NASA CONTRACTOR REPORT

NASA CR-708

A REPORT OF THE PHYSIOLOGICAL, PSYCHOLOGICAL, AND BACTERIOLOGICAL ASPECTS OF 20 DAYS IN FULL PRESSURE SUITS, 20 DAYS AT 27,000 FEET ON 100% OXYGEN, AND 34 DAYS OF CONFINEMENT

PARTS I, II, III

by Kenneth R. Coburn

Prepared by
U. S. NAVAL AIR ENGINEERING CENTER
Philadelphia, Pa.
for Manned Spacecraft Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • FEBRUARY 1967

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ADMINISTRATIVE INFORMATION

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The principal investigator wishes to express his appreciation to the Research Groups for their efforts. Sections 3 through 12 of this report were authored by them, and the names of the responsible investigators appear on the flyleaf which heads each section.

Special mention must be made of the fine group of young officers who acted as subjects for this study. Without their absolute dedication, this study would have been impossible. They are:

LTJG James B. Abbitt, USN
CAPT Karl A. Foster, USMC
LT Kenneth C. Juergens, USN
LTJG William R. McBride, USNR
LTJG Jerry W. Munger, USN
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LTJG Cyrus W. Strickler III, USNR
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This technical documentary report has been reviewed and is approved.

HENRY G. WAGNER
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Director

ABSTRACT

The study was designed to validate the 100% oxygen (258 mmHg) gaseous environment for 20 days with 7 days pre and post run evaluations. Studies include: renal and pulmonary function, retinal vascular changes, rather extensive blood work, nutrition, metabolic and water balance, bacteriological flora alterations, psychological manifestations, and full pressure suit and personal hygiene evaluations.

While certain significant psychological alterations were observed, the physiological studies disclosed no significant variations from normal values. The atmosphere was well tolerated; however, 20 days constant full pressure suit wear posed some special problems.

Aerospace Crew Equipment Laboratory

A REPORT OF THE PHYSIOLOGICAL, PSYCHOLOGICAL, AND BACTERIOLOGICAL ASPECTS OF 20 DAYS IN FULL PRESSURE SUITS, 20 DAYS AT 27,000 FEET ON 100% OXYGEN, AND 34 DAYS OF CONFINEMENT

CDR Kenneth R. Coburn, MSC, USN
Principal Investigator

NAEC-ACEL-535, Part I 1 APRIL 1966

SECTION 1

GENERAL INTRODUCTION AND METHODS

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SECTION 1

INTRODUCTION

A decision to utilize an atmosphere of 100% oxygen in United States manned spacecraft has led to intensive research in an effort to determine the partial pressure at which prolonged human exposure to this gas ceases to be of optimum value and begins to produce deleterious effects. This decision, necessitated by engineering considerations, has posed the problem of selecting an atmosphere which may be less than the best of all possible atmospheres. From an a priori point of view, air at approximately 760 millimeters of mercury should be the atmosphere of choice and might be eventually the most practical selection for spacecraft configurations of the future. Payload weight constraints, for example, which dictated a single gas atmosphere should diminish progressively as increasingly powerful U. S. booster vehicles in the multi-million pound thrust range become operationally available.

Nevertheless, we are posed with the original fascinating problem - at what point on a hypothetical pO_2 versus time curve does oxygen begin to limit rather than optimally sustain human physiological processes?

Many earlier studies[1-8] have produced contradictory results which require clarification. It was with this in mind that the current study was conceived; to confine six men for a period of 34 days, 20 days of which were spent at 27,000 feet on 100% oxygen and a total time in full pressure suits of 21 days with two other men to serve as sea level controls.

GENERAL METHODS

It is not the intent to describe here in any detail the specific methods employed to measure the many variables which occupied our collective interests in the several areas of concern. They are to be found in Sections 3 through 13 in the main text of this paper. In this portion the over-all aims of the study will be dealt with as will general methods used to implement the entire program.

Due to the complex nature of this investigation, it was decided by the principal investigator to utilize a simplified Program Evaluation and Review Technique (PERT) to identify events, determine critical paths and, generally, to give form to the mass of separate actions which had to be performed prior to the first experimental day. This was particularly true for two essential networks, (1) the selection and procurement of subjects and (2) the modification of the Aerospace Crew Equipment Laboratory Bio-Astronautic Test Facility into the desired double-wall configuration.

SUBJECT SELECTION

The subjects in this study were selected from a group of outstanding USN and USMC aviators who had volunteered for astronautics. This list was obtained from the U. S. Naval School of Aviation Medicine, Pensacola, Florida.[9]

The criteria for inclusion on this list were:

"a. An expressed willingness to volunteer for highly demanding technological assignments such as space flight.

b. Technical aptitude equal to or exceeding that of the Mercury Astronauts. Tests used in common with the Mercury selection program were the Minnesota Engineering Anologies Test, the Doppelt Mathematical Reasoning Test, the U. S. Navy's Mechanical Comprehension Test and the U. S. Navy's Aviation Qualification Test. In addition technical performance in naval air training was noted. Those volunteers with average or below performance records were not accepted. Each man was graded on technical aptitude as follows:

A grade of three (3) indicated that the man scored in the lower range of scores attained by the Mercury Astronauts.

A grade of two (2) indicated that the men scored in the middle range of scores attained by the Mercury Astronauts.

A grade of one (1) indicated that the man equalled or exceeded the highest scores attained by the Mercury Astronauts.

It should be stressed that even the lowest range of scores, i.e., the 3's represents an ability level well above the average of the aviator population, which in turn is a superior group compared to the general population.

c. Verbal aptitude equal to or exceeding that of the Mercury Astronauts. The tests used in common with the Mercury selection program were the U. S. Navy's Aviation Qualification Test and the Miller Analogies Test. Many graduate schools use the latter for screening applicants. The same three point scale was used to describe each man with respect to the Mercury group.

d. Superior flying ability as measured by flight grades in naval aviation training. A rating of three (3) represents about average for designated aviators. A two (2) represents well above average flight grades, and a one (1) represents exceptional flight grades.

e. Rigorous physical examination with particular attention to the cardio-vascular system."

Some forty officers whose names appeared on this list were contacted by letter and asked if they would be willing, to participate as subjects and, if they were willing to include anthropomorphic data to aid in determining what size full pressure suit would be required. Those officers who volunteered were sent follow-up letters and their respective commands were contacted to obtain permission to order the officers to Aerospace Crew Equipment Laboratory for the required sixty-day period. Thus, based upon their availability and the sizing data, the eight subjects were chosen.

All subjects are university graduates with degrees in science, engineering or mathematics.

Training and Orientation - During the two weeks prior to the start of the 34 day experimental period, the eight subjects received intensive training and orientation in the overall research program. This was particularly important, in view of the desire to follow the microbiological aspects of this relatively long term confinement as special sampling techniques had to be taught. Once the subjects entered their respective spaces, there was no direct contact with staff personnel except for the brief period required to obtain fundus photographs. As a result of this requirement, the subjects had to become competent in various technical procedures. These included venipuncture, pulmonary function testing, and microbial sampling of their bodies, chamber walls, and air.

This initial period was also used to obtain baseline data of a physiological and psychological nature. This included arterial punctures to determine blood pO_2, pCO_2, and pH.

Complete flight hazardous duty physical examinations were conducted by USN flight surgeons.

EXPERIMENTAL DESIGN

Six officers were selected to act as the experimental group, the remaining two comprising a small control group. The variables and the time sequence are shown in Table 1-1.

Aerospace Crew Equipment Laboratory Bioastronautics Test Facility (BATF) - The interior of the large low pressure chamber was equipped with a cylindrical aluminum liner 22 feet long and 8-1/2 feet in diameter. The necessary fittings for long term, multi-manned habitation were installed as shown in Figure 1-1. Although not used in this study, provision for personal hygiene and toilet facilities were included for use in subsequent studies.

The purpose of the double-walled chamber was to insure that any gas leakage would be outboard. This was accomplished by evacuating the annulus between

inner and outer walls to a pressure slightly below the 258 mmHg required. These pressures were maintained automatically as were temperature and relative humidity by MKS Baratron Meters, Type 77 and Honeywell Recorder-Controller equipment see Figures 1-2 and 1-3. Manual observer/controllers were also on constant duty.

The 100% oxygen environment was obtained from liquid derived oxygen. The atmosphere was constantly monitored by a Beckman Model F3 O_2 Analyzer, and a Beckman L/B Infra-red Analyzer, Model 15A, was used for determining CO_2. Continuous recording of O_2 and CO_2 percentages were obtained on a Minneapolis-Honeywell Continuous Drive Recorder, Model Y153X65.

Control Facility - The control facility was located adjacent to the Bioastronautics Test Facility and was essentially a plywood cottage 8 X 8 X 16 feet. The interior was furnished with equipment similar to that found in the Bioastronautics Test Facility. The layout is shown in Figure 1-4. The schedule followed by the control subjects was similar to that followed by the experimental group, with the exception of operating on a two-shift schedule.

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TABLE 1-1

EXPERIMENTAL DESIGN

Group	DAY 1-7	DAY 8-14	DAY 15-27	DAY 28-34
EXPERIMENTAL	S. L. * - No Suit	ALTITUDE** - No Suit	ALTITUDE** - Suit	S. L. - Suit
CONTROL	S. L. - No Suit	S. L. - No Suit	S. L. - Suit	S. L. - Suit

* S. L. = Sea Level

** ALTITUDE - 27,000 Feet on 100% OXYGEN

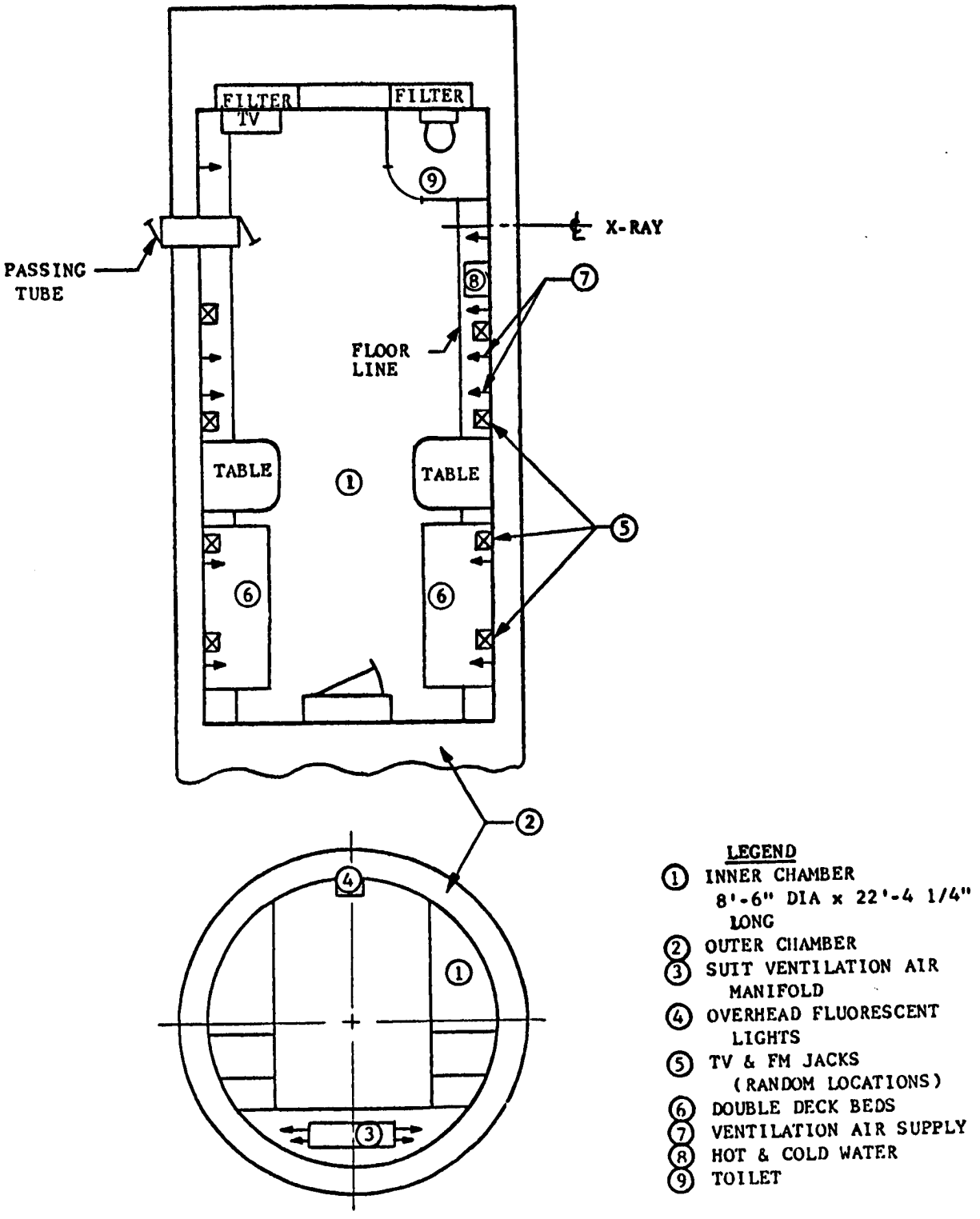

FIG. 1-1BIOASTRONAUTICS TEST FACILITY LAYOUT

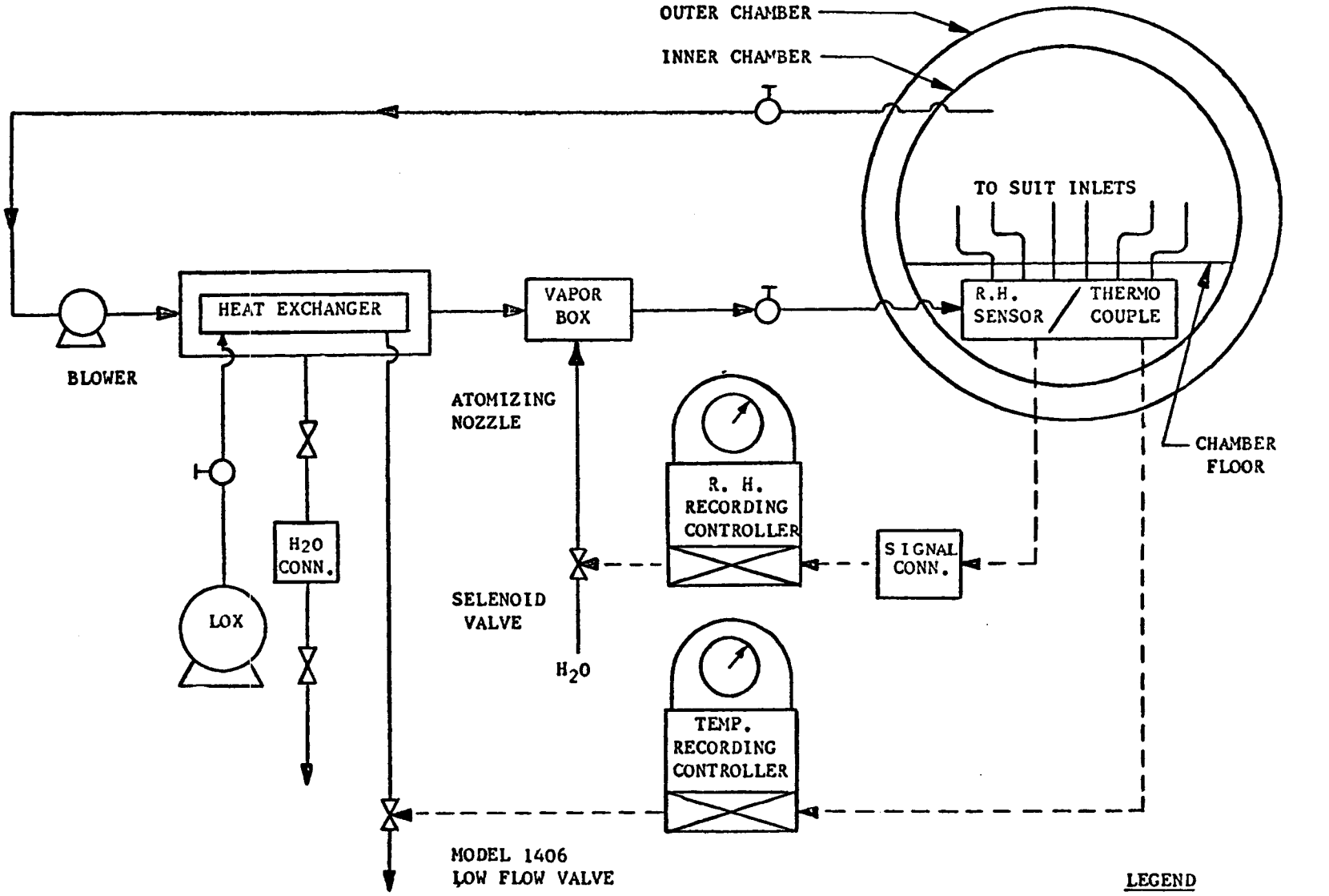

FIG. 1-2 SUIT TEMPERATURE & HUMIDITY CONTROLS SYSTEM

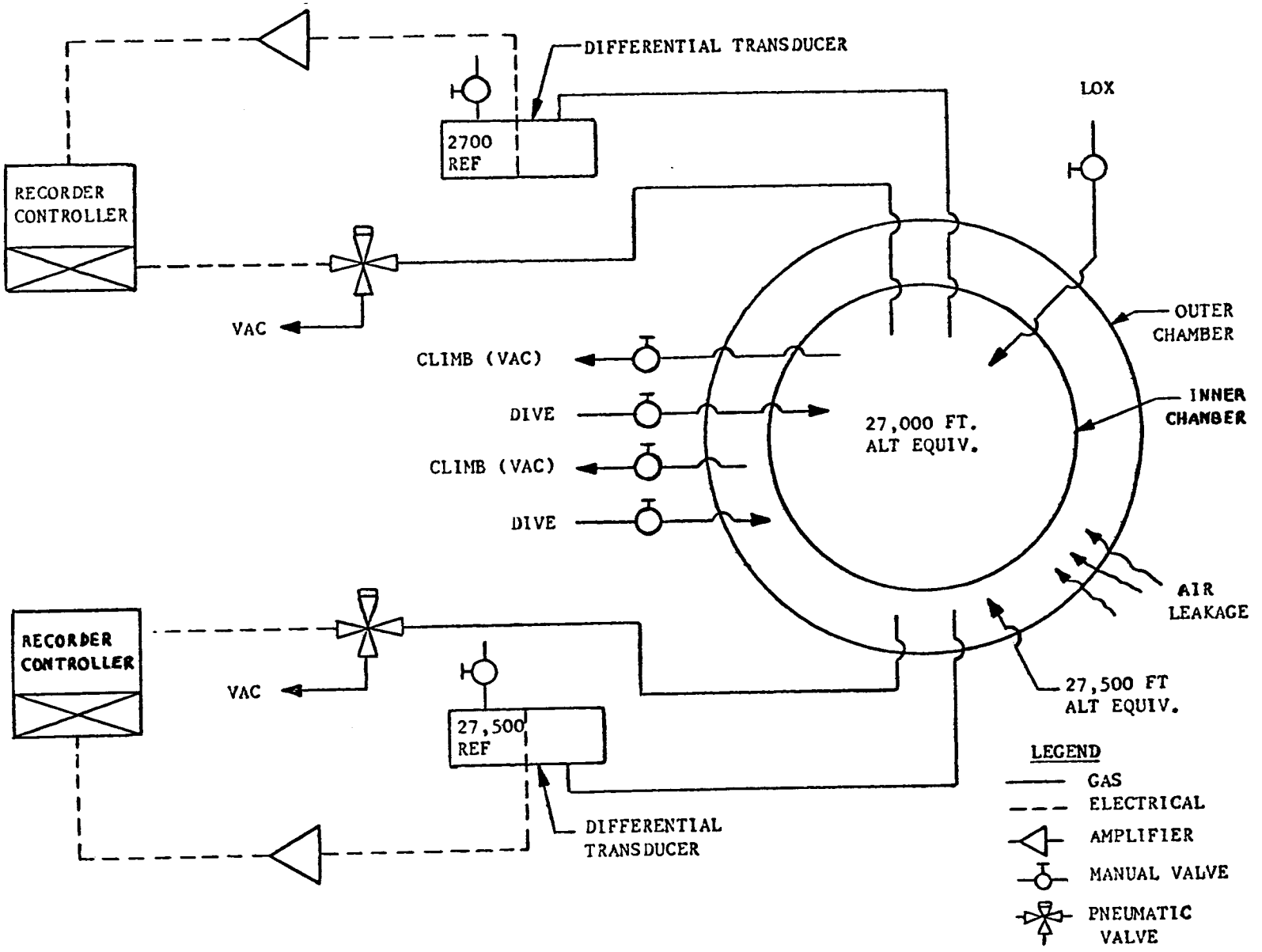

FIG. 1-3 AUTOMATIC PRESSURE CONTROL

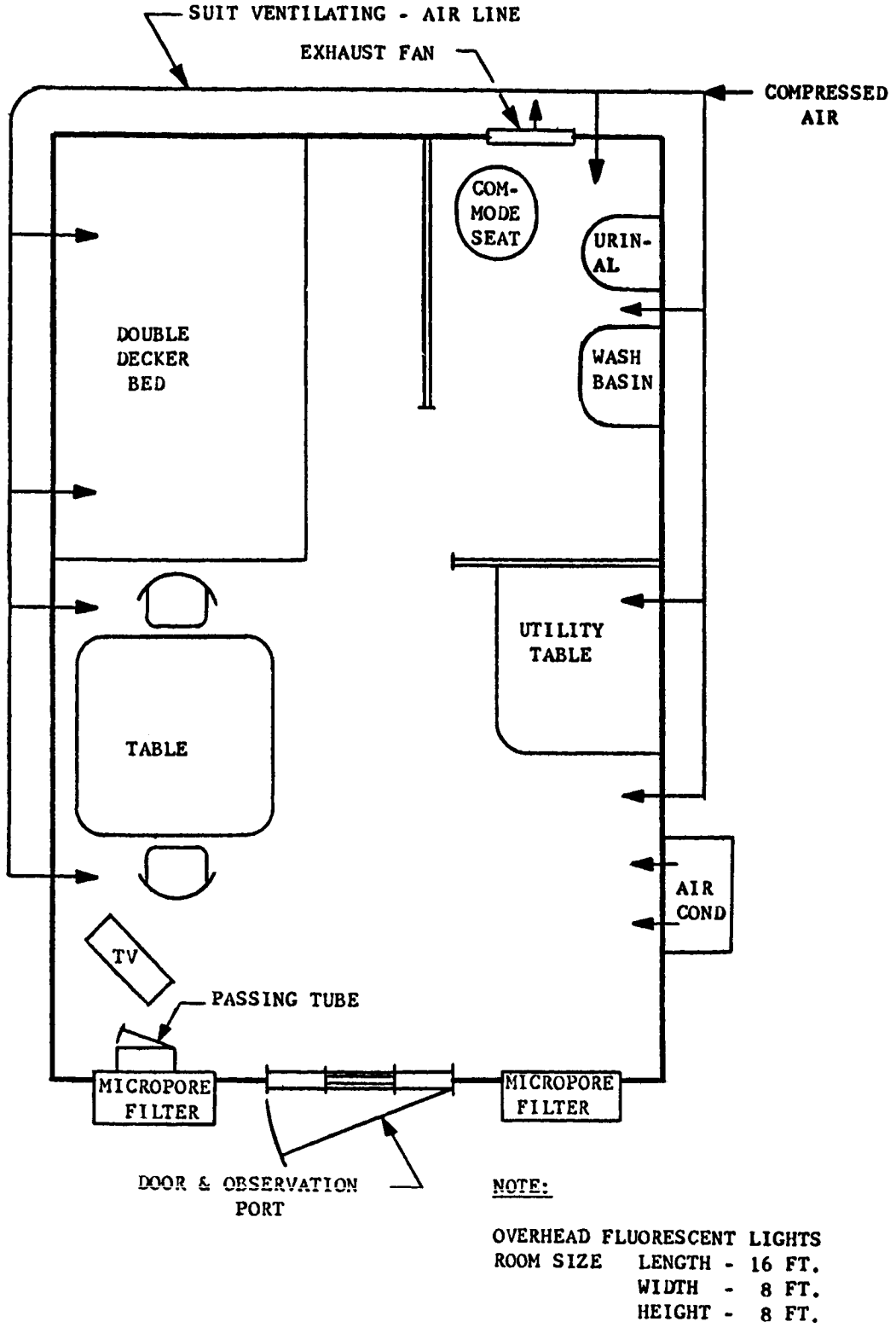

FIG. 1-4 CONTROL FACILITY LAYOUT

SECTION 2

GENERAL DISCUSSION OF RESULTS AND CONCLUSIONS

CDR Kenneth R. Coburn, MSC, USN

SECTION 2

GENERAL DISCUSSION OF RESULTS AND CONCLUSIONS

Aside from the inverse relationship between retinal blood vessel caliber and pO_2, there were no positive findings. In the case of the renal function and pulmonary function this is not surprising, as previous reports had led us to believe that none would occur as a result of our experimental design.

The wide variations noted in the creatinine levels must be ascribed to technical difficulties. Only one of the subjects showed any significant change in weight or surface area; subject 3 who deliberately although surreptitiously lost 15 pounds during the 34 days of confinement. However, the variations in creatinine excretion in this subject were no more marked than those observed in other subjects. The most probable source of error is the manner of urine collection.

Certain changes were anticipated but not observed in the case of the hematological and blood biochemistry sections. Helvey et al[1] reported changes in the blood picture of his subjects at all three pressures studied, i.e., 7.4, 5.0 and 3.8 psia. The alterations were much more apparent at 7.4 psia than at the two lower pressures of 5.0 and 3.8 psia.

Possibly the most striking change reported by Helvey et al[1] was the flattening of the peaks and shift to the left of the Price-Jones Curves. Our data indicates no such changes. In the absence of Price-Jones changes or any other alterations in blood morphology/biochemistry we can only suppose that some factor other than those anticipated was as least partially responsible for the changes noted in the Helvey study. This factor might have been mercury vapor as several mercury containing instruments were inadvertantly broken in the low pressure chamber during the course of the reported series of investigations.

The absence of significant alterations in the activities of the blood enzyme studies conducted by NMRI tend to substantiate our morphological findings. From our data, we can conclude that our experimental design produced no detectable alterations in the reduction-oxidation balance of the red blood cells. This appears to agree with A. A. Thomas[2] who has stated that a pO_2 of 300 mmHg appears to be the toxic threshold for oxygen.

The bacteriological studies indicate that although there was a general buildup of microorganisms on the bodies of the subjects and in their respective environments, this posed no special problem. However, a warning note was sounded. The isolation of Shigella Poly B, Bethesda Ballerup, and a coagulase-positive phage typeable staphlococcus, all potential pathogens, would seem to indicate a necessity for eliminating all potentially pathogenic organisms from each individual of a proposed space crew. Although there was only minimal intra-personal transfer between subjects, it must be emphasized that overt transfer can occur, and if a highly virulent strain of Shigella or Salmonella, for example, is introduced, the resulting affect could well be catastrophic in a manned spacecraft environment.

The nutritional aspect of this study is noteworthy only in that the diet was very well accepted and appeared to be adequate in all aspects.

There were no significant variations noted in the balance studies.

The psychological portion of this study, Sections 9, 9a, 10 and 11 reports changes which have significance only when related to confinement in the Bioastronautical Test Facility or control facility. No changes were noted which are considered relevent to the 100% oxygen or reduced pressure.

Some general comments arising from the debriefing session, which included both subjects and investigators, are in order. Probably the most common single source of annoyance to the subjects was the ratio of temperature/humidity. Although fairly precise control could be maintained by the automatic equipment it appears that no single set of conditions could satisfy all of the six experimental subjects for very long. There are a number of perfectly valid reasons for this.

1. The variety of suits used; i.e., USN Mark 4, USN Mark 5, NASA-MA-10 and NASA Apollo, was such that there were no common thermal characteristics. Each suit has quite different properties.

2. The suits were worn fully donned, except for the faceplate, for only about four hours a day. The remainder of the time the helmets and gloves were removed. In the case of the USN Mark 4 suits the rubber booties were cut off when moisture began to accumulate in them. All of these modifications to the various suits or the configuration in which they were worn produced a virtually insolvable problem when it came to providing not only a satisfactory temperature and humidity but in supplying vent gas flow at an optimum rate. This rate had been stipulated prior to the beginning of the run and was therefore maintained at 12 liters per minute. This was insufficient under the conditions mentioned above. Future studies of this type should provide individual control of vent gas.

Several other problems relating to the wearing of the full pressure suits arose. Sleeping presented a problem which was partially solved by "buttoning up" the suit. This not only insured optimum ventilation but, donning the helmet avoided pressure points on the neck which resulted from trying to sleep on the neck ring.

The flaking of skin and sloughing of hair has been mentioned previously but is raised again because of its pertinence in actual manned spaceflight. The flaking occurred in quantities sufficient to impair gas flow through the filters in the process of circulation and to litter the floor of the living compartment. Under weightless conditions this settling would not occur and the detritus would remain suspended in the environment.

Constant wearing of full pressure suits greatly impairs the effecting of adequate personal hygiene procedures. Although no build-up of pathogens occurred, all surfaces became markedly contaminated with coliform microorganisms. In this connection the use of the "O Gravity Sink" did nothing to improve personal hygiene, in fact quite the opposite. Microorganism levels reached staggering proportions and the use of the "Sink" was discontinued at the end of the first week. The washcloths remained a source of contamination throughout the entire period of the run. From a purely subjective point of view the subjects' attitudes with regard to his own state of personal hygiene at the end of the 34 days varied considerably. While no one considered himself to be "clean" not all of them felt "filthy" either.

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(2) Thomas, A.A.: Personal Communication.

SECTION 3

RETINAL VASCULAR RESPONSE TO OXYGEN AT INCREASED PARTIAL PRESSURES

LT Talvaris Turaids, MC, USN
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SECTION 3

RETINAL VASCULAR RESPONSE TO OXYGEN AT INCREASED PARTIAL PRESSURES

Normal retinal arteries and veins constrict when the concentration of inspired oxygen rises and dilate when it falls.[1,2] In the immature retina, vasoconstriction due to chronic hyperoxia is followed by irreversible changes, such as obliteration of the vessels.[3,4] Adults breathing 100% oxygen at sea level show a 10.5 to 37.7% decrease in the caliber of retinal vessels.[1,5] The degree of constriction, which is more marked in the veins, is substantially complete within five minutes after passing from breathing air to oxygen at one atmosphere of pressure.[5,6] At the same time, no untoward opthalmologic symptoms or signs have developed in subjects breathing 100% oxygen at sea level for 4 to 24 hours.[6,7] However, inhalation of 100% oxygen at three atmospheres has resulted in a striking reversible impairment of vision in adults after four hours.[8] It has been suggested that the vasoconstriction in the eye in response to oxygen may serve a defensive purpose to protect the tissues from too high a concentration of oxygen.[1,9]

METHOD

A Nikon Fundus camera, using Kodak Tri-X Pan black and white film, was utilized to obtain retinal photographs of the six experimental subjects while breathing air at sea level, during the period of pre-oxygenation with 100% oxygen at sea level prior to ascent to altitude, 5 - 30 minutes after ascent to 27,000 ft on 100% oxygen, and after the subjects had been at altitude, breathing 100% oxygen for 19 days. The pupil of the test eye was dilated with tropicamide (Mydriacyl 1.0% Alcon) prior to each study. The 35 mm film was magnified 15 times on a glass screen using an IBM Microfilm Reader, and the larger retinal vessels were measured with a caliper and steel rule with 1/64 inch divisions.

The same three arteries and veins were measured on each photograph. Easily recognizable points on both veins and arteries were selected using the optic disc or a prominent A-V crossing as a reference. The diameter of the optic disc was the same in all enlargements, thus insuring that any changes noted were not due to differences in the focus or the distance at which the pictures were taken. Mean values were obtained for the three arteries or veins measured and the percent change from the control photographs was calculated (Table 3-1).

RESULTS AND DISCUSSION

Retinal photographs taken after the subjects had been breathing 100% oxygen at sea level for 5 to 30 minutes, show a decrease of approximately 17% in the caliber of the arteries and 20% in the veins, see Figure 3-1. Five to 30 minutes after the

ascent to 27,000 ft while breathing 100% oxygen, there was only a 6 to 8% decrease in the diameter of retinal veins and arteries. This degree of decrease remained essentially the same after 19 days at altitude on 100% oxygen.

There appears to be a direct correlation of the degree of vessel constriction to the oxygen tension of arterial blood.[6,10] Smaller vessels decrease disproportionally more than larger ones,[9] and thus the original diameter of the vessel has to be considered. This may in part account for the different values of retinal vessel caliber in response to oxygen as reported by various investigators.

The decrease in the diameter of retinal vessels is directly related to the decrease in circumference, however, without further studies, it would be difficult to attempt to correlate the diameter changes with changes in vascular resistance, and hence in the blood flow. It appears that the increase in blood oxygen transport during hyperbaric oxygenation more than compensates for the reduction in retinal blood flow due to vasoconstriction. This is evidenced by the fact that the color of blood in the veins changes to approximate that of the arteries[1,10] and that hyperbaric oxygen preserves vision for long periods of time during retinal ischemia.[11,12]

Vasoconstriction in response to increased partial pressures of oxygen may not be limited to the retina. It has been demonstrated that cerebral blood flow in man decreases by about 12% when 100% oxygen is breathed at one atmosphere and up to 24% at two atmospheres pressure.[13,14,15] Moreover, this vascular response to hyperoxia may be a general or a systemic one. An increased arterial blood oxygen tension, even at one atmosphere, will increase peripheral vascular resistance and decrease the cardiac output and heart rate.[16,17] The stroke volume and mean blood pressure do not change, however.

CONCLUSION

The fundus oculi offers a unique opportunity for the observation of alterations in vessel caliber during changes in arterial gas tensions. Measurements from retinal photographs are a convenient way of assessing such changes. Experiment results show that both retinal arteries and veins decrease progressively in size as arterial oxygen tension is increased.

Certain questions may be raised with respect to future investigations:

1. Is there a linear relationship between the caliber of retinal blood vessels and the partial pressure of inspired oxygen?

2. Does the retina have an autoregulatory mechanism for the control of its circulation; are retinal vessels particularly sensitive to oxygen, or is vasoconstriction a general response to hyperoxia?

3. Is the vasoconstriction due to a direct response to the increase in oxygen pressure, certain metabolic changes in the tissues, or to a homestatic mechanism to maintain tissue oxygen levels within fairly close limits and thus mitigate against possible deleterious effect of hyperbaric oxygen?

4. Is this effect due to local action of a chemical factor on the nervous cells or smooth muscle, or is the response mediated through certain neurohumeral mechanisms?

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TABLE 3-1

PERCENT CHANGE IN DIAMETER OF RETINAL ARTERIES AND VEINS BREATHING 100% OXYGEN AT SEA LEVEL AND AT SIMULATED ALTITUDE OF 27,000 FT.

	100% O_2 at sea level, 5 - 30 min	100% O_2 at 27,000 ft, 5 - 30 min	100% O_2 at 27,000 ft, 19 days
		ARTERIES	
SUBJECT			
1	-12.72%	-7.47%	-10.50%
2	-23.88%	-9.88%	-13.22%
3	-19.44%	-9.25%	- 5.55%
4	-11.42%	-2.38%	+ 2.38%
5	-13.46%	+3.03%	- 3.70%
6	-20.19%	-10.65%	- 5.12%
MEAN	-16.68%	-7.88%	- 6.74%
		VEINS	
SUBJECT			
1	-19.34%	-10.71%	- 8.92%
2	-23.88%	-9.88%	-13.22%
3	-13.80%	-5.12%	- 2.00%
4	-19.36%	-5.55%	- 2.22%
5	-20.60%	-4.60%	- 7.35%
6	-20.74%	-5.12%	- 7.21%
MEAN	-19.55%	-5.87%	- 5.31%

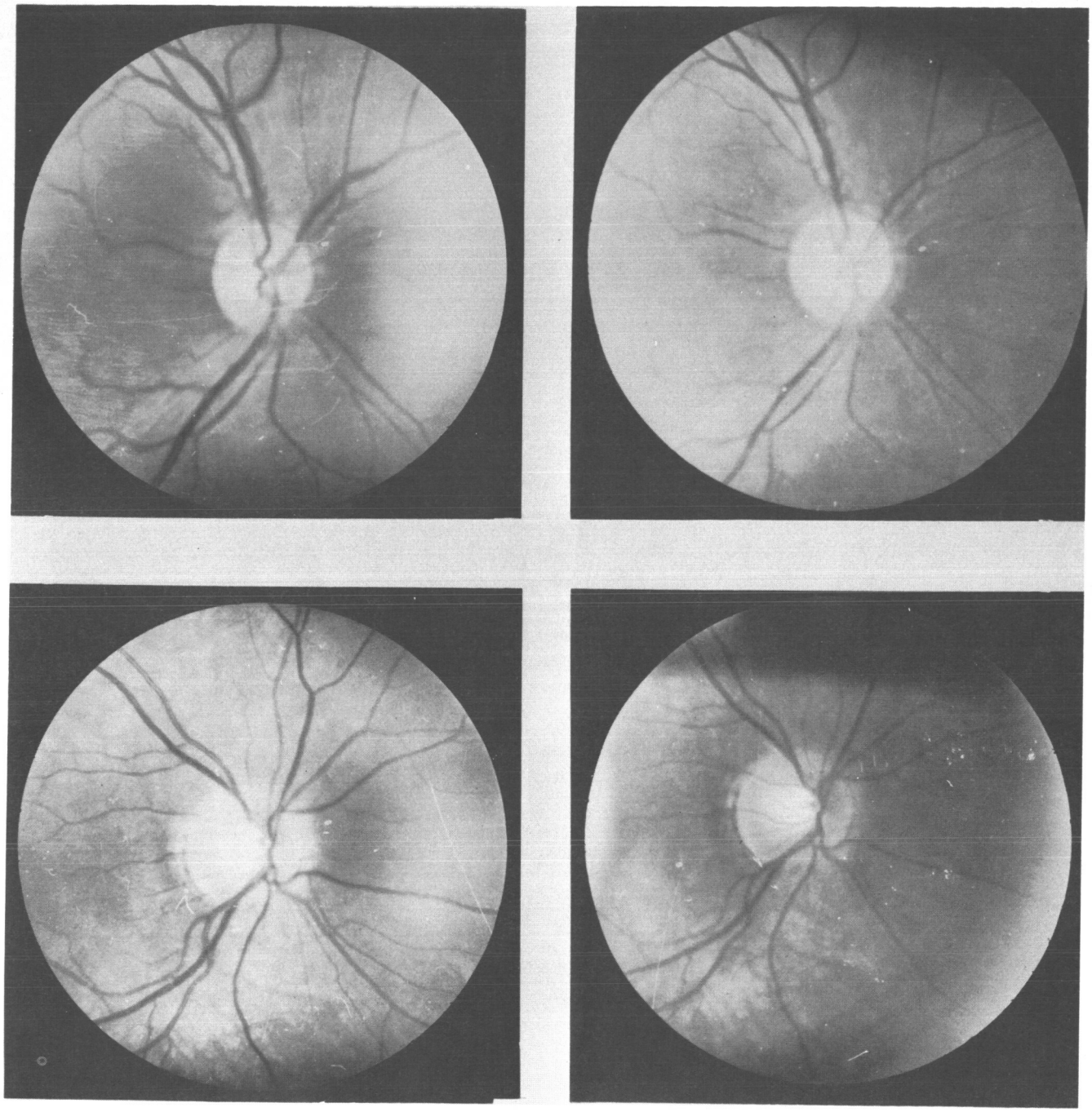

Figure 1 Retinal photographs of two subjects before (left) and while breathing 100% oxygen at sea level (right) showing a decrease in caliber of vessels.

PHOTO NO: CAN-371596(L)-10-65

SECTION 4

RENAL FUNCTION AND WATER BALANCE

LT Talvaris Turaids, MC, USN

SECTION 4

RENAL FUNCTION AND WATER BALANCE

Routine urinalyses, including microscopic examination, were performed periodically. Protein, sugar, and pH were determined using Hema-Combistix reagent strips manufactured by the Ames Company. When the presence of albumin was suspected from a doubtful reaction of the reagent strip, the sulfasalicylic acid turbidity test for protein was also done. Likewise, to rule out a false positive reaction for glucose, the presence or absence of the latter was also determined using Clinitest Reagent Tablets (Ames). Specific gravity was determined using an urinometer, and acetate with Acetest Tablets (Ames Company). Serum and urinary creatinine clearance were determined once every three days. Methods used in all of the above tests were taken from standard Navy laboratory manuals published by the U. S. Naval Medical School, National Naval Medical Center, Bethesda, Md.

The subjects kept a record of their water intake and also of the volume of urine produced. These records were handled on daily basis to provide data on water requirements. The amount of water used for personal hygiene was not recorded, however.

Urine was collected in 4000 ml polyethylene bottles and passed out through a small air lock each morning for analysis.

RESULTS AND DISCUSSION

Urinalysis data were essentially negative, with occasional white blood cells, and with no indication of red blood cells, casts, protein, sugar, or acetone. (Table 4-1).

The daily water intake and urine output data is presented in Table 4-2 and a summary of water requirements in Table 4-3. The average water usage, excluding that used for personal hygiene, was 1732 ml per man per day. The average water available to the body from all sources including preformed water in the food and water of oxidation was 2048 ml per day. Water excreted from the kidneys and in feces averaged 1110 ml/man/day. Assuming that the subjects were in a state of normal water balance, the difference between the water available to the body and the water excreted will be the insensible loss of 938 ml/man/day. Insensible loss at sea level has been estimated to be on the order of 900 ml/day.[1,2] These data are also in good agreement with previously published studies.[3,4]

Table 4-4 presents the data on serum and urinary creatinine and creatinine clearance. The values were found to vary excessively from day to day and the accuracy of the data is questionable. Several factors may account for this:

1) The subjects in drawing their own blood frequently produced hemolysis, 2) No preservative was used in the urine as it would have interfered with other chemical determinations. 3) On several occasions the subjects used urine bottles other than their own, 4) The urine samples collected in the mornings were not necessarily exactly 24 hour specimens. Any or all of the above may have influenced the creatinine concentration and hence its clearance. Thus, no conclusions can be drawn about this aspect of body metabolism or kidney function.

