.1

PLASMA VOLUME (ml)

| Subject Number | Pre-Run | Post-Run |
|---|---|---|
| 11 | | 3710 |
| 12 | | 3170 |
| 13 | | 3160 |
| 15 | | 3060 |
| 16 | | 3470 |
| 17 | | 2920 |
| 31 | 3150 | 3820* |
| 32 | 3380 | 4220* |
| 33 | 3050 | 3630* |
| 35 | | |
| 36 | 3530 | 7740* |
| 37 | 2642 | 4800* |
| 42 | 2900 | 2630 |
| 43 | 3580 | 3485 |
| 44 | 3220 | 3150 |
| 45 | 3220 | 3500 |
| 46 | 2940 | 3130 |
| 47 | 3140 | 3196 |
| 51 | 3120 | 2920 |
| 52 | 4090 | |
| 53 | 2281 | 2774 |
| 54 | 2630 | 2518 |
| 56 | 2570 | 2735 |
| *Doubtful Value | | |

TABLE 1.4.1

ARTERIAL $pO_2$ (mm Hg), $pCO_2$ (mm Hg), pH, $O_2$ CONTENT (Vol %)

$O_2$ CAPACITY (Vol %), % SATURATION, AND $CO_2$ CONTENT (mM/l)

| Test | Subject Number | Pre-Run | | Day 5 | Post-Run | | | | Test | Subject Number | Pre-Run | | Day 5 | Post-Run | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Room Air | 100% $O_2$ | In Cham | In Cham | Room A | 100% $O_2$(SL) | | | | Room Air | 100% $O_2$ | In Cham | In Cham | Room Air | 100% $O_2$(SL) |
| Sea Level | | | | | | | | | | | | | | | | |
| $pO_2$ | 11 | 98 | | 94 | 98 | | 461+ | | $pO_2$ | 15 | 92 | | 96 | 103 | | 541+ |
| $pCO_2$ | | 36 | | 38 | 41 | | 37 | | $pCO_2$ | | 38 | | 38 | 42 | | 34 |
| pH | | 7.40 | | 7.42 | 7.41 | | 7.44 | | pH | | 7.40 | | 7.39 | 7.41 | | 7.46 |
| $O_2$ Cont | | 18.8 | | 21.7 | 20.8 | | 20.5 | | $O_2$ Cont | | 17.4 | | 20.4 | 17.9 | | 23.5 |
| $O_2$ Cap | | 19.7 | | 22.0 | 20.5 | | 20.5 | | $O_2$ Cap | | 18.5 | | 22.3 | 21.0 | | 23.0 |
| $O_2$% Sat | | 95 | | 99 | 100+1.5 | | 100 | | $O_2$ % Sat | | 94 | | 92 | 85 | | 100+2.2 |
| $CO_2$ Cont | | 24.6 | | 26.4 | 25.1 | | 25.2 | | $CO_2$ Cont | | 23.8 | | 27.8 | 27.0 | | 26.1 |
| $pO_2$ | 12 | 101 | | 94 | 111 | | 680+ | | $pO_2$ | 16 | 90 | | 117 | 114 | | 491+ |
| $pCO_2$ | | 36 | | 37 | 37 | | 38 | | $pCO_2$ | | 38 | | 38 | 33 | | 30 |
| pH | | 7.42 | | 7.40 | 7.43 | | 7.43 | | pH | | 7.41 | | 7.40 | 7.47 | | 7.48 |
| $O_2$ Cont | | 19.1 | | 19.2 | 18.4 | | 18.6 | | $O_2$ Cont | | 19.3 | | 20.4 | 17.9 | | 20.0 |
| $O_2$ Cap | | 20.3 | | 21.3 | 23.3 | | 23.3 | | $O_2$ Cap | | 20.5 | | 23.7 | 22.7 | | 21.5 |
| $O_2$% Sat | | 94 | | 90 | 79 | | 80 | | $O_2$% Sat | | 94 | | 86 | 79 | | 33 |
| $CO_2$ Cont | | 21.6 | | 26.3 | 25.9 | | 25.3 | | $CO_2$ Cont | | 27.1 | | 25.0 | 23.4 | | 23.1 |
| $pO_2$ | 13 | 96 | | 92 | 104 | | 573+ | | $pO_2$ | 17 | 96 | | 111 | 100 | | 570+ |
| $pCO_2$ | | 40 | | 40 | 39 | | 39 | | $pCO_2$ | | 37 | | 41 | 42 | | 39 |
| pH | | 7.40 | | 7.42 | 7.42 | | 7.42 | | pH | | 7.45 | | 7.40 | 7.43 | | 7.43 |
| $O_2$ Cont | | 21.7 | | 22.3 | 20.8 | | 21.7 | | $O_2$ Cont | | 20.8 | | 19.3 | 20.5 | | 23.4 |
| $O_2$ Cap | | 21.4 | | 22.3 | 21.9 | | 21.0 | | $O_2$ Cap | | 22.1 | | 21.6 | 20.5 | | 20.7 |
| $O_2$% Sat | | 100 + 1.4 | | 100 | 95 | | 100+3.3 | | $O_2$% Sat | | 94 | | 89 | 100 | | 100+1.3 |
| $CO_2$ Cont | | 27.4 | | 27.0 | 26.7 | | 26.6 | | $CO_2$ Cont | | 28.6 | | 27.3 | 26.7 | | 27.6 |

TABLE 1.4.1 (Cont)

ARTERIAL $pO_2$ (mm Hg), $pCO_2$ (mm Hg), pH, $O_2$ CONTENT (Vol %)

$O_2$ CAPACITY (Vol %), % SATURATION, AND $CO_2$ CONTENT (mM/l)

| Test | Subject Number | Pre - Run | | Day 5 | Post-Run | | |
|---|---|---|---|---|---|---|---|
| | | Room Air | 100% $O_2$ | In Cham | In Cham | Room Air | 100%$O_2$(SI) |
| 5.0 psi | | | | | | | |
| $pO_2$ | 31 | 91 | 561+ | 147 | 149 | 103 | 449+ |
| $pCO_2$ | | 39 | 26 | 41 | 48 | 39 | 31 |
| pH | | 7.41 | 7.53 | 7.41 | 7.43 | 7.42 | 7.48 |
| $O_2$ Cont | | 19.3 | 21.2 | 19.4 | 19.9 | | |
| $O_2$ Cap | | 19.9 | 20.4 | 19.5 | 19.6 | | |
| $O_2$% Sat | | 97 | 100 | 100 | 100+1.5 | | |
| $CO_2$ Cont | | 24.7 | | 27.0 | 23.3 | 23.0 | |
| $pO_2$ | 32 | 103 | 564+ | 163 | 167 | 111 | 437+ |
| $pCO_2$ | | 38 | 28 | 39 | 41 | 38 | |
| pH | | 7.42 | 7.51 | 7.42 | 7.43 | 7.43 | |
| $O_2$ Cont | | 18.8 | 20.2 | 20.7 | 20.4 | | |
| $O_2$ Cap | | 20.4 | 19.9 | 19.5 | 19.9 | | |
| $O_2$% Sat | | 92 | 100+1.5 | 100+6.2 | 100+2.5 | | |
| $CO_2$ Cont | | 25.5 | | 26.0 | 23.6 | 23.4 | |
| $pO_2$ | 33 | 99 | 545+ | 168 | 153 | 99 | 541+ |
| $pCO_2$ | | 38 | 29 | 42 | 42 | 37 | |
| pH | | 7.42 | 7.50 | 7.41 | 7.39 | 7.42 | |
| $O_2$ Cont | | 19.1 | 21.8 | 18.9 | 19.9 | | |
| $O_2$ Cap | | 19.2 | 20.7 | 18.5 | 19.4 | | |
| $O_2$% Sat | | 99 | 100+5.3 | 100+2.2 | 100+2.6 | | |
| $CO_2$ Cont | | 23.9 | | 23.5 | 23.2 | 23.4 | |

| Test | Subject Number | Pre-Run | | Day 5 | Post-Run | | |
|---|---|---|---|---|---|---|---|
| | | Room Air | 100% $O_2$ | In Cham | In Cham | Room Air | 100%$O_2$(SI) |
| $pO_2$ | 35 | 103 | 515+ | 160 | 159 | 99 | 491+ |
| $pCO_2$ | | 33 | 36 | 42 | 33 | 39 | |
| pH | | 7.38 | 7.41 | 7.40 | 7.45 | 7.40 | |
| $O_2$ Cont | | 17.5 | 20.0 | 19.4 | 18.7 | 18.7 | |
| $O_2$ Cap | | 19.0 | 18.7 | 19.0 | 18.7 | | |
| $O_2$% Sat | | 92 | 100+7.0 | 100+2.1 | 100 | | |
| $CO_2$ Cont | | 20.0 | | 24.6 | 23.9 | 24.8 | |
| $pO_2$ | 36 | 104 | 554+ | 156 | 155 | 101 | 540+ |
| $pCO_2$ | | 35 | 33 | 40 | 39 | 36 | |
| pH | | 7.43 | 7.46 | 7.40 | 7.44 | 7.43 | |
| $O_2$ Cont | | 20.0 | 19.3 | 20.2 | 19.2 | 19.6 | |
| $O_2$ Cap | | 20.6 | 19.2 | 19.5 | 19.1 | | |
| $O_2$% Sat | | 97 | 100+.5 | 100+3.6 | 100+.5 | | |
| $CO_2$ Cont | | 23.9 | | 25.0 | 24.8 | 25.0 | |
| $pO_2$ | 37 | 93 | 483+ | 165 | 162 | 98 | 340+ |
| $pCO_2$ | | 43 | 41 | 43 | 40 | 38 | |
| pH | | 7.41 | 7.42 | 7.42 | 7.40 | 7.45 | |
| $O_2$ Cont | | 20.6 | 20.1 | 19.4 | 19.8 | 19.8 | |
| $O_2$ Cap | | 20.9 | 20.1 | 18.6 | 19.6 | | |
| $O_2$% Sat | | 99 | 100 | 100+4.3 | 100+1 | | |
| $CO_2$ Cont | | 25.5 | | 26.9 | 25.3 | 24.6 | |

TABLE 1.4.1 (Cont)

ARTERIAL $pO_2$ (mm Hg), $pCO_2$ (mm Hg), pH, $O_2$ CONTENT (Vol %)

$O_2$ CAPACITY (Vol %), % SATURATION, AND $CO_2$ CONTENT (mM/l)

| Test | Subject Number | Pre-Run | | Day 5 | Post-Run | | |
|---|---|---|---|---|---|---|---|
| | | Room Air | 100% $O_2$ | In Cham | In Cham | Room Air | 100% $O_2$(S1) |
| 7.4 psi | | | | | | | |
| $pO_2$ | 42 | 108 | 421+ | 251 | 263 | 103 | |
| $pCO_2$ | | 35 | 34 | 39 | 38 | 41 | |
| pH | | 7.43 | 7.52 | 7.42 | 7.45 | 7.41 | |
| $O_2$ Cont | | 18.8 | 19.3 | 23.8 | 18.5 | 17.5 | |
| $O_2$ Cap | | 18.9 | | 22.5 | 19.9 | | |
| $O_2$% Sat | | 100 | | 100+5.8 | 93 | | |
| $CO_2$ Cont | | 23.3 | 23.4 | 23.1 | 22.7 | 22.2 | |
| $pO_2$ | 43 | 104 | 504+ | 246 | 266 | 93 | |
| $pCO_2$ | | 36 | 41 | 43 | 42 | 41 | |
| pH | | 7.42 | 7.42 | 7.42 | 7.44 | 7.43 | |
| $O_2$ Cont | | 18.9 | 19.8 | 18.4 | 17.5 | 17.0 | |
| $O_2$ Cap | | 19.3 | | 17.7 | 17.7 | | |
| $O_2$% Sat | | 78 | | 100+4 | 99 | | |
| $CO_2$ Cont | | 23.6 | 24.0 | 23.1 | 23.4 | 22.9 | |
| $pO_2$ | 44 | 104 | 523+ | 261 | 277 | 105 | |
| $pCO_2$ | | 41 | | 36 | 37 | 37 | |
| pH | | 7.42 | | 7.45 | 7.46 | 7.42 | |
| $O_2$ Cont | | 20.5 | 21.0 | 20.4 | 16.3 | 16.5 | |
| $O_2$ Cap | | 20.6 | | 19.1 | 16.4 | | |
| $O_2$% Sat | | 100 | | 100+6.8 | 100 | | |
| $CO_2$ Cont | | 22.8 | 23.1 | 23.0 | 23.0 | 22.5 | |

| Test | Subject Number | Pre-Run | | Day 5 | Post-Run | | |
|---|---|---|---|---|---|---|---|
| | | Room Air | 100% $O_2$ | In Cham | In Cham | Room Air | 100% $O_2$(S1) |
| $pO_2$ | 45 | 97 | 526+ | 242 | 268 | 103 | |
| $pCO_2$ | | 41 | | 42 | 38 | 41 | |
| pH | | 7.42 | | 7.41 | 7.45 | 7.41 | |
| $O_2$ Cont | | 19.8 | 21.2 | 19.6 | 17.5 | 17.8 | |
| $O_2$ Cap | | 20.1 | | 19.5 | 17.7 | | |
| $O_2$% Sat | | 99 | | 100+.5 | 99 | | |
| $CO_2$ Cont | | 21.8 | 22.1 | 23.3 | 22.5 | 22.6 | |
| $pO_2$ | 46 | 103 | 515+ | 271 | 266 | 113 | |
| $pCO_2$ | | 38 | | 41 | 40 | 38 | |
| pH | | 7.40 | | 7.42 | 7.43 | 7.43 | |
| $O_2$ Cont | | 18.2 | 180 | 19.4 | 15.1 | 15.1 | |
| $O_2$ Cap | | 19.1 | | 18.9 | 16.9 | | |
| $O_2$% Sat | | 95 | | 100+2.6 | 89 | | |
| $CO_2$ Cont | | 21.0 | 21.0 | 22.4 | 23.3 | 23.5 | |
| $pO_2$ | 47 | 98 | 493+ | 258 | 257 | 111 | |
| $pCO_2$ | | 39 | | 39 | 40 | 39 | |
| pH | | 7.43 | | 7.40 | 7.43 | 7.41 | |
| $O_2$ Cont | | 19.1 | 20.0 | 19.7 | 17.0 | 16.8 | |
| $O_2$ Cap | | 19.4 | | 18.1 | 19.7 | | |
| $O_2$% Sat | | 99 | | 100+8.8 | 86 | | |
| $CO_2$ Cont | | | | | 23.2 | 23.4 | |

TABLE 1.4.1 (Cont)

ARTERIAL $pO_2$ (mm Hg), $pCO_2$ (mm Hg), pH, $O_2$ CONTENT (Vol %)

$O_2$ CAPACITY (Vol %), % SATURATION, AND $CO_2$ CONTENT (mM/l)

| Test | Subject Number | Pre-Run | | Day 5 | Post-Run | | | Test | Subject Number | Pre-Run | | Day 5 | Post-Run | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Room Air | 100% $O_2$ | In Cham | In Cham | Room Air | 100% $O_2$(SL) | | | Room Air | 100% $O_2$ | In Cham | In Cham | Room Air | 100% $O_2$(SL) |
| 3.8 psi | | | | | | | | | | | | | | | |
| $pO_2$ | 51 | 94 | 295 | 102 | 97 | 93 | | $pO_2$ | 54 | 90 | 485+ | 102 | 107 | 102 | |
| $pCO_2$ | | 38 | 38 | 39 | 43 | 41 | | $pCO_2$ | | 37 | 39 | 40 | 38 | 41 | |
| pH | | 7.43 | 7.42 | 7.43 | 7.41 | 7.41 | | pH | | 7.44 | 7.45 | 7.43 | 7.44 | 7.45 | |
| $O_2$ Cont | | 20.0 | 19.3 | 18.5 | 19.7 | 20.6 | | $O_2$ Cont | | 20.6 | | 18.5 | 20.6 | 20.9 | |
| $O_2$ Cap | | 20.3 | | 18.2 | 19.6 | | | $O_2$ Cap | | 22.0 | | 18.2 | 19.2 | | |
| $O_2$ % Sat | | 99 | | 100+1.6 | 100+.5 | | | $O_2$% Sat | | 94 | | 100+1.6 | 100+7 | | |
| $CO_2$ Cont | | 21.0 | 23.3 | 23.6 | 25.0 | 23.4 | | $CO_2$ Cont | | 27.5 | | 24.1 | 24.2 | 24.7 | |
| $pO_2$ | 52 | 93 | 471+ | 106 | 103 | 101 | | $pO_2$ | 56 | 97 | 553+ | 103 | 102 | 101 | |
| $pCO_2$ | | 39 | 38 | 43 | 43 | 43 | | $pCO_2$ | | 42 | 30 | 39 | 41 | 43 | |
| pH | | 7.41 | 7.42 | 7.41 | 7.42 | 7.43 | | pH | | 7.40 | 7.53 | 7.44 | 7.43 | 7.44 | |
| $O_2$ Cont | | 20.1 | 21.1 | 18.3 | 19.2 | 21.4 | | $O_2$ Cont | | 21.7 | | 19.2 | 20.2 | 19.5 | |
| $O_2$ Cap | | 21.0 | 21.0 | 18.4 | 18.9 | | | $O_2$ Cap | | 22.7 | | 18.2 | 20.9 | | |
| $O_2$% Sat | | 96 | 100+.5 | 100 | 100+1.5 | | | $O_2$% Sat | | 96 | | 100+5.5 | 97 | | |
| $CO_2$ Cont | | 24.8 | 23.9 | 24.8 | 23.6 | 24.2 | | $CO_2$ Cont | | 27.1 | | 24.8 | 24.6 | 24.5 | |
| $pO_2$ | 53 | 95 | 536+ | 104 | 103 | 102 | | | | | | | | | |
| $pCO_2$ | | 37 | 35 | 36 | 41 | 39 | | | | | | | | | |
| pH | | 7.42 | 7.47 | 7.45 | 7.43 | 7.42 | | | | | | | | | |
| $O_2$ Cont | | 20.5 | | 18.5 | 21.1 | | | | | | | | | | |
| $O_2$ Cap | | 19.6 | | 18.4 | 20.6 | | | | | | | | | | |
| $O_2$ % Sat | | 100+4.5 | | 100+.5 | 100+2.4 | | | | | | | | | | |
| $CO_2$ Cont | | 26.9 | | 23.4 | 25.7 | 25.2 | | | | | | | | | |

## 3. Hematological Data

TABLE 2.1.1

RED BLOOD CELLS (millions/mm$^3$), HEMOGLOBIN (gm %), HEMATOCRIT (cc %),

AND % RETICULOCYTES

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| RBC | 11 | 4720 | | 4520 | | 4840 | | | 4730 | | 4730 | | 4710 | | 4850 | | |
| HBG | | 15.1 | | Qns | | 15.0 | | | 15.0 | | 15.4 | | 15.3 | | 15.2 | | |
| Hemat | | 50 | | 42 | | 49 | | | 46 | | 48 | | 47 | | 50 | | |
| Ret | | .7 | | 2.2 | | 2.1 | | | 1.4 | | 1.0 | | 1.6 | | 2.6 | | |
| RBC | 12 | 4450 | | 4360 | | 4710 | | | 4790 | | 4340 | | 4940 | | 4500 | | |
| HBG | | 15.0 | | | | 15.9 | | | 14.9 | | | | 15.0 | | 15.1 | | |
| Hemat | | 50 | | 48 | | 48 | | | 48 | | 48 | | 48 | | 47 | | |
| Ret | | 1.7 | | 1.7 | | 1.7 | | | 0.9 | | 2.1 | | 1.3 | | 1.8 | | |
| RBC | 13 | 4430 | | 4400 | | 4840 | | | 4470 | | 4520 | | 4580 | | 4830 | | |
| HBG | | 14.9 | | 15.7 | | 16.0 | | | | | 15.0 | | 15.2 | | 15.0 | | |
| Hemat | | 52 | | 47 | | 50 | | | 48 | | 48 | | 49 | | 46 | | |
| Ret | | 2.1 | | 3.2 | | 3.1 | | | 1.8 | | 2.0 | | 1.9 | | 1.6 | | |
| RBC | 15 | 4430 | | 4890 | | 5010 | | | 4540 | | 4800 | | 5180 | | 4990 | | |
| HBG | | 14.9 | | 14.8 | | 16.0 | | | 14.9 | | 15.0 | | 15.3 | | 14.9 | | |
| Hemat | | 48 | | 46 | | 50 | | | 50 | | 50 | | 50 | | 50 | | |
| Ret | | 1.1 | | 2.0 | | 2.0 | | | 3.2 | | 1.9 | | 1.6 | | 1.5 | | |
| RBC | 16 | 4510 | | 4490 | | 4540 | | | 4850 | | 4550 | | 4750 | | 5020 | | |
| HBG | | 15.0 | | 15.8 | | 16.5 | | | 15.2 | | 15.1 | | 15.2 | | 15.2 | | |
| Hemat | | 50 | | | | 52 | | | 49 | | 46 | | 48 | | 49 | | |
| Ret | | 0.6 | | 1.3 | | 2.5 | | | 2.9 | | 1.4 | | 2.2 | | 1.9 | | |
| RBC | 17 | 4730 | | 4760 | | 4840 | | | 4810 | | 4930 | | 4840 | | 4760 | | |
| HBG | | 15.1 | | 15.9 | | 16.5 | | | 15.3 | | 16 | | 15.2 | | 15.1 | | |
| Hemat | | 50 | | 48 | | 48 | | | 49 | | 50 | | 48 | | 49 | | |
| Ret | | 1.0 | | 2.0 | | 2.1 | | | 3.4 | | 3.2 | | 3.2 | | 1.7 | | |
| RBC | 31 | 5450 | | 5100 | | 4930 | | | 5870 | | 5100 | | 4990 | | | 5190 | |
| HBG | | 15.0 | | 15.9 | | 16.0 | | | 15.5 | | 15.4 | | 15.9 | | | 16.0 | |
| Hemat | | 49 | | 49 | | 50 | | | 48 | | 49 | | 49 | | | 50 | |
| Ret | | 0.7 | | 0.8 | | 1.8 | | | 1.4 | | 1.3 | | 2.0 | | | 2.2 | |
| RBC | 32 | 4800 | | 5200 | | 4590 | | | 4970 | | | | 4990 | | | 4870 | |
| HBG | | 15.9 | | 15.9 | | 15.8 | | | | | | | 16.2 | | | 15.9 | |
| Hemat | | 48 | | 49 | | 49 | | | 49 | | | | 49 | | | 43 | |
| Ret | | 0.6 | | 0.9 | | 1.3 | | | 0.8 | | | | 2.0 | | | 2.4 | |
| RBC | 33 | 5560 | | 4990 | | 5190 | | | 4860 | | 4690 | | 4250 | | | 4990 | |
| HBG | | 16.9 | | 15.8 | | 16.3 | | | 15.9 | | 15.0 | | 15.2 | | | 16.0 | |
| Hemat | | 48 | | 48 | | 46 | | | 47 | | 43 | | 46 | | | 45 | |
| Ret | | 0.5 | | 1.2 | | 1.2 | | | 0.8 | | 1.7 | | 2.2 | | | 2.1 | |

TABLE 2.1.1 (Cont)

RED BLOOD CELLS (millions/mm$^3$), HEMOGLOBIN (gm %), HEMATOCRIT (cc %),

AND % RETICULOCYTES

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| RBC | 35 | 5460 | | 5140 | | 5140 | | | 5020 | | 5010 | | 3910 | | | 4000 | |
| HBG | | 15.8 | | 15.8 | | 14.8 | | | 14.0 | | 14.0 | | 12.7 | | | 10.5 | |
| Hemat | | 43 | | 45 | | 42 | | | 43 | | 43 | | 43 | | | 41 | |
| Ret | | 0.6 | | 0.6 | | 1.9 | | | 1.2 | | 4.0 | | 5.0 | | | 3.5 | |
| RBC | 36 | 5610 | | 5480 | | 5060 | | | 4470 | | 4890 | | 5370 | | | 4970 | |
| HBG | | 15.8 | | 15.9 | | 15.8 | | | 15.3 | | 15.1 | | 15.9 | | | 15.9 | |
| Hemat | | 49 | | 49 | | 47 | | | 49 | | 49 | | 49 | | | 45 | |
| Ret | | 1.2 | | 0.8 | | 1.9 | | | 0.8 | | 1.9 | | 2.4 | | | 2.0 | |
| RBC | 37 | 5220 | | 4980 | | 4960 | | | 4900 | | 4920 | | 4110 | | | 4450 | |
| HBG | | 16.0 | | 15.9 | | 16.0 | | | 16.5 | | 15.2 | | 14.8 | | | 13.8 | |
| Hemat | | 47 | | 49 | | 50 | | | 47 | | 45 | | 47 | | | 48 | |
| Ret | | 0.8 | | 1.1 | | 1.5 | | | 1.1 | | 1.6 | | 1.2 | | | 3.0 | |
| RBC | 42 | 5280 | | 4790 | 4750 | 4800 | 4390 | | 4600 | | 4380 | | 4640 | | 4980 | | 5010 |
| HBG | | 16.4 | | 15.1 | 14.05 | 13.80 | 13.8 | | 13.8 | | 14.0 | | 14.80 | | 14.8 | | 14.80 |
| Hemat | | 50 | | 52 | 48 | 42 | 42 | | 45 | | 45 | | 48 | | 48 | | 49 |
| Ret | | 0.8 | | | | 4.1 | | | 4.1 | | 5.0 | | | | 4.2 | | 4.5 |
| RBC | 43 | 5000 | | 4970 | 4480 | 4420 | 4450 | | 4760 | | 4480 | | 3870 | | 4260 | | 4130 |
| HBG | | 16.0 | | 15.1 | 14.25 | 14.05 | 15.5 | | 14.05 | | 14.0 | | 13.30 | | 13.8 | | 11.89 |
| Hemat | | 50 | | 50 | 50 | 45 | 47 | | 45 | | 42 | | 43 | | 40 | | 47 |
| Ret | | 1.2 | | | | 3.1 | | | 4.2 | | 5.0 | | | | 4.6 | | 3.8 |
| RBC | 44 | 5600 | | 4900 | 4470 | 4370 | 4550 | | 4000 | | 4500 | | 3710 | | 4090 | | 4530 |
| HBG | | 16.3 | | 14.8 | 14.25 | 13.80 | 14.7 | | 13.05 | | 14.05 | | 12.40 | | 12.8 | | 14.8 |
| Hemat | | 51 | | 45 | 44 | 45 | 46 | | 42 | | 42 | | 39 | | 41 | | 49 |
| Ret | | 0.7 | | | | 3.0 | | | 4.9 | | 5.1 | | | | 3.2 | | 3.4 |
| RBC | 45 | 4990 | | 5100 | 4650 | 4880 | 4420 | | 4060 | | 4870 | | 4360 | | 4510 | | 4720 |
| HBG | | 16.3 | | 15.1 | 13.02 | 14.30 | 14.05 | | 13.06 | | 14.05 | | 13.60 | | 14.0 | | 14.8 |
| Hemat | | 51 | | 43 | 48 | 50 | 47 | | 46 | | 47 | | 46 | | 48 | | 49 |
| Ret | | 0.8 | | | | 3.4 | | | 4.7 | | 4.6 | | | | 4.6 | | 4.8 |
| RBC | 46 | 4710 | | 4630 | 4330 | 4030 | 4200 | | 4020 | | 4010 | | 3510 | | 3830 | | 4150 |
| HBG | | 15.8 | | 14.8 | 12.72 | 13.05 | 14.6 | | 13.06 | | 12.80 | | 12.12 | | 12.3 | | 13.47 |
| Hemat | | 47 | | 49 | 45 | 43 | 46 | | 40 | | 41 | | 41 | | 40 | | 44 |
| Ret | | 1.2 | | | | 3.8 | | | 4.5 | | 4.8 | | | | 5.1 | | 3.0 |
| RBC | 47 | 4920 | | 4860 | 4010 | 4240 | Qns | | 4050 | | 4190 | | 3900 | | 4090 | | 4120 |
| HBG | | 15.9 | | 15.2 | 14.25 | 14.05 | 15.8 | | 14.05 | | 14.05 | | 13.30 | | 13.3 | | 14.0 |
| Hemat | | 49 | | 49 | 49 | 46 | Qns | | 46 | | 47 | | 45 | | 45 | | 45 |
| Ret | | 0.8 | | | | 3.0 | | | 5.3 | | 5.2 | | | | 5.0 | | 2.6 |

TABLE 2.1.1 (Cont)

RED BLOOD CELLS (Millions/mm$^3$), HEMOGLOBIN (gm %), HEMATOCRIT (cc %),

AND % RETICULOCYTES

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| RBC | 51 | 5510 | | 4730 | | 4530 | | | 4960 | | 4660 | | 4660 | | | 4580 | |
| HBG | | 15.6 | | 14.8 | | 14.8 | | | 14.4 | | 14.3 | | 14.30 | | 14.48 | 14.9 | |
| Hemat | | 50 | | 49 | | 50 | | | 48 | | 49 | | 48 | | 48 | 49 | |
| Ret | | 2.1 | | 2.5 | | 3.8 | | | 3.5 | | 6.6 | | 4.8 | | 7.0 | 4.6 | |
| RBC | 52 | 5290 | | 5020 | | 4980 | | | 4790 | | 4350 | | 4510 | | | 4500 | |
| HBG | | 15.6 | | 14.4 | | 15.06 | | | 14.05 | | 13.55 | | 13.55 | | 13.80 | 14.9 | |
| Hemat | | 51 | | 50 | | 49 | | | 47 | | 46 | | 47 | | 46 | 50 | |
| Ret | | 2.9 | | 2.7 | | 5.8 | | | 5.1 | | 4.3 | | 9.1 | | 3.5 | 5.0 | |
| RBC | 53 | 4930 | | 4720 | | 4880 | | | 4430 | | 5216 | | 4910 | | | 4520 | |
| HBG | | 15.2 | | 15.05 | | 15.08 | | | 14.9 | | 14.9 | | 14.8 | | 14.93 | 15.3 | |
| Hemat | | 46 | | 51 | | 48 | | | 48 | | 50 | | 49 | | 47 | 51 | |
| Ret | | 2.4 | | 3.1 | | 2.8 | | | 5.6 | | 6.5 | | 4.3 | | 10.0 | 6.8 | |
| RBC | 54 | 4650 | | 4500 | | 4500 | | | 4350 | | 4510 | | 4610 | | | 5030 | |
| HBG | | 14.3 | | 14.36 | | 14.06 | | | 14.4 | | 14.8 | | 14.3 | | 14.48 | 14.9 | |
| Hemat | | 47 | | 51 | | 47 | | | 48 | | 47 | | 48 | | 48 | 50 | |
| Ret | | 2.5 | | 2.6 | | 2.6 | | | 6.3 | | 10.4 | | 5.3 | | 11.0 | 6.6 | |
| RBC | 56 | 5540 | | 5720 | | 5010 | | | 5000 | | 4660 | | 48.70 | | | 5168 | |
| HBG | | 15.6 | | 15.99 | | 15.56 | | | 14.9 | | 14.8 | | 15.3 | | 15.31 | 15.4 | |
| Hemat | | 50 | | 53 | | 50 | | | 49 | | 51 | | 51 | | 51 | 52 | |
| Ret | | 1.9 | | 2.8 | | 2.7 | | | 7.1 | | 10.8 | | 9.7 | | 5.0 | 7.1 | |

TABLE 2.1.2

MEAN CORPUSCULAR VOLUME ($\mu^3$), MEAN CORPUSCULAR HEMOGLOBIN ($\gamma\gamma$), AND MEAN CORPUSCULAR HEMOGLOBIN CONCENTRATION (%)

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 7 | 9 | 11 | 13 | 14 |
| MCV | 11 | 104 | 90 | | 100 | | 96 | 100 | 98 | | 104 |
| MCH | | 30 | | | 31 | | 31 | 30 | 30 | | 30 |
| MCHC | | 31 | | | 31 | | 32 | 32 | 32 | | 32 |
| MCV | 12 | 110 | 108 | | 100 | | 100 | 108 | 105 | | 103 |
| MCH | | 33 | | | 30 | | 32 | | 30 | | 32 |
| MCHC | | 32 | | | 34 | | 32 | | 32 | | 32 |
| MCV | 13 | 108 | 105 | | 104 | | 105 | 105 | 108 | | 98 |
| MCH | | 34 | 35 | | 33 | | | 33 | 33 | | 32 |
| MCHC | | 29 | 34 | | 32 | | | 32 | 32 | | 33 |
| MCV | 15 | 106 | 96 | | 94 | | 108 | 104 | 98 | | 102 |
| MCH | | 33 | 31 | | 32 | | 33 | 31 | 30 | | 31 |
| MCHC | | 32 | 32 | | 32 | | 31 | 31 | 32 | | 31 |
| MCV | 16 | 110 | 96 | | 104 | | 110 | 100 | 100 | | 98 |
| MCH | | 33 | 35 | | 37 | | 30 | 31 | 32 | | 28 |
| MCHC | | 31 | 36 | | 31 | | 31 | 34 | 32 | | 32 |
| MCV | 17 | 104 | 100 | | 100 | | 105 | 100 | 100 | | 104 |
| MCH | | 31 | 33 | | 34 | | 31 | 31 | 31 | | 31 |
| MCHC | | 30 | 32 | | 34 | | 32 | 32 | 32 | | 32 |
| MCV | 31 | 90 | 93 | | 102 | | 82 | 96 | 100 | | 96 |
| MCH | | 28 | 31 | | 32 | | 27 | 30 | 32 | | 34 |
| MCHC | | 32 | 33 | | 33 | | 32 | 32 | 32 | | 32 |
| MCV | 32 | 100 | 94 | | 108 | | | | 100 | | 90 |
| MCH | | 32 | 30 | | 34 | | | | 32 | | 33 |
| MCHC | | 35 | 33 | | 32 | | | | 34 | | 36 |
| MCV | 33 | 84 | 98 | | 90 | | 98 | 92 | 110 | | 90 |
| MCH | | 30 | 31 | | 32 | | 33 | 32 | 35 | | 32 |
| MCHC | | 35 | 34 | | 36 | | 35 | 35 | 33 | | 36 |
| MCV | 35 | 80 | 86 | | 82 | | 86 | 92 | 110 | | 102 |
| MCH | | 29 | 32 | | 29 | | 28 | 28 | 32 | | 26 |
| MCHC | | 36 | 35 | | 35 | | 33 | 30 | 30 | | 25 |
| MCV | 36 | 89 | 90 | | 91 | | 110 | 104 | 91 | | 90 |
| MCH | | 28 | 29 | | 31 | | 33 | 31 | 28 | | 31 |
| MCHC | | 33 | 33 | | 34 | | 32 | 32 | 32 | | 34 |
| MCV | 37 | 86 | 98 | | 100 | | 94 | 90 | 111 | | 104 |
| MCH | | 30 | 32 | | 32 | | 33 | 31 | 35 | | 31 |
| MCHC | | 35 | 33 | | 33 | | 36 | 35 | 34 | | 29 |

TABLE 2.1.2 (Cont)

MEAN CORPUSCULAR VOLUME ($\mu^3$), MEAN CORPUSCULAR HEMOGLOBIN ($\gamma\gamma$), AND MEAN CORPUSCULAR HEMOGLOBIN CONCENTRATION (%)

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 7 | 9 | 11 | 13 | 14 |
| MCV | 42 | 94 | 109 | 101 | 90 | 96 | 100 | 108 | 110 | 108 | 98 |
| MCH | | 33 | 31 | 29 | 29 | 32 | 30 | 33 | 32 | 30 | 30 |
| MCHC | | 31 | 30 | 30 | 30 | 32 | 30 | 33 | 30 | 30 | 30 |
| MCV | 43 | 93 | 100 | 112 | 104 | 106 | 94 | 93 | 112 | 94 | 118 |
| MCH | | 34 | 32 | 32 | 34 | 30 | 30 | 32 | 35 | 33 | 30 |
| MCHC | | 32 | 30 | 33 | 32 | 29 | 32 | 32 | 30 | 32 | 26 |
| MCV | 44 | 93 | 92 | 98 | 102 | 102 | 104 | 91 | 92 | 111 | 110 |
| MCH | | 30 | 30 | 33 | 32 | 33 | 32 | 32 | 33 | 32 | 32 |
| MCHC | | 34 | 32 | 32 | 32 | 33 | 32 | 35 | 30 | 32 | 32 |
| MCV | 45 | 100 | 85 | 110 | 105 | 108 | 112 | 93 | 112 | 108 | 105 |
| MCH | | 28 | 30 | 28 | 30 | 32 | 32 | 31 | 31 | 30 | 30 |
| MCHC | | 30 | 35 | 27 | 27 | 30 | 28 | 33 | 29 | 30 | 32 |
| MCV | 46 | 102 | 108 | 106 | 106 | 108 | 100 | 100 | 118 | 108 | 110 |
| MCH | | 32 | 32 | 30 | 32 | 33 | 32 | 34 | 34 | 32 | 32 |
| MCHC | | 32 | 30 | 28 | 30 | 32 | 34 | 33 | 30 | 30 | 32 |
| MCV | 47 | 112 | 89 | 122 | 110 | 92 | 115 | 100 | 112 | 110 | 110 |
| MCH | | 34 | 32 | 35 | 33 | 28 | 34 | 31 | 33 | 32 | 34 |
| MCHC | | 32 | 29 | 32 | 30 | 32 | 32 | 32 | 32 | 32 | 32 |
| MCV | 51 | 90 | 102 | | 109 | | 99 | 106 | 100 | 105 | |
| MCH | | 29 | 31 | | 33 | | 30 | 30 | 31 | 31 | |
| MCHC | | 32 | 31 | | 30 | | 31 | 30 | 30 | 31 | |
| MCV | 52 | 93 | 99 | | 99 | | 100 | 106 | 104 | 102 | |
| MCH | | 30 | 30 | | 29 | | 30 | 31 | 30 | 30 | |
| MCHC | | 32 | 30 | | 31 | | 30 | 30 | 30 | 30 | |
| MCV | 53 | 92 | 110 | | 99 | | 109 | 92 | 92 | 104 | |
| MCH | | 31 | 32 | | 31 | | 34 | 29 | 29 | 32 | |
| MCHC | | 33 | 30 | | 32 | | 32 | 30 | 30 | 32 | |
| MCV | 54 | 108 | 111 | | 105 | | 110 | 104 | 104 | 104 | |
| MCH | | 31 | 31 | | 31 | | 33 | 32 | 31 | 31 | |
| MCHC | | 31 | 28 | | 30 | | 33 | 32 | 32 | 32 | |
| MCV | 56 | 90 | 91 | | 100 | | 99 | 104 | 104 | 98 | |
| MCH | | 29 | 27 | | 31 | | 30 | 31 | 30 | 30 | |
| MCHC | | 29 | 31 | | 30 | | 32 | 29 | 30 | 30 | |

TABLE 2.1.3

WHITE BLOOD COUNT (per $mm^3$), % POLYMORPHONUCLEAR LEUKOCYTES, % LYMPHOCYTES, % MONOCYTES, AND SEDIMENTATION RATE (mm/hr)

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| Sea Level | | | | | | | | | | | | | | | | | |
| wbc | 11 | 8, 350 | | 8, 500 | | 11, 100 | | | 8, 500 | | 11, 950 | | 9, 000 | | | 10, 450 | |
| Poly's | | 59 | | 51 | | 71 | | | 60 | | 47 | | 36 | | | 46 | |
| Lymph's | | 37 | | 44 | | 27 | | | 34 | | 46 | | 49 | | | 42 | |
| Mono | | 4 | | 5 | | 2 | | | 6 | | 7 | | 15 | | | 12 | |
| Sed rate | | 2 | | 2 | | 3 | | | 2 | | 2 | | 2 | | | 2 | |
| wbc | 12 | 8, 050 | | 8, 600 | | 8, 650 | | | 5, 500 | | 9, 000 | | 10, 000 | | | 7, 450 | |
| Poly's | | 61 | | 58 | | 67 | | | 38 | | 48 | | 58 | | | 52 | |
| Lymph's | | 37 | | 39 | | 27 | | | 55 | | 42 | | 35 | | | 36 | |
| Mono | | 2 | | 3 | | 7 | | | 7 | | 10 | | 7 | | | 12 | |
| Sed rate | | 4 | | 5 | | 5 | | | 3 | | 5 | | 4 | | | 2 | |
| wbc | 13 | 6, 700 | | 8, 100 | | 10, 450 | | | 7, 550 | | 13, 100 | | 10, 300 | | | 8, 800 | |
| Poly's | | 45 | | 44 | | 50 | | | 27 | | 34 | | 40 | | | 34 | |
| Lymph's | | 53 | | 53 | | 45 | | | 67 | | 58 | | 51 | | | 51 | |
| Mono | | 2 | | 3 | | 5 | | | 6 | | 8 | | 9 | | | 15 | |
| Sed rate | | 5 | | 4 | | 2 | | | 2 | | 3 | | 4 | | | 2 | |
| wbc | 15 | 8, 650 | | 9, 750 | | 9, 500 | | | 7, 350 | | 11, 950 | | 11, 250 | | | 7, 750 | |
| Poly's | | 63 | | 48 | | 49 | | | 54 | | 46 | | 58 | | | 58 | |
| Lymph's | | 36 | | 50 | | 47 | | | 37 | | 46 | | 36 | | | 30 | |
| Mono | | 1 | | 2 | | 6 | | | 9 | | 8 | | 6 | | | 12 | |
| Sed rate | | 3 | | 2 | | 4 | | | 3 | | 3 | | 5 | | | 4 | |
| wbc | 16 | 9, 550 | | 7, 800 | | 8, 450 | | | 11, 200 | | 10, 900 | | 10, 350 | | | 8, 650 | |
| Poly's | | 62 | | 57 | | 43 | | | 49 | | 45 | | 38 | | | 45 | |
| Lymph's | | 34 | | 41 | | 49 | | | 42 | | 44 | | 55 | | | 48 | |
| Mono | | 4 | | 2 | | 8 | | | 9 | | 11 | | 7 | | | 7 | |
| Sed rate | | 10 | | 10 | | 6 | | | 5 | | 6 | | 6 | | | 8 | |
| wbc | 17 | 8, 000 | | 8, 200 | | 9, 350 | | | 8, 560 | | 11, 850 | | 9, 800 | | | 7, 400 | |
| Poly's | | 76 | | 63 | | 55 | | | 66 | | 58 | | 45 | | | 45 | |
| Lymph's | | 21 | | 32 | | 38 | | | 27 | | 30 | | 49 | | | 41 | |
| Mono | | 3 | | 5 | | 7 | | | 7 | | 12 | | 6 | | | 14 | |
| Sed rate | | 4 | | 2 | | 3 | | | 2 | | 2 | | 2 | | | 3 | |