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TABLE 4-1

SUMMARY OF URINALYSIS DATA*

Day		Subject 1	2	3	4	5	6	7	8
2	Spec. grav.	1.031	1.028	1.030	1.022	1.025	1.021	1.029	1.032
	Microscopic	neg	0-2 WBC	0-2 WBC	neg	0-2 WBC	neg	neg	3-4 WBC
3	Spec. grav.	1.027	1.024	1.024	1.021	1.023	1.014	1.025	1.030
	Microscopic	2-3 WBC	0-2 WBC	neg	0-2 WBC	0-2 WBC	neg	0-2 WBC	2-4 WBC
5	Spec. grav.	1.030	1.032	1.032	1.025	1.028	1.015	1.037	1.035
	Microscopic	2-3 WBC	2-3 WBC	0-2 WBC	0-2 WBC	0-2 WBC	neg	neg	2-4 WBC
11	Spec. grav.	1.027	1.025	1.022	1.013	1.027	1.027	1.029	1.029
	Microscopic	1-2 WBC	neg	0-1 WBC	0-2 WBC	0-1 WBC	neg	0-2 WBC	2-3 WBC
20	Spec. grav.	1.029	1.023	1.028	1.015	1.030	1.030	1.032	1.030
	Microscopic	2-5 WBC	0-2 WBC	0-1 WBC	0-2 WBC	0-1 WBC	0-1 WBC	neg	1-2 WBC
22	Spec. grav.	1.028	1.025	1.028	1.015	1.030	1.030	1.031	1.030
	Microscopic	0-2 WBC	0-2 WBC	0-2 WBC	neg	neg	neg	neg	neg
23	Spec. grav.	1.025	1.024	1.027	1.027	1.027	1.027	1.030	1.022
	Microscopic	0-1 WBC	0-2 WBC	1-2 WBC	0-1 WBC	0-1 WBC	neg	neg	neg
24	Spec. grav.	1.028	1.028	1.030	1.015	1.025	1.021	1.031	1.032
	Microscopic	0-2 WBC	2-3 WBC	neg	neg	neg	neg	0-2 WBC	neg
25	Spec. grav.	1.025	1.024	1.030	1.015	1.025	1.030	1.030	1.024
	Microscopic	1-2 WBC	12-14 WBC	0-1 WBC	neg	neg	2-4 WBC	1-3 WBC	neg
26	Spec. grav.	1.030	1.025	1.032	1.020	1.022	1.027	1.032	1.025
	Microscopic	3-4 WBC	5-6 WBC	neg	neg	neg	neg	2-3 WBC	neg
27	Spec. grav.	1.027	1.020	1.025	1.010	1.020	1.030	1.030	1.025
	Microscopic	4-6 WBC	neg	0-1 WBC	neg	neg	neg	neg	neg
28	Spec. grav.	1.028	1.020	1.025	1.010	1.022	1.028	1.030	1.025
	Microscopic	2-4 WBC	neg	neg	neg	2-3 WBC	0-2 WBC	neg	2-4 WBC
29	Spec. grav.	1.026	1.026	1.020	1.020	1.024	1.026	1.024	1.020
	Microscopic	0-2 WBC	0-2 WBC	neg	0-3 WBC	neg	0-2 WBC	2-3 WBC	0-1 WBC
31	Spec. grav.	1.025	1.021	1.025	1.011	1.019	1.025	1.028	1.025
	Microscopic	0-1 WBC	0-1 WBC	3-4 WBC	1-2 WBC	0-1 WBC	0-1 WBC	1-2 WBC	0-2 WBC
33	Spec. grav.	1.023	1.027	1.024	1.013	1.019	1.016	1.028	1.026
	Microscopic	neg	neg	neg	neg	neg	neg	neg	neg
34	Spec. grav.	1.025	1.020	1.025	1.012	1.020	1.020	1.026	1.023
	Microscopic	neg	0-1 WBC	0-2 WBC	neg	0-2 WBC	neg	0-2 WBC	neg

* There was no indication of casts, protein, sugar, acetone, or red blood cells. Reaction was acid in all cases.

TABLE 4-2

DAILY WATER INTAKE AND URINE OUTPUT (ml/day)

Day		Subject 1	2	3	4	5	6	7	8	Mean
1	Intake	1491	1388	1347	2109	1375	1811	1021	1326	1483
	Output	900	1020	900	1740	680	1120	1220	1200	1098
2	Intake	1641	1633	1573	2363	1966	1804	1574	1967	1815
	Output	920	980	980	1400	1100	2120	1080	850	1179
3	Intake	2152	1697	1402	2582	1878	2407	1588	2445	2018
	Output	900	1300	1100	1400	1100	1200	920	520	1055
4	Intake	1784	1536	1616	2500	1887	2131	1503	1786	1842
	Output	740	740	740	1980	1580	1650	720	880	1116
5	Intake	1584	1699	1517	2146	1851	2747	1786	1772	1887
	Output	810	1170	1040	1230	920	1340	1020	995	1065
6	Intake	1532	1804	1403	2778	1704	2017	1432	2111	1847
	Output	1120	1140	920	1440	1120	1600	740	860	1122
7	Intake	1593	1783	2069	2443	1789	2583	1673	2411	2043
	Output	1000	940	1000	1480	1040	1460	540	940	1050
8	Intake	1844	1844	1531	2276	1777	2009	1134	1584	1749
	Output	650	1000	640	1240	800	1370	730	790	903
9	Intake	1778	1770	1077	2053	1783	2002	1375	1657	1686
	Output	770	1160	880	2330	880	1002	1000	1000	1130
10	Intake	2081	2471	1687	2276	1721	1928	1758	2187	2013
	Output	900	850	820	1250	1160	1080	660	600	915
11	Intake	2092	1693	1660	1963	1886	1632	1616	2114	1832
	Output	1100	960	820	1120	1020	960	1040	1180	1025
12	Intake	1770	1633	1418	1856	1806	2073	1333	1619	1688
	Output	900	1460	780	1000	1020	1240	800	940	1017

TABLE 4-2 (Continued)

Day		Subject 1	2	3	4	5	6	7	8	Mean
13	Intake	1804	1748	1517	2066	1874	1831	1318	1574	1716
	Output	960	980	740	1000	1060	1260	800	780	947
14	Intake	1741	1911	1304	2365	2143	2349	1063	2001	1859
	Output	1060	1050	740	1280	940	1040	840	900	981
15	Intake	1900	1845	1758	2265	1609	2021	1346	1268	1751
	Output	900	1020	480	1820	1080	1180	1040	820	1042
16	Intake	1808	1602	1588	2315	2113	1321	1389	1618	1817
	Output	980	1020	800	1600	1220	860	880	800	1030
17	Intake	1528	1819	1120	2234	1846	1896	1431	1535	1676
	Output	860	970	620	1280	1280	1020	780	980	973
18	Intake	1795	1881	1658	2433	2095	1836	1361	2020	1884
	Output	1020	900	700	1760	1040	1600	640	700	1045
19	Intake	1867	2132	1148	2463	1826	1523	1672	904	1691
	Output	1040	800	660	1860	1180	1000	740	800	1010
20	Intake	1663	1641	907	3257	1990	1191	1503	1744	1737
	Output	800	540	620	2300	1540	1120	1020	700	1080
21	Intake	1663	1586	1630	2435	1927	1376	950	1677	1655
	Output	840	1000	480	1940	880	420	800	700	882
22	Intake	2137	2013	907	2719	2242	1713	1431	2026	1898
	Output	1080	960	570	1360	1180	960	580	920	951
23	Intake	1557	1669	1148	2663	1815	1588	1361	1380	1647
	Output	1160	1320	720	3120	1880	1080	1000	720	1375
24	Intake	1649	1388	655	1949	2127	1647	1021	1595	1503
	Output	900	1140	570	1820	1460	820	740	920	1046
25	Intake	1518	1709	1418	1782	2003	1251	1119	1634	1554
	Output	880	1060	500	1560	920	1160	740	900	965

TABLE 4-2 (Continued)

Day		Subject 1	2	3	4	5	6	7	8	Mean
26	Intake	1755	1638	1077	3143	2208	1231	1404	1433	1736
	Output	1100	1340	660	2220	1380	1200	680	920	1187
27	Intake	1448	2028	1389	2492	1944	2017	1517	1411	1780
	Output	1040	1320	600	1780	1280	980	920	900	1100
28	Intake	1351	1401	1191	2006	2064	1385	1134	1789	1540
	Output	1300	1640	700	2440	2240	1420	800	940	1435
29	Intake	1535	1534	780	2577	2038	1545	1077	1167	1531
	Output	1300	1160	600	2180	1240	1300	760	760	1162
30	Intake	1541	1716	1531	2321	2010	1560	1262	2294	1779
	Output	1100	1400	590	2440	1360	880	940	960	1207
31	Intake	1438	1419	824	2822	1975	1588	1432	1611	1638
	Output	1100	1340	720	2300	1560	980	900	840	1217
32	Intake	1310	1507	1304	2348	2072	1547	1134	1619	1605
	Output	1020	1280	580	2200	1920	1180	700	960	1230
33	Intake	1239	1697	913	3789	1981	1396	1474	1129	1702
	Output	840	1080	660	2000	1220	1400	720	1060	1112
34	Intake	1647	1913	1262	707	1924	2383	1163	1334	1541
	Output	1080	1280	600	2375	1200	1400	720	620	1159
Mean intake		1676	1728	1344	2331	1919	1805	1366	1692	1732
Mean output		972	1097	721	1773	1217	1188	829	866	1082

TABLE 4-3

SUMMARY OF WATER DATA*

	1	2	3	4	5	6	7	8
Liquids (ml/day)	1084	1166	944	1623	1313	1338	890	1215
Food rehydration	588	562	400	708	606	467	476	477
Water in food	16	16	16	16	16	16	16	16
Water of oxidation	300	300	300	300	300	300	300	300
Total water available	1988	2044	1660	2647	2235	2121	1682	2008
Water excreted	1003	1117	752	1795	1248	1216	856	892
Urine	972	1097	721	1773	1217	1188	829	866
Feces	31	20	31	22	31	28	27	26
Evaporative water loss	986	927	908	852	987	905	826	1116

* Daily Averages

TABLE 4-4

SERUM AND URINARY CREATININE AND CREATININE CLEARANCE

Day		Subject 1	2	3	4	5	6	7	8	Mean
5	Serum creatinine (mg%)	0.78	1.00	1.00	1.16	0.78	0.78	1.00	0.78	0.91
	Urine creatinine (mg%)	100	70	260	160	180	120	220	90	150
	Creatinine clearance (ml/min)	73	55	159	113	240	145	220	79	135
9	Serum creatinine	1.21	1.38	0.92	1.05	1.43	1.43	1.55	2.61	1.44
	Urine creatinine	277	262	388	225	155	300	347	274	278
	Creatinine clearance	125	157	77	351	67	154	86	72	136
12	Serum creatinine	1.00	1.32	1.44	0.80	0.92	1.44	0.92	1.44	1.16
	Urine clearance	143	195	207	143	132	143	249	201	176
	Creatinine clearance	90	148	143	124	102	87	148	89	116
15	Serum creatinine	1.16	1.16	1.40	1.00	1.32	1.16	1.24	1.44	1.23
	Urine creatinine	201	178		100	132		144	249	167
	Creatinine clearance	114	108		161	75		66	83	101
18	Serum creatinine	1.10	1.32	2.00	1.55	1.00	1.43		1.21	1.37
	Urine creatinine	146	137	166	76	137	76	166	128	129
	Creatinine clearance	98	124	40	63	100	56		56	77
21	Serum creatinine	1.32	1.44	1.66	1.22	1.44	1.44	1.66	1.32	1.43
	Urine creatinine	249	247	273	121	165	237	166	286	218
	Creatinine clearance	107	113	54	128	69	57	43	101	84
24	Serum creatinine	1.25	1.34	1.16	1.43	1.45	1.61	1.61	1.25	1.38
	Urine creatinine	201	328	273	121	121	201	202	95	192
	Creatinine clearance	100	186	64	102	81	68	67	49	89
27	Serum creatinine	1.40	1.40	1.61	2.04	0.85	2.60	1.61	1.61	1.64
	Urine creatinine	189	166	274	121	144	178	212	237	190
	Creatinine clearance	97	108	70	70	150	48	104	88	91
30	Serum creatinine	1.32	1.43	1.00	1.10	0.95	1.10	1.30	1.21	1.17
	Urine creatinine	110	80	154	40	35	121	110	143	99
	Creatinine clearance	62	53	62	57	40	67	104	77	65
35	Serum creatinine	1.00	1.00	0.70	0.90	1.32	2.00	1.10	1.00	1.12
	Urine creatinine	70	132	161	100	143	110	236	286	154
	Creatinine clearance	57	132	159	199	97	85	95	134	119

SECTION 5

BLOOD STUDIES

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SECTION 5

BLOOD STUDIES

INTRODUCTION

The problem of oxygen toxicity is well known and has been studied since the days of Priestley. However, there are conflicting opinions with regard to the toxic effect of this gas upon red blood cells. Early reports indicated that increased partial pressures of oxygen could be breathed with no deleterious effect upon the blood. Clamann and Becker-Freyseng[1] reported in 1939 that two subjects breathing 0.9 atmospheres oxygen (578 mm Hg) for 65 hours showed no change in erythrocyte count, however the average hemoglobin fell from 17.3 grams on day two and then returned to 17.2 grams on day three. In 1947 Ohlsson[2] found no changes in the formed blood elements, except for a rise in the WBC from 7,600 to 12,000 cell/mm^3 in one subject following exposure to 78-88% oxygen at 1 atmosphere for about 55 hours.

In contrast, Tinsley et al.[3], in 1949, noted that when normal subjects were given 50% to 100% oxygen by mask at 1 atmosphere, small but significant decreases in red blood cell count and hemoglobin were noted during the first few days of the experiment. These values remained depressed until air breathing was resumed. Reticulocyte count fell by 1/3 and radio-iron uptake was reduced during the period of oxygen administration.

With concern over oxygen toxicity to the red blood cell established, two major theories have evolved in explanation for the possible mechanism. These are hemolysis due to oxidation, and bone marrow suppression due to lowered erythropoietin levels. The first theory has much experimental and theoretical support. Jandl et al.[4], in 1960, showed that incubation of red cells in vitro under high concentrations of oxygen caused hemolysis accompanied by changes similar to those seen in Heinz body anemias. It is also known that certain individuals with a deficiency of glucose-6 phosphate dehydrogenase in their red cells may develop severe hemolytic episodes following ingestion of oxidizing drugs such as primaquine. In theory, the red blood cells of the body may have adapted to withstand that partial pressure of oxygen experienced by man in his normal range of environments. If this delicately balanced arrangement were upset, either by an increase in oxygen or a reduction in the enzyme, hemolysis could occur.

The theory of bone marrow suppression is more difficult to support. It is known that reduced oxygen tension causes a rise in blood erythropoietin levels with a resulting secondary polycythemia. From this, it would seem that erythropoietin production may be regulated by blood oxygen saturation, and increased oxygen might reduce the erythropoietin output of the kidney. Gyllensten and Swaubeck[5] may have substantiated this with an experiment reported in 1959. They found that in growing mice, exposure to high concentration of oxygen damages the erythrocyte-producing

or regulating mechanisms with subsequent changes in the circulating blood after a "free interval" with apparently normal blood findings.

It therefore appears that there is considerable variation of opinion as to the effect of increased oxygen tension upon the red blood cell and, if there is an effect, by what mechanism it is brought about. With this in mind, there was obviously reasonable concern when a one gas system was decided upon for our spacecraft atmospheres as future efforts would require long exposures to it.

We must emphasize that although our atmosphere is 100% oxygen, our results cannot be compared with early experiments done at similar concentrations at sea level. Two hundred fifty eight mmHg of oxygen represents 163 mmHg oxygen in the alveolus, according to the alveolar equation. This is an increase of only 62 mmHg over the oxygen pressure in the alveolus which results from breathing ambient air at sea level. Although reduced total pressure and lack of nitrogen must also be considered as variables, comparison will be made to prior studies only on the basis of the effective partial pressure of oxygen.

Recent studies using increased partial pressures of oxygen along with reduction in total pressure have shown essentially no effect upon the red cell. Michel et al.[6] noted that hemograms done on six subjects exposed to 80% oxygen at an altitude of 10,000 feet for seven days were within normal limits. More recently, Hall and Martin[7] demonstrated that a subject could tolerate 3.5 psi of 100% oxygen for 72 hours with no abnormal changes in the hematologic studies. These experiments were of relatively short duration and at altitudes different than those used in this study.

Two recent, long duration experiments have been performed using 27,000 feet altitude. Zalusky et al.[8] exposed four of eight subjects to a total pressure of 258 mmHg at 98.5% oxygen and 0.2% nitrogen and four subjects to a total pressure of 700 mmHg at 33% oxygen and 62.3% nitrogen for a period of 30 days. Except for slight changes in red cell values and a hematocrit reduction of 6.7% and 9.1% in the 258 mmHg group and the 700 mmHg group, respectively, most of the results of the hematopoietic studies were normal. His conclusion was that it appeared "30 days exposure to the increased oxygen partial pressures used in this study does not significantly alter hematopoiesis." A study carried out by Helvey[9] in 1963 showed quite different results. In this study, twenty eight men were divided into four groups and placed for fourteen days in a sealed chamber at sea level (control, 7.4 psi (380 mmHg; 18,000 feet), 5 psi (258 mmHg; 27,000 feet), 3.8 psi (196 mm Hg; 33,000 ft.). The hematologic findings are most striking and appear in the following author's summary.

Summary of Data

"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 subject 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)"[9].

Obviously, the contradictory results of the preceding studies indicates the need for a clear and intensive study of the problem before manned spacecraft can be planned for long duration experiments utilizing the 100% oxygen environment.

METHODS AND MATERIALS

A series of hematologic studies were performed with the primary purpose of determining if there was any change in the rate of red blood cell production or destruction These included a complete blood count, red cell indices, reticulocyte count, Price-Jones curves, osmotic and mechnical fragilities, and direct and indirect bilirubin. Blood enzyme activity is reported separately in Section 6. The blood for analysis was drawn by venipuncture approximately every third day with an effort made to get as close as possible to the beginning and end of each set of conditions during the run. For uniformity, no food was eaten for six hours prior to each blood letting. Eleven ml. of blood were taken at each sampling.

Subjects were trained over a period of two weeks to perform venipunctures on each other. In this manner, sampling could be taken during the study without the necessity of moving personnel in and out of the chamber. Twenty-one gauge needles were used for the drawing and were removed from the syringe before expelling the blood down the walls of the collecting tubes.

The complete blood count and red cell indices were performed in the standard manner using a Max Levy counting chamber with the improved Neubauer ruling. Differential slides were stained with Wright's solution. Hemoglobin was determined by the cyanmethemoglobin method using the Klett-Summerson colorimeter. The microhematocrit determination was used. Reticulocyte counts were made using the

Hartman-Leddan methylene blue reticulocyte stain. Price-Jones curves were drawn by measuring the diameters of 200 red cells through an Okular-Schraubernikrometer to the nearest 0.1 micron. Curves were then made by connecting the peaks of columns of cells in each category. Osmotic fragility was measured by monitoring beginning and complete hemolysis after two hours of standing in tubes containing salt solutions ranging from 0.5% to 0.24%. Mechanical fragility was done using 1 ml of blood in 7.5 ml stoppered test tubes containing 50 glass beads of 4 mm diameter which were then agitated on a pipette shaker at 270 strokes per minute with a stroke distance of two inches for a period of five minutes. Before and after microhematocrits indicated the drop in hematocrit due to breakdown of red cells. A time sufficient to cause a 3% drop was selected in order that any increased tendency toward mechanical hemolysis would become apparent. Direct and indirect bilirubin determinations were made with the diazo technique using a Beckman Spectrophotometer.

RESULTS

As seen in Figure 5-1, the averaged hematocrit of the subjects varied no more than 2.5 percent throughout the entire run. The controls are noted to maintain an almost constant elevation of approximately 2.5 mm above that of the subjects, however this elevation was established prior to the beginning of the test atmosphere, and did not change appreciably throughout the remainder of the run.

The red blood cell (Fig. 5-2) count is seen to correspond closely to the graph of the hematocrit. Here again, essentially no change was seen in the subjects before and after exposure to the test atmosphere, nor is there any change in their relationship to the controls during this period. It must be noted at this time that the slight elevation of the controls in both of these graphs is the result of the exceptionally high readings of one control subject. The othere control subject maintained readings almost identical to those of the six experimental subjects.

The hemoglobin concentration (Fig. 5-3) showed an initial climb which was roughly parallel between subjects and controls during the first week of confinement. This climb leveled off in the control group at the end of the first week and maintained a range between 16.5 and 17.5 grams percent. There was an abrupt drop in the subject's hemoglobin concentration back to pre-run levels following the onset of the test atmosphere with a moderate rise again during the week following a return to sea level conditions.

The difference seen between the two groups is due primarily to the same subject as mentioned previously. The other control subject also maintained somewhat higher values during that portion of the run. It must be noted that although the values for the experimental subjects were below the control subjects, all values were within normal limits and never dropped below pre-run levels.

From the preceding data the red blood cell indices were calculated. These include the mean corpuscular hemoglobin concentration, (Fig. 5-4), mean corpuscular hemoglobin (Fig. 5-5) and mean corpuscular volume (Fig. 5-6). These data show that the slight change observed appears to be in the hemoglobin content of the cells. A relatively small increase was noted in the control subjects.

The white blood count (Fig. 5-7) varied greatly, but remained within normal limits for all subjects for the duration of the run. Essentially no difference was noted between the two groups, nor between the values of the pre, during, or post exposure determinations.

The reticulocyte count (Fig. 5-8) remained within normal limits throughout the entire run for both groups with no subject reaching as high as two percent. There was a very slight rise in both groups during the exposure period, but this could tend to indicate a variation in laboratory technique rather than a significant change.

Price-Jones curves (Fig. 5-9; 5-10) were compared and evaluated as to height of the mean and the lateral spread. These varied only slightly and the curves were shown to maintain essentially their initial shape throughout the run for both groups.

Beginning and complete hemolysis for the osmotic fragility test (Fig. 5-11) was almost identical for both groups and, again, no change was seen before and after exposure to the test atmosphere.

The fall in hematocrit due to mechanical fragility (Fig. 5-12) accelerated slightly in both groups throughout the run. In the experimental group it amounted to four percent the day following descent to sea level. Because of the minimal degree of change, and because the control and experimental group so closely approximated each other, it is felt that this change fails to demonstrate increased mechanical fragility of the red cell.

It is interesting to note that although the increase in mechanical fragility on the thirtieth day is very slight, small changes occurred on this data in several other tests. There was a slight drop in the subjects' mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, and reticulocyte count. There was a slight rise in red blood cell count. These changes are listed only to make note of them, for it is felt that they are so small and contrast so poorly with the control group that they are of no significance.

Indirect bilirubin (Fig. 5-13) was calculated by subtracting direct from total bilirubin (Fig. 5-14). Fluctuations were greatest in the control group. The experimental group maintained a generally lower indirect bilirubin with no evidence of change during the experimental period.

DISCUSSION

From previously published reports relating to hematologic data, our interest was directed toward the toxic effects of oxygen only upon the red blood cell. To investigate these effects, three parameters were measured. These were the red cell itself, the breakdown products and what, if any, response the protective mechanisms made.

The red blood cell was studied for change in size by means of the mean corpuscular volume and the Price-Jones curves. Since red blood cells decrease in size up to maturity, a release of immature red cells from the marrow could be shown in this manner. Another test indicating changes in the blood forming mechanisms is the reticulocyte count. Reticulocytes are immature red cells containing a network of filaments or granules. Since these granulofilamentous substances remain demonstrable for a few days after the erythrocytes are delivered to the peripheral blood, the reticulocyte count is employed as a measure of the physiological activity of the bone marrow.[10]

Our data show no indication of change in the activity of bone marrow. The height, width and mean peaks of the Price-Jones curves of the experimental group show essentially no change throughout the experiment. The control group showed greater variation, but this is to be expected due to the smaller sample.

The mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, hematocrit and hemoglobin are all means of studying possible changes in the nature of the circulating red cell. These are of special interest in that there was no significant decrease in any of these values. Although an unexplained increase in hemoglobin occurred in the controls, especially in one subject it must be conceded that no appreciable change in the status of the circulating red cells occurred. The white blood cell count tends to verify that there was no concentration or dilution of the blood cell mass.

If there were an increase in red cell aging as in glucose-6-phosphate dehydrogenase deficiency, an increase in red cell fragility might be expected. The small, but consistent rise in mechanical fragility is of some concern. However, the similarity of the curves of the experimentals and the controls makes it seem that technique variations are responsible and that nothing here indicates increased fragility as a result of the conditions imposed.

The bilirubin, both indirect and total, would show an increase if the hemolysis of red cells was so great that the liver could not clear the breakdown products. Although variations due to technique are high in this test, it is safe to say that hemolysis, if it occurred, was within the capacity of the liver to clear it.

Finally, the protective mechanism using glucose-6-phosphate dehydrogenase was not affected at all during the experiment. This is not a proof that no protective efforts are being carrier out as a defense against oxidation, but rather, a demonstration that no change does occur in the one known enzyme system whose deficiency can cause a hemolytic anemia.

CONCLUSION

There have now been three separate studies under essentially the same environmental conditions, i.e., 100% oxygen at 27,000 foot simulated altitude for extended periods of time. From the findings of this study it appears that essentially none of the hematologic changes, such as those reported in the Republic experiment, were found of particular interest in that experiment, was the large number of mercury containing instruments broken inside the chamber. These included six oral thermometers, and two sling psychrometers. Since stippled red cells were noted, it is of special concern that a toxic agent such as mercury vapor may have been involved.

With this in mind, and since our findings so well agree with the work done by Zaluskey[7], it is felt that this environment can be accepted by man for at least twenty days with no deleterious effect upon the red blood cell.

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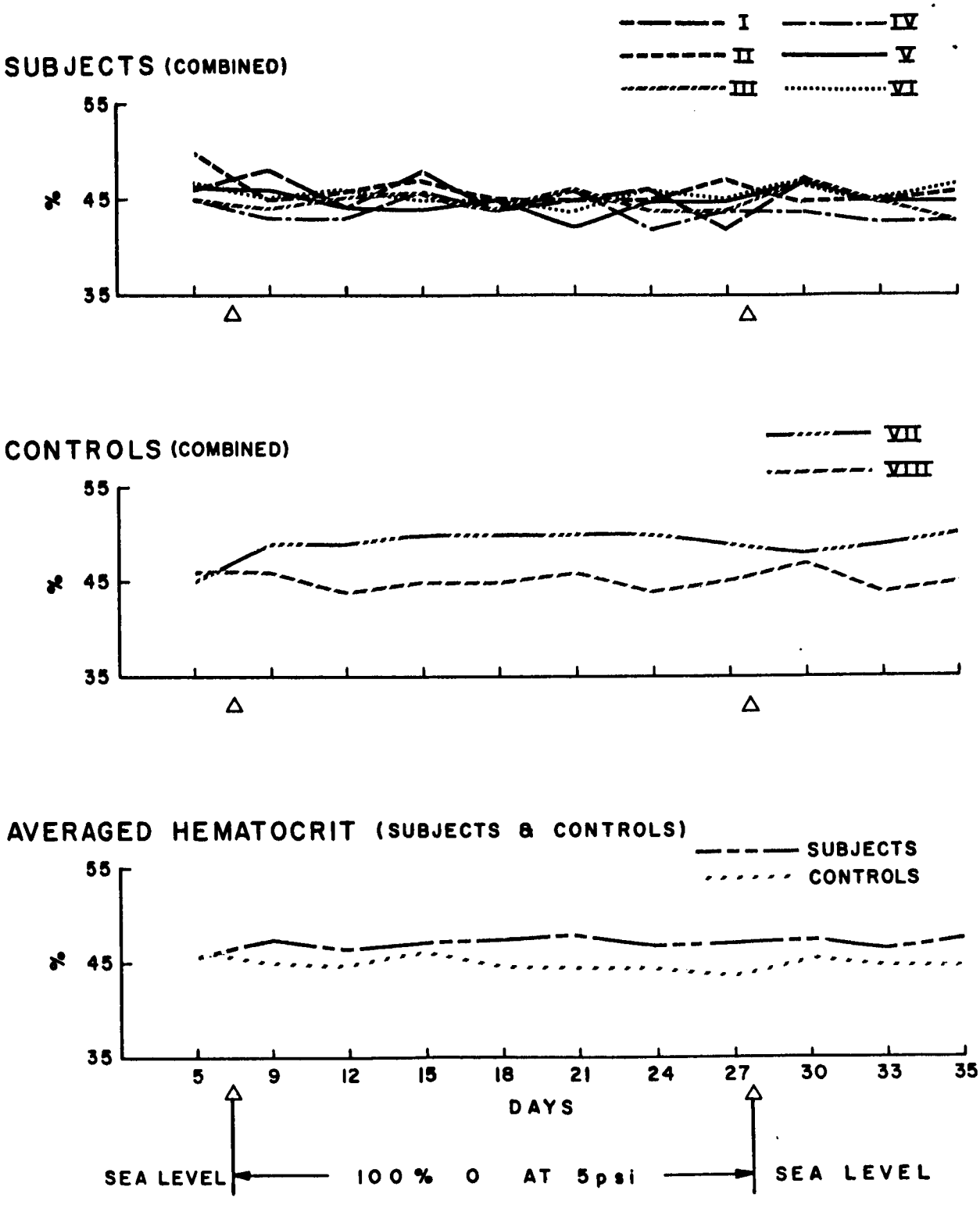


FIGURE 5-I. HEMATOCRIT

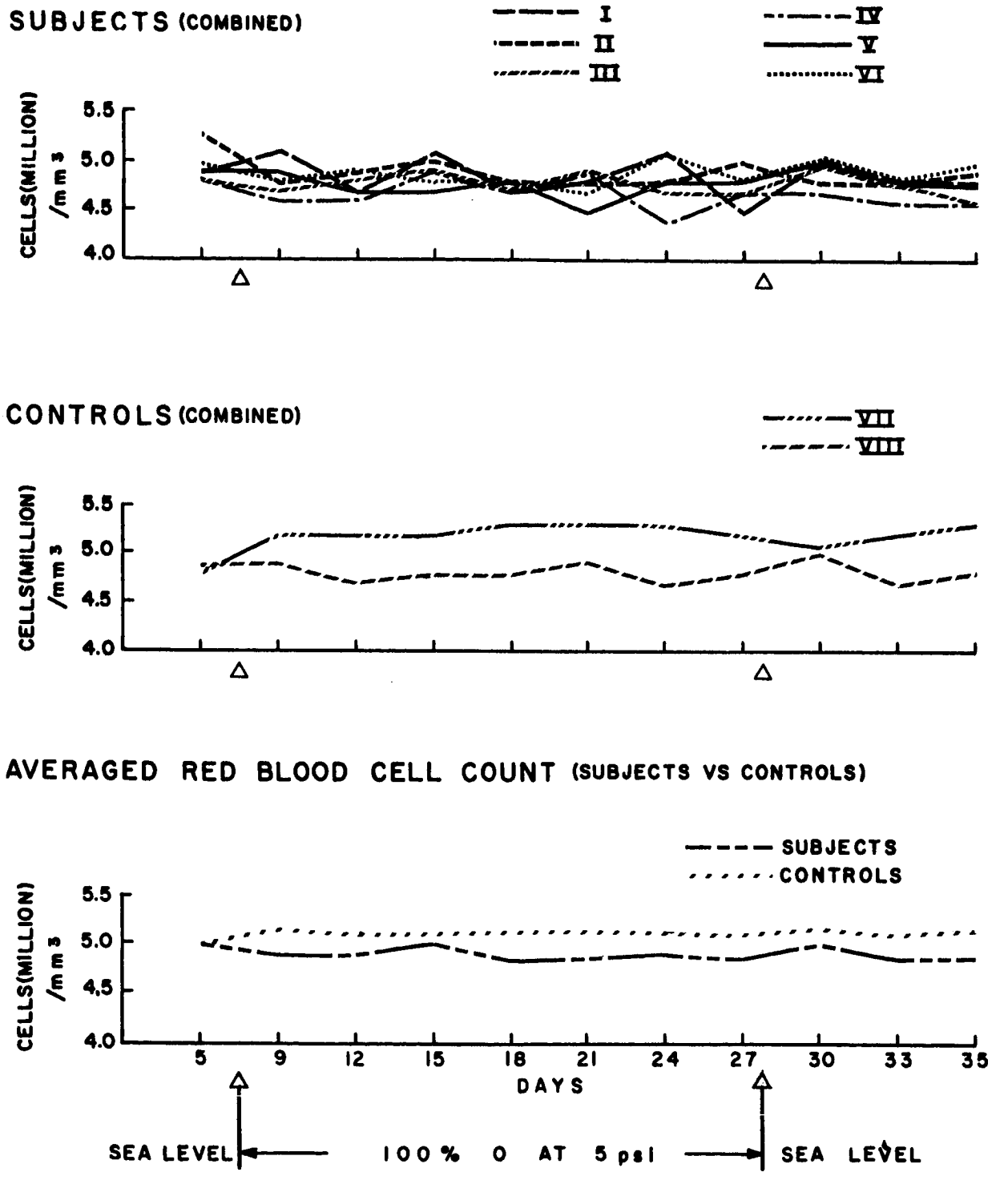


FIGURE 5-2 RED BLOOD CELL COUNT

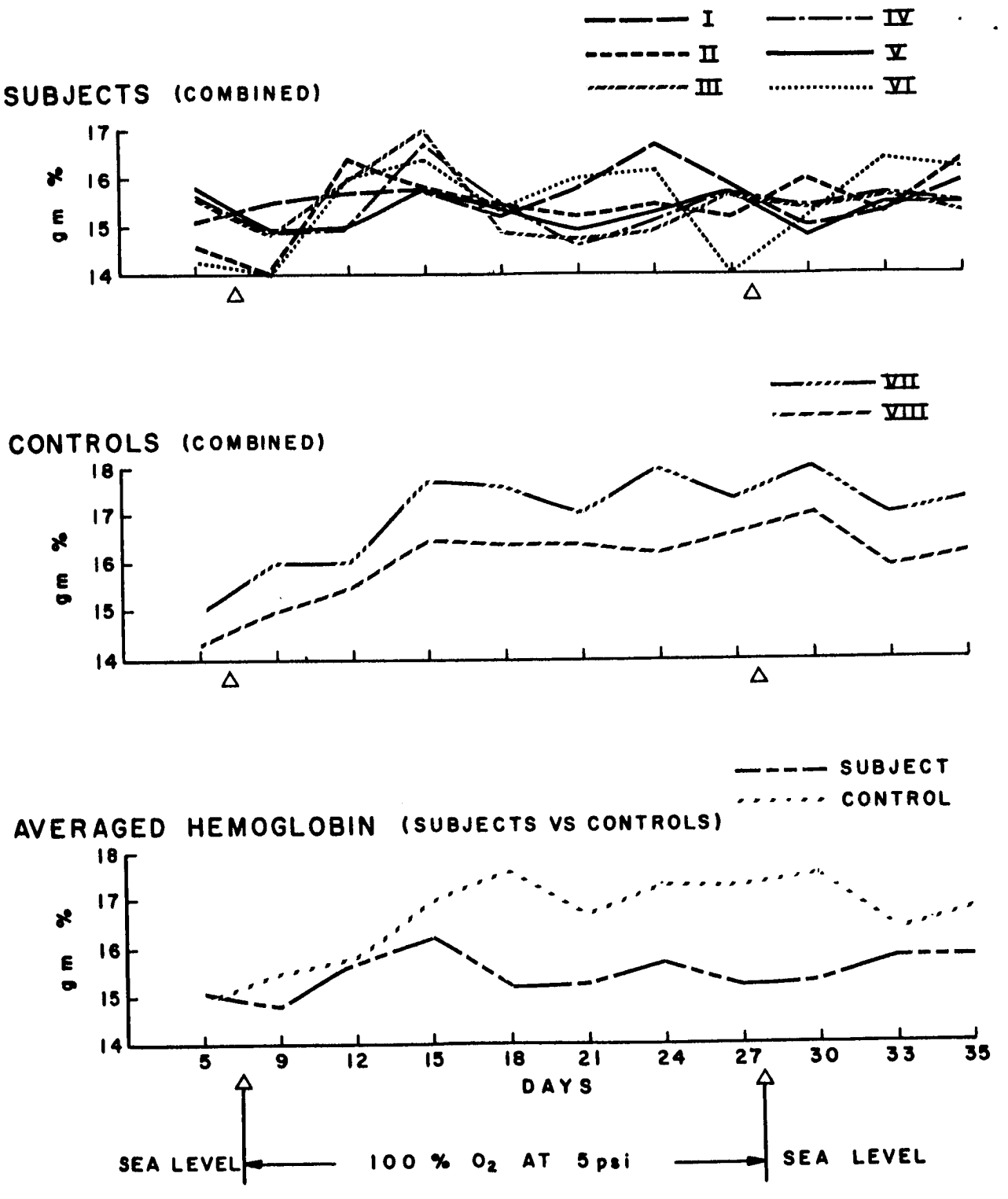


FIGURE 5-3. HEMOGLOBIN

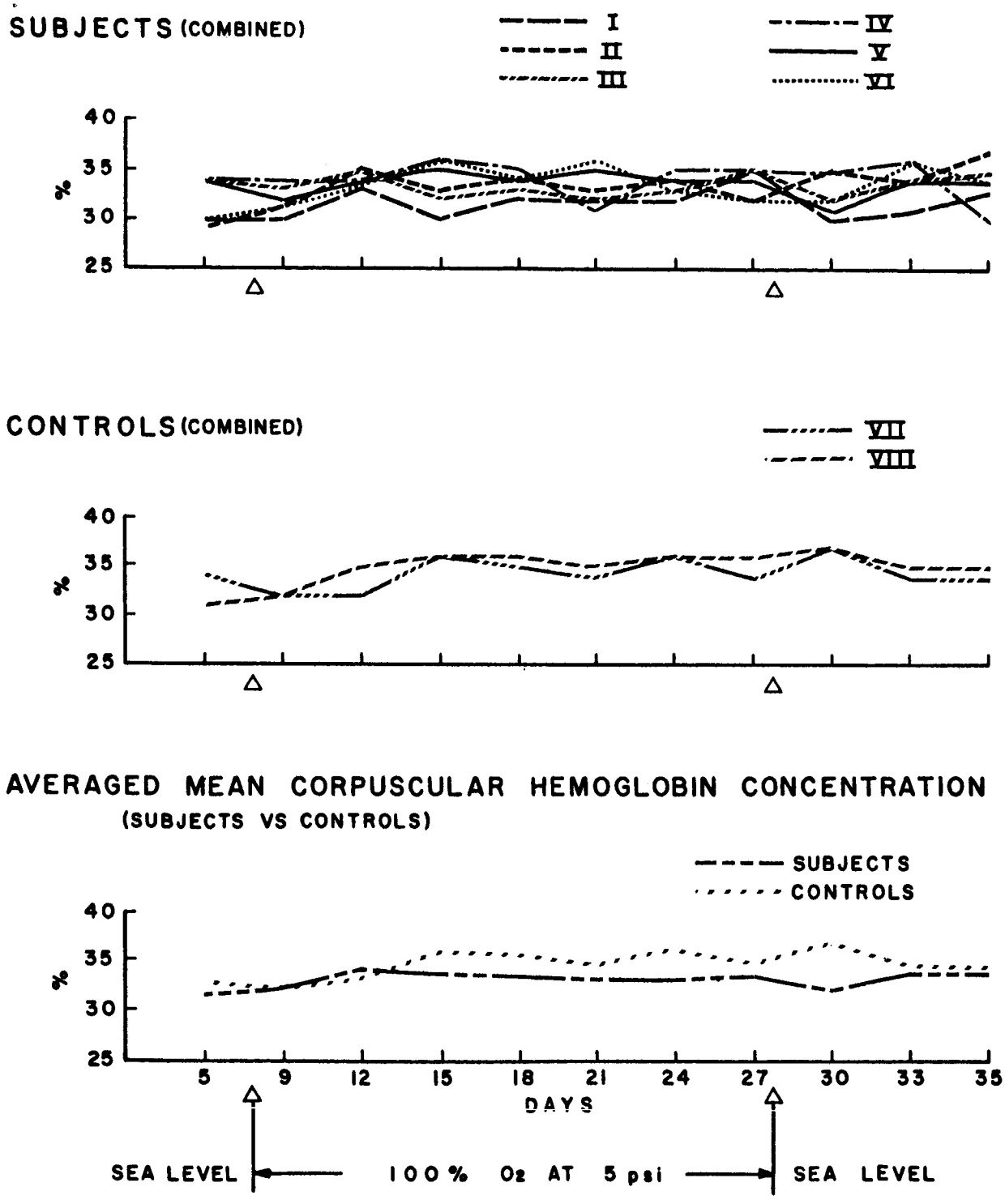


FIGURE 5-4. RED BLOOD CELL INDICES - MEAN CORPUSCULAR HEMOGLOBIN CONCENTRATION

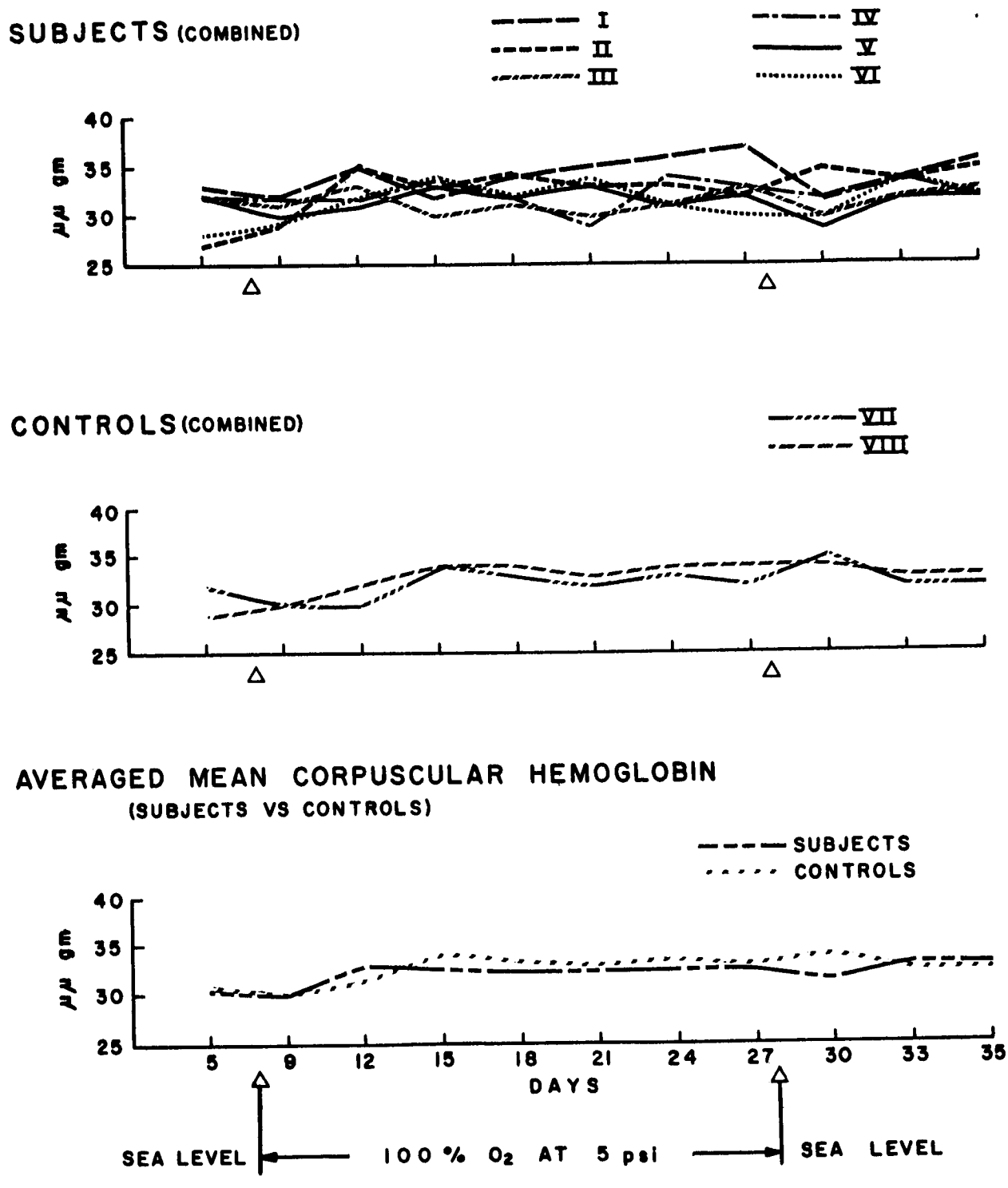


FIGURE 5-5. RED BLOOD INDICES - MEAN CORPUSCULAR HEMOGLOBIN

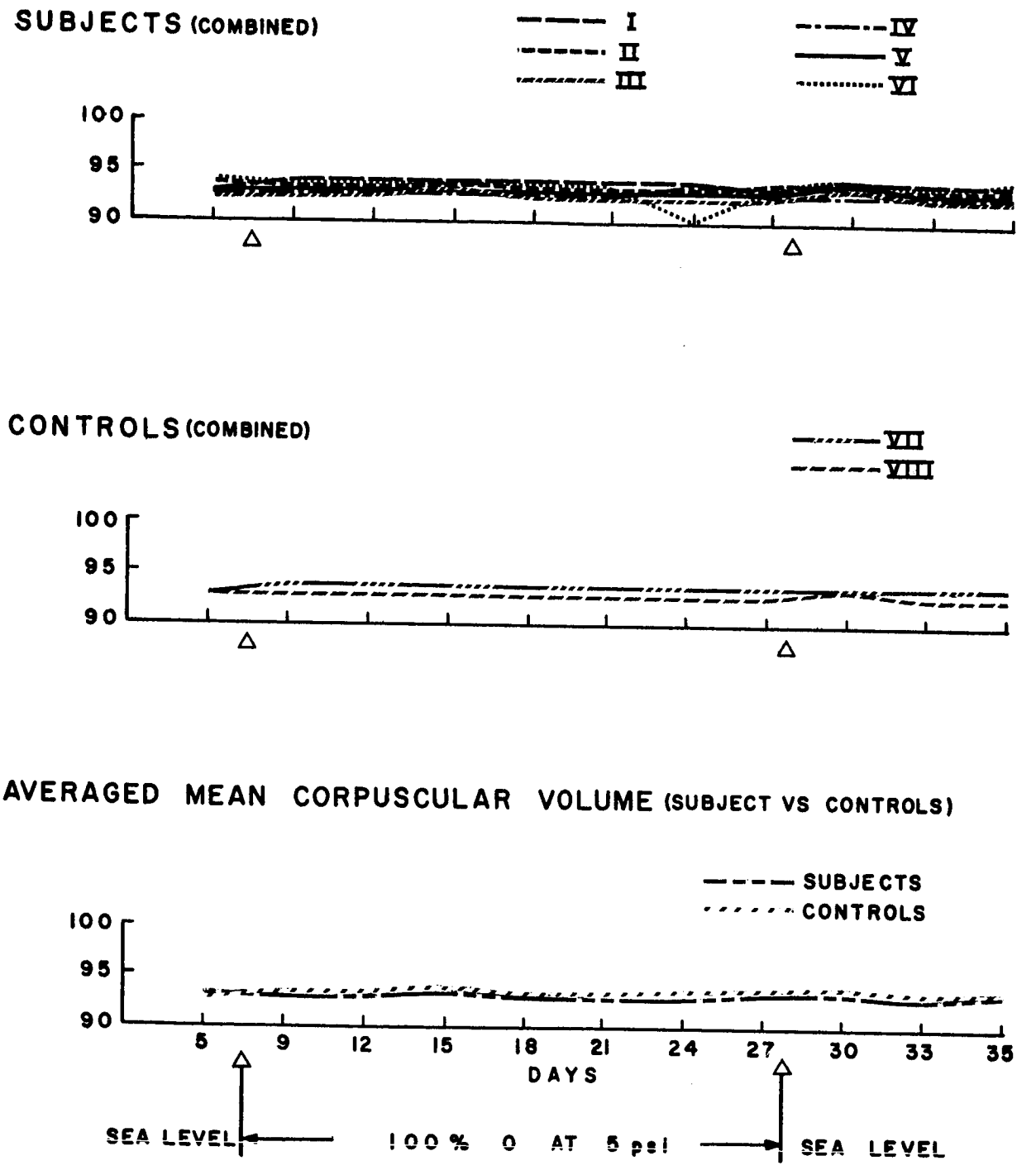


FIGURE 5-6. RED BLOOD INDICES - MEAN CORPUSCULAR VOLUME

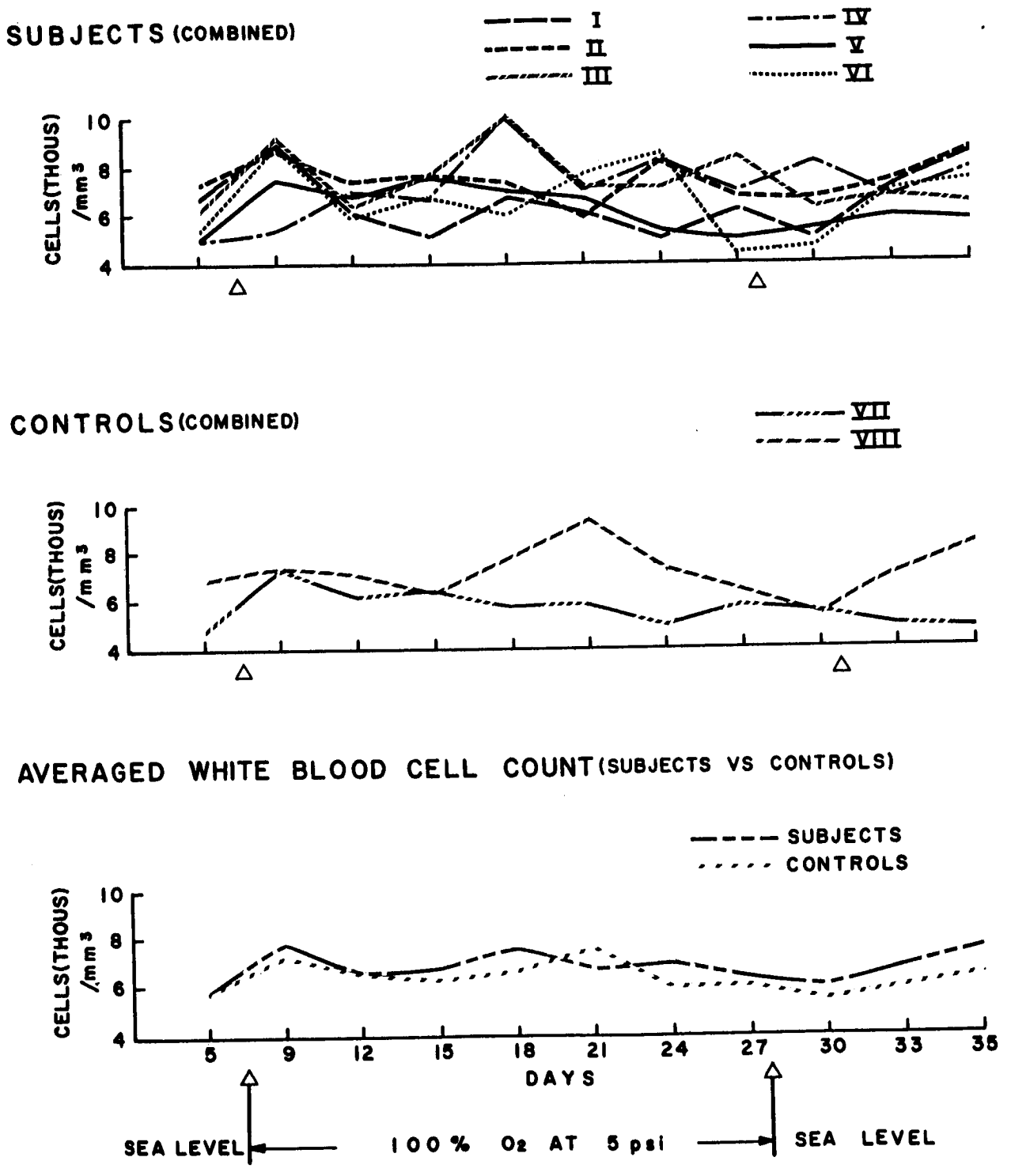


FIGURE 5-7. WHITE BLOOD CELL COUNT

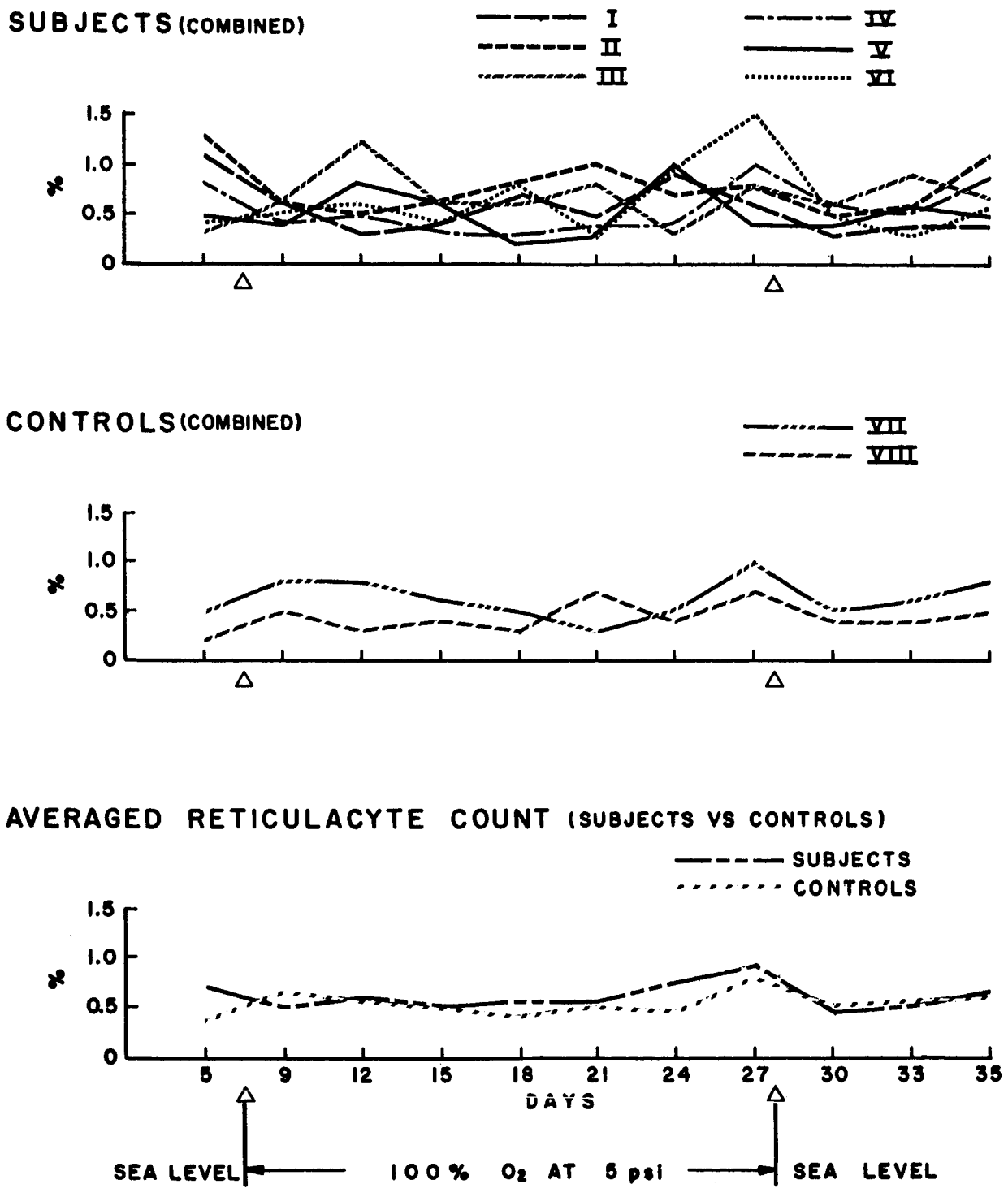


FIGURE 5-8. RETICULOCYTE COUNT

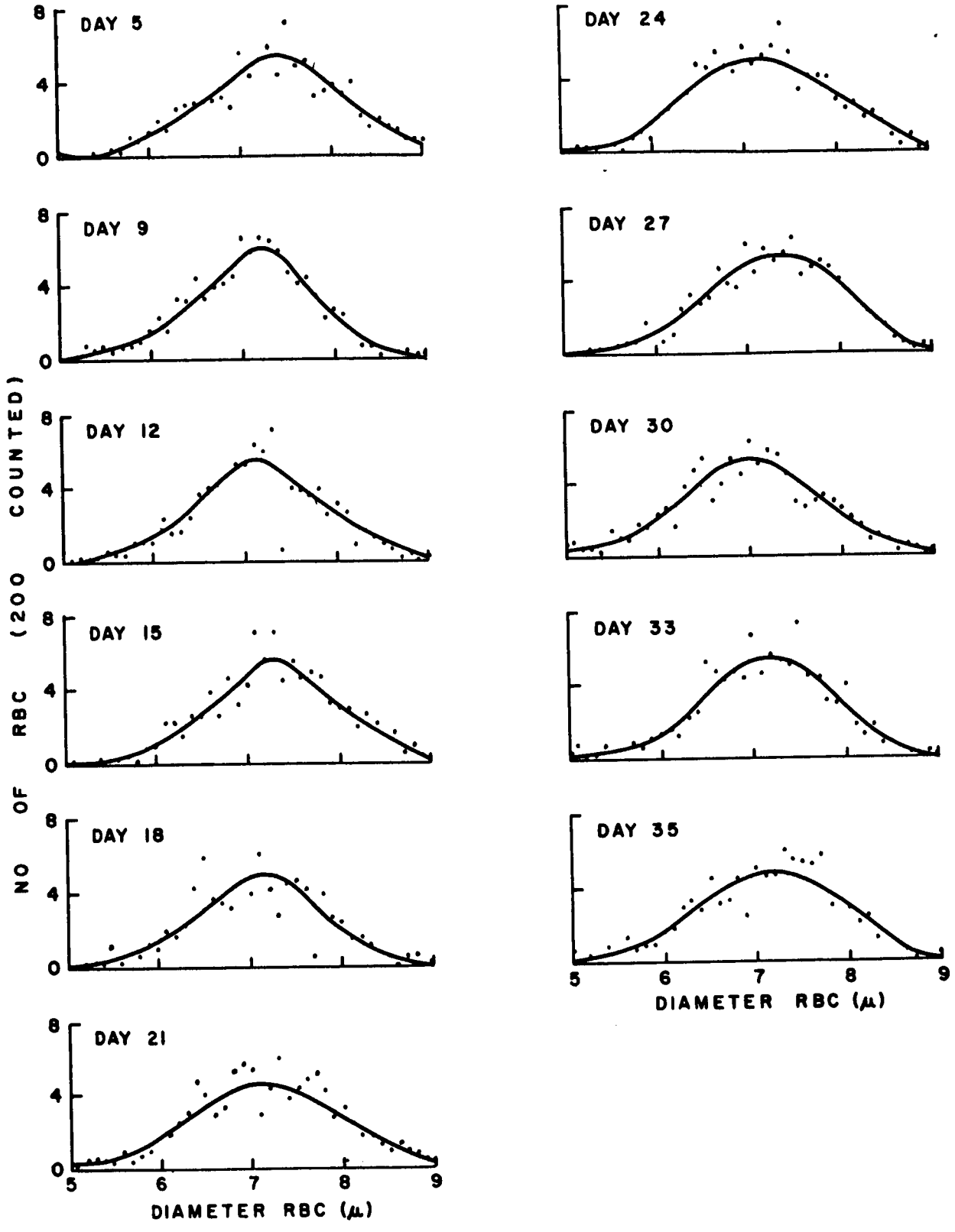


FIGURE 5-9. PRICE-JONES CURVE - SUBJECTS (AVERAGED)

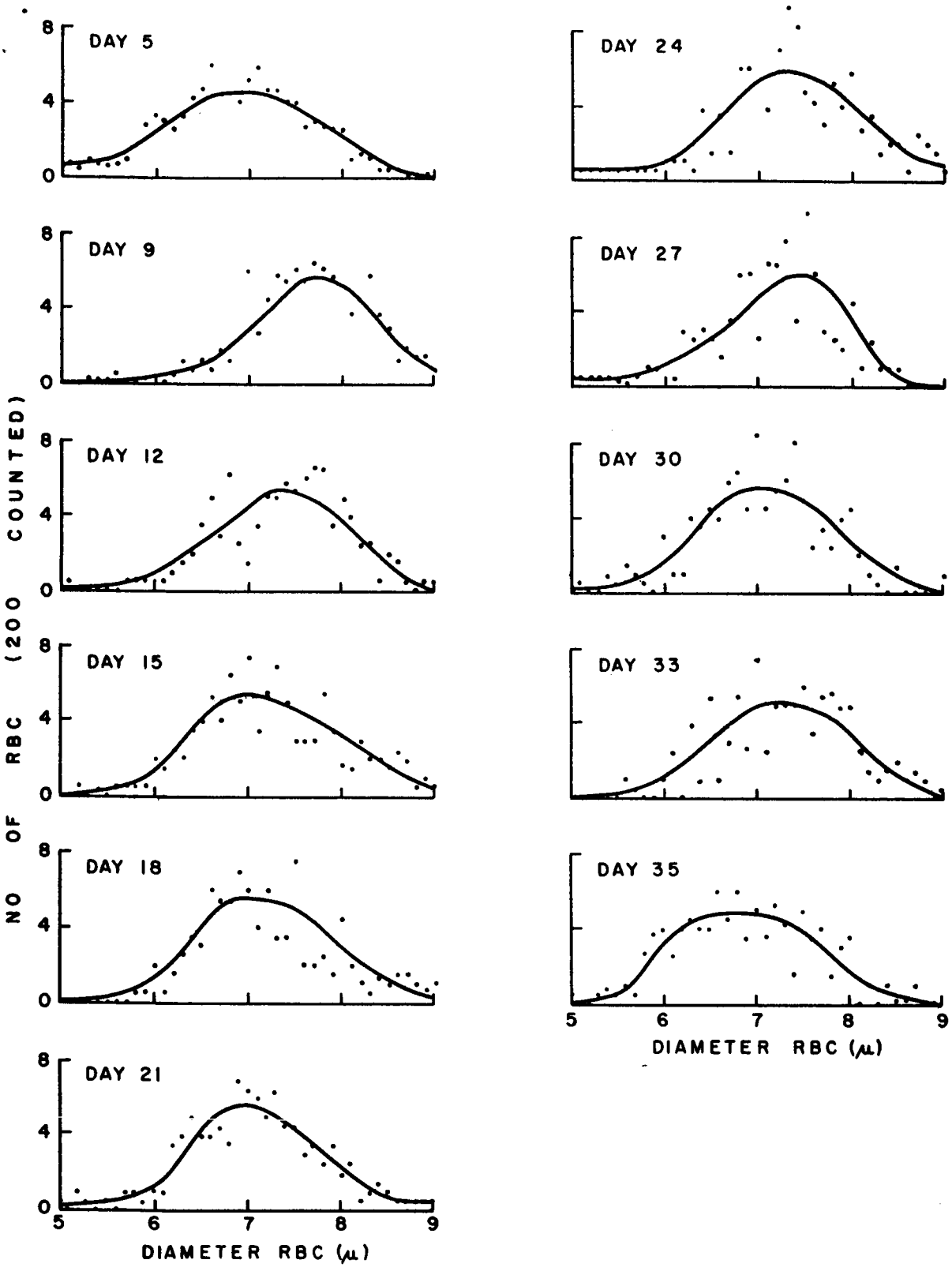


FIGURE 5-10. PRICE-JONES CURVE - CONTROLS (AVERAGED)

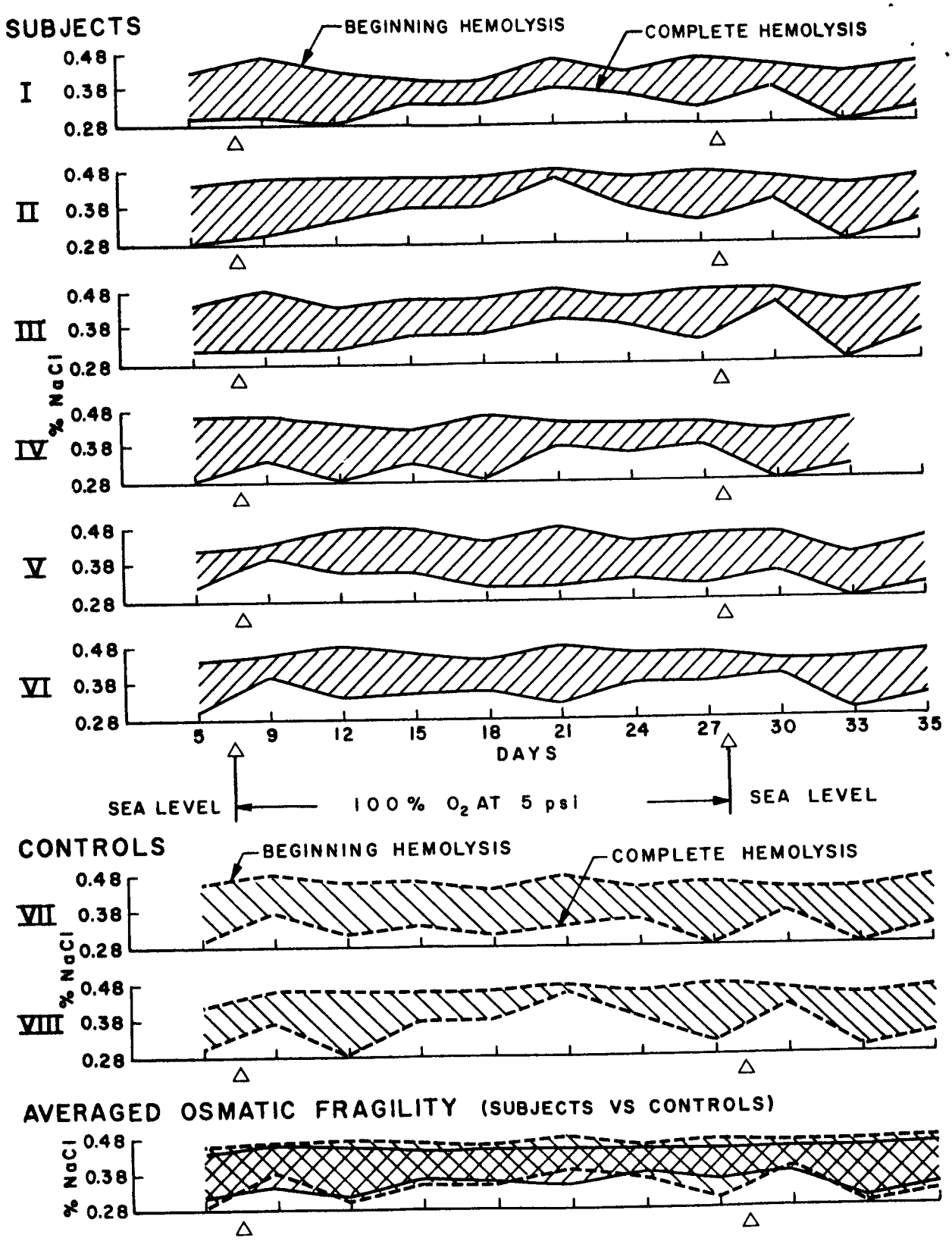


FIGURE 5-11. OSMOTIC FRAGILITY

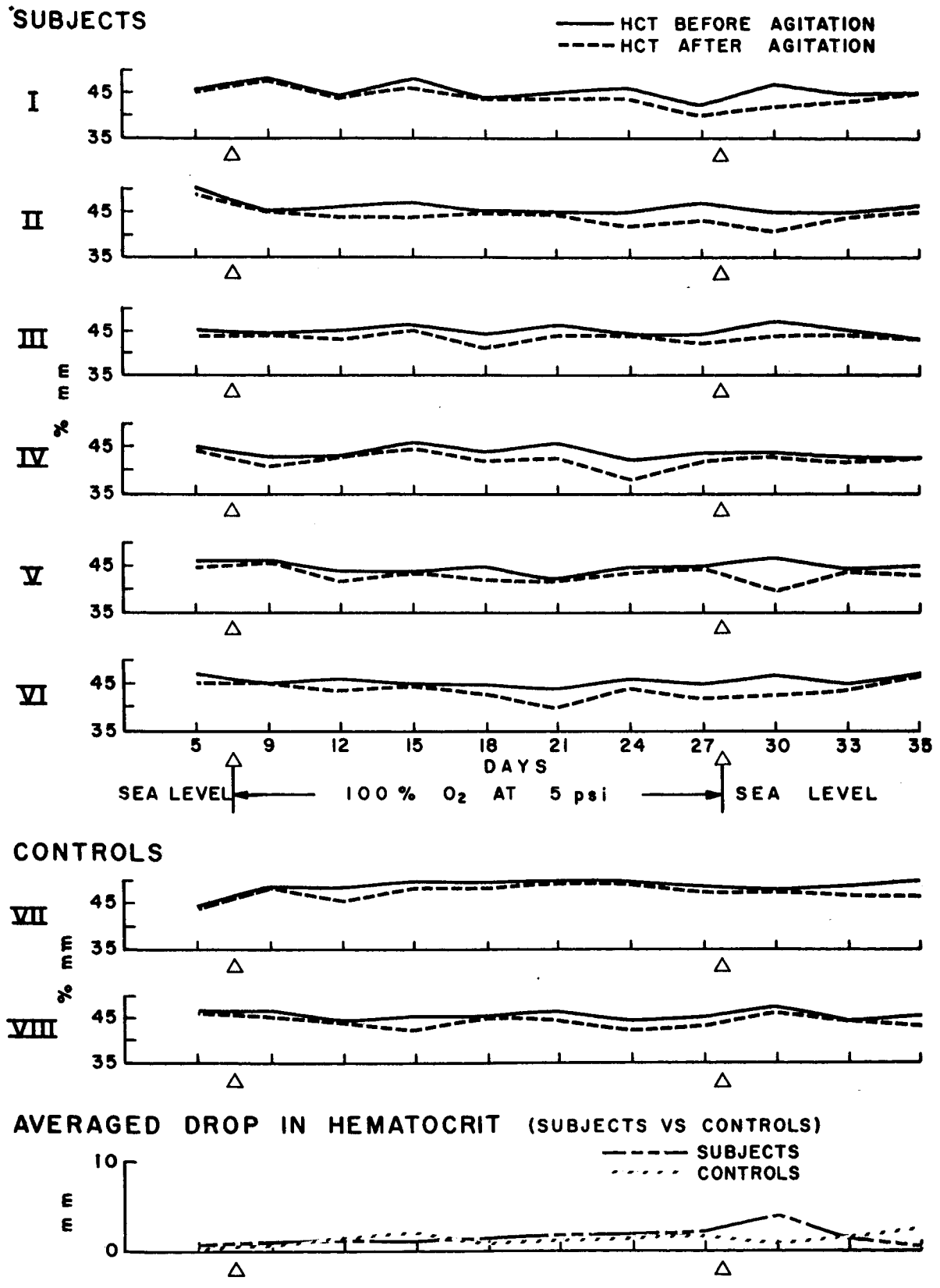
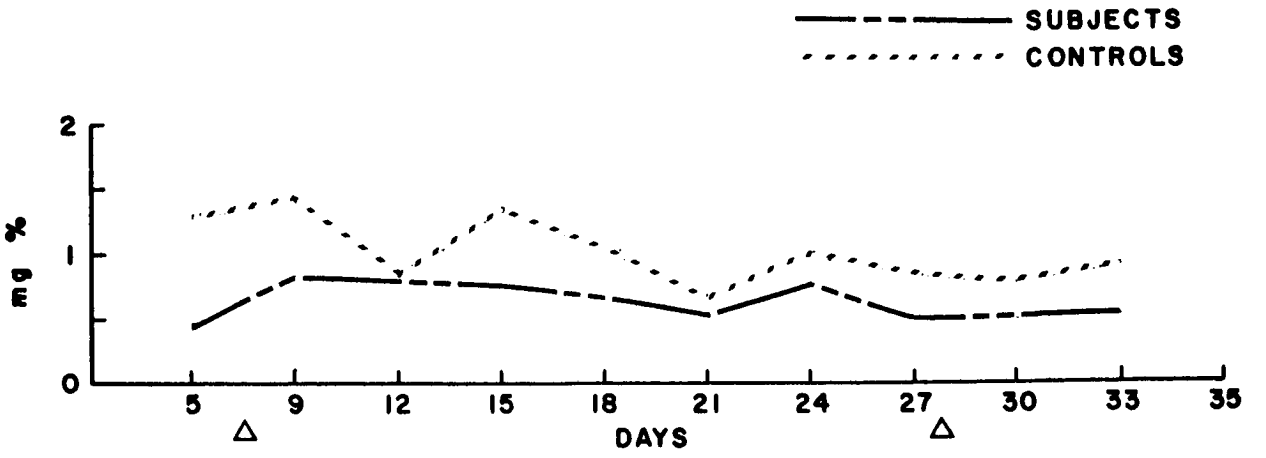
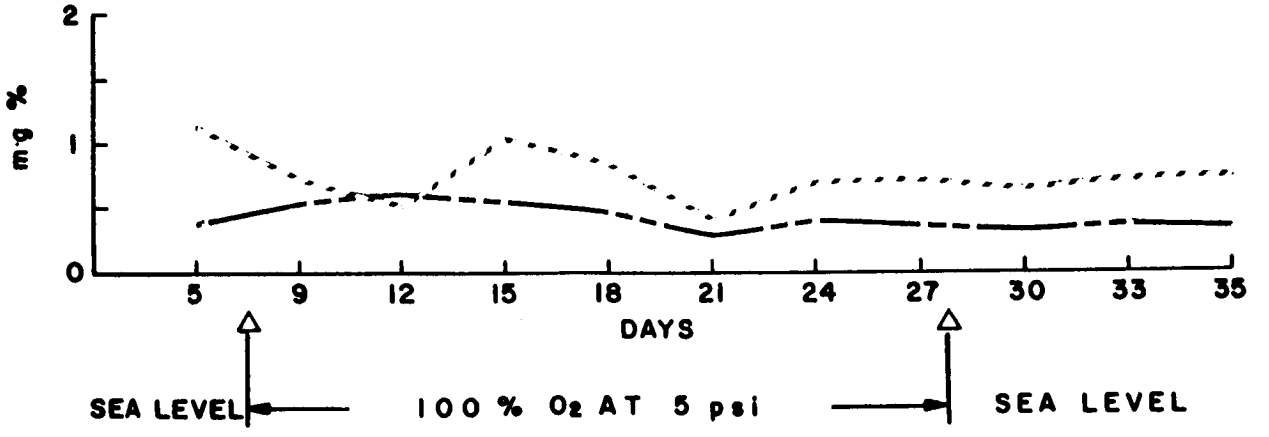


FIGURE 5-12. MECHANICAL FRAGILITY



AVERAGED TOTAL BILIRUBIN



AVERAGE INDIRECT BILIRUBIN

FIGURE 5-13.

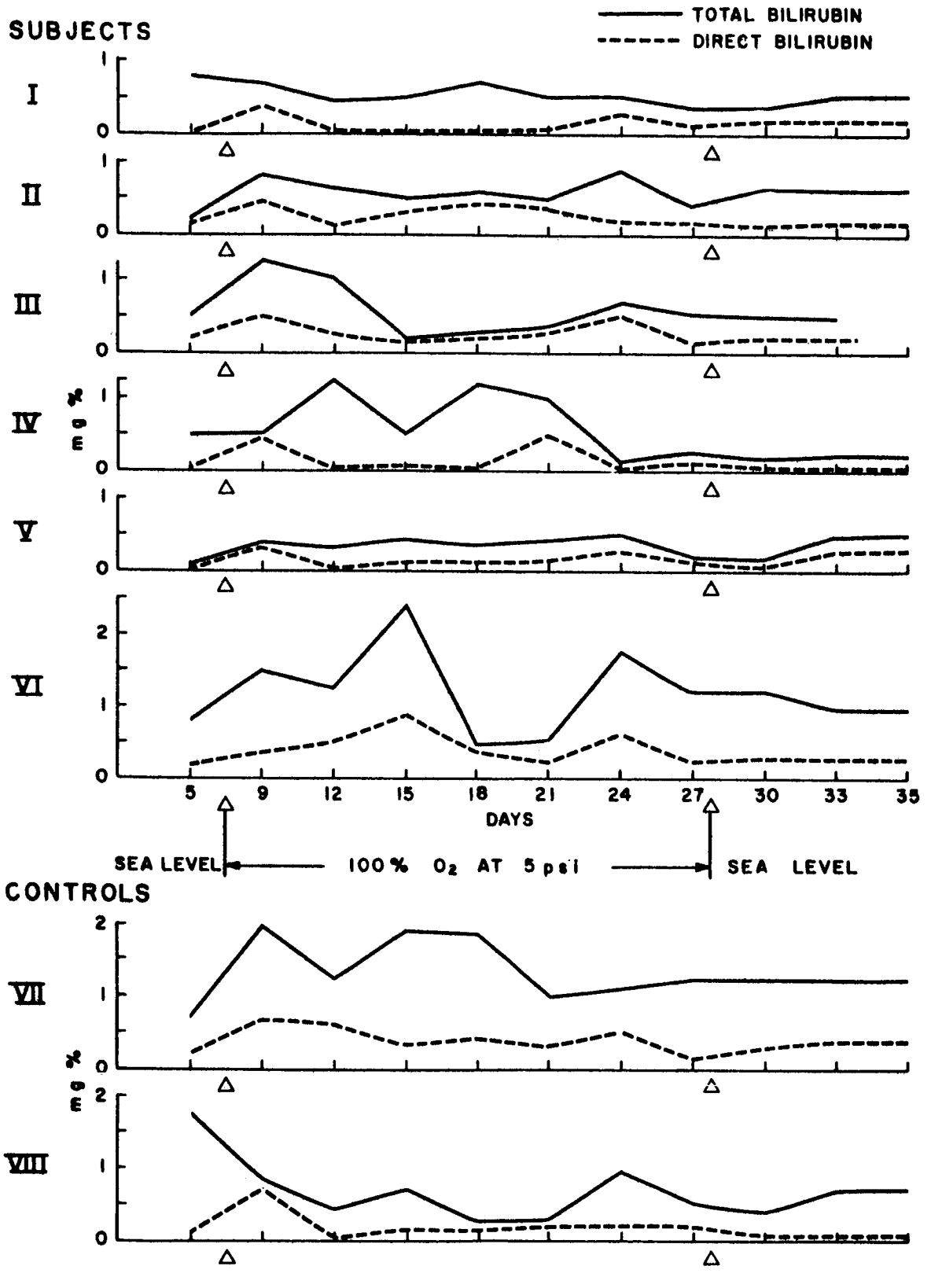


FIGURE 5-14 TOTAL AND DIRECT BILIRUBIN

SECTION 6

BIOCHEMICAL EFFECTS OF PROLONGED EXPOSURE TO AN ATMOSPHERE OF 100% OXYGEN AT A SIMULATED ALTITUDE OF 27,000 FEET

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SECTION 6

BIOCHEMICAL EFFECTS OF PROLONGED EXPOSURE TO AN ATMOSPHERE OF 100% OXYGEN AT A SIMULATED ALTITUDE OF 27,000 FEET

In the course of evaluating the proposed single gas system for spacecraft atmospheres, several reports have concerned themselves with the physiological effects of 100% oxygen atmosphere of these vehicles. In one of the early reports[1] several physiological effects of the system were noted on human volunteers. The most striking of these was an apparent tendency toward in vivo hemolysis. Within several hours of the time of entry a rise in circulating serum bilirubin was noted in the subjects with a corresponding loss of hemoglobin. It was concluded that there were toxic manifestations of the oxygen atmosphere and further study of the physiological and biochemical effects of the oxygen atmosphere was indicated.

In several other reports[2,3,4], various biochemical determinations were done on human subjects that were exposed to atmospheres containing increased oxygen partial pressures at reduced atmospheric pressure, but not necessarily 100% oxygen. Although the question of hemolyses was not specifically examined, no mention was made of any observations concerning it other than a slight drop in hematocrit which subsequently returned to pre-exposure levels[4]. There were no untoward effects described in the subjects.

In one recent study[5] particular consideration was directed to the possible hemolytic effects of atmospheres containing increased partial pressures of oxygen on human subjects. A slight drop in the hematocrit was observed ranging from 6.7% to 9.1%, but normal Cr^{51} red cell survival, normal bilirubin and urobilinogen excretion, and low reticulocyte counts led the authors to the conclusion that there was no hemolytic process active. They also investigated the pentose phosphate pathway in the red cell by measuring the activity of glucose-6-phosphate dehydrogenase activity and glutathione stability and found, by these criteria, that oxidative hemolysis was not occurring. This study was conducted in atmospheres that ranged from 33% to 98.5% oxygen.

There have been several indications that one of the potential hazards concerned with human survival in atmospheres of increased oxygen tension is the inactivation of certain enzymes[6]. It has been noted that the dehydrogenases are particularly susceptible to this type of toxic action.

Previous studies in this laboratory[7] have shown a definite increase in the activity of serum isocitrate dehydrogenase in several human subjects exposed to an atmosphere of 100% oxygen at varying atmospheric pressures for periods of time up to 72 hours. In view of this, it was deemed advisable to include the assay of serum isocitrate dehydrogenase activity in the current experiment.

In view of conflicting reports in the literature concerning the influence of increased oxygen tensions on the activity of glucose-6-phosphate dehydrogenase in the erythrocyte, the measurement of the activity of this enzyme in the red cell was included.

In one of the previously cited studies[1] one of the subjects who showed a definite hemolytic response to an atmosphere of pure oxygen was later diagnosed as having a thalassemia trait. For this reason, and in order to adequately screen our subjects before exposing them to the high oxygen atmosphere, electrophoretic analysis of their hemoglobin types was conducted.

Haptoglobin is an alpha-2 globulin which can combine with hemoglobin in the serum to form a weak peroxidase. When hemoglobin is liberated into the serum, as in hemolysis, it combines with haptoglobin until the binding capacity of the haptoglobin is exceeded. In hemolytic conditions, therefore, the plasma level of free haptoglobin is reduced. In order to further screen for possible hemolytic effects, electrophoretic analysis of serum hemoglobin binding capacity was carried out.

It was also noted in previous experiments in this laboratory that there appeared to be, in certain subjects, an increase in the lipoidal content of the serum as evidenced by a turbid, lactescent serum. It is known that there is virtually no "free" lipid material in the serum, but that most of it is bound to protein. In many types of lipemia it is more valuable to determine the distribution of the relative concentrations of the lipoprotein fractions than the total concentration of a specific lipid in the serum[8]. Lipoprotein electrophoresis was carried out on the sera of the subjects of this study.

METHODS

All subjects for this study were Navy and Marine Corps aviators who were between 25 and 28 years old. All were considered to be in excellent physical condition, having been drawn from a pool of potential astronaut candidates who had successfully met the exacting physical and psychological qualifications set down by the National Aeronautics and Space Administration for astronauts.

The subjects were confined in a low pressure chamber for a total of 34 days. During the first 7 days the chamber was maintained at ambient sea level conditions. On the 8th day, the chamber was pumped out to a simulated altitude of 27,000 feet and an atmosphere of 100% oxygen was introduced. These conditions were maintained for twenty days. On the 28th day, sea level conditions were restored to the chamber, but the subjects remained inside for an additional 7 days.

Two of the subjects, Numbers 3 and 6, served as controls and were maintained in an adjacent chamber under ambient conditions for the duration of the experiment. Except for the conditions of altitude and atmosphere, they were treated the same as the experimental subjects.

Isocitrate dehydrogenase activity was determined in the serum by a method based on that of Wolfson and Williams-Ashman[9] in which nicotinamide adenine dinucleotide phosphate (NADP) is incubated with isocitrate and manganese in a 1 centimeter long cell in a Beckman DU spectrophotometer. Following the addition of an aliquot of serum containing the enzyme, the increase in optical density caused by the generation of the reduced form of the co-enzyme is measured at a wavelength of 340 millimicrons and plotted against time. The conversion of one millimole of NADP to NADPH is caused by the oxidation of one millimole of substrate by the enzyme and the subsequent transfer of the hydrogen to the co-enzyme. One "unit" of enzyme activity is the oxidation of one millimicromole of substrate per hour per milliliter of serum.

Glucose-6-phosphate activity was determined in a similar fashion by a method based on that of Kornberg and Horecker[10] in which the erythrocytes are washed several times with physiological saline in order to insure that any activity measured comes from the enzyme in the red cell and not in the plasma. The washed cells are then hemolyzed and incubated with NADP at a pH of 7.6 and the rate of appearance of NADPH is followed at 340 mu in a spectrophotometer following the addition of glucose-6-phosphate substrate. Activity of the enzyme is reported as micromoles of substrate oxidized per minute per gram of hemoglobin.

Hemoglobin electrophoresis was carried out in an acrylamide gel medium and the results were quantitated using a densitometer with a 500 mu interference filter, and compared with known standard types.

Haptoglobin levels were also determined by an electrophoretic technique using an acrylamide gel medium. In this technique, hemoglobin in a known quantity is added to unhemolyzed serum and, following electrophoretic separation, the gels are scanned in a recording densitometer using a 500 mu interference filter. The unbound hemoglobin migrated ahead of the hemoglobin-haptaglobin complex. Any reduction in the free hemoglobin level is due to binding by the serum haptoglobins. A standard is run for comparison and the free hemoglobin in the unknowns is compared with the standard. The resulting amount of hemoglobin (in milligrams) bound by the haptoglobin is then calculated.

Lipoprotein electrophoresis was carried out on paper strips in a Durrum type cell. Following separation of the lipoprotein into the fractions that migrate with the alpha and beta globulin fractions, the strips are stained with oil red O and are scanned in a recording densitometer.

RESULTS

The results of the hemoglobin electrophoresis on the eight subjects used in the study are shown in Table 6-1. It can be seen that all are quite similar and do not demonstrate any high concentrations of hemoglobin type A_2. In normal subjects, type A_2 may be as high as 4.9 percent to these normal levels would indicate the absence of a thalassemia trait in any of the subjects. Alkali denaturation tests showed that there was no type F in any of the subjects.

Serum isocitrate dehydrogenase activities are shown in Table 6-2. Although there are slight variations in the day to day activities in several of the subjects, there is no consistent trend. For these determinations as well as for the glucose-6-phosphate dehydrogenase determinations, specimens drawn during the 5th and 7th days that the subjects were in the chamber are used as baselines, since during this time the atmosphere of the chamber was ambient air at sea level pressure. Subjects No. 3 and 6 were the "controls" who were isolated during the same period of time, but were not exposed to any conditions of altitude or changes in atmosphere.

The activities of glucose-6-phosphate dehydrogenase in the erythrocytes are shown in Table 6-3. Hemolysates were made of red cells that had been drawn with heparin as anticoagulant and washed three times with physiological saline. The hemoglobin content of the hemolysate was determined and enzyme activity related to this rather than to a volume of blood in order to eliminate erroneous results that could arise from cells being lost during the washing procedure.

The results of the electrophoretic determination of serum haptoglobin levels are presented in Table 6-4. Care was taken to insure that the sera analyzed were clear and unhemolyzed in order to eliminate spurious results that could arise from mechanical hemolysis.

The distribution of the serum lipoproteins between the fractions that migrate electrophoretically with the alpha and beta globulins are presented in Table 6-5.

DISCUSSION

The values for the serum isocitrate dehydrogenase are all constant and show no elevation or depression. It must be emphasized that subject selection was different in this experiment than in the ones that have previously been done in this laboratory. In the first series of experiments, the elevations that occurred were in two subjects that were in their late thirties, and were not considered to be in extremely good physical condition. The subjects for this study were all young pilots and in excellent physical condition. In earlier work in this field, subjects for the most part were of a relatively young age.

Glucose-6-phosphate dehydrogenase activity also remained constant in the erythrocytes of the subjects. This agrees with previous studies in this laboratory as well as those of another group[5]. There appears to be no type or oxidative hemolysis occurring in our subjects. Therefore, the hemolysis which has been reported by others still remains unexplained.

All of the subjects included in this study had normal hemoglobin types. It would seem advisable however, in view of a literature report of a hemolytic episode that occurred in one subject exposed to a pure oxygen atmosphere[1] who had an abnormal hemoglobin, the identification of hemoglobin types be carried out in all subjects to be exposed to atmospheres of this type.

The levels of serum haptoglobin appear to remain relatively constant throughout the course of the experiment based on hemoglobin binding capacity, There is some variation in the day to day levels, but it is felt that these are within the limits of the method. At any rate, there is no definite increase in the amount of circulating haptoglobin-bound hemoglobin which is evidence that there was no hemolysis occurring.

There is also some variation in the day to day levels of the serum lipoprotein electrophoretic fractions. These are well within the limits of the method and do not show any trend that would be indicative of an interference with lipid metabolism. In the previous studies in this laboratory the subjects were not considered to be in as good physical condition as the subjects used in this study. There were also several cases of dysbarism in the subjects used in the previous study which accounted for some degree of emotional stress in the other subjects. In contrast, there was no apparent degree of stress or apprehension on the part of the subjects used in the current study. It has been observed many times in the past that emotional stress can account for the appearance of varying degrees of lipid material in the circulating blood as the stores of depot lipid are mobilized and transported.

SUMMARY AND CONCLUSIONS

Six human subjects were exposed to an atmosphere of 100% oxygen for a period of 20 days at a simulated altitude of 27,000 feet in the low-pressure chamber of the Aerospace Crew Equipment Laboratory, Naval Air Engineering Center, Philadelphia, Pa. Two subjects were subjected to the same regimen, in an adjacent chamber with the exception that they remained in an atmosphere of ambient, sea-level air, and served as controls.