TABLE 2.1.3 (Cont)

WHITE BLOOD COUNT (per $mm^3$), % POLYMORPHONUCLEAR LEUKOCYTES, % LYMPHOCYTES, % MONOCYTES, AND SEDIMENTATION RATE (mm/hr)

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| | | | 5 psi | | | | | | | | | | | | | | |
| wbc | 31 | 10,100 | | 8,600 | | 8,400 | | | 8,100 | | 7,250 | | 10,350 | | | 10,500 | |
| Poly's | | 69 | | 67 | | 62 | | | 57 | | 63 | | 61 | | | 58 | |
| Lymph's | | 27 | | 22 | | 31 | | | 42 | | 33 | | 37 | | | 38 | |
| Mono | | 4 | | 10 | | 7 | | | 1 | | 4 | | 2 | | | 4 | |
| Sed rate | | 2 | | 3 | | 3 | | | 3 | | 2 | | 2 | | | 3 | |
| wbc | 32 | 6,600 | | 9,800 | | 10,600 | | | | | | | 10,750 | | | 13,100 | |
| Poly's | | 65 | | 54 | | 51 | | | | | | | 59 | | | 64 | |
| Lymph's | | 33 | | 40 | | 45 | | | | | | | 35 | | | 30 | |
| Mono | | 2 | | 6 | | 4 | | | | | | | 6 | | | 6 | |
| Sed rate | | 1 | | 12 | | 18 | | | | | | | 17 | | | 22 | |
| wbc | 33 | 9,300 | | 9,100 | | 13,150 | | | 11,450 | | 9,100 | | 11,050 | | | 12,100 | |
| Poly's | | 58 | | 58 | | 60 | | | 56 | | 68 | | 59 | | | 57 | |
| Lymph's | | 27 | | 27 | | 30 | | | 30 | | 25 | | 36 | | | 39 | |
| Mono | | 15 | | 15 | | 10 | | | 14 | | 7 | | 5 | | | 4 | |
| Sed rate | | 3 | | 3 | | 7 | | | 3 | | 10 | | 6 | | | 5 | |
| wbc | 35 | 11,100 | | 16,100 | | 15,900 | | | 14,000 | | 14,050 | | 14,750 | | | 19,100 | |
| Poly's | | 80 | | 88 | | 81 | | | 68 | | 75 | | 72 | | | 85 | |
| Lymph's | | 13 | | 11 | | 13 | | | 26 | | 22 | | 18 | | | 12 | |
| Mono | | 7 | | 1 | | 6 | | | 6 | | 3 | | | | | 3 | |
| Sed rate | | 2 | | 3 | | 10 | | | 6 | | 7 | | 5 | | | 10 | |
| wbc | 36 | 10,100 | | 9,200 | | 15,700 | | | 5,000 | | 7,700 | | 9,400 | | | 8,900 | |
| Poly's | | 56 | | 66 | | 85 | | | 55 | | 65 | | 40 | | | 56 | |
| Lymph's | | 36 | | 28 | | 12 | | | 40 | | 28 | | 50 | | | 36 | |
| Mono | | 8 | | 6 | | 3 | | | 5 | | 7 | | 10 | | | 8 | |
| Sed rate | | 2 | | 2 | | 6 | | | 10 | | 5 | | 2 | | | 4 | |
| wbc | 37 | 8,100 | | 10,100 | | 9,900 | | | 9,800 | | 10,800 | | 12,500 | | | 12,600 | |
| Poly's | | 51 | | 57 | | 49 | | | 53 | | 73 | | 67 | | | 70 | |
| Lymph's | | 44 | | 37 | | 44 | | | 44 | | 22 | | 26 | | | 30 | |
| Mono | | 5 | | 7 | | 7 | | | 3 | | 5 | | 7 | | | | |
| Sed rate | | 3 | | 3 | | 4 | | | 8 | | 3 | | 15 | | | 18 | |

TABLE 2.1.3 (Cont)

WHITE BLOOD COUNT (per $mm^3$), % POLYMORPHONUCLEAR LEUKOCYTES, % LYMPHOCYTES, % MONOCYTES, AND SEDIMENTATION RATE (mm/hr)

| Test | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.4 psi | | | | | | | | | | | | | | | | | |
| wbc | 42 | 10,100 | | 10,700 | 7,800 | 6,200 | 6,800 | | 7,000 | | 9,100 | | 8,800 | | 12,900 | 9,400 | |
| Poly's | | 49 | | 66 | 52 | 50 | 60 | | 46 | | 47 | | 56 | | 33 | 51 | |
| Lymph's | | 46 | | 30 | 43 | 46 | 26 | | 49 | | 42 | | 34 | | 50 | 45 | |
| Mono | | 5 | | 4 | 7 | 6 | 4 | | 5 | | 11 | | 10 | | 7 | 4 | |
| Sed rate | | 5 | | 5 | | 12 | 12 | | 8 | | 12 | | 8 | | 14 | 18 | |
| wbc | 43 | 12,400 | | 11,300 | 6,150 | 6,000 | 11,100 | | 6,000 | | 9,100 | | 8,300 | | 7,600 | 9,450 | |
| Poly's | | 49 | | 65 | 71 | 68 | 73 | | 56 | | 59 | | 60 | | 54 | 38 | |
| Lymph's | | 48 | | 27 | 21 | 22 | 20 | | 38 | | 32 | | 24 | | 42 | 58 | |
| Mono | | 3 | | 8 | 8 | 10 | 7 | | 6 | | 9 | | 16 | | 4 | 4 | |
| Sed Rate | | 2 | | 1 | | 12 | 20 | | 18 | | 17 | | 18 | | 12 | 12 | |
| wbc | 44 | 12,300 | | 10,500 | 9,800 | 10,000 | 9,300 | | 9,300 | | 9,900 | | 8,400 | | 11,300 | 11,300 | |
| Poly's | | 64 | | 44 | 45 | 59 | 73 | | 62 | | 64 | | 70 | | 62 | 74 | |
| Lymph's | | 30 | | 55 | 47 | 28 | 17 | | 32 | | 26 | | 26 | | 28 | 24 | |
| Mono | | 6 | | 1 | 8 | 3 | 10 | | 6 | | 10 | | 4 | | 11 | 2 | |
| Sed rate | | 1 | | 4 | | 7 | 14 | | 14 | | 16 | | 12 | | 12 | 4 | |
| wbc | 45 | 11,000 | | 11,800 | 6,600 | 7,900 | 8,100 | | 7,100 | | 8,800 | | 7,600 | | 9,900 | 10,200 | |
| Poly's | | 71 | | 70 | 58 | 54 | 77 | | 54 | | 55 | | 61 | | 63 | 49 | |
| Lymph's | | 27 | | 26 | 35 | 43 | 23 | | 38 | | 38 | | 28 | | 27 | 36 | |
| Mono | | 2 | | 4 | 7 | 6 | | | 8 | | 7 | | 11 | | 10 | 15 | |
| Sed rate | | 1 | | 1 | | 2 | 8 | | 2 | | 3 | | 3 | | 3 | 4 | |
| wbc | 46 | 7,400 | | 7,900 | 6,800 | 7,400 | 9,400 | | 6,450 | | 9,800 | | 9,000 | | 7,850 | 9,350 | |
| Poly's | | 83 | | 35 | 42 | 67 | 70 | | 67 | | 55 | | 55 | | 65 | 68 | |
| Lymph's | | 17 | | 61 | 56 | 19 | 25 | | 26 | | 34 | | 40 | | 29 | 26 | |
| Mono | | | | 4 | 2 | 8 | 5 | | 7 | | 11 | | 5 | | 6 | 6 | |
| Sed rate | | 1 | | 2 | | 4 | 3 | | 5 | | 4 | | 5 | | 4 | 4 | |
| wbc | 47 | 10,000 | | 9,800 | 5,100 | 6,500 | 9,100 | | 7,000 | | 9,600 | | 6,800 | | 10,750 | 7,450 | |
| Poly's | | 52 | | 61 | 44 | 53 | 73 | | 45 | | 47 | | 51 | | 56 | 57 | |
| Lymph's | | 40 | | 34 | 48 | 42 | 25 | | 52 | | 48 | | 33 | | 38 | 35 | |
| Mono | | 8 | | 5 | 8 | 5 | 2 | | 3 | | 5 | | 16 | | 6 | 7 | |
| Sed rate | | 1 | | 1 | | 5 | 8 | | 5 | | 3 | | 4 | | 5 | 6 | |

TABLE 2.1.3 (Cont)

WHITE BLOOD COUNT (per $mm^3$), % POLYMORPHONUCLEAR LEUKOCYTES, % LYMPHOCYTES, % MONOCYTES, AND SEDIMENTATION RATE (mm/hr)

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| 3.8 psi | | | | | | | | | | | | | | | | | |
| wbc | 51 | 7,100 | | 7,800 | | 7,100 | | | 8,500 | | 7,800 | | 6,550 | | 7,100 | | |
| Poly's | | 58 | | 56 | | 47 | | | 54 | | 57 | | 49 | | 56 | | |
| Lymph's | | 35 | | 35 | | 46 | | | 32 | | 31 | | 35 | | 31 | | |
| Mono | | 7 | | 9 | | 7 | | | 14 | | 12 | | 16 | | 13 | | |
| Sed rate | | 2 | | 4 | | 4 | | | 6 | | 3 | | 5 | | 5 | | |
| wbc | 52 | 10,700 | | 9,800 | | 9,450 | | | 11,100 | | 11,100 | | 9,800 | | 10,350 | | |
| Poly's | | 82 | | 77 | | 73 | | | 76 | | 62 | | 74 | | 70 | | |
| Lymph's | | 14 | | 18 | | 19 | | | 17 | | 26 | | 17 | | 21 | | |
| Mono | | 4 | | 5 | | 8 | | | 9 | | 12 | | 9 | | 9 | | |
| Sed rate | | 3 | | 6 | | 4 | | | 4 | | 3 | | 2 | | 6 | | |
| wbc | 53 | 9,300 | | 9,300 | | 11,000 | | | 14,700 | | 14,000 | | 13,800 | | 10,300 | | |
| Poly's | | 59 | | 81 | | 59 | | | 71 | | 64 | | 52 | | 55 | | |
| Lymph's | | 35 | | 15 | | 33 | | | 24 | | 21 | | 38 | | 27 | | |
| Mono | | 6 | | 4 | | 8 | | | 5 | | 15 | | 10 | | 8 | | |
| Sed rate | | 4 | | 5 | | 7 | | | 4 | | 5 | | 7 | | 5 | | |
| wbc | 54 | 8,350 | | 8,500 | | 7,650 | | | 8,200 | | 6,000 | | 7,650 | | 9,000 | | |
| Poly's | | 47 | | 62 | | 58 | | | 73 | | 58 | | 71 | | 68 | | |
| Lymph's | | 45 | | 31 | | 35 | | | 22 | | 36 | | 20 | | 28 | | |
| Mono | | 8 | | 7 | | 7 | | | 5 | | 6 | | 9 | | 4 | | |
| Sed rate | | 2 | | 2 | | 2 | | | 2 | | 2 | | 2 | | 2 | | |
| wbc | 56 | 8,300 | | 7,800 | | 7,400 | | | 8,450 | | 8,400 | | 10,400 | | 7,900 | | |
| Poly's | | 77 | | 75 | | 63 | | | 63 | | 51 | | 65 | | 66 | | |
| Lymph's | | 16 | | 21 | | 33 | | | 27 | | 39 | | 21 | | 28 | | |
| Mono | | 7 | | 4 | | 4 | | | 10 | | 10 | | 14 | | 6 | | |
| Sed rate | | 2 | | 2 | | 1 | | | 1 | | 2 | | 2 | | 2 | | |

TABLE 2.1.4

VAN DEN BERGH (mg %), ICTERUS INDEX, EHRLICH'S UROBILINOGEN AND FECAL OCCULT BLOOD

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| van den Bergh | 42 | 1.61 | | 2.36 | 2.62 | 2.25 | 2.28 | | 1.87 | | 2.21 | | 2.17 | | 2.06 | | 1.76 |
| Icteric | | | | | | 18.7 | 5 | | 23.5 | | 10 | | 13 | | 10 | | |
| Ehrlich's | | neg. | | | 1/64 | | | | | 1/128 | | 1/256 | | 1/40 | | | |
| Occult Blood | | | | + | + | Trace | | + | | + | | + | | + | | | |
| van den Bergh | 43 | 1.57 | | 1.3 | 1.91 | 2.32 | 1.98 | | Qns | | 1.76 | | Qns | | 1.72 | | 1.68 |
| Icteric | | | | | | 5.5 | 15 | | 25.5 | | 10.6 | | 15.16 | | 8.6 | | 15.8 |
| Ehrlich's | | neg. | | | 1/64 | | | | | 1/128 | | 1/256 | | neg. | | | |
| Occult Blood | | | | + | + | + | | + | | + | | + | | + | | | |
| van den Bergh | 44 | 1.61 | | 5.8 | 1.91 | 1.91 | 1.94 | | 1.53 | | Qns | | 1.76 | | 1.65 | | 1.61 |
| Icteric | | | | | | 7.3 | 11 | | 11.5 | | 17 | | 11 | | 6.1 | | 6 |
| Ehrlich's | | neg. | | | 1/64 | | | | | Trace | | 1/128 | | 1/20 | | | |
| Occult Blood | | | | + | + | + | | 0 | | + | | -H +G | | 0 | | | |
| van den Bergh | 45 | 1.53 | | 6.84 | 2.55 | 2.36 | 3.07 | | 1.95 | | 2.13 | | 2.17 | | 2.43 | | 2.43 |
| Icteric | | | | | 11 | 11.5 | 7.5 | | 21.5 | | 10 | | 15 | | 15.9 | | 15 |
| Ehrlich's | | neg. | | | 1/32 | | | | | 1/64 | | 1/128 | | 1/40 | | | |
| Occult Blood | | | | + | + | + | | + | | + | | + | | -H +G | | | |
| van den Bergh | 46 | 1.53 | | Qns | 2.06 | 2.33 | 3.07 | | 1.61 | | 1.95 | | 1.88 | | 2.02 | | 1.76 |
| Icteric | | | | | | 15 | 9.1 | | 6.5 | | 14 | | 7.2 | | 7.8 | | 8.3 |
| Ehrlich's | | neg. | | | 1/32 | | | | | 1/64 | | 1/128 | | neg. | | | |
| Occult Blood | | | | + | + | | | + | | 0 | | 0 | | + | | | |
| van den Bergh | 47 | 1.52 | | 5.47 | 2.25 | 2.4 | 1.5 | | 1.87 | | 1.98 | | 1.95 | | 2.10 | | 1.90 |
| Icteric | | | | | | 15.5 | 11 | | 3.8 | | 11 | | 13 | | 9 | | 6.2 |
| Ehrlich's | | neg. | | | 1/32 | | | | | 1/128 | | 1/128 | | 1/20 | | | |
| Occult Blood | | | | + | | + | | Trace | | + | | + | | -H +G | | | |
| van den Bergh | 51 | 1.7 | | 1.72 | | 2.06 | | | 1.5 | | 1.05 | | 1.91 | | | | |
| Icteric | | 10 | | 11.5 | | 11.5 | | | 12 | | 9 | | 9 | | Qns | | |
| Ehrlich's | | 1/8 | | | 1/32 | | | 1/16 | | | 1/16 | | 1/16 | | | | |
| Occult Blood | | | | -H +G | + | | | | trace H -G | | 0 | | | | | | |
| van den Bergh | 52 | 1.6 | | 1.87 | | 1.91 | | | 1.88 | | 1.12 | | 2.12 | | 1.72 | | |
| Icteric | | 4.5 | | 13.5 | | 10 | | | 25.5 | | 15 | | 11 | | 8.9 | | |
| Ehrlich's | | 1/8 | | | 1/16 | | | 1/16 | | | 1/16 | | 1/8 | | | | |
| Occult Blood | | | | -G +H | + | | | | Trace | | 0 | | | | | | |
| van den Bergh | 53 | .96 | | 1.73 | | 1.8 | | | 1.88 | | 1.05 | | 2.28 | | 1.68 | | |
| Icteric | | 11.5 | | 9.6 | | 18.5 | | | 12.6 | | 16 | | 10 | | 10 | | |
| Ehrlich's | | 1/8 | | | | | | 1/16 | | | 1/16 | | 1/8 | | | | |
| Occult Blood | | | | -G +H | Trace | | | | + | | +H -G | | | | | | |

TABLE 2.1.4 (Cont)

VAN DEN BERGH (mg %), ICTERUS INDEX, EHRLICH'S UROBILINOGEN AND FECAL OCCULT BLOOD

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| van den Bergh | 54 | 1.7 | | 1.8 | | 2.06 | | | 2.02 | | 1.16 | | 3.2 | | 1.72 | | |
| Icteric | | 5.3 | | 30 | | 13 | | | 15 | | 12 | | 9 | | 13 | | |
| Ehrlich's | | 1/8 | | | 1/16 | | | 1/8 | | | 1/8 | | 1/8 | | | | |
| Occult Blood | | | | +G -H | Trace | | | | + | | + | | | | | | |
| van den Bergh | 56 | 1.1 | | 2.10 | | 2.55 | | | 2.13 | | 1.23 | | 2.85 | | 1.91 | | |
| Icteric | | 4.5 | | 10.9 | | 12.5 | | | 10.8 | | 11 | | 10 | | 10 | | |
| Ehrlich's | | 1/16 | | | 1/24 | | | 1/16 | | | 1/16 | | 1/16 | | | | |
| Occult Blood | | | | -H +G | + | | | | + | | + | | | | | | |

Note: H = Hematist

G = Guaiac Test

TABLE 2.1.5

RED CELL FRAGILITY (DEGREE OF HEMOLYSIS)

| Subject Number | Pre-Run | | Day 3 | | Day 5 | | Post-Run | |
|---|---|---|---|---|---|---|---|---|
| | Inc | Comp | Inc | Comp | Inc | Comp | Inc | Comp |
| Control | | | | | | | .38 | .34 |
| 31 | | | | | | | .44 | .42 |
| 32 | | | | | | | .44 | .42 |
| 33 | | | | | | | .44 | .42 |
| 35 | | | | | | | .46 | .44 |
| 36 | | | | | | | .42 | .38 |
| 37 | | | | | | | .42 | .38 |
| Control | .42 | .38 | .44 | .34 | .44 | .38 | .44 | .38 |
| 42 | .40 | .34 | .46 | .38 | .44 | .38 | .44 | .38 |
| 43 | .42 | .34 | .48 | .38 | .44 | .40 | .46 | .38 |
| 44 | .42 | .36 | .46 | .36 | .48 | .36 | .42 | .36 |
| 45 | .44 | .34 | .44 | .36 | .44 | .38 | .42 | .38 |
| 46 | .42 | .34 | .44 | .34 | .40 | .36 | .42 | .36 |
| 47 | .46 | .38 | .44 | .36 | .48 | .38 | .46 | .38 |
| Control | .42 | .38 | | | | | .44 | .40 |
| 51 | .42 | .38 | | | | | .52 | .44 |
| 52 | .46 | .36 | | | | | .52 | .44 |
| 53 | .50 | .38 | | | | | .54 | .44 |
| 54 | .48 | .40 | | | | | .50 | .42 |
| 56 | .48 | .38 | | | | | .52 | .44 |

TABLE 2.1.6

FOLLOW-UP, HEMATOLOGICAL DATA

| Date | Subject Number | RBC ($10^6/mm^3$) | Hbg (gm %) | Hemat (cc %) | % Ret | MCV ($\mu^3$) | MCH (YY) | MCHC (%) | WBC (per $mm^3$) | % Poly's | % Lymph | % Mono | van den B (mg %) | Icteric Index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9-26-62 | 11 | 4823 | 14 | 46 | 1 | 94 | 29 | 32 | 5100 | 44 | 50 | 6 | 1.65 | 5 |
| 10-10-62 | | 4610 | 14.4 | 50 | 2.8 | 104 | 30 | 29 | 7350 | 47 | 48 | 5 | 1.5 | 8 |
| 10-5-62 | 12 | 4410 | 15.3 | 45 | 0.6 | 100 | 32 | 33 | 5900 | 51 | 46 | 3 | 0.5 | 6 |
| 9-26-62 | 16 | 5030 | 13.8 | 46 | 1.1 | 92 | 29 | 30 | 5300 | 59 | 36 | 5 | 3.75 | 4.7 |
| 10-10-62 | | 5000 | 14.5 | 48 | 1.1 | 94 | 29 | 30 | 6300 | 60 | 36 | 4 | 2.87 | 9 |
| 9-26-62 | 17 | 5380 | 15.3 | 50 | 2.3 | 100 | 30 | 32 | 7300 | 65 | 31 | 4 | 1.72 | 4.7 |
| 10-10-62 | | 5100 | 14.5 | 49 | 1.0 | 96 | 29 | 30 | 8600 | 63 | 32 | 5 | 1.6 | 11 (H) |
| 9-26-62 | 31 | 4130 | 12.8 | 47 | 0.5 | 114 | 31 | 28 | 8500 | 68 | 29 | 3 | 1.88 | 4.25 |
| 10-10-62 | | 4940 | 14.6 | 49 | 3.0 | 100 | 29 | 30 | 10150 | 61 | 36 | 3 | | |
| 8-7-62 | 32 | 4090 | 15.8 | 50 | 2 | 122 | 38 | 32 | 9100 | | | | | |
| 9-26-62 | | 3340 | 13.5 | 44 | 0.8 | 130 | 38 | 30 | 12500 | 65 | 32 | 3 | 1.77 | 7 |
| 10-10-62 | | 4010 | 14.6 | 45 | 1.2 | 110 | 35 | 32 | 7900 | 52 | 41 | 7 | 1.5 | 8 |
| 9-26-62 | 33 | 4790 | 13.8 | 45 | 0.8 | 94 | 30 | 30 | 9000 | 46 | 47 | 7 | 1.8 | 8.5 |
| 10-10-62 | | 4290 | 14.0 | 45 | 4.8 | 108 | 32 | 32 | 10300 | 36 | 58 | 6 | 1.4 | 9 |
| 8-13-62 | 35 | 4860 | 13.0 | 41 | 3.3 | 84 | 24 | 32 | 9350 | 80 | 14 | 6 | 2.62 | 7.2 |
| 9-26-62 | | 5480 | 12.8 | 45 | 3.5 | 82 | 24 | 30 | 10650 | 78 | 19 | 3 | 1.56 | 4.7 |
| 10-10-62 | | 5010 | 12.55 | 47 | 3.0 | 92 | 24 | 28 | 11700 | 48 | 44 | 8 | 1.4 | Qns |
| 9-26-62 | 36 | 4880 | 14.3 | 48 | 1.8 | 100 | 29 | 30 | 8150 | 72 | 24 | 4 | 2.4 | 8 |
| 10-10-62 | | 4800 | 14.5 | 46 | 2.1 | 94 | 30 | 32 | 8050 | 62 | 32 | 6 | 2.47 | 10 |
| 8-13-62 | 37 | 4670 | 14.8 | 45 | 2.7 | 96 | 32 | 34 | 11450 | 57 | 37 | 6 | 1.61 | 2.76 |
| 9-26-62 | | 4580 | 14 | 45 | 3.0 | 100 | 31 | 32 | 8600 | 62 | 34 | 4 | 1.64 | 4.65 |
| 10-10-62 | | 4200 | 14.5 | 45 | 3.0 | 106 | 33 | 32 | 7850 | 63 | 31 | 6 | 1.1 | 7 |
| 8-21-62 | 42 | 4650 | 15.7 | 40.5 | 5.6 | 90 | 32 | 36 | | | | | | |
| 9-26-62 | | 5320 | 15.3 | 49 | 2.0 | 91 | 29 | 30 | 6150 | 43 | 56 | 1 | 1.98 | 5 |
| 10-10-62 | | 5360 | 14.8 | 47 | 1.7 | | | | 7200 | 39 | 58 | 3 | 1.8 | 9 |
| 8-23-62 | 43 | 4530 | 14.9 | 46 | 4.1 | 100 | 32 | 32 | 10050 | 64 | 24 | 12 | | |
| 9-26-62 | | 4370 | 15.1 | 48 | 5 | 100 | 34 | 31 | 6500 | 58 | 41 | 1 | 1.87 | 8.5 |
| 10-10-62 | | 4190 | 14.5 | 49 | 1.1 | 113 | 35 | 32 | 6350 | 55 | 40 | 5 | 1.5 | 8 |
| 8-29-62 | 44 | 4900 | 14.3 | 43 | 0.7 | 90 | 32 | 34 | | | | | | |
| 9-26-62 | | 4550 | 14.8 | 49 | 0.9 | 91 | 29 | 30 | 6150 | 43 | 56 | 1 | 1.98 | 5 |
| 10-10-62 | | 4640 | 14.0 | 50 | 2 | | | | 7200 | 39 | 58 | 3 | 1.8 | 9 |
| 8-23-62 | 45 | 4980 | 15.8 | 49 | 2.2 | 98 | 31 | 33 | 10300 | 59 | 35 | 6 | | |
| 9-26-62 | | 5520 | 14.8 | 49 | 3 | 88 | 27 | 30 | 12150 | 66 | 26 | 8 | 1.76 | 8.5 |
| 10-10-62 | | 4510 | 14.6 | 49 | 4 | 104 | 32 | 30 | 7350 | 60 | 34 | 6 | 1.98 | |
| 9-26-62 | 46 | 4460 | 14.8 | 47 | 3.1 | 104 | 33 | 32 | 9700 | 64 | 31 | 5 | 1.57 | 4.7 |
| 10-10-62 | | 4740 | 14.5 | 48 | 3.8 | 100 | 31 | 30 | 7050 | 56 | 35 | 9 | 1.5 | 10 |
| 9-14-62 | 52 | 4600 | 14.1 | 44 | 9.4 | 98 | 30 | 32 | 10300 | 66 | 31 | 3 | 3.75 | 12.1 |
| 10-10-62 | | 4990 | 14.5 | 49 | 3.2 | 92 | 29 | 30 | 7350 | 64 | 32 | 4 | 1.8 | 11 |
| 9-26-62 | 54 | 4020 | 14.8 | 48 | 4.4 | 120 | 36 | 31 | 7050 | 72 | 20 | 8 | 1.77 | 11 |
| 10-10-62 | | 4020 | 14.6 | 49 | 3.0 | 120 | 35 | 32 | 5750 | 67 | 27 | 6 | 1.61 | 5 |
| 9-26-62 | 56 | 5540 | 15.3 | 48 | 6 | 86 | 28 | 30 | 7850 | 58 | 31 | 11 | | |

4. Biochemical Data

TABLE 2.2.1

BLOOD SODIUM (meq), POTASSIUM (meq), AND CHLORIDE CONCENTRATIONS (mg %)

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 4 | 7 | 9 | 11 | 13 | 14 |
| $Na^+$ | 11 | | 145.5 | 144.7 | 140.8 | 141.6 | 140.3 | | 141.2 |
| $K^+$ | | | 4.77 | 4.2 | 4.25 | 4.12 | 4.2 | | 4.28 |
| $Cl^-$ | | 453.8 | 457 | | 465.3 | 452 | | | 443.9 |
| Na | 12 | | 147.8 | 145.0 | 139.5 | 141.7 | 139.8 | | 139.3 |
| K | | | 5.06 | 4.23 | 3.7 | 4.1 | 4.13 | | 4.12 |
| Cl | | 460.0 | 459 | | 379.5 | 380 | 435.6 | | 451.5 |
| Na | 13 | | 148.0 | 141.8 | 143.4 | 144.6 | 139.9 | | 140.5 |
| K | | | 6.9 | 3.7 | 4.03 | 3.9 | 3.96 | | 3.65 |
| Cl | | 472.0 | 473 | | 552.1 | | | | 448.8 |
| Na | 15 | | 151.8 | 144.8 | 139.3 | 141.0 | 140.7 | | 139.5 |
| K | | | 4.83 | 4.41 | 3.6 | 3.88 | 4.0 | | 4.02 |
| Cl | | 482.0 | 481 | | 552.1 | | | | 551.5 |
| Na | 16 | | 144.7 | | 137.0 | 136.3 | 139.1 | | 138.5 |
| K | | | 4.03 | | 3.52 | 4.1 | 3.68 | | 4.47 |
| Cl | | 487.2 | 473 | | 460.4 | | | | 471.9 |
| Na | 17 | | 147.2 | 143.3 | 139.1 | 138.5 | 137.8 | | 148.7 |
| K | | | 4.73 | 3.75 | 3.65 | 5.3 | 4.82 | | 4.08 |
| Cl | | 465.3 | 449.2 | | 460.4 | | | | 455.0 |
| Na | 31 | 141.8 | 143.3 | 146.3 | 140.7 | 137.3 | 138.6 | | 141.0 |
| K | | 4.36 | 4.43 | 4.33 | 4.23 | 3.63 | 3.77 | | 3.86 |
| Cl | | 457 | 462 | 446 | 457 | 457 | 450 | | 447 |
| Na | 32 | 142.8 | 145.6 | 143.5 | 141.0 | QNS | QNS | | 139 |
| K | | 4.33 | 5.1 | 4.0 | 4.35 | QNS | QNS | | 3.9 |
| Cl | | 450 | 446 | 483 | 462 | QNS | QNS | | 429 |
| Na | 33 | 141.8 | 142.6 | 142.3 | 139.7 | QNS | 139 | | 142.8 |
| K | | 4.9 | 4.53 | 4.1 | 4.36 | QNS | 4.43 | | 4.63 |
| Cl | | 478 | QNS | 462 | 456 | QNS | 457 | | 470 |
| NA | 35 | 139.6 | 137.3 | 139.6 | 141.5 | 138 | 137.0 | | 140.6 |
| K | | 453 | 4.7 | 4.72 | 4.43 | 3.65 | 5.03 | | 48 |
| Cl | | 486 | 457 | 457 | 470 | 457 | 462 | | 435 |
| Na | 36 | 141.6 | 141.8 | 142.7 | 142.3 | 139.8 | 139 | | 146.6 |
| K | | 4.03 | 5.23 | 4.32 | 4.95 | 3.55 | 4.68 | | 4.1 |
| Cl | | 457 | 454 | 466 | 462 | 440 | 462 | | 450 |
| Na | 37 | 145.3 | 143.5 | 144.7 | 143.3 | 139 | 138.7 | | 142.6 |
| K | | 4.07 | 3.7 | 3.9 | 4.32 | 3.83 | 4.52 | | 4.66 |
| Cl | | 470 | 478 | 462 | 470 | 462 | 474 | | 457 |

TABLE 2.2.1 (Cont)

BLOOD SODIUM (meq), POTASSIUM (meq), AND CHLORIDE CONCENTRATIONS (mg %)

| Test | Subject Number | Pre-Run | Days In Chamber | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 4 | 7 | 9 | 11 | 13 | 14 |
| Na | 42 | 145 | | | | 142 | | 144.6 | |
| K | | 4.23 | | | | 3.6 | | 4.03 | |
| Cl | | 460 | | | | | 420 | 433 | |
| Na | 43 | 144.2 | 140.3 | | | 139.5 | 145.8 | 137.5 | |
| K | | 4.46 | 4.47 | | | 4.45 | 5.0 | 4.53 | |
| Cl | | 450 | | | | 450 | 450 | 450 | |
| Na | 44 | 144 | 143 | | | 142.5 | 145.3 | QNS | |
| K | | 4.6 | 4.83 | | | 4.6 | 4.78 | QNS | |
| Cl | | 457 | | | | 462 | 450 | 457 | |
| Na | 45 | 140.6 | 142.2 | | | 144.8 | 145.2 | QNS | |
| K | | 4.76 | 5.06 | | | 4.7 | 4.27 | QNS | |
| Cl | | 452 | | | | 450 | 452 | 446 | |
| Na | 46 | 142 | | | | QNS | 142.3 | 139.8 | |
| K | | 4.1 | | | | QNS | 4.0 | 4.53 | |
| Cl | | 457 | 466 | | | 457 | 446 | 462 | |
| Na | 47 | 143.6 | 144 | | | 142.7 | 147.6 | 145 | |
| K | | 4.56 | 4.58 | | | 4.52 | 4.53 | 3.92 | |
| Cl | | 460 | 441 | | | 460 | 441 | 474 | |
| Na | 51 | 146.8 | 146.5 | 146.6 | QNS | 142.3 | 145 | | |
| K | | 4.03 | 4.6 | 4.35 | QNS | 4.25 | 4.02 | | |
| Cl | | 450 | 464 | 433.5 | 450 | 440 | 454 | | 459 |
| Na | 52 | 142.5 | 142.7 | 146.2 | QNS | 146.7 | 144.8 | | 144.8 |
| K | | 4.6 | 4.63 | 4.5 | | 4.26 | 4.73 | | 4.66 |
| Cl | | 446 | 457 | 429 | 446 | 433 | 448 | | 454 |
| Na | 53 | 148.2 | 141.2 | | QNS | 142.7 | 147.3 | | 144.6 |
| K | | 5.46 | 4.8 | | | 4.5 | 4.42 | | 4.53 |
| Cl | | 454 | 452 | 431 | 429 | 446 | 468 | | 430 |
| Na | 54 | 146.6 | 143.2 | 148.5 | QNS | QNS | 146.5 | | 146.0 |
| K | | 4.5 | 4.6 | 4.5 | | | 4.66 | | 4.40 |
| Cl | | 462 | 462 | 456 | 448 | 439 | 463 | | 460 |
| Na | 56 | 146.5 | 144.6 | 146.7 | QNS | 144.2 | 146.5 | | 148.0 |
| K | | 4.12 | 4.93 | 4.3 | | 4.13 | 4.5 | | 4.14 |
| Cl | | 446 | 446 | 446 | 435 | 460 | 463 | | 448 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

TABLE 2.2.2

BLOOD GLUCOSE (mg %)

| Subject Number | Pre-Run | Days in Chamber | | | |
|---|---|---|---|---|---|
| | | 2 | 7 | 13 | 14 |
| 11 | 109 | 107 | 97 | | 93.7 |
| 12 | 105 | 103 | 95 | | 90.1 |
| 13 | 109 | 100 | 98 | | 93.7 |
| 15 | 103 | 100 | 100 | | 93.7 |
| 16 | 111 | 97 | 97 | | 88.2 |
| 17 | 111 | 100 | 93 | | 93.7 |
| 31 | 100 | | 94 | | 96 |
| 32 | 98 | | 100 | | 97 |
| 33 | 105 | | 105 | | 100 |
| 35 | 100 | | 103 | | 97 |
| 36 | 100 | | 101 | | 97 |
| 37 | 103 | | 100 | | 96 |
| 42 | 95 | | 100 | 103 | |
| 43 | 100 | | QNS | 90 | |
| 44 | 105 | | 92 | 95 | |
| 45 | 98 | | 97 | 100 | |
| 46 | 113 | | 95 | 101 | |
| 47 | 100 | | 98 | 103 | |
| 51 | 100 | | 103 | 100 | |
| 52 | 98 | | 101 | 97 | |
| 53 | 92 | | 94.5 | 94 | |
| 54 | 95 | | 100 | 97 | |
| 56 | 101 | | 95 | 102 | |

TABLE 2.2.3

BLOOD UREA NITROGEN (mg %)

| Subject Number | Pre-Run | Days in Chamber | | | | |
|---|---|---|---|---|---|---|
| | | 2 | 7 | 9 | 11 | 14 |
| 11 | 13.9 | 11 | 13.8 | 13.1 | 14.1 | 12.7 |
| 12 | 11.7 | 11.9 | 14.7 | 11.8 | 15.1 | 14.9 |
| 13 | 13.7 | 11.1 | 15.9 | 13.9 | 14.3 | 15.3 |
| 15 | 10.1 | 11 | 15.4 | 13.2 | 14.7 | 13.5 |
| 16 | 10.1 | 14.6 | 17.5 | 14 | 15.1 | 15.8 |
| 17 | 12.3 | 14.6 | 16.6 | 14.4 | 15.9 | 14.9 |
| 31 | 15.9 | 17 | 15.9 | | | 15.6 |
| 32 | 17.9 | 14.4 | 15.4 | | | 15.2 |
| 33 | 16.9 | 14.5 | 14.3 | | | 14.5 |
| 35 | 15.2 | 14.4 | 14.5 | | | 12.7 |
| 36 | 14.9 | 13.9 | 15.9 | | | 14.3 |
| 37 | 20.0 | 14.6 | 14.5 | | | 16.1 |
| 42 | 16.1 | | 15.6 | 14.7 | | 13.5 |
| 43 | 16.7 | | QNS | QNS | | 15.4 |
| 44 | 18.2 | | 18.5 | 17.2 | | 15.6 |
| 45 | 14.9 | | 15.4 | 14.1 | | 13.7 |
| 46 | 18.9 | | 18.9 | 16.1 | | 15.9 |
| 47 | 16.4 | | 18.5 | 15.7 | | 15.6 |
| 51 | 16.4 | | 15.2 | | | 14.1 |
| 52 | 14.9 | | 16.4 | | | 14.7 |
| 53 | 14.9 | | 13.9 | | | 13.5 |
| 54 | 15.9 | | 14.7 | | | 14.7 |
| 56 | 16.1 | | 17.9 | | | 15.9 |

TABLE 2.2.4

URINARY 17-HYDROXYCORTICOSTEROIDS

(mg/24 hr.)

| Test | Subject Number | Day 1 | Day 8 | Post-Run |
|---|---|---|---|---|
| Sea Level | 11 | 17.0 | 17.1 | -- |
| | 12 | 15.8 | 14.1 | 17.7 |
| | 13 | 3.9 | 17.7 | 16.7 |
| | 15 | 29.8 | 21.9 | 25.2 |
| | 16 | 16.3 | 17.4 | 19.2 |
| | 17 | 9.9 | 11.6 | 18.6 |
| 5 psi | 31 | 12.9 | 10.4 | 19.1 |
| | 32 | 12.3 | 11.8 | 11.0 |
| | 33 | 14.9 | 10.0 | 13.6 |
| | 35 | 10.5 | 8.2 | 14.9 |
| | 36 | 12.1 | 12.8 | 16.6 |
| | 37 | 9.4 | 7.9 | 13.0 |
| 7.4 psi | 42 | 5.3 | 7.5 | 9.2 |
| | 43 | 6.7 | 7.5 | 7.2 |
| | 44 | 9.5 | 8.2 | 9.8 |
| | 45 | 8.1 | 8.0 | 10.4 |
| | 46 | 6.1 | 7.9 | 9.3 |
| | 47 | 7.7 | 7.9 | 6.7 |
| 3.8 psi | 51 | 6.8 | 10.0 | 7.2 |
| | 52 | 12.0 | 11.4 | 6.1 |
| | 53 | 13.0 | 13.0 | 10.6 |
| | 54 | 7.3 | 9.5 | 6.0 |
| | 55 | 6.2 | | |
| | 56 | 9.5 | 11.0 | 8.5 |