There was no evidence obtained from biochemical data to suggest that a 100% oxygen atmosphere at a simulated altitude of 27,000 feet is injurious to otherwise healthy subjects.

The activities of serum isocitrate dehydrogenase, and erythrocytic glucose-6-phosphate dehydrogenase remained constant throughout the period of exposure and did not deviate from baseline or control levels.

Similarly, there was no deviation from baseline or control levels of serum haptoglobin as evidenced by the ability of that serum protein to bind hemoglobin or in the relative distribution of serum lipoproteins between the alpha and beta fractions.

ACKNOWLEDGMENTS

The electrophoretic analyses reported in this paper were performed by LCDR T. G Ferris, MSC, USNR, Officer in Charge, Rear Admiral Calver's Physical Chemistry Laboratory, Naval Medical School, National Naval Medical Center, Bethesda, Maryland, 20014.

Many of the enzyme analyses and much of the monitoring of the experiment were done by HMC B. G. Kester, USN.

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TABLE 6-1

HEMOGLOBIN TYPES

Subject No.	Hgb. Type A	Hgb. Type A_2
1	95.9%	4.1%
2	98.5%	1.5%
3 (control)	97.0%	3.0%
4	98.5%	1.5%
5	96.3%	3.7%
6 (control)	97.5%	2.5%
7	99.6%	0.4%
8	97.8%	2.2%

TABLE 6-2

SERUM ISOCITRATE DEHYDROGENASE ACTIVITY
(MILLIMICROMOLES OF SUBSTRATE OXIDIZED PER HOUR PER MILLILITER OF SERUM)

	Day in chamber										
Subject Number	5*	7*	9	12	15	18	21	24	27	30	35
1	44	58	52	52	41	46	52	46	58	45	45
2	89	116	104	52	81	70	99	87	81	104	88
3 (control)	78	52	58	46	47	N. S.	52	46	65	64	58
4	87	81	81	102	64	58	81	87	64	99	58
5	58	76	81	58	70	70	75	75	58	75	70
6 (control)	51	76	70	52	46	59	70	87	87	70	52
7	88	87	99	76	52	52	70	99	104	99	64
8	73	58	80	46	73	41	64	87	87	70	64

*Baseline values

TABLE 6-3

ERYTHROCYTE GLUCOSE-6-PHOSPHATE DEHYDROGENASE ACTIVITY
(MICROMOLES OF SUBSTRATE OXIDIZED PER MINUTE PER GRAM OF HEMOGLOBIN)

	Day in chamber											
Subject Number	5*	7*	9	12	15	18	21	24	27	30	33	35
1	3.6	3.2	3.8	3.4	4.1	5.4	4.2	5.8	5.3	4.2	3.3	4.5
2	4.6	4.5	5.5	3.3	5.0	5.7	5.6	5.4	6.4	5.1	4.7	5.0
3 (control)	3.6	3.6	3.9	3.0	4.7	4.6	3.4	4.0	3.3	4.2	3.6	4.0
4	3.7	3.0	3.8	4.4	3.9	4.5	2.7	4.8	5.2	4.7	4.7	4.4
5	4.1	3.7	4.0	4.4	4.4	4.0	3.5	4.7	5.4	4.3	5.4	4.2
6 (control)	4.2	3.9	4.0	4.4	4.0	5.4	4.4	4.2	5.5	5.2	3.2	4.5
7	3.9	3.6	4.4	5.2	4.8	4.2	3.8	4.1	5.5	4.4	4.7	4.7
8	4.1	3.8	4.4	3.5	4.3	4.5	4.5	4.8	5.3	4.6	4.2	4.9

*Baseline values

TABLE 6-4

SERUM HEMOGLOBIN BINDING CAPACITY
(MILLIGRAMS OF HEMOGLOBIN BOUND BY SERUM HAPTOGLOBIN)

	Day in chamber								
Subject Number	9*	12*	18	21	24	27	30	33	35
1	223	178	223	NS	225	179	183	256	308
2	NS	151	215	246	196	185	209	202	177
3 (control)	132	261	292	231	174	NS	222	162	236
4	193	NS	246	238	218	296	300	243	272
5	NS	NS	269	308	196	NS	208	196	207
6 (control)	NS	NS	269	193	131	156	208	217	183
7	NS	NS	292	269	189	185	202	182	207
8	182	172	162	246	182	193	234	189	248

*Baseline values

NS-No specimen

TABLE 6-5

SERUM LIPOPROTEIN FRACTIONS
(PERCENT DISTRIBUTION)

Subject Number	Day in Chamber									
	5*	9*	12	18	21	24	27	30	33	35
1 Alpha	11.9	18.9	12.6	23.5	21.1	14.5	19.1	11.9	13.6	13.2
Beta	88.1	81.1	87.4	76.5	78.9	85.5	80.0	88.1	86.4	86.8
2 Alpha	8.0	NS	6.8	23.9	20.0	16.0	15.0	5.4	16.5	12.3
Beta	92.0		93.2	76.1	80.0	84.0	85.0	94.6	83.5	87.7
3 Alpha	7.7	15.3	8.1	21.4	18.0	12.0	13.2	9.7	16.8	13.2
Beta	92.3	84.7	91.9	78.6	82.0	88.0	86.8	90.3	83.2	86.8
4 Alpha	6.6	9.5	5.1	14.8	6.5	8.0	8.0	5.2	5.9	9.3
Beta	93.4	90.5	94.9	85.2	93.5	92.0	92.0	94.8	94.1	90.7
5 Alpha	11.0	17.3	10.9	16.0	18.4	13.0	13.0	12.8	11.3	13.3
Beta	89.0	82.7	89.1	84.0	81.6	86.1	87.00	87.2	88.7	86.7
6 Alpha	9.4	17.4	13.8	22.4	20.0	12.8	16.0	10.3	9.8	13.0
Beta	90.6	82.6	86.2	77.6	80.0	87.2	84.0	89.7	90.2	87.0
7 Alpha	6.1	20.8	4.4	32.6	20.6	NS	23.8	15.6	19.5	27.5
Beta	93.9	79.2	95.6	67.4	79.4		76.2	84.4	80.5	72.5
8 Alpha	14.3	11.0	15.4	22.0	22.7	16.4	12.6	12.0	13.8	15.7
Beta	85.7	89.0	84.6	78.0	77.3	83.6	87.4	88.0	86.2	84.3

*Baseline values

NS-No specimen

SECTION 7

PULMONARY FUNCTION AND X-RAY

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SECTION 7

PULMONARY FUNCTION AND X-RAY

The response of the respiratory system to the internal environment of manned spacecraft has been of interest to many investigators. The use of 100% oxygen at reduced pressures has prompted concern over the possibility of producing alterations in the normal patterns associated with pulmonary function.[1-11] Although a recent study involving 14 subjects at 258 mmHg. on 100 percent oxygen produced no demonstrable changes in pulmonary function, it was decided to extend the period of exposure and to test the validity of previously collected data.

Test and Methods

The following tests and measurements were performed: tidal volume (TV), expiratory reserve volume (ERV), inspiratory capacity (IC), vital capacity (VC), functional residual capacity (FRC) and carbon monoxide diffusing capacity (D_{CO}). In addition, base line data was obtained for arterial P_{O2}, P_{CO2}, and pH so that a more complete work up could be accomplished if any clinical signs, symptoms, or other measurements indicated a need.

The subjects were trained to perform the tests and record the data. Lung volumes were determined using a standard 13.5 liter Collins Respirometer. D_{CO} was determined by the single breath technique 13, 14. The alveolar volume during breath holding was determined by adding the inspired volume to the residual volume. The inspired volume was read from the spirometer record and the residual volume calculated by body plethysmography prior to confinement. The time of breath holding was taken from the start of inspiration to the start of alveolar sample collection.

Prior to confinement each subject breathed 100% oxygen at sea level for thirty minutes or more before arterial samples were drawn from the anesthetized femoral artery into a heparinized, 10 cc syringe. The sample was then immediately introduced into the blood gas analysis apparatus (Instrumentation Laboratory Model 5113) which was located only a few feet from the subject. The apparatus was calibrated with both tonometered blood and wet gases. The calibration was again checked immediately preceding the introduction of each new sample.

TV, ERV, IC, VC determinations were made daily throughout the entire test profile, always in the morning before eating. FRC determinations were made during the week prior to confinement. The subjects were taken to the University of Pennsylvania where Dr. Arthur DuBois determined FRC and Dr. Gordon Powers familiarized the subjects with the single breath D_{CO} instrumentation and techniques. This equipment was then borrowed and set up in the altitude chamber at Aerospace Crew Equipment Laboratory (ACEL) and the subjects trained. A total of nine D_{CO} determinations were made on each test subject and six on each of the controls. Gas analysis and data reduction were completed at the University of Pennsylvania by Dr. Powers. The measurements were made prior to and following the altitude-100% oxygen environment exposure.

The FRC determinations were repeated five times on each of the subjects prior to the start of the run. These data are presented in Table 7-3. As there were no changes noted in other pulmonary function tests made during and after the altitude phase no follow up measurements were made. These data were collected solely as baseline data against which any observed change in pulmonary function could be compared. No such changes occurred.

Results

Tables 7-1 and 7-2 summarize the lung volume data for individuals and the group respectively. The tidal volumes appear high, however, these are not resting values. The subjects were engaged in routine activities of food preparation and body hygiene just prior to pulmonary function determinations. Beginning on the 22nd day of confinement subject #2 began to have abnormally high lung volumes which we subsequently determined to be erroneous due to technique. However, this could not be done until completion of the confinement period. Consequently the data on this subject from the 22nd day to the completion of the test profile were discarded and 3 determinations were made after confinement to complete the table. There appears to be a slight loss in vital capacity, approximately 150 cc, at altitude. This loss is so slight that if it were due to an anatomic or functional change it would be extremely difficult, if not impossible, to verify with present techniques and instrumentation.

Table 7-4 shows the D_{CO} values. In general the D_{CO} values are high normal and the variation is within the limits of experimental error especially since the tests were performed by the subjects on each other with relatively little training. No difference between pre-and post-altitude values are evident. The area and properties of the lung membrane and capillaries effecting gas exchange within the pulmonary alveoli did not measurably change as a result of the test profile or if any changes did occur they were rapidly reversible.

Table 7-5 presents the baseline data, collected for the same reason as the FRC, concerning arterial pH, P_{O2} and P_{CO2}.

The chest x-rays were obtained in the posterior-anterior and lateral projections two weeks prior to the study and on the twenty-sixth experimental day, that is, after the subjects had been at altitude breathing 100% oxygen for 19 days. X-ray films at altitude were made using a 200 ma., 100 kvp x-ray unit shooting through a 3.2 mm thick aluminum port in the outer chamber wall and through the inner chamber wall of 4.8 mm thick aluminum. The method for taking X-rays through the chamber walls is described in more detail in a previous report.[12]

Roentgenograms were interpreted by the Radiology Department of the U. S. Naval Hospital, Philadelphia, Chest x-rays obtained on the twenty-sixth experimental day showed no change from those taken two weeks prior to the study. Subject 5 had a small harmless osteoma on the left sixth rib which remain unchanged.

Discussion

Aside from the very slight drop in vital capacities there were no changes noted and, as the x-rays showed no evidence of astelectasis, the arterial punctures and FRC determinations were not repeated following the run.

It is possible that vital capacity measurements or chest x-rays may not be sensitive enough to detect small degrees of atelectasis. However, arterial oxygen tension as a measure of right to left shunt could also be insensitive as a measure of atelectasis because blood may cease to flow through the collapsed regions.

Conclusions

It would appear that healthy young men show no significant alterations in pulmonary function as a result of exposure to 100 percent oxygen at a pressure of 258 mmHg for 20 days.

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TABLE 7-1

MEAN LUNG VOLUMES LITERS BTPS FOR INDIVIDUAL TEST AND CONTROL SUBJECTS

Subject		TV	ERV	IC	VC
1	A	930	2420	3700	6280
	B	800	2570	3530	6140
	C	800	2020	3840	6110
	D	980	2070	4170	6450
2	A	900	2780	3900	6700
	B	820	2910	3660	6750
	C	780	3120	3360	6650
	D*	853	2850	3850	6700
3	A	1120	2860	3260	6230
	B	1250	2770	3160	5970
	C	1290	2800	3200	5960
	D	1240	3200	2900	6240
4	A	870	2710	3600	6350
	B	1070	2350	3600	6270
	C	1070	1920	3920	5970
	D	1180	2410	3830	6380
5	A	880	1100	3120	4210
	B	910	910	3130	4100
	C	720	980	3240	4140
	D	980	1031	3380	4320
6	A	840	1840	2750	4600
	B	1080	1780	2590	4430
	C	1080	1770	2720	4530
	D	1180	1980	2810	5090
7	A_c	890	3030	3020	5640
	B_c	930	3110	2920	5620
	C_c	1360	2480	3270	5550
	D_c	1795	1900	3630	5500
8	A_c	1280	2020	3060	5380
	B_c	1250	2240	3330	5540
	C_c	1400	2210	3390	5520
	D_c	1300	2180	3410	5590

Legend for Table 7-1

A - Sea Level - Air - No suit - Average of 24 determinations

B - Altitude - 100% O2 - No suit - Average of 21 determinations

C - Altitude - 100% O2 - Suited - Average of 39 determinations

D - Sea Level - Air - Suited - Average of 18 determinations

A_c and B_c - Sea Level - Air No Suit

C_c and D_c - Sea Level - Air - Suited

*As explained in test data for this subject had to be discarded.

This line is the mean of three determinations made after confinement.

TABLE 7-2

MEAN LUNG VOLUMES (LITERS BTPS) OF TEST AND CONTROL SUBJECTS

	TV		ERV		IC		VC	
	Control	Test	Control	Test	Control	Test	Control	Test
Sea Level	N 46	N 146	N 46	N 146	N 46	N 146	N 46	N 146
Air - No suit	1085	945	2625	2285	3040	3388	5510	4728
Alt. -100% O_2	N 42	N 126	N 42	N 126	N 42	N 126	N 42	N 126
No suit	1090	988	2675	2215	3125	3278	5580	5610
Alt. -100% O_2	N 78	N 216	N 78	N 216	N 78	N 216	N 78	N 216
Suited	1380	957	2345	2102	3300	3380	5535	5560
Sea Level - Air	N 36	N 93	N 36	N 93	N 36	N 93	N 36	N 93
Suited	1565	1069	2040	2257	3520	3423	5545	5863

TABLE 7-3

FUNCTIONAL RESIDUAL CAPACITIES
LITERS BTPS

SUBJ.	1	2	3	4	5	6	7	8	
	3.9	5.0	3.3	2.8	2.3	2.6	4.0	4.1	
	3.9	5.0	3.3	2.9	2.3	2.6	3.8	3.9	
	3.9	5.0	3.5	2.9	2.5	2.6	3.9	3.9	
	3.9	5.0	3.5	2.9	2.4	2.7	4.2	3.9	
	4.0	5.0	3.5	2.9	2.3	2.6	4.1	3.7	
	3.92	5.00	3.42	2.88	2.36	2.62	4.00	3.89	MEAN

TABLE 7-4

SINGLE BREATH CO DIFFUSING CAPACITIES

	TEST SUBJECTS						CONTROL SUBJECTS	
	1	2	3	4	5	6	7	8
Sea Level Air	37.1*	31.2	33.9	30.8	29.7	25.9	42.7	42.0
Pre-Chamber	32.9	38.4	35.0	29.2	29.7	27.8	34.7	42.0
No Suit	32.9	41.5	42.5	37.0	28.8	28.4	38.6	45.3
Sea Level Air	38.6	33.0	38.2	33.4	33.2	30.8	-	-
Pre-Altitude	43.1	40.4	33.9	33.9	29.2	27.0	-	-
No Suit	43.2	40.0	29.5	31.9	28.6	29.8	-	-
Post Altitude	35.0	33.6	30.0	30.4	27.8	28.0	35.6	43.2
Sea Level Air	38.4	35.6	32.5	26.2	27.7	32.2	39.2	-
Suited	36.2	35.5	33.4	31.1	31.1	34.5	32.5	38.8
Mean	37.5	36.6	34.3	31.5	29.5	29.1	37.2	42.3

*Carbon monoxide diffusing capacities expressed in ml of CO per minute per millimeter of mercury pressure.

TABLE 7-5

ARTERIAL BLOOD GASES & pH

Subject	pH	pO_2	pCO_2
1	7.42	670 mmHg	34 mmHg
2	7.45	684	32
3	7.47	688	27
4	7.47	676	34.2
5	7.46	679	32.8
6	7.47	640	27
7	7.43	680	36
8	7.48	684	25.6

Aerospace Crew Equipment Laboratory

A REPORT OF THE PHYSIOLOGICAL, PSYCHOLOGICAL, AND BACTERIOLOGICAL ASPECTS OF 20 DAYS IN FULL PRESSURE SUITS, 20 DAYS AT 27,000 FEET ON 100% OXYGEN, AND 34 DAYS OF CONFINEMENT

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SECTION 8

SOME PSYCHOLOGICAL MEASURES ON SIX MEN CONFINED 34 DAYS IN A SEALED CABIN

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SECTION 8

SOME PSYCHOLOGICAL MEASURES ON SIX MEN CONFINED 34 DAYS IN A SEALED CABIN

INTRODUCTION

The successful launching and recovery of manned satellites has opened up entirely new areas for research. In less than eight years man has progressed from the orbiting of the unmanned Sputnik I on October 4, 1957 to the more recent flights of multi-manned capsules and extravehicular feats. The next decade may well experience the landing of man on other bodies within the solar system, the establishment of manned orbital laboratories, and the use of rendezvous or other space vehicles.

These events will subject the crew to abnormal and hostile environments over prolonged periods of time. The use of the full pressure suit, reduced ambient cabin pressure, elevated oxygen concentrations, the reduced and structured sensory, social, and physical environments, in addition to the altered gravitational field, radiation, new and unique nutritional and elimination problems, altered sleep, work, and cognitive activities, etc., all may have their effect on the human organism.

Previous studies[4,12] on the efficiency of performance during short term confinement wherein sensory stimulation is minimized indicate that decrements in performance and abnormal phenomena may occur. With the lengthening of the confinement period as will be necessary in future celestial voyages, studies on the perceptual motor processes and behavioral functioning of man during long term confinement are clearly indicated.

The present study represents a phase of the above problem and was undertaken to determine the effects on performance of six men confined for 34 days in an area of approximately 100 cubic feet per man under variable conditions of oxygen concentration, simulated altitude, and wearing apparel. It was generally postulated that during any prolonged type of confinement the physical, social, and sensory environments become highly structured. This patterned environment affects the perceptual processes and social interactions of the confined subjects. Since the higher level mental functions are dependent upon the lower level processes, an alteration of one of the lower processes will exert its effect on the higher centers.

Within this frame of reference it was hypothesized that (1) an individual's performance on a constant demand, multiple stimuli, high level cognitive task requiring immediate decision making and different motor responses will deteriorate as the length of confinement is increased, (2) group cohesiveness, as measures by performance on a similar cognitive task requiring group participation, will deteriorate as the length of confinement is increased, and (3) goal seeking behavior, as measured by the level of aspiration, will deteriorate as the length of confinement is increased. Three experiments designed to test these three hypotheses were conducted.

METHOD

The dangers of recording psychological responses with electronic equipment inside an oxygen saturated chamber were fully recognized. While most of the electronic apparatus could be installed outside the capsule, a major problem appeared to be the use of reliable spark-proof switches inside the chamber in order for the subjects to respond. Since most of the apparatus used for group performance consisted of independent circuits entirely within the chamber, they were designed to operate on 1-1/2 volts and enclosed in metal chassis and conduits with soldered connections. The main switch box, however, which was used for individual performance and by the last man in the group performance, required 28 volts to activate the relays controlling the oscillators outside the chamber. Furthermore, it was calculated that these switches would be used approximately 300,000 times during the 34 days of the study.

The problem was resolved by the use of a gravity dependent, sealed mercury switch manufactured by the Microswitch Division of Minneapolis-Honeywell Corp. The bulb of each miniature switch was safety wired to its clip and bolted into the cut out portion of a brass lever as shown in Figure 8-1. Each lever was then mounted on an axle which was housed inside a metal chassis. A hinged metal face piece mounted on each chassis permitted all switch levers to be covered when not in use. Stop bars located 12 degrees above and below the horizontal permitted the mercury to open or close the circuit as the angle of the lever was changed by pressing or releasing it. The toxicity and increased amount of mercury vapor at reduced capsule pressures made it mandatory that the miniature sealed bulbs not be broken. The assembled switches were explosively decompressed from sea level to 80,000 feet, dropped from a height of eight feet onto a concrete floor, and repeatedly operated in a rough manner before the study in order to demonstrate and check their durability.

The perceptual motor tasks that were used to investigate changes in the levels of individual performance, group performance, and aspiration during the 34 days of the study were as follows:

1. Individual Performance. The subject was comfortably seated facing a stimulus light panel which was located outside the chamber but could be viewed through the port as shown on the left in Figure 8-2. The response panel contained 16 gravity dependent mercury switches arranged in a 4 by 4 matrix representing columns 1, 2, 3, 4 and rows 1, 2, 3, 4 as displayed on the right of Figure 8-2. The stimulus panel contained five green lights arranged horizontally to designate the correct column and row in which the response was to be made.

The two outer green lights on the stimulus panel (lights 1 and 5 reading from left to right) designated the correct column in which to respond as follows:

columns 1, 2, 3, or 4 when both, right only, left only, or neither light was activated, respectively. The two green lights immediately inside the two outer lights (numbers 2 and 4 reading from left to right) indicated the correct row in which to respond as follows: rows 1, 2, 3, or 4 when neither, left only, right only, or both lights were activated, respectively.

In addition, the green light located in the center of the five green lights instructed the subject to reverse the response to the rows, but not the columns, when it was activated. Thus, there were 32 random stimulus patterns requiring any one of 16 responses. A new stimulus pattern appeared immediately after each response and remained on until the response was completed so that the speed of the task was governed by the rate at which the subject performed. Positive feedback was displayed by an amber error light located beneath the five green lights which was activated whenever an incorrect response occurred.

Automatically programmed stimuli were randomly presented by means of oscillators located outside the chamber. All data was recorded on cumulative counters and included the total number of responses, the number of correct responses, the number of row errors, the number of column errors, and the number of combined row and column errors. The objective was to quantitatively measure the efficiency of performance in a constant demand, multiple stimuli cognitive situation requiring immediate decision making and different motor responses under the severely altered and structured conditions of the physical, social, and sensory environment during the 34 days of the study.

Each subject individually performed the above task for exactly 20 minutes each day. The daily work period was divided into four quarters of five minutes each with 30 seconds rest intervals. At the end of each five minute quarter, the readings of all counteres were recorded and the subject instructed to stop working. He was then told his number of correct responses, asked to estimate his score on the next five minute quarter (described more fully under Level of Aspiration), and instructed to begin working. After a short warm up period of two or three responses the counters were returned to zero and the clock started for the next five minute interval. This procedure was repeated four times each day for each subject and, as described below, four times each day for the performance of the group.

The six men worked individually in two shifts. Group A, composed of S_4, S_5, and S_6, performed on a staggered basis from approximately 0400 to 0500. Group B, composed of S_1, S_2, and S_3, performed on a staggered basis from approximately 1600 to 1700.

2. Group Performance. The overall procedure for group performance was similar to the procedure for individual performance. S_1 could not see the stimulus panel but was the one who had to make the final responses. S_2, who could observe the stimulus patterns, activated two microammeters, one to indicate the correct column and one to indicate the correct row, by means of two sets of four switches as shown on the right in Figure 8-3. S_3 observed the pointers on the two meter dials and then informed S_1 of the correct response to make by activating another small light panel inside the capsule containing one of two lights to indicate the correct column and one of two lights to indicate the correct row as shown at the upper right of Figure 8-2. Thus, a series of nonverbal informations had to be passed along the three subjects in order for S_1 to correctly respond.

The two groups worked approximately 12 hours apart. Group A, consisting of S_4, S_5, and S_6, performed as a group from approximately 0600 to 0630. Group B, consisting of S_1, S_2, and S_3, performed as a group from approximately 2000 to 2030.

The objective was to obtain a quantitative measure of group cohesiveness as displayed by the efficiency of group performance in the above cognitive situation. This required a continuous chain of information to be passed among the three subjects. A breakdown in performance of any one subject would cause a deterioration in the performance of the group which is here interpreted as a breakdown in group cohesiveness. Furthermore a deterioration in the performance of several individuals within the group would be additive toward, and detrimental to, the level of working efficiency on the group task.

3. Level of Aspiration. The procedure for measuring the level of aspiration made use of the same apparatus described above. The subject was told his number of correct responses after each five minute quarter and then asked to estimate his number of correct responses for the next five minute quarter. The subject's statement of his intended level of performance before each repetition, based in part on his knowledge of immediate past performance, was taken to represent his level of aspiration at the time. Changes in the differences between his estimates and his number of correct responses during the 34 day period are perhaps more meaningful.

This procedure was repeated four times each day for each subject and four times each day for the performance of each of the two groups. The objective was to quantitatively measure changes in each subject's (and each group's) estimate of performance four times during each of the 34 days of confinement. These estimates, used as an index of the level of aspiration, have been used by Frank[5] to demonstrate that leaders have a higher level of aspiration than nonleaders, and by Hanawalt, et al[9, 17] to indicate that leaders tend to express higher goals than nonleaders. The objective here was an attempt to evaluate changes in leadership and goal seeking qualities that may occur during the confinement period.

RESULTS

Overall, the experimental data on errors reveals only minor fluctuations from day to day with minimal or no decrement in performance over time. This is true whether one examines either the individual or the group performance errors and regardless of the altitude, oxygen concentration, or flight clothing condition.

Figure 8-4 demonstrates that the mean row errors and mean column errors for individual performance remain relatively constant during the 34 days. The mean row errors, however, occur approximately twice as often as the mean column errors. This would be expected from the complexity of the task, i.e., individual performance on the row response sometimes involved a reversal operation whereas performance on the column response did not contain a reverse procedure. Thus, it appears that the wearing of a full pressure suit, the breathing of 100 percent oxygen, or a simulated altitude of 27,000 feet, even for periods of several days, did not markedly alter the quality or quantity of either the row errors or column errors for individual performance.

The mean errors for individual performances were also plotted according to the work period. In general, it was found that those working during the early morning hours displayed 86.4 percent more row errors and 100.0 percent more column errors than those working during the late afternoon hours. Although the graphs are not shown, one can compare the errors of the three men working during the late afternoon hours (S_1, S_2, and S_3) by examining Tables 8-1 and 8-2 which tabulate the errors by quarters for the various capsule conditions. It may be noted that whereas those performing in the morning committed more row errors and more column errors than those performing in the afternoon, the differences tended to remain approximately the same over time. In addition, those working in the afternoon responded with a greater number of correct responses than those working during the morning hours leading one to suspect that the two groups were not equally matched. The possibility exists, however, that performance was influenced by the time period in which it occurred.

Figure 8-5 shows that the mean row errors and mean column errors for group performance remained relatively constant during the 34 days. Group performance, however, displayed more nearly equal numbers of row and column errors than individual performance, the two plots crossing each other several times. Thus, whereas the row response of the first man of the group sometimes contained a reversal operation, the other members of the group were not concerned with row reversals. This apparently resulted in a smaller difference between the number of row and column errors for the group performance as compared to individual performance.

The errors for group performance were also plotted according to the work period. Group A, which included those men working during the early morning hours, displayed 16.1 percent more row errors and 28.6 percent more column errors during the 34 days than Group B which worked during the late afternoon hours. The total number

and the differences between the row and column errors which Group A displayed when working as a team appeared to be much less than when the same men worked as individuals. Although not shown, the graph of two groups crossed each other many times during the 34 days and displayed only moderate variability. One can compare the errors between the two groups by examining Tables 8-3 and 8-4 which tabulate the errors by quarters for the various capsule conditions. Thus, whereas a marked difference appeared in both the row and column errors between the day and night shift for individual performance, this difference was much less for the row and column errors for the group performance.

An analysis of the errors for the 20 minute daily work periods by quarters for individual performance during the various capsule conditions is shown in Tables 8-1 and 8-2 and in Figure 8-6. By inspection of the tables one can readily compare the row or column errors not only between subjects or between quarters but also between chamber conditions. For example, variability in row errors between subjects during the entire 34 days of the study ranged from 195 for S_3 to 659 for S_5 while variability during Days 1 - 7 ranged from 27 for S_1 to 243 for S_5. Furthermore, the sum of the row errors by all subjects during the first seven days (sea level, no pressure suit) was 620 whereas the sum of the row errors by all subjects during the last seven days (sea level, full pressure suit) was 624. Note that the number of errors shown for Days 15 - 27 (a total of 12 days since data for one day was not obtained) should be reduced to 7/12 of their values when comparing them with the other capsule conditions which were each of seven days duration.

The cumulative number of row or column errors occurring in each of the quarters may also be readily compared in Tables 8-1 and 8-2 for each of the capsule conditions. This comparison is more easily observed, however, in Figure 8-6 which shows that both the row and column errors tend to drop from the first quarter to the second quarter, to rise during the third quarter as much as or more than they had dropped, and to fall to their lowest values during the last quarter. This could indicate that the men were not fatigued either physically or mentally during the 20 minutes of complex mental activity since the lowest number of errors tended to occur in the last quarter regardless of the simulated altitude, suit condition, or oxygen concentration. Again, it may be observed from Figure 8-6 that for individual performance the number of row errors is approximately twice the number of column errors. In general, Figure 8-6 and Tables 8-1 and 8-2 indicate that Subjects display great variability. Quarters only moderate variability, and Conditions (altitude, suit, oxygen concentration) very slight variability.

An analysis of the errors for the 20 minute daily work periods by quarters for group performance during the various capsule conditions is shown in Tables 8-3 and 8-4 and in Figure 8-7. One can readily compare the row or column errors not only between the two groups or between quarters but also between chamber conditions by inspection of the tables. For example, variability in row errors between the two groups during

Days 15 - 27 (27,000 feet and wearing the full pressure suit) ranges from 89 for Group B to 104 for Group A while the column errors for the same time period ranged from 76 for Group B to 100 for Group A. In addition, the sum of the column errors by both groups during the first seven days (sea level, no pressure suit) was 86 whereas the sum of the column errors by both groups during the last seven days (sea level, full pressure suit) was 96. Note again that the number of errors shown for Days 15 -27 (a total of 12 days since the data for one day was not obtained) should be reduced to 7/12 of their values when comparing them with the other capsule conditions which were each of seven days duration.

The cumulative number of row or column errors occurring in each of the quarters for group performance may also be readily compared in Tables 8-3 and 8-4 for each of the capsule conditions. This comparison is more easily observed, however, in Figure 8-7 which shows that the errors were usually highest in the first quarter and then decreased in succeeding quarters but not always in the same manner. The fourth quarter usually displayed the smallest number of row errors (always less than the third quarter) whereas the column errors appearing in the fourth quarter were always greater than those appearing in the third quarter. It would appear that the men in the group were not fatigued during their work period since the number of errors tended to decrease from the first quarter to the last quarter regardless of the simulated altitude, suit condition, or oxygen concentration. In general, Figure 8-7 and Tables 8-3 and 8-4 indicate that the two groups displayed relatively great variability, Quarters only moderate variability, and Conditions (altitude, suit, oxygen concentration) very slight variability.

In terms of the number of correct responses, a learning factor was quite apparent for individual performance during the first 14 days of the study. This occurred even though each subject received daily practice for two weeks prior to the experiment. It appears that the complexity of the task allowed a wide margin for individual task efficiency, both for speed and accuracy of performance.

As shown in Figure 8-8 the number of correct responses for individual performance after the fourteenth day of the study remained fairly constant except for minor fluctuations from day to day regardless of the suit, oxygen concentration, or altitude condition. It is important to note that a deterioration in the number of correct responses did not appear for either individual or group performance after a plateau had been reached.

Figure 8-8 demonstrates that the mean correct responses and mean estimates for individual performance remained relatively similar during the 34 days. Initially, the mean estimates were slightly below the mean correct responses. After the third day, however, the mean estimates for individual performance were always greater with one exception than the mean number of correct responses for the remainder of the study.

Although not shown, the mean estimates and mean correct responses for individual performance were also plotted according to the work period. It was found that the mean estimates for individual performance of the subjects working during the afternoon hours (S_1, S_2, and S_3) were considerably higher than those of the men working during the early morning hours (S_4, S_5, and S_6) for the first nine days of the study. This was associated with the mean number of correct responses for individual performance which were greater for the day shift than for the night shift for the first ten days of the study. From Days 10 through 14 the mean estimates were approximately the same as the mean correct responses, the two curves crossing each other four times. After the fourteenth day, however, the mean estimates of the day shift were considerably lower than those of the night shift. Thus, the mean estimates of the day shift were higher than those of the night shift for the first nine days, about the same for the next five days, and definitely lower for the last 20 days of the study. The mean estimates, of course, were dependent in large part on the number of correct responses occurring at the time.

The day shift performed with a greater number of correct responses for individual performance than the night shift for the first ten days of the study but performance of the two shifts was nearly equal during the next three days. The number of correct responses by the day shift was less than that of the night shift for the remainder of the study although the differences were very slight after the 25th day.

In terms of the level of aspiration, it is perhaps more meaningful to examine the differences between estimates and correct responses rather than the estimates per se. These differences between the mean estimates and the mean number of correct responses are displayed in Figure 8-9 on a daily basis for individual performance. It may be observed that the differences tended to increase in a positive direction as the study progressed, i.e., the estimates tended to be greater than the number of correct responses the longer the men were confined. The variable curve in Figure 8-9 indicates the mean differences calculated on a daily basis. In order to more easily determine the general trend of these differences, a curve was drawn through the grand mean of the differences for each of the four chamber conditions as indicated by the relatively straight and rising curve superimposed on the graph. It would appear from the data that goal seeking behavior of the men working as individuals, as measured by the level of aspiration, tended to increase with time of confinement. This could be interpreted as an indication of a high level of morale among the men who are expecting (or estimating) to perform even better than they had in the past.

A learning factor based on the number of correct responses was also apparent for group performance as shown in Figure 8-10. Performance by the group required a greater number of operations than in the case of individual performance, the improvement of group performance requiring the first 20 days of the study and then remaining relatively steady. Again, the mean estimates of the group were closely associated with the mean number of correct responses as shown in Figure 8-10.

The estimates and correct responses for group performance were also plotted according to the work period. Although not shown, it was found that the estimates for group performance of the subjects working during the late afternoon hours and early morning hours were approximately the same, the two curves crossing each other 12 times. This was associated with the mean number of correct responses for group performance which were also approximately the same for the two groups, the two curves crossing each other 15 times during the 34 days. Thus, whereas the two groups differed in their estimates and number of correct responses for individual performance, the two groups displayed a striking similarity for estimates and correct responses for group performance.

The differences between the estimates and the number of correct responses for group performance are shown in Figure 8-11. As with individual performance, the differences between estimates and correct responses for group performance tended to become greater as the study progressed. Again, the estimates tended to be greater than the number of correct responses the longer the men were confined. The variable curve in Figure 8-11 indicates the differences calculated on a daily basis whereas the relatively straight line is drawn through the grand mean of the differences for each of the four chamber conditions. It would appear that goal seeking behavior of the men working as a group, as measured by the level of aspiration, tended to increase with time of confinement. This could indicate a high level of morale among the members of each group who anticipated performing better in the future than they had in the past.

DISCUSSION

The three hypotheses stated at the beginning of this paper indicated that a deterioration in performance or breakdown in behavior might be expected as the period of confinement was increased. This expectation was thought to be enhanced by the abnormal and hostile physical conditions within the chamber, i.e., the simulated altitude of 27,000 feet, the 100 percent oxygen atmosphere, and the wearing of the full pressure suit, each condition for a period of two weeks. In addition, there have been widespread reports on the deterioration of man's ability to function under confined conditions.

Many studies in this area have structured the environment but, in general, have used a man gratification approach, i.e., prisons, submarines, ships, etc.[1, 23, 28]. Other studies have isolated the individual(s) and more severely structured and controlled the sensory environment, i.e., sealed cabins, flight simulators, solitary confinement, etc.,[4, 7, 10, 11, 12, 13, 19, 20]. Still other studies have greatly restricted the sensory input or attempted complete sensory deprivation.[2, 3, 8, 14, 16, 24, 25, 26, 27] Many review articles have recently appeared in the field,[15, 21, 22, 29, 30]. In general, many of these studies have reported decrements in one form or another of behavior, performance, perception, cognition, learning, imagery, or motor responses. It was within this context that the hypotheses of this paper were formulated.

A careful evaluation of all the data collected fails to support the stated hypotheses. Errors did not tend to increase and correct responses did not tend to decrease during the 34 days of isolation and confinement for either individual or group performance and regardless of the simulated altitude, the oxygen concentration, or the use of the full pressure suit.

An inspection of the curves for mean row errors or mean column errors does not reveal an increased number of errors for either individual or group performance during the 34 days of the study. The row errors were approximately twice as great as the column errors for individual performance and slightly greater for group performance but the row response was much more complex for individual performance and more complex for the first man in the group performance. Whereas the individuals and the group working during the day shift exhibited fewer errors than the night shift, those working the day shift made a greater number of correct responses and estimates than the night shift leading one to believe that the subjects in the two shifts were not equally matched. Although the subjects varied considerably in their number of errors and moderate variability appeared during the four quarters of each day the number of daily errors remained surprisingly constant during the 34 days when one considers the changing physical conditions within the chamber.

The curves for mean estimates and mean correct responses do not display a deterioration for either individual or group performance once a plateau was reached. The negatively accelerating curves for these functions appear to be normal learning curves for a complex mental task. As with errors, there was moderately wide variability in the number of correct responses and estimates among subjects, some variation from quarter to quarter, but only slight variability once a plateau had been reached during the 34 days of the study. Altitude, oxygen concentration, or pressure suit did not appear to influence these operations.

Perhaps the major finding of this study was the increase in differences between estimates and correct responses with time. This finding, defined here as the level of aspiration, was revealed for both individual and group performance. One's evaluation of himself plays an important role in personality and motivation. Consequently, a fruitful approach to certain personal, environmental, and social factors which influence one's evaluation of his own ability appears to be germane to an examination of the level of aspiration.

Early work in this area was conducted by Frank[5]. He found that the average difference between the level of aspiration and the level of past performance in a given task is highly reliable and largely independent of the physical nature of the tasks in which it is determined. This difference represents a "relatively permanent characteristic of the personality, and this permanence can be demonstrated regardless of the type of ability which the task requires." He further concluded that a "single trait is measured which manifests itself both in tasks

differing in performance scale and in tasks requiring different types of ability." In other words, a consistent and general trait of the personality is measured which manifests itself just as strongly in tasks having only motor ability in common as in tasks having only a speed scale in common. Therefore, Frank feels that the trait depends "neither on the performance scale alone nor on the type of ability alone." He finally concluded that the traits being measured are "largely independent not only of the tasks used but of the entire experimental situation."

The use of this method in the study of personality has been reviewed by Rotter[18] and by Frank[6]. In studies on the relationship of leadership to the Bernreuter Personality measures, Richardson and Hanawalt[17] found that the average college leader is more dominant, extroverted, and self-confident than the average nonleader. By means of an item analysis, Hanawalt et al[9] found relatively few items in the Bernreuter inventory in which there was a significant difference in the responses of the two groups. The differences revealed by this method, however, would indicate that the leaders would express higher goals than those of the nonleaders. Thus, whether one speaks of leadership qualities, goal seeking behavior, or level of aspiration, it appears that these entities tended to remain stable or improve during the 34 days of the study as measured by the differences between estimates and correct responses. This finding occurred not only in the structured physical, social, and sensory environment of confinement but during simulated altitude, 100 percent oxygen atmosphere, and while wearing the full pressure suit.

The experimental data has demonstrated no marked deterioration in group cohesiveness, individual performance, level of aspiration, goal seeking behavior, or leadership. Although in very preliminary stages, the absence of any deterioration among the subjects appears to be in agreement with the findings of other investigators in this study, i.e., respiratory physiology, biochemistry, hematology, dermatology, dietetics, and the clinical findings of the medical staff. Furthermore, the successful launch and recovery of the recent Gemini 4 flight for 62 orbits did not appear to overstress the crew. This is not to say that stressors are lacking. Gemini 4 pilot James A. McDivitt, during his futile chase of the booster rocket, consistently reported the rocket five times closer to him than it actually was. Such perceptual distortions on more advanced space adventures could prove to be serious. It would appear that more extensive and sophisticated experiments in the life sciences both on the ground and during celestial flight are indicated.

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TABLE 8-1

ROW ERRORS DURING THE VARIOUS CAPSULE CONDITIONS FOR INDIVIDUAL PERFORMANCE

	Days 1 - 7 Sea Level No P. Suit					Days 8 - 14 27,000 feet No P. Suit					Days 15 - 27 27,000 feet Full P. Suit				
	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum
S_1	10	8	3	6	27	16	13	11	18	58	30	33	18	14	95
S_2	26	29	39	26	120	10	13	29	22	74	39	30	33	47	149
S_3	12	14	14	14	54	11	11	8	5	35	15	14	19	15	63
S_4	23	26	27	32	108	37	17	24	26	104	35	45	42	54	176
S_5	65	59	63	56	243	51	24	24	36	135	60	44	35	47	186
S_6	20	16	20	12	68	20	16	28	15	79	66	41	54	39	200
Sum	156	152	166	146	620	145	94	124	122	485	245	207	201	216	869

	Days 28 - 34 Sea Level Full P. Suit					Sum of Days 1 - 34					Mean of Days 1 - 34				
	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum
S_1	17	13	25	14	69	73	67	57	52	249	2.1	2.0	1.7	1.5	7.3
S_2	33	27	28	32	120	108	99	129	127	463	3.2	2.9	3.8	3.7	13.6
S_3	9	5	14	15	43	47	44	55	49	195	1.4	1.3	1.6	1.4	5.7
S_4	33	38	36	26	133	128	126	129	138	521	3.8	3.7	3.8	4.1	15.3
S_5	23	16	31	25	95	199	143	153	164	659	5.9	4.2	4.5	4.8	19.4
S_6	40	48	52	24	164	146	121	154	90	511	4.3	3.6	4.5	2.6	15.0
Sum	155	147	186	136	624	701	600	677	620	2598	20.6	17.6	19.9	18.2	76.4

TABLE 8-2

COLUMN ERRORS DURING THE VARIOUS CAPSULE CONDITIONS FOR INDIVIDUAL PERFORMANCE

	Days 1 - 7 Sea Level No P. Suit					Days 8 - 14 27,000 feet No P. Suit					Days 15 - 27 27,000 feet Full P. Suit				
	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum
S_1	10	4	4	6	24	13	9	7	6	35	18	14	11	10	53
S_2	11	13	17	8	49	4	1	6	11	22	12	13	10	9	44
S_3	4	13	15	11	43	5	13	3	1	22	7	9	14	12	42
S_4	20	13	12	13	58	12	8	9	13	42	23	15	20	22	80
S_5	36	33	36	34	139	26	18	28	17	89	14	20	14	7	55
S_6	18	15	10	11	54	7	15	14	7	43	33	30	30	23	116
Sum	99	91	94	83	367	67	64	67	55	253	107	101	99	83	390

	Days 28 - 34 Sea Level Full P. Suit					Sum of Days 1 - 34					Mean of Days 1 - 34				
	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum
S_1	7	4	14	8	33	48	31	36	30	145	1.4	.9	1.1	.9	4.3
S_2	6	6	7	17	36	33	33	40	45	151	1.0	1.0	1.2	1.3	4.4
S_3	3	4	7	5	19	19	39	39	29	126	.6	1.1	1.1	.9	3.7
S_4	7	23	12	16	58	62	59	53	64	238	1.8	1.7	1.6	1.9	7.0
S_5	7	7	5	11	30	83	78	83	69	313	2.4	2.3	2.4	2.0	9.2
S_6	21	17	28	14	80	79	77	82	55	293	2.3	2.3	2.4	1.6	8.6
Sum	51	61	73	71	256	324	317	333	292	1266	9.5	9.3	9.8	8.6	37.2

TABLE 8-3

ROW ERRORS DURING THE VARIOUS CAPSULE CONDITIONS FOR GROUP PERFORMANCE

	Days 1 - 7 Sea Level No P. Suit					Days 8 - 14 27,000 feet No P. Suit					Days 15 - 27 27,000 feet Full P. Suit				
	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum
Group A	15	17	18	12	62	18	19	25	12	74	32	23	23	26	104
Group B	11	16	13	15	55	22	15	14	9	60	27	24	21	17	89
Sum	26	33	31	27	117	40	34	39	21	134	59	47	44	43	193

	Days 28 - 34 Sea Level Full P. Suit					Sum of Days 1 - 34					Mean of Days 1 - 34				
	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum
Group A	25	22	18	19	84	90	81	84	69	324	2.6	2.4	2.5	2.0	9.5
Group B	22	15	21	17	75	82	70	69	58	279	2.4	2.1	2.0	1.7	8.2
Sum	47	37	39	36	159	172	151	153	127	603	5.1	4.4	4.5	3.7	17.7

TABLE 8-4

COLUMN ERRORS DURING THE VARIOUS CAPSULE CONDITIONS FOR GROUP PERFORMANCE

	Days 1 - 7 Sea Level No P. Suit					Days 8 - 14 27,000 feet No P. Suit					Days 15 - 27 27,000 feet Full P. Suit				
	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum
Group A	18	15	9	8	50	10	13	12	9	44	23	27	19	31	100
Group B	7	10	6	13	36	18	12	10	13	53	21	19	21	15	76
Sum	25	25	15	21	86	28	25	22	22	97	44	46	40	46	176

	Days 28 - 34 Sea Level Full P. Suit					Sum of Days 1 - 34					Mean of Days 1 - 34				
	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum	Q_1	Q_2	Q_3	Q_4	Sum
Group A	17	13	14	18	62	68	68	54	66	256	2.0	2.0	1.6	1.9	7.5
Group B	8	7	9	10	34	54	48	46	51	199	1.6	1.4	1.4	1.5	5.9
Sum	25	20	23	28	96	122	116	100	117	455	3.6	3.4	2.9	3.4	13.4

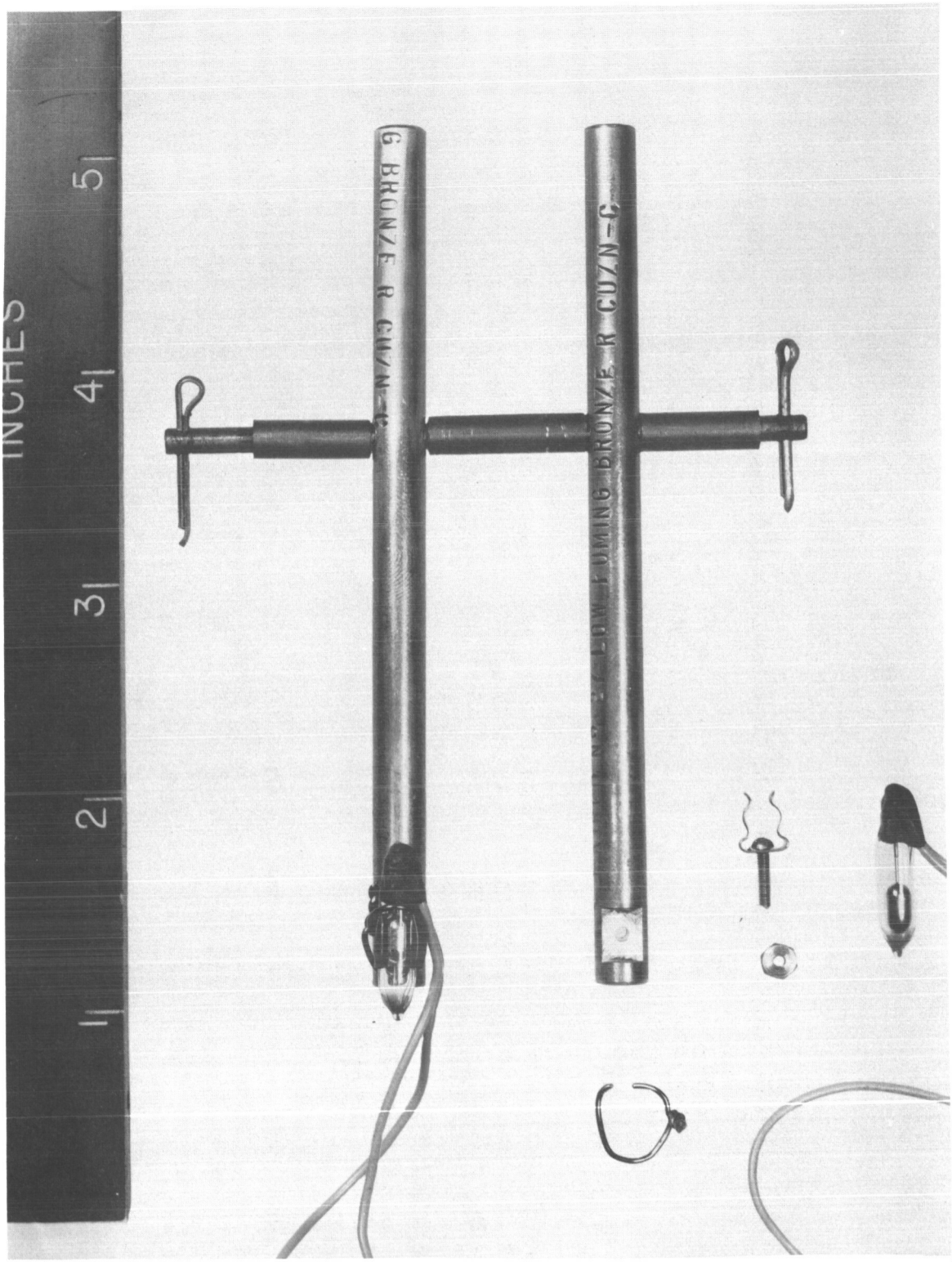

Figure 8-1 EXPLODED VIEW OF SWITCHES USED IN 100% OXYGEN ATMOSPHERE

PHOTO NO: CAN-369211(L)-6-65

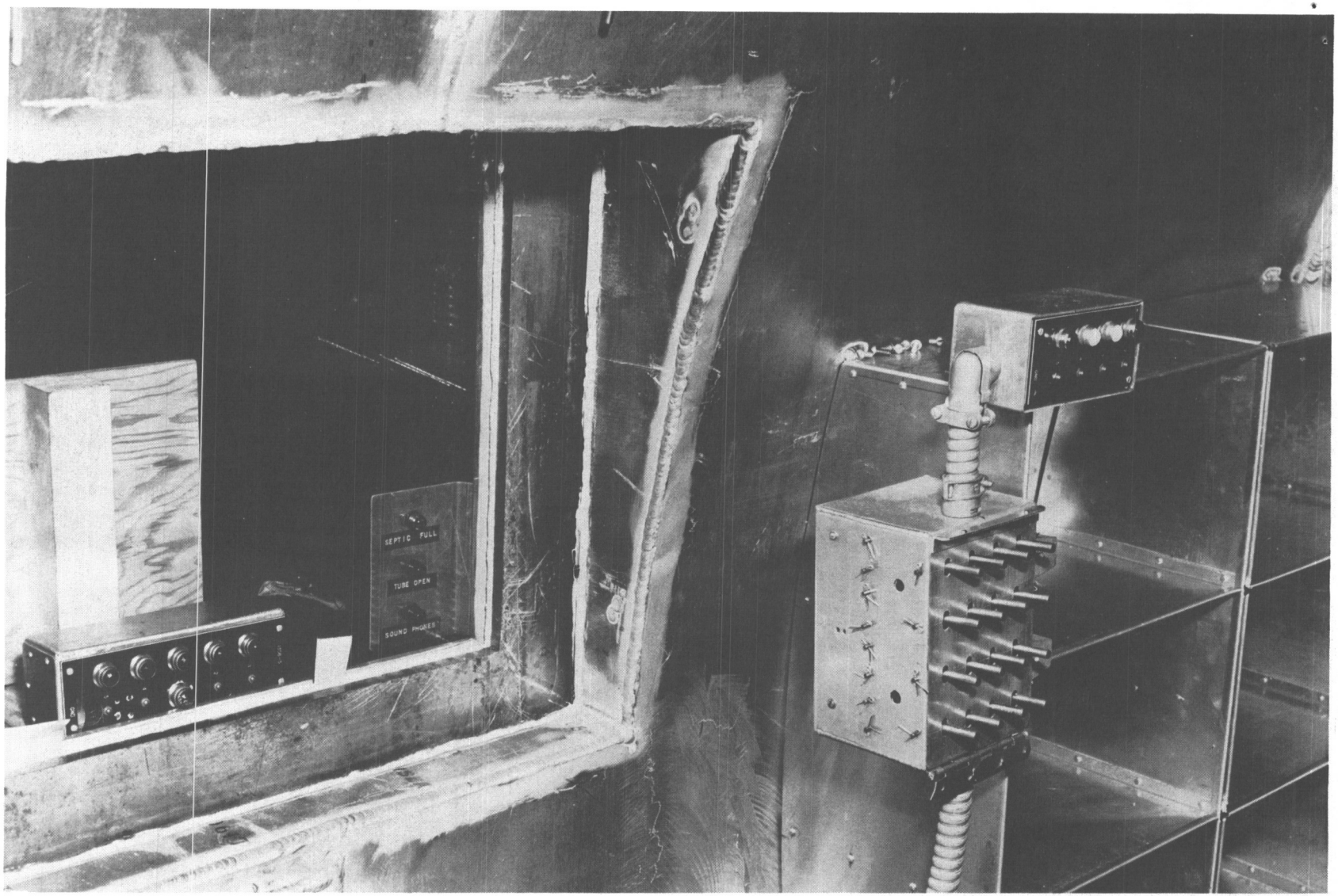

Figure 8-2 APPARATUS FOR INDIVIDUAL PERFORMANCE INSIDE THE CHAMBER

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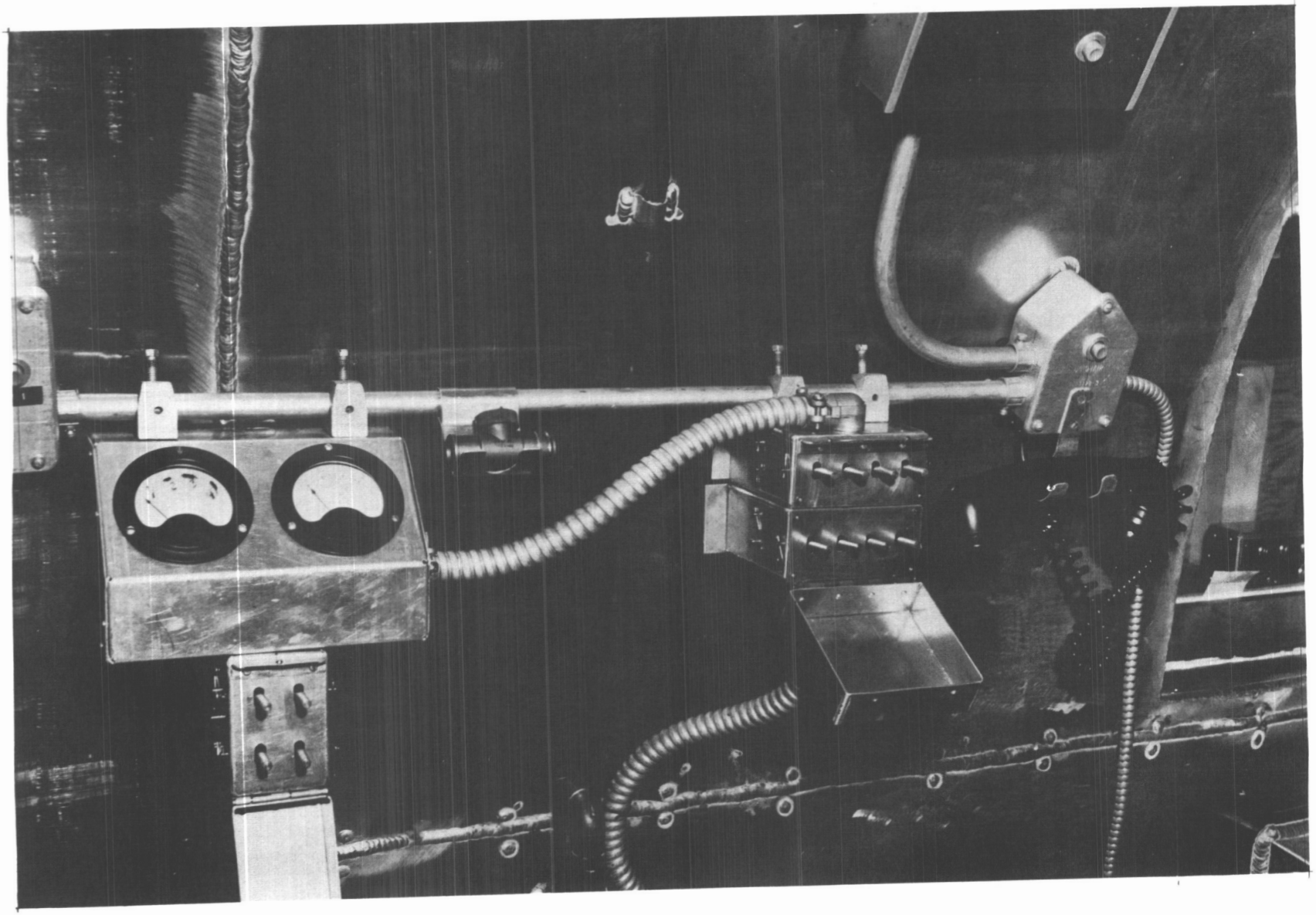

Figure 8-3 APPARATUS FOR GROUP PERFORMANCE INSIDE THE CHAMBER

PHOTO NO: CAN-368774(L)-5-65

COMPLEX MENTAL ACTIVITY: INDIVIDUAL PERFORMANCE

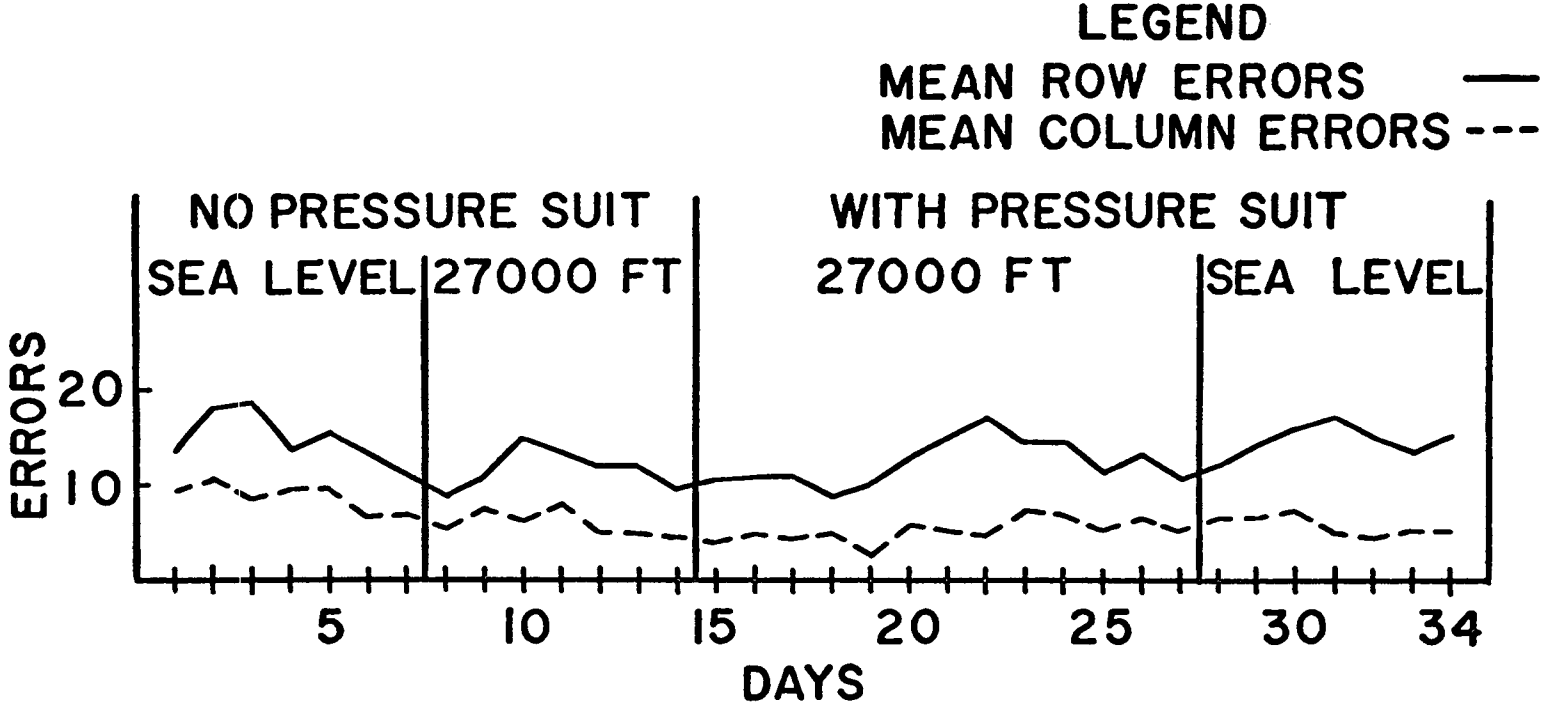

FIG 8-4. MEAN ERRORS PER DAY FOR THE SIX SUBJECTS

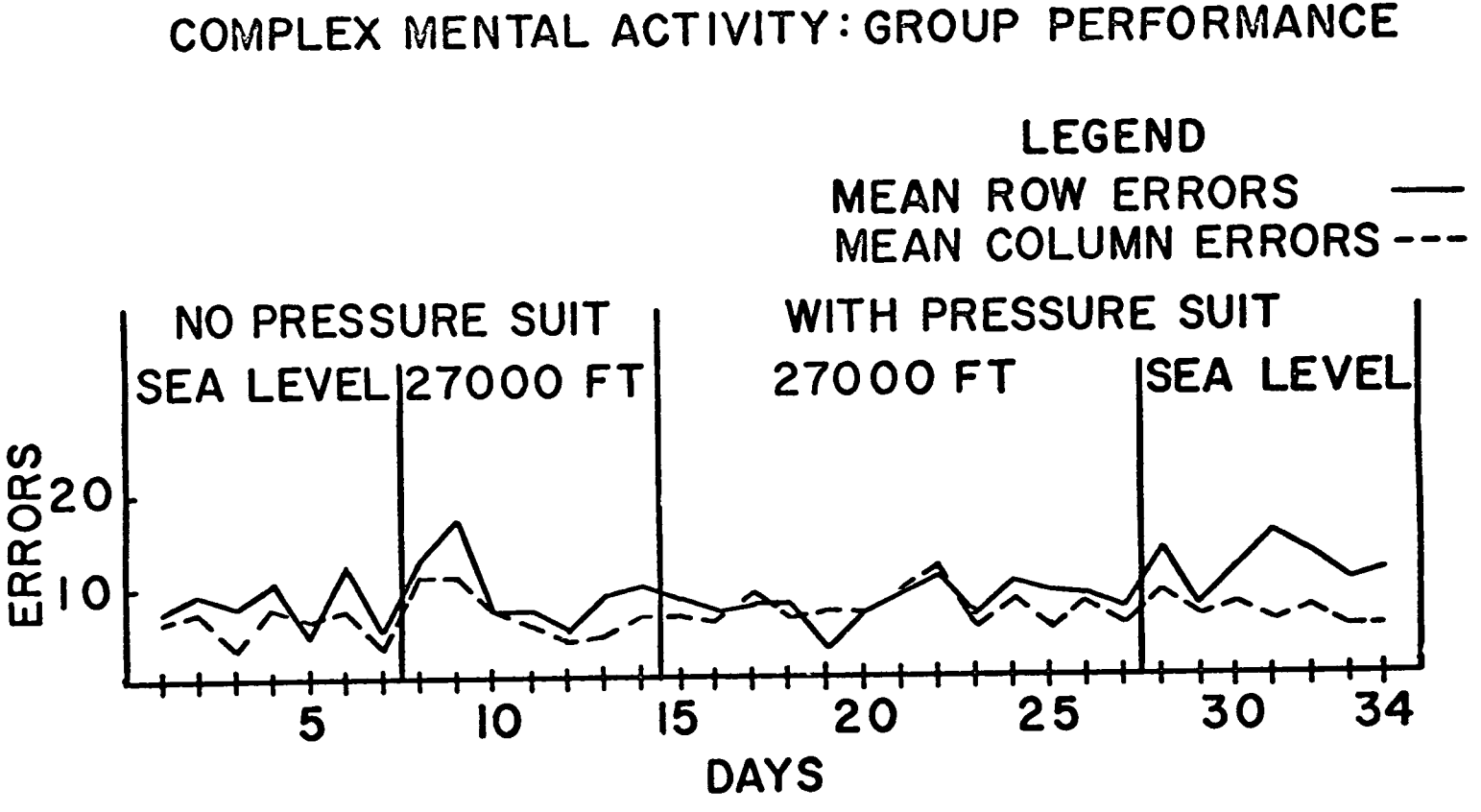

FIG 8-5 MEAN ERRORS PER DAY FOR THE TWO GROUPS

COMPLEX MENTAL ACTIVITY: INDIVIDUAL PERFORMANCE

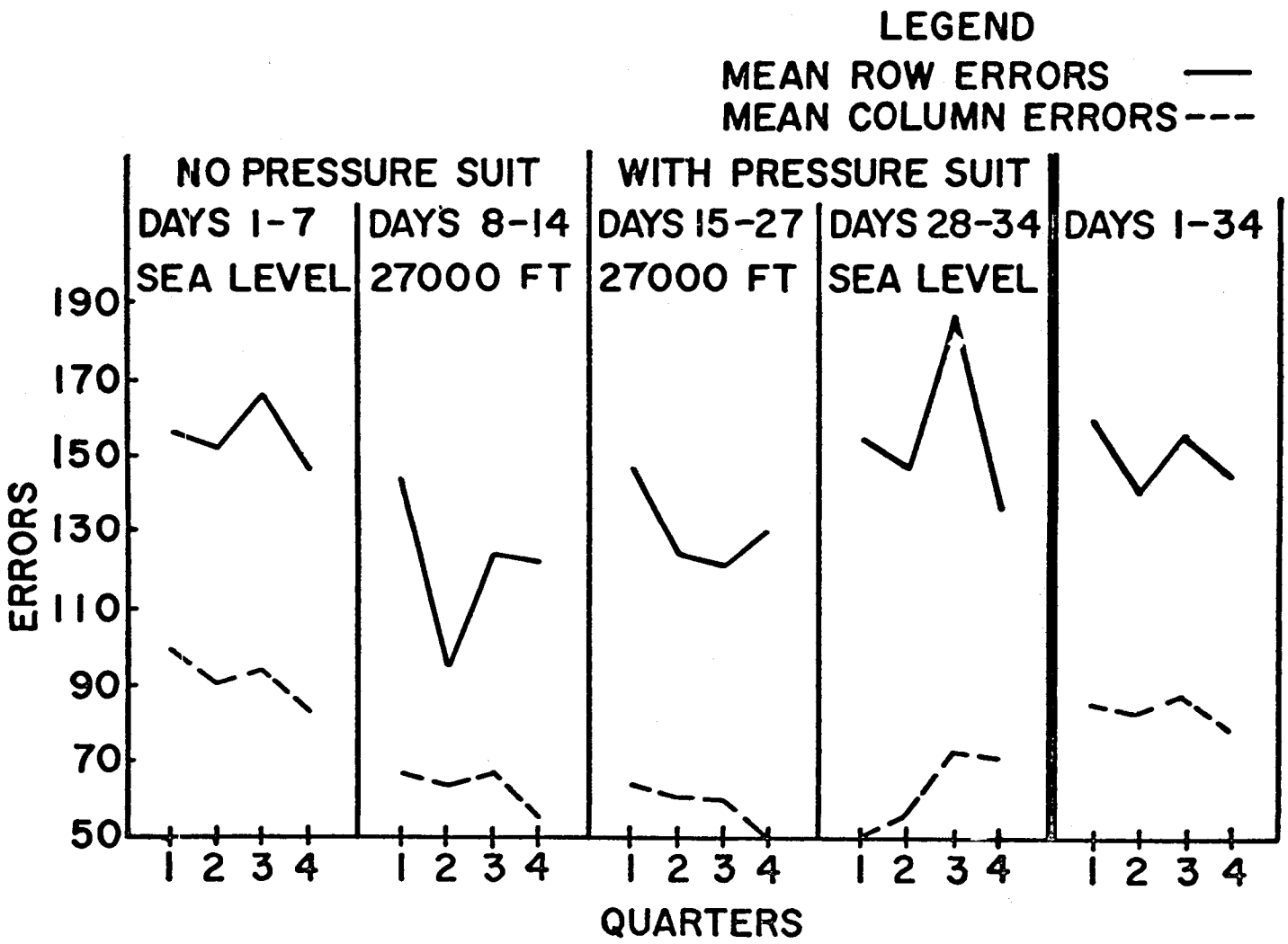

FIG 8-6 ROW & COLUMN ERRORS BY QUARTERS

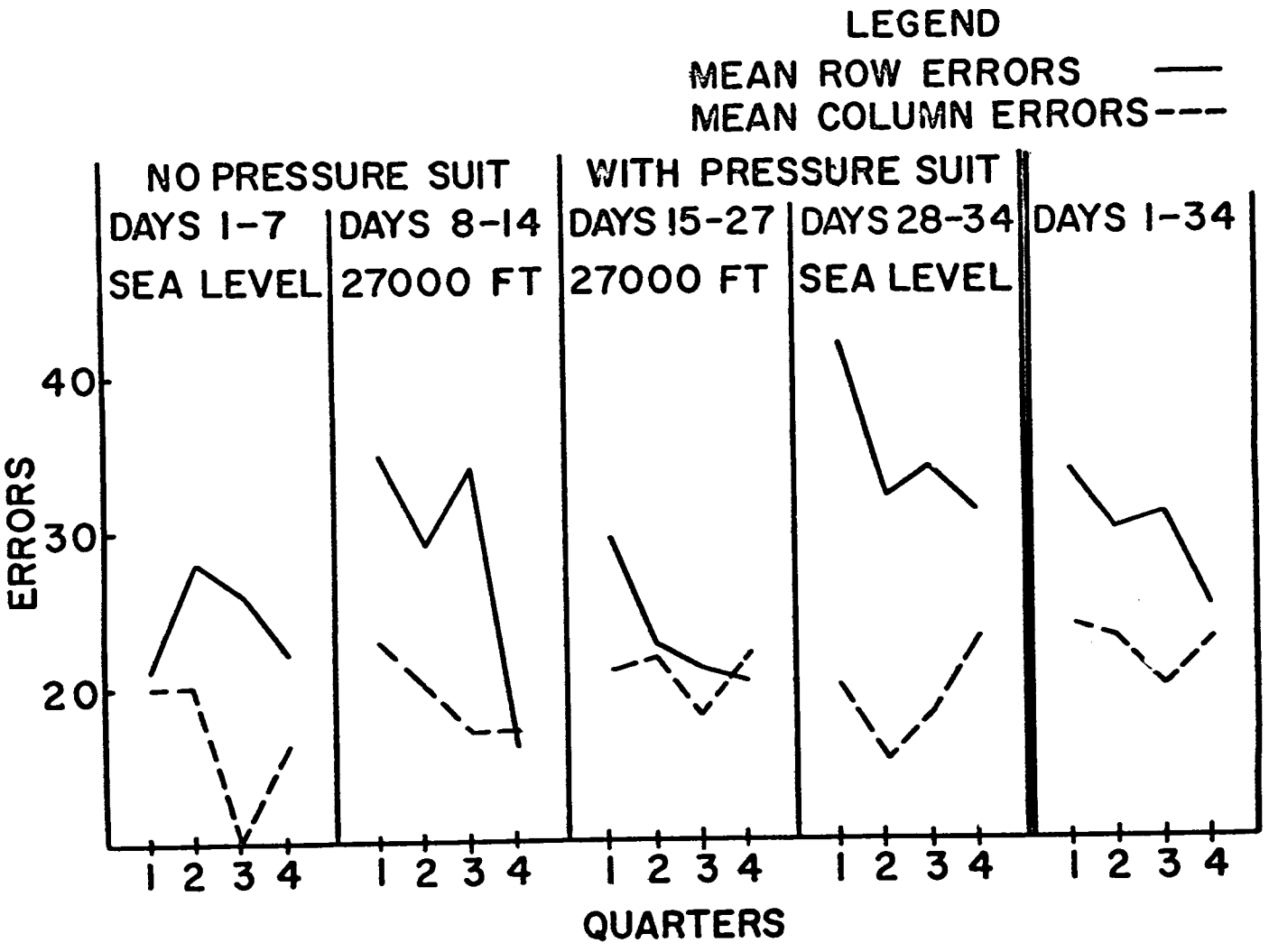

FIG 8-7 ROW & COLUMN ERRORS BY QUARTERS

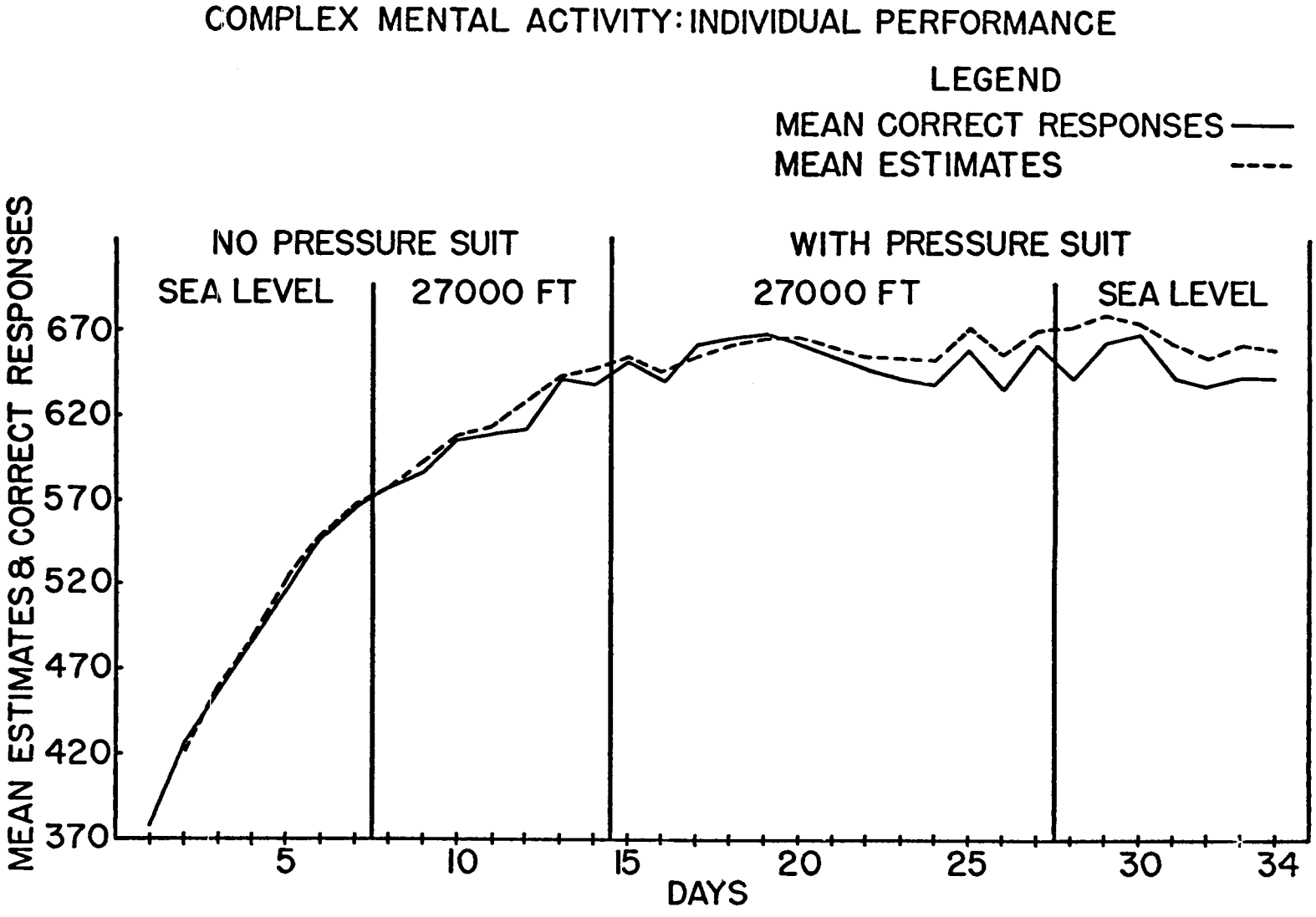

FIG. 8-8 MEAN NUMBER OF ESTIMATES & CORRECT RESPONSES

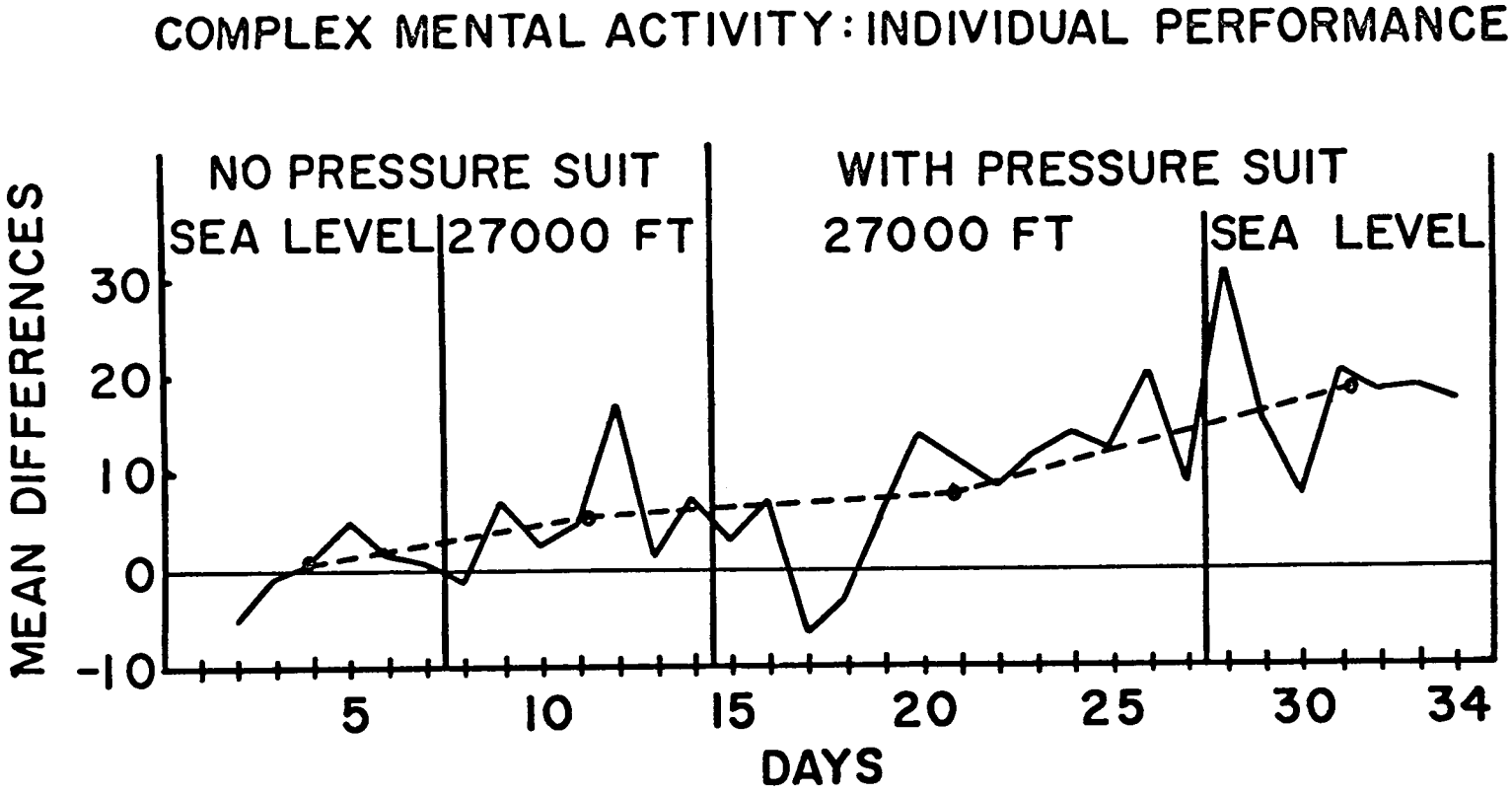

FIG 8-9 MEAN NUMBER OF ESTIMATES MINUS MEAN NUMBER OF CORRECT RESPONSES

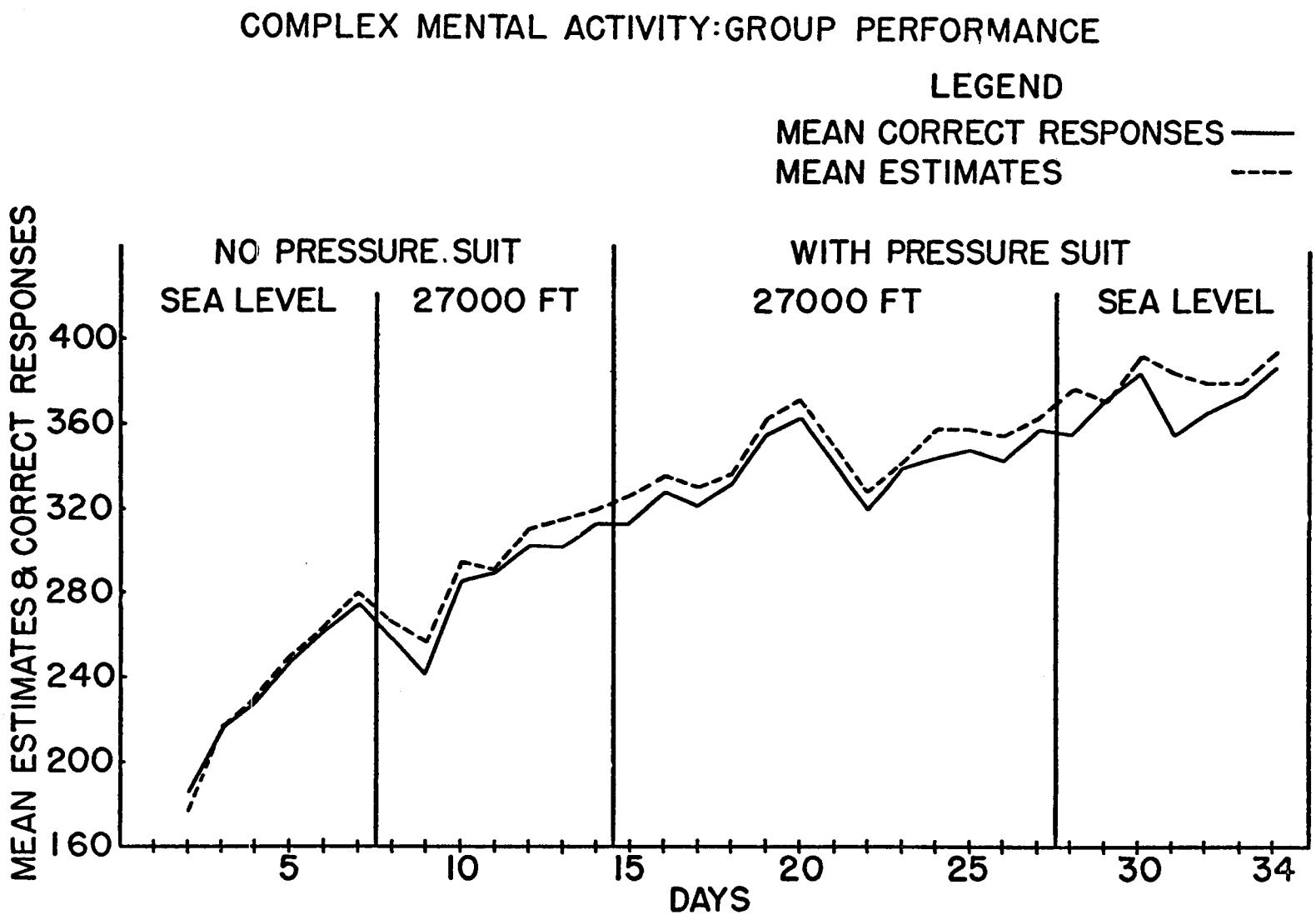

FIG 8-10 MEAN NUMBER OF ESTIMATES & CORRECT RESPONSES

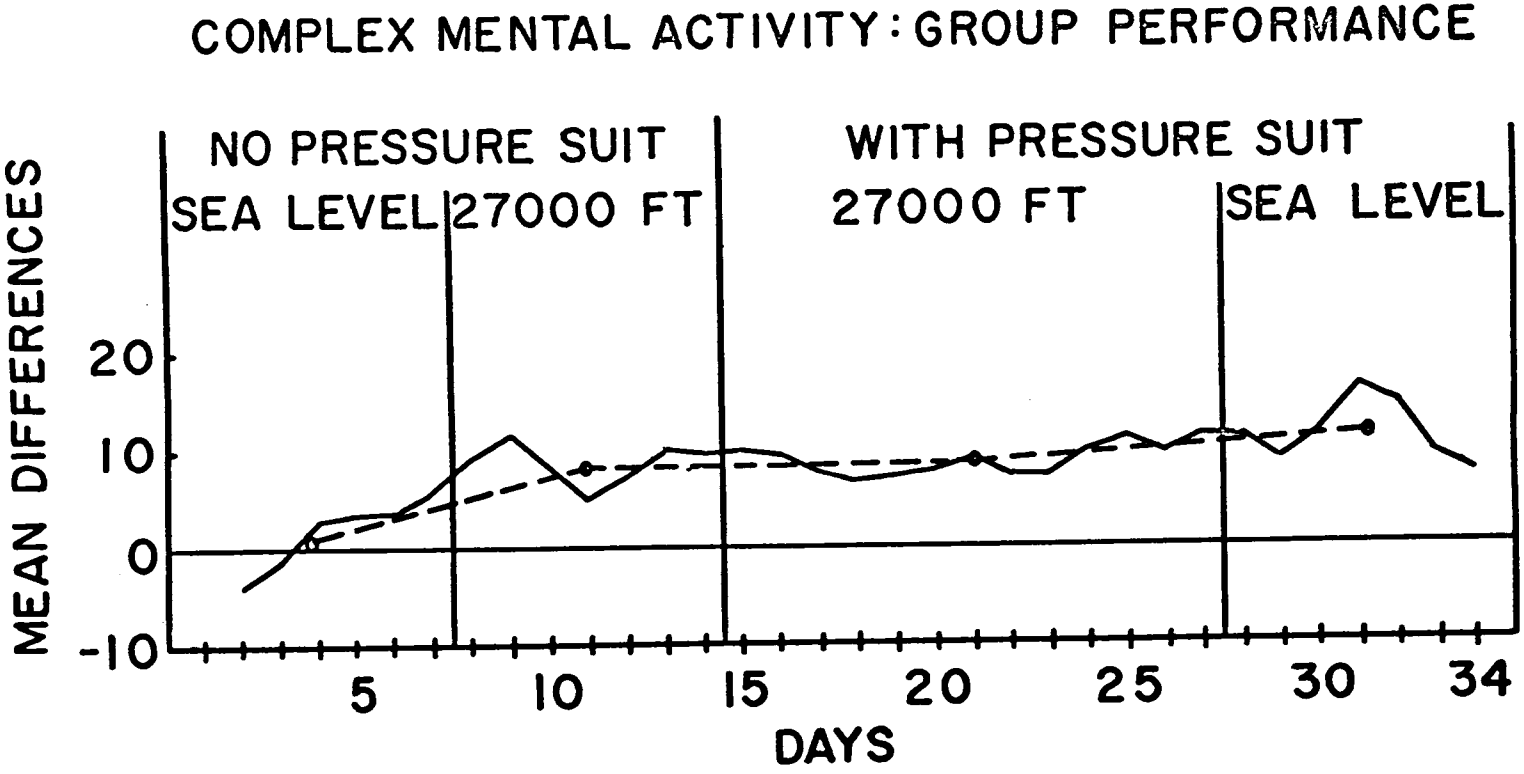

FIG 8-11 MEAN NUMBER OF ESTIMATES MINUS MEAN NUMBER OF CORRECT RESPONSES PER DAY

SECTION 9

CHANGES IN THE FREQUENCY DISTRIBUTION OF MUSCLE ACTION POTENTIALS FOLLOWING THE ACQUISITION OF A SIMPLE MOTOR SKILL (MIRROR TRACING)

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SECTION 9

CHANGES IN THE FREQUENCY DISTRIBUTION OF MUSCLE ACTION POTENTIALS FOLLOWING THE ACQUISITION OF A SIMPLE MOTOR SKILL (Mirror Tracing)

INTRODUCTION

The contraction of muscle fibres in the living organism is accompanied by low intensity electrical discharges known as "muscle action potentials" or MAP. These low intensity bio-electric impulses may be picked up at the surface of the skin by the use of electrodes. They may then be amplified, recorded, and analyzed.