5. Renal Data

TABLE 2.3.1

RENAL DATA

| Urines Test | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Gravity | 11 | 1.022 | | 1.015 | | 1.015 | | | 1.024 | | 1.010 | | 1.016 | | | 1.020 | |
| Protein | | neg | | neg | | neg | | | 15 mg | | neg | | neg | | | neg | |
| Micros. | | neg | | neg | | neg | | | neg | | neg | | neg | | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 12 | 1.024 | | 1.020 | | 1.015 | | | 1.005 | | 1.020 | | 1.020 | | | 1.024 | |
| Protein | | neg | | neg | | neg | | | neg | | neg | | neg | | | neg | |
| Micros. | | neg | | neg | | neg | | | neg | | neg | | neg | | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 13 | 1.022 | | 1.012 | | 1.018 | | | 1.016 | | 1.016 | | 1.028 | | | 1.026 | |
| Protein | | trace | | neg | | neg | | | neg | | neg | | neg | | | neg | |
| Micros. | | neg | | neg | | neg | | | neg | | neg | | neg | | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 15 | 1.024 | | 1.028 | | 1.028 | | | 1.022 | | 1.028 | | 1.012 | | | 1.025 | |
| Protein | | neg | | neg | | neg | | | neg | | 15 mg | | neg | | | neg | |
| Micros. | | neg | | neg | | neg | | | neg | | neg | | neg | | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 16 | 1.028 | | 1.022 | | 1.020 | | | 1.026 | | 1.028 | | | | | Qns | |
| Protein | | trace | | neg | | neg | | | 30 mg | | neg | | | | | neg | |
| Micros. | | neg | | neg | | neg | | | neg | | neg | | | | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 17 | 1.022 | | 1.016 | | 1.015 | | | 1.016 | | 1.028 | | | | | 1.026 | |
| Protein | | neg | | neg | | 30 mg | | | neg | | 15 mg | | | | | neg | |
| Micros. | | neg | | neg | | rare hyl | | | neg | | neg | | | | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 31 | Qns | | 1.030 | | 1.025 | | | 1.023 | | 1.023 | | Qns | | | 1.026 | |
| Protein | | 30 mg | | trace | | neg | | | trace | | trace | | 30 mg | | | 15 mg | |
| Micros. | | neg | | few hyl | | neg | | | neg | | few hyl | | neg | | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 32 | Qns | | 1.030 | | 1.024 | | | 1.021 | | 1.021 | | 1.025 | | | 1.031 | |
| Protein | | 30 mg | | trace | | neg | | | trace | | trace | | 15 mg | | | 15 mg | |
| Micros. | | rare hyl | | neg | | neg | | | neg | | neg | | neg | | | few hyl | |
| | | | | | | | | | | | | | | | | rare f.g. | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 33 | Qns | | 1.022 | | | | | 1.020 | | 1.018 | | 1.021 | | | 1.028 | |
| Protein | | neg | | trace | | | | | trace | | trace | | trace | | | 15 mg | |
| Micros. | | neg | | neg | | | | | neg | | neg | | neg | | | few hyl | |

TABLE 2.3.1 (Cont)

RENAL DATA

| Test | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Gravity | 35 | 1.028 | | 1.016 | | 1.024 | | | 1.027 | | 1.017 | | 1.021 | | | 1.013 | |
| Protein | | neg | | trace | | neg | | | trace | | trace | | trace | | | neg | |
| Micros. | | neg | | neg | | neg | | | neg | | neg | | few hyl | | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 36 | Qns | | 1.021 | | 1.027 | | | 1.021 | | 1.018 | | 1.016 | | | 1.025 | |
| Protein | | neg | | trace | | neg | | | trace | | trace | | trace | | | trace | |
| Micros. | | neg | | neg | | neg | | | neg | | neg | | neg | | | many hyl | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 37 | 1.030 | | 1.025 | | 1.021 | | | 1.027 | | 1.020 | | 1.021 | | | 1.030 | |
| Protein | | 30 mg | | trace | | neg | | | trace | | trace | | trace | | | trace | |
| Micros. | | few hyl | | neg | | neg | | | neg | | neg | | few g.c. | | | few hyl | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 42 | | 1.017 | | 1.027 | | 1.025 | | | | | 1.027 | | 1.028 | | 1.027 | |
| Protein | | | neg | | trace | | 15 mg | | | | | neg | | neg | | 15 mg | |
| Micros. | | | neg | | neg | | neg | | | | | few hyl | | neg | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 43 | | Qns | | Qns | | 1.019 | | | | | 1.026 | | 1.023 | | Qns | |
| Protein | | | 15 mg | | 15 mg | | trace | | | | | neg | | neg | | 30 mg | |
| Micros. | | | rare hyl | | few f.g. | | neg | | | | | neg | | neg | | neg | |
| | | | rare f.g. | | many hyl | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 44 | | Qns | | 1.028 | | 1.028 | | | | | Qns | | 1.01 | | 1.013 | |
| Protein | | | 15 mg | | 15 mg | | 30 mg | | | | | neg | | neg | | neg | |
| Micros. | | | neg | | neg | | neg | | | | | neg | | neg | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 45 | | 1.021 | | 1.016 | | 1.020 | | | | | 1.024 | | Qns | | 1.024 | |
| Protein | | | trace | | neg | | neg | | | | | neg | | neg | | neg | |
| Micros. | | | neg | | neg | | neg | | | | | neg | | neg | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 46 | | 1.025 | | 1.022 | | 1.013 | | | | | 1.015 | | 1.013 | | 1.014 | |
| Protein | | | 15 mg | | neg | | trace | | | | | neg | | neg | | neg | |
| Micros. | | | neg | | neg | | rare hyl | | | | | neg | | neg | | neg | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 47 | | 1.026 | | 1.022 | | 1.014 | | | | | 1.01 | | 1.020 | | 1.022 | |
| Protein | | | 30 mg | | trace | | neg | | | | | neg | | neg | | neg | |
| Micros. | | | neg | | neg | | neg | | | | | few hyl | | neg | | neg | |

TABLE 2.3.1 (Cont)

RENAL DATA

| Test | Subject Number | Pre-Run | Days In Chamber 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sp. Gravity | 51 | | 1.020 | | 1.024 | | 1.025 | | | 1.021 | | 1.022 | | 1.025 | | 1.025 | |
| Protein | | | neg | | neg | | 30 mg | | | neg | | neg | | 30 mg | | trace | |
| Micros. | | | neg | | neg | | many | | | neg | | few hyl | | many | | many hyl | |
| | | | | | | | sperm | | | | | rare f.g. | | sperm | | few f.g. | |
| | | | | | | | | | | | | | | rare f.g. | | | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 52 | | 1.015 | | 1.023 | | 1.025 | | | 1.023 | | 1.022 | | 1.022 | | 1.020 | |
| Protein | | | neg | | neg | | neg | | | neg | | neg | | neg | | trace | |
| Micros. | | | neg | | neg | | num hyl | | | neg | | num f.g. | | rare f.g. | | few hyl | |
| | | | | | | | rare f.g. | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 53 | | 1.022 | | 1.016 | | 1.020 | | | 1.019 | | 1.015 | | 1.015 | | 1.028 | |
| Protein | | | neg | | neg | | neg | | | neg | | neg | | neg | | trace | |
| Micros. | | | neg | | neg | | few hyl | | | neg | | rare f.g. | | few hyl | | many hyl | |
| | | | | | | | | | | | | | | | | mod. f.g. | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 54 | | 1.023 | | 1.019 | | 1.025 | | | 1.022 | | 1.025 | | 1.021 | | 1.030 | |
| Protein | | | neg | | neg | | neg | | | neg | | neg | | neg | | 30 mg | |
| Micros. | | | neg | | neg | | neg | | | neg | | neg | | many hyl | | num. f.g. | |
| | | | | | | | | | | | | | | few f.g. | | num. hyl | |
| | | | | | | | | | | | | | | | | | |
| Sp. Gravity | 56 | | 1.023 | | 1.027 | | 1.022 | | | 1.028 | | 1.022 | | 1.020 | | 1.025 | |
| Protein | | | neg | | neg | | neg | | | neg | | neg | | neg | | trace | |
| Micros. | | | neg | | neg | | neg | | | neg | | many hyl | | few hyl | | sperm | |
| | | | | | | | | | | | | rare f.g. | | | | | |

# 6. Microbiological Data

TABLE 2.4.1

SKIN AND THROAT CULTURES

(Data in parentheses = $\beta$-hemolitic)

| Test | Subject Number | Pre-Run | | 2 | | 4 | | 7 | | 9 | | 11 | | 14 | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | |
| Skin Culture | 11 | neg | rods | (staph | staph | neg | staph | | strep | (staph | staph | | staph | neg | staph | |
| (Sea Level) | | | coccus | 2 col) | | | | | rods | 1 col) | strep | | | | | |
| | | | | | | | | | | | rods | | | | | |
| | | | | | | | | | | | | | | | | |
| | 12 | neg | cocci | neg | staph | neg | staph | | staph | | staph | (staph | staph | (staph | staph | |
| | | | | | | | strep | | | | strep | 1 col) | | 5 col) | strep | |
| | | | | | | | | | | | | | | | | |
| | 13 | | staph | | staph | | staph | | staph | neg | staph | | staph | (staph | staph | |
| | | | | | | | rods | | | | | | strep | 3 col) | | |
| | | | | | | | | | | | | | | | | |
| | 15 | | staph | | staph | | staph | | staph | (staph | staph | (staph | staph | (staph | staph | |
| | | | rods | | | | | | | 1 col) | | 1 col) | rods | 7 col) | strep | |
| | | | | | | | | | | | | | | num. | | |
| | | | | | | | | | | | | | | col. | | |
| | 16 | neg | rods | (staph | staph | (staph | staph | | staph | neg | staph | (staph | staph | (staph | staph | |
| | | | staph | 2 col) | | 5 col) | rods | | | | | 1 col) | | 5 col) | strep | |
| | | | | | | | | | | | | | | 30 col | | |
| | | | | | | | | | | | | | | | | |
| | 17 | | rods | (staph | staph | (staph | staph | | staph | num. | staph | (staph | staph | (staph | staph | |
| | | | | 2 col) | | 1 col) | strep | | | col. | | 2 col) | | 6 col) | | |
| | | | | | | | | | | | | | | 16 col | | |
| | | | | | | | | | | | | | | | | |
| Skin Culture | 31 | neg | staph | | staph | | staph | | staph | | staph | | rods | | staph | |
| (5 psi) | | | | | | | strep | | strep | | | | strep | | | |
| | | | | | | | | | | | | | | | | |
| | 32 | neg | staph | | staph | | staph | | staph | | staph | | staph | | staph | |
| | | | | | rod | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | 33 | | staph | | staph | neg | | | staph | | staph | | staph | neg | staph | |
| | | | | | | | | | | | | | | | strep | |
| | | | | | | | | | | | | | | | | |
| | 35 | neg | rods | | staph | | staph | | rods | neg | staph | | staph | | staph | |
| | | | staph | | | | | | staph | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | 36 | | strep | (rod | staph | (staph) | staph | | staph | (rods | staph | | staph | | staph | |
| | | | rods | 1 col) | | | | | | 1 col) | rods | | | | rods | |
| | | | staph | | | | | | | | strep | | | | | |

TABLE 2.4.1 (Cont)

SKIN AND THROAT CULTURES

(Data in parentheses = $\beta$-hemolitic)

| Test | Subject Number | Pre-Run | | 2 | | 4 | | 7 | | 9 | | 11 | | 14 | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | |
| | 37 | | staph | | staph | neg | rods | | staph | | staph | | staph | | staph | |
| Skin Culture (7.4 psi) | 42 | | staph | neg | staph | neg | strep<br>staph | no sample | | | strep<br>staph | | staph | | rods<br>staph | |
| | 43 | | staph | | staph<br>rods | neg | strep<br>staph | no sample | | | staph | neg | staph | neg | staph | |
| | 44 | | staph | | rods | neg | staph | no sample | | neg | strep<br>staph | neg | rods<br>staph | neg | staph | |
| | 45 | | staph | | strep<br>staph | | staph | no sample | | neg | neg | | staph | neg | staph | |
| | 46 | | staph | neg | staph | | strep<br>rods | no sample | | neg | staph | neg | neg | | staph | |
| | 47 | | staph | | staph | neg | staph | no sample | | | staph<br>strep | neg | staph | | staph | |
| Skin Culture (3.8 psi) | 51 | neg | neg | neg | neg | neg | neg | neg | staph<br>rods | | staph | | strep<br>staph | neg | staph | |
| | 52 | | staph<br>strep<br>rods | neg | strep | neg | rods | neg | staph | neg | staph | neg | neg | neg | neg | |
| | 53 | | staph | neg | staph | | staph<br>strep | | neg | | neg | neg | strep | | staph | |
| | 54 | | staph<br>rods | neg | neg | neg | staph | neg | staph | | staph | | staph | neg | staph | |
| | 56 | | rods | neg | strep<br>rods | | staph<br>rods | neg | staph | | staph | neg | strep | neg | strep<br>staph | |

TABLE 2.4.1 (Cont)

SKIN AND THROAT CULTURES

(Data in parentheses = $\beta$-hemolitic)

| Test | Subject Number | Pre-Run | | 2 | | 4 | | 7 | | 9 | | 11 | | 14 | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | |
| Throat Culture | 11 | (coccus | staph | | rods | | rods | | rods | (staph | staph | | strep | (staph | staph | |
| (Sea Level) | | 1 col) | rods | | staph | | staph | | staph | 3 col) | strep | | staph | 3 col) | strep | |
| | | | strep | | | | | | | | rods | | rods | | rods | |
| | 12 | | staph | (staph | staph | | staph | | strep | (staph | staph | (staph | strep | | strep | |
| | | | strep | 2 col) | strep | | strep | | rods | 3 col) | strep | several) | staph | | | |
| | 13 | | strep | | staph | | strep | | strep | (staph | staph | (staph | staph | | staph | |
| | | | | | strep | | staph | | staph | num) | | 1 col) | strep | | strep | |
| | | | | | rods | | | | | | | | | | rods | |
| | 15 | | staph | | strep | (staph | staph | | rods | | staph | (staph | staph | | strep | |
| | | | rods | | rods | few col) | rods | | staph | | strep | several) | rods | | staph | |
| | | | strep | | | | strep | | strep | | | | | | rods | |
| | 16 | | staph | | strep | | strep | (staph | staph | (staph | staph | (staph | staph | | strep | |
| | | | rods | | staph | | staph | 2 col) | strep | 1 col) | strep | several) | strep | | staph | |
| | | | strep | | | | | | | | | | | | | |
| | 17 | | staph | neg | rods | | staph | neg | strep | essent | staph | essent. | staph | neg | strep | |
| | | | strep | | strep | | strep | | staph | neg | strep | neg | strep | | | |
| | | | | | | | | | | | rods | | | | | |
| Throat Culture | 31 | (staph | staph | | strep | (rods-1) | strep | | staph | | strep | (rods | staph | | staph | |
| (5 psi) | | 2 col) | strep | | | (staph-1) | staph | | strep | | staph | 10 col) | strep | | strep | |
| | | | | | | | | | | | | | rods | | | |
| | 32 | | rods | (rods-1) | staph | (staph) | strep | (rods-1) | staph | | strep | | staph | | strep | |
| | | | staph | | strep | | staph | | strep | | staph | | strep | | staph | |
| | | | strep | | | | | | | | | | | | | |
| | 33 | | staph | | staph | (rods-3) | strep | | staph | | staph | | strep | | staph | |
| | | | strep | | | (staph-2) | staph | | strep | | strep | | staph | | strep | |
| | | | | | | | | | rods | | | | rods | | | |

TABLE 2.4.1 (Cont)

SKIN AND THROAT CULTURES

(Data in parentheses = $\beta$-hemolitic)

| Test | Subject Number | Pre-Run | | 2 | | 4 | | 7 | | 9 | | 11 | | 14 | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | |
| | 35 | | staph | | staph | (strep-1) | strep | | staph | | staph | (strep) | staph | | staph | |
| | | | strep | | strep | | rods | | strep | | strep | | strep | | strep | |
| | | | | | rods | | | | | | | | | | | |
| | 36 | | strep | (rods | strep | (rods- | strep | (rods- | strep | | strep | (rods) | staph | | strep | |
| | | | staph | many) | staph | many) | | many) | | | staph | (strep) | strep | | staph | |
| | | | | | | (strep- | | (strep- | | | | | | | | |
| | | | | | | many) | | many) | | | | | | | | |
| | 37 | | strep | | strep | (staph-3) | staph | | strep | | strep | | staph | | strep | |
| | | | staph | | | (rods-3) | strep | | staph | | staph | | strep | | staph | |
| Throat Culture | 42 | | strep | | strep | | strep | | strep | | strep | (staph-1) | strep | | staph | |
| (7.4 psi) | | | staph | | staph | | staph | | staph | | staph | | staph | | strep | |
| | | | rods | | | | | | | | | | | | | |
| | 43 | (strep-1) | staph | | staph | (staph-1) | strep | (staph-3) | strep | (rods-4) | strep | | strep | | strep | |
| | | (staph-1) | strep | | rods | | rods | | rods | (staph) | staph | | | | | |
| | | | | | | | | | | | rods | | | | | |
| | 44 | | strep | | strep | | strep | | staph | | strep | | strep | neg | neg | |
| | | | staph | | rods | | staph | | strep | | staph | | | | | |
| | | | rods | | | | rods | | rods | | rods | | | | | |
| | 45 | | staph | | strep | (rods-1) | staph | | strep | | rods | (rods-1) | strep | | staph | |
| | | | strep | | staph | | strep | | rods | | strep | (strep-1) | staph | | rods | |
| | | | | | rods | | | | | | staph | | | | | |
| | 46 | | strep | | strep | | strep | | strep | | strep | | strep | | staph | |
| | | | staph | | staph | | staph | | rods | | rods | | staph | | strep | |
| | | | | | | | | | staph | | staph | | | | | |
| | 47 | | staph | | strep | (rods-4) | staph | | strep | | staph | | strep | | strep | |
| | | | strep | | staph | | rods | | staph | | strep | | staph | | | |
| | | | | | | | | | rods | | rods | | | | | |

TABLE 2.4.1 (Cont)

SKIN AND THROAT CULTURES

(Data in parentheses = $\beta$-hemolitic)

| Test | Subject Number | Pre-Run | | 2 | | 4 | | 7 | | 9 | | 11 | | 14 | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | Plate | Broth | |
| Throat Culture | 51 | | strep | | strep | (rods- | rods | neg | strep | | staph | | strep | | strep | strep |
| (3.8 psi) | | | rods | | rods | some) | staph | | | | strep | | staph | | rods | |
| | | | | | | | strep | | | | rods | | rods | | | |
| | | | | | | | | | | | | | | | | |
| | 52 | | staph | | strep | | staph | | strep | | staph | slight | strep | slight | strep | strep |
| | | | strep | | rods | | strep | | rods | | strep | growth | | growth | | staph |
| | | | rods | | staph | | rods | | | | rods | | | | | |
| | | | | | | | | | | | | | | | | |
| | 53 | | staph | | strep | | staph | neg | staph | slight | strep | slight | strep | slight | strep | strep |
| | | | strep | | staph | | strep | | strep | growth | staph | growth | | growth | staph | staph |
| | | | rods | | | | rods | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | 54 | | strep | | strep | (rods-1) | staph | | strep | slight | strep | slight | strep | slight | strep | strep |
| | | | rods | | rods | | strep | | rods | growth | rods | growth | | growth | staph | |
| | | | | | | | | | staph | | | | | | | |
| | 56 | | staph | | strep | | rods | slight | staph | slight | strep | slight | strep | slight | staph | strep |
| | | | strep | | | | strep | growth | strep | growth | staph | growth | | growth | strep | staph |
| | | | rods | | | | staph | | | | | | | | | |

# 7. Chamber Environmental Monitoring Data

TABLE 2.5.1

CHAMBER ENVIRONMENTAL MONITORING

| Average | Time | Pre-Run | Sea Level 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp. °F 6 hr. | 0001-0600 | | 75 | 78 | 74 | 75 | 74 | 78 | 75 | 74 | 75 | 73 | 72 | 74 | 73 | 74 | 75 |
| | 0600-1200 | | 76 | 75 | 78 | 75 | 77 | 76 | 75 | 74 | 75 | 76 | 74 | 76 | 75 | 73 | |
| | 1200-1800 | | 76 | 74 | 76 | 76 | 76 | 78 | 76 | 75 | 76 | 77 | 76 | 77 | 76 | 72 | |
| | 1800-2400 | | 77 | 76 | 75 | 77 | 78 | 77 | 76 | 75 | 76 | 74 | 77 | 75 | 77 | 75 | |
| R/H % 6 hr. | 0001-0600 | | 65 | 78 | 46 | 50 | 42 | 45 | 48 | 52 | 55 | 56 | 52 | 46 | 56 | 48 | 50 |
| | 0600-1200 | | 60 | 60 | 58 | 60 | 56 | 40 | 52 | 55 | 54 | 56 | 54 | 48 | 56 | 52 | |
| | 1200-1800 | | 58 | 55 | 60 | 56 | 55 | 45 | 48 | 58 | 53 | 58 | 52 | 52 | 50 | 60 | |
| | 1800-2400 | | 60 | 63 | 62 | 70 | 53 | 53 | 55 | 55 | 54 | 54 | 48 | 56 | 52 | 56 | |
| $N_2$ % 6 hr. | 0001-0600 | | 76.8 | 78 | 77.2 | 78 | 79 | 78 | 78.5 | 78.8 | 78 | 79 | 78.8 | 78.5 | 79 | 78.8 | 78.3 |
| | 0600-1200 | | 78 | 79 | 78 | 78 | 78 | 79 | 78.6 | 79 | 78 | 79 | 78.5 | 78.5 | 78.5 | 78.5 | |
| | 1200-1800 | | 78 | 79 | 78 | 78 | 78 | 79 | 78.8 | 79 | 78.5 | 79 | 79 | 79 | 79 | 79 | |
| | 1800-2400 | | 78 | 78 | 78 | 79 | 79 | 79 | 78.8 | 79 | 79 | 79 | 79 | 79 | 79 | 79 | |
| $CO_2$ % 6 hr. | 0001-0600 | | 0.28 | 0.15 | 0.20 | 0.15 | 0.15 | 0.10 | 0.12 | 0.12 | 0.15 | 0.20 | 0.16 | 0.11 | 0.11 | 0.12 | 0.17 |
| | 0600-1200 | | 0.30 | 0.10 | 0.15 | 0.16 | 0.10 | 0.15 | 0.14 | 0.12 | 0.18 | 0.18 | 0.11 | 0.11 | 0.11 | 0.15 | |
| | 1200-1800 | | 0.30 | 0.15 | 0.20 | 0.16 | 0.15 | 0.10 | 0.15 | 0.09 | 0.18 | 0.15 | 0.14 | 0.12 | 0.18 | 0.15 | |
| | 1800-2400 | | 0.22 | 0.30 | 0.20 | 0.20 | 0.20 | 0.15 | 0.15 | 0.09 | 0.15 | 0.15 | 0.12 | 0.11 | 0.11 | 0.15 | |
| | | | | | | | | 5 psi | | | | | | | | | |
| Temp. °F 6 hr. | 0001-0600 | | | 75 | 74 | 73 | 70 | 70 | 74 | 75 | 74 | 74 | 75 | 73 | 74 | 72 | 72 |
| | 0600-1200 | | | 75 | 75 | 75 | 72 | 72 | 72 | 74 | 74 | 73 | 76 | 73 | 77 | 72 | |
| | 1200-1800 | | 74 | 73 | 75 | 73 | 73 | 73 | 73 | 74 | 75 | 73 | 76 | 73 | 77 | 74 | |
| | 1800-2400 | | 73 | 73 | 74 | 72 | 73 | 73 | 74 | 75 | 76 | 75 | 74 | 75 | 76 | 76 | |
| R/H % 6 hr. | 0001-0600 | | | 50 | 32 | 36 | 49 | 55 | 30 | 30 | 38 | 36 | 74 | 60 | 55 | 44 | 60 |
| | 0600-1200 | | | 52 | 36 | 45 | 50 | 49 | 29 | 37 | 54 | 43 | 70 | 53 | 62 | 50 | |
| | 1200-1800 | | 50 | 50 | 56 | 42 | 51 | 54 | 37 | 38 | 57 | 48 | 60 | 58 | 62 | 57 | |
| | 1800-2400 | | 59 | 59 | 57 | 50 | 45 | 57 | 40 | 50 | 66 | 63 | 63 | 59 | 71 | 67 | |
| $N_2$ % 6 hr. | 0001-0600 | | | 0.15 | 0.10 | 0.15 | 0.10 | 0.10 | 0.15 | 0.10 | 0.10 | 0.15 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| | 0600-1200 | | | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.20 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| | 1200-1800 | | 0.50 | 0.15 | 0.10 | 0.10 | 0.30 | 0.10 | 0.10 | 0.15 | 0.30 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | |
| | 1800-2400 | | 0.20 | 0.10 | 0.10 | 0.10 | 0.20 | 0.10 | 0.05 | 0.15 | 0.20 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | |
| $CO_2$ % 6 hr. | 0001-0600 | | | 0.15 | 0.15 | 0.10 | 0.30 | 0.10 | 0.20 | 0.30 | 0.50 | 0.55 | 0.70 | 0.50 | 0.45 | 0.36 | 0.50 |
| | 0600-1200 | | | 0.60 | 0.15 | 0.20 | 0.15 | 0.45 | 0.60 | 0.55 | 0.30 | 0.60 | 0.85 | 0.55 | 0.55 | 0.60 | 0.50 |
| | 1200-1800 | | 0.12 | 0.30 | 0.50 | 0.50 | 0.10 | 0.35 | 0.56 | 0.80 | 0.25 | 0.50 | 0.65 | 0.52 | 0.55 | 0.55 | |
| | 1800-2400 | | 0.30 | 0.10 | 0.16 | 0.45 | 0.10 | 0.30 | 0.75 | 0.50 | 0.30 | 0.50 | 0.55 | 0.72 | 0.60 | 0.70 | |

TABLE 2.5.1 (Cont)

CHAMBER ENVIRONMENTAL MONITORING

| Average | Time | Pre-Run | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 7.4 psi | | | | | | | | | | | | | | |
| Temp. °F 6 hr. | 0001-0600 | | | 71 | 72 | 74 | 70 | 70 | 72 | 70 | 71 | 74 | 73 | 73 | 70 | 73 | 70 |
| | 0600-1200 | | | 74 | 73 | 74 | 72 | 73 | 75 | 71 | 71 | 71 | 73 | 74 | 70 | 74 | |
| | 1200-1800 | | 72 | 77 | 75 | 75 | 72 | 72 | 75 | 75 | 72 | 73 | 72 | 75 | 74 | 74 | |
| | 1800-2400 | | 76 | 75 | 76 | 76 | 73 | 72 | 74 | 73 | 73 | 74 | 74 | 74 | 73 | 74 | |
| R/H % 6 hr. | 0001-0600 | | | 58 | 60 | 58 | 60 | 50 | 63 | 58 | 58 | 58 | 60 | 60 | 61 | 60 | 58 |
| | 0600-1200 | | | 60 | 66 | 60 | 62 | 56 | 67 | 69 | 60 | 60 | 60 | 60 | 69 | 64 | |
| | 1200-1800 | | 50 | 62 | 63 | 64 | 72 | 55 | 65 | 60 | 65 | 68 | 63 | 61 | 66 | 58 | |
| | 1800-2400 | | 54 | 75 | 67 | 66 | 66 | 60 | 61 | 55 | 60 | 60 | 65 | 73 | 63 | 64 | |
| $N_2$ % 6 hr. | 0001-0600 | | | 0.25 | 0.15 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| | 0600-1200 | | | 0.35 | 0.20 | 0.10 | 0.15 | 0.15 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | |
| | 1200-1800 | | 0.40 | 0.15 | 0.20 | 0.15 | 0.15 | 0.13 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | |
| | 1800-2400 | | 0.25 | 0.20 | 0.15 | 0.10 | 0.20 | 0.15 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | |
| $CO_2$ % 6 hr. | 0001-0600 | | | 0.60 | 0.50 | 0.35 | 0.45 | 0.50 | 0.40 | 0.45 | 0.35 | 0.35 | 0.50 | 0.35 | 0.50 | 0.40 | 0.40 |
| | 0600-1200 | | | 0.35 | 0.30 | 0.56 | 0.65 | 0.55 | 0.50 | 0.50 | 0.45 | 0.50 | 0.60 | 0.35 | 0.44 | 0.55 | |
| | 1200-1800 | | 0.30 | 0.40 | 0.60 | 0.50 | 0.40 | 0.50 | 0.35 | 0.30 | 0.45 | 0.55 | 0.55 | 0.30 | 0.35 | 0.45 | |
| | 1800-2400 | | 0.30 | 0.25 | 0.35 | 0.45 | 0.65 | 0.35 | 0.35 | 0.45 | 0.35 | 0.55 | 0.60 | 0.25 | 0.45 | 0.52 | |
| | | | | | | | | | | | | | | | | | |
| | | | 3.8 psi | | | | | | | | | | | | | | |
| Temp. °F 6 hr. | 0001-0600 | | | 71 | 71 | 71 | 72 | 72 | 74 | 72 | 74 | 74 | 71 | 75 | 73 | 73 | 74 |
| | 0600-1200 | | | 70 | 70 | 70 | 71 | 71 | 71 | 72 | 69 | 71 | 71 | 71 | 70 | 69 | |
| | 1200-1800 | | 73 | 69 | 70 | 73 | 73 | 70 | 70 | 72 | 70 | 70 | 70 | 71 | 70 | 71 | |
| | 1800-2400 | | 72 | 71 | 70 | 72 | 73 | 70 | 70 | 71 | 71 | 71 | 70 | 71 | 71 | 73 | |
| R/H % 6 hr. | 0001-0600 | | | 37 | 28 | 30 | 32 | 30 | 34 | 35 | 32 | 30 | 30 | 35 | 36 | 36 | 38 |
| | 0600-1200 | | | 32 | 42 | 32 | 33 | 33 | 36 | 41 | 32 | 30 | 36 | 40 | 38 | 43 | |
| | 1200-1800 | | 34 | 33 | 36 | 32 | 33 | 34 | 38 | 31 | 30 | 30 | 43 | 36 | 47 | 32 | |
| | 1800-2400 | | 36 | 31 | 36 | 38 | 42 | 31 | 37 | 32 | 34 | 29 | 30 | 36 | 25 | 34 | |
| $N_2$ % 6 hr. | 0001-0600 | | | 0.45 | 0.15 | 0.30 | 0.35 | 0.20 | 0.20 | 0.30 | 0.20 | 0.25 | 0.30 | 0.25 | 0.25 | 0.40 | 0.42 |
| | 0600-1200 | | 70/1300 | 0.30 | 0.25 | 0.30 | 0.35 | 0.30 | 0.30 | 0.25 | 0.25 | 0.25 | 0.20 | 0.30 | 0.30 | 0.25 | |
| | 1200-1800 | | 0.55 | 0.30 | 0.30 | 0.30 | 0.30 | 0.20 | 0.15 | 0.25 | 0.30 | 0.30 | 0.20 | 0.20 | 0.30 | 0.20 | |
| | 1800-2400 | | 0.50 | 0.25 | 0.32 | 0.30 | 0.30 | 0.20 | 0.10 | 0.20 | 0.32 | 0.30 | 0.20 | 0.20 | 0.30 | 0.25 | |
| $CO_2$ % 6 hr. | 0001-0600 | | | 0.40 | 0.35 | 0.35 | 0.30 | 0.15 | 0.21 | 0.25 | 0.30 | 0.20 | 0.25 | 0.30 | 0.18 | 0.40 | 0.40 |
| | 0600-1200 | | | 0.38 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.45 | 0.30 | 0.40 | 0.30 | 0.30 | 0.30 | 0.30 | |
| | 1200-1800 | | 0.50 | 0.50 | 0.40 | 0.30 | 0.35 | 0.35 | 0.35 | 0.30 | 0.32 | 0.40 | 0.30 | 0.35 | 0.25 | 0.25 | |
| | 1800-2400 | | 0.40 | 0.35 | 0.55 | 0.15 | 0.22 | 0.27 | 0.40 | 0.25 | 0.20 | 0.20 | 0.25 | 0.32 | 0.30 | 0.30 | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

# 8. Psychological Performance Data

TABLE 3.1.1

MEANS AND STANDARD DEVIATIONS FOR DISCRETE SECTORS TO COARSE FLICKER POINT (in cycles per second) FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post-Run | Row (Day) Values |
| Sea Level | $\bar{X}$ | 9.00 | 9.00 | 9.33 | 9.50 | 8.83 | 8.17 | 8.50 | 7.83 | 7.67 | 8.65 |
| | $\sigma$ | 1.63 | 1.91 | 2.49 | 2.63 | 2.54 | 1.86 | 2.06 | 1.34 | 1.60 | 2.01 |
| 3.8 psi | $\bar{X}$ | 7.50 | 8.17 | 8.83 | 8.83 | 7.67 | 8.00 | 8.00 | 7.83 | 8.00 | 8.09 |
| | $\sigma$ | 0.96 | 0.90 | 1.21 | 1.34 | 1.11 | 1.15 | 1.15 | 1.34 | 1.15 | 1.15 |
| 5.0 psi | $\bar{X}$ | 6.50 | 7.33 | 7.83 | 6.83 | 7.50 | 7.33 | 7.33 | 7.33 | 7.50 | 7.28 |
| | $\sigma$ | 0.76 | 1.49 | 1.34 | 0.90 | 1.26 | 0.94 | 0.75 | 0.47 | 1.12 | 1.00 |
| 7.4 psi | $\bar{X}$ | 7.67 | 7.67 | 9.17 | 9.17 | 9.17 | 9.67 | 9.67 | 10.50 | 10.50 | 9.24 |
| | $\sigma$ | 2.81 | 2.43 | 2.27 | 2.85 | 2.73 | 2.62 | 2.29 | 2.63 | 3.35 | 2.66 |
| Column | $\bar{X}$ | 7.67 | 8.04 | 8.79 | 8.58 | 8.29 | 8.29 | 8.38 | 8.37 | 8.42 | 8.32 |
| Values | $\sigma$ | 1.54 | 1.68 | 1.83 | 1.93 | 1.91 | 1.64 | 1.56 | 1.44 | 1.80 | 1.70 |

TABLE 3.1.2

MEANS AND STANDARD DEVIATIONS FOR COARSE FLICKERS TO FINE FLICKER POINT (in cycles per second) FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post-Run | Row (Day) Values |
| Sea Level | $\bar{X}$ | 23.17 | 22.67 | 21.83 | 22.67 | 21.67 | 20.67 | 20.50 | 19.0 | 19.0 | 21.24 |
| | $\sigma$ | 3.13 | 3.54 | 5.43 | 4.23 | 4.78 | 5.15 | 3.68 | 4.83 | 5.13 | 4.43 |
| 3.8 psi | $\bar{X}$ | 23.33 | 20.0 | 21.17 | 22.17 | 19.83 | 23.0 | 21.83 | 22.33 | 23.67 | 21.93 |
| | $\sigma$ | 2.29 | 4.62 | 3.89 | 2.60 | 3.34 | 3.56 | 3.67 | 5.96 | 4.64 | 3.84 |
| 5.0 psi | $\bar{X}$ | 23.33 | 24.83 | 22.83 | 20.50 | 22.33 | 21.50 | 20.67 | 21.83 | 22.67 | 22.28 |
| | $\sigma$ | 2.69 | 3.72 | 4.22 | 5.77 | 5.09 | 5.25 | 5.02 | 5.67 | 5.06 | 4.72 |
| 7.4 psi | $\bar{X}$ | 19.83 | 20.17 | 22.33 | 22.83 | 22.50 | 24.0 | 23.17 | 23.50 | 24.33 | 22.52 |
| | $\sigma$ | 3.34 | 3.18 | 3.68 | 4.06 | 4.07 | 4.04 | 4.41 | 4.65 | 4.78 | 4.02 |
| Column | $\bar{X}$ | 22.41 | 21.92 | 22.04 | 22.04 | 21.58 | 22.29 | 21.54 | 21.66 | 22.42 | 21.99 |
| Values | $\sigma$ | 2.86 | 3.76 | 4.30 | 4.16 | 4.32 | 4.50 | 4.19 | 5.28 | 4.90 | 4.25 |

TABLE 3.1.3

MEANS AND STANDARD DEVIATIONS FOR FINE FLICKER TO FUSION POINT (in cycles per second) FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post-Run | Row (Day) Values |
| Sea Level | $\bar{X}$ | 33.33 | 26.17 | 33.83 | 34.83 | 34.83 | 33.50 | 33.17 | 32.50 | 31.83 | 32.66 |
| | $\sigma$ | 1.89 | 5.84 | 6.28 | 7.06 | 8.05 | 7.32 | 7.01 | 6.10 | 8.07 | 6.40 |
| 3.8 psi | $\bar{X}$ | 35.33 | 33.0 | 33.17 | 35.50 | 36.33 | 37.67 | 35.83 | 36.67 | 37.67 | 35.68 |
| | $\sigma$ | 3.35 | 5.35 | 4.41 | 2.69 | 3.90 | 3.20 | 1.21 | 2.75 | 2.29 | 3.24 |
| 5.0 psi | $\bar{X}$ | 35.33 | 38.17 | 37.83 | 36.0 | 37.50 | 36.50 | 37.00 | 38.00 | 38.33 | 37.18 |
| | $\sigma$ | 4.61 | 4.22 | 5.18 | 6.63 | 6.29 | 6.90 | 7.12 | 7.05 | 5.02 | 5.89 |
| 7.4 psi | $\bar{X}$ | 33.0 | 33.83 | 35.33 | 36.50 | 35.67 | 36.17 | 36.67 | 36.83 | 37.33 | 35.70 |
| | $\sigma$ | 2.08 | 3.53 | 3.30 | 2.50 | 3.30 | 2.54 | 3.35 | 3.53 | 3.86 | 3.11 |
| Column | $\bar{X}$ | 34.25 | 32.79 | 35.04 | 35.71 | 36.08 | 35.96 | 35.67 | 36.00 | 36.29 | 35.30 |
| Values | $\sigma$ | 2.98 | 4.74 | 4.79 | 4.72 | 5.38 | 4.99 | 4.67 | 4.86 | 4.81 | 4.66 |

TABLE 3.1.4

ANALYSIS OF VARIANCE OF DISCRETE TO COARSE FLICKER POINT FOR FOUR RUNS, TEST DATA COLLECTED EVERY OTHER DAY

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 113.04 | 3 | 37.68 | 1.12 |
| Between Subjects in Same Group | 638.00 | 19 | 33.58 | |
| Days | 19.51 | 8 | 2.44 | 3.35* |
| EA x D | 69.38 | 24 | 2.90 | 3.98* |
| Interaction: Pooled Subjects x Days | 110.67 | 152 | 0.728 | |
| Total | 950.59 | 206 | | |

* Significant at $P \geq 0.01$ level

TABLE 3.1.5

ANALYSIS OF VARIANCE OF COARSE TO FINE FLICKER POINT FOR FOUR RUNS, TEST DATA COLLECTED EVERY OTHER DAY

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmospheres | 50.09 | 3 | 16.70 | 0.0992 |
| Between Subjects in Same Group | 3197.22 | 19 | 168.27 | |
| Days | 22.48 | 8 | 2.81 | 0.478 |
| EA x D | 389.74 | 24 | 16.24 | 2.76 * |
| Interaction: Pooled Subjects x Days | 894.44 | 152 | 5.88 | |
| Total | 4553.98 | 206 | | |

* Significant at $P \geq 0.01$ level

TABLE 3.1.6

ANALYSIS OF VARIANCE OF FINE TO FUSION FLICKER POINT FOR FOUR RUNS, TEST DATA COLLECTED EVERY OTHER DAY

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmospheres | 583.16 | 3 | 194.39 | 0.824 |
| Between Subjects in Same Group | 4481.72 | 19 | 235.88 | |
| Days | 246.76 | 8 | 30.84 | 4.63 * |
| EA x D | 374.46 | 24 | 15.60 | 2.34 * |
| Interaction: Pooled Subjects x Days | 1012.11 | 152 | 6.66 | |
| Total | 6698.21 | 206 | | |

* Significant at $P \geq 0.01$ level

TABLE 3.1.7

MEANS AND STANDARD DEVIATIONS FOR THE BRIGHTNESS CONTRAST TEST OF THE ARMY NIGHT SEEING TEST FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | Row (Day) Values |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post Run | |
| Sea Level | $\bar{X}$ | 46.83 | 50.17 | 56.67 | 60.17 | 54.0 | 54.83 | 60.33 | 61.17 | 57.67 | 55.76 |
| | $\sigma$ | 10.14 | 13.38 | 7.87 | 4.45 | 4.90 | 6.57 | 6.75 | 4.84 | 5.40 | 7.14 |
| 3.8 psi | $\bar{X}$ | 51.33 | 55.17 | 52.17 | 53.67 | 51.83 | 51.0 | 50.33 | 52.0 | 51.67 | 52.13 |
| | $\sigma$ | 3.54 | 4.41 | 6.34 | 3.40 | 4.14 | 4.65 | 3.30 | 5.45 | 4.53 | 4.44 |
| 5.0 psi | $\bar{X}$ | 47.0 | 56.83 | 52.0 | 53.33 | 54.17 | 51.83 | 58.83 | 55.67 | 58.17 | 54.20 |
| | $\sigma$ | 16.04 | 6.89 | 7.96 | 10.86 | 7.20 | 4.18 | 3.43 | 5.34 | 4.06 | 7.33 |
| 7.4 psi | $\bar{X}$ | 41.33 | 48.33 | 38.5 | 44.67 | 47.67 | 43.83 | 47.50 | 47.33 | 51.67 | 45.65 |
| | $\sigma$ | 19.64 | 11.91 | 19.54 | 17.24 | 10.87 | 11.11 | 16.88 | 11.18 | 12.59 | 14.55 |
| Column Values | $\bar{X}$ | 46.62 | 52.63 | 49.84 | 52.96 | 51.92 | 50.37 | 54.25 | 54.04 | 54.80 | 51.93 |
| | $\sigma$ | 12.34 | 9.15 | 10.43 | 8.99 | 6.78 | 6.63 | 7.59 | 6.70 | 6.65 | 8.36 |

TABLE 3.1.8

MEANS AND STANDARD DEVIATIONS FOR THE LINE RESOLUTION TEST OF THE ARMY NIGHT SEEING TEST FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post Run | Row (Day) Values |
| Sea Level | $\bar{X}$ | 39.50 | 21.17 | 36.67 | 47.0 | 49.67 | 38.50 | 51.67 | 54.83 | 39.33 | 42.03 |
| | $\sigma$ | 20.83 | 25.60 | 23.06 | 11.25 | 9.10 | 24.49 | 6.57 | 8.57 | 20.69 | 16.68 |
| 3.8 psi | $\bar{X}$ | 28.67 | 44.33 | 39.83 | 49.83 | 34.0 | 38.17 | 33.17 | 45.83 | 37.83 | 39.07 |
| | $\sigma$ | 18.32 | 14.30 | 12.94 | 14.62 | 14.42 | 12.55 | 13.28 | 17.56 | 13.07 | 14.56 |
| 5.0 psi | $\bar{X}$ | 45.33 | 45.33 | 39.67 | 35.33 | 37.83 | 34.83 | 66.0 | 56.0 | 55.33 | 46.18 |
| | $\sigma$ | 22.83 | 23.16 | 21.63 | 27.90 | 29.5 | 25.29 | 8.27 | 18.87 | 11.22 | 20.16 |
| 7.4 psi | $\bar{X}$ | 31.67 | 35.0 | 20.67 | 35.0 | 28.83 | 29.50 | 30.17 | 31.0 | 22.33 | 29.35 |
| | $\sigma$ | 22.44 | 25.13 | 14.19 | 26.03 | 21.93 | 25.44 | 27.71 | 20.07 | 20.02 | 22.55 |
| Column Values | $\bar{X}$ | 36.29 | 36.46 | 34.21 | 41.79 | 37.58 | 35.25 | 45.25 | 46.92 | 38.71 | 36.94 |
| | $\sigma$ | 21.10 | 22.05 | 17.96 | 19.95 | 18.74 | 21.94 | 13.96 | 16.27 | 16.25 | 18.80 |

TABLE 3.1.9

ANALYSIS OF VARIANCE OF BRIGHTNESS CONTROL TEST DATA OF THE ARMY NIGHT SEEING TEST FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmospheres | 3241.90 | 3 | 1080.63 | 1.438 |
| Between Subjects in Same Group | 14282.87 | 19 | 751.73 | 4.257 |
| Days | 1291.87 | 8 | 55.49 | 1.463 |
| EA x D | 1331.72 | 24 | 37.93 | |
| Interaction: Pooled Subjects x Days | 5765.28 | 152 | | |
| Total | 25913.65 | 206 | | |

TABLE 3.1.10

ANALYSIS OF VARIANCE OF LINE RESOLUTION TEST DATA OF THE ARMY NIGHT SEEING TEST FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmospheres | 8307.24 | 3 | 2769.07 | 0.8785 |
| Between Subjects in Same Group | 59886.31 | 19 | 3151.91 | |
| Days | 3982.87 | 8 | 486.61 | 0.3256 |
| EA x D | 10036.05 | 24 | 418.17 | 0.2639 |
| Interaction: Pooled Subjects x Days | 24084.80 | 152 | 1584.52 | |
| Total | 106207.27 | 206 | | |

TABLE 3.1.11

MEANS AND STANDARD DEVIATIONS FOR ESOPHORIA (ORTHO-RATER) SCORES FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post-Run | Row (Day) Value |
| Sea Level | $\bar{X}$ | 9.50 | 6.50 | 8.33 | 8.50 | 8.50 | 8.17 | 8.50 | 8.50 | 8.33 | 8.31 |
| | $\sigma$ | 1.71 | 3.69 | 1.89 | 1.38 | 1.61 | 1.07 | 1.26 | 1.26 | 1.25 | 1.68 |
| 3.8 psi | $\bar{X}$ | 8.00 | 8.83 | 8.33 | 8.17 | 8.33 | 8.00 | 8.00 | 8.17 | 8.67 | 8.28 |
| | $\sigma$ | 0.82 | 1.07 | 0.94 | 0.69 | 0.47 | 0.82 | 0.58 | 0.37 | 0.47 | 0.69 |
| 5.0 psi | $\bar{X}$ | 8.33 | 8.50 | 8.50 | 8.33 | 9.17 | 8.83 | 8.83 | 8.67 | 7.67 | 8.54 |
| | $\sigma$ | 2.13 | 2.63 | 2.70 | 2.45 | 2.03 | 2.19 | 1.77 | 1.80 | 1.70 | 2.15 |
| 7.4 psi | $\bar{X}$ | 7.67 | 7.33 | 7.83 | 7.83 | 8.00 | 7.50 | 7.50 | 8.00 | 7.50 | 7.68 |
| | $\sigma$ | 1.97 | 2.49 | 1.57 | 1.57 | 1.53 | 1.89 | 1.26 | 1.63 | 1.12 | 1.67 |
| Column | $\bar{X}$ | 8.88 | 7.29 | 8.25 | 8.21 | 8.50 | 8.13 | 8.21 | 8.34 | 8.04 | 8.21 |
| Value | $\sigma$ | 1.66 | 2.47 | 1.78 | 1.52 | 1.41 | 1.49 | 1.22 | 1.27 | 1.14 | 1.55 |

TABLE 3.1.12

MEANS AND STANDARD DEVIATIONS FOR EXOPHORIA (ORTHO-RATER) SCORES FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post-Run | Row (Day) Value |
| Sea Level | $\bar{X}$ | 5.17 | 5.50 | 5.33 | 5.17 | 5.33 | 5.17 | 5.17 | 5.17 | 5.00 | 5.22 |
| | $\sigma$ | 0.37 | 0.76 | 0.75 | 0.69 | 0.94 | 0.69 | 0.69 | 0.69 | 0.58 | 0.68 |
| 3.8 psi | $\bar{X}$ | 5.33 | 5.33 | 5.17 | 5.17 | 5.33 | 5.67 | 5.33 | 5.17 | 5.17 | 5.30 |
| | $\sigma$ | 0.47 | 0.47 | 0.37 | 0.37 | 0.47 | 0.47 | 0.47 | 0.37 | 0.37 | 0.43 |
| 5.0 psi | $\bar{X}$ | 5.00 | 5.33 | 5.33 | 4.67 | 5.50 | 5.53 | 5.50 | 5.33 | 5.17 | 5.26 |
| | $\sigma$ | 2.08 | 1.49 | 1.25 | 1.80 | 1.50 | 0.94 | 1.50 | 1.25 | 1.07 | 1.43 |
| 7.4 psi | $\bar{X}$ | 5.83 | 6.00 | 5.83 | 5.83 | 6.00 | 5.67 | 6.33 | 6.17 | 5.83 | 5.94 |
| | $\sigma$ | 1.67 | 1.15 | 1.34 | 1.21 | 1.63 | 1.11 | 1.37 | 1.46 | 1.07 | 1.33 |
| Column | $\bar{X}$ | 5.33 | 5.54 | 5.42 | 5.46 | 5.54 | 5.51 | 5.58 | 5.46 | 5.29 | 5.46 |
| Value | $\sigma$ | 1.15 | 0.97 | 0.93 | 1.02 | 1.14 | 0.80 | 1.01 | 0.94 | 0.77 | 0.97 |

TABLE 3.1.13

MEANS AND STANDARD DEVIATIONS FOR BOTH EYE ACUITY (ORTHO-RATER) SCORES FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | 10.83 | 11.0 | 11.0 | 10.33 | 11.17 | 10.17 | 10.83 | 10.50 | 11.0 | 10.76 |
| | $\sigma$ | 1.77 | 1.0 | 1.41 | 2.05 | 1.21 | 2.11 | 1.34 | 1.61 | 1.0 | 1.50 |
| 3.8 psi | $\bar{X}$ | 10.83 | 10.17 | 10.67 | 10.17 | 10.0 | 10.17 | 10.83 | 10.33 | 10.67 | 10.43 |
| | $\sigma$ | 0.69 | 1.07 | 1.25 | 0.90 | 1.53 | 1.57 | 1.07 | 1.60 | 0.94 | 1.18 |
| 5.0 psi | $\bar{X}$ | 9.83 | 10.17 | 10.33 | 11.0 | 10.33 | 11.33 | 11.50 | 10.83 | 10.17 | 10.61 |
| | $\sigma$ | 1.67 | 1.07 | 1.25 | 0.82 | 1.49 | 1.11 | 0.50 | 0.69 | 1.07 | 1.07 |
| 7.4 psi | $\bar{X}$ | 10.0 | 9.83 | 9.67 | 10.17 | 9.33 | 9.33 | 9.83 | 9.33 | 11.0 | 9.83 |
| | $\sigma$ | 2.08 | 2.54 | 2.43 | 2.19 | 2.21 | 1.97 | 1.77 | 2.13 | 1.53 | 2.09 |
| Column | $\bar{X}$ | 10.37 | 10.29 | 10.42 | 10.42 | 10.21 | 10.25 | 10.75 | 10.25 | 10.71 | 10.41 |
| Value | $\sigma$ | 1.55 | 1.42 | 1.59 | 1.49 | 1.61 | 1.69 | 1.17 | 1.51 | 1.14 | 1.46 |

TABLE 3.1.14

MEANS AND STANDARD DEVIATIONS FOR RIGHT EYE ACUITY (ORTHO-RATER) SCORES FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post-Run | Row (Day) Value |
| Sea Level | $\bar{X}$ | 9.17 | 10.50 | 11.0 | 10.17 | 11.17 | 10.33 | 10.50 | 10.67 | 11.0 | 10.50 |
| | $\sigma$ | 2.03 | 0.96 | 1.0 | 1.67 | 0.90 | 0.94 | 1.38 | 1.37 | 1.41 | 1.30 |
| 3.8 psi | $\bar{X}$ | 10.33 | 9.33 | 9.67 | 10.67 | 9.83 | 10.17 | 10.0 | 10.17 | 10.67 | 10.09 |
| | $\sigma$ | 0.75 | 1.49 | 1.60 | 1.37 | 1.57 | 1.67 | 1.29 | 1.57 | 0.94 | 1.36 |
| 5.0 psi | $\bar{X}$ | 8.17 | 8.83 | 10.50 | 10.17 | 10.17 | 10.0 | 10.67 | 10.50 | 9.67 | 9.85 |
| | $\sigma$ | 2.41 | 0.90 | 0.96 | 1.21 | 1.34 | 0.82 | 0.75 | 0.96 | 0.94 | 1.14 |
| 7.4 psi | $\bar{X}$ | 9.50 | 8.67 | 8.67 | 8.67 | 8.67 | 9.33 | 9.33 | 9.33 | 9.33 | 9.06 |
| | $\sigma$ | 2.75 | 2.21 | 2.56 | 1.97 | 2.69 | 2.43 | 1.70 | 2.56 | 2.43 | 2.37 |
| Column | $\bar{X}$ | 9.29 | 9.33 | 9.96 | 9.92 | 9.71 | 9.95 | 10.12 | 10.17 | 10.17 | 9.85 |
| Value | $\sigma$ | 1.99 | 1.39 | 1.53 | 1.56 | 1.63 | 1.47 | 1.28 | 1.62 | 1.43 | 1.54 |

TABLE 3.1.15

MEANS AND STANDARD DEVIATIONS FOR LEFT EYE ACUITY (ORTHO-RATER) SCORES FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post-Run | Row (Day) Value |
| Sea Level | $\bar{X}$ | 8.83 | 9.67 | 9.33 | 9.17 | 10.0 | 9.83 | 9.50 | 9.0 | 10.17 | 9.50 |
| | $\sigma$ | 2.85 | 1.49 | 1.60 | 2.80 | 1.91 | 1.95 | 1.50 | 2.16 | 1.67 | 1.99 |
| 3.8 psi | $\bar{X}$ | 10.0 | 9.33 | 9.33 | 9.67 | 9.17 | 11.17 | 9.83 | 10.33 | 10.33 | 9.91 |
| | $\sigma$ | 1.73 | 1.11 | 1.25 | 1.11 | 1.46 | 0.37 | 1.77 | 1.37 | 1.25 | 1.27 |
| 5.0 psi | $\bar{X}$ | 9.0 | 10.17 | 9.50 | 10.33 | 10.0 | 11.0 | 10.17 | 10.67 | 10.17 | 10.11 |
| | $\sigma$ | 2.77 | 1.21 | 1.26 | 0.94 | 1.41 | 0.82 | 1.07 | 0.75 | 1.07 | 1.26 |
| 7.4 psi | $\bar{X}$ | 9.50 | 9.67 | 9.50 | 9.0 | 9.0 | 10.33 | 9.33 | 9.67 | 10.0 | 9.57 |
| | $\sigma$ | 2.06 | 2.43 | 1.61 | 2.08 | 2.16 | 1.80 | 2.13 | 2.05 | 1.83 | 2.02 |
| Column | $\bar{X}$ | 9.33 | 9.71 | 9.42 | 9.54 | 9.54 | 10.58 | 9.71 | 9.92 | 10.17 | 9.77 |
| Value | $\sigma$ | 2.35 | 1.56 | 1.43 | 1.73 | 1.74 | 1.24 | 1.62 | 1.58 | 1.46 | 1.63 |

TABLE 3.1.16

MEANS AND STANDARD DEVIATIONS FOR DEPTH PERCEPTION (ORTHO-RATER) SCORES FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Experimental Condition | | Days In Chamber | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Post-Run | Row (Day) Value |
| Sea Level | $\bar{X}$ | 3.83 | 4.33 | 3.50 | 4.00 | 4.83 | 3.67 | 4.67 | 4.17 | 4.17 | 4.13 |
| | $\sigma$ | 1.21 | 2.75 | 2.36 | 2.31 | 1.77 | 2.92 | 2.49 | 2.79 | 2.48 | 2.34 |
| 3.8 psi | $\bar{X}$ | 7.67 | 7.00 | 7.00 | 6.67 | 6.17 | 6.83 | 7.17 | 7.00 | 7.00 | 6.95 |
| | $\sigma$ | 0.94 | 1.00 | 1.00 | 0.94 | 1.46 | 0.69 | 0.69 | 0.58 | 1.41 | 0.97 |
| 5.0 psi | $\bar{X}$ | 3.00 | 3.67 | 3.17 | 2.67 | 4.83 | 2.50 | 3.17 | 4.00 | 4.00 | 3.44 |
| | $\sigma$ | 1.63 | 0.75 | 1.34 | 1.11 | 1.95 | 1.38 | 1.57 | 1.53 | 1.63 | 1.43 |
| 7.4 psi | $\bar{X}$ | 4.50 | 5.83 | 5.33 | 5.50 | 5.83 | 5.50 | 5.33 | 5.17 | 5.33 | 5.37 |
| | $\sigma$ | 2.50 | 3.08 | 2.81 | 3.20 | 2.73 | 2.87 | 3.20 | 3.39 | 3.45 | 3.03 |
| Column | $\bar{X}$ | 4.75 | 5.21 | 4.75 | 4.71 | 5.42 | 4.63 | 5.09 | 5.09 | 4.13 | 4.86 |
| Value | $\sigma$ | 1.57 | 1.90 | 1.88 | 1.89 | 1.98 | 1.97 | 1.99 | 2.07 | 2.24 | 1.94 |

TABLE 3.1.17

ANALYSIS OF VARIANCE OF ESOPHORIA (ORTHO-RATER) SCORES FOR FOUR RUNS, TEST DATA COLLECTED EVERY OTHER DAY

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 21.48 | 3 | 7.16 | 0.273 |
| Between Subjects in Same Group | 498.67 | 19 | 26.25 | |
| Days | 8.12 | 8 | 1.02 | 0.944 |
| EA x D | 36.77 | 24 | 1.53 | 1.42 |
| Interaction: Pooled Subjects x Days | 164.00 | 152 | 1.08 | |
| Total | 729.04 | 206 | | |

TABLE 3.1.18

ANALYSIS OF VARIANCE OF EXOPHORIA (ORTHO-RATER) SCORES FOR FOUR RUNS, TEST DATA COLLECTED EVERY OTHER DAY

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 19.52 | 3 | 6.51 | 0.5923 |
| Between Subjects in Same Group | 208.85 | 19 | 10.99 | |
| Days | 3.06 | 8 | 0.383 | 1.36 |
| EA x D | 4.56 | 24 | 0.190 | 0.674 |
| Interaction: Pooled Subjects x Days | 42.81 | 152 | 0.282 | |
| Total | 278.81 | | | |

TABLE 3.1.19

ANALYSIS OF VARIANCE OF BOTH EYES
VISUAL ACUITY (ORTHO-RATER) SCORES FOR FOUR RUNS,
TEST DATA COLLECTED EVERY OTHER DAY

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 26.74 | 3 | 8.91 | 0.4077 |
| Between Subjects in Same Group | 415.19 | 19 | 21.85 | |
| Days | 7.48 | 8 | 0.94 | 1.37 |
| EA x D | 32.93 | 24 | 1.37 | 1.97** |
| Interaction: Pooled Subjects x Days | 105.82 | 152 | 0.696 | |
| Total | 588.15 | 206 | | |

**Significant at $P \geq 0.01$ Level

TABLE 3.1.20

ANALYSIS OF VARIANCE OF RIGHT EYE VISUAL ACUITY (ORTHO-RATER) SCORES FOR FOUR RUNS, TEST DATA COLLECTED EVERY OTHER DAY

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 116.42 | 3 | 38.81 | 1.09 |
| Between Subjects in Same Group | 682.36 | 19 | 35.91 | |
| Days | 143.09 | 8 | 17.89 | 2.00* |
| EA x D | 351.87 | 24 | 14.66 | 1.64* |
| Interaction: Pooled Subjects x Days | 1356.81 | 152 | 8.926 | |
| Total | 2650.55 | 206 | | |

*Significant at $P \geq 0.05$ Level

TABLE 3.1.21

ANALYSIS OF VARIANCE OF LEFT EYE
VISUAL ACUITY (ORTHO-RATER) SCORES FOR FOUR RUNS,
TEST DATA COLLECTED EVERY OTHER DAY

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 13.72 | 3 | 4.57 | 0.1897 |
| Between Subjects in Same Group | 457.59 | 19 | 24.08 | |
| Days | 30.42 | 8 | 3.80 | 3.02** |
| EA x D | 24.61 | 24 | 1.03 | 0.817 |
| Interaction: Pooled Subjects x Days | 190.07 | 152 | 1.26 | |
| Total | 716.43 | 206 | | |

**Significant at $P \geq 0.01$ Level

TABLE 3.1.22

ANALYSIS OF VARIANCE OF DEPTH PERCEPTION (ORTHO-RATER) SCORES FOR FOUR RUNS, TEST DATA COLLECTED EVERY OTHER DAY

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 382.98 | 3 | 127.66 | 3.09 |
| Between Subjects in Same Group | 784.84 | 19 | 41.31 | |
| Days | 14.17 | 8 | 1.77 | 1.37 |
| EA x D | 37.02 | 24 | 1.54 | 1.19 |
| Interaction: Pooled Subjects x Days | 196.83 | 152 | 1.29 | |
| Total | 1415.83 | 206 | | |

TABLE 3.2.1

DAILY MEANS AND STANDARD DEVIATIONS OF THE DIFFERENTIAL REACTION TIMES (IN SECONDS) FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days in Chamber | | | | | | | | | | | | | | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | .48 | .47 | .46 | .47 | .48 | .43 | .43 | .42 | .40 | .42 | .40 | .40 | .42 | .42 | .38 | .43 |
| | $\sigma$ | .126 | .076 | .107 | .101 | .080 | .180 | .088 | .088 | .070 | .072 | .077 | .075 | .081 | .074 | .072 | .093 |
| 3.8 psi | $\bar{X}$ | .37 | .37 | .39 | .38 | .38 | .38 | .37 | .38 | .39 | .40 | .41 | .39 | .40 | .37 | .37 | .39 |
| | $\sigma$ | .065 | .059 | .103 | .073 | .072 | .057 | .067 | .074 | .075 | .076 | .116 | .074 | .082 | .071 | .074 | .079 |
| 5.0 psi | $\bar{X}$ | .43 | .48 | .42 | .42 | .39 | .40 | .41 | .38 | .39 | .41 | .39 | .38 | .39 | .38 | .37 | .40 |
| | $\sigma$ | .072 | .156 | .070 | .077 | .056 | .048 | .052 | 054 | .072 | .065 | .071 | .061 | .074 | .077 | .064 | .079 |
| 7.4 psi | $\bar{X}$ | .43 | .38 | .37 | .39 | .39 | .38 | .37 | .37 | .37 | .40 | .36 | .38 | .39 | .36 | .35 | .38 |
| | $\sigma$ | .025 | .069 | .074 | .070 | .064 | .079 | .051 | .085 | .053 | .117 | .056 | .066 | .089 | .073 | .062 | .076 |
| Column Values | $\bar{X}$ | .43 | .43 | .41 | .42 | .41 | .40 | .40 | .39 | .39 | .41 | .39 | .39 | .40 | .38 | .36 | .45 |
| | $\sigma$ | .130 | .120 | .090 | .094 | .100 | .079 | .070 | .079 | .092 | .085 | .084 | .069 | .080 | .075 | .101 | .93 |

TABLE 3.2.2

ANALYSIS OF VARIANCE OF THE DIFFERENTIAL REACTION TIME DATA FOR THE FOUR EXPERIMENTAL GROUPS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 1482.77 | 3 | 494.26 | 2.348 |
| Between Subjects in Same Group | 3999.58 | 19 | 210.50 | |
| Days | 750.62 | 14 | 53.62 | 5.77** |
| EA x D | 1064.22 | 42 | 25.34 | 2.72** |
| Interaction: Pooled Subjects x Days | 2474.08 | 266 | 9.30 | |
| Total | 9771.27 | 344 | | |

**Significant at the P $\geq$ 0.01 Level

TABLE 3.2.3

DAILY MEANS AND STANDARD DEVIATIONS OF THE TAPPING SCORES FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Conditions | | Pre-Run | Days in Chamber | | | | | | | | | | | | | | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | 117 | 127 | 134 | 140 | 147 | 154 | 157 | 149 | 164 | 146 | 136 | 140 | 140 | 151 | 157 | 143.8 |
| | $\sigma$ | 15.5 | 19.3 | 32.0 | 22.6 | 14.7 | 15.7 | 12.4 | 23.0 | 16.5 | 23.1 | 11.2 | 19.3 | 11.6 | 16.5 | 12.1 | 22.0 |
| 3.8 psi | $\bar{X}$ | 144 | 144 | 149 | 153 | 141 | 145 | 145 | 146 | 149 | 145 | 148 | 146 | 157 | 158 | 153 | 148.2 |
| | $\sigma$ | 16.1 | 9.3 | 10.7 | 10.7 | 14.7 | 11.2 | 10.9 | 7.0 | 10.3 | 12.3 | 16.0 | 17.6 | 9.6 | 9.5 | 9.6 | 12.98 |
| 5.0 psi | $\bar{X}$ | 121 | 130 | 134 | 140 | 132 | 134 | 131 | 135 | 134 | 135 | 137 | 137 | 141 | 137 | 137 | 133.5 |
| | $\sigma$ | 7.7 | 19.2 | 8.1 | 9.6 | [illegible] | 14.2 | 11.6 | 10.6 | [illegible] | 10.2 | 15.3 | 11.0 | 13.0 | 11.4 | 16.7 | 13.50 |
| 7.4 psi | $\bar{X}$ | 124 | 131 | 131 | 136 | 129 | 137 | 136 | 139 | 138 | 139 | 135 | 134 | 136 | 134 | 137 | 134.5 |
| | $\sigma$ | 6.5 | 11.0 | 12.5 | 14.3 | 13.2 | 13.9 | 15.4 | 12.0 | [illegible] | 9.6 | 10.9 | 11.4 | 6.7 | 10.4 | 12.9 | 12.21 |
| Column Values | $\bar{X}$ | 126.5 | 130.5 | 137.0 | 142.2 | 137.2 | 142.5 | 142.2 | 142.2 | 146.2 | 141.2 | 139 | 139.2 | 143.5 | 145.0 | 146.0 | 13.80 |
| | $\sigma$ | 15.62 | 17.89 | 19.89 | 16.52 | 14.72 | 16.11 | 16.72 | 15.81 | 16.74 | 15.52 | 14.36 | 15.72 | 13.06 | 15.50 | 15.96 | 14.95 |

TABLE 3.2.4

ANALYSIS OF VARIANCE FOR THE DAILY MEANS OF THE TAPPING SCORES FOR THE FOUR EXPERIMENTAL GROUPS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmospheres | 13555.03 | 3 | 4518.34 | 2.290 |
| Between Subjects in Same Group | 37481.96 | 19 | 1972.73 | |
| Days | 10579.45 | 14 | 755.68 | 6.902** |
| EA x D | 8990.68 | 42 | 214.06 | 1.955** |
| Interaction: Pooled Subjects x Days | 29121.13 | 266 | 109.48 | |
| Total | 99728.24 | 344 | | |

**Significant at the $P \geq 0.01$ Level

TABLE 3.2.5

DAILY MEANS AND STANDARD DEVIATIONS OF BALLISTIC AIMING SCORES FOR THE FOUR EXPERIMENTAL GROUPS

| | | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | | 10.8 | 15.2 | 17.5 | 17.8 | 17.8 | 21.2 | 18.7 | 19.2 | 20.0 | 19.5 | 22.0 | 21.0 | 21.5 | 21.3 | 18.8 |
| | $\sigma$ | | 6.3 | 6.5 | 5.8 | 3.5 | 3.1 | 3.8 | 5.8 | 4.9 | 4.5 | 6.8 | 4.3 | 3.9 | 6.9 | 4.9 | 6.0 |
| 3.8 psi | $\bar{X}$ | 13.4 | 15.4 | 17.8 | 16.2 | 17.2 | 16.0 | 19.2 | 21.0 | 20.8 | 20.6 | 25.0 | 21.6 | 21.6 | 23.2 | 22.4. | 19.4 |
| | $\sigma$ | 1.0 | 3.0 | 5.1 | 4.7 | 3.9 | 4.8 | 6.0 | 1.4 | 4.6 | 2.0 | 3.6 | 4.8 | 4.7 | 5.6 | 3.1 | 5.2 |
| 5.0 psi | $\bar{X}$ | 13.0 | 17.0 | 18.3 | 19.8 | 22.3 | 21.0 | 24.7 | 23.5 | 25.2 | 20.0 | 24.0 | 24.3 | 23.8 | 23.0 | 23.4 | 21.5 |
| | $\sigma$ | 2.6 | 4.6 | 6.1 | 4.4 | 2.7 | 4.0 | 3.2 | 3.1 | 1.8 | 1.3 | 2.3 | 5.1 | 0.9 | 3.3 | 1.9 | 4.6 |
| 7.4 psi | $\bar{X}$ | 11.8 | 13.5 | 16.3 | 16.5 | 19.3 | 14.7 | 18.2 | 19.5 | 18.3 | 19.0 | 20.7 | 20.0 | 18.0 | 20.2 | 19.5 | 17.7 |
| | $\sigma$ | 2.1 | 4.6 | 3.5 | 4.5 | 5.0 | 4.61 | 4.6 | 3.9 | 3.5 | 3.6 | 3.3 | 2.7 | 4.2 | 6.0 | 6.2 | 4.9 |
| Column Values | $\bar{X}$ | 12.7 | 14.2 | 16.9 | 17.5 | 17.4 | 17.4 | 20.8 | 20.7 | 20.8 | 19.9 | 22.3 | 22.0 | 21.1 | 22.0 | 21.6 | 19.15 |
| | $\sigma$ | 1.8 | 5.4 | 5.6 | 4.9 | 4.3 | 4.8 | 4.6 | 4.5 | 4.5 | 3.2 | 4.9 | 7.6 | 4.3 | 5.7 | 6.3 | 4.83 |

TABLE 3.2.6

ANALYSIS OF VARIANCE FOR THE DAILY MEANS OF THE BALLISTIC AIMING SCORES FOR THE FOUR EXPERIMENTAL GROUPS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmospheres | 811.27 | 3 | 270.42 | 1.963 |
| Between Subjects in Same Run | 2617.99 | 19 | 137.78 | |
| Days | 3094.97 | 14 | 221.07 | 15.678** |
| EA x D | 460.52 | 42 | 10.96 | .733 |
| Interaction: Pooled Subjects x Days | 3750.17 | 266 | 14.10 | |
| Total | 10735.92 | 344 | | |

**Significant at the P > 0.01 Level

TABLE 3.3.1

ANALYSIS OF VARIANCE TABLES FOR
ARITHMETIC: RIGHT PSYCHOMOTOR PERFORMANCE
TESTING SYSTEM FOR 7.4 psi AND 3.8 psi
EXPERIMENTAL GROUPS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 2.35 | 1 | 2.35 | 0.060 |
| Between Subjects in Same Group | 350.03 | 9 | 38.89 | |
| Days | 9963.46 | 5 | 1992.69 | 161.61** |
| EA x D | 36.24 | 5 | 7.25 | 0.588 |
| Interaction: Pooled Subjects x Days | 554.81 | 45 | 12.33 | |
| Total | 10906.87 | 65 | | |

**Significant at P ≥ 0.01 Level

TABLE 3.3.2

ANALYSIS OF VARIANCE TABLES FOR ARITHMETIC: WRONG PSYCHOMOTOR PERFORMANCE TESTING SYSTEM FOR 7.4 psi AND 3.8 psi EXPERIMENTAL GROUPS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 8.68 | 1 | 8.68 | 0.249 |
| Between Subjects in Same Group | 313.47 | 9 | 34.83 | |
| Days | 532.57 | 5 | 106.51 | 13.36** |
| EA x D | 7.90 | 5 | 1.58 | 0.198 |
| Interaction: Pooled Subjects x Days | 358.70 | 45 | 7.97 | |
| Total | 1221.32 | 65 | | |

**Significant at P ≥ 0.01 Level

TABLE 3.3.3

ANALYSIS OF VARIANCE TABLES FOR ARITHMETIC: NO RESPONSE PSYCHOMOTOR PERFORMANCE TESTING SYSTEM FOR 7.4 psi AND 3.8 psi EXPERIMENTAL GROUPS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 17.01 | 1 | 17.01 | 0.494 |
| Between Subjects in Same Group | 310.14 | 9 | 34.46 | |
| Days | 8176.74 | 5 | 1635.35 | 221.59** |
| EA x D | 11.74 | 5 | 2.35 | 0.3198 |
| Interaction: Pooled Subjects x Days | 332.03 | 45 | 7.38 | |
| Total | 8847.65 | 65 | | |

**Significant at P 0.01 Level

TABLE 3.3.4

ANALYSIS OF VARIANCE TABLES FOR PATTERN DISCRIMINATION: RIGHT PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 14.22 | 1 | 14.22 | 0.406 |
| Between Subjects in Same Group | 314.95 | 9 | 34.99 | |
| Days | 4086.83 | 5 | 817.37 | 87.61** |
| EA x D | 39.44 | 5 | 7.89 | 0.846 |
| Interaction: Pooled Subjects x Days | 420.06 | 45 | 9.33 | |
| Total | 4875.50 | 65 | | |

**Significant at P $\geq$ 0.01 Level

TABLE 3.3.5

ANALYSIS OF VARIANCE TABLES FOR PATTERN DISCRIMINATION: WRONG PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 24.50 | 1 | 24.50 | 0.851 |
| Between Subjects in Same Group | 259.11 | 9 | 28.79 | |
| Days | 2465.11 | 5 | 493.02 | 47.87** |
| EA x D | 51.67 | 5 | 10.33 | 1.00 |
| Interaction: Pooled Subjects x Days | 463.56 | 45 | 10.30 | |
| Total | 3263.94 | 65 | | |

**Significant at $P \geq 0.01$ Level

TABLE 3.3.6

ANALYSIS OF VARIANCE TABLES FOR PATTERN DISCRIMINATION: NO RESPONSE PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 0.125 | 1 | 0.125 | 0.021 |
| Between Subjects in Same Group | 53.70 | 9 | 5.97 | |
| Days | 102.24 | 5 | 20.45 | 8.56** |
| EA x D | 17.46 | 5 | 3.49 | 1.46 |
| Interaction: Pooled Subjects x Days | 107.47 | 45 | 2.39 | |
| Total | 280.99 | 65 | | |

**Significant at $P \geq 0.01$ Level

TABLE 3.3.7

ANALYSIS OF VARIANCE TABLES FOR RIGHT SCALE POSITION MONITORING PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 260.68 | 1 | 260.68 | 3.56 |
| Between Subjects in Same Group | 658.80 | 9 | 73.20 | |
| Days | 20362.57 | 5 | 4072.51 | 35.39** |
| EA x D | 860.90 | 5 | 172.18 | 1.50 |
| Interaction: Pooled Subjects x Days | 5179.02 | 45 | 115.09 | |
| Total | 27321.98 | 65 | | |

**Significant at P ≥ 0.01 Level

TABLE 3.3.8

ANALYSIS OF VARIANCE TABLES FOR WRONG SCALE POSITION MONITORING PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 64.22 | 1 | 64.22 | 0.347 |
| Between Subjects in Same Group | 1665.44 | 9 | 185.05 | |
| Days | 12972.33 | 5 | 2594.47 | 27.08** |
| EA x D | 2072.78 | 5 | 414.56 | 4.33** |
| Interaction: Pooled Subjects x Days | 4311.22 | 45 | 95.80 | |
| Total | 21086.00 | 65 | | |

**Significant at P $\geq$ 0.01 Level

TABLE 3.3.9

ANALYSIS OF VARIANCE TABLES FOR EXTRANEOUS RESPONSE SCALE POSITION MONITORING PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Square | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 4.01 | 1 | 4.01 | 0.0999 |
| Between Subjects in Same Group | 361.14 | 9 | 40.13 | |
| Days | 1150.74 | 5 | 230.15 | 6.86** |
| EA x D | 483.07 | 5 | 96.61 | 2.88* |
| Interaction: Pooled Subjects x Days | 1510.36 | 45 | 33.56 | |
| Total | 3509.31 | 65 | | |

* Significant at P $\geq$ 0.05 Level
**Significant at P $\geq$ 0.01 Level

TABLE 3.3.10

ANALYSIS OF VARIANCE TABLES FOR
AUDITORY VIGILANCE: RIGHT
PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmospheres | 14.22 | 1 | 14.22 | 0.651 |
| Between Subjects in Same Group | 196.55 | 9 | 21.84 | |
| Days | 256.28 | 5 | 51.26 | 7.898** |
| EA x D | 31.28 | 5 | 6.26 | 0.965 |
| Interaction: Pooled Subjects x Days | 292.12 | 45 | 6.49 | |
| Total | 790.44 | 65 | | |

**Significant at P $\geq$ 0.01 Level

TABLE 3.3.11

ANALYSIS OF VARIANCE TABLES FOR
AUDITORY VIGILANCE: WRONG
PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 0.125 | 1 | 0.125 | 0.0028 |
| Between Subjects in Same Group | 42.03 | 9 | 4.67 | |
| Days | 39.90 | 5 | 7.98 | 3.45** |
| EA x D | 10.46 | 5 | 2.09 | 0.905 |
| Interaction: Pooled Subjects x Days | 104.14 | 45 | 2.31 | |
| Total | 196.65 | 65 | | |

**Significant at $P \geq 0.01$ Level

TABLE 3.3.12

ANALYSIS OF VARIANCE TABLES FOR
AUDITORY VIGILANCE: NO RESPONSE
PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 49.99 | 1 | 49.99 | 3.42 |
| Between Subjects in Same Group | 131.61 | 9 | 14.62 | |
| Days | 36.11 | 5 | 7.22 | 1.34 |
| EA x D | 90.17 | 5 | 18.03 | 3.35* |
| Interaction: Pooled Subjects x Days | 242.06 | 45 | 5.38 | |
| Total | 549.94 | 65 | | |

*Significant at $P \geq 0.05$ Level

TABLE 3.3.13

ANALYSIS OF VARIANCE TABLES FOR
RED WARNING LIGHTS: TIMERS
PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 3156.42 | 1 | 3156.42 | 1.24 |
| Between Subjects in Same Group | 22958.02 | 9 | 2550.90 | |
| Days | 171547.62 | 5 | 34309.52 | 72.35** |
| EA x D | 2790.99 | 5 | 558.20 | 1.18 |
| Interaction: Pooled Subjects x Days | 21339.25 | 45 | 474.21 | |
| Total | 221792.30 | 65 | | |

**Significant at P $\geq$ 0.01 Level

TABLE 3.3.14

ANALYSIS OF VARIANCE TABLES FOR
RED WARNING LIGHTS: COUNTERS
PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 2289.39 | 1 | 2289.39 | 0.910 |
| Between Subjects in Same Group | 22641.22 | 9 | 2515.69 | |
| Days | 187824.27 | 5 | 37564.85 | 85.93** |
| EA x D | 2293.62 | 5 | 458.72 | 1.05 |
| Interaction: Pooled Subjects x Days | 19672.07 | 45 | 437.16 | |
| Total | 234720.56 | 65 | | |

**Significant at P $\geq$ 0.01 Level

TABLE 3.3.15

ANALYSIS OF VARIANCE TABLES FOR
GREEN WARNING LIGHTS: TIMERS
PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 8676.62 | 1 | 8676.62 | 2.02 |
| Between Subjects in Same Group | 38615.66 | 9 | 4290.63 | |
| Days | 183038.83 | 5 | 36607.77 | 19.48** |
| EA x D | 6831.07 | 5 | 1366.21 | 0.727 |
| Interaction: Pooled Subjects x Days | 84551.69 | 45 | 1878.93 | |
| Total | 321703.88 | 65 | | |

**Significant at P $\geq$ 0.01 Level

TABLE 3.3.16

ANALYSIS OF VARIANCE TABLES FOR
GREEN WARNING LIGHTS: COUNTERS
PSYCHOMOTOR PERFORMANCE TESTING SYSTEM

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 9022.72 | 1 | 9022.72 | 2.33 |
| Between Subjects in Same Group | 34902.05 | 9 | 3878.01 | |
| Days | 183678.92 | 5 | 36735.79 | 20.85** |
| EA x D | 7775.78 | 5 | 1555.16 | 0.883 |
| Interaction: Pooled Subjects x Days | 79281.22 | 45 | 1761.80 | |
| Total | 314657.70 | 65 | | |

**Significant at P $\geq$ 0.01 Level

TABLE 3.3.17

MEANS AND SIGMAS OF STANDARDIZED SCORES* FOR THE

PSYCHOMOTOR PERFORMANCE TESTING SYSTEM ARITHMETIC:
RIGHT FOR THE EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days In Chamber | | | | | | | | | | | | | Post-Run |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | |
| Sea Level | $\bar{X}$ | | | | | | | | | | | | | | | |
| | $\sigma$ | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| Tape No. | | 2(1-5) | 4 | 7 | 8 | 5 | | 3 | | 2 | 4 | 7 | 3 | 8 | 5 | 6(4,5,7,8) |
| 3.8 psi | $\bar{X}$ | 55.347 | 45.618 | 49.374 | 46.000 | 58.603 | | 53.526 | | 48.156 | 63.615 | 55.963 | 57.316 | 59.752 | 62.302 | 50.000 |
| | $\sigma$ | 3.220 | 5.914 | 3.562 | 3.971 | 3.871 | | 6.674 | | 13.080 | 4.558 | 1.366 | 4.715 | 11.614 | 7.439 | 6.360 |
| | | | | | | | | | | | | | | | | |
| Tape No. | | 1(4-7) | 2(1-5) | | | 3 | 4 | 5 | | 6 | 2 | 1(4-7) | | | | |
| 5.0 psi | $\bar{X}$ | 48.658 | 41.768 | | | 48.889 | 48.034 | 49.337 | | 48.043 | 51.571 | 51.296 | | | | |
| | $\sigma$ | 4.938 | 10.239 | | | 6.278 | 8.711 | 8.919 | | 3.293 | 6.540 | 13.117 | | | | |
| | | | | | | | | | | | | | | | | |
| Tape No. | | 2(1-5) | 4 | 7 | 8 | 5 | 6 | 3 | | | | | | | | |
| 7.4 psi | $\bar{X}$ | 53.838 | 44.280 | 51.020 | 45.241 | 47.408 | 51.957 | 52.053 | | | | | | | | |
| | $\sigma$ | 7.323 | 6.100 | 3.144 | 4.893 | 6.093 | 2.784 | 9.375 | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| Tape No. | | 1(4-7) | 2(1-5) | 2(1-8) | 3 | 4 | 5 | 6 | 6(4,5,7,8,) | 7 | 8 | | | | | |
| Column | $\bar{X}$ | 4.25 | 7.398 | 30.27 | 24.16 | 19.55 | 35.73 | 22.25 | 16.17 | 31.68 | 46.746 | | | | | |
| Values | $\sigma$ | 4.322 | 3.314 | 1.464 | 5.70 | 6.206 | 3.471 | 11.498 | 2.472 | 16.182 | 4.362 | | | | | |
| | | | | | | | | | | | | | | | | |