It has been shown[1] that the muscle action potentials have a rather limited frequency distribution, with most of their energies lying between 20 and 200 cycles per second. Subsequent experiments[2, 3] have produced evidence that the frequency distribution of the muscle action potentials may be altered by prolonged isometric contractions of the muscles. The alteration of the frequency distribution is such that lower frequency components (below 50 cycles per second) tend to increase in mean intensity, while higher frequency components (above 50 cycles per second) tend to decrease in mean intensity as the subject becomes progressively more fatiqued. Associated with these changes in the frequency distribution of the muscle action potentials is a corresponding decrease in the precision of performance of a motor task.

Based upon these observations, it was conjectured that the precision of performance of a motor task is directly related to the frequency distribution of the muscle action potentials emitted in the performance of the task. From this conjecture, it would follow that:

> If decreased precision is associated with decreased intensity of higher frequency muscle action potentials and increased intensity of lower frequency muscle action potentials, then increased precision should be associated with increased intensity of higher frequency muscle action potentials and decreased intensity of lower frequency muscle action potentials.

The problem, then, is to establish a condition in which the precision of performance of a motor task can be increased. One such method involves the acquisition of a motor skill through practice, i.e., motor learning.

METHOD

Each of eight subjects attempted to trace with an electrified stylus the outlines of five different geometric forms. They traced each of the forms for a period of

three minutes while viewing both the form and the tracing hand in a mirror. The forms (a triangle, a square, a pentagon, a hexagon, and a circle) were made by etching their inner and outer boundaries in copper printed circuit material. All forms measured 1/4" from their inner to their outer boundaries, and the distances around their perimeters were all 22". The printed circuit material was wired so that the number of errors, i.e., the number of times the subject failed to keep the stylus between the boundaries of the forms, and the number of revolutions, i.e., the number of times the subject completed a full rotation about the perimeter of the forms, were recorded by counters.

A photograph showing one of the geometric forms (the square) used in this experiment is presented in Figure 1.

FIGURE 1

On each of five successive days, the subjects practiced the mirror tracing task. At the same time, muscle action potentials were obtained from various muscles of the working arm. The signals were amplified by an Offner Type R Dynograph, and the output of the Dynograph was recorded continuously on magnetic tape. The amplifier gain of the Dynograph was constant over all subjects. Throughout each session in which muscle action potentials were recorded, the subject was seated in an electrostatically shielded room. The lead wires carrying the electromyographic information ran out of the shielded room and into a separate room in which the Dynograph and tape recorder were located.

Following the initial practice sessions, all subjects were confined for a period of 34 days. They practiced the mirror tracing task daily for fifteen minutes each day, spending three minutes on each of the five geometric forms. Muscle action potentials were not recorded during this 34 day confinement-practice period.

At the end of the 34 day confinement-practice period each subject was again required to perform the same mirror tracing task for five additional days, as he did in the initial pre-practice sessions. As in the initial pre-practice sessions, muscle action potentials were recorded.

RESULTS AND DISCUSSION

Measures of Performance:

Changes in the performance of the mirror tracing task are shown in Figures 2, 3 and 4.

FIGURES 2, 3 and 4

The mean number of times that each subject traced the outlines of the

geometric forms in each 3 minute trial is presented in Figure 2. As shown in Figure 2, the subjects became progressively more rapid in the performance of the mirror tracing task.

As shown in Figure 3, the subjects tended to make progressively fewer errors per trial as the number of practice sessions increased, although there is a slight rise in the absolute number of errors during the post-practice sessions. This is probably due to the greatly increased speed of performance shown in Figure 2.

Figure 4 clearly illustrates the increased precision in the performance of the mirror tracing task. Whereas the subjects initially made an average of 1.86 errors per revolution during the first pre-practice session, the post-practice sessions were much better, with between .26 and .41 errors per revolution.

Measures of Muscle Action Potentials:

Analysis of the muscle action potentials was performed by playing the tape recorded signals through a Technical Products Wave Analyzer System. The analyzer was tuned at a central frequency of 20, 30, 40, 50, 70, 80, 100, 140, 160, or 200 cycles per second. An effective 5 cycle per second band-pass filter was centered about each of these frequencies, thereby allowing signals plus or minus 2.5 cycles per second from the center tuned frequency to pass through the filters. The signals passing through the filters were continuously integrated for a period of three minutes, i.e., the time employed for each trial with each of the forms, for each of the subjects on each of the trials at each of the frequencies specified. A plotting of the total integrated electrical energy as a function of frequency yields the frequency distribution of the muscle action potentials employed in this experiment and presented in Figure 5.

FIGURE 5

Figure 5 illustrates the changes in the frequency distribution of the muscle action potentials obtained from the extensor digitorum communis muscle of the working arm both before and after the 34 day confinement-practice period. As shown in Figure 5, the lower frequency components of the muscle action potentials, 50 cycles per second and below, do not appear to show any significant change in intensity as a function of practice. On the other hand, the higher frequency components, those above 50 cycles per second, are of a greater intensity after practice than before.

CONCLUSIONS

The observed changes in the frequency distribution of the muscle action potentials suggest that precision of performance in a motor task is associated with the frequency-intensity characteristics of the muscle action potentials emitted in the performance of the task, and that the acquisition of a motor skill may be associated with increased activity of higher frequency action potential components of the performing muscles.

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(3) Klein, S. J. and Cohen, M. M., Frequency distribution of muscle action potentials during isometric work. Paper presented at the meetings of the Society for Psychophysiological Research, October, 1964.

LIST OF FIGURES

Figure 1: Photograph of geometric form used in this experiment.

Figure 2: Revolutions per trial as a function of practice.

Figure 3: Errors per trial as a function of practice.

Figure 4: Errors per revolution as a function of practice.

Figure 5: Changes in frequency spectrum of MAP as a function of practice.

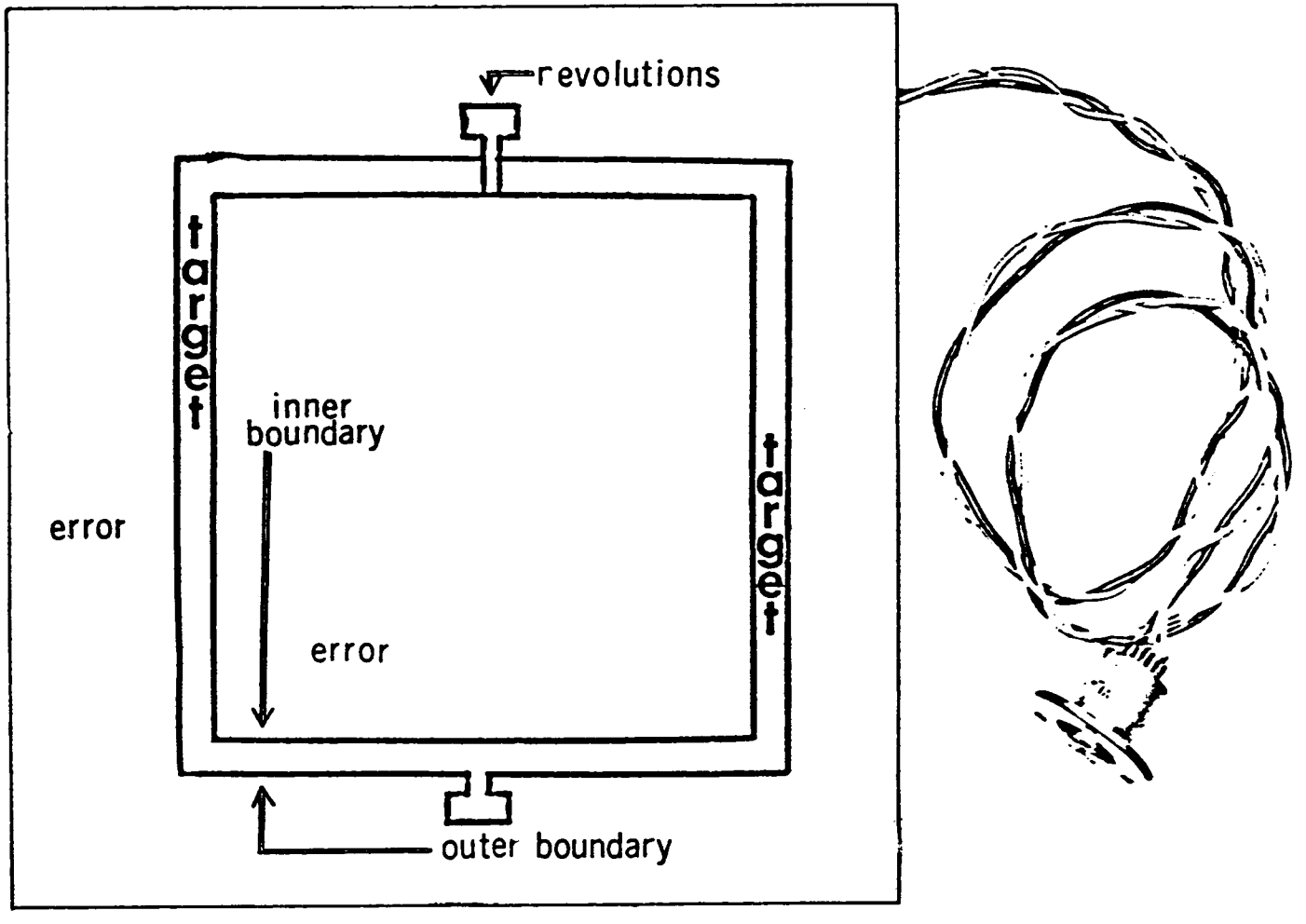

FIG. 9-1 GEOMETRIC FORM USED IN EXPERIMENT

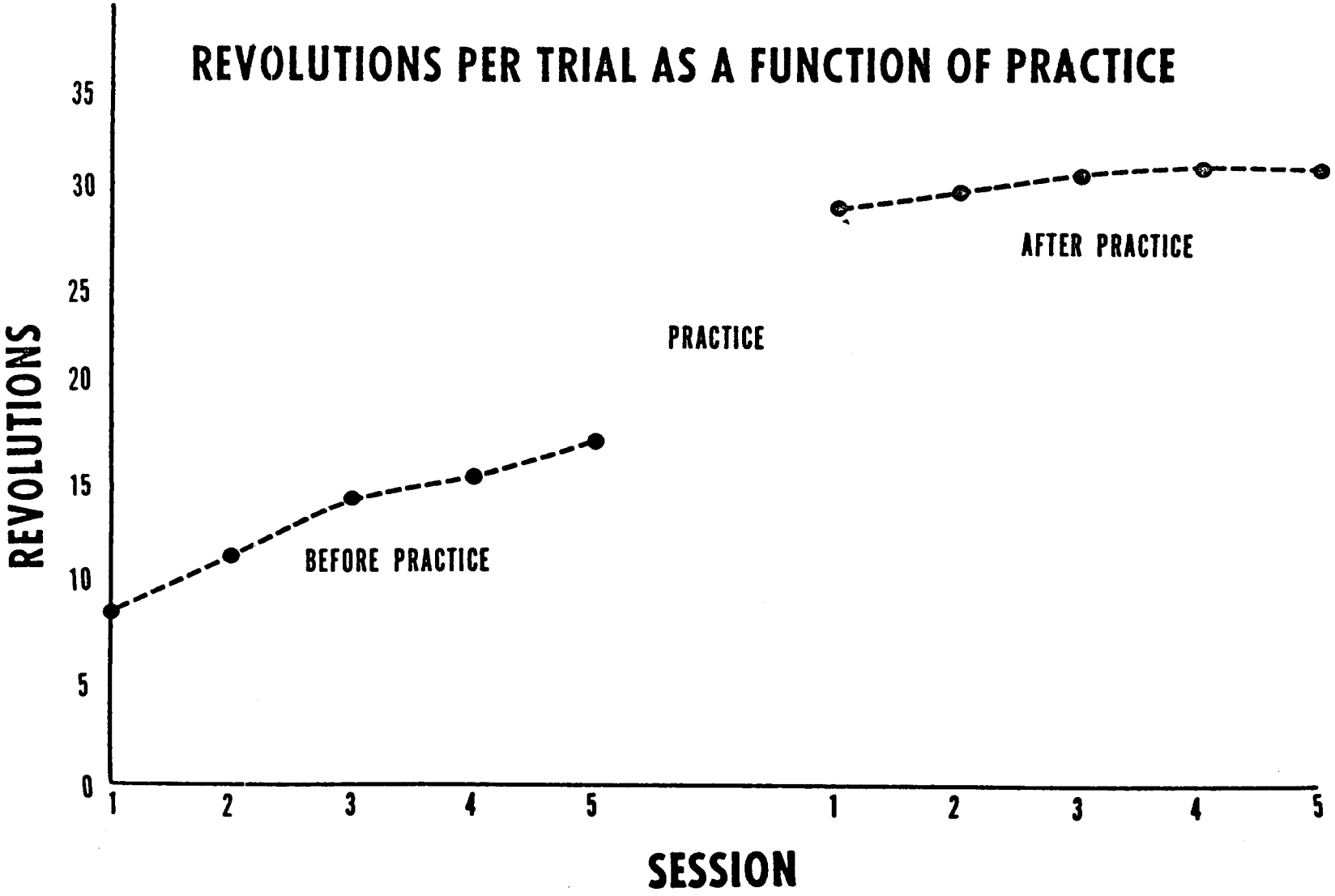
REVOLUTIONS PER TRIAL AS A FUNCTION OF PRACTICE
REVOLUTIONS
35
30
25
20
15
10
5
0
BEFORE PRACTICE
PRACTICE
AFTER PRACTICE
1
2
3
4
5
1
2
3
4
5
SESSION

FIG. 9-2

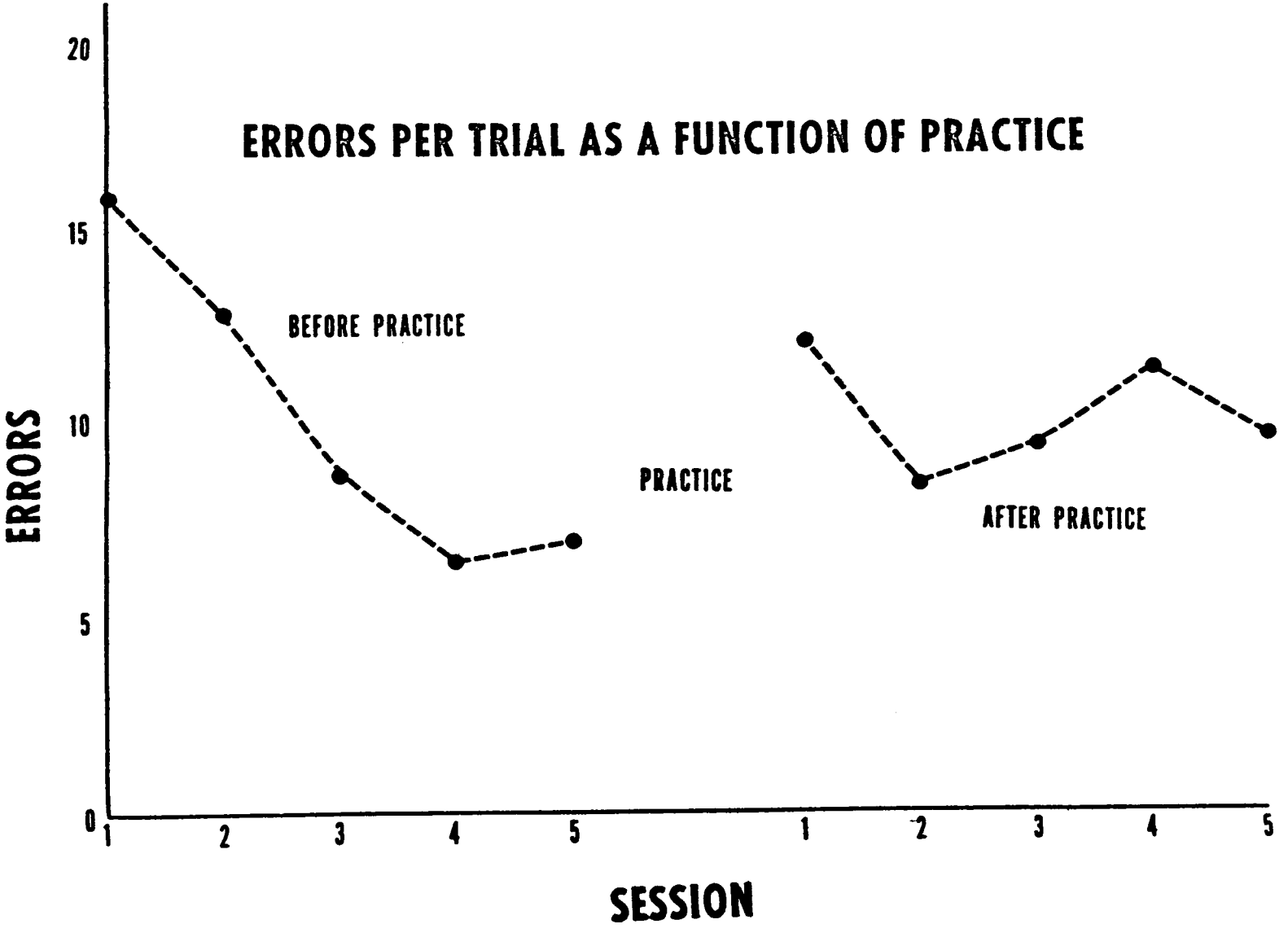
ERRORS PER TRIAL AS A FUNCTION OF PRACTICE
ERRORS
20
15
10
5
0
BEFORE PRACTICE
PRACTICE
AFTER PRACTICE
1
2
3
4
5
1
2
3
4
5
SESSION

FIG. 9-3

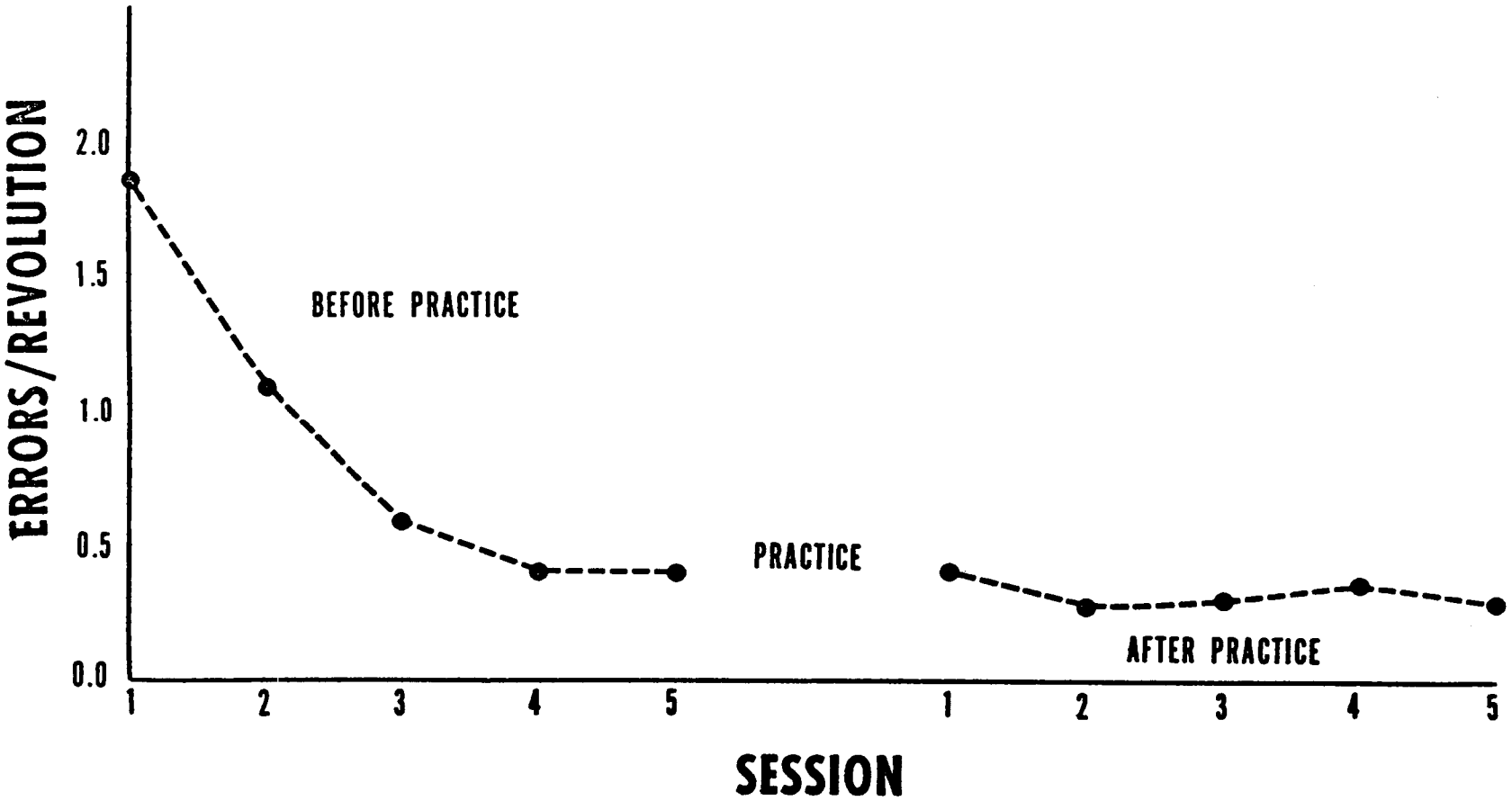
ERRORS PER REVOLUTION AS A FUNCTION OF PRACTICE
ERRORS/REVOLUTION
2.0
1.5
1.0
0.5
0.0
BEFORE PRACTICE
PRACTICE
AFTER PRACTICE
1
2
3
4
5
1
2
3
4
5
SESSION

FIG. 9-4

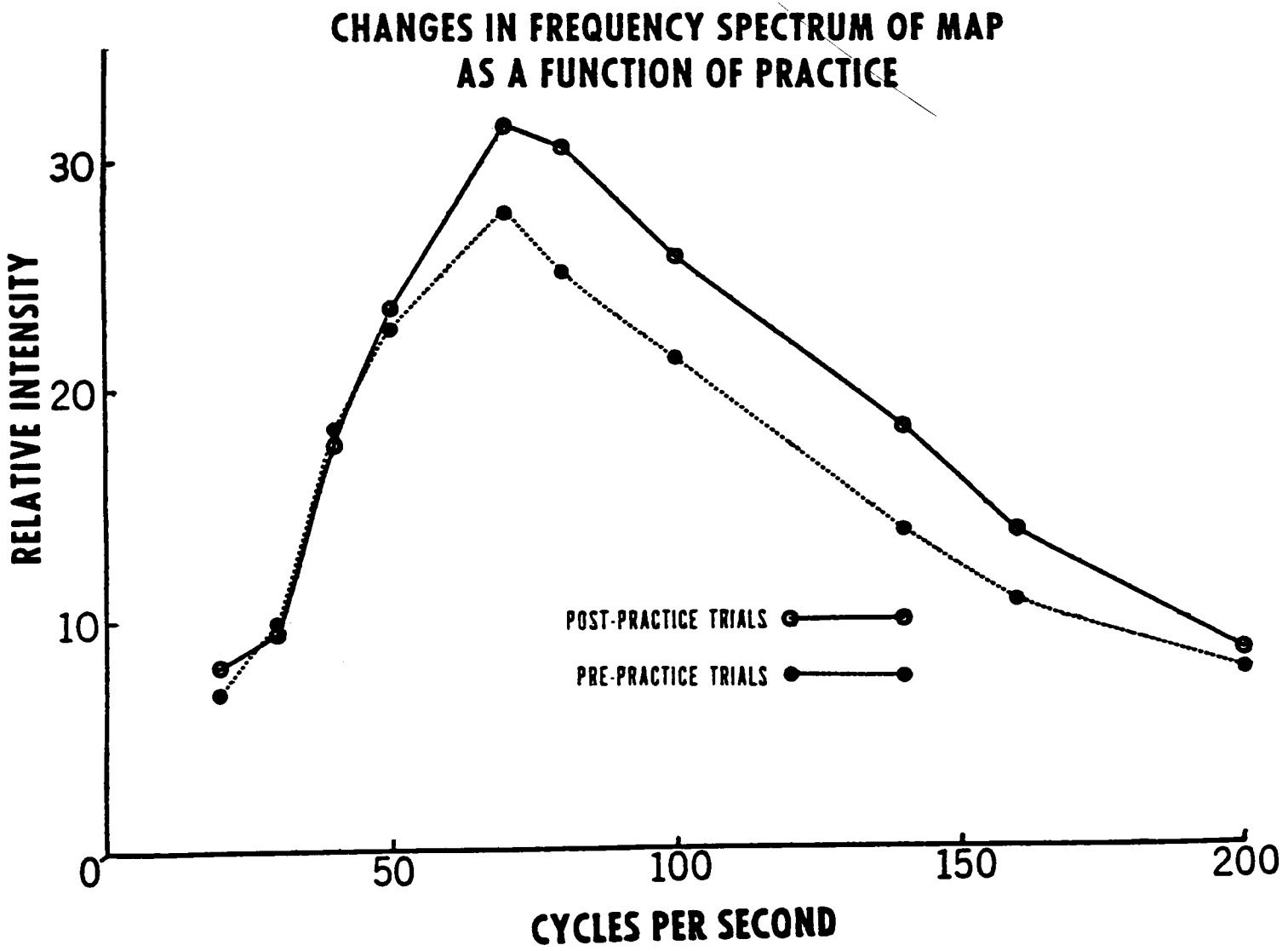
CHANGES IN FREQUENCY SPECTRUM OF MAP
AS A FUNCTION OF PRACTICE
RELATIVE INTENSITY
30
20
10
0
50
100
150
200
CYCLES PER SECOND
POST-PRACTICE TRIALS
PRE-PRACTICE TRIALS

FIG. 9-5

SECTION 9A

CURVATURE AFTER-EFFECTS AS A FUNCTION OF THE MAGNITUDE OF CURVATURE OF THE INSPECTED MATERIAL

Malcolm M. Cohen, Ph. D.

SECTION 9A

CURVATURE AFTER-EFFECTS AS A FUNCTION OF THE MAGNITUDE OF CURVATURE OF THE INSPECTED MATERIAL

INTRODUCTION

Curved lines viewed for prolonged periods of time appear progressively less curved. Straight lines viewed subsequently appear to curve in a direction opposite to that of the previously viewed curved lines. These changes of apparent curvature, termed "adaptation" and "after-effect" respectively, have been of interest to phychologists for a considerable period of time.

Early investigators of the curvature after-effect phenomenon indicated that the magnitude of the after-effect was independent of the magnitude of curvature of the previously viewed curved lines.[1,2] For example, Gibson[1] pointed out that "a strongly curved line did not seem to give a significantly better effect than a rather weak curvature". Also, Bales & Follansbee[2] stated that "the greater curvature of the stimulus line did not increase the after-effect".

Both Gibson and Bales & Follansbee employed an experimental methodology requiring their subjects to view a single curved line during an exposure period and then to adjust a single line of variable curvature until it appeared to be straight. Because several recent investigators[3,4,5,6] have suggested that the magnitude of an after-effect may be influenced both by the techniques employed during the exposure period and by the techniques employed to measure the after-effect once it is present, it seems likely that the results obtained by Gibson and by Bales & Follansbee were influenced by the specific experimental methodology employed.

The experimental methodology employed in the current study was somewhat different from that of Gibson and Bales & Follansbee. It was hoped that, through the use of this different methodology, the generality of their earlier findings might better be evaluated.

METHODS

Apparatus

The specially constructed apparatus illustrated in Figure 1 was employed throughout this experiment.

FIGURE 1

The apparatus was used both to present the subject with lines of different degrees of curvature during an exposure period, and to measure the apparent curvatures of lines both before and after each exposure period by means of a nulling procedure. The apparatus consisted of an aluminum box (40.5 centimeters high by 37.5 centimeters wide by 30.5 centimeters deep) which was fitted with a variable power and adjustable prism near the front and a grating of straight vertical lines (Zip-a-tone Z474 MBF-3) at the rear. The lines were mounted on milk glass and were illuminated from behind by ambient chamber lighting. The dioptric power of the prism in the apparatus was adjusted manually by turning an adjustment knob at the right of the box. Adjustments of the prism's dioptric power optically altered the apparent curvature of the grating of lines. With increased base left adjustments, the lines appeared to curve more convexly to the left, and with increased base right adjustments, the lines appeared to curve more convexly to the right.

Technique:

Before each exposure period, each of six subjects was required to view the grating of lines in the apparatus and to adjust the dioptric power of the prism until he reported that the lines appeared to be straight. The subject viewed the lines with his right eye while making the adjustments; his left eye was occluded. A series of six adjustments was made by the subject before each exposure period, and, before each adjustment was made, the experimenter set the starting position of the prism alternately at either ten diopters base left or at ten diopters base right.

When the series of six pre-exposure adjustments for apparent straightness was completed, the subject was exposed to the lines through the prism for a period of ten minutes. During this ten minute exposure period, the subject viewed the lines through the prism with his right eye; his left eye was occluded. The prism was set at 20, 10, or 5 diopters base left, at 0 diopters, or at 5, 10, or 20 diopters base right throughout the entire exposure period. A series of photographs, illustrating the optical effects of the prism, is presented in Figure 2.

FIGURE 2

All six subjects were exposed to the lines through the prism set at each of the seven dioptric powers indicated above, and a period of at least one day separated consecutive exposures for each subject. The order in which the subject was exposed to each of the curvatures provided by the prism was determined according to a table of random numbers. Each subject was exposed to all seven curvatures twice while the chamber was at sea level conditions and twice while the chamber was at a simulated altitude of 27,000 feet, yielding a total of twenty-eight exposure periods per subject.

Following each ten minute exposure period, the subject was again required to adjust the dioptric power of the prism in the apparatus as he had before the exposure period. The difference between the means of the six pre-exposure adjustments for apparent straightness and the means of the six post-exposure adjustments for apparent straightness served as a measure of the curvature after-effect brought about by exposure under each of the experimental conditions.

Results and Discussion

As shown in the analysis of variance of Table 1, the only significant sources were Curvature and Altitude.

TABLE 1

Figure 3 illustrates the effects of viewing different magnitudes of curvature of the inspected material as it relates to the magnitude of the curvature after-effect.

FIGURE 3

As seen in Figure 3, the magnitude of the curvature after-effect is a monotonic increasing function of the magnitude of curvature of the inspected material. Following exposure to the lines through the prism set at 20 diopters base left power, the magnitude of the after-effect was 1.60 diopters base left, indicating that the image of the lines was optically curved more convexly to the left when reported as straight. Following exposure to the lines through the prism set at 20 diopters base right power, the magnitude of the after-effect was 2.10 diopters base right, indicating that the image of the lines was optically curved more convexly to the right when reported as straight. For intermediate curvatures of the inspected material, intermediate magnitudes of curvature after-effects were obtained.

These results stand in direct opposition to those reported by Gibson[1] and by Bales & Follansbee[2]. Whereas both of those investigators reported that the magnitude of the after-effect was independent of the magnitude of curvature of the inspected material, these results clearly indicate that the magnitude of the after-effect is dependent upon the magnitude of curvature of the inspected material.

The divergence of these results from those reported by Gibson and Bales & Follansbee probably was due to differences in the experimental methods employed. For example, our subjects were required to view multiple curved lines during the exposure period rather than to view a single curved line; also, our subjects were required to adjust multiple lines for apparent straightness rather than to adjust a single line.

On the other hand, it is possible that our results diverged from those reported by Gibson and by Bales & Follansbee because our use of optical corrections by means of a variable prism provided a more sensitive measure of the after-effect than did the direct physical adjustments employed both by Gibson and Bales & Follansbee.

Additional research will be required to elucidate the basis for the divergence of these results from those reported by Gibson and by Bales & Follansbee.

The curvature after-effects tended to be more base right (i.e., the lines were optically curved more convexly to the right when reported as straight) at sea level conditions than at a simulated altitude of 27,000 feet, as shown in Figure 4.

FIGURE 4

The mean after-effect at sea level conditions across all curvatures of the inspected material was 0.33 diopters base right; the mean after-effect at altitude conditions across all curvatures of the inspected material was 0.50 diopters base left.

The difference in the magnitude of the curvature after-effect as a function of altitude is very perplexing. At present, no adequate theoretical explanation is available to account for this difference in the magnitude of the after-effect as a function of altitude, and it would appear that further research is required to specify the factors which underlie it.

CONCLUSIONS

Under the conditions of this experiment, the magnitude of the curvature after-effect was shown to be a monotonic increasing function of the magnitude of curvature of the inspected material. Because these results stand in opposition to those reported previously by Gibson and by Bales & Follansbee, they indicate that, at least under certain experimental conditions, a generalization which has been in the psychological literature for more than thirty years may be in error.

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Figure 1: Curvature Apparatus

Figure 2: Grating of Lines as Seen Through Prism In Apparatus Set at Various Dioptric Powers

Figure 3: Curvature After-Effects as a Function of Inspected Material

Figure 4: Curvature After-Effects as a Function of Altitude

TABLE 1

ANALYSIS OF VARIANCE

Source	SSq	df	MSq	F	p
Curvature (C)	261.87	6	43.65	9.43	< 0.01
Altitude (A)	28.79	1	28.79	6.22	< 0.05
Subjects (S)*	7.12	5	1.42	----	----
C X A	6.15	6	1.03	----	----
C X S*	101.97	30	3.40	1.10	N.S.
A X S*	34.90	5	6.98	2.27	N.S.
C X A X S	92.47	30	3.08	----	----
Error	383.97	83	4.63	----	----
Totals	917.24	166	-----	----	----

* F computed with C X A X S as error term

CURVATURE APPARATUS

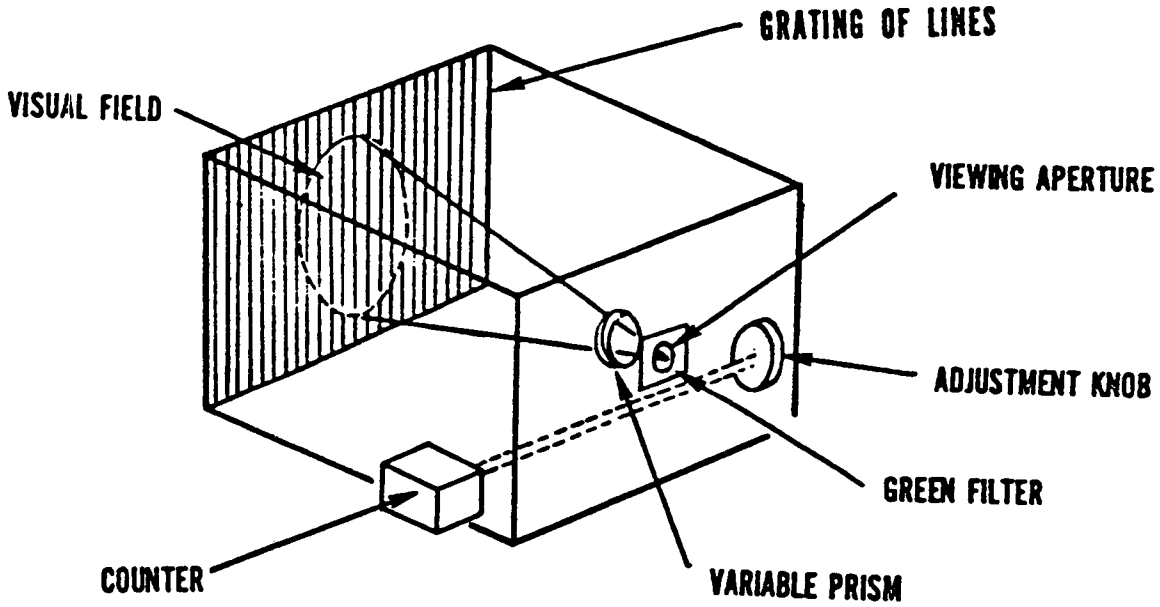


FIG. 9A-1

GRATING OF LINES AS SEEN THROUGH PRISM IN APPARATUS SET AT VARIOUS DIOPTRIC POWERS

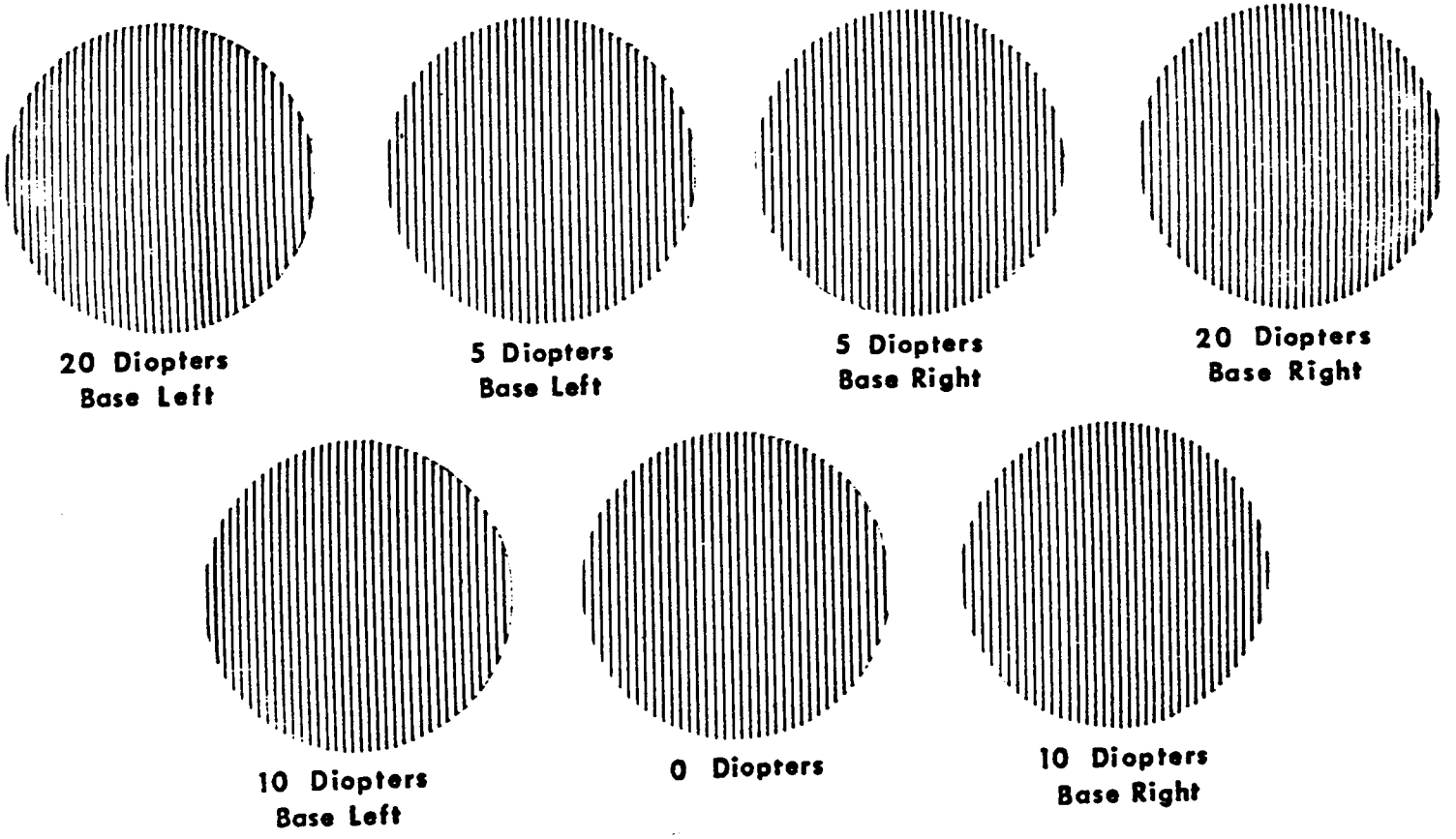
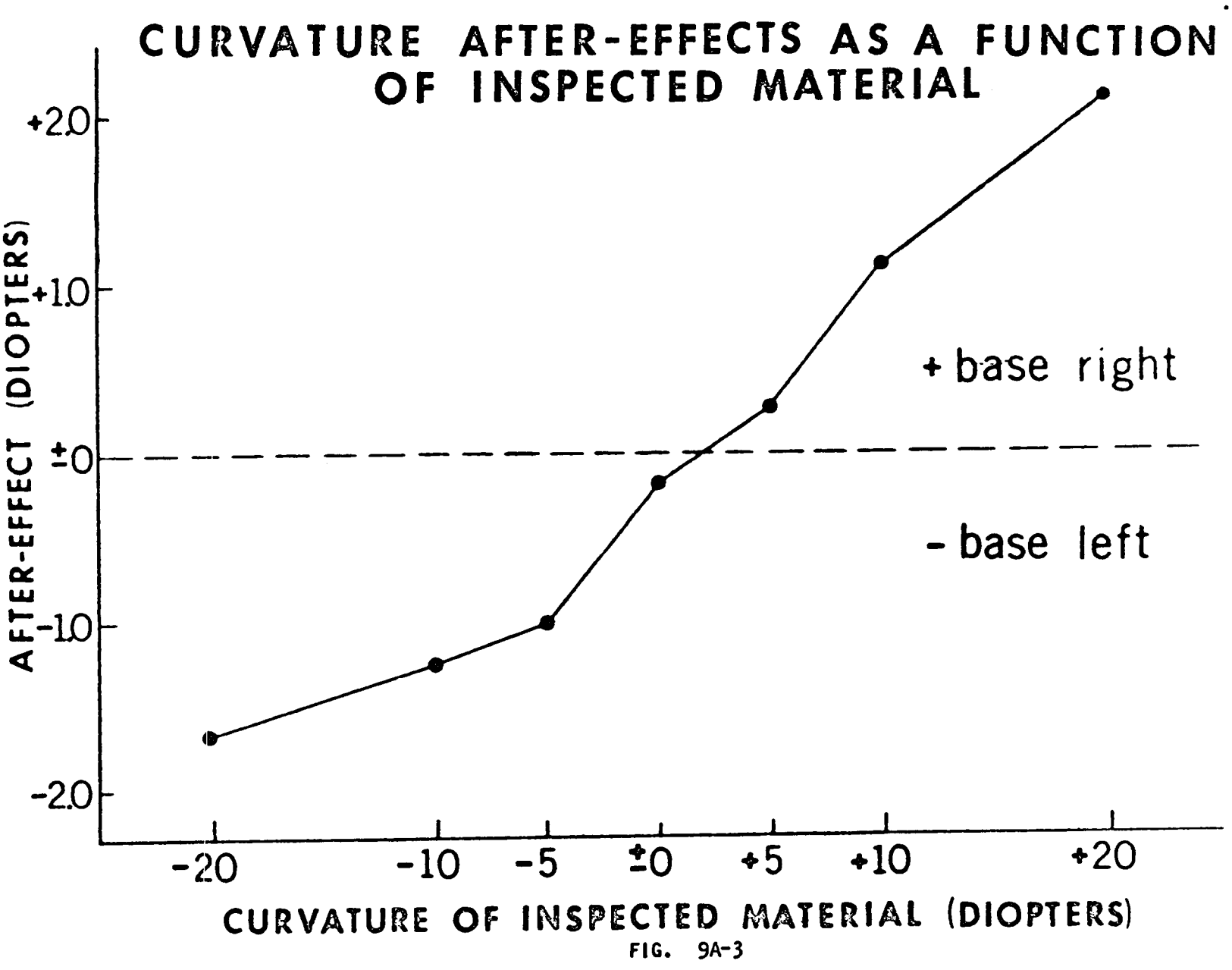


FIG. 9A-2


CURVATURE AFTER-EFFECTS AS A FUNCTION OF INSPECTED MATERIAL
AFTER-EFFECT (DIOPTERS)
+2.0
+1.0
±0
-1.0
-2.0
+ base right
- base left
-20
-10
-5
±0
+5
+10
+20
CURVATURE OF INSPECTED MATERIAL (DIOPTERS)
FIG. 9A-3

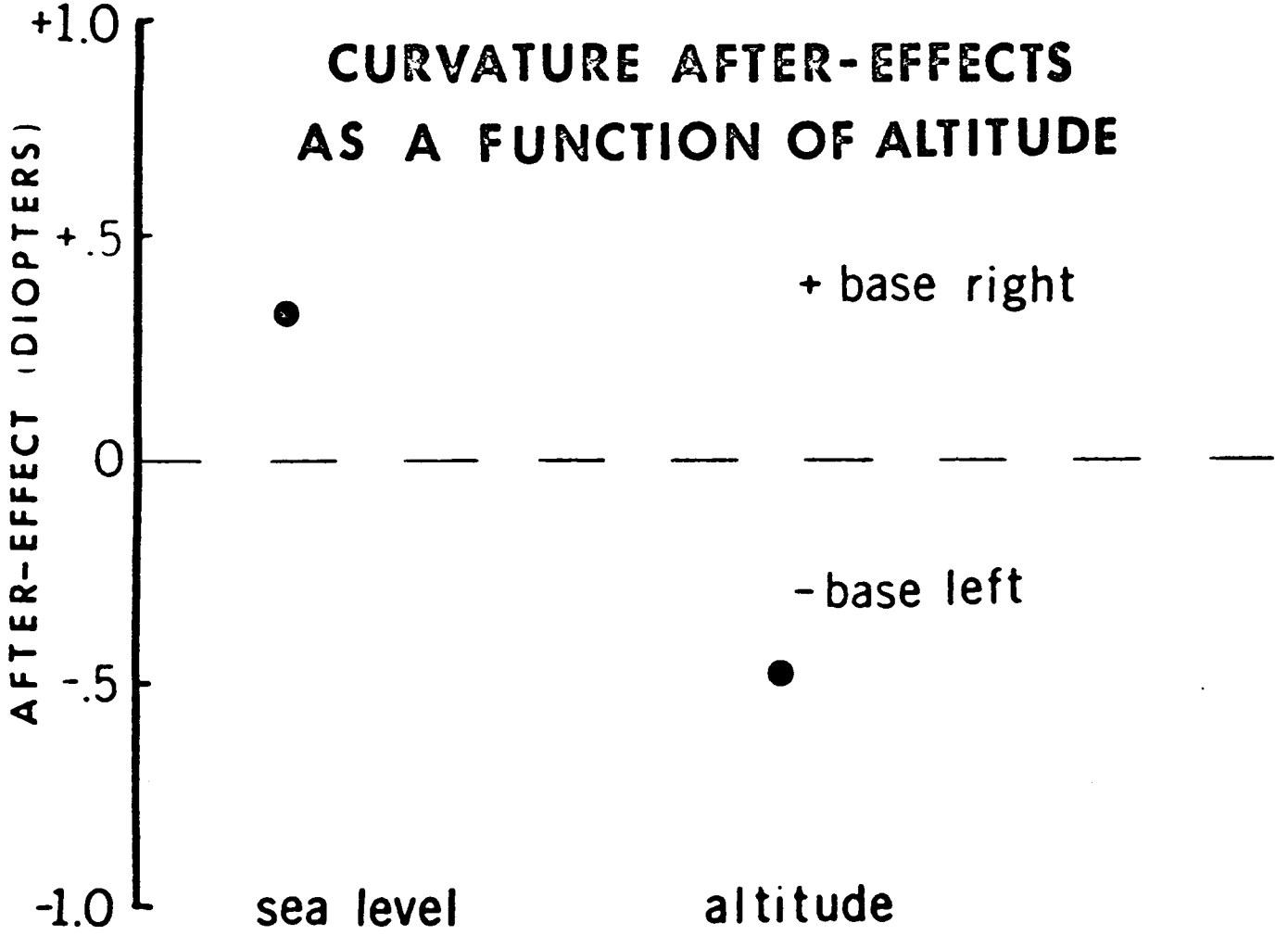

CURVATURE AFTER-EFFECTS
AS A FUNCTION OF ALTITUDE
AFTER-EFFECT (DIOPTERS)
+1.0
+.5
0
-.5
-1.0
+ base right
- base left
sea level
altitude

FIG. 9A-4

SECTION 10

THE EFFECTS OF STRESS PRODUCED BY CONFINEMENT IN SMALL GROUPS

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SECTION 10

THE EFFECTS OF STRESS PRODUCED BY CONFINEMENT IN SMALL GROUPS

INTRODUCTION

This study was designed to gain further knowledge with regard to physiological and psychological effects of (1) breathing pure oxygen at reduced pressures, (2) long-term full pressure suit occupancy, and (3) habitability aspects of confinement in small spaces. However, since there appears to be no detrimental effects to behavior of breathing pure oxygen at reduced pressure[1] or of long-term full pressure suit occupancy,[2] the emphasis of this part of the psychological investigation centered on the habitability aspects of confinement in small spaces.

Specifically, the confinement aspect of this experiment was studied through investigating changes in verbal learning and affect change, group cohesiveness, motivation, and symptoms of confinement. Since the conditions of the study required a long-term confinement, it was felt that the stresses in such a situation might bring about changes in the variables stated above.

Also, there was an attempt made to make the tasks that measured these variables as complex as possible since it was found that in confinement, routine tasks produced inconsistent performance[3]. So it was thought desirable to select tests that would be complex enough and yet measure the variables referred to above in a long-term confinement study. The three areas that were chosen to be investigated in this confinement situation were: (1) verbal learning and affective changes, (2) interpersonal relations, and (3) related tests conducted in other studies.

In reviewing literature on confinement in small groups, Rohrer[4] found that there seemed to be a pattern of affective changes that occurred as a result of three affective stages within these studies--an initial brief anticipatory period of heightened anxiety, a long period where the crew was affectively "settled down" (with considerable repressive processes taking place), and a brief final anticipatory period characterized by heightened affective expression. This would seem to indicate that the stresses of confinement do appear to produce affective changes. Recently, Bummer and Rosenthal[5] found that affectively-toned words were significantly less well retained than common words. In this study, these "traumatic" words were probably less well retained because they were repressed during acquisition. So, these studies would indicate that through the learning and retention of verbal materials, affective changes might be detected in a confinement situation.

In a prior confinement study in this laboratory, observation on group cohesiveness and suggestibility revealed that as length of confinement increased, integrated

interpersonal behavior tended to disintegrate[6]. In a thirty day simulated space flight, it was found that the "inflight" group cohesiveness decrement reflected a decline in group unity[7]. Therefore, extended confinement does seem to produce a deterioration of interpersonal behavior of those confined.

As a possible indicator of daily fluctuations in motivation, a hand dynamometer was used in an extended confinement study[8]. In this study it was concluded that data derived from measures of performance and motivational commitment to the program appeared to be highly correlated with the hand dynamometer scores. Thus, the hand dynamometer was used as a possible measure of relative levels of motivation.

Symptoms of confinement have been reported as a result of 11.5 days in a submarine[9]. Symptoms reported were increase in the frequence and severity of headaches, decrease of the quality of the sleep, difficulty in arising for watch duty, unpleasant dreams, and unusual dizziness, and deterioration of group morale. After eight days of confinement in a chamber, six men reported symptoms of irritability, "edgy", inactivity, loss of time referent, "bloodshot" eyes, restless sleep, tiredness, weak and sore muscles, feeling of dirtiness, boredom, low morale, and low motivation[10]. Strollo[11] reported symptoms of sleep disturbances, depression, irritability and anxiety in a confinement study. So there seems to be certain symptoms common to confinement.

Meade[12] found that under high motivation, subjects progressively over estimated time at intermediate and near distances from the goal, while at far distances, they underestimated time. In another study, ability to estimate a 90-sec. time interval was found to deteriorate (i.e., increasing underestimation of time) with increasing days of confinement[3]. Also, a later confinement study showed that six men progressively overestimated the time intervals as the days of confinement increased in an eight day study[6]. In a non-confinement time estimation study, the scores of ten subjects on a Manifest Anxiety Scale correlated significantly with an underestimation of two of the four time intervals[13]. Confinement, then, seems to produce progressive underestimation of time. Also, time estimation has been related to other psychological variables such as motivation and anxiety.

These were the areas that were thought to be effected by the stresses of confinement, so a methodology was set up to test them.

METHODS

The definitions, procedures, and expectations of each measure will be considered separately. The measures of verbal learning and affective change, group cohesiveness, motivation, symptoms of confinement, and time estimation will be discussed in that order.

Verbal Learning and Affective Change: Although verbal learning and affective change comprise a single test, it can easily be separated into two parts. The verbal learning part of the test was learning to associate pairs of nonsense syllables and meaningful words. The word portion of the paired-associates was one of two kinds of works - neutral or potentially affective. The potentially affective words were obtained from written reports of subjects in a previous confinement study[10]. These words were selected for their frequency of use and the emphasis upon them in their context. These words were then matched to neutral words with respect to alphabetical closeness and frequency of use. To test that the affective and neutral words elicited essentially the same affective response in a nonconfinement situation, an association test was given prior to the study and it was found that there was no difference in affective response (as determined by changes in electrodermal conductance) between the neutral and potentially affective words. Both potentially affective and neutral words were then paired with nonsense syllables in order to make the paired-associate, these syllables had 100% intralist association value. To some degree the high intralist association value matched the nonsense syllables in the same manner in which the meaningful words were matched. Thus, it made the discrimination between syllables more difficult, and thereby forced the association between syllable and word to some other basis of association than by simple memorization. It was assumed that this other basis of association would primarily be determined by the extent of affective change in certain words that would be brought about by confinement.

After some time in the confinement situation, it was expected that the stresses of this situation would produce a strong affective feeling associated with specific words (see Appendix A for paired-associate lists). It was proposed that this change in affect could be detected in two ways: (1) by differences in retention between affective and neutral words and (2) by relative changes in electrodermal conductance as the affective words were presented or spoken. All words were intended to be recalled in response to the presentation of the syllables associated with each of them. Thus, the syllables served as stimuli to elicit the associated word. It was thought that since the emotional response to the affective words would be stronger, affective words would be associated faster with the syllable, and consequently recalled easier than the neutral words. When recalling the affective words, it was assumed that when one such word was recalled, the response to it would produce a decrement in the electrodermal resistance in the skin and this would be detected in a GSR instrument. It was therefore thought that GSR change which would accompany the response of the word would indicate the extent of affective feeling which this word had acquired through the stresses of confinement. Thus, it was thought that differential retention and changes in GSR would measure the extent of affective change in words.

The design of this test of verbal learning and affective change consisted of two main parts - the learning sessions and the retention sessions. In the learning session, the ten paired-associates were each presented seven times in random order, for a total of 70 presentations. These were spaced at two second intervals. The paired-

associates were projected by a Kodak Carousel Projector which changed automatically to the next slide by a continuous tape recorder. Also, during the learning of the paired-associates, the subject's GSR was being measured by a Tissue Resistance Monitor (Model 152-A, Airborne Instrument Laboratory). The deflections from the baseline GSR were recorded as a measure of the strength of affect of the word. This procedure made up the learning session.

The second part of this test was the retention sessions. There were two retention sessions - a five minute and a 24 hour retention session. In these sessions, the same equipment described in the preceding paragraph was used. Whereas in the learning session, paired associates were presented, in the retention session only ten nonsense syllables were presented in random order. The syllables were to serve as stimuli to indicate which associate was to be recalled. The syllables were projected at two-second intervals and GSR changes were recorded in both sessions. The five minute and 24 hour retention sessions were similar in all respects, except for the elapsed time after learning.

The entire test (learning and retention sessions) was given three times during the three periods of confinement. These three periods were delineated by Rohrer[4] as given in the preceding section. The test was administered in these three periods to detect changes in affect between periods of confinement.

As a result of the design as set forth above, it was expected that certain findings would result. First, it was expected that since the affective words would have a stronger association with the nonsense syllables, they would be learned faster and retained better than the neutral words. Second, because the affective would produce a stronger reaction in the autonomic nervous system, it was expected that the response to the affective words would produce a greater conductance in the skin than the neutral words in both the learning and recall sessions. Third, it was expected that in the initial period of confinement, the subjects' anxiety would be higher according to Rohrer[4]. Anxiety was measured by the Iowa Manifest Anxiety Scale. Fourth, it was expected that some of the nonverbal motivations could be measured by using cognate nonsense syllables. (See Appendix B for a list of the cognates.) Finally, a semantic differential was devised using affective words from a prior confinement study [10] and dimensions from astronaut's personality assessments[14] to detect changes in meaning between affective and neutral words produced by confinement. (A copy of an example page can be found in Appendix C).

Group Cohesiveness: Group cohesiveness, in this study, was the psychological distance between subjects as measured by an adjective scale developed by Fiedler[15] and modified by Borislow[16]. The psychological distance was measured by the difference between the adjective scales of the subject's perception of himself and his fellow subjects. These differences were squared and then summed over the subject's responses to derive the group cohesiveness index.

This measure was administered twice before, six times during, and once after the confinement period. Subjects rated all other subjects that were confined with them and also those who were confined separately after they had rated themselves. It was thought that rating other subjects with whom they were not confined would stabilize their ratings of each other. After being out of confinement for a few days, subjects were also asked to estimate their group's cohesiveness during their time in confinement.

It was proposed that the group cohesiveness would decrease to some point, level-off, and not decrease after that point. In light of the conditions of this study, it was felt that this was as specific as this hypothesis could be made.

Motivation: To get a relative measure of motivation from day to day, a hand dynamometer was used. The instrument worked on a hydraulic principle, so that when the subject squeezed it, there was no displacement of the grip. Thus, immediate feedback was eliminated. Each day, the subjects squeezed the hand dynamometer as hard as possible with each hand. It was expected that the hand dynamometer results would show an increase in peak force emission level over the period of confinement. Also, it was hoped to significantly correlate this measures of this study.

Symptoms of confinement: As stated in the preceding section, there have been certain symptoms that have been found to result from the confinement situation. In this study, these symptoms found in past confinement studies were asked to be reported in a questionnaire devised for this purpose. (A copy of this questionnaire can be found in the Appendix D.) Within each symptom area, some latitude of response was provided. This was intended to give a more accurate description of the quality and/or quantity of the symptom. The questionnaire was administered daily and the subject was asked to report on and symptoms or change in symptoms in the last 24 hour period. It was expected that, in general, there would be an increase in symptoms reported with increases in confinement. Also it was felt that this questionnaire would have a certain therapeutic value in allowing the subjects to express themselves to the people on the "outside" about their symptoms and feelings.

Time Estimation: The time estimation task was comprised by the estimation of four intervals - 15, 90, 180 and 300 seconds. The length of the intervals estimated were indicated by subject pressing a button that started a timer and then stopped it the next time it was pressed. Intervals to be estimated were asked for in random order so that the subject could not anticipate the interval to be estimated. To keep subjects busy during the estimation interval so they could not merely count or use some other aid in their estimates, a symbol cancellation task was given them to perform during the interval (a copy of an example sheet can be found in Appendix E). On the basis of previous studies reported in the preceding section, it was expected that the subjects would progressively overestimate the time intervals. Also, it was hoped to correlate the results of this test with results of other measures in this study.

This, then, was the methodology employed to assess some of the stresses of confinement for a period of 34 days.

RESULTS

The results of the measures given will be presented in the order that they were described in the preceding section.

Verbal learning and affective change: The test of verbal learning and affective change had several hypotheses and related hypotheses associated with it. The first expectation was that subjects would recall the affective words better than the neutral words in both retention sessions. The Analyses of Variance Test was used to analyze the date. As can be seen from Table 10-1, there was no significant variance due to Words; in fact, there was almost no variation in this main effect beyond chance variance. Therefore, it can be concluded that under the conditions of this study, there was no difference in recall between the neutral and affective words as a whole. The recall scores were taken from both the five minute and 24 hour retention sessions. More weight was given to retention in the 24 hour session since a longer time had elapsed since original learning. The formula used was 0.05 (S) + 0.55 (L) = T, where S = five minute recall scores, L = 24 hour recall scores, and T = total weighted recall score for each subject.

The second hypothesis dealing with this test stated that there would be a marked decrease in tissue resistance when the affective words were presented during the learning session. The results of this hypothesis can be seen in Table 10-2. There was no significant variance due to Words. Since the main effect of Words was not significant in Table 10-2, it can be concluded that there was no marked decrease in tissue resistance in general when the affective words were presented in the learning session. This analysis used numbers that assigned values to the amount of electrical skin conductance increase when each word was presented during the learning session. The values were assigned in this way: (1) for increase in conductance that remained the same after the presentation of the next few words, a value of "1" was assigned to that word, (2) for increase in conductance that was larger than (1), and remained the same after the next few words, a value of "2" was assigned to that word, and (3) for increase in conductance followed by a decrease after the next few words, a value of "3" was assigned to that word.

Hypothesis three for this test was that there would be a decrease in skin resistance when the affective words were spoken by the subjects in the retention sessions. As can be seen from Table 10-3, the source of variance due to Words was not found to be significant in the recall sessions. Thus, it is evident that there was no significant decrease in skin resistance when the affective words were spoken by the subjects in the retention sessions. The numbers used in Table 10-3 were also a result of assignment of values to decreases in electrical skin resistance. Using the assignment of values described in the preceding paragraph and substituting them

into a constructed formula (24 R (1.0) + 5R (.8) = N, where 24 R stands for 24 hour retention session scores and 5R is 5 minute retention scores) gave appropriate weight to the number of words recalled, length of time after learning, and the extent of change in skin conductance.

Although the proposed hypotheses of this test of verbal learning and affective change were not substantiated, it appeared from the results that certain words had taken on some affect and that the subjects had reacted to them. To test these observations statistically, a series of analyses were performed to get the most out of the data obtained. The first part of the additional analysis examined recall and tissue conductance change (in learning sessions and recall sessions), except that instead of comparing affective vs. neutral words as in the analysis of the hypotheses, subjects vs. words for each list were compared. Number of words recalled were analyzed on the first list. The values used were the same as in the previous recall analysis. In Table 10-4, Words were found to be significant at less than the .05 level. To see which words were significantly different, the Duncan Multiple Range Test was applied to the words. The only word pair that was found to be significantly different in recall was "chamber" and "cheap". This means then that "chamber" was significantly better recalled than the word "cheap" in the first list. The second list was analyzed in this manner. Table 10-5 reveals that both Words and Subjects were a significant source of variance at the .01 level of confidence. The Duncan Multiple Range Test was applied to the Words data and it was found that "to" was significantly better recalled than "time" at the .01 level of significance and that "cigarettes" was recalled significantly better than "circuit" at the .05 level of confidence. The Duncan Test applied to the subject's data revealed that there was no significant differences between the three designated groups in recall. In analyzing the third list as to recall, it was found that there was no significant variance (see Table 10-6).

In analyzing the learning data of the first list, only the variance due to Subjects was found to be significant (seen in Table 10-7). The application of the Multiple Range Test revealed that all three groups were significantly different in respect to change in skin conductance in the learning session. Group C had the largest change, Group A had the next largest change, and Group B had the smallest change. The results of the second list in analyzing the learning data showed no significant variance beyond change. (See Table 10-8). However, the third list in respect to affective change in the learning session showed that both Subjects and Words were significant sources of variance. This can be seen in Table 10-9. The word pairs found to be significantly different by the Multiple Range Test were "shower" and "shed" (.05 level) and "wife" and "wide" (.05 level). The Duncan Test showed that Group C was significantly greater in affective change than either Groups B or A in the third learning session.

To see if there was a change in skin conductance in the recall sessions, three analyses were made. In the results of the first list, the single significant source

of variance was due to Subjects as seen in Table 10-10. Here, the Duncan Test showed that Group A was significantly higher than either Groups B or C in skin conductance in the first list recall sessions. The results of the second list is shown in Table 10-11. Words were a significant source of variation, which was at the .05 level of confidence. The word pairs that were significantly different at the .05 level were "time" and "to" and "female" and "fan". The third list revealed no significant sources of variance (see Table 10-12).

The lists themselves were analyzed by comparing subjects and words with respect to recall in the five minute and 24 hour sessions, magnitude of change, and skin conductance in learning, 5 minute recall, and 24 hour recall sessions. The formula that was devised was S=L (0.7) + 24 R (1.0) + 5 R (.8) + M (.2) + Re (.5), where L, 24R, and 5R were increases in skin conductance in the learning, 24 hour recall, and 5 minute recall sessions respectively, M was magnitude of increase in skin conductance, and Re was whether the word was recalled in the 24 hour, 5 minute, neither, or both retention sessions. The three lists were analyzed using this formula to obtain the scores in each list. The first list revealed significant variance at the .01 level due only to subjects as seen in Table 10-13. The multiple Range Test showed that Group C had significantly stronger responses to the affective words in the first list than either Groups A or B. In analyzing the second list in this manner, results showed that the only significant source of variance was due to Words at the .05 level (see Table 10-14). The additional test showed that the word pair that was significantly reacted to was "time" and "to". Analyses of the third list revealed that Words were a significant source of variation at the .01 level (see Table 10-15). The Duncan Test revealed that the word pairs that were reacted to significantly different were "shower" and "shed" and "wife" and "wide". These analyses of the lists themselves showed similar results as those in the preceding paragraphs.

Further analyses were made in respect to the three groups involved in the study- Groups A, B, and C. This analysis was the same as that in the previous paragraph with the exception of the breakdown into groups. On list one, Group A had no significant reaction (see Table 10-16). Also on the second list, no significant reaction was found (see Table 10-17). However, on list three, the group reacted significantly, with Words being the significant source of variance at the .01 level (see Table 10-18). The Duncan Test revealed that the significant word pairs were "shower" and "shed" and "wife" and "wide". Group B reacted to list one with Subjects being the significant source of variance at the .01 level (see Table 10-19). The Multiple Range Test was not applied since it was obvious that Subject #5 reacted significantly more than Subjects #1 and #2 to the affective words. On lists two and three, this group had no significant reaction. It can be seen in Tables 10-20 and 10-21 that there was no significant variation. Group C showed no significant reaction to list one as seen in Table 10-22. However, on the second list this group did react to the words as can be seen in Table 10-23. The Words source of variance was significant at the .05 level of confidence. The pairs of words that were

significantly different in amount of reaction to them as shown by the Duncan Test were "female" and "fan", "hope" and "home", and "time" and "to". On the third list, Group C had no significant reaction as seen in Table 10-24. This completes the analysis of the test results of the Verbal Learning and Affective Change Measure.

A test related to the Measure of Verbal Learning and Affective Change was the Cognate Nonsense Syllable Test. It was expected that nonverbal motivations could be measured by this test. However, the results show that no more significant number of "motivational words" were made out of the cognates than "neutral words," as shown in Table 10-25 ($t = 1.218$; $t > .10$, difference is not significant). Also, this table shows that the affective reaction to the "motivational words" was no greater in number than that to the "neutral words" ($t = 1.282$, $t > .10$, not a significant difference). This was contrary to expectations. However, the cumulative affect associated with the "neutral words" was greater than that associated with the "motivational words" ($t = 3.815$, $t < .01$, significant difference). Finally, there was a significant correlation between absence of affect associated with the cognate syllable and number of desired words made from them ($r_s = .589$, $t < .005$, significant correlation). So when the subject was successful in making the desired word there was no affect detected.

Another similar test to the Verbal Learning and Affective Change Test was a Semantic Differential. This test was intended to detect changes in meaning between affective and neutral words. Table 10-26 shows that over the experimental days this test failed to reveal any significant difference between the potentially affective and neutral words. But there was a significant difference between days of administration ($F < .05$). The Duncan Test showed each administration yielded scores that are significantly different at the .05 level. Analyses of the individual administrations were done. Tables 10-27, 10-28, and 10-29 show that there were no differences between affective and neutral words, but there were differences between subjects (all significant at the .01 level). The Duncan Multiple Range Test revealed that on the days of administration that Subjects #1 and #5 changed the meaning of their words significantly more than Subjects #8 and #2. Thus, the expected differences between "affective and neutral" words were not found in this measure of change in meaning, but differences between subjects were found.

The test of anxiety (IMAS) was given at intervals throughout the study to determine if there was any change in anxiety due to the apprehensions that were a result of the stresses of this confinement. Table 10-30 shows no significant change in anxiety over the period of the study. Specifically, it was expected that there would be a change in anxiety immediately before and after entrance into the chamber, and also during the first initial period in the chamber. However, the data did not support this expectation, as can be seen in Table 10-31. The source of variance due to Days was not significant. Therefore, as measured by this test the level of anxiety for the subjects did not change appreciably during the confinement situation.

Group cohesiveness: The second major test was the Measure of Group Cohesiveness. It was expected that cohesiveness would decrease to a point and then remain constant for the remainder of the study. Graphically, this would seem to be born out, at least to some extent: Figure 10-1 shows that during the experimental days, cohesiveness of all groups decreased to a point, increased, and then decreased again. So it would seem that the expected result was found. However, a statistical analysis of the separate groups shows no significant change over the duration of the study (see Table 10-32); also this is shown graphically in Figure 10-2. Therefore, the group cohesiveness did not significantly change during the study. After confinement, the subjects were asked to give their own perception of the cohesiveness of their own group over the experimental days. Figures 10-3, 10-4, and 10-5 show the perception of group cohesiveness by the members of Groups A, B, and C. Group A overestimated both the rate of increase in cohesiveness and relative extent of cohesiveness over the days of confinement, especially about two-thirds through the study. For the first six days, Group B's perception followed their cohesiveness closely, but after about six days through the study, Group B did not perceive the changes in cohesiveness or the amplitude of these changes. Group C did not perceive the small changes in cohesiveness, but over-all there was a close correspondence between the perceived and measured cohesiveness. A stability index was derived from the subjects self descriptions -- a model description was found and the differences between it and the individual descriptions were computed. Figure 10-6 shows the stability of the self descriptions for Group A. For the first six experimental days, subjects in this group were quite homogeneous in their stability index and increased in their stability at the same rate. However, after day six these subjects became less homogeneous in their stability and less consistent in amount of stability until about day 12. After this day, there was a fluctuation of stability around the point reached on day six. Most of the changing of relative position was done by Subject #6. while the other subjects remained relatively the same. Group B had a different profile of stability than Group A as can be seen from Figure 10-7. Subjects #1 and #5 were much less stable at the beginning than subjects in Group A. Subject #2 started with a higher stability than either of these two. All subjects in Group B increased in stability to day 18. From days 18 to 22 they decreased in stability and then remained about the same to day 32. After getting out of the chamber, they increased in stability. Subjects #1 and #2 remained relatively the same for the last part of the study, whereas it was Subject #5 that changed in his relative stability to others in the group. The stability of Group C can be seen in Figure 10-8. The profile for this group is similar to that of Group A: Subjects remained relatively the same in stability to day six, after which they fluctuated until day 28 and remained about the same after this. Day 18 seems to be a day of peak stability in this group as well as in Group B, but in Group A, day 22 seems to be the day of peak stability.

The subjects' rating of the groups were also derived from the group cohesiveness data. Figure 10-9 shows subjects in Group A rating the two other members of the group. Before and after confinement ratings of the group were somewhat homogeneous

(with the exception of Subject #6 after confinement), but during the confinement the ratings were more heterogeneous. The ratings of Subjects #4 and #6 were more consistent, while the rating of Subject #3 was quite variable. The high point of closeness for Subjects #4 and #6 was on day 12, which is consistent with the group cohesiveness results. In comparison to the ratings of Subjects in Group A, the ratings of Group B by its members was highly variable (as seen in Figure 10-10). In fact, as a whole, the members of Group B rated their group more distant than members of Group A. Before confinement, members of Group B rated themselves psychologically distant from the group. After a short time in confinement, the subjects felt closer, but after the sixth day, they felt themselves progressively more distant until day 28. From here, and after confinement, Subjects #2 and #5 felt closer to the group, but Subject #1 felt less close (he felt more distant throughout the experimental days except for day 28). After confinement, there was a wide divergence of ratings of the group by its members. The cohesiveness in Group B (as can be seen in Figure 10-2) was generally less than other groups in the study. The estimates of Group C by its members is seen in Figure 10-11. The ratings of the group remained about the same, except for day 18 when Subject #7 felt closer to the group and day 22 when Subject #8 felt less close to the group. After confinement, Subject #7 felt even less close to his group.

Finally, out of the group cohesiveness data, results were derived that described group ratings of each subject. For Group A (as seen in Figure 10-12) the results were opposite that of subject's ratings of the group: Subject #4 felt closest to the group, but generally was rated as most distant, and Subject #6 rated himself most distant for half of the time while generally the group rated him as closest. Also, the rating of the individual subjects in Group A were more heterogeneous than were the ratings of the group by its members. Finally, before and after confinement, subjects of Group A were rated closer by the group than during confinement. For Group B (seen in Figure 10-13), group ratings of each subject were also opposite that of individual ratings of the group. Around days 18 and 22 the ratings were at their lowest during confinement for this group. Also, there was a greater heterogeneity of the group ratings than individual ratings, similar to that found for Group A. For Group C, seen in Figure 10-14, the group ratings are just the opposite that of the individual ratings since there were only two subjects in that group.

Motivation: The third major test was that of the Hand Dynamometer. It was expected that there would be an overall increase in maximum force emitted and the day to day variations in maximum force would reflect the relative changes in motivation. The results of all subjects for the experimental period can be seen in Figure 10-15. It is apparent that there was an increase in maximum force emitted over the days of confinement as predicted. Also, there is revealed day to day fluctuations in the maximum force emitted. Thus, the expectations were confirmed for this test. In comparing the left and right hands, it can be seen that the left hand is much more erratic in peak force than the right hand. The right hand seems to reflect a more

clear-cut pattern than the left hand. In the first few days (up to day eight), there is a constant increase in peak force emitted showing a good level of motivation. After day 12, though, the motivational decrease is shown by a drop in the peak force emitted. This continued until about day 18; after this day there was a constant increase until about day 30. Subsequently, there was a drop in peak force emitted. Thus, there is obtained a profile of general change during confinement - a period of high motivation, a short period of leveling off, a period of decrease in motivation, an increase motivation, another leveling off period, and finally a decrease in motivation. To see how well this profile held up for the individual groups, Figure 10-16 was plotted for the right hand only. Groups A and B show this same profile also, with the exact days of change and the peak force emission levels differing. For Group A, the peak of the initial motivation was day seven; for Group B it was day 11. The leveling-off period for Group A was days 7-13, while for Group B, it was days 11-14. The lowest point for Group A was day 17 and for Group B it was days 18 and 19. The second peak of motivation for Group A was day 28, but for Group B it was day 24. Group A had a leveling of motivation between days 28 and 32, while Group B had this leveling between days 24 and 31. For the last two or three days, the motivation of both groups dropped off. Group C was fairly constant throughout the days of confinement with peaks of motivation around days 15, 24, and 28 and lows around days 13, 20, and 27. Figure 10-17 shows the performance of the left hand for the three groups on the Hand Dynamometer. The profile of the left hand for each group is similar to that of the right hand, but it is not as clearly patterned as for the right hand profile. The left hand results show that for the last week of confinement, all groups were quite homogeneous in their peak force emitted. The individual performances on the motivation measure can be found in Figures 10-18 through 10-25. Subject #1 shows essentially the same profile as in the group profile; however, his peak output was much higher in the last part of the confinement as compared with the first part. Subject #2 showed a higher peak force for his right hand in the first part of the period, but a greater force with his left hand in the second half of confinement. The similarity to the group profile is also found in Subject #2's profile (seen in Figure 10-19). Subject #3 had strained his hand so much in performing this task, that he pulled loose the cartilage of the middle finger of his right hand. This necessitated discontinuing this task for him for the rest of the study. The right hand results of this subject in the first part of confinement shows that his performance was higher than that of all other subjects and it finally exceeded even his own physiological limit. It is not possible to closely compare this subject's results with the group profile since so much of his data is missing. The Hand Dynamometer results for Subject #4 (seen in Figure 10-21) showed a very close resemblance to the group profile: the two high peaks of motivation and the low in the middle. Subject #5 showed similar results to the group profile, but with much more peak force emitted in the second half of the experimental period. There also is a close similarity between Subject's #1 and #5 profiles in respect to the much higher output in the latter half of the study. The results of Subject #6's performance (seen in Figure 10-24) only grossly resembles that of the group. Mainly, his output remained fairly constant. There does seem to be a peak around day 15, a low around day 24,

and a high around day 30, which in general is similar to the group profile. Subjects #7 and #8 were confined separately as control subjects and showed a different general curve than the rest of the subjects. Their profiles (seen in Figures 10-24 and 10-25) are fairly constant throughout the experimental period. Subject #7 showed a gradual increase in motivation.

Symptoms of confinement: The Daily Questionnaire was the fourth major test in this section of psychological performance. It was generally expected that there would be an increase in symptoms reported as the study progressed. Also, it was hoped that this would serve as a frustration outlet for the subjects. The reported irritability can be seen in Figure 10-26. The frequence of "impatience" with other subjects was greatest around days 4, 10, and 18. Also, there was a slight increase in frequency of "impatience' around days 28-33. The more intense irritation with other subjects of being "provoked" was greatest around days 13, 28, and 30. Subjects in the Control Group reported no impatience at all during confinement. The symptoms of irritability increased in intensity, but not in frequency with increased confinement. The anxiety that was reported can be found in Figure 10-27. It can be seen that the greatest frequency of "uncomfortableness" was reported seen on days 5-7, 9 and 16. The more intense frequency of "uneasiness" was reported on days 14, 24 and 25. It was Subject #7 who reported the most frequent anxiety during the experimental period. In fact, the Control Group accounted for nearly all of the reported anxiety. Only a few subjects did not report noises each day of confinement. All degrees or kinds of noises were reported (as seen in Figure 10-28). The greatest frequency of just "noises" was reported on days 2, 5, and 6. After this period, the reports of "noise" decreased, but remained at a fairly high level for the rest of confinement for these subjects. The most intense noises, "a racket", was most frequently reported on day 7. Instances of "a clamor" were reported several times and the most frequent report in this category was on day 23. "A hubbub" was reported several times and a "din" reported on day 16. The reports of noises were heavily spread throughout the study, but most frequent in the early part.

The report of inactivity as a symptom can be seen in Figure 10-29. The symptom of "sluggish" was reported most frequently on days 5, 6, 15, 16, 20 and 23. The more intense symptom of "inacitivity" was reported most frequently on days 24 and 25. However, only a few subjects reported these most frequent periods of inactivity. Subjects #4, #7, and #8, account for most of the reports of inactivity. The more intense reports of inactivity were in the latter part of confinement. Some specific symptoms of confinement that had been found in previous studies were reported. These results are seen in Figure 10-30. "Restless sleep" was the most frequently reported symptom. As can be seen, this was particularly noticeable about day 14 - the day the full pressure suits were donned. The most frequent reports of bloodshot eyes were received a few days after exposure to 100% oxygen. This was particularly true of the group that performed their tasks at night. "Weak and sore muscles" was reported mainly in the early period and only once near the end. "Boredom" was reported by Subjects #3 and #8 about one third through the study. "Low morale" was most frequently

reported on day 12. The majority of these reports of boredom and low morale were given by Subjects #7 and #8. Most of these symptoms of confinement were reported in the first part of the study. The amount of reported dirtiness increased as confinement wore on, as might be expected. This can be seen in Figure 10-31. The most frequent report of "dirty" was around day 16 when six subjects reported that they and their surroundings were "dirty". The reports of "filthy" were reported in three separate periods: days 8-14, day 24, and days 30-34. One subject #8 reported that he was "foul" from day 17 on. Generally, it may be said that during days 1-6 their dirtiness was not noticeable; during days 6-29 they felt "dirty" and during days 30-34 they felt "filthy". The result on interest is found in Figure 10-32. High interest was shown during days 3 and 4; some interest was shown through most of the study, the most frequent mediocre interest was shown on days 23 and 30, and disinterest was reported during days 1-5, 16-18, 21 and 24-26. In general, after day 17, interest declined somewhat to day 30. Overall efficiency was reported to decline somewhat during the middle part of confinement as seen in Figure 10-33. More efficiency than usual was reported with the greatest frequency around day 4. Less efficiency than normal was most frequent on days 9, 12, and 17. The subjects most frequently reported less efficiency than normal on days 12-20. The reports of ease of concentration from day to day is shown in Figure 10-34. Day 4 was most frequently reported to be the day that permitted the easiest concentration. Day 11 was indicated to produce conditions most adverse to concentration. Days 11-19 were the most difficult for concentration in this study. The reported changes in depression are shown in Figure 10-35. The days of less depression were most frequently indicated to be day 6 and days 27-33. Day 6 was reported to be in the category of "most depression", while days 3, 12, 16-18 were reported to be in the "more depression" category. Thus, more depression was reported in the first part of the study. The general expectation of an increase of reported symptoms as a function of number of days in confinement was not completely confirmed by the results. Only in the symptoms of irritability, inactivity, dirtiness, and interest did the reports become more frequent toward the end. The expectation that this test would serve as an outlet for frustrations other than those sampled was confirmed. Subjects in Group A wrote-in the question, "How irritable have you been in your relations with the men on the outside?" They marked it accordingly for each day of the confinement period.

Time estimation: The Time Estimation Test was the fifth major test in this psychological assessment of the effects of confinement. It was expected that the subjects would progressively overestimate the time intervals in this test after underestimating them. Also, it was hoped that this test could be related to some of the other measures given in this psychological assessment. The first expectation of this test was not confirmed by the results as seen in Figure 1-36. All estimates were transformed by the formula (S-R 10/C where S is the interval to be estimated, R is the subject's estimate, and C is a constant for each interval)[17]. This transformation made possible the equating of the estimates for the four intervals used, as seen in Figure 10-36. In the first part of the study, subjects overestimated the intervals, particularly the 15, 180, and 300 second intervals. The overestimation seems to be the greatest on day 10.

After this day, the subjects progressively underestimated the interval more and more until at the end of confinement, their estimates were more accurate than at any time during the study. The results of the correlation of the mean interval estimates with the Iowa Manifest Anxiety Scale can be seen in Figure 10-37. It can be observed that r_s (Rho) failed to reach significance for any of the intervals. Thus, for the conditions of this study, there was no significant correlation between amount of anxiety and overestimation of time. So, none of the expectations of the Time Estimation Test were confirmed by the results.

Additional analyses: Additional analyses were performed in retrospect on the data that was obtained in this study. Certain relationships appeared in studying the data, and these relationships were tested statistically. The possibility of a relationship of emotional symptomology and stress to group composition was suggested by Haythorn et al.[18]. They suggested that a confinement situation would produce enough stress within certain groups that would cause symptoms of emotion and stress. Data from the Daily Questionnaire was used as indicating emotional and stress symptoms. The questions on Irritability, Anxiety, Activity, some of the symptoms, Interest, Efficiency, Concentration, and Depression were used as indicators of emotional symptoms. The questions to be used as evidence of stress were concerning Noise, Dirty, some other of the symptoms, and Efficiency. These data were broken down into groups and analyzed. The results of analysis of emotion for the three groups is seen in Table 10-33. It can be observed that both Group and Questions were significant sources of variance. The Duncan Test revealed that Group C showed more symptoms of emotion than did either Groups A or B. This Multiple Range Test also shows that questions on the symptoms of confinement and Interest revealed significantly more responses indicative of emotion than the other questions used as indicative of emotional symptoms. The results of the analysis of stress can be seen in Table 10-34. The only significant source of variance was due to Groups. The Duncan Test shows that Group C revealed more symptoms of stress than the other groups. To determine the different group compositions, results obtained by the Edwards Personal Preference Schedule on the subjects were used. The variables that were desired were need Achievement, need Affiliation, and need Dominance as seen in Table 10-35. In regard to need Achievement, Groups A and B were heterogeneous (i.e., two high, one average) and Group C was homogenously low. Groups A (high, average, low), B (average, low, low), and C (average, low) were all heterogeneous with regard to need Affiliation. Groups A and B were heterogeneous (i.e., one high, two average) with regard to need Dominance while Group C was homogeneously average. Groups A and B were heterogeneous in all three needs, while Group C was homogeneous in regard to need Achievement and need Dominance. Thus, there was a difference in reported emotional symptoms and stress, but which need substantially contributed to this cannot be stated with assurance.

The second analysis compared the group data for the Hand Dynamometer, Group Cohesiveness, Time Estimation, and Daily Questionnaire for days 7-28. In comparing Figures 10-1 and 10-15, it is particularly apparent that around days 17-19 there

is a decrease in Group Cohesiveness and a drop in peak force emitted on the Hand Dynamometer. This drop in these two measures appear to have occurred during the days 7-28. Therefore, rank correlations (the Kendall rank correlation coefficient, T, was used) were made between the data of these measures to see if there was, in fact, significant correlations between these measures on those days (this can be seen in Table 10-36). Group Cohesiveness was correlated with peak force emitted on the Hand Dynamometer on days 7-28. The correlation between the two was .307, which is significant at the .02 level. Again, Group Cohesiveness was correlated with the average deviation from the time intervals for days 7-28. The correlation was 0.134, which was not significant. The peak force emitted on the Hand Dynamometer was correlated with the average deviation from the time intervals for days 7-28. The correlation was .221, which is not significant. A correlation was made between the average deviation from the time intervals and symptoms of irritability on the Daily Questionnaire for days 7-28. The correlation was - .203, being not significant. The symptoms of irritability on the Daily Questionnaire was correlated with the peak force emitted on the Hand Dynamometer for days 7-28. The correlation was - .272, force emitted on the Hand Dynamometer for days 7-28. The correlation was - .275, which is significant at the .04 level. Thus, for the middle part of the experiment, Group Cohesiveness was positively correlated to the Hand Dynamometer results and negatively correlated to the symptoms of irritability reported on the Daily Questionnaire.

DISCUSSION

The results will be discussed separately since all the results are not directly comparable. They will be discussed in some detail and in the same order that they were given in the preceding section.

Verbal learning and affective change: All the hypotheses and expectations made concerning the verbal learning and affective change test and those made concerning related tests were not confirmed by the results. These hypotheses will be discussed individually in an attempt to understand better why the results of these tests came about differently than expected.

Hypothesis 1 was that subjects would recall the designated affective words better than the designated neutral words, but the results did not support this hypothesis. In the recall of the first list, the subjects recalled more affective words than neutral words, but in the second and third lists, they recalled the neutral words slightly better than the affective ones. Why? It would seem that since the same procedure of this test was repeated on the second and third lists, the subjects anticipated the requirement to recall the pairs, and learned the associations better during the presentation. In fact, the recall for lists two and three were better than for list one. On the second and third list learning sessions, subjects seemed to be more intent on learning as many associations as possible, since they knew they would be asked to recall all the associations that were presented. In contrast, these same subjects in the first sessions

were not trying to learn as many associations and the associations made between word and syllable were primarily made on the basis of affect. This is thought to be why subjects recalled neutral words better in the second and third lists.

Hypotheses 2 and 3 were that there would be a marked decrease in tissue resistance when the affective words were presented (in the learning sessions) and spoken (in the recall sessions) by the subjects. However, the data did not bear out these expectations. The results show that the subjects reacted only slightly differently to the two kinds of words. In the learning of the first list, neutral words evoked a little less reaction than affective words, and a little more reaction than the affective words in the second list. However, reaction to affective words in the third list was somewhat greater than to the neutral words. These results can be explained by two factors. First of all, the method of recording changes in tissue resistance was poor since there was no electrical read-out of the GSR changes, but these were recorded as E watched the change on the machine. This method was poor at best. However, it is felt that the main reason for the increasing differences between affective and neutral words was due to the cumulating effects of the stresses of confinement. As the anxiety, depression, and deprivation of the confinement situation accumulated, the affective words acquired a stronger affect. Thus, toward the end of the study, there was a relatively stronger reaction to the affective words in the learning session. Concerning GSR change in the recall sessions, the data shows that subjects reacted slightly more to the neutral words than affective words in the first list, and reacted relatively more to the affective words than neutral words in the second and third lists, particularly the second list. The reasons for the subjects reacting more to the affective words in the latter lists are the same as those stated above.