*Scores Standardized to Mean -50 St. Dev. =10

TABLE 3.3.18

MEANS AND SIGMAS OF STANDARDIZED SCORES * FOR THE

PSYCHOMOTOR PERFORMANCE TESTING SERVICE PATTERN: RIGHT FOR THE EXPERIMENTAL GROUPS

| | | | Days In Chamber | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre-Run | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run |
| Sea Level | $\bar{X}$ | | | | | | | | | | | | | | | |
| | $\sigma$ | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| Tape No. | | 2(1-5) | 4 | 7 | 8 | 5 | | 3 | | 2 | 4 | 7 | 3 | 8 | 5 | 6(4,5,7,8,) |
| 3.8 psi | $\bar{X}$ | 52.678 | 45.457 | 52.868 | 50.002 | 52.291 | | 49.187 | | 53.396 | 55.854 | 49.167 | 53.051 | 49.781 | 54.487 | 50.000 |
| | $\sigma$ | 1.169 | 6.494 | 7.402 | 6.318 | 5.926 | | 4.793 | | 8.246 | 2.287 | 10.466 | 3.914 | 6.642 | 9.563 | 4.416 |
| | | | | | | | | | | | | | | | | |
| Tape No. | | 1(4-7) | 2(1-5) | | | 3 | 4 | 5 | | 6 | 2 | 1(4-7) | | | | |
| 5.0 psi | $\bar{X}$ | 55.671 | 51.964 | | | 50.299 | 54.848 | 53.294 | | 52.448 | 47.201 | 44.330 | | | | |
| | $\sigma$ | 3.547 | 10.759 | | | 1.841 | 9.787 | 6.062 | | 5.664 | 10.485 | 11.122 | | | | |
| | | | | | | | | | | | | | | | | |
| Tape No. | | 2(1-5) | 4 | 7 | 8 | 5 | 6 | 3 | | | | | | | | |
| 7.4 psi | $\bar{X}$ | 48.259 | 47.226 | 48.358 | 42.562 | 44.940 | 47.522 | 48.143 | | | | | | | | |
| | $\sigma$ | 6.830 | 10.671 | 10.931 | 6.493 | 4.057 | 12.389 | 4.328 | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| Tape No. | | 1(4-7) | 2(1-5) | 2(1-8) | 3 | 4 | 5 | 6 | 6(4,5,7,8,) | 7 | 8 | | | | | |
| Column | $\bar{X}$ | 8.00 | 12.39 | 28.42 | 14.49 | 13.41 | 25.79 | 14.84 | 10.17 | 30.01 | 28.16 | | | | | |
| Values | $\sigma$ | 4.999 | 2.241 | 2.684 | 6.028 | 3.284 | 4.190 | 3.388 | 5.138 | 4.079 | 4.016 | | | | | |
| | | | | | | | | | | | | | | | | |

*Scores Standardized to mean -50 St. Dev. =10

| Measures | 1 | 6 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Profile Discrimination | | 04 | 174 | -335 | -352 | -185 | 419 | 172 | 084 | 1. |
| 2. Scale Position Monitoring | | 54 | -195 | -141 | -005 | 058 | 141 | -369 | -111 | 2. |
| 3. Incomplete Matrices | | 61 | -283 | -734 | -316 | -450 | 509 | -460 | -285 | 3. |
| 4. Axis Intersection | | 39 | 403 | -426 | -293 | 052 | 287 | 017 | -019 | 4. |
| 5. Arithmetic Computation | | 88 | -371 | -326 | -172 | 105 | -238 | -609 | -337 | 5. |
| 6. Vector Construction | | 55 | -091 | -350 | -250 | 070 | -007 | -312 | -081 | 6. |
| 7. Pattern Discrimination | | 68 | -601 | 144 | -217 | -475 | 311 | -194 | -029 | 7. |
| 8. Elapsed Time | | 54 | 034 | -548 | -359 | -355 | 191 | -379 | -440 | 8. |
| 9. Arithmetic (Right) | | 43 | -155 | 411 | 372 | 192 | 057 | 398 | 466 | 9. |
| 10. Arithmetic (Wrong) | | 29 | 217 | 140 | -025 | 104 | -518 | -198 | -651 | 10. |
| 11. Arithmetic (No Response) | | 51 | -714 | -151 | -244 | -213 | 237 | -315 | 125 | 11. |
| 12. Pattern Discrimination (Right) | | 55 | -493 | 187 | 268 | -050 | 284 | -041 | 000 | 12. |
| 13. Pattern Discrimination (Wrong) | | 31 | 249 | 115 | -391 | 175 | -562 | 187 | 074 | 13. |
| 14. Pattern Discrimination (No Response) | | 07 | -306 | -361 | 328 | -128 | 342 | -348 | 151 | 14. |
| 15. Scale Position Monitoring (Right) | | 21 | -599 | 344 | 180 | 045 | 135 | 208 | 239 | 15. |
| 16. Scale Position Monitoring (Wrong) | | 31 | 141 | 061 | 072 | -144 | -099 | 079 | 193 | 16. |
| 17. Scale Position Monitoring Extraneous Reponses | | 45 | -471 | -304 | -001 | -505 | 144 | 078 | 271 | 17. |
| 18. Auditory Vigilance (Right) | | 63 | -333 | 100 | 416 | 310 | -283 | -501 | -392 | 18. |
| 19. Auditory Vigilance (Wrong) | | 56 | -185 | -379 | 202 | 071 | -197 | -741 | -455 | 19. |
| 20. Auditory Vigilance (No Response) | | 44 | 365 | -195 | -408 | -357 | 311 | 400 | 289 | 20. |
| 21. Red Warning Lights (Timers) | | 10 | 056 | 396 | 384 | -160 | -093 | -087 | -146 | 21. |
| 22. Red Warning Lights (Counters) | | 86 | -002 | 362 | 384 | -160 | -093 | -087 | -146 | 22. |
| 23. Green Warning Lights (Timers) | | 24 | 051 | 063 | -512 | -616 | -074 | -044 | -537 | 23. |
| 24. Green Warning Lights (Counters) | | 07 | 066 | 057 | -504 | -592 | -097 | -077 | -563 | 24. |
| 25. GATB-G | | 54 | 584 | 603 | 370 | 662 | -702 | 263 | -085 | 25. |
| 26. GATB-V | | | 632 | 422 | 315 | 677 | 741 | 060 | -276 | 26. |
| 27. GATB-N | | | | -061 | 205 | 484 | -320 | 169 | -058 | 27. |
| 28. GATB-S | | | | | 218 | 138 | -379 | 322 | 015 | 28. |
| 29. GATB-P | | | | | | 428 | 088 | -135 | 135 | 29. |
| 30. GATB-Q | | | | | | | -563 | -010 | 044 | 30. |
| 31. GATB-K | | | | | | | | 113 | 424 | 31. |
| 32. GATB-f | | | | | | | | | 736 | 32. |
| 33. GATB-m | | | | | | | | | | 33. |

TABLE 3.3.20

MEANS AND STANDARD DEVIATIONS FOR PAPER AND PENCIL ANALOG ARITHMETIC COMPUTATION FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days In Chamber 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sea Level | $\bar{x}$ | 4.50 | 3.50 | 3.33 | 3.17 | 3.33 | 3.83 | 5.17 | | 4.17 | 4.00 | 2.83 | 2.00 | 2.17 | 1.17 | 2.00 | 3.23 |
| | $\sigma$ | 2.43 | 1.71 | 1.60 | 2.27 | 3.15 | 3.58 | 3.76 | | 3.29 | 2.00 | 1.77 | 1.30 | 1.68 | 0.90 | 1.16 | 2.59 |
| | | | | | | | | | | | | | | | | | |
| 3.8 psi | $\bar{x}$ | 5.17 | 4.00 | 3.40 | 2.00 | 3.40 | 3.20 | 0.60 | | 1.00 | 1.20 | 1.20 | 0.80 | 0.80 | 1.20 * | 1.80 | 2.11 |
| | $\sigma$ | 3.53 | 4.15 | 2.06 | 2.28 | 2.25 | 2.48 | 0.49 | | 0.63 | 1.47 | 0.75 | 0.75 | 1.17 | 0.75 * | 2.23 | 2.53 |
| | | | | | | | | | | | | | | | | | |
| 5.0 psi | $\bar{x}$ | 3.17 | 3.33 | 2.17 | 2.50 | 2.00 | 1.33 | 1.50 | | 1.67 | 1.17 | 1.00 | 2.00 | 0.83 | 1.83 | 1.00 * | 1.82 |
| | $\sigma$ | 1.68 | 2.36 | 1.57 | 2.29 | 1.41 | 0.94 | 0.96 | | 1.49 | 1.07 | 0.58 | 1.16 | 0.69 | 1.57 | 0.58 * | 1.61 |
| | | | | | | | | | | | | | | | | | |
| 7.4 psi | $\bar{x}$ | 2.17 | 1.67 | 1.50 | 2.17 | 2.00 | 1.33 | 2.33 | | 2.00 | 1.00 | 1.33 | 2.00 | 0.67 | 1.33 | 2.33 | 1.70 |
| | $\sigma$ | 2.79 | 1.25 | 1.50 | 1.57 | 1.53 | 1.11 | 0.94 | | 1.83 | 1.00 | 0.94 | 1.63 | 0.94 | 0.94 | 2.21 | 1.62 |
| | | | | | | | | | | | | | | | | | |
| Column | $\bar{x}$ | 3.65 | 3.09 | 2.57 | 2.48 | 2.65 | 2.39 | 2.48 | | 2.26 | 1.87 | 1.61 | 1.74 | 1.13 | 1.39 | 1.78 | 2.22 |
| Value | $\sigma$ | 2.96 | 2.67 | 1.86 | 2.16 | 2.30 | 2.55 | 2.67 | | 2.40 | 1.92 | 1.34 | 1.36 | 1.33 | 1.13 | 1.74 | 2.21 |
| | | | | | | | | | | | | | | | | | |

*Synthetic Entry

TABLE 3.3.21

ANALYSIS OF VARIANCE OF
ARITHMETIC COMPUTATION SCORES
IN THE PAPER AND PENCIL ANALOG
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 122.18 | 3 | 40.73 | 1.70 |
| Between Subjects in Same Group | 455.46 | 19 | 23.97 | |
| Days | 154.79 | 13 | 11.91 | 4.21 ** |
| EA x D | 161.53 | 39 | 4.14 | 1.46 * |
| Interaction: Pooled Subjects x Days | 698.04 | 247 | 2.83 | |
| Total | 1591.99 | 321 | | |

* Significant at $P \geq 0.05$ Level
** Significant at $P \geq 0.01$ Level

TABLE 3.3.22

MEANS AND STANDARD DEVIATIONS FOR PAPER AND PENCIL ANALOG PATTERN DISCRIMINATION FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days In Chamber 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sea Level | $\bar{X}$ | 1.67 | 1.83 | 2.50 | 2.50 | 3.17 | 2.50 | 1.17 | | 1.33 | 3.00 | 1.50 | 1.67 | 2.00 | 3.50 | 1.83 | 2.16 |
| | $\sigma$ | 2.06 | 2.41 | 1.71 | 1.71 | 1.34 | 2.50 | 1.46 | | 1.37 | 2.31 | 1.89 | 2.06 | 1.41 | 1.26 | 1.21 | 1.94 |
| | | | | | | | | | | | | | | | | | |
| 3.8 psi | $\bar{X}$ | 1.83 | 2.40 | 1.40 | 1.80 | 1.20 | 1.40 | 1.80 | | 1.40 | 3.00 | 0.80 | 1.60 | 1.80 | 1.80 * | 1.00 | 1.69 |
| | $\sigma$ | 2.34 | 1.86 | 1.50 | 2.23 | 3.69 | 1.02 | 2.64 | | 1.50 | 2.10 | 0.75 | 1.02 | 1.72 | 1.72 * | 0.89 | 1.79 |
| | | | | | | | | | | | | | | | | | |
| 5.0 psi | $\bar{X}$ | 0.33 | 0.83 | 0.50 | 0.67 | 1.50 | 1.17 | 1.33 | | 0.83 | 1.00 | 0.50 | 1.17 | 0.50 | 1.67 | 1.00 * | 0.93 |
| | $\sigma$ | 0.75 | 0.90 | 0.50 | 0.75 | 0.96 | 1.07 | 0.84 | | 0.90 | 1.16 | 0.50 | 1.21 | 0.50 | 1.49 | 1.16 * | 1.03 |
| | | | | | | | | | | | | | | | | | |
| 7.4 psi | $\bar{X}$ | 1.00 | 1.67 | 0.83 | 2.17 | 2.17 | 1.50 | 2.33 | | 0.67 | 2.83 | 2.00 | 1.67 | 1.83 | 3.00 | 0.67 | 1.74 |
| | $\sigma$ | 1.41 | 1.11 | 0.80 | 1.34 | 0.90 | 0.96 | 1.80 | | 0.75 | 3.13 | 5.48 | 0.75 | 2.04 | 0.82 | 1.11 | 1.65 |
| | | | | | | | | | | | | | | | | | |
| Column | $\bar{X}$ | 1.26 | 1.65 | 1.30 | 1.83 | 2.04 | 1.65 | 1.65 | | 1.04 | 2.44 | 1.22 | 1.52 | 1.52 | 2.52 | 1.13 | 1.62 |
| Value | $\sigma$ | 1.87 | 1.76 | 1.44 | 1.67 | 1.33 | 1.42 | 1.83 | | 1.20 | 2.45 | 1.50 | 1.38 | 1.63 | 1.56 | 1.19 | 1.69 |
| | | | | | | | | | | | | | | | | | |

*Synthetic Entry

TABLE 3.3.23

ANALYSIS OF VARIANCE OF PATTERN DISCRIMINATION SCORES IN THE PAPER AND PENCIL ANALOG FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 65.87 | 3 | 21.96 | 1.46 |
| Between Subjects in Same Group | 284.99 | 19 | 14.99 | |
| Days | 62.54 | 13 | 4.81 | 2.63 ** |
| EA x D | 58.59 | 39 | 1.50 | 0.819 |
| Interaction: Pooled Subjects x Days | 452.51 | 247 | 1.83 | |
| Total | 924.50 | 321 | | |

**Significant at $P \geq 0.01$ Level

TABLE 3.3.24

MEANS AND STANDARD DEVIATIONS FOR THE PAPER AND PENCIL ANALOG SCALE POSITION MONITORING FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days in Chamber | | | | | | | | | | | | | | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | 2.17 | 1.00 | 1.50 | 1.67 | 1.33 | 1.83 | 1.17 | | 1.50 | 1.17 | 0.67 | 0.67 | 1.33 | 0.67 | 1.67 | 1.31 |
| | $\sigma$ | 2.85 | 1.41 | 1.80 | 1.80 | 1.11 | 3.29 | 1.86 | | 1.38 | 1.07 | 1.49 | 0.94 | 1.60 | 1.11 | 2.93 | 1.95 |
| | | | | | | | | | | | | | | | | | |
| 3.8 psi | $\bar{X}$ | 1.00 | 2.60 | 0.00 | 0.40 | 0.00 | 0.04 | 0.00 | | 0.40 | 0.20 | 0.00 | 0.60 | 0.40 | 0.00 | 1.60 | 0.54 |
| | $\sigma$ | 1.41 | 2.94 | 0.00 | 0.80 | 0.00 | 0.45 | 0.00 | | 0.80 | 0.40 | 0.00 | 1.20 | 0.80 | 0.00 | 3.20 | 1.52 |
| | | | | | | | | | | | | | | | | | |
| 5.0 psi | $\bar{X}$ | 0.00 | 0.00 | 0.33 | 0.00 | 0.17 | 0.17 | 0.17 | | 0.00 | 0.00 | 0.83 | 0.17 | 0.33 | 0.17 | 0.00 | 0.19 |
| | $\sigma$ | 0.00 | 0.00 | 0.47 | 0.00 | 0.37 | 0.37 | 0.37 | | 0.00 | 0.00 | 1.21 | 0.37 | 0.75 | 0.37 | 0.00 | 0.55 |
| | | | | | | | | | | | | | | | | | |
| 7.4 psi | $\bar{X}$ | 0.50 | 1.17 | 0.83 | 0.83 | 0.83 | 0.50 | 0.50 | | 0.67 | 0.67 | 0.67 | 0.33 | 0.83 | 1.33 | 1.17 | 0.77 |
| | $\sigma$ | 0.76 | 1.21 | 1.21 | 1.07 | 1.21 | 1.12 | 0.76 | | 1.11 | 0.94 | 1.49 | 0.47 | 1.46 | 1.11 | 1.67 | 1.19 |
| | | | | | | | | | | | | | | | | | |
| Column Value | $\bar{X}$ | 0.96 | 1.13 | 0.70 | 0.74 | 0.61 | 0.70 | 0.48 | | 0.65 | 0.52 | 0.61 | 0.44 | 0.74 | 0.56 | 1.17 | 0.71 |
| | $\sigma$ | 1.85 | 1.78 | 1.27 | 1.29 | 1.01 | 1.92 | 1.14 | | 1.13 | 0.88 | 1.26 | 0.82 | 1.29 | 0.97 | 2.37 | 1.45 |

TABLE 3.3.25

ANALYSIS OF VARIANCE OF SCALE POSITION MONITORING SCORES IN THE PAPER AND PENCIL ANALOG FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 51.21 | 3 | 17.07 | 1.10 |
| Between Subjects in Same Group | 296.03 | 19 | 15.58 | |
| Days | 17.64 | 13 | 1.36 | 0.119 |
| EA x D | 57.29 | 39 | 1.47 | 0.129 |
| Interaction: Pooled Subjects x Days | 280.63 | 247 | 1.14 | |
| Total | 702.81 | 321 | | |

TABLE 3.3.26

MEANS AND STANDARD DEVIATIONS FOR PAPER AND PENCIL ANALOG MATRICES FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | 4.83 | 3.00 | 4.33 | 5.83 | 4.50 | 3.83 | 6.33 | | 1.67 | 1.50 | 2.00 | 2.00 | 3.50 | 2.00 | 2.83 | 3.44 |
| | $\sigma$ | 1.34 | 1.92 | 3.68 | 2.48 | 3.95 | 2.97 | 3.82 | | 1.70 | 2.57 | 1.16 | 0.82 | 1.50 | 1.16 | 1.63 | 2.85 |
| | | | | | | | | | | | | | | | | | |
| 3.8 psi | $\bar{X}$ | 3.67 | 2.00 | 5.80 | 7.60 | 7.00 | 7.00 | 4.20 | | 2.20 | 1.60 | 1.40 | 3.80 | 3.60 | 5.60* | 5.60 | 4.39 |
| | $\sigma$ | 3.15 | 1.79 | 3.06 | 2.33 | 3.16 | 2.83 | 2.79 | | 1.17 | 1.74 | 1.02 | 2.14 | 1.86 | 3.01* | 3.01 | 3.20 |
| | | | | | | | | | | | | | | | | | |
| 5.0 psi | $\bar{X}$ | 2.67 | 2.67 | 4.00 | 6.00 | 6.00 | 5.17 | 4.17 | | 1.33 | 1.33 | 2.67 | 3.33 | 3.00 | 3.00 | 3.00* | 3.45 |
| | $\sigma$ | 2.36 | 2.56 | 2.38 | 3.11 | 3.37 | 2.27 | 2.41 | | 2.56 | 1.11 | 1.70 | 1.11 | 2.38 | 2.16 | 2.16* | 2.74 |
| | | | | | | | | | | | | | | | | | |
| 7.4 psi | $\bar{X}$ | 2.83 | 3.67 | 2.33 | 8.83 | 7.83 | 5.00 | 4.33 | | 1.83 | 1.17 | 1.67 | 4.17 | 3.17 | 3.00 | 5.17 | 3.93 |
| | $\sigma$ | 2.54 | 2.98 | 2.29 | 3.89 | 2.67 | 1.53 | 2.98 | | 1.34 | 0.69 | 1.49 | 2.27 | 2.54 | 1.53 | 2.04 | 3.18 |
| | | | | | | | | | | | | | | | | | |
| Column Value | $\bar{X}$ | 3.56 | 2.87 | 4.04 | 7.04 | 6.30 | 5.17 | 4.78 | | 1.74 | 1.39 | 1.96 | 3.30 | 3.30 | 3.30 | 4.09 | 3.78 |
| | $\sigma$ | 2.62 | 2.46 | 3.14 | 4.23 | 3.56 | 2.68 | 3.19 | | 1.82 | 1.69 | 1.46 | 1.87 | 2.14 | 2.40 | 2.55 | 3.01 |
| | | | | | | | | | | | | | | | | | |

*Synthetic Entry

TABLE 3.3.27

ANALYSIS OF VARIANCE OF INCOMPLETE MATRICES SCORES IN THE PAPER AND PENCIL ANALOG FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 53.10 | 3 | 17.70 | 0.496 |
| Between Subjects in Same Group | 677.68 | 19 | 35.67 | |
| Days | 850.47 | 13 | 65.42 | 13.83** |
| EA x D | 246.02 | 39 | 6.31 | 1.33 |
| Interaction: Pooled Subjects x Days | 1167.16 | 247 | 4.73 | |
| Total | 2999.42 | 321 | | |

** Significant at $P \geq 0.01$ Level

TABLE 3.3.28

MEANS AND STANDARD DEVIATIONS FOR PAPER AND PENCIL ANALOG PROFILE DISCRIMINATION FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days in Chamber | | | | | | | | | | | | | | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | 15.83 | 8.00 | 9.00 | 9.17 | 10.00 | 12.67 | 16.17 | | 31.00 | 22.83 | 20.83 | 8.33 | 30.67 | 20.50 | 26.83 | 17.27 |
| | $\sigma$ | 19.42 | 4.16 | 8.39 | 4.45 | 10.25 | 12.22 | 8.99 | | 22.86 | 18.82 | 15.85 | 8.28 | 15.70 | 15.28 | 20.27 | 16.10 |
| | | | | | | | | | | | | | | | | | |
| 3.8 psi | $\bar{X}$ | 18.67 | 8.00 | 12.00 | 18.80 | 9.60 | 12.00 | 13.80 | | 26.60 | 13.20 | 11.60 | 11.80 | 16.20 | 12.00* | 16.80 | 14.42 |
| | $\sigma$ | 5.96 | 4.24 | 9.32 | 20.93 | 5.95 | 6.48 | 6.68 | | 11.74 | 6.77 | 7.23 | 8.28 | 9.89 | 6.48* | 13.38 | 10.78 |
| | | | | | | | | | | | | | | | | | |
| 5.0 psi | $\bar{X}$ | 14.00 | 13.50 | 10.17 | 10.33 | 9.17 | 14.00 | 12.67 | | 15.67 | 17.67 | 9.67 | 10.33 | 12.17 | 10.33 | 15.67* | 12.52 |
| | $\sigma$ | 3.32 | 3.86 | 6.77 | 10.40 | 7.03 | 12.56 | 13.16 | | 13.43 | 9.70 | 11.13 | 12.53 | 12.58 | 10.24 | 13.43* | 10.85 |
| | | | | | | | | | | | | | | | | | |
| 7.4 psi | $\bar{X}$ | 34.33 | 31.83 | 28.83 | 32.50 | 24.83 | 32.17 | 39.50 | | 46.33 | 35.50 | 26.67 | 24.83 | 31.83 | 23.00 | 26.83 | 31.36 |
| | $\sigma$ | 20.65 | 15.08 | 15.90 | 16.76 | 11.88 | 18.90 | 22.07 | | 23.57 | 21.39 | 17.83 | 16.71 | 23.59 | 16.36 | 25.54 | 20.33 |
| | | | | | | | | | | | | | | | | | |
| Column Value | $\bar{X}$ | 20.96 | 15.65 | 15.13 | 17.65 | 13.57 | 17.96 | 20.83 | | 30.04 | 22.70 | 17.43 | 13.91 | 23.00 | 16.65 | 21.74 | 19.09 |
| | $\sigma$ | 15.61 | 13.01 | 13.51 | 17.10 | 11.20 | 15.94 | 18.10 | | 22.00 | 17.74 | 15.51 | 13.79 | 18.67 | 14.04 | 19.79 | 16.96 |
| | | | | | | | | | | | | | | | | | |

*Sythetic Entry

TABLE 3.3.29

ANALYSIS OF VARIANCE OF PROFILE DISCRIMINATION SCORES IN THE PAPER AND PENCIL ANALOG FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 17826.17 | 3 | 5942.06 | 2.43 |
| Between Subjects in Same Group | 46471.25 | 19 | 2445.86 | |
| Days | 6140.51 | 13 | 472.34 | 5.94** |
| E A x D | 5230.79 | 39 | 134.12 | 1.69** |
| Interaction: Pooled Subjects x Days | 19625.84 | 247 | 79.46 | |
| Total | 95294.55 | 321 | | |

** Significant at $P \geq 0.01$ Level

TABLE 3.3.30
MEANS AND STANDARD DEVIATIONS FOR PAPER AND PENCIL
ANALOG VECTOR CONSTRUCTION
FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | 6.85 | 8.82 | 2.94 | 6.68 | 3.32 | 3.57 | 3.71 | | 5.29 | 5.89 | 3.15 | 2.85 | 2.64 | 3.52 | 2.42 | 4.40 |
| | $\sigma$ | 6.72 | 9.08 | 1.69 | 2.68 | 2.17 | 2.33 | 3.34 | | 2.99 | 6.29 | 1.46 | 1.18 | 2.02 | 1.50 | 1.16 | 4.38 |
| | | | | | | | | | | | | | | | | | |
| 3.8 psi | $\bar{X}$ | 4.85 | 3.92 | 1.97 | 1.97 | 2.62 | 2.01 | 1.97 | | 2.85 | 2.32 | 3.86 | 3.06 | 5.58 | 2.73* | 2.73 | 3.08 |
| | $\sigma$ | 6.43 | 2.37 | 0.25 | 0.29 | 0.73 | 0.33 | 0.23 | | 1.10 | 0.24 | 2.86 | 0.28 | 3.51 | 0.41* | 0.41 | 2.60 |
| | | | | | | | | | | | | | | | | | |
| 5.0 psi | $\bar{X}$ | 3.25 | 5.03 | 3.78 | 2.34 | 3.22 | 3.08 | 2.27 | | 2.39 | 2.48 | 2.75 | 3.82 | 2.13 | 3.14 | 2.75* | 3.03 |
| | $\sigma$ | 2.18 | 4.17 | 2.85 | 0.75 | 1.64 | 2.77 | 0.63 | | 0.61 | 0.49 | 0.75 | 2.13 | 0.50 | 1.43 | 0.75* | 2.04 |
| | | | | | | | | | | | | | | | | | |
| 7.4 psi | $\bar{X}$ | 2.36 | 2.91 | 2.99 | 4.30 | 5.45 | 3.20 | 2.95 | | 2.93 | 2.97 | 3.03 | 3.50 | 2.45 | 3.52 | 2.30 | 3.20 |
| | $\sigma$ | 0.87 | 1.02 | 0.98 | 2.21 | 2.37 | 1.49 | 2.06 | | 1.55 | 1.67 | 0.99 | 3.01 | 1.44 | 1.52 | 1.20 | 1.88 |
| | | | | | | | | | | | | | | | | | |
| Column | $\bar{X}$ | 4.45 | 5.22 | 2.96 | 3.90 | 3.69 | 3.00 | 2.76 | | 3.39 | 3.46 | 3.20 | 3.32 | 3.10 | 3.25 | 2.54 | 3.44 |
| Value | $\sigma$ | 5.16 | 5.18 | 1.88 | 2.61 | 2.16 | 2.08 | 2.14 | | 2.16 | 3.64 | 3.53 | 2.02 | 2.47 | 1.36 | 0.97 | 2.97 |
| | | | | | | | | | | | | | | | | | |

*Synthetic Entry

TABLE 3.3.31

ANALYSIS OF VARIANCE OF
VECTOR CONSTRUCTION SCORES
IN THE PAPER AND PENCIL ANALOG
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 108.22 | 3 | 36.07 | 0.989 |
| Between Subjects in Same Group | 692.60 | 19 | 36.45 | |
| Days | 149.38 | 13 | 11.49 | 1.856* |
| EA x D | 365.23 | 39 | 9.36 | 1.512* |
| Interaction: Pooled Subjects x Days | 1529.81 | 247 | 6.19 | |
| Total | 2845.25 | 321 | | |

*Significant at P $\geq$ 0.05 Level

TABLE 3.3.32

MEANS AND STANDARD DEVIATIONS FOR PAPER AND PENCIL ANALOG AXIS INTERSECTION FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | 4.62 | 3.08 | 4.92 | 4.45 | 5.31 | 5.46 | 5.29 | | 3.84 | 4.83 | 4.85 | 7.35 | 5.21 | 5.12 | 5.33 | 4.96 |
| | $\sigma$ | 3.73 | 0.79 | 2.38 | 1.78 | 0.50 | 0.61 | 0.99 | | 1.28 | 2.51 | 1.31 | 3.37 | 2.36 | 1.07 | 1.07 | 2.16 |
| | | | | | | | | | | | | | | | | | |
| 3.8 psi | $\bar{X}$ | 2.40 | 3.96 | 2.90 | 2.75 | 3.79 | 3.76 | 3.72 | | 3.26 | 3.98 | 3.58 | 4.31 | 2.96 | 4.58* | 4.58 | 3.60 |
| | $\sigma$ | 0.57 | 2.03 | 1.26 | 0.29 | 0.75 | 0.84 | 0.71 | | 0.53 | 0.73 | 0.89 | 1.05 | 0.83 | 0.47* | 0.47 | 1.31 |
| | | | | | | | | | | | | | | | | | |
| 5.0 psi | $\bar{X}$ | 2.32 | 3.15 | 3.40 | 2.62 | 4.08 | 3.50 | 3.70 | | 3.37 | 3.26 | 3.52 | 4.76 | 3.77 | 3.93 | 3.93* | 3.52 |
| | $\sigma$ | 0.69 | 1.02 | 1.33 | 0.98 | 0.97 | 0.79 | 1.18 | | 1.10 | 1.11 | 1.32 | 1.46 | 2.13 | 1.05 | 1.05* | 1.34 |
| | | | | | | | | | | | | | | | | | |
| 7.4 psi | $\bar{X}$ | 4.77 | 5.47 | 5.34 | 5.01 | 5.53 | 5.43 | 5.33 | | 4.56 | 5.10 | 4.33 | 5.62 | 4.36 | 4.70 | 4.78 | 5.02 |
| | $\sigma$ | 2.13 | 1.43 | 1.59 | 2.79 | 1.48 | 1.10 | 1.29 | | 0.82 | 1.04 | 1.63 | 1.44 | 1.12 | 1.48 | 1.46 | 1.62 |
| | | | | | | | | | | | | | | | | | |
| Column | $\bar{X}$ | 3.56 | 3.91 | 4.19 | 3.75 | 4.72 | 4.57 | 4.54 | | 3.78 | 4.30 | 4.09 | 5.56 | 4.12 | 4.58 | 4.66 | 4.31 |
| Value | $\sigma$ | 2.53 | 1.68 | 1.99 | 2.05 | 1.25 | 1.25 | 1.34 | | 1.11 | 1.70 | 1.44 | 2.37 | 1.94 | 1.18 | 1.03 | 1.78 |
| | | | | | | | | | | | | | | | | | |

*Synthetic Entry

TABLE 3.3.33

ANALYSIS OF VARIANCE OF
AXIS INTERSECTION SCORES IN THE
PAPER AND PENCIL ANALOG FOR THE
FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 173.65 | 3 | 57.88 | 5.02** |
| Between Subjects in Same Group | 219.24 | 19 | 11.53 | |
| Days | 82.78 | 13 | 6.37 | 3.12** |
| EA x D | 67.30 | 39 | 1.73 | 0.8439 |
| Interaction: Pooled Subjects x Days | 505.15 | 247 | 2.05 | |
| Total | 1048.11 | 321 | | |

**Significant at P $\geq$ 0.01 Level

TABLE 3.3.34

MEANS AND STANDARD DEVIATIONS FOR PAPER AND PENCIL ANALOG ELAPSED TIME FOR THE FOUR EXPERIMENTAL GROUPS

| Experimental Condition | | Pre-Run | Days In Chamber | | | | | | | | | | | | | | Row (Day) Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Post-Run | |
| Sea Level | $\bar{X}$ | 42.88 | 48.50 | 46.25 | 51.13 | 56.04 | 46.58 | 54.50 | | 26.46 | 28.58 | 28.88 | 35.13 | 32.21 | 40.04 | 34.83 | 40.86 |
| | $\sigma$ | 4.74 | 3.86 | 4.34 | 9.02 | 8.63 | 6.03 | 6.21 | | 4.71 | 4.65 | 5.95 | 4.16 | 7.69 | 7.47 | 5.65 | 11.43 |
| | | | | | | | | | | | | | | | | | |
| 3.8 psi | $\bar{X}$ | 32.88 | 34.15 | 33.80 | 31.00 | 32.75 | 38.60 | 32.45 | | 20.50 | 21.90 | 24.40 | 27.20 | 27.25 | 24.40* | 29.55 | 29.35 |
| | $\sigma$ | 4.84 | 1.44 | 1.98 | 1.78 | 4.27 | 7.53 | 2.91 | | 2.43 | 2.75 | 4.09 | 6.22 | 4.76 | 4.09* | 4.37 | 6.58 |
| | | | | | | | | | | | | | | | | | |
| 5.0 psi | $\bar{X}$ | 39.00 | 35.63 | 34.88 | 41.25 | 40.08 | 44.83 | 36.17 | | 23.33 | 23.67 | 25.04 | 27.88 | 27.63 | 28.25 | 28.25* | 32.56 |
| | $\sigma$ | 4.49 | 5.01 | 4.30 | 2.89 | 4.80 | 8.57 | 4.88 | | 2.99 | 3.04 | 10.02 | 2.33 | 3.41 | 2.13 | 2.13* | 8.03 |
| | | | | | | | | | | | | | | | | | |
| 7.4 psi | $\bar{X}$ | 33.71 | 34.08 | 32.92 | 39.54 | 35.63 | 40.13 | 32.83 | | 20.92 | 22.50 | 24.46 | 30.13 | 27.54 | 27.71 | 26.00 | 30.58 |
| | $\sigma$ | 5.72 | 5.56 | 5.19 | 6.29 | 4.45 | 6.14 | 8.69 | | 3.99 | 5.05 | 6.26 | 8.01 | 5.87 | 9.17 | 4.99 | 8.52 |
| | | | | | | | | | | | | | | | | | |
| Column | $\bar{X}$ | 37.33 | 38.26 | 37.10 | 41.15 | 41.49 | 42.71 | 39.27 | | 22.90 | 24.26 | 25.75 | 30.21 | 28.72 | 30.35 | 29.66 | 33.51 |
| Value | $\sigma$ | 6.48 | 7.53 | 6.91 | 9.14 | 10.83 | 7.83 | 11.03 | | 4.38 | 8.58 | 5.40 | 6.39 | 6.06 | 8.74 | 5.58 | 9.98 |
| | | | | | | | | | | | | | | | | | |

*Synthetic Entry

TABLE 3.3.35

ANALYSIS OF VARIANCE OF ELAPSED TIME SCORES IN THE PAPER AND PENCIL ANALOG FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 6687.99 | 3 | 2229.33 | 7.80** |
| Between Subjects in Same Group | 5435.02 | 19 | 285.80 | |
| Days | 14077.59 | 13 | 1082.89 | 65.79** |
| EA x D | 2412.27 | 39 | 61.85 | 3.76** |
| Interaction: Pooled Subjects x Days | 4066.83 | 247 | 16.46 | |
| Total | 32679.72 | 321 | | |

**Significant at P $\geq$ 0.01 Level

TABLE 3.3.36

SUMMARY OF ANALYSIS OF VARIANCE
FOR THE PAPER AND PENCIL ANALOG

| Variable Name | Source of Variance | | |
|---|---|---|---|
| | Atmosphere | Days | Interaction |
| Arithmetic Computation | | ** | ** |
| Pattern Discrimination | | ** | |
| Scale Position Monitoring | | | |
| Incomplete Matrices | | ** | |
| Profile Discrimination | | ** | ** |
| Vector Construction | | * | |
| Axis Intersection | ** | ** | |
| Total Elapsed Time | ** | ** | ** |

** = $P \geq 0.01$
* = $P \geq 0.05$

TABLE 3.3.37

INTERCORRELATIONS OF PAPER AND PENCIL ANALOG VARIABLES ON SUBJECTS UNDER 7.4 PSI AND 3.8 PSI OXYGEN ATMOSPHERES

| | Profile | SPM | Matrices | Axis | Arith | Vector | Pattern | Time |
|---|---|---|---|---|---|---|---|---|
| Profile | | 0.485 | 0.540 * | 0.898 * | -0.014 | 0.348 | 0.329 | 0.363 |
| SPM | | | 0.535 * | 0.497 * | 0.547 * | 0.712 * | 0.438 | 0.043 |
| Matrices | | | | 0.514 * | 0.462 | 0.555 * | 0.229 | 0.519 |
| Axis | | | | | -0.027 | 0.391 | 0.071 | 0.420 |
| Arith | | | | | | 0.789 * | 0.238 | -0.088 |
| Vector | | | | | | | 0.109 | -0.205 |
| Pattern | | | | | | | | 0.199 |
| Time | | | | | | | | |

* $P \geq 0.05$

TABLE 3.3.38

GENERAL APTITUDE TEST BATTERY
SUMMARY STATISTICS OF APTITUDE SCORES
FOR THE SUBJECTS OF THE FOUR EXPERIMENTAL GROUPS

| | | "G" | | "V" | | "N" | | "S" | | "P" | | "Q" | | "K" | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Form | N | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ |
| A - 1 | 6 | 120.50 | 7.27 | 129.17 | 15.67 | 118.33 | 7.06 | 100.00 | 11.20 | 114.17 | 14.66 | 118.83 | 7.69 | 108.67 | 15.24 |
| B | 6 | 133.00 | 18.17 | 133.00 | 17.71 | 130.33 | 11.60 | 116.00 | 9.20 | 112.17 | 9.03 | 125.33 | 7.23 | 123.83 | 16.85 |
| A - 2 | 6 | 142.83 | 7.08 | 144.00 | 14.28 | 130.33 | 8.26 | 128.00 | 7.57 | 127.67 | 10.24 | 135.00 | 11.49 | 128.50 | 20.71 |
| | | | | | | | | | | | | | | | |
| A - 1 | 5 | 132.17 | 12.37 | 128.33 | 15.49 | 118.83 | 7.36 | 131.00 | 13.66 | 125.00 | 10.12 | 128.67 | 11.93 | 111.83 | 12.90 |
| B | 5 | 144.33 | 7.74 | 142.00 | 12.06 | 129.00 | 7.66 | 138.17 | 9.72 | 134.33 | 10.70 | 132.83 | 16.79 | 121.67 | 10.81 |
| A - 2 | 5 | 152.67 | 7.50 | 148.33 | 13.06 | 126.83 | 5.87 | 158.17 | 4.10 | 142.00 | 17.78 | 147.33 | 16.56 | 129.67 | 13.00 |
| | | | | | | | | | | | | | | | |
| A - 1 | 6 | 128.67 | 11.98 | 127.67 | 12.09 | 125.50 | 10.18 | 114.50 | 19.79 | 117.83 | 7.15 | 124.17 | 11.10 | 120.00 | 13.03 |
| B | 6 | 136.33 | 10.84 | 131.50 | 12.49 | 136.00 | 11.31 | 119.67 | 14.57 | 121.00 | 4.12 | 136.50 | 9.81 | 130.00 | 13.89 |
| A - 2 | 6 | 138.50 | 10.47 | 138.83 | 16.05 | 134.00 | 9.43 | 126.33 | 18.91 | 134.00 | 9.07 | 144.50 | 9.83 | 140.33 | 12.12 |
| | | | | | | | | | | | | | | | |
| A - 1 | 6 | 134.50 | 14.01 | 134.83 | 17.09 | 132.83 | 6.12 | 119.67 | 15.98 | 122.33 | 12.78 | 126.50 | 15.72 | 112.50 | 8.28 |
| B | 6 | 140.50 | 10.44 | 144.83 | 7.80 | 135.00 | 5.72 | 125.17 | 21.21 | 125.00 | 10.77 | 142.00 | 5.83 | 119.17 | 9.10 |
| A - 2 | 6 | 151.00 | 12.01 | 150.67 | 11.26 | 138.33 | 7.04 | 141.83 | 14.37 | 138.00 | 14.41 | 157.00 | 10.25 | 131.17 | 11.95 |

| | | "F" | | "M" | |
|---|---|---|---|---|---|
| Form | N | $\bar{X}$ | σ | $\bar{X}$ | σ |
| A - 1 | 6 | 92.67 | 14.86 | 104.83 | 15.51 |
| B | 6 | | | | |
| A - 2 | 6 | | | | |
| | | | | | |
| A - 1 | 5 | 106.67 | 11.61 | 106.33 | 12.91 |
| B | 5 | | | | |
| A - 2 | 5 | | | | |
| | | | | | |
| A - 1 | 6 | 112.50 | 9.74 | 118.50 | 11.30 |
| B | 6 | | | | |
| A - 2 | 6 | | | | |
| | | | | | |
| A - 1 | 6 | 105.83 | 13.33 | 98.83 | 17.71 |
| B | 6 | | | | |
| A - 2 | 6 | | | | |

TABLE 3.3.39

ANALYSIS OF VARIANCE OF
GENERAL INTELLIGENCE "G"
OF GENERAL APTITUDE TEST BATTERY
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 1592.28 | 3 | 530.76 | 1.331 |
| Between Subjects in Same Group | 7579.22 | 19 | 398.91 | |
| Days | 3602.08 | 2 | 1801.04 | 43.992** |
| EA x D | 334.137 | 6 | 55.69 | 1.036 |
| Interaction: Pooled Subjects x Days | 1555.77 | 38 | 40.94 | |
| Total | 14663.49 | 68 | 215.64 | |

**Significant at P ≥ 0.01 Level

TABLE 3.3.40

ANALYSIS OF VARIANCE OF
VERBAL "V"
OF GENERAL APTITUDE TEST BATTERY
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 1207.81 | 3 | 402.60 | 0.5766 |
| Between Subjects in Same Group | 12266.00 | 19 | 698.21 | |
| Days | 2867.69 | 2 | 1433.89 | 28.92** |
| EA x D | 253.30 | 6 | 42.41 | |
| Interaction: Pooled Subjects x Days | 1884.16 | 38 | 49.58 | 0.85135 |
| Total | 18478.98 | 68 | 271.75 | |

**Significant at P ≥ 0.01 Level

TABLE 3.3.41

ANALYSIS OF VARIANCE OF
NUMERICAL APTITUDE "N"
OF GENERAL APTITUDE TEST BATTERY
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Squares | F |
|---|---|---|---|---|
| Experimental Atmosphere | 1284.55 | 3 | 428.18 | 10.38** |
| Between Subjects in Same Group | 1237.61 | 19 | 41.25 | |
| Days | 1185.02 | 2 | 592.51 | 6.052** |
| EA x D | 200.19 | 6 | 33.365 | 0.3437 |
| Interaction: Pooled Subjects x Days | 3803.72 | 38 | 97.89 | |
| Total | 7711.10 | 68 | 113.398 | |

**Significant at P ≥ 0.01 Level

TABLE 3.3.42

ANALYSIS OF VARIANCE OF
SPATIAL APTITUDE "S"
OF GENERAL APTITUDE TEST BATTERY
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmosphere | 7921.15 | 3 | 2640.38 | 4.20* |
| Between Subjects in Same Group | 11926.06 | 19 | 627.68 | |
| Days | 6078.58 | 2 | 3039.29 | 42.73** |
| EA x D | 689.30 | 6 | 114.88 | 1.6152 |
| Interaction: Pooled Subjects x Days | 2702.77 | 38 | 71.12 | |
| Total | 29317.86 | 68 | 431.14 | |

*Significant at P ≥ 0.05 Level
**Significant at P ≥ 0.01 Level

TABLE 3.3.43

ANALYSIS OF VARIANCE OF
FORM PERCEPTION "P"
OF GENERAL APTITUDE TEST BATTERY
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmosphere | 2400.70 | 3 | 800.23 | 2.159 |
| Between Subjects in Same Group | 7043.29 | 19 | 370.69 | |
| Days | 3238.08 | 2 | 1619.04 | 25.79** |
| EA x D | 208.58 | 6 | 34.76 | 0.5538 |
| Interaction: Pooled Subjects x Days | 2385.20 | 38 | 62.77 | |
| Total | 15275.85 | 68 | 224.64 | |

**Significant at P ≥ 0.01 Level

TABLE 3.3.44

ANALYSIS OF VARIANCE OF
CLERICAL PERCEPTION "Q"
OF GENERAL APTITUDE TEST BATTERY
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmosphere | 2203.77 | 3 | 734.59 | 2.2377 |
| Between Subjects in Same Group | 6237.35 | 19 | 328.28 | |
| Days | 5522.86 | 2 | 2761.43 | 28.943* |
| EA x D | 473.46 | 6 | 78.91 | 0.8271 |
| Interaction: Pooled Subjects x Days | 3625.64 | 38 | 95.41 | |
| Total | 18063.08 | 68 | 265.63 | |

*Significant at P ≥ 0.05 Level

TABLE 3.3.45

ANALYSIS OF VARIANCE OF
MOTOR COORDINATION "K"
OF GENERAL APTITUDE TEST BATTERY
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Experimental Atmosphere | 1181.44 | 3 | 393.81 | 0.5886 |
| Between Subjects in Same Group | 12711.89 | 19 | 669.05 | |
| Days | 4419.44 | 2 | 22097.20 | 1701.09** |
| EA x D | 142.55 | 6 | 23.76 | 1.8291 |
| Interaction: Pooled Subjects x Days | 493.77 | 38 | 12.99 | |
| Total | 18949.09 | 68 | 278.66 | |

**Significant at P ≥ 0.01 Level

TABLE 3.3.46

ANALYSIS OF VARIANCE OF
FINGER DEXTERITY "F"
OF GENERAL APTITUDE TEST BATTERY
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Between Atmospheres | 1262.83 | 3 | 420.95 | 2.12 |
| Within Atmospheres | 3771.00 | 19 | 198.47 | |
| Total | 5033.83 | 22 | | |

TABLE 3.3.47

ANALYSIS OF VARIANCE OF
MANUAL DEXTERITY "M"
OF GENERAL APTITUDE TEST BATTERY
FOR THE FOUR EXPERIMENTAL GROUPS BY DAYS

| Source | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Between Atmospheres | 1224.13 | 3 | 408.04 | 1.52 |
| Within Atmospheres | 5090.50 | 19 | 267.92 | |
| Total | 6314.63 | 22 | | |

TABLE 3.3.48

INTERCORRELATIONS OF THE ABILITY MEASURES
OF THE GENERAL APTITUDE TEST BATTERY ON
SUBJECTS UNDER 7.4 PSI AND 3.8 PSI $O_2$ ATMOSPHERES (N = 11)

| | Verbal | Number | Spatial | Form Perception | Clerical Perception | Motor Coordination | Finger Dexterity | Manual Dexterity |
|---|---|---|---|---|---|---|---|---|
| "G" | 0.954 * | 0.583 * | 0.603 * | 0.370 | 0.662 * | -0.702 * | 0.263 | -0.085 |
| Verbal | | 0.632 * | 0.422 | 0.315 | 0.677 * | -0.741 * | 0.060 | -0.276 |
| Number | | | -0.026 | 0.205 | 0.484 | -0.320 | 0.169 | -0.058 |
| Spatial | | | | 0.218 | 0.138 | -0.379 | 0.322 | 0.014 |
| Form Perception | | | | | 0.428 | 0.088 | -0.135 | 0.135 |
| Clerical Perception | | | | | | -0.563 * | -0.010 | 0.044 |
| Motor Coordination | | | | | | | 0.113 | 0.424 |
| Finger Dexterity | | | | | | | | 0.734 * |
| Manual Dexterity | | | | | | | | |

* Significant at the P = 0.05 level

APPENDIX D

# THE EFFECT OF SEQUENTIAL EXPOSURE TO ACCELERATION AND THE GASEOUS ENVIRONMENT OF THE SPACE CAPSULE UPON THE PHYSIOLOGIC ADAPTION OF MAN

By Lt. Robert E. Mammen, MC, USN, Dr. George T. Critz, MC, USN,
Dr. Donald W. Dery, LCDR Francis M. Highly, Jr., MC, USN,
and Dr. Edwin Hendler

Air Crew Equipment Laboratory
U. S. Naval Air Material Center
Philadelphia, Pennsylvania

Contract number T-9753-G

U. S. NAVAL AIR ENGINEERING CENTER
Philadelphia 12, Pa.

AIR CREW EQUIPMENT LABORATORY

PROBLEM ASSIGNMENT NO. 005-AE13-15
EVALUATION OF PROPOSED GEMINI ENVIRONMENTAL PROFILE

# The Effect of Sequential Exposure to Acceleration and the Gaseous Environment of the Space Capsule Upon the Physiologic Adaptation of Man

NAEC-ACEL-498 14 JUNE 1963


Reported by: Robert E. Mammen, LT, MC, USN

George T. Critz, CDR, MC, USN

Donald W. Dery, Ph.D.
Research Physiologist

Francis M. Highly, Jr.,
LCDR, MC, USN

Edwin Hendler, Ph.D.
Supervisory Physiologist

Approved by: L. W. Meakin
Technical Director

Approved and released by: R. A. Bosee, CAPT, MSC, USN
Director

## ADMINISTRATIVE INFORMATION

Defense Purchase Request T-9753-G of 29 August 1962 was assigned to the Air Crew Equipment Laboratory by the National Aeronautics and Space Administration, Manned Spacecraft Center, Houston 1, Texas. This study was conducted to obtain data concerning the physical effects on subjects using a proposed 100 per cent oxygen, 5 psia atmosphere while being exposed to the anticipated launch and re-entry G loads associated with Project GEMINI.

This study was conducted with the active collaboration of Mr. E. L. Michel, MSC, NASA, and CDR B. F. Burgess, Aviation Medical Acceleration Laboratory, Naval Air Development Center, Johnsville, Pa.

Test subjects who participated in the study are:

BEAN, Alan L., LT, USN
GEBO, Gary G., 1/Lt, USMC
GEIGER, William J., CAPT, USMC
GERSTENSCHLAGER, Val, ENS, USN
MARSHALL, Stephen E., ENS, USNR
WEIR, Kenneth W., CAPT, USMC

Alternate and control subjects who participated are:

LANGHER, Frank S., Jr., LTJG, USNR
MITCHELL, David G., ENS, USNR

The authors are indebted to Dr. C. J. Lambertsen and Dr. A. B. DuBois of the University of Pennsylvania for valuable support in the planning and execution of this study. Without the active cooperation of many personnel of the Air Crew Equipment Laboratory, Aviation Medical Acceleration Laboratory, and the U. S. Naval Hospital, this study could not have been completed.

## INTRODUCTION

One of the atmospheres under consideration for use in future long term space flights consists of 100% oxygen at a total pressure of 258 mmHg. This is the environment presently used in Project MERCURY, and the suitability of this atmosphere for prolonged habitation has only recently been investigated (1, 2, 3, 4). Increased oxygen pressure has been proven to be toxic for mammals (5, 6, 7, 8) and has produced pulmonary and central nervous system damage (9, 10, 11). The central damage has been ascribed to interference with carbon dioxide transport (12, 13).

Aero-atelectasis has been shown to occur following accelerations while breathing 100% oxygen (14, 15, 16, 17). In a biologically active atmosphere of pure oxygen, the rate of lung collapse has been shown to be fifty times the rate occurring in the presence of an inert gas (18). Constriction of the chest, as occurs in the space suit, has been demonstrated to reduce vital capacity, total lung volume, and compliance (19). Oxygen toxicity may also further the development of atelectasis (20). Fully developed atelectasis requires greater than normal pressures to reinflate terminal alveoli (21, 22), and reinflation may be incomplete, furthering the production of increased pulmonary vascular resistance, loss of compliance, decreased pulmonary circulation, and subsequent reduction in oxyhemoglobin (23).

Prolonged resting states at high concentrations of oxygen, even at reduced pressure, may also lead to pulmonary fibrosis (24, 25, 26, 27) and alveolo-capillary block, the "Hammond-Rich syndrome" (28).

Thus, the 100% oxygen environment, prolonged acceleration, and chest constriction, due to the pressure suit, all favor the production of atelectasis during extended space flight. As a reduced oxygen saturation occurs, as blood is perfused through unventilated, atelectatic portions of the lung (23), neuromuscular and mental function may be seriously impaired.

The purpose of the present study was to investigate the combined effects of acceleration and continuous exposure for 14 days to 100% oxygen at 258 mmHg pressure on subjects representative of the astronaut population.

## THE STUDY

The subjects selected for this study were eight healthy males, between 24 and 32 years of age. All subjects were experienced Navy and Marine pilots, and were selected on the basis of their high scores in the Aviation Qualifications Test and the Flight Aptitude Rating at U. S. Naval Air Training Command, Pensacola, Fla. These tests have been shown to be of value in identification of potential astronauts (29).

All subjects were found to be extremely physically fit at the time of the study. Subject 1 gave a past history of hemorrhagic prostatitis three years ago without recurrence. Subject 2 ruptured his appendix eight months previously with post-operative development of a probable pulmonary infarction. Subject 3 was rejected from three previous astronaut studies due to an abnormally formed, low voltage T wave in all standard leads of his electrocardiographic trace. He has subsequently shown ST segment depression in leads 2 and 3 and a UR during a Harvard Step Test consistent with early coronary artery disease. All other subjects gave negative histories and had negative physical findings.

A ten-day control period was assigned for investigation of the subjects. During this time, they were interviewed and histories and physical examinations were completed. Urine was collected daily for analysis. Blood was drawn every other day for hematological study and blood chemistries. For blood gas analysis, two arterial punctures were taken while breathing 20% oxygen at sea level, two while breathing 100% oxygen at sea level, and one while breathing 100% oxygen at an altitude of 27,000 feet (258 mmHg). An electrocardiogram was obtained on each subject and baseline spirometry measurements collected. The subjects were given indoctrination in use of Mercury-type pressure suits and were exposed to the experimental acceleration profile at the Aviation Medical Acceleration Laboratory (AMAL), Johnsville, Pa. They were trained in the psychological performance task and the paper analog test.

Certain test capabilities were not available at ACEL and were performed by the U. S. Naval Hospital, Philadelphia. These were renal function tests, electroencephalograms, liver function tests (cephalin flocculation and thymol turbidity), and protein bound iodine. Other services were rendered by the Bacteriology Department, USNH, which performed all bacterial cultures and identification and the Radiology Department, which integrated all X-rays taken.

Three days prior to the commencement of the study, the subjects were isolated in one wing of the Bachelor Officers' Quarters and offered a dehydrated food diet supplied by the National Aeronautics and Space Administration (see appendix D-1). Naso-pharyngeal smears were obtained from the subjects and from all persons involved in the study who were to come in direct contact with the subjects. These were sent to the Naval Hospital for culture and identification.

Simulating the actual flight, the subject and his alternate were awakened at 0500 in the morning and examined. (Due to space limitations within the capsule, only one subject could be exposed to the launch acceleration profile daily.* This made it necessary to launch each subject separately in sequence over a six-day period.) Electrocardiographic electrodes were attached to each man's torso, and they donned their full pressure suits. Each suit also had a microphone mounted thermistor at the nasal orifice to follow respiratory rate. The suits were sealed and pressurized with 100% oxygen and the preoxygenation period begun. During preoxygenation, the subject and his backup were transported from ACEL to AMAL, Johnsville. They were accompanied by a flight surgeon, pressure suit and electronic technicians.

After four to five hours of preoxygenation, the subject entered a portable altitude capsule which had been attached to the centrifuge arm. The chamber was sealed and evacuated to a simulated altitude of 33,000 feet. The subject was maintained on 100% oxygen at an equivalent altitude of 27,000 feet within the pressure suit. The launch acceleration profile consisted of two pulses of acceleration of about seven G, lasting about two minutes each (Figure 1). The force of the acceleration was directed from the front to the back surface of the body. The chamber was detached from the centrifuge and transported directly to ACEL with the subject still encased. The portable chamber was mated to the Bio-astronautical Test Facility (BATF), and pressures were equalized at 258 mmHg. The subject entered the living quarters of the chamber. The attending physicians immediately divested him of his pressure suit and moved

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*Further technical details may be seen in Federation Proceedings: American Physiological Society (in press).

him directly to the medical area. There, the observers performed an arterial puncture for blood gas analysis (also taken on days 4, 10, and 13), completed a physical examination, and obtained a vital capacity on the spirometer. A PA and left lateral chest X-ray were taken (also on days 4, 7, 10, and 13) and finally venous blood was drawn. A thirty-six hour day with a 6 hour cycle had been established for each subject to follow after entry into the BATF. This consisted of an orderly sequence of sleep, hygiene, preparation and eating of food, task performance, and recreation. The cycle was interrupted once daily by a physical examination including spirometry, urinalysis, and venous blood drawing for hematological and electrolyte determinations.

On each subject's 15th day, the ECG electrodes were reattached and he donned his pressure suit. He re-entered the portable altitude chamber and was taken by van back to AMAL. The capsule was reattached to the centrifuge arm, and the subject received the re-entry acceleration profile of about 11 peak g (Figure 1). The portable chamber was then repressurized to ambient sea level pressure and the subject was removed. He was taken to a medical examination room in his pressure suit while breathing 100% oxygen from a portable supply. The subject held his breath while the pressure suit helmet and neck ring were removed. A mask delivering 100% oxygen at about 2 cm $H_2O$ positive pressure was then applied to his face. The remainder of the suit was removed and the subject was prepared for arterial blood sampling. The first arterial sample was collected while the subject was breathing 100% oxygen; a second sample was drawn after the oxygen mask had been removed and the subject had been breathing room air for 7 minutes. Following the arterial puncture, a physical examination, spirometry, and X-rays of the chest were completed.

Immediate post-run observations continued for three days, during which time the subjects were allowed to resume a normal daily routine. Final renal function tests were obtained from 3 to 14 days post-run, and the hematological follow-up extended three months post-run.

## METHODS

During the chamber period, complete physical examinations were performed daily. Temperatures were taken by thermistors to eliminate the possibility of accidental introduction of mercury within the chamber. (Mercury had been implicated as a cause of abnormal urinary findings in the study conducted by Republic Aviation Corporation (2).)

### Blood Gas Analysis

In the 10 day control period, two sets of arterial samples were analyzed on each of nine subjects. The first consisted of an arterial blood sample taken while the subject was breathing ambient gas and then after seven minutes of breathing 100% oxygen (2 cm $H_2O$ positive pressure) at sea level. The second procedure was carried out in the BATF and required three separate samples. The first was drawn while the subject was respiring the ambient gaseous environment, the second after breathing 100% oxygen at sea level for 20 minutes, and the last after ascent to 27,000 feet and breathing 100% oxygen (258 mmHg). (At this time, one subject was disqualified due to extreme hyperventilation.) The control subjects were exposed to 100% oxygen at sea level under positive pressure for one and one-half hours. An arterial sample was drawn and the

oxygen then discontinued. Seven minutes later, a second sample was obtained to simulate a control period equal to that of the re-entry portion of the flight profile.

Arterial blood was obtained from the anesthetized femoral artery by introducing a 2-1/8 inch, 20 gauge spinal needle attached to a refrigerated, heparinized, 10 cc Luer Lok syringe into the artery. The heparinized dead space was washed with blood and the washings discarded through a three-way stopcock. A 10 cc sample of blood was drawn, the stopcock removed, and a fresh needle attached. Blood was extruded from the needle, which was then sealed with a rubber stopper. After vigorous agitation, the syringe was placed in a container with crushed ice and passed to the outside of the chamber through a small, secondary pressure lock for analysis.

Instrumentation Laboratory's model 5113 $pO_2$-$pCO_2$-pH blood gas analysis apparatus was used, with modifications as suggested by J. W. Severinghaus (30) including:

(1) polypropylene membrane for the oxygen electrode;

(2) nylon hose, 51 denier, replacing the cuprophane in the carbon dioxide electrode; and

(3) plating and polishing of the oxygen Pt-Ag-AgCl electrode.

The above resulted in a modified Clark electrode as established in the determination of blood oxygen tension by Severinghaus and others (30, 31, 32, 33, 34, 35).

The electrical outputs proportional to the tensions of the blood gases were recorded on a Honeywell 10 mv, $\frac{1}{4}$-second response time (full scale deflection) strip chart recorder. The recorder had been adapted to the electrode system by a current divider. Two comparable polarographic blood gas analyzing systems were in operation, one at ACEL and the other at AMAL. Each was calibrated against known gases, saturated with water at 37°C, prior to each series of determinations. The two systems had been given similar preparatory treatment (30).

The error in the 0-160 mmHg $pO_2$ scale of the instrument was ignored. The error in the 0-800 mmHg $pO_2$ scale has two primary sources. The first is an inherent error due to peroxide formation (36) producing a decreasing electrical output with increasing $pO_2$. This can only be estimated, at best, in present electrode systems by extrapolation of the output recording back to zero time. Thus, arterial samples obtained from subjects breathing 100% oxygen at sea level are expected to show low $pO_2$'s, and this must be taken into account. The second is a systematic personal error on the part of the experimenter in adjusting the slope of the $O_2$ curve. Duplicate sample analyses were conducted utilizing standard Van Slyke and Kopp Natelson gasometric devices as backups for the primary system described above.

Shunts were calculated from $PaO_2$ and pH using Dills nomogram (Figure 2) for saturations and W. A. Briscoe's shunt calculation (2) for denitrogenated man as follows:

$$\frac{\dot{Q}_s}{\dot{Q}_t} = \left[\frac{P_AO_2 - P_aO_2}{5 \text{ Vol. } \%}\right]\left[\frac{\alpha}{760} + \text{Capacity.}\ \frac{ds}{dpO_2}\right]$$

Where:

$\dot{Q}_t$ = volume flow of blood in l/min

$\dot{Q}_s$ = maximum percentage of cardiac output shunting through unventilated channels

$P_AO_2$ = alveolar oxygen (inspired $pCO_2$)

$P_aO_2$ = measured arterial oxygen tension

5 Vol. % = the assumed arterial-venous oxygen difference

$\alpha$ = solubility coefficient of oxygen in blood

Capacity = oxygen capacity of blood (assumed to be 20 Vol. %)

$\frac{ds}{dpO_2}$ = change in saturation due to change in $pO_2$ or the slope of the oxygen dissociation curve.

There was a varying partial pressure of nitrogen within the BATF system (4-10 mmHg) which was neglected in the calculations of "shunting," creating falsely high shunt values.

Spirometry

All lung volume measurements were made with the subjects seated, their elbows resting on their knees, and their hands holding the mouthpiece.

The usual corrections for differences in body and temperature were used:

$$Vo = Vc \left[\frac{B - p(H_2O)_1}{B - p(H_2O)_2}\right]\left[\frac{273 + T_2}{273 + T_1}\right]$$

Where:

Vo = calculated lung volume at BTPS in liters

Vc = measured lung volume at ATPS in liters

B = barometric pressure in mmHg

$p(H_2O)_1$ = vapor pressure of water at temperature of spirometer in mmHg

$p(H_2O)_2$ = vapor pressure of water at the alveolar surface assumed to be at 37°C and constant at 47 mmHg

$T_1$ = spirometer temperature in °C

$T_2$ = body temperature in °C

During the chamber run, the barolyme $CO_2$ absorber was inadvertently placed in the exhalation line of the Collins spirometer. This decreased the measured vital capacity within the chamber by the amount of $CO_2$ absorbed, and was measured subsequent to the study by transferring the barolyme from inhalation to exhalation side and measuring the difference in vital capacity due to the abnormal placement. An average correction of 350 cc has been added to the measured vital capacities.

X-ray

A port of 5/8 inch steel was constructed in the outer chamber wall (Figure 3). A 4 mm thick aluminum end-plate, 7 inches in diameter, was inserted within the larger steel case. The inner chamber wall (located behind the aforementioned end-plate) was constructed of aluminum 3/16 inch (4.8 mm) thick. Inherent filter characteristics of the X-ray tube used was equal to 0.5 mm aluminum. The total filtration, or 9.3 mm of aluminum, removed extraneous irradiation and passed only usable X-ray. By radiac packs located in and around the chamber and densiometer calculations, it was found that the area in direct line inside the chamber received 14 mr per exposure at 90 KVP, 1/20 sec., 200 milliamperes. Elsewhere, the radiacs indicated no higher than background radiation levels. Each subject received an estimated 35 mr per pair of exposures. X-rays were obtained on the 1st, 7th, 10th, and 13th day and after the re-entry acceleration profile. Total roentgen exposure over the two-week period was about 250 mr, well within recommended dosage limitation (0.3 REM per week) (37). All exposures were obtained in standard posterior-anterior and left lateral positions at full inspiration.

Hematology

Determinations relating to hematology included cell counts (RBC, WBC, differential, and reticulocytes), platelet counts, sedimentation rate, osmotic fragility, specific gravity, hematocrit, and hemoglobin.

With the exception of hemoglobin and hematocrit, the techniques used were as described in (38). Hemoglobin was determined by the cyanmethemoglobin method as described in (39). Hematocrits were determined with the Drummond Microhematocrit.

Blood Chemistry

Chemical analysis of blood serum included determinations of bilirubin, chloride, glucose, potassium, sodium, and urea nitrogen. The following methods were used:

Bilirubin - Malloy and Evelyn (38);
Chloride - Schales and Schales (38);
Creatinine clearance - concentration test, U. S. Naval Hospital, Philadelphia;
Glucose - glucostat procedure of Worthington Biochemical Corp.;
Protein bound iodine - U. S. Naval Hospital, Philadelphia;
Sodium and potassium - flame photometry as described by Beckman Instruments, Inc.; and
Urea nitrogen - glucostat procedure of Worthington Biochemical Corp.

## Urinalyses

The following methods were used:

Acetone - Acetest reagent tablets, Ames Company, Inc., Elkart, Ind.
Glucose - Combistix reagent strips, Ames Company
Specific gravity - urometer
Occult blood - Hemastix reagent strips, Ames Company
Proteins - Combistix reagent strips
pH - Combistix
Urobilinogen - Wallace and Diamond method as described in (40)
Microscopic examination

## Bacteriologic Culture

Nasal and pharyngeal smears for culture were obtained from all subjects and contacts three times during the control period and three times during the chamber confinement, and sent to the U. S. Naval Hospital for bacteriologic study.

## Performance Measurement

During the fourteen day simulated space flight, an attempt was made to measure psychomotor and mental performance. A performance measuring device, designed by the School of Aerospace Medicine, Brooks Air Force Base, San Antonio, Texas, was constructed and used. This device was developed to measure neuromuscular and intellectual function by a compact, five element task. The task consisted of two elements programmed at random and shared in time with three elements operated on special schedules determined by the experimenter. The five sub-elements were designed to measure (a) vigilance, (b) arithmetic, (c) compensatory tracking, (d) short term memory, and (e) problem solving. Before the run, each subject was given practice on the performance task until a plateau in proficiency was reached.

## Other

Electrocardiograms were recorded using the Sanborn "Visicorder" and the Sanborn models 150 and 350 during the actual experimental procedure.

Electroencephalograms were obtained from each subject before and after the chamber run by the Neuropsychiatry Department at the U. S. Naval Hospital, Philadelphia.

Post-run dark adaptation was evaluated using the Hecht-Shlaer dark adaptometer (41) with the stimulus located at 7° and 17° right nasal retina. No pre-run determinations were made, as the discovery of the changes in dark adaptation occurred during the course of the experimentation.

## RESULTS

### General

Physical tolerance to the simulated flight was demonstrated by general good health and performance. There was a consistent though slight drop in oral temperature throughout the chamber period. Pulse rate, blood pressure, respiratory rate, and weight were not significantly altered (Figure 4).

Transient bends due to inadequate preoxygenation occurred in the wrists and knees of the medical observers on their first exposure to altitude. The subjects were free of respiratory infections during their isolation period. One observer entered the confinement with nasopharyngitis, followed by serous otitis media bilaterally. His white count was undisturbed and cultures showed only normal bacterial flora. Two subjects also developed serous otitis, which cleared with decongestants and Valsalva maneuvers.

### Blood Gases

There was no significant variation in arterial $pO_2$, $pCO_2$, or pH during the chamber period (Table I). Calculations of "shunted" blood (i.e., blood perfusing alveoli but not oxygenated) amounting to 3% ± 1% were in close agreement with those of previous series (1,2) (Figure 5).

There was a significant lowering of the recovery $P_aO_2$ (ambient) following re-entry acceleration as compared to values obtained from control subjects under similar conditions, but this difference was insignificant when compared to preacceleration ambient arterial oxygen tension of all subjects. The difference in barometric pressure at ACEL (760 mmHg) and AMAL (747 mmHg) may also account for the difference in ambient arterial tension found.

### Vital Capacity

There was no essential change in vital capacities, converted to BTPS, during the test conditions as compared to prerun studies (Table II). A study of pulmonary mechanics and carbon monoxide diffusing capacity of each of the three subjects who completed the re-entry profile and of the two control subjects was performed at the University of Pennsylvania; these were reported as normal for the entire group and indicate that no permament pathology occurred as a result of the experimental procedure (42).

### Roentgenograms of Chest

No changes attributable to the test conditions were found and the interpretation from the Radiology Department of the U. S. Naval Hospital, Philadelphia is as follows:

Subject:

1. 1 Nov 62 thru 14 Nov 62; Negative

2. 2 Nov 62 thru 15 Nov 62: There is a nodular density projected over the second right anterior interspace which together with calcific densities in

the right hilar region probably represent old healed granulomatous disease. There is also tenting of the right hemidiaphragm with pleural thickening along the right lateral wall which is suggestive of old pleural disease. There is no evidence of active pulmonary disease.

3. 3 Nov 62 thru 16 Nov 62; Negative

4. 4 Nov 62 thru 18 Nov 62: There is an 8 mm nodule projective over the right 8th anterior interspace. This appears to have a calcified center and probably represents old healed granulomatous disease. The remainder of the lung fields appear clear.

5. 4 Nov 62 thru 19 Nov 62; Negative

6. 6 Nov 62 thru 17 Nov 62; Negative

Hematology

(See Tables III, IV, V, and Figures 6 and 7)

The following significant changes in the blood picture occurred during the test period. Hemoglobin and hematocrit values dropped. White blood cell counts increased. The differential counts indicated a rise in neutrophils and a decrease in other cell types. Platelet counts showed a marked increase. Other changes which were not statistically significant included a slight rise in reticulocytes and slight decreases in Mean Corpuscular Volume and Mean Corpuscular Hemoglobin. All other measured parameters remained normal. The three month post-run hematologic picture, for the subjects who completed the entire test sequence, showed a return to approximately pre-test values.

It should be stressed here that these same changes occurred in the two control subjects as well as the experimental subjects.

Blood Chemistries

All blood chemistries were within normal limits during the entire procedure (Tables VI and VII).

Urinalysis

Slight traces of albumin and acetone were found in two subjects during the test period and then only in a few specimens. Mucus was found in relatively large quantities in all test subjects in both the pre-run and run periods. Calcium oxalate crystals were found in much greater quantity during the test than in the control period. A few hyaline and granular casts were found in the urine of three subjects on arrival. These cleared in the first few days and no casts were observed throughout the study (Table VIII).

The subjects who received burns demonstrated normal renal capacity during recovery.

Renal Function Studies

No alteration in concentration ability or clearance was found (Table VIII).

Electroencephalograms were unchanged.

Electrocardiography

No arrhythmias or other abnormalities occurred. Of particular interest is the series done on subject 3. Figure 10 shows pre- and post-run ECG's during his Harvard Step Test, and the responses during acceleration and truck transit.

Dark Adaptation

Following the discovery of decreased peripheral scotopic vision in a medical observer, the subjects were examined for dark adaptation after completing the chamber run. Subject 2 showed a 30 fold decrease in sensitivity. Subjects 1 and 3 showed a 10 fold decrease, as did the medical monitor. Subject 2 returned to the normal range in 72 hours (Figure 9). These findings have since been confirmed in another study and will be published at a later date.

## SUMMARY AND CONCLUSIONS

Six Naval and Marine aviators were subjected to the environmental circumstances anticipated in the forthcoming 14-day orbital flights in an attempt to validate the suitability of the proposed gaseous environment. No evidence of physiological alteration of note was detected during the study with the exception of temporary impairment of peripheral scotopic vision.

Fire occurred in the BATF, requiring removal of the remaining subjects and early termination of the experiment.

No atelectasis was established by the four major parameters here utilized (18). Although no atelectasis was demonstrated on X-ray, it cannot be stated absolutely that a certain degree of alveolar collapse did not occur. No attempt was made to preserve or clear the condition, if it occurred. Several hours elapsed after the launch acceleration, and 20-30 minutes after re-entry, before X-rays could be taken. It is likely that alveolar collapse could have cleared spontaneously during this interval. It is also reasonable to assume that no alteration of diffusion across the capillary membranes occurred since post-run diffusion capacity was normal (42). This essentially agrees with the conclusions drawn from similar work done at S.A.M., Brooks AFB (1) and at Republic Aviation Corp. (2), differing only in that acceleration was not incorporated into their experimental design.

Hematological changes were detected during the study. The average drop in hemoglobin and hematocrit was significantly different from pre-run figures. There was no rise in bilirubin or urinary urobilinogen, a slight rise in reticulocytes, a significant rise in neutrophils and platelets, and a tendency to hypochromia and microcytosis. The erythrocytes were not unusually shaped. Inasmuch as sampling resulted in blood loss of 700 cc, we can only conclude that at lease a major percentage of the changes noted between pre-test and test periods was due to blood loss. The blood picture was indicative of acute blood loss rather than hemolysis or marrow hypoplasia. There was little found in this investigation to support the possibility of oxidative hemolysis, such as was indicated in the Republic Aviation Corp. series (2). Unfortunately, however, no search for methemoglobin was carried out here.

As a high incidence of microscopic cylindruria was noted at Republic Aviation Corp. (but not at Brooks AFB), an intensive study of the urinary sediment before, during, and after the run was undertaken. Even though three subjects were passing casts on arrival, they ceased to do so during the control period, and no casts of any description were passed thereafter during the entire study. Normal renal concentration tests and clearing ability was shown. The subjects who were involved in the fire (43) and who had 10 to 20% of body area second degree burns, recovered without renal difficulty. This is evidence that renal function was undisturbed.

Electrocardiograms were uniformly normal. The subject who had previously shown a "positive" Harvard Step Test exhibited no changes in the S-T segment of his electrocardiograms during the entire run.

During the run, the subjects soon became bored with the performance task, as such, and found unique ways to "beat" the programmer and scoring units to improve their score. On the problem task, they were successful. All of the subjects improved their scores on all five elements. Figure 8 shows the results of four of the five elements for a typical subject.

Dark adaptation showed a decrease in rate and final sensitivity at 17° nasal retinal field (Figure 9). This was, of course, done without control studies, as the discovery was made during the run. If one is to accept the implications from this small series at face value, one would conclude that some mechanism interferes with the normal process of rhodopsin formation (44). Visual disturbances have been noted in the past (45, 46) under oxygen at 2 atmospheres, but not at reduced barometric pressure. Until these facts are understood more completely, no conclusion may be drawn. However, a study of the effects of oxygen on the enzymes of vision seems warranted.

Finally, from the data and observations made during this study, no evidence was obtained to indicate that any physiological detriment of operational significance would be suffered by astronauts exposed to these conditions.

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TABLE I

BLOOD GAS ANALYSES

| Control Period $P_aO_2$ | | | | Control Period $P_aCO_2$* | | | 14-Day Study 100% $O_2$ - 27,000' | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100% $O_2$ | | | 100% $O_2$ | | | | | | |
| Subj. | Ambient+ | Sea Level | 27,000' | Ambient+ | Sea Level | 27,000' | Subj. | $P_aO_2$ | $P_aCO_2$* | % Sat. | Shunt° |
| 6 | 80.0 | 580 | | 37 | ž | | 1 | 131 | 32.5 | 98.6 | 5.1 |
| 7 | 76.5 | 428 | | 40.7 | 43.4 | | 2 | 142 | 30 | 99 | 3.3 |
| 5 | 89.0 | 598 | | 37.6 | 34.2 | | 3 | 147 | 34.2 | 99 | 2.5 |
| 4 | 78.0 | 536 | | 35.5 | ž | | 4 | 130 | 40.1 | 98.3 | 5.2 |
| 8 | 87.6 | ž | | 38.5 | ž | | 1 | 153 | 41.5 | 99 | 1.6 |
| 3 | 87.5 | 563 | | 38.8 | ž | | 5 | 134 | 42.5 | 98.8 | 4.6 |
| 2 | 87.5 | 525 | | ž | 29 | | 2 | 148 | 35.5 | 99 | 2.4 |
| 1 | 90.5 | 560 | | 37.5 | 37.6 | | 6 | 138 | 34 | 98.7 | 3.9 |
| 6 | 93.5 | 530 | 150 | 36.5 | 39.6 | 36.4 | 4 | 138 | ž | 99 | 3.9 |
| 4 | 90.0 | 634 | 160 | ž | ž | ž | 5 | 143 | 39.4 | 98.7 | 3.2 |
| 7 | 93.0 | 674 | 173 | 41.2 | 38.0 | 38.0 | 6 | 141 | 35.5 | 99 | 3.4 |
| 5 | 85.0 | 624 | 151 | 35.5 | 40.8 | 39.0 | 1 | 157 | 37.5 | 99 | .9 |
| 8 | 87.4 | 546 | 156 | 40.5 | 39.0 | 37.5 | 2 | 146 | 35 | 99 | 2.7 |
| 1 | 85.6 | 569 | 148 | 37.3 | ž | 35.0 | 3 | 153 | 36.5 | 99 | 1.6 |
| 3 | 87.5 | 630 | 151 | ž | ž | ž | 4 | 139.5 | 32.9 | 98 | 3.5 |
| 2 | 96.5 | 535 | 173 | ž | 29.0 | ž | 1 | 145.5 | 37.7 | 99 | 2.7 |
| | | | | | | | 5 | 126.5 | 39.9 | 98.5 | 5.6 |
| $\bar{x}$ | 87.2 | 568 | 157.8 | 38.1 | 36.7 | 37.2 | 2 | 135.5 | 39.8 | 98.8 | 4.3 |
| | | | | | | | 6 | 128 | 34.3 | 98.6 | 5.5 |
| $\sigma$ | ±7.8 | ±56 | ±18.7 | ±1.8 | ±4.6 | -- | 3 | 157 | 34.5 | 99 | .9 |
| | | | | | | | 5 | 135 | ž | 98.8 | 4.4 |
| | | | | | | | 3 | 148 | 32.5 | 99 | 2.4 |
| | | | | | | | 4 | 136 | 37.5 | 98.7 | 4.3 |
| | | | | | | | $\bar{x}$ | 142 | 36.2 | 98.8 | 3.3 |
| | | | | | | | $\sigma$ | ±8.5 | ±3.3 | -- | ±1.0 |

* = Vol. % $CO_2$ from Van Slyke and Kopp Natelsons were used to calculate $P_aCO_2$, utilizing the equation

$$pH = pk_1 + \log\left[\frac{\text{Vol. \%}}{.1316 \quad PCO_2} - 1\right]$$

+ = Average barometric pressure for series at ACEL - 755-760 mmHg.

° = Shunts calculated using Briscoe's formula for denitrogenated man.

°(1) $$\frac{Qs}{Qt} = \frac{P_AO_2 - P_aO_2}{5 \text{ Vol. \%}} \times \left[\frac{\alpha}{760} + \text{Capacity} \times \frac{ds}{dPO_2}\right]$$

°(2) Calculation of shunt is overestimated due to negation of 6-10 mmHg. $PN_2$ in the atmosphere breathed.

ž = Sample lost

TABLE I

BLOOD GAS ANALYSES (CONTINUED)

| Subj. | Post Re-Entry Subjects $P_aO_2$ 100% $O_2$ SL | $P_aO_2$ Air+ | $P_aCO_2$ 100% $O_2$ SL | Air | Blood pH Air | 100% $O_2$ SL | 27,000' | Test | Post Re-Entry Subjects | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 575 | 85 | 40.6 | 44.4 | 7.312 | 7.355 | | 7.447 | 7.460 | 7.420 |
| | | | | | .405 | .390 | | .485 | .408 | .415 |
| 2 | 470 | 76 | 46.3 | 47.8 | .420 | .450 | | .440 | .380 | .416 |
| | | | | | .425 | .380 | | .380 | | |
| 3 | 604 | 85 | 45.0 | 51.8 | .420 | .410 | | .425 | Post Re-Entry Controls | |
| | | | | | .418 | .440 | | .420 | .410 | .480 |
| | Control Subjects | | | | .420 | .500 | | .447 | .480 | .453 |
| 7 | 468 | 112 | 43.5 | 43.0 | .410 | .420 | | .412 | .404 | .374 |
| | | | | | .432 | .410 | 7.432 | .472 | | |
| 8 | 460 | 113 | 42.8 | 43.8 | .432 | .440 | .425 | .395 | | |
| | | | | | .400 | .420 | .420 | .470 | | |
| 7 | 508 | 115 | 38.8 | 37.5 | .420 | .420 | .419 | .418 | | |
| | | | | | .431 | .430 | .430 | .450 | | |
| | | | | | .406 | .425 | .412 | .415 | | |
| | | | | | .430 | .430 | .458 | .461 | | |
| | | | | | .494 | .480 | .480 | .420 | | |
| | | | | | | | | .423 | | |
| | | | | | | | | .423 | | |
| | | | | | | | | .450 | | |
| | | | | | | | | .452 | | |
| | | | | | | | | .423 | | |
| | | | | | | | | .465 | | |
| | | | | | | | | .418 | | |
| | | | | $\bar{x}$ | 7.425 | 7.425 | 7.434 | 7.435 | | |
| | | | | $\sigma$ | ±0.03 | ±0.04 | ±0.03 | ±0.06 | | |

TABLE II

VITAL CAPACITY

| Subj. | Pre-Run $VC_o$ | 27,000' 14-Day Test $VC_o$ | Post-Run $VC_o$ |
|---|---|---|---|
| 1 | 5.320L | 5.120±.267L | 5.260L |
| 2 | 5.900L | 5.640±.140L | 5.650L |
| 3 | 5.300L | 5.300±.230L | 5.140L |
| 4 | 5.580L | 5.450±.280L | LOST DUE TO FIRE |
| 5 | 7.320L | 7.180±.160L | |
| 6 | 5.430L | 5.060±.280L | |
| $A_1$ | 5.740L | | |
| $A_2$ | 5.480L | | |

TABLE III

HEMOGLOBIN - HEMATOCRIT

| Subj. | Hemoglobin (Grams) Control | Test | Post | Hematocrit (%) Control | Test | Post |
|---|---|---|---|---|---|---|
| 1 | 14.5±.2 | 13.4±.2 | -- | 43.2±1.3 | 40.8± .6 | -- |
| 2 | 14.5±.3 | 14.0±.2 | 14.9± .7 | 44.4±1.1 | 42.2± .5 | 44.5±2.3 |
| 3 | 14.1±.5 | 13.0±.2 | 13.6±1.0 | 43.2±1.6 | 40.1± .6 | 41.5±1.7 |
| 4 | 15.2±.3 | 13.7±.2 | 14.2± .2 | 45.6± .7 | 41.5± .5 | 43.0±1.2 |
| 5 | 16.5±.4 | 14.8±.4 | -- | 46.4±1.6 | 44.5±1.8 | -- |
| 6 | 15.9±.4 | 13.9±.3 | -- | 47.2±1.0 | 41.4± .7 | -- |
| $\bar{X}$ | 15.1±.3 | 13.8±.3 | 14.2± .4 | 45.0± .7 | 41.7± .6 | 43.0± .9 |
| Controls | | | | | | |
| 7 | 13.4±.2 | 13.2±.2 | 12.9±0 | 43.0± .7 | 40.8± .9 | 41.0±2.8 |
| 8 | 14.4±.2 | 13.8±.1 | 14.1± .4 | 47.5± .5 | 43.5± .7 | 45.5± .7 |

TABLE IV

CELL COUNTS AND SEDIMENTATION RATE

| Subj. | White Blood Cells x $10^3$ Pre | Test | Post | Red Blood Cells x $10^6$ Pre | Test | Post | Platelets x $10^3$ Pre | Test | Post |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.3±.44 | 9.4 ± .89 | | 4.82±.4 | 4.63±.08 | | 302±30 | 380±44 | |
| 2 | 6.6±.61 | 7.1 ± .46 | 6.2 | 5.27±.2 | 5.0 ±.11 | 5.18 | 244±44 | 356±21 | 169 |
| 3 | 7.0±.84 | 7.7 ± .77 | 7.2 | 5.1 ±.25 | 4.35±.34 | | 267±16 | 320±30 | |
| 4 | 5.8±.51 | 7.0 ± .52 | 6.6 | 4.7 ±.2 | 5.0 ±.19 | 4.67 | 292±13 | 447±54 | 250 |
| 5 | 5.8±.47 | 7.0 ± .87 | | 4.46±.2 | 4.95±.13 | | 240±6 | 420±52 | |
| 6 | 6.8±.35 | 10.5 ±1.04 | | 4.71±.08 | 4.6 ±.16 | | 300±11 | 413±43 | |
| $\bar{X}$ | 6.4±.2 | 8.12± .60 | 6.7±.9 | 4.84±.12 | 4.76±.11 | 4.93±.3 | 274±11.4 | 389.3±12.7. | 209.5±48 |
| 7 | 6.5±.31 | 9.4 ±1.3 | 7.5 | 4.55±.2 | 4.92±.07 | 5.7 | 247±10 | 374±44 | 400 |
| 8 | 6.0±.97 | 6.1 ± .33 | | 4.84±.05 | 5.42±.06 | | 302±11 | 506±11 | |

| Subj. | Reticulocytes% Pre | Test | Post | Sedimentation Rate Pre | Test | Post |
|---|---|---|---|---|---|---|
| 1 | 0.67 | 0.50 | | 5.2±1.3 | 12.4± .4 | |
| 2 | 0.25 | 0.43 | .6 | 2.8± .9 | 2.4± .3 | 1.5 |
| 3 | 0.25 | 0.75 | | 1.6± .2 | 3.1± .6 | 4 |
| 4 | 0.40 | 0.25 | 0.70 | 4.4± .9 | 5.1±1.2 | 4.7 |
| 5 | 1.60 | 0.50 | | 1.0±0 | 1.5± .3 | |
| 6 | 0.60 | 0.60 | | 6.1±1 | 3.1±1 | |
| $\bar{X}$ | .63±.2 | .51±.2 | .65±.1 | 3.5± .8 | 4.6±1.6 | 3.4±1.0 |
| 7 | 1.16 | 0.60 | 1.1 | 12.5±2.1 | 19.6±3.7 | 20* |
| 8 | 0.4 | 0.25 | | 1.6 | 2.6± .7 | |

*Subject had an abscessed tooth extracted near end of experimental period

TABLE V

DIFFERENTIAL COUNT

| Subj. | Neutrophils % Pre | Neutrophils % Test | Neutrophils % Post | Lymphocytes % Pre | Lymphocytes % Test | Lymphocytes % Post | Monocytes % Pre | Monocytes % Test | Monocytes % Post |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 54.8±3.4 | 69.2±1.6 | | 36.2±4.1 | 24.2±1.1 | | 6.0±1.2 | 4.2±0.3 | |
| 2 | 52.2±2.4 | 54.2±3.3 | 52 | 41.2±1.8 | 38.2±1.8 | 38 | 3.0±1.3 | 3.5±1.1 | 5.5 |
| 3 | 50 ±5.1 | 48.2±2.7 | 55 | 43.8±4.7 | 44.8±2.7 | 35 | 4.5±0.5 | 2.2± .9 | 2.5 |
| 4 | 50.8±2.1 | 51.9±2.8 | 55 | 38.0±2.0 | 40.5±2.3 | 38 | 6.8±1.8 | 3.8±1.2 | 5.5 |
| 5 | 49 ±2.7 | 63.2±1.9 | | 40.6±1.8 | 30.8± .6 | | 5.6±1.2 | 3.5±1.3 | |
| 6 | 55.6±2.8 | 61.4±1.7 | | 36.4±3.7 | 32.4±2.6 | | 5.6±1.6 | 4.2±1.2 | |
| $\bar{X}$ | 52.5±1.1 | 58 ±3.2 | 53.5±1.5 | 39.4±1.2 | 35.2±2.5 | 37.0±1.0 | 5.2±0.5 | 3.7±0.3 | 4.5±.3 |
| 7 | 52 ±1.0 | 61.2±3.0 | 63.0 | 33.7±2.9 | 31.8±3.8 | 28.5 | 4.7±0.5 | 3.8±1.9 | 4.5 |
| 8 | 47.6±2.4 | 49.2±3.4 | 45.0 | 44.6±2.2 | 43.6±2.8 | 45.0 | 4.8±0.5 | 3.8±1.8 | 6.0 |

| Subj. | Eosinophils % Pre | Eosinophils % Test | Eosinophils % Post | Basophils % Pre | Basophils % Test | Basophils % Post |
|---|---|---|---|---|---|---|
| 1 | 5.3±1.0 | 1.4±0.6 | | 0.7±0.3 | 0.5±0.5 | |
| 2 | 2.8±0.9 | 1.6±0.4 | 3.5 | 0.2±0.3 | 0.4±0.3 | 0 |
| 3 | 1.2±0.7 | 1.5±0.5 | 1.5 | 0.2±0.3 | 0.8±0.4 | 0 |
| 4 | 4.0±0.9 | 2.0±0.5 | 2.0 | 0.4±0.3 | 0.2±0.2 | 1 |
| 5 | 2.8±0.7 | 2.0±0.8 | | 1.6±0.9 | 0.5±0.2 | |
| 6 | 1.4±0.7 | 1.6±0.3 | | 0.6±0.4 | 0.6±0.4 | |
| $\bar{X}$ | 2.9±0.7 | 1.7±0.3 | 2.3±0.9 | 0.6±0.2 | 0.5±0.1 | 0.33±0.66 |
| 7 | 7.2±1.8 | 2.6±0.3 | 2.5 | 1.2±0.4 | 0.6±0.6 | 1.5 |
| 8 | 5.4±0.5 | 4.2±0.8 | 4.5 | 0.4±0.4 | 0.2±0.2 | 0.5 |

TABLE VI

BLOOD CHEMISTRY, GLUCOSE, BILIRUBIN, AND BLOOD UREA NITROGEN

| Subj. | Glucose Pre | Glucose Test | Glucose Post | Bilirubin Pre | Bilirubin Test | Bilirubin Post | Blood Urea Nitrogen Pre | Blood Urea Nitrogen Test | Blood Urea Nitrogen Post |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 88. ±4.0 | 90.8 ±3.1 | -- | I" 0.136±0.08<br>T 0.66 ±0.13 | I" 0.068±0.03<br>T 0.45 ±0.16 | I" --<br>T -- | 12.0±0.7 | 10.8±0.5 | -- |
| 2 | 82.7±3.1 | 91.7 ±4.0 | 78 | I" 0.09 ±0.13<br>T 0.40 ±0.4 | I" 0.1 ±0.066<br>T 0.43 ±0.3 | I" 0.095<br>T 0.25 | 14.5±0.7 | 13.3±0.5 | 15 |
| 3 | 89.8±4.4 | 89.5 ±5.4 | 76 | I" 0.07 ±0.09<br>T 0.52 ±0.4 | I" 0.09 ±0.05<br>T 0.32 ±0.12 | I" 0.07<br>T 0.25 | 15.3±1.1 | 16.0±0.5 | 18 |
| 4 | 79.7±1.7 | 84.0 ±5.3 | 69 | I" 0.11 ±0.11<br>T 0.34 ±0.33 | I" 0.12 ±0.12<br>T 0.62 ±0.4 | I" 0.045<br>T 0.40 | 13.0±0.6 | 12.0±0.7 | 10 |
| 5 | 84.2±2.8 | 84.0 ±1.5 | -- | I" 0.09 ±0.12<br>T 0.84 ±0.6 | I" 0.11 ±0.09<br>T 0.61 ±0.24 | I" --<br>T -- | 11.5±1.2 | 11.5±1.2 | -- |
| 6 | 83.7±5.0 | 81.8 ±3.4 | -- | I" 0.09 ±0.08<br>T 0.76 ±0.48 | I" 0.08 ±0.08<br>T 0.78 ±0.96 | I" --<br>T -- | 13.8±0.7 | 12.2±0.6 | -- |
| $\bar{X}$ | 84.7±1.5 | 86.97±1.7 | 74.3 | I" 0.096± .001<br>T 0.59 ±0.02 | I" 0.094± .001<br>T 0.54 ±0.01 | I" .07<br>T 0.30 | 13.4±0.6 | 12.6±0.8 | 14.3 |
| 7 | 80.3±1.8 | -- | -- | I" 0.094±0.05<br>T 0.56 ±0.28 | --<br>-- | --<br>-- | 12.9±0.3 | -- | -- |
| 8 | 79.1±1.8 | -- | -- | I" 0.134±0.09<br>T 0.54 ±0.29 | --<br>-- | --<br>-- | 12.7±0.5 | -- | -- |

TABLE VII

BLOOD CHEMISTRY, SODIUM POTASSIUM, AND CHLORIDE

| Subj. | Control Sodium | Control Potassium | Control Chloride | Test Sodium | Test Potassium | Test Chloride | Post* Sodium | Post* Potassium | Post* Chloride |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 134.2±2.7 | 4.2±0.1 | 102 ±4.0 | 138 ±2.9 | 4.4 ±0.1 | 95±1.0 | -- | -- | -- |
| 2 | 135 ±2.5 | 4.7±0.3 | 111 ±1.3 | 134.7±2.1 | 4.5 ±0.2 | 104±2.0 | 131.0 | 3.9 | 103 |
| 3 | 135.7±2.5 | 4.6±0.3 | 110 ±2.3 | 134.5±1.2 | 4.5 ±0.1 | 98±2.0 | 130.0 | 3.9 | 99 |
| 4 | 136.2±2.7 | 4.1±0.2 | 112 ±2.0 | 134.6±2.3 | 4.5 ±0.2 | 101±2.0 | 135.0 | 4.0 | 97 |
| 5 | 136.5±1.7 | 4.4±0.1 | 103 ±1.7 | 134.5±1.3 | 4.4 ±0.1 | 100±2.0 | -- | -- | -- |
| 6 | 136.3±2.4 | 4.4±0.03 | 101 ±5.3 | 134.4±1.2 | 4.4 ±0.2 | 102±2.0 | -- | -- | -- |
| $\bar{X}$ | 135.7±0.35 | 4.4±0.09 | 106.5±2.1 | 135.1±0.6 | 4.45±0.02 | 100±1.29 | 132±1.28 | 3.9±0.002 | 99.7±2.1 |
| 7 | 135.4±1.3 | 4.5±0.1 | 106 ±1.0 | | | | | | |
| 8 | 136.6±1.3 | 4.4±0.1 | 101 ±2.3 | | | | | | |

*Post-Run NaKdCl data obtained at U. S. Naval Hospital, Philadelphia

TABLE VIII

URINALYSIS AND CLEARANCE TESTS

| Subj. | Pre Urine | Pre Creatinine clearance* Plasma cleared ml/min | Test Urine | Post Urine | Post Creatinine clearance* Plasma cleared ml/min |
|---|---|---|---|---|---|
| 1 | Essent. Neg. | 130 | Neg. | Neg. | 110. |
| 2 | " " | 119 | " | " | 98 |
| 3 | " " | 138 | " | " | 128 |
| 4 | " " | 125 | " | " | |
| 5 | " " | 106 | " | " | |
| 6 | " " | 124 | " | " | |
| 7 | " " | 118 | " | " | 121 |
| 8 | " " | 93 | " | " | 115 |

*Normal range of plasma clearance 80 to 206 ml/min.

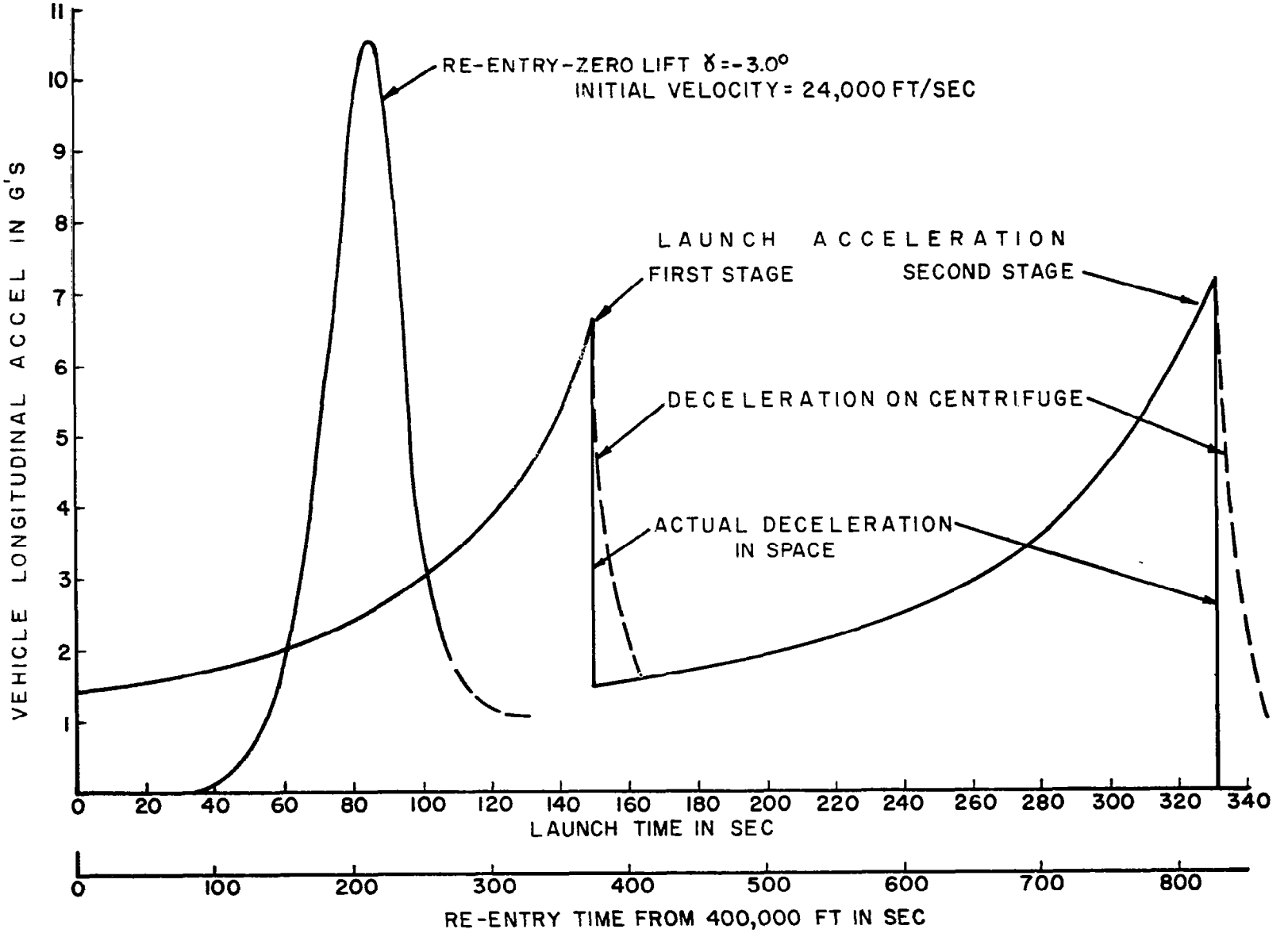
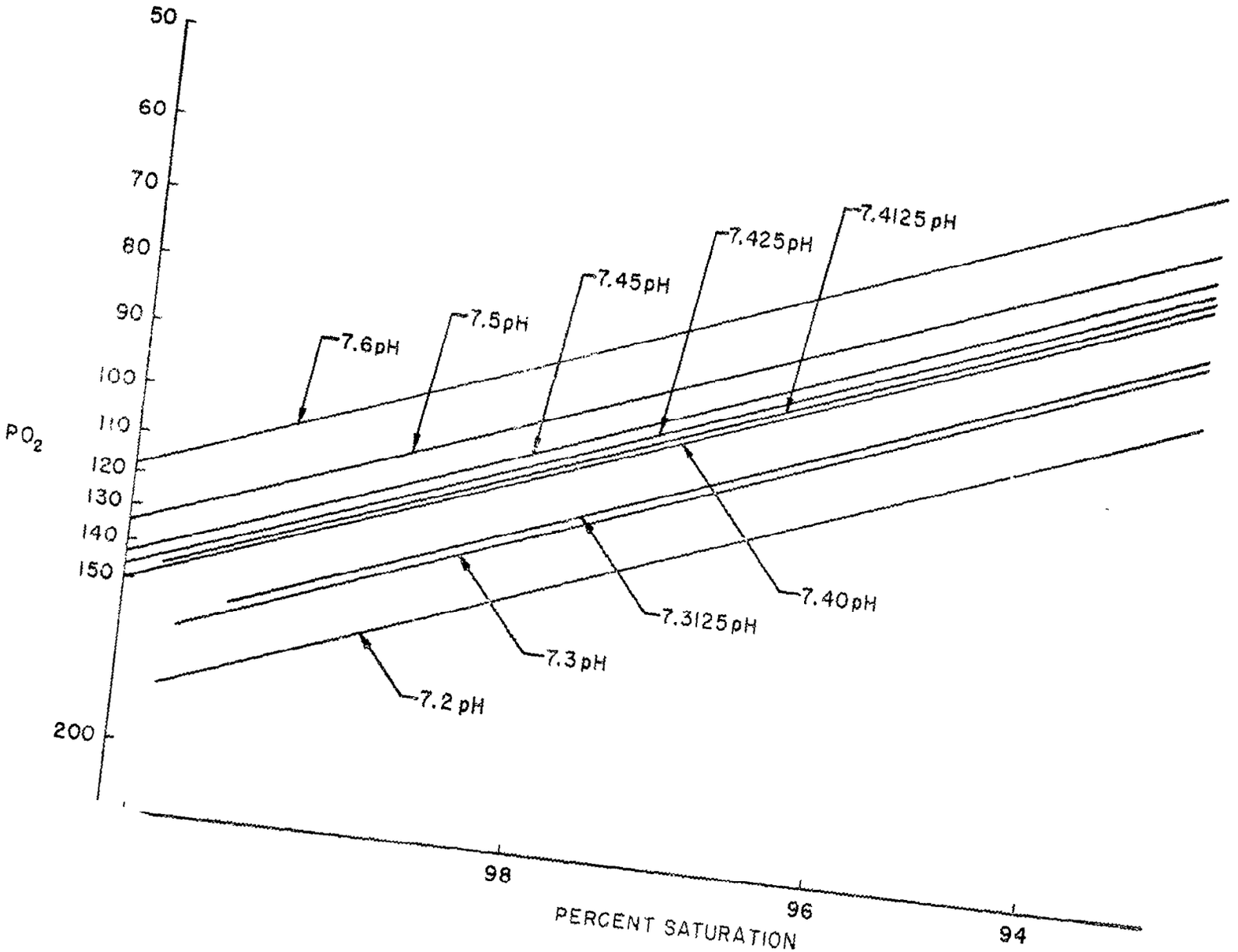



FIG. 1 GEMINI ACCELERATION PROFILES


50
60
70
80
90
100
110
120
130
140
150
200
$PO_2$
7.6pH
7.5pH
7.45pH
7.425pH
7.4125pH
7.40pH
7.3125pH
7.3pH
7.2pH
98
96
94
PERCENT SATURATION

NOMOGRAM

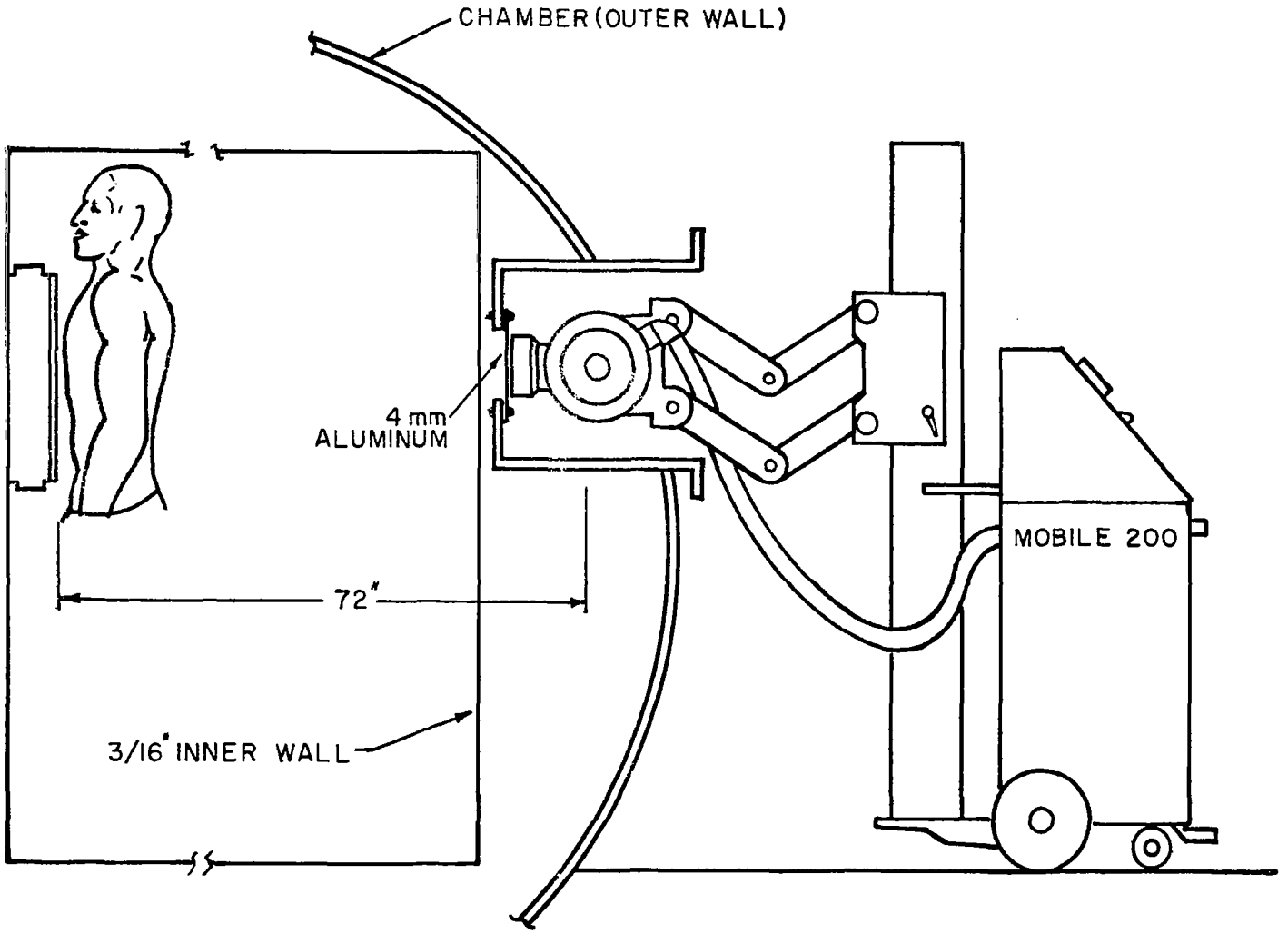



FIG. 3 X-RAY PORT

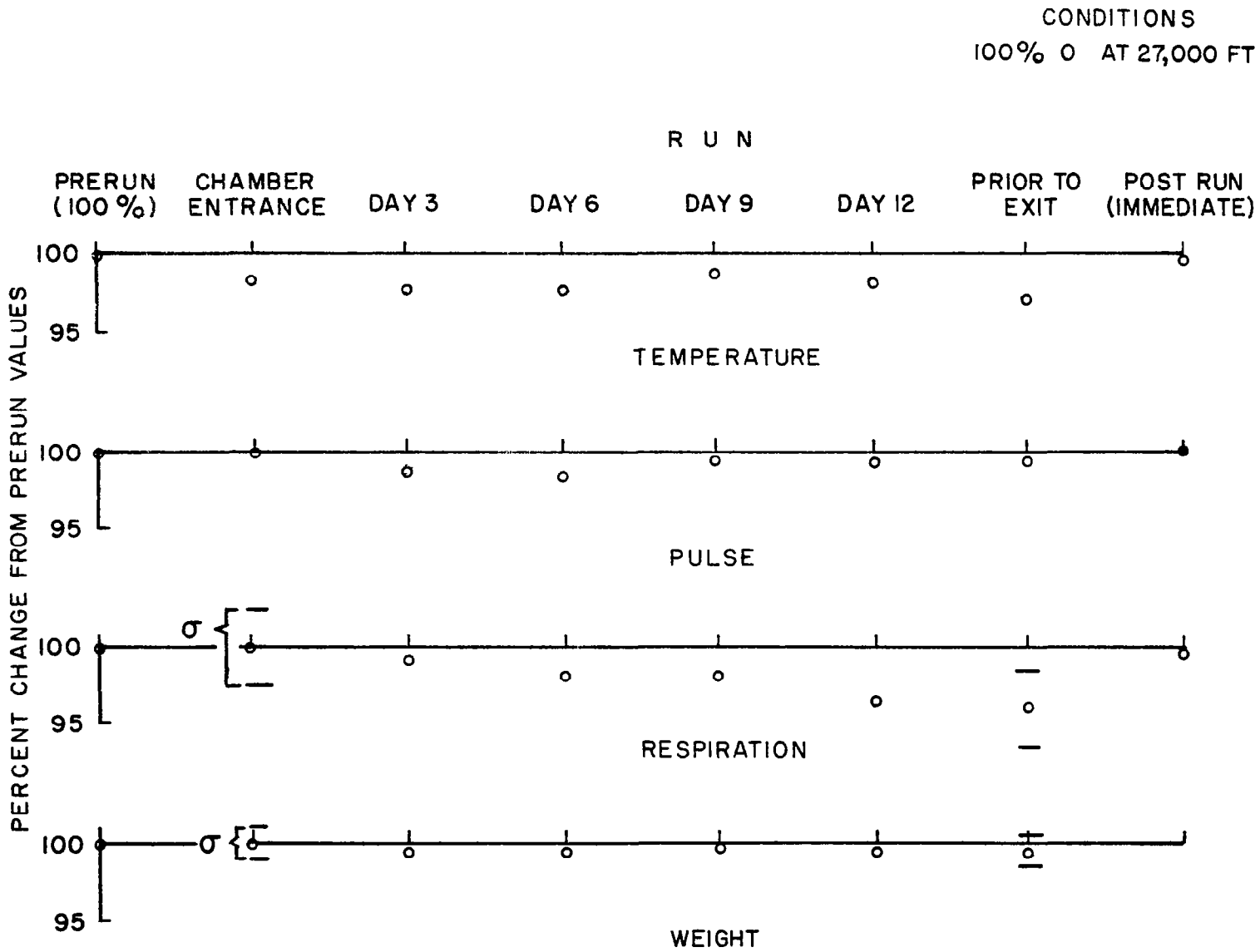



FIG. 4. VITAL SIGNS DURING 14 DAY SIMULATED SPACE FLIGHT

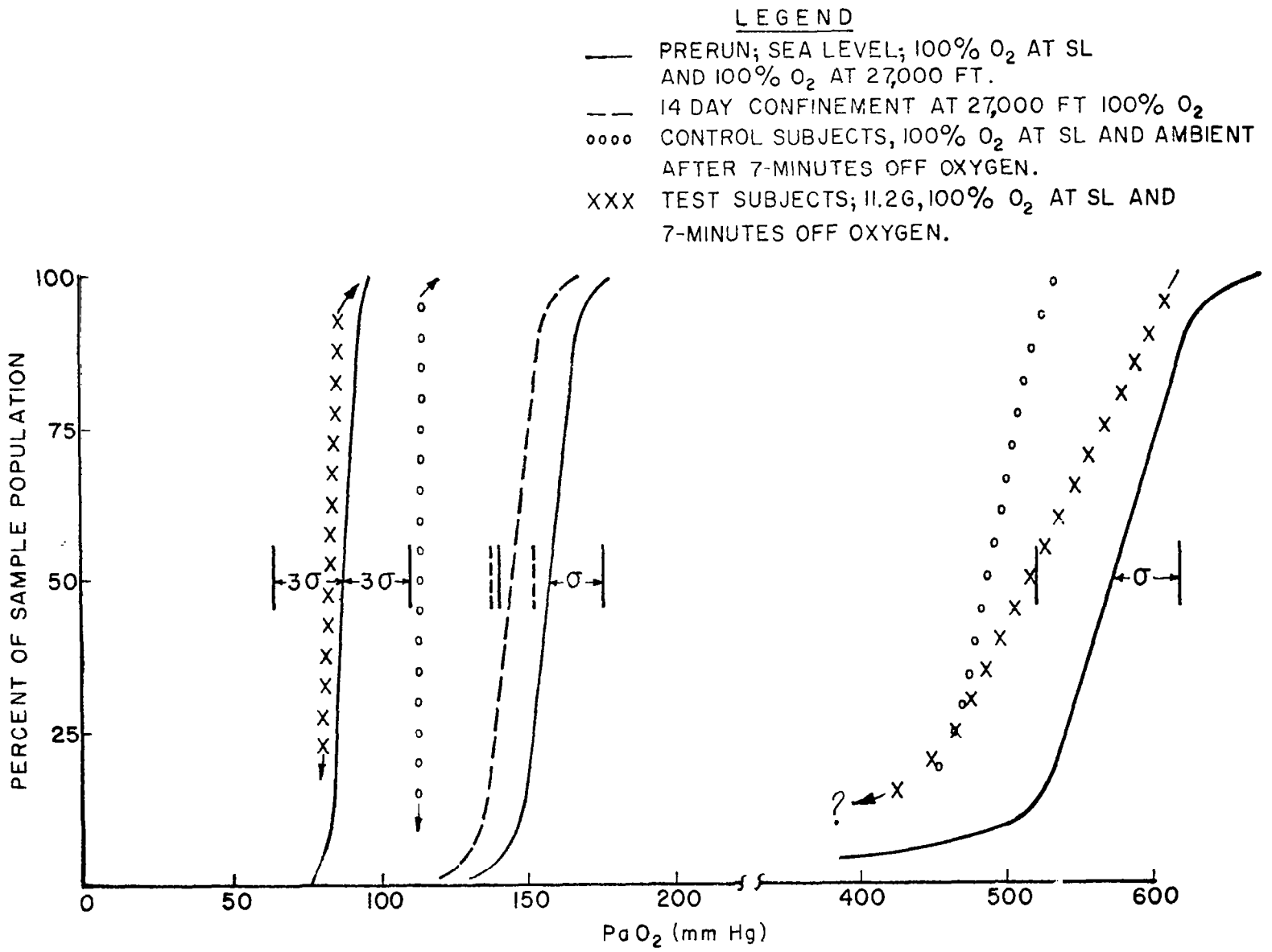



FIG. 5 ACCUMULATIVE FREQUENCY DISTRIBUTION OF ARTERIAL OXYGENTENSION UNDER VARIOUS TEST CONDITIONS STANDARD DEVIATIONS ONLY WHERE N>8

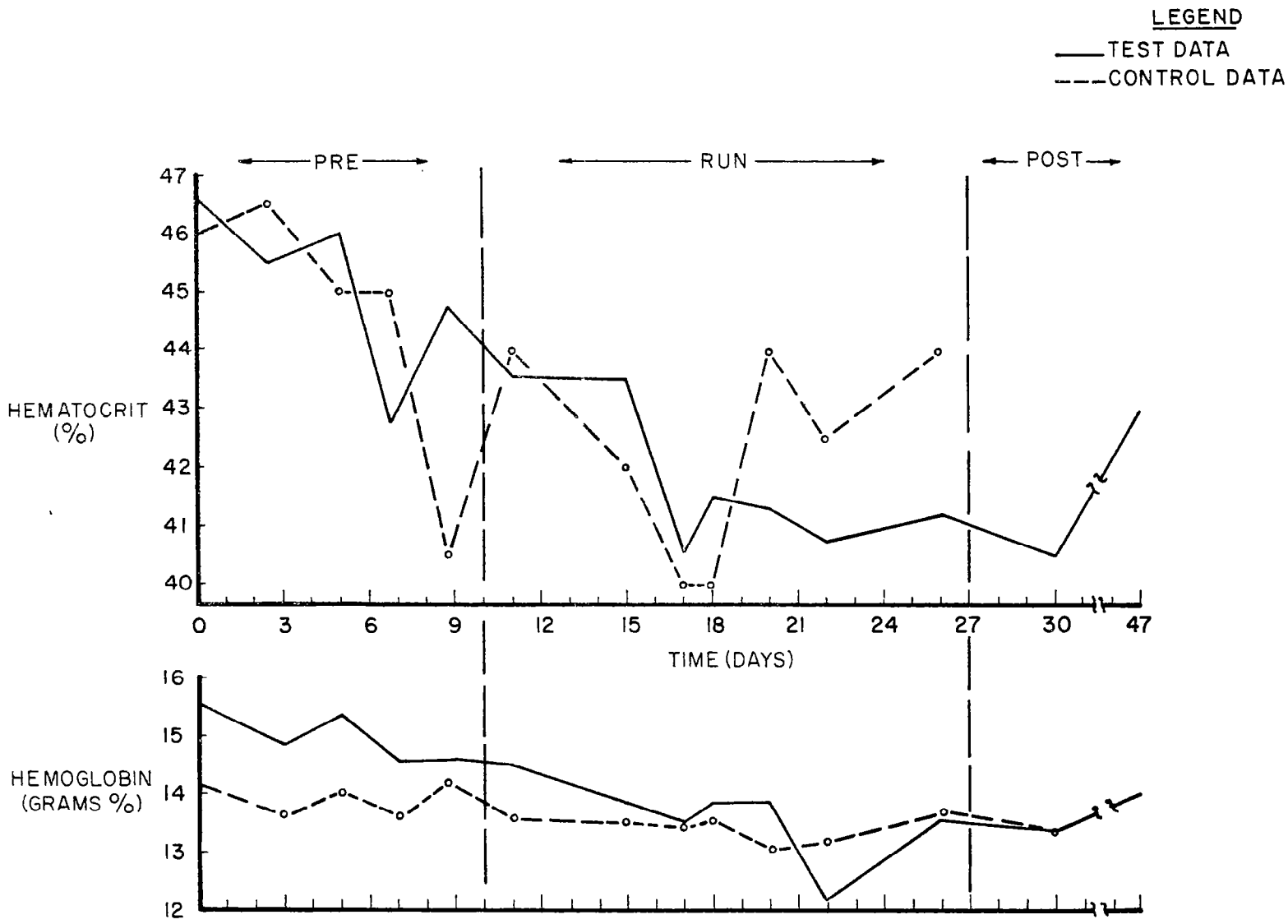



FIG. 6. AVERAGE HEMOGLOBIN & HEMATOCRIT VALUES OF SUBJECTS DURING SIMULATED ORBITAL FLIGHT INCLUDING PRE; POST-RUN PERIODS

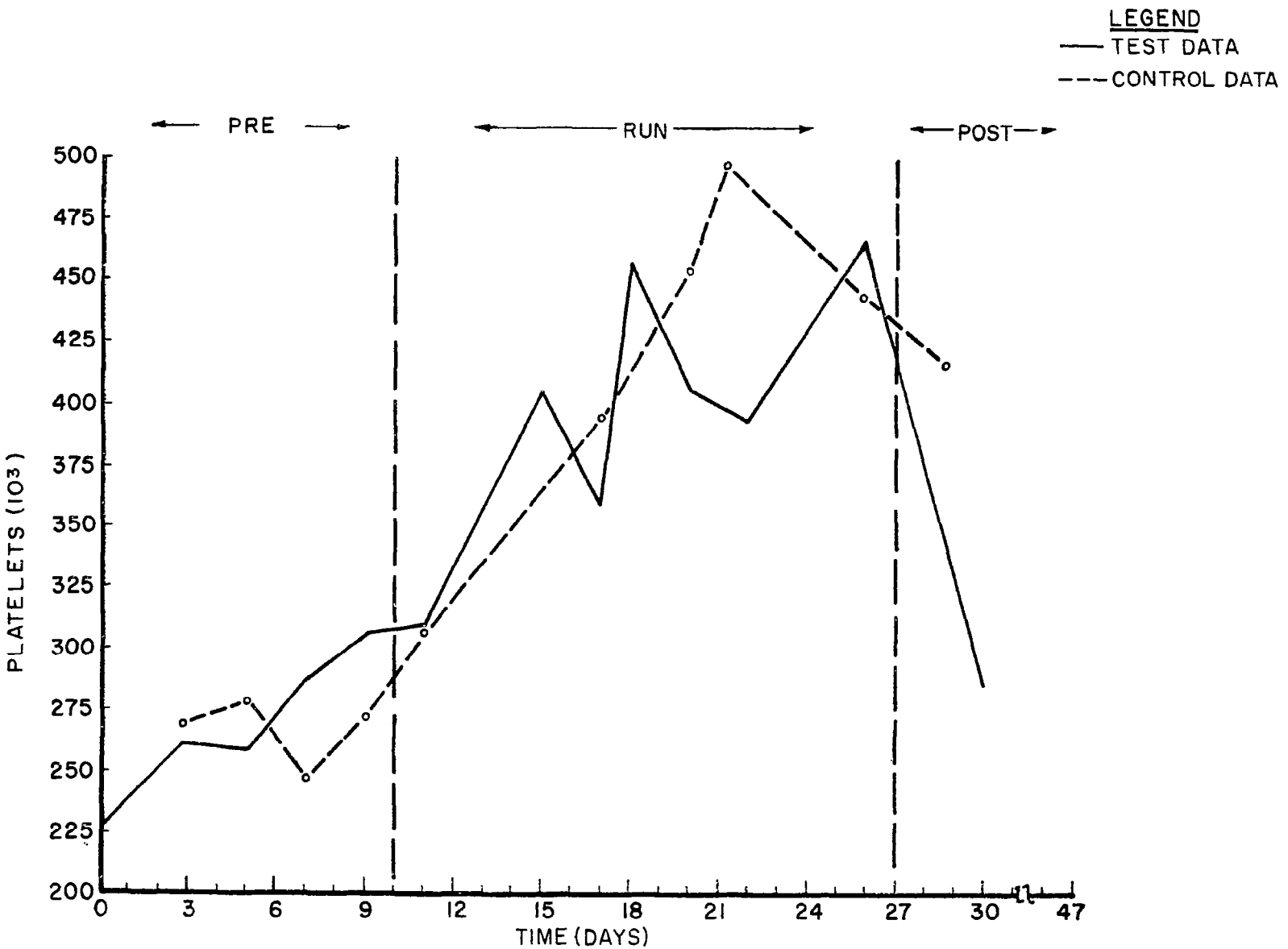



FIG 7. AVERAGE PLATELETS COUNTS OF SUBJECTS DURING SIMULATED ORBITAL FLIGHT INCLUDING PRE; POST-RUN PERIODS

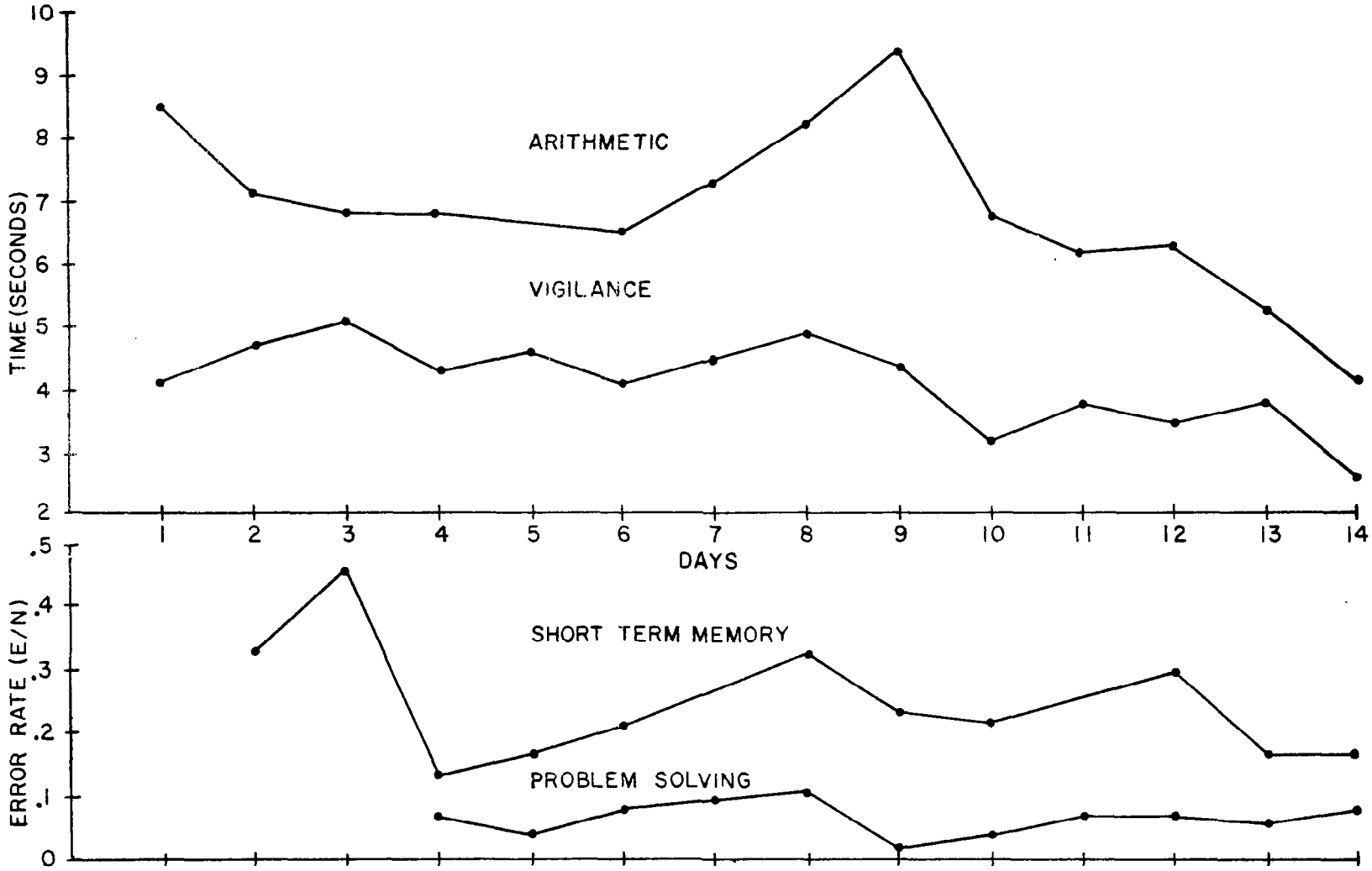



FIG. 8 RESULTS OF THE PERFORMANCE TASK FOR SUBJECT I (TYPICAL FOR ALL SUBJECTS)

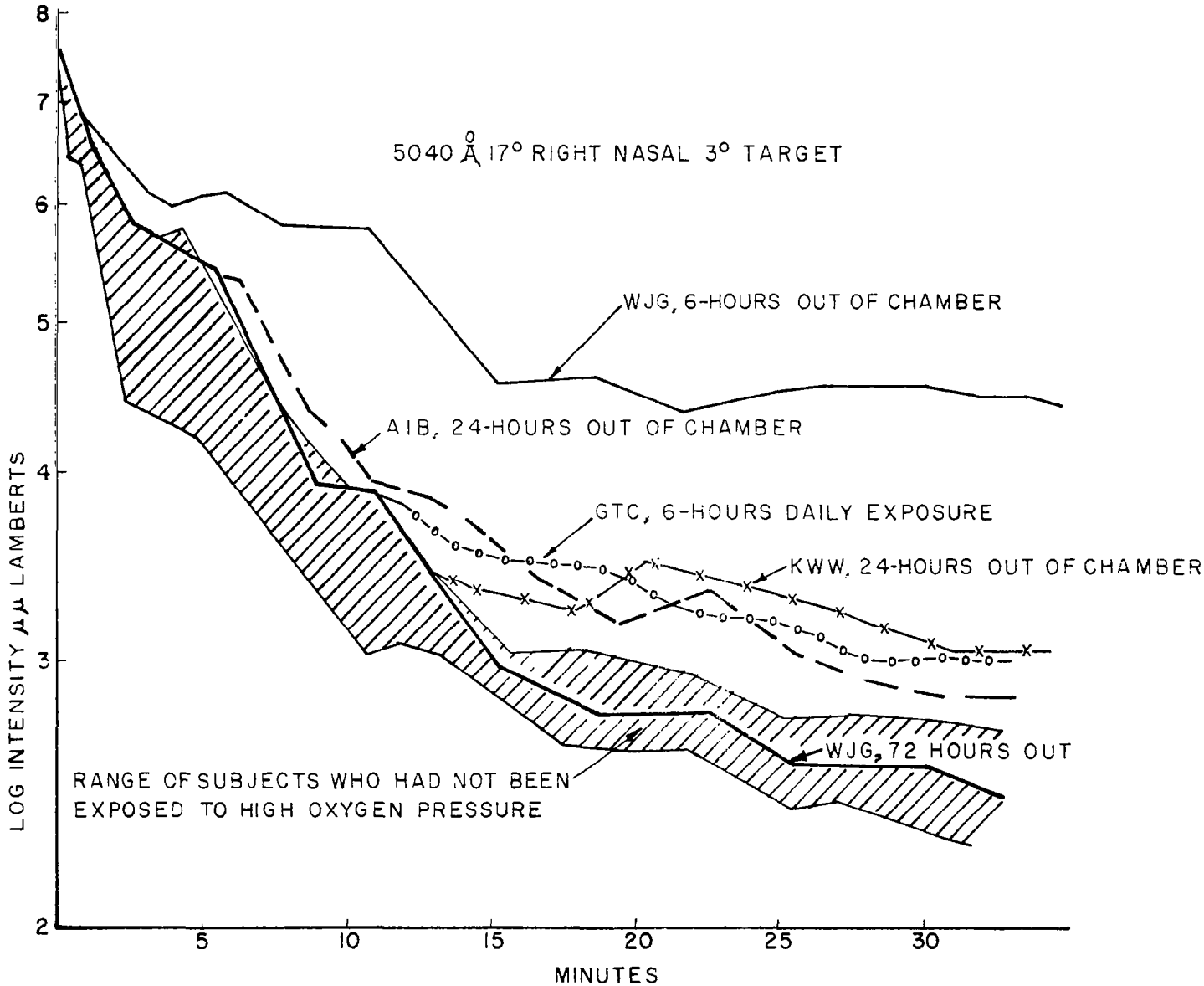



FIG. 9. POST RUN EVALUATION OF DARK ADAPTATION

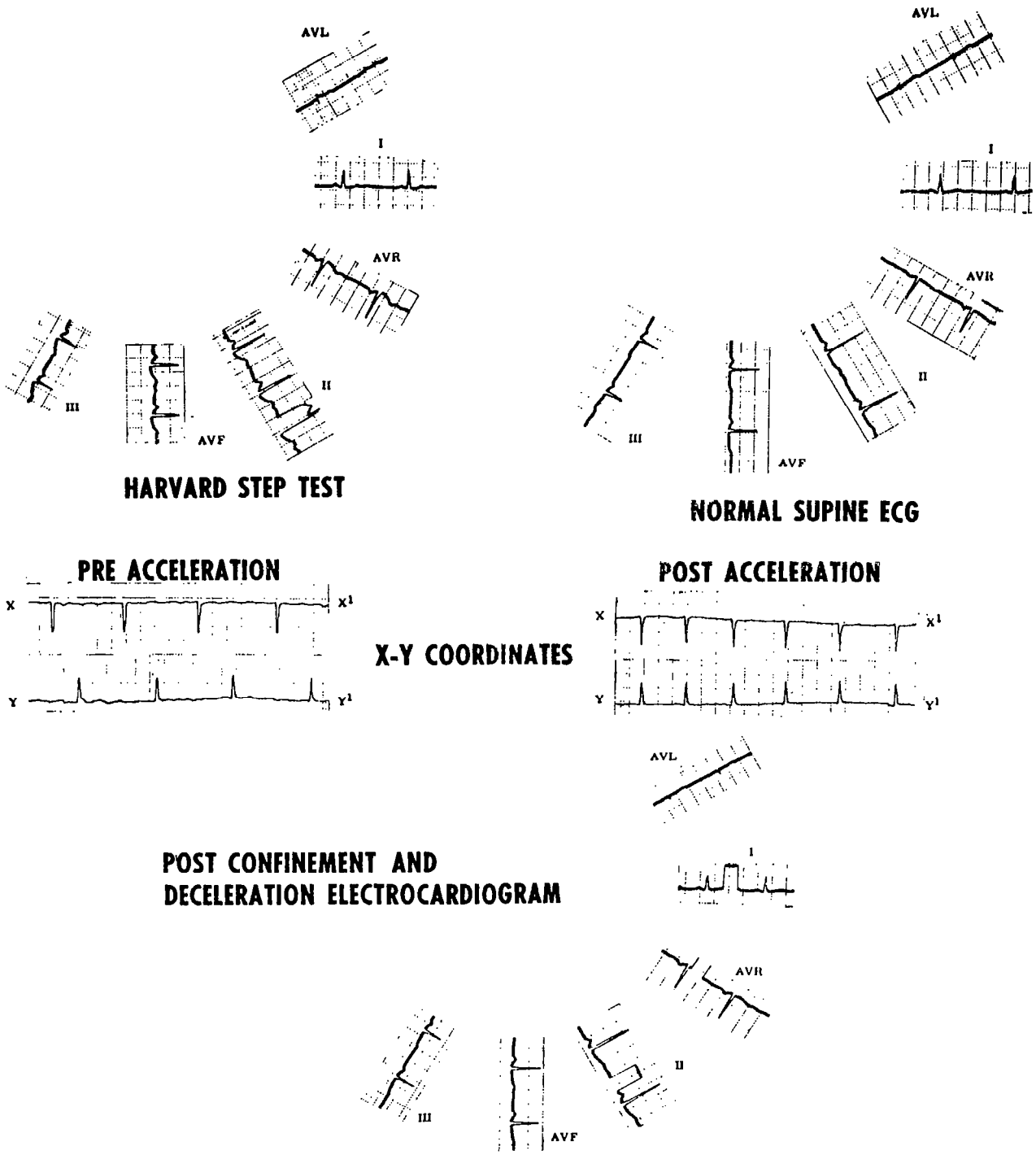



FIG. 10 ELECTROCARDIOGRAMS OF SUBJECT 3, SHOWING CHANGES OF ST SEGMENT DURING HARVARD STEP TEST AND NO ABNORMALITIES DURING ENTIRE SIMULATED SPACE PROFILE.

APPENDIX D-1

# NUTRITIONAL ASPECTS OF A DIET USED IN A STUDY OF A SIMULATED SPACE ENVIRONMENT

Thomas D. Hanna
Air Crew Equipment Laboratory, Naval Air Engineering Center,
Philadelphia 12, Pa.

The dehydrated foods used in this study were supplied by the Army Quartermaster Corps, Chicago, Illinois, through the Manned Spacecraft Center, National Aeronautics and Space Administration, Houston, Texas. All food items were packaged in cans, pouches, envelopes, or packets as shown in Tables 1 and 2. and were consumed directly from these containers with plastic utensils. In general, each container contained 1 serving of a given food item for one individual. Crackers, however, were bulk packed in 5 gallon cans, as were special dessert pieces which were supplied in cans containing 10 individual portions. Liquids were constituted with water from individual packets of powdered coffee, tea, cream, milk, cocoa, and fruit juices. The food items for each meal were individually assembled for each subject, placed in a paper bag, and delivered to the subject on a daily basis. Each bag contained a napkin, paper cups, packets of coffee, tea, sugar, cream, and plastic eating utensils which included a knife, fork, teaspoon, and soupspoon.

A master menu (Table 1) which repeated itself every 6 days was used throughout the study, except for minor modifications such as the substitution of fish items for meat items on Fridays, etc. The menu was administered beginning 3 days prior to the actual study (in order to obtain control values) until the termination of the study.

Instructions for preparing each of the food items were given orally to the subjects prior to the study by a physiologist who supplied the meals on a daily basis. In addition, techniques of preparation were demonstrated for representative food items. The subjects were each given a chart listing the amount and the temperature of the water to be added to the various food items. For example, the meat and vegetable items required boiling water for greatest acceptability, whereas most of the desserts, juices, and fruits required cold water. Some items, such as the cereals, puddings, prunes, apricots, and cocoa were prepared on a hedonic basis, i.e., the subject was able to choose between cold, hot, or boiling water for greater individual satisfaction.

Except for 4 items, all dehydrated foods were reconstituted by adding exactly 2, 3, 4, or 8 ounces of either cold, hot, or boiling water. Graduated beakers were made available for this purpose, since the amount of water used for reconstitution is critical to insure or increase palatability and acceptability.

The six subjects, a medical observer, and the two alternate subjects each subsisted during the study solely on the dehydrated foods. The daily menus varied from 2,053 to 2,285 Calories, as shown in Table 1, which also indicates the caloric value of each individual food item. Table 2 contains detailed

information for each food item such as the net weight, the amount of water required for reconstitution, the caloric content, the type of container, the frequency of appearance, and instructions for certain food substitutions during the course of the study. Water intake during the study was not limited.

Informal interviews and clinical observation which included the recording of uneaten food were used to assess food acceptability, palatability, and physical symptoms.

Initially, there were many complaints concerning individual food items, which became less frequent as the study progressed. While all subjects registered preferences for certain food items and encountered some initial hedonic distresses, it appears that both a physiological and psychological adjustment occurred.

Judging by unused foods, open interviews, and observations, the least desirable of all food items appeared to be scrambled eggs, Spanish rice, and milk. In general, these items became even less palatable as the study progressed. The most desirable items appeared to be cocoa, the fruit juices, puddings, and some of the fruits. Palatability of individual meat and vegetable items exhibited more variance among the subjects but were placed intermediate in hedonic judgments, i.e., they were not markedly "liked" or "disliked." The more acceptable items as well as the "neutral" items did not appear to become less palatable over time.

While there were some reports of loose bowel movements and constipation, no marked gastrointestinal changes occurred, such as heartburn, dryness of mouth, nausea, gas production, stomach cramps, halitosis, acid stomach, or vomiting. Daily interviews also revealed no symptoms of headache, weakness, insomnia, or drowsiness. These negative physical symptoms were accompanied by few comments concerning insufficient variety, inadequate bulk, objectionable or odoriferous items, or monotony of foods, although certain food items were definitely preferred over others. Changes in weight, urinalyses, metabolic and blood findings for the study are reported elsewhere in this report.

The food supply for extended aerospace missions should be nutritionally adequate, acceptable to the crew, easily prepared, possess minimum weight and volume, keep indefinitely without refrigeration, and be able to be consumed while wearing the full pressure (space) suit. Most conventional food items do not meet these requirements. Semisolid foods, or dehydrated foods which can be reconstituted with water, possess the above characteristics with the possible exception of overall acceptability of some food items. Furthermore, dehydrated foods may be packaged in toothpaste-type tubes which can be reconstituted and self administered while wearing the pressurized full pressure suit.

Accordingly, one of the major areas to be investigated appears to be that of palatability. It has been suggested (Ref. 1) that strangeness of food samples may lead to their relative rejection in the comparative absence

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Ref. 1. Seaton, R. W. and B. W. Gardner: *Acceptance measurement of unusual foods.* Food Research, 24:271-278, 1959.

of cues within which judgment may take place, i.e., a semiliquid, reconstituted food which under normal circumstances is solid may be rejected solely because of appearance. It also appears that when food is eaten directly out of opaque containers, such factors as appearance, texture, odor, and temperature become more dominant in its final evaluation. In one study using dehydrated foods (Ref. 2), it was found that overall satisfaction appeared to be less among those who were served preplanned meals than among those who planned their own menu cycles, even though the foods were the same. This could be the result of combining certain foods on a particular menu to give greater palatability. Thus, the objective of the nutritional phase of this study was largely to evaluate the palatability and acceptability of a variety of dehydrated food items and their effect on physical symptomatology.

When and if dehydrated foods are adopted for long term aerospace missions, it appears that a period of adjustment may be necessary to overcome some of the psychophysiological effects of this type of diet. This may indicate the integration of a dietary adjustment period on the use and consumption of dehydrated foods into the overall training program of future astronauts. Whereas the prolonged use of dehydrated foods may not produce adverse physiological effects on the digestive system, the initial psychological effects may have to be overcome. The acceptance of dehydrated foods will depend upon individual preferences, since an attitude toward a given food in its natural state tends to influence an individual's subjective preference for the same food in a dehydrated condition. It is even probable that a strong dislike for a particular dehydrated food by one individual may be found to be extremely satisfying to another individual.

It now appears that future astronauts will wear some type of space suit at least part of the time on prolonged missions. Feeding problems while wearing the suit in a weightless and hostile environment must be solved. It may be necessary to supply nourishment through the plastic facepiece of the protective garment. Dehydrated foods may be packaged in squeeze-type tubes to be kept indefinitely without refrigeration and yet be readily reconstituted with water.

Although survival is possible on a diet consisting solely of dehydrated foods, there is a lack of mastication. The intermittent use of chewing gum or hard food materials could perhaps alleviate this condition. This would also increase the variety and texture of the food items. It is doubtful that the dehydrated foods employed in this study or the feeding problems in themselves would necessitate aborting an aerospace mission of moderate duration. This represents another area of stress, however, which when summed with other stresses of space travel, may be sufficient to increase the overall stress beyond the tolerable limit. Additional research in the area of nutrition is needed before definitive answers may be evolved.

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Ref. 2. Kamen, J. R. and D. R. Peryam: Effects of repetitive eating of limited groups of food items on food acceptance. WADD Technical Report 60-750, December 1960.

TABLE I

30-DAY MENU CYCLE FOR NASA AIR CREW EQUIPMENT LABORATORY SIMULATOR TEST

(Figures represent approximate caloric value per one food portion)

10 Sept. 1962

| | Menu I | | Menu II | | Menu III | |
|---|---|---|---|---|---|---|
| Issued on: | Days 1, 7, 13, 19 and 25 | | Days 2, 8, 14, 20 and 26 | | Days 3, 9, 15, 21 and 27 | |
| BREAKFAST | Orange/Grapefruit Juice | 99 | Orange Juice | 96 | Orange Juice | 96 |
| | Allstar Cereal | 88 | Corn Chex | 126 | Frosted Flakes 1/ | 140 |
| | Scrambled Eggs | 165 | Beef Hash | 119 | Bacon | 177 |
| | Jelly (2) | 74 | Jelly (2) | 74 | Jelly | 37 |
| | Crackers | 155 | Crackers | 155 | Crackers | 155 |
| | Milk | 103 | Cocoa | 102 | Milk | 103 |
| | Coffee or Tea | | Coffee or Tea | | Coffee or Tea | |
| | | 684 | | 672 | | 708 |
| LUNCH | Chicken Rice Soup | 17 | Vegetable Soup | 32 | Beef Rice Soup | 24 |
| | Beef with Vegetables | 80 | Beef Pot Roast | 113 | Fish Creole | 139 |
| | Spanish Rice | 76 | Peas | 66 | Carrots in Cream Sauce | 141 |
| | Wax Beans in Cream Sauce | 57 | Rice | 101 | Crackers | 124 |
| | Apricots | 63 | Crackers | 124 | Jelly | 37 |
| | Crackers | 124 | Jelly | 37 | Pineapple 4a/ | 90 |
| | Jelly | 37 | Peaches | 84 | Cocoa | 102 |
| | Special Dessert - Coconut | 155 | Milk | 103 | Coffee or Tea | |
| | Cocoa | 102 | Coffee or Tea | | | |
| | Coffee or Tea | | | | | |
| | | 711 | | 660 | | 657 |
| DINNER | Orange Juice | 96 | Apricots | 63 | Orange/Grapefruit Juice | 99 |
| | Noodles w/Meat Sauce 7/ | 120 | Chicken with Gravy 8/ | 114 | Beef Pot Roast | 113 |
| | Lima Beans | 111 | Green Beans, Plain | 22 | Corn 2/ | 70 |
| | Mashed Potatoes | 73 | Potato Sticks | 155 | Diced Potatoes | 58 |
| | Crackers | 124 | Crackers | 124 | Crackers | 124 |
| | Jelly | 37 | Jelly | 37 | Jelly | 37 |
| | Chocolate Pudding | 97 | Special Dessert - Banana Solids | 138 | Special Dessert - Chopped Peanuts | 153 |
| | Coffee or Tea | | Fruitcake Bar | 180 | Pears 4/ Apricots | 80 |
| | | | Coffee or Tea | | Coffee or Tea | |
| | | 658 | | 833 | | 704 |
| | | 2053 | | 2165 | | 2069 |

TABLE 1
(Continued)

30-DAY MENU CYCLE FOR NASA AIR CREW EQUIPMENT LABORATORY SIMULATOR TEST

(Figures represent approximate caloric value per one food portion)

10 Sept. 1962

| | Menu IV | | Menu V | | Menu VI | |
|---|---|---|---|---|---|---|
| Issued on: | Days 4, 10, 16, 22 and 28 | | Days 5, 11, 17, 23 and 29 | | Days 6, 12, 18, 24 and 30 | |
| BREAKFAST | Orange/Grapefruit Juice | 99 | Prunes 5/ | 97 | Orange/Grapefruit Juice | 99 |
| | Oatmeal | 94 | Cream of Wheat/Cream of Rice | 90 | Ralston | 90 |
| | Scrambled Eggs | 165 | Beef Hash | 119 | Scrambled Eggs | 165 |
| | Jelly | 37 | Jelly (2) | 74 | Bacon | 177 |
| | Crackers | 155 | Crackers | 155 | Jelly | 37 |
| | Cocoa | 102 | Cocoa | 102 | Crackers | 155 |
| | Coffee or Tea | | Coffee or Tea | | Coffee or Tea | |
| | | 652 | | 637 | | 723 |
| LUNCH | Chicken Noodle Soup | 17 | Chicken Consomme | 5 | Consomme of Beef | 4 |
| | Meat Loaf with Gravy | 289 | Fish Creole 6/ | 139 | Beef Hash | 119 |
| | Lima Beans | 111 | W. K. Corn | 70 | Peas | 66 |
| | Diced Potatoes 10/ | 58 | Crackers | 124 | Crackers | 124 |
| | Crackers | 124 | Jelly | 37 | Jelly | 37 |
| | Jelly | 37 | Special Dessert - Candied Fruit | 192 | Fruitcake Bar | 180 |
| | Special Dessert - Orange & Almonds | 140 | Strawberries | 133 | Cocoa | 102 |
| | Milk | 103 | Milk | 103 | Coffee or Tea | |
| | Coffee or Tea | | Coffee or Tea | | | |
| | | 879 | | 803 | | 632 |
| DINNER | Beef with Vegetables | 80 | Orange/Grapefruit Juice | 99 | Fruit Cocktail 3/ | 59 |
| | Wax Beans in Cream Sauce | 57 | Beef w/Mushroom Gravy 9/ | 161 | Chicken with Gravy | 289 |
| | Rice with Gravy 11/ | 92 | Potato Sticks | 155 | Plain Green Beans | 22 |
| | Crackers | 124 | Tomatoes | 25 | Mashed Potatoes | 73 |
| | Jelly | 37 | Crackers | 124 | Crackers | 124 |
| | Starch Jelly Bar | 203 | Jelly | 37 | Jelly | 37 |
| | Coffee or Tea | | Special Dessert - Walnuts & Raisins | 144 | Special Dessert - Candied Orange Peel | 132 |
| | | | Butterscotch Pudding | 100 | Milk | 103 |
| | | | Coffee or Tea | | Coffee or Tea | |
| | | 593 | | 845 | | 839 |
| | | 2124 | | 2285 | | 2194 |

TABLE 1
(Continued)

1/ Substitute Frosty O's for Frosted Flakes on Day 27 (Breakfast).

2/ Substitute Cream Style Corn for W. K. Corn on Day 27 (Dinner).

3/ Substitute Apricots for Fruit Cocktail on Day 30 (Dinner).

4a/ Pineapple is one serving short and one can of pears is included for substitution (required for one person only).

4/ Substitute Applesauce for Pears on Days 15. 21 and 27 (Dinner).

5/ Substitute Peaches for Prunes on Days 23 and 29 (Breakfast).

6/ Substitute Chicken w/Rice for Fish Creole on Day 29 (Lunch).

7/ Substitute brown pouches of chicken & gravy for cans specified on Days 20 and 26 (Dinner).

8/ Substitute Beef w/Gravy on Day 23 and Beef Pot Roast on Day 29 for Beef w/Mushroom Gravy (Dinner).

9/ Substitute sweet potatoes for diced potatoes on day 26 (Lunch).

10/ Substitute rice (pouch) for rice w/gravy (cans) on day 28 (Dinner).

11/ Figures in parenthesis following crackers, and special dessert pieces denote number of crackers and dessert pieces per each serving.

QMASO Form 12-410
8 Feb 62

# TABLE 2

## MENUS FOR NASA AIR CREW EQUIPMENT LAB. SIMULATOR TEST (10 MEN - 30 DAYS)

(6 day cycle of menus - to be repeated 5 times)

9 Sept. 1962

| | Net Wt. (Grams) | Water Required | Calories | Breakfast | | | | | | Lunch | | | | | | Dinner | | | | | | Unit | No. of Units Supplied |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | I | II | III | IV | V | VI | I | II | III | IV | V | VI | I | II | III | IV | V | VI | | |
| | | (Oz.) | | | | | | | | | | | | | | | | | | | | | |
| Orange Juice | 28.35 | 8 | 96 | | 1 | 1 | | | | | | | | | | 1 | | | | | | Envelope | 150 |
| Orange/Grapefruit Juice | 28.35 | 8 | 99 | 1 | | | 1 | | 1 | | | | | | | | | 1 | | 1 | | Envelope | 250 |
| Allstar Cereal | 24.00 | 3 | 88 | 1 | | | | | | | | | | | | | | | | | | Can | 50 |
| Corn Chex | 33.00 | 3 | 126 | | 1 | | | | | | | | | | | | | | | | | Can | 50 |
| Frosted Flakes 1/ | 36.75 | 3 | 140 | | | 1 | | | | | | | | | | | | | | | | Can | 40 |
| Frosty O's 1/ | 21.00 | 3 | 81 | | | * | | | | | | | | | | | | | | | | Can | 10 |
| Oatmeal | 22.57 | 3 | 94 | | | | 1 | | | | | | | | | | | | | | | Can | 50 |
| Cream of Wheat 1a/ | 22.57 | 3 | 90 | | | | | 1 | | | | | | | | | | | | | | Can | 48 |
| Ralston | 22.57 | 3 | 90 | | | | | | 1 | | | | | | | | | | | | | Can | 50 |
| Cream of Rice 1a/ | 22.57 | 3 | 90 | | | | | * | | | | | | | | | | | | | | Can | 2 |
| Peas | 18.50 | 2½ | 66 | | | | | | | | 1 | | | | 1 | | | | | | | Pouch | 100 |
| Lima Beans | 30.00 | 3 | 111 | | | | | | | | | | 1 | | | | | | | | | Can | 50 |
| Lima Beans | 30.50 | 3 | 111 | | | | | | | | | | | | | 1 | | | | | | Pouch | 50 |
| Wax Beans in Cream Sauce | 15.00 | 3 | 57 | | | | | | | 1 | | | | | | | | | 1 | | | Can | 100 |
| W. K. Corn 2/ | 20.50 | 3 | 70 | | | | | | | | | | | 1 | | | | 1 | | | | Pouch | 90 |
| Cream Style Corn 2/ | 25.00 | 3 | 88 | | | | | | | | | | | | | | | * | | | | Can | 10 |
| Plain Green Beans | 7.00 | 3 | 22 | | | | | | | | | | | | | | 1 | | | | 1 | Can | 100 |
| Tomatoes | 9.00 | 3 | 25 | | | | | | | | | | | | | | | | | 1 | | Can | 50 |
| Carrots in Cream Sauce | 28.00 | 3 | 141 | | | | | | | | | 1 | | | | | | | | | | Can | 50 |
| Apricots 3/ | 23.40 | 2 | 63 | | | | | | | 1 | | | | | | | 1 | | | | * | Can | 110 |
| Fruit Cocktail 3/ | 14.80 | 3 | 59 | | | | | | | | | | | | | | | | | | 1 | Can | 40 |
| Pineapple 4a/ | 25.00 | 3 | 90 | | | | | | | | | 1 | | | | | | | | | | Can | 49 |

1/ Substitute Frosty O's for Frosted Flakes on Day 27 (Breakfast). 1a/ Cream of Wheat or Cream of Rice

2/ Substitute Cream Style Corn for W. K. Corn on Day 27 (Dinner).

3/ Substitute Apricots for Fruit Cocktail on Day 30 (Dinner).

4a/ Pineapple is one serving short and one can of pears is included for substitution (required for one person only).

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TABLE 2 (Continued)
MENUS FOR NASA AIR CREW EQUIPMENT LAB. SIMULATOR TEST (10 MEN - 30 DAYS)
(6 day cycle of menus - to be repeated 5 times)

9 Sept. 1962

| | Net Wt. (Grams) | Water Required | Calories | Breakfast I | Breakfast II | Breakfast III | Breakfast IV | Breakfast V | Breakfast VI | Lunch I | Lunch II | Lunch III | Lunch IV | Lunch V | Lunch VI | Dinner I | Dinner II | Dinner III | Dinner IV | Dinner V | Dinner VI | Unit | No. of Units Supplied |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Oz.) | | | | | | | | | | | | | | | | | | | | | |
| Pears 4a/ | 22.50 | 3 | 80 | | | | | | | | | * | | | | | | 1 | | | | Can | 21 |
| Applesauce 4/ | 18.60 | 3 | 66 | | | | | | | | | | | | | | | * | | | | Can | 30 |
| Prunes 5/ | 27.00 | 3 | 97 | | | | | 1 | | | | | | | | | | | | | | Can | 30 |
| Peaches 5/ | 23.00 | 3 | 84 | | | | | * | | | 1 | | | | | | | | | | | Can | 70 |
| Strawberries | 35.00 | 2 | 133 | | | | | | | | | | | 1 | | | | | | | | Pouch | 50 |
| | | | | | | | | | | | | | | | | | | | | | | | |
| Chicken Rice Soup | 8.00 | 3 | 17 | | | | | | | 1 | | | | | | | | | | | | Can | 50 |
| Vegetable Soup | 2.00 | 3 | 32 | | | | | | | | 1 | | | | | | | | | | | Can | 50 |
| Beef Rice Soup | 8.00 | 3 | 24 | | | | | | | | | 1 | | | | | | | | | | Can | 50 |
| Chicken Noodle Soup | 6.00 | 3 | 17 | | | | | | | | | | 1 | | | | | | | | | Can | 50 |
| Chicken Consomme | 2.00 | 3 | 5 | | | | | | | | | | | 1 | | | | | | | | Can | 50 |
| Beef Consomme | 10.00 | 3 | 4 | | | | | | | | | | | | 1 | | | | | | | Can | 50 |
| | | | | | | | | | | | | | | | | | | | | | | | |
| Fish Creole 6/ | 31.00 | 3 | 139 | | | | | | | | | 1 | | 1 | | | | | | | | Can | 90 |
| Chicken w/Rice 6/ | 32.00 | 3 | 118 | | | | | | | | | | | * | | | | | | | | Can | 10 |
| Beef w/vegetables | 19.00 | 3 | 80 | | | | | | | 1 | | | | | | | | | 1 | | | Can | 100 |
| Beef Hash | 28.35 | 3 | 119 | | 1 | | | 1 | | | | | | | 1 | | | | | | | Can | 150 |
| Noodles w/meat sauce | 26.00 | 3 | 120 | | | | | | | | | | | | | 1 | | | | | | Can | 50 |
| | | | | | | | | | | | | | | | | | | | | | | | |
| Chicken w/gravy 8/ | 30.00 | 3 | 114 | | | | | | | | | | | | | | 1 | | | | | Can | 49 |
| Chicken & gravy 8/ | 65.00 | 5 | 289 | | | | | | | | | | | | | | * | | | | 1 | Pouch | 51 |
| Beef Pot Roast 9/ | 24.00 | 3 | 113 | | | | | | | | 1 | | | | | | | 1 | | * | | Can | 110 |
| Beef w/Mushroom gravy 9/ | 36.00 | 3 | 161 | | | | | | | | | | | | | | | | | 1 | | Can | 30 |
| Beef w/gravy 9/ | 36.00 | 3 | 161 | | | | | | | | | | | | | | | | | * | | Can | 10 |

4/ Substitute Applesauce for Pears on Days 15, 21, 27 (Dinner).
5/ Substitute Peaches for Prunes on Days 23 and 29 (Breakfast).
6/ Substitute Chicken w/Rice for Fish Creole on Day 29 (Lunch).
9/ Substitute Beef w/Gravy on Day 23 and Beef Pot Roast on Day 29 for Beef w/Mushroom Gravy (Dinner).

8/ Substitute brown pouch of chicken & gravy for can specified on Day 28 (Dinner) for one man only

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TABLE 2 (Continued)

MENUS FOR NASA AIR CREW EQUIPMENT LAB. SIMULATOR TEST (10 MEN - 30 DAYS)
(6 day cycle of menus - to be repeated 5 times)

9 Sept. 1962

| | Net Wt. (Grams) | Water Required (Oz.) | Calories | Breakfast I | Breakfast II | Breakfast III | Breakfast IV | Breakfast V | Breakfast VI | Lunch I | Lunch II | Lunch III | Lunch IV | Lunch V | Lunch VI | Dinner I | Dinner II | Dinner III | Dinner IV | Dinner V | Dinner VI | Unit | No. of Units Supplied |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Meat Loaf w/gravy | 52.00 | 5 | 289 | | | | | | | | | | 1 | | | | | | | | | Pouch | 50 |
| Bacon | 42.00 | 3 | 177 | | | 1 | | | 1 | | | | | | | | | | | | | Can | 100 |
| Scrambled Eggs | 28.00 | 3 | 165 | 1 | | | 1 | | 1 | | | | | | | | | | | | | Can | 100 |
| Spanish Rice | 23.60 | 4 | 76 | | | | | | | 1 | | | | | | | | | | | | Can | 50 |
| Mashed Potatoes | 20.00 | 4 | 73 | | | | | | | | | | | | | 1 | | | | | 1 | Can | 100 |
| Diced Potatoes (plain or w/parsley) 10/ | 15.00 | 3 | 58 | | | | | | | | | | 1 | | | | | 1 | | | | Can | 90 |
| Sweet Potatoes 10/ | 51.75 | 3 | 195 | | | | | | | | | | * | | | | | | | | | Can | 10 |
| Rice w/gravy 11/ | 25.20 | 4 | 92 | | | | | | | | | | | | | | | | 1 | | | Can | 40 |
| Rice 11/ | 29.35 | 2½ | 101 | | | | | | | | 1 | | | | | | | | * | | | Pouch | 60 |
| Potato Sticks | 28.35 | -- | 155 | | | | | | | | | | | | | | 1 | | | 1 | | Pouch | 57 |
| Crackers (5) 12/ | 37.35 | | | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | 5 gal can | ) 64 # |
| Crackers (4) 12/ | 28.35 | | 124 | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | bulk packed) | |
| Jelly | 14.17 | | 37 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Envelope | 1250 |
| Chocolate Pudding | 27.00 | 3 | 97 | | | | | | | | | | | | | 1 | | | | | | Can | 38 |
| Butterscotch Pudding | 27.00 | 3 | 100 | | | | | | | | | | | | | * | | | | | | Can | 62 |
| Butterscotch Pudding | 27.00 | 3 | 180 | | | | | | | | | | | | | | | | | 1 | | Pouch | 50 |
| Fruit Cake Bar | 56.70 | | 180 | | | | | | | | | | | | 1 | | 1 | | | | | Envelope | 100 |
| Special Dessert Pieces: 12/ | | | | | | | | | | | | | | | | | | | | | | | |
| Orange peel and almonds (4) | 27.00 | | 140 | | | | | | | | | | 1 | | | | | | | | | Can w/10 portions | 5 |
| Coconut (4) | 27.00 | | 155 | | | | | | | 1 | | | | | | | | | | | | " | 5 |
| Banana Solids (4) | 27.00 | | 138 | | | | | | | | | | | | | | 1 | | | | | " | 5 |
| Candied Fruit (6) | 40.00 | | 192 | | | | | | | | | | | 1 | | | | | | | | " | 5 |

10/ Substitute sweet potatoes for diced potatoes on day 26 (Lunch).

~~11/ Substitute rice (pouch) for rice w/gravy (cans) on day 28 (Dinner).~~

12/ Figures in parenthesis following crackers, and special dessert pieces denote number of crackers and dessert pieces per each serving.

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Table 2 (Continued)
MENUS FOR NASA AIR CREW EQUIPMENT LAB. SIMULATOR TEST (10 MEN - 30 DAYS)
(6 day cycle of menus - to be repeated 5 times)

9 Sept. 1962

| | Net Wt. (Grams) | Water Required | Calories | Breakfast I | Breakfast II | Breakfast III | Breakfast IV | Breakfast V | Breakfast VI | Lunch I | Lunch II | Lunch III | Lunch IV | Lunch V | Lunch VI | Dinner I | Dinner II | Dinner III | Dinner IV | Dinner V | Dinner VI | Unit | No. of Units Supplied |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (Oz.) | | | | | | | | | | | | | | | | | | | | | |
| Chopped peanuts(4) | 27.00 | | 153 | | | | | | | | | | | | | | | 1 | | | | Can w/10 portions | 5 |
| Candied Orange Peel (4) | 27.00 | | 132 | | | | | | | | | | | | | | | | | | 1 | " | 5 |
| Walnuts & Raisins(4) | 27.00 | | 144 | | | | | | | | | | | | | | | | | 1 | | " | 5 |
| Starch jelly bar | 56.70 | | 203 | | | | | | | | | | | | | | | | 1 | | | Bar | 50 |
| Cocoa | 28.35 | 5½ | 102 | | 1 | | 1 | 1 | | 1 | | 1 | | | 1 | | | | | | | | 300 |
| Coffee | 2.50 | 8 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 900 |
| Tea | 0.65 | 8 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 900 |
| Cream | 4.00 | | 21 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 900 |
| Sugar | 6.00 | | 24 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 900 |
| Milk | 28.35 | 8 | 103 | 1 | | 1 | | | | | 1 | | 1 | 1 | | | | | | | 1 | | 300 |

NOTE: Menu I to be issued on days 1, 7, 13, 19 and 25; Menu II on days 2, 8, 14, 20 and 26; Menu III on days 3, 9, 15, 21 and 27; Menus IV on days 4, 10, 16, 22, and 28; Menus V on days 5, 11, 17, 23, and 29 and Menus VI on days 6, 12, 18, 24 and 30. All data are provided on a one(1) unit (serving) basis, except special dessert pieces are packaged on a 10 unit basis. Wherein "can" is specified as the unit package this also pertains to the foil bags of comparable size and shape with reconstituting instructions provided on each unit. The word "pouch" refers to the brown bag marked with the name of the product only. Reconstituting instructions for these latter "pouch" products are provided separately.

NOTE: Attention is directed to the fact that some units of Beef with vegetables and Beef Pot Roast are in flat foil colored pouches, but are labeled with preparation instructions.