But why did the subjects not react stronger to the affective words which would have supported the hypotheses? There may be four possible reasons: (1) the stress situations were not great enough to produce more affect associated with the affect words, (2) the subjects were the type that can easily withstand great psychological stress, (3) the words that were selected were not appropriate, i.e., they were not testing the real stress areas of the subjects. (4) the methods employed were not sensitive enough to detect otherwise significant differences between the words. There probably was an interaction of both (1) and (2) since the extent of the confinement was only partial and since these subjects were found to have the types of personalities that could tolerate more psychological stress than the average person according to the MMPI and Edwards Personal Preference Scale. Alternative (3) may have played some part in the results, but it is unlikely, since the words were taken from the responses of subjects in a prior confinement study to questions concerning the most severe deprivations of confinement. It is thought that these deprivations are common to most everyone that is confined. The fourth alternative seems to be the strongest reason for the lack of support of the hypotheses as will be discussed further.

Since it appeared that certain words produced a stronger change in tissue resistance than others, further analyses were performed to see in fact, if they did produce

a significant change. The results did show that certain words and subjects were significantly different than others.

The first analysis examined recall in each list. Words were found to be significant in the first list with "chamber" being significantly better recalled than "cheap". So in the first list, only one word pair gave support to Hypothesis 1. In the second list, both Words and Subjects were significant with "to" being better recalled than "time" and "cigarettes" better recalled than "curcuit." Group differences were desired rather than individual differences, but no significant differences were found. No significant recall was found in the third list. With only "chamber" and "cigarettes" supporting Hypothesis 1 and with "to" against the expectation, it is clearer why this expectation was not supported. Had the stresses been greater on the subjects and had the subjects not anticipated the procedure, given these hypothetical conditions, the hypothesis concerning recall probably would have been supported. The first list did show, however, that the hypothesis did have some foundation because the only word pair significantly different in recall was in favor of the hypothesis.

Next, the affective response in the learning session was analyzed. In the first list, variance between subjects were significant; in fact, the three groups were significantly different in their affective response during the learning session. The second list revealed no significant responses, but the third list had significant differences both between Words and Subjects. The word pairs that were different were "shower" and "shed" and "wife" and "wide", while Group C was significantly different from Groups A and B. It is quite evident that these results offer meager support for Hypothesis 2. Very likely the reason for this is the fact that this method of analyzing the learning session was a somewhat insensitive method. Only subjects that had greater stress as a result of this study, for example, Group C (as will be discussed later) reacted more to words in the learning session. In further support of this contention is the fact that it was not until the third list (given late in the study) that enough stress had cumulated to show up as a difference between word pairs. So Hypothesis 2 was probably not supported because this method was somewhat insensitive.

Closely aligned with the reaction during the learning session, was the reaction to the words during the recall sessions. In the first list there was a significant difference between subjects in the recall sessions as there was in the first list in the learning session. Group A, however, had a significantly higher reaction to words in the recall sessions, whereas Group C had the highest reaction in the learning session for this list. The second list showed Words to be significantly reacted to in recall. The word pairs that were differentially reacted to were "time" and "to" and "female" and "fan". The Words source of variance for list three was almost significant, with an F-ratio of 1.99, while 2.03 is required for significance at the .05 level. Also, this method gives little support to Hypothesis 3 with only a few words in list two being reacted to as expected. But this method is seen to be more sensitive than the learning method since there was a significant reaction in the second list and nearly one in the third. However, this method is thought to be sensitive to somewhat different words (as will be discussed later).

Thus, we can see more clearly why the hypotheses were not supported since only a few words were reacted to in the expected way. However, nearly all of the significant differences found supported the hypotheses. If the methods had been more sensitive, it is expected that the results would have supported the hypotheses more clearly.

In order to get the most out of the data obtained, a formula was devised (given in the preceding section) to include all of the information available in analyzing the lists. Results of the first list showed Subjects to be significantly different. Group C was found to be significantly different from Groups A and B in reaction to words in the first list. The second list showed words to be significant with "time" and "to" having different affect. Words also were significant in the third list with "shower" and "shed" and "wife" and "wide" being the word pairs that were different in affect. This analysis was likely the most accurate since it took advantage of the most information, because the control subjects had the greatest amount of stress on them early in the study, and because it required until the presentation of the second list in the study to acquire enough stress of confinement on the experimental subjects to detect any change with this test. Further analysis of the lists by groups showed that in list one, Group C significantly reacted to the words "female" "hope", and "time", while in the third list Group A had significant reactions to the words "shower" and "wife". These results show on which list there was significant difference in affect detected within each group.

It is of particular interest to discuss the significant reactions. The significant word in the first list was "chamber", indicating that anxiety was associated with the meaning of the word. Early in the study, this word became a source of anxiety to those in the chamber who had yet to endure its hazards and confines. To those subjects not confined in the chamber the word was a source of disappointment that either they were not going to be in the chamber or that the study was not what they anticipated it to be. This word of course, had many other connotations also to each subject, but it did have more affect associated with it in the early part of this study than it ever had before to the subjects. The fact that the control subjects knew that they were going into a nonchanging, nonglamorous, and rather lonely environment for the rest of the study caused strong psychological stress to be put upon them. Also, since they were not selected for experimental subjects, they felt rejected and somewhat resentful in this stage of the study. All of these stresses acting on the control subjects caused them to significantly react to the words in the first part of the study. The most significant word in the second list was "time". This was to be expected, though, since this was the middle part of the study and "time" was what they were "serving" and "time" was a reminder of the rigors that they had been through and would yet experience. In addition, since this was the middle of the study, the faster "time" passed, the better, since the stresses were greatest and the procedure most monotonous at the point in the study. Since most of these subjects were married, it is self-evident why "female" was reacted to significantly in the middle part of this study. The same reason can be given for the significant reaction to "wife" in the

third list. Since the subjects had not had a bath for a month, it is not surprising that they significantly reacted to the word "shower" in the last part of this study.

Some support for Rohrer's profile of confinement is found in type of words that the different methods revealed as significant. The recall method seemed to reveal the words that had the most anxiety connected with them. The reasons for this is that the recall method was the only one that revealed any significant words in the first period (which is the only period in which anxiety would be manifest) and that the word "chamber" is certainly a word that would have produced anxiety in this period. The method of tissue conductance change in the recall session as the words were spoken seems to have revealed the repressed words. The reasons for this seem to be that this method revealed significant words only during the middle part of confinement and the significant words that this method revealed, "time" and "female" were the poorest recalled (or repressed) on the recall analysis of the second list. This would seem to be in agreement with the findings of Bommer and Rosenthal (1963). The significant words detected by the method of tissue conductance change in the learning session were "shower" and "wife." These seem to be heightened affective (manic) words for two reasons. First, this was the only method to reveal these significant words in the last part of the experimental period. Second, there is, as a result of this method of analysis a high correlation between these significant words and the word "irritable" (as reported in the Daily Questionnaire). Whereas, the results of other methods on the third list reveal no such correlation. It is well known that irritability is a symptom of manic behavior; therefore, these significant words seem to be connected with the manic period. Rohrer's profile concerning anxiety, repression, and mania during confinement seems to be supported by the three methods.

Tests related to the test of verbal learning and affective change all showed no significant results. In general, these tests were either poorly designed or inappropriately applied. The anxiety test was one such test that in retrospect appeared to be misapplied. This test was expected to reveal an increase in anxiety around the early part of the confinement period, but failed to show any. It is thought that the reason why it did not and why this test was apparently misapplied was that this test is intended to show long-term or general personality anxiety, (i.e., some subjects had higher manifest anxiety than others throughout the study as seen in Table 10-34). But the kind of anxiety that was desired to be detected is an anxiety of a more situational nature, not part of the general personality, but manifest in a stress situation. The recall method discussed above is thought to measure this type of anxiety. Thus, the Iowa Manifest Anxiety Test failed to reveal that which was intended since it was inappropriately applied.

The tests of cognate nonsense syllables and sematic differential were poorly designed. This is shown for the Cognate Syllable Test when there was a significant correlation between the words intended and lack of affect. Some of the cognates were unintentionally constructed such that no subject made the desired word; such cognates were "cmpastn" (compensation), "pil" (pilot) and "sed" (speed). The words selected

also were not ones that the subjects reacted to with a change in skin conductance. So this test was poorly constructed. Also, the semantic differential test was also constructed improperly. The words to be described were correct, since they had been taken from a previous confinement study [10]. But although the dimensions were taken from astronauts' personality assessments[14] and thought to be the variables whereby astronauts evaluate the world around them, apparently they are not or they did not apply to these subjects. The dimensions used by Osgood et. al.[19] probably would have revealed a better differentiation between the words. Also, it may have been that the words picked to acquire an affect did not, because other words thought to remain neutral acquired some affect due to confinement.

Group Cohesiveness: Group Cohesiveness tended to decrease around day 18, but not significantly. However, in a prior confinement study, Borislow[16] found that subjects significantly decreased in cohesiveness. However, the subjects in Borislow's study worked independently for the most part, whereas in this present study the subjects had to work together most of the time. In another confinement study, subjects were observed to disintegrate in interpersonal behavior with increased confinement[6], but these subjects worked quite independent of each other also. It is thought that when subjects are forced to work and relax together, they learn a great deal about each other and realize the common traits between themselves and other subjects with whom they are forced to associate. Only when temporary stresses and frictions build up do subjects perceive themselves differently from those they work with, and with a change in activity (decrease in stress and friction) these perceptions return to the original. This was borne out by the results. Subjects in this study were psychologically sound enough and mature enough to realize that they had to live with each other for 34 days, so they never allowed themselves to build up undue animosities. Also the change in activities and the necessary working together helped the group cohesiveness. Probably the two most important factors to consider in group cohesiveness in confinement are the personalities of the subjects and the activities required of them. It appears that the subjects tended to overestimate their group's cohesiveness because they wanted to be regarded by others in their group as thinking their group's cohesiveness was high. Also, the subjects in each group overtly worked together very well, and it was likely that their perceptions were based primarily on the overt harmony in the groups. All subjects increased in stability of self perception, particularly Subjects #1 and #5 in Group B. This rating of themselves gave these subjects a more accurate perception of themselves as they had the opportunity several times to compare their self-perceptions with the perceptions others would reflect back to them through interpersonal relations. This increase in stability of self-perception has been found also in a prior confinement study [16]. Subjects' "psychological nearness" to their groups were nearly opposite their group's perception of them. This is true because there were so few subjects in each group (three, three, and two) that the other subjects' perception of each subject is also nearly the group's perception. Therefore, the subject's perception of the group and the group's perception of the subject are generally nearly opposite in very small groups. Finally, it is of interest to note that in Groups B and C, the subjects low in need Affiliation were the same that progressively perceived

themselves as getting more psychologically distant from the group as confinement progressed; this relationship was not so clear in Group A. This may be due to the fact that Group A had the highest group cohesiveness for most of the study. Group B had the lowest and accounted for most of the decrease in cohesiveness of the subjects. This finding can most likely be accounted for by the different group compositions. Groups heterogeneous in regard to need Affiliation, homogeneously low in regard to need Dominance, and homogeneously high in regard to need Achievement (which Group A seemed to be) seem to have the highest group cohesiveness.

Motivation: The Hand Dynamometer results turned out as expected. The overall increase in peak force emitted was most likely due to practice and strengthening of the hand muscles. This task is thought to be a good indicator of relative motivation from day to day since the subject receives no interpretation or reward for this task. To corroborate this as a motivation measure, the results of the Hand Dynamometer (Figure 10-15) can be compared with the reports of overall efficiency (Figure 10-33). The days of greatest increase in motivation (days 3-6) are the same days that showed the most frequency of "more efficient than usual." Likewise, the days of the decrease in motivation (days 12-20) were also the days that the lowest frequency of "as efficient as usual" and the greatest frequency of "less efficient than usual". So it seems very clear that the hand dynamometer is an excellent measure of relative motivation from day to day. The subjects showed a fairly clear-cut profile of increasingly high motivation early, then a decrease in the middle, and another increase was followed by a decrease at the end of the study. The experimental groups showed this more clearly than the control group did. The control group was more constant and showed smaller changes. It is thought that the reason for this is that the experimental subjects were undergoing constant changes from one experimental situation to another, while the control subjects remained in the same condition. The anticipation of new experiences and change is thought to account for the sharp rises in motivation in the experimental group. Further, the decrease in motivation for the experimental subjects can be accounted for due to the monotony and routine of the middle part of the study, where these subjects were in one condition for 13 days (days 14-27: where the greatest decrease in motivation was observed). With further changes in the experiment toward the end of the study, the experimental subjects increased in motivation again. There also seems to be a difference between the profiles of the left and right hands. It appears that the right hand (or dominant hand, usually) shows the clearest or most accurate changes, while the left hand (or least dominant hand, usually) shows only a general trend. This can be observed in the Figures 10-15 through 10-17.

Symptoms of Confinement: The data of the Daily Questionnaire seems to be quite accurate. Irritability was reported to be most intense at the last of confinement because this is the period where the symptoms of mania according to Rohrer,[4] are manifest. Anxieties and having to work with the other subjects probably accounted for the "impatience" at the beginning of confinement. Anxiety was most frequent at the beginning of this study, where it should have been if the subjects were attempting to be honest concerning the uncertainties of the hazards involved in the study. Although

the most frequent reports of noises were at the beginning of the study, the intense noises were reported on or after a change in the experimental conditions. So it would seem that new noises were encountered with each experimental change and were reported until the subjects became accustomed to them. Inactivity was reported most frequently by the experimental subjects around the end of their longest experimental period (days 24-25) indicating some monotony had begun to be felt. The control subjects reported inactivity most frequently and most often (to be expected since they had less to do) in the early part of the study. Apparently they adjusted to their routine for the last part of their confinement since they stopped reporting inactivity. The reports on dirtiness seem to validate this questionnaire since the subjects show just when the feeling of dirtiness became more intense. Interest seemed to be maintained at a higher level than expected since the study was so long. As was expected, difficulty in concentration, decrease in efficiency, and increase in depression increased a little during the middle part of the study. Most of the specific symptoms of confinement were caused by physical conditions-the dry oxygen and sleeping during the day (blood-shot eyes), full pressure suits (restless sleep), and lack of activity (weak and sore muscles). The disappointment and resentment of the control subjects showed up in the symptoms of low morale and boredom which they reported most frequently in the first part of the study. Apparently they adjusted in the last part of the study because these reports ceased.

Time estimation: Results of the Time Estimation Test were similar to Mead's[12] findings that under high motivation, subjects progressively over-estimated time at intermediate and near distances to the goal (in this case, end of confinement). The periods of greatest overestimation seem to be around days 19 and 33 in this study. Contrary to Gaito et al.,[3] the subjects' ability to estimate time intervals improved over increasing days of confinement. Probably the reason for the difference between these results can be ascribed to greater motivation and ability that subjects in this present study exhibited. Also conflicting with the results of this study are the findings of Burns and Gifford[13] which showed that their subjects progressively overestimated the time intervals as the days of confinement increased. The discrepancy between these results is thought to be due to the difference in methods employed. Burns and Gifford[13] used no activity to keep their subjects busy during the interval to be estimated, whereas in this study, a symbol cancellation task was used during the interval to prevent the subjects from using some means to help them in their estimates. It is thought that when a task is used during the interval, this makes time pass faster for the subjects and thus, they overestimate the intervals at first. Whereas, without a task, it is thought that the time would go much slower for the subject, and he would tend to think the interval was over before it was. This same method seems to account for the difference between the results of this study and the Burns and Gifford[13] study where manifest anxiety was correlated with overestimation of time. Burns and Gifford[13] found a significant correlation between the variables on two intervals, whereas in this study no such results were obtained. The use of the symbol cancellation task and more highly motivated subjects seem to

explain the difference between the results of this study and other confinement studies with regard to time estimation.

Additional analyses: Further analyses on the results show that Group C reported more stress and emotional symptoms than did Groups A and B. The explanation of this has already been given in part above, but it would be clearer if they were summarized here. The control subjects (Group C) were disappointed in their expectations of the study and the conditions in which the control subjects were required to live. Little activity and monotonous conditions led to boredom and low morale early in the study until they adjusted to it. The feelings of being left-out and being of secondary interest in the study added to their psychological stress. These stresses in part produced the symptoms that were found to be greater than reported in Groups A and B. The group composition was also a factor in producing some of the stresses in Group C. In the Results it was stated that it was unclear whether the need Affiliation difference or the need Dominance difference in this group produced the most interpersonal friction in this group. This is based on the study of Haythorn, et. al.[18] in which he found that groups with homogeneously low need Achievement produced less stress and emotional symptomatology than either groups with heterogeneous need Achievement or homogeneously high need Achievement. But, groups with homogenously low need Dominance produced more subjective stress and emotional symptomatology than groups heterogenous with regard to need Dominance. Since Group C in the present study had a group composition of homogeneously average need Dominance, it is thought that this was the factor that, in part, produced the reports of greater stress and emotional symptoms. This clarifies, somewhat, the explanation of the results of the control subjects.

Additional analysis revealed that for the middle part of the study, group cohesiveness was positively correlated with the Hand Dynamometer results and negatively correlated to the symptoms of irritability reported on the Daily Questionnaire. Group cohesiveness seems to correlate negatively with irritability because irritability would naturally be accompanied by low cohesiveness in groups. It is felt that this decrease in Group Cohesiveness and motivation (as measured by the Hand Dynamometer) around days 14-20 is a very important result to come out of this study. This is thought to be so because in spite of the fact that the subjects were performing well on their assigned tasks and overtly there were no interpersonal tensions, however covertly there were feelings, opinions, and motivations which were contrary to this apparent harmony. This indicates that performance does not always reflect the actual functioning of a group. Although Borislow[16] suggests that we should not concern ourselves with covert feelings of a group, but only performance, it is thought by this author that these findings should not be wholly disregarded. These findings indicate a weakness in the group, and as such, with enough stress put upon that weakness it will break-up the group and be revealed in its performance. These results also indicate that there are covert symptoms of the stress of confinement that can be detected before the overt performance makes it apparent.

Recommendations: It appears that the results of this study will have implications for future confinement situations. The results have not been explored to the extent that they will provide accurate prediction of behavior in confinement situations. The main value of these results, therefore, would seem to be in providing avenues of research for investigators of the behavior modification brought about by confinement. The changes in affect, group cohesiveness, and motivation should be investigated in a realistic mission profile to determine if they are significant in such a confinement setting. For the more basic research, it is suggested that he vary the intensities of stress of confinement to determine how much stress is necessary to produce significant decrements in behavior. (Only further investigations can put into proper perspective the true importance of the results of this study.) It is hoped that future investigations will consider the results of this study in determining guidelines for their studies of the effects of confinement.

CONCLUSIONS

This investigation was designed to inquire into the effects of confinement over a duration of a month. Areas of inquiry that were thought worthwhile to investigate were verbal learning and affective change, group cohesiveness, symptoms of confinement, motivation, and time estimation.

In order to investigate these areas, several measures were devised. To study verbal learning and affective change, paired associates (nonsense syllables paired with potentially affective and neutral words) were presented to each subject at three specified times during the study. Each pair was presented seven times to each subject; after five minutes and also 24 hours after the presentation, the subject was asked to recall the words that were associated with each syllable. Group cohesiveness was detected by administering an adjective scale measuring "psychological distance". This scale was administered 9 times; the first two were given 11 and four days before confinement, the experimental days for this test were 6, 12, 18, 22, 28 and 32, the last administration was given four days after confinement. The subjects were also asked to recall their group's "cohesiveness" during confinement. To get a measure of motivation, a hand dynamometer was squeezed as hard as possible with each hand each day during the period of confinement. A questionnaire was given every day to assess the symptoms of stress in the subjects due to confinement. Alternatives relating to each symptom were made to allow the subject latitude in describing fluctuations within each symptom area. The subjects were asked to estimate time intervals of 15, 30, 180, and 300 seconds to assess the effects of confinement on temporal judgement.

As a result of the verbal learning and affective change test it was expected that the affective words would be recalled better than the neutral words and that there would be a decrease in tissue resistance when they were spoken in the learning sessions and five minute and 24 hour recall sessions. None of these expectations

was confirmed by the results, but it was found that certain potentially affective words did acquire some affect as a result of the stresses of confinement. It was expected that the findings would show a decrease and a leveling-off of group cohesiveness. The statistical analysis of this data showed that group cohesiveness did not significantly change for the three groups in the study. The subjects overestimated the extent of their group's cohesiveness, but were accurate in their perception of the changes in their interpersonal relationships. It was expected that the Hand Dynamometer results would reveal an overall increase in peak force emission level. This expectation was confirmed and this task seemed to be a good measure of intra-experimental motivation. The daily questionnaire was expected to show some insights into the symptoms produced, the conditions of the study, and, serve therapeutically to allow the subjects to express themselves to the people on the "outside." These expectations were found, to some extent. The reports made on this form seemed quite accurate. It was expected that the subjects would progressively overestimate the time intervals after first underestimating them and that there would be a significant correlation between manifest anxiety and underestimation of the time intervals. Neither expectation of time estimation was confirmed. Further analyses showed Group C reported more symptoms of stress and emotion than did Groups A and B. Also, the middle days of the study were significantly correlated in respect to the decrease in group cohesiveness and motivation.

In conclusion, it was found that stresses in confinement do change the affective connotation of words, change the affective response between groups, and produce symptoms of stress and emotion. To the future investigators of the effects of confinement situation, these effects should be considered in attempting to assess what changes will take place in their subjects' performance and behavior.

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TABLE 10-1

SUMMARY OF THE ANALYSIS OF VARIANCE OF RECALL SCORES FOR ALL LISTS

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	0.0338	1	0.03380	0.000	Ω1.00
Lists	72.2159	2	36.10795	5.08	>.10
Error	14.2074	2	7.1037	-	
TOTAL	86.4571	5			

TABLE 10-2

SUMMARY OF THE ANALYSIS OF VARIANCE OF TISSUE RESISTANCE CHANGE IN LEARNING SESSIONS FOR ALL TESTS

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	37.5	1	37.5	0.30	>.20
Lists	453.0	2	226.5	1.83	>.20
Error	247.0	2	123.5	-	
TOTAL	737.5	5			

TABLE 10-3

SUMMARY OF THE ANALYSIS OF VARIANCE OF TISSUE RESISTANCE CHANGE IN RECALL SESSION FOR ALL LISTS

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	5.3770	1	5.37700	1.92	>.20
Lists	9.4533	2	4.72665	1.69	>.20
Error	5.6070	2	2.80350	-	
TOTAL	20.4373	5			

TABLE 10-4

SUMMARY OF THE ANALYSIS OF VARIANCE OF NUMBER OF WORDS RECALLED ON THE FIRST LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	1.29	9	0.14333	2.10	$<.05$
Subjects	0.83	7	0.11857	1.73	$>.20$
Error	4.31	63	0.06841	-	
TOTAL	6.43	79			

TABLE 10-5

SUMMARY OF THE ANALYSIS OF VARIANCE OF NUMBER OF WORDS RECALLED IN THE SECOND LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	0.85	9	0.0944	2.83	$<.01$
Subjects	0.70	7	0.10000	3.00	$<.01$
Error	2.10	63	0.0333	-	
TOTAL	3.65	79			

TABLE 10-6

SUMMARY OF THE ANALYSIS OF VARIANCE OF NUMBER OF WORDS RECALLED IN THE THIRD LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	0.7388	9	0.0821	1.66	$>.20$
Subjects	0.5945	7	0.0849	1.72	$>.20$
Error	3.1164	63	0.0495	-	
TOTAL	4.4497	79			

TABLE 10-7

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE TISSUE RESISTANCE CHANGE IN THE LEARNING SESSIONS OF THE FIRST LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	11.30	9	1.25556	1.45	$>.20$
Subjects	31.55	7	4.50714	5.19	$<.01$
Error	54.70	63	0.86825	-	
TOTAL	97.55	79	0.86825		

TABLE 10-8

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE TISSUE RESISTANCE CHANGE IN THE LEARNING SESSION OF THE SECOND LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	17.3625	9	1.92916	1.62	$>.20$
Subjects	4.4875	7	0.64107	0.54	$>.20$
Error	75.1375	63	1.19266	-	
TOTAL	96.9875	79			

TABLE 10-9

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE TISSUE RESISTANCE CHANGE IN THE LEARNING SESSIONS OF THE THIRD LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	36.95	9	4.1056	3.59	$<.01$
Subjects	25.20	7	3.6000	3.15	$<.01$
Error	72.05	63	1.1437	-	
TOTAL	134.20	79			

TABLE 10-10

SUMMARY OF THE ANALYSIS OF VARIANCE OF TISSUE RESISTANCE CHANGE IN THE RECALL SESSIONS OF THE FIRST LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	0.1458	9	0.0162	0.73	$>.20$
Subjects	0.4210	7	0.0601	2.71	$<.05$
Error	1.4004	63	0.0222	-	
TOTAL	1.9672	79			

TABLE 10-11

SUMMARY OF THE ANALYSIS OF VARIANCE OF TISSUE RESISTANCE CHANGE IN THE RECALL SESSIONS OF THE SECOND LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	0.4673	9	0.05192	2.06	$<.05$
Subjects	0.1649	7	0.023560	0.93	$>.20$
Error	1.5891	63	0.02522	-	
TOTAL	2.2213	79			

TABLE 10-12

SUMMARY OF THE ANALYSIS OF VARIANCE OF TISSUE RESISTANCE CHANGE IN THE RECALL SESSIONS OF THE THIRD LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	0.8562	9	0.09513	1.99	$>.05$
Subjects	0.2086	7	0.02980	0.62	$>.20$
Error	3.0072	63	0.04773	-	
TOTAL	4.0720	79			

TABLE 10-13

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE FIRST LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	19.31	9	2.15	0.66	$>.20$
Subjects	82.32	7	11.83	3.61	$<.01$
Error	206.30	63	3.28	-	
TOTAL	308.43	79			

TABLE 10-14

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE SECOND LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	79.11	9	8.79	2.38	$<.05$
Subjects	21.59	7	3.08	0.84	$>.20$
Error	232.48	63	3.69	-	
TOTAL	333.18	79			

TABLE 10-15

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE THIRD LIST

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	173.86	9	19.3178	3.60	$<.01$
Subjects	56.53	7	8.0757	1.51	$>.20$
Error	337.99	63	5.3649	-	
TOTAL	568.40	79			

TABLE 10-16

SUMMARY OF ANALYSIS OF VARIANCE OF THE FIRST LIST FOR GROUP A

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	20.14	9	2.24	0.48	$>.20$
Subjects	14.31	2	7.16	1.54	$>.20$
Error	83.69	18	4.65	-	
TOTAL	118.14	29			

TABLE 10-17

SUMMARY OF ANALYSIS OF VARIANCE OF THE SECOND LIST FOR GROUP A

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	40.86	9	4.54	1.21	$>.20$
Subjects	0.35	2	0.18	0.05	$>.20$
Error	67.30	18	3.74	-	
TOTAL	108.51	29			

TABLE 10-18

SUMMARY OF ANALYSIS OF VARIANCE OF THE THIRD LIST FOR GROUP A

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	134.99	9	15.00	3.90	$<.01$
Subjects	8.96	2	4.48	1.16	$>.20$
Error	69.29	18	3.85	-	
TOTAL	239.70	29			

TABLE 10-19

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE FIRST LIST FOR GROUP B

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	12.00	9	1.33	1.08	$>.20$
Subjects	81.20	2	40.60	33.83	$<.01$
Error	21.57	18	1.20	-	
TOTAL	114.77	29			

TABLE 10-20

SUMMARY OF ANALYSIS OF VARIANCE OF THE SECOND LIST FOR GROUP B

Source of Variation	Sum Squares	Degrees of Freedom	Sum Square	F	P
Words	19.99	9	2.22	.37	$>.20$
Subjects	10.05	2	5.03	.80	$>.20$
Error	112.09	18	6.23	-	
TOTAL	142.13	29			

TABLE 10-21

SUMMARY OF THE ANALYSIS OF VARIANCE FOR THE THIRD LIST FOR GROUP B

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	95.47	9	10.61	1.97	$>.20$
Subjects	29.07	2	14.54	2.70	$>.20$
Error	96.99	18	5.39	-	
TOTAL	221.53	29			

TABLE 10-22

SUMMARY OF THE ANALYSIS OF VARIANCE FOR THE FIRST LIST FOR GROUP C

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	27.79	9	3.09	1.10	$>.20$
Subjects	3.29	1	3.29	1.17	$>.20$
Error	25.41	9	2.82	-	
TOTAL	56.49	19			

TABLE 10-23

SUMMARY OF THE ANALYSIS OF VARIANCE FOR THE SECOND LIST FOR GROUP C

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	56.35	9	6.26	3.75	$<.05$
Subjects	0.06	1	0.06	0.04	$>.20$
Error	15.00	9	1.67	-	
TOTAL	71.41	19			

TABLE 10-24

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE THIRD LIST FOR GROUP C

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	59.07	9	6.56	1.05	$>.20$
Subjects	2.86	1	2.86	0.46	$>.20$
Error	56.06	9	6.23	-	
TOTAL	117.99	19			

TABLE 10-25

NUMBER OF WORDS MADE AND CHANGE IN TISSUE RESISTANCE FOR AFFECTIVE AND NEUTRAL WORDS IN COGNATE SYLLABLE TEST

	SUBJECT'S NUMBER								Words	Affect	Cumulative Affect
	1	2	3	4	5	6	7	8	x	a	c
Words Made out of Cognate nonsense Syllables:											
AFFECTIVE											
Astronaut		X	X	X	X	X	X	X	7	0	0
Commander	X	X	X	X	X	X	X	X	8	0	0
Flight	X	X	X	X	X	X	X. 25	X	8	1	.25
Group	X	X	X			X			4	0	0
Hotrod			X						1	0	0
Leader	X	X	X	X	X	X. 25	X	X1. 00	8	2	1. 25
Pilot									0	0	0
Speed							.25		0	1	.25
"Stovepipe"	X		X			X		.50	3	1	.50
"Tiger"	X	X	X. 25	X	X. 25		X	X	7	2	.50
								Σx	46	Σa 7	Σc 2.75
NEUTRAL											
Compensation						.50			0	1	.50
Dresser	.50								0	1	.50
Explain	X. 25		1. 00	X	X		X	X	5	2	1. 25
Impulsive	X. 25	X. 25		.50	X	X	X		5	3	1. 00
Intend	X		X				X	X	4	0	0
Inward		.25							0	1	.25
Morn	X. 25	.25						X	2	2	2. 00
Nod	X	X	X	X			X	X	6	0	0
Rover								.50	0	1	.50
Told	X. 50	X	X	X	X		X	X	7	1	.50
								Σx	29	Σa 12	Σc 6.50

TABLE 10-26

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE SEMANTIC DIFFERENTIAL OVER THE EXPERIMENTAL DAYS

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	7.3296	1	73926.0	4.87	$>.20$
Days	71.2363	2	356181.5	23.47	$<.05$
Error	3.0357	2	15178.5	-	
TOTAL	81.6646	2			

TABLE 10-27

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE SEMANTIC DIFFERENTIAL FOR THE FIRST EXPERIMENTAL ADMINISTRATION

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	16930.41	27	626.08	1.37	$>.20$
Individuals	27444.78	7	3920.68	8.55	$<.01$
Error	86695.84	189	488.71	-	
TOTAL	131071.03	223			

TABLE 10-28

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE SEMANTIC DIFFERENTIAL FOR THE SECOND EXPERIMENTAL ADMINISTRATION

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	24689.00	27	914.4074	1.05	$>.20$
Subjects	84377.80	7	12063.9714	13.89	$<.01$
Error	163992.82	189	867.6869	-	
TOTAL	273059.62	223			

TABLE 10-29

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE SEMANTIC DIFFERENTIAL FOR THE THIRD EXPERIMENTAL ADMINISTRATION

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Words	18200.84	27	674.1052	1.01	$>.20$
Subjects	54407.05	7	7772.4357	11.67	$<.01$
Errors	125914.95	189	666.2167	-	
TOTAL	198522.84	223			

TABLE 10-30

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE IOWA MANIFEST ANXIETY SCALE OVER DAYS OF ADMINISTRATION

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Subject	352	7	50.0286	19.24	$<.01$
Days	24	5	4.8000	1.85	$>.20$
Error	91	35	2.6000	-	
TOTAL	467	47			

TABLE 10-31

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE IOWA MANIFEST ANXIETY SCALE DURING THE FIRST PERIOD OF CONFINEMENT

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Subject	150.50	7	21.50	5.764	$<.01$
Days	1.08	2	0.54	0.144	$>.20$
Error	52.25	14	3.73	-	
TOTAL	203.83	23			

TABLE 10-32

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE GROUP COHESIVENESS INDEX OVER DAYS OF ADMINISTRATION

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Groups	3.2720	2	1.63600	3.11	$>.05$
Days	1.8819	8	0.23524	0.45	$>.20$
Error	8.4043	16	0.52527	-	
TOTAL	13.5582	26			

TABLE 10-33

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE EMOTIONAL SYMPTOMS

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Groups	925.01	2	462.51	4.11	$<.05$
Questions	2319.73	7	331.39	2.95	$<.05$
Error	1573.95	14	112.43	-	
TOTAL	4818.69	23			

TABLE 10-34

SUMMARY OF THE ANALYSIS OF VARIANCE OF THE STRESS SYMPTOMOLOGY

Source of Variation	Sum Squares	Degrees of Freedom	Mean Square	F	P
Questions	1762.32	3	587.44	4.10	$>.20$
Groups	2380.07	2	1190.04	8.31	$<.05$
Error	858.92	6	143.15	-	
TOTAL	5001.31	11			

TABLE 10-35

GROUP COMPOSITIONS OF THE EXPERIMENTAL GROUPS FOR THE VARIABLES OF NEED ACHIEVEMENT, NEED AFFILIATION AND NEED DOMINANCE

GROUP	SUBJECT	NEED		
		Achievement	Affiliation	Dominance
A	3	Very high	High	Average
	4	Average	Low	High
	6	Very high	Average	High
B	1	Average	Low	Average
	2	High	Low	Average
	5	High	Average	Very high
C	7	Average	Low	Average
	8	Average	Average	Average

TABLE 10-36

CORRELATIONS MADE BETWEEN DATA OBTAINED FOR THE HAND DYNAMOMETER, GROUP COHESIVENESS, TIME ESTIMATION AND DAILY QUESTIONNAIRE FOR DAYS 7-28

	Group Cohesiveness Index	Hand Dynamometer	Time Estimation	Daily Questionnaire
Group Cohesiveness Index		.307*	.134	-.275*
Hand Dynamometer	.307*		.221	
Time Estimation	.134	.221		-.203
Daily Questionnaire	-.275*		-.203	

* Significance level less than .05

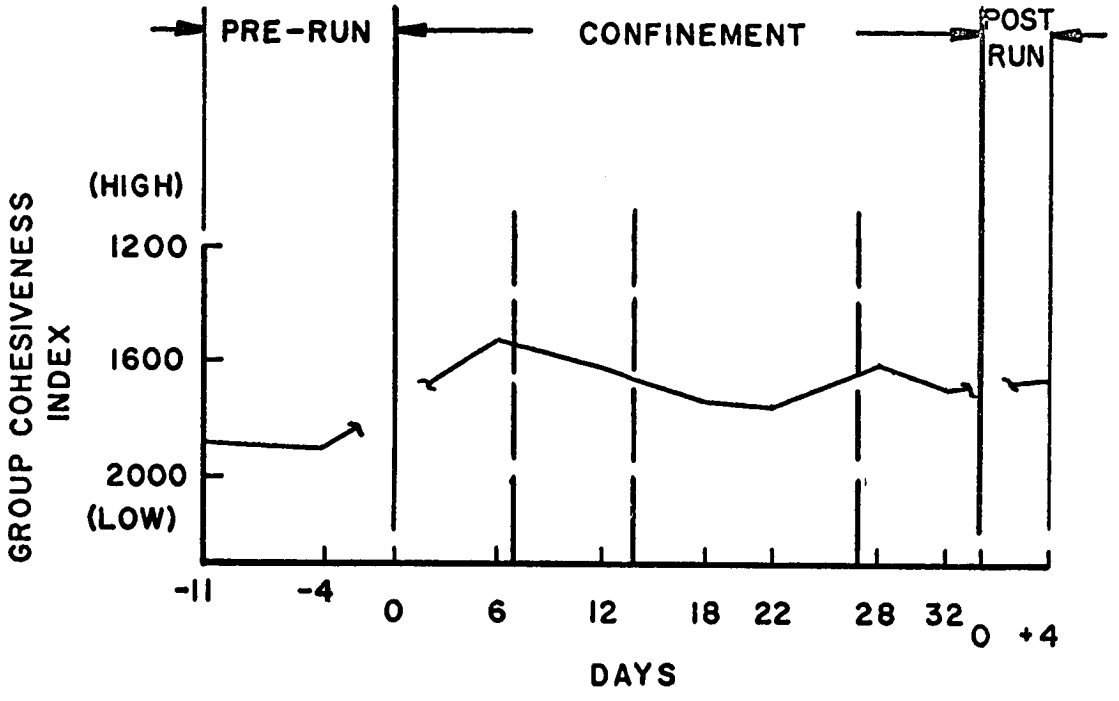


FIG. 10-1 GROUP COHESIVENESS FOR ALL SUBJECTS

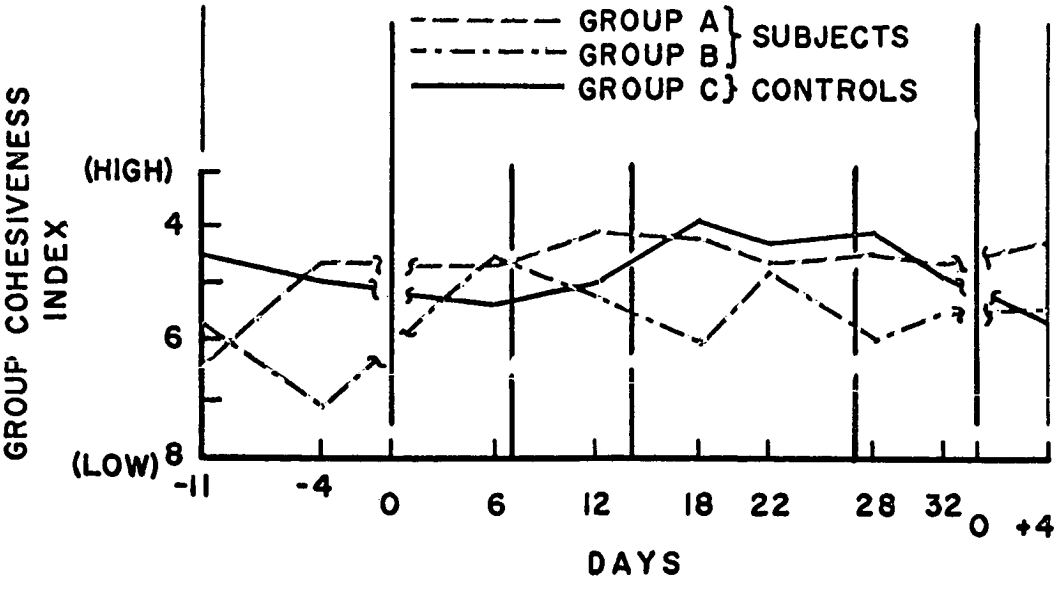


FIG. 10-2 GROUP COHESIVENESS FOR SEPARATE GROUPS

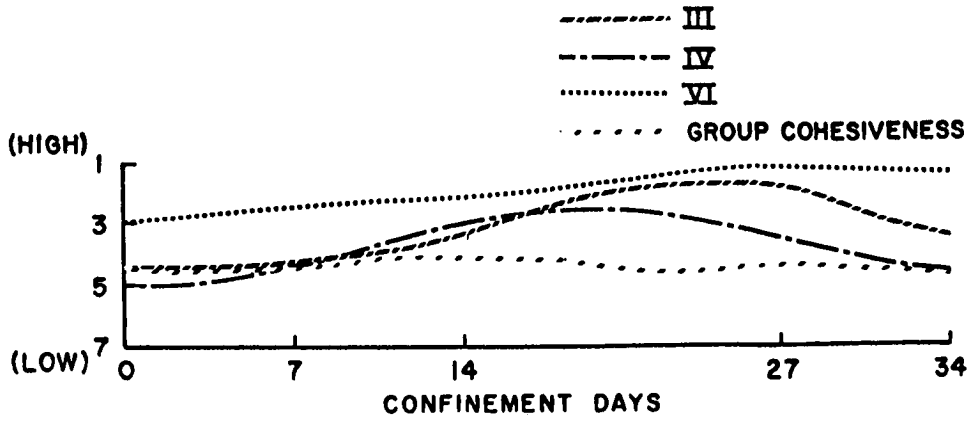


FIG. 10-3 PERCEPTION OF GROUP COHESIVENESS-GROUP A

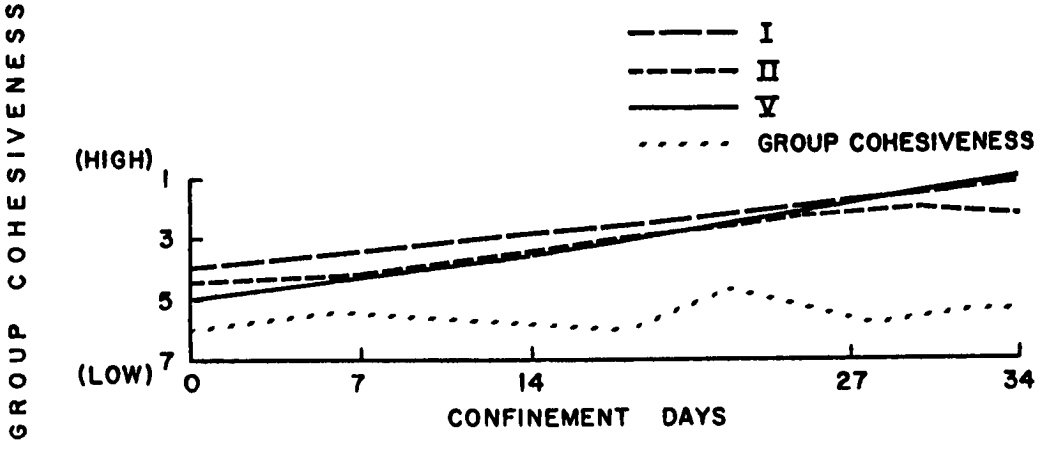


FIG. 10-4 PERCEPTION OF GROUP COHESIVENESS-GROUP B

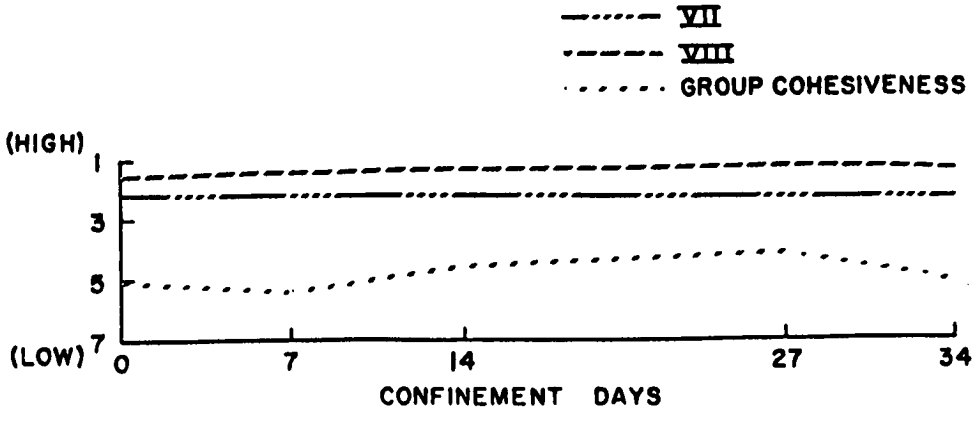


FIG. 10-5 PERCEPTION OF GROUP COHESIVENESS-GROUP C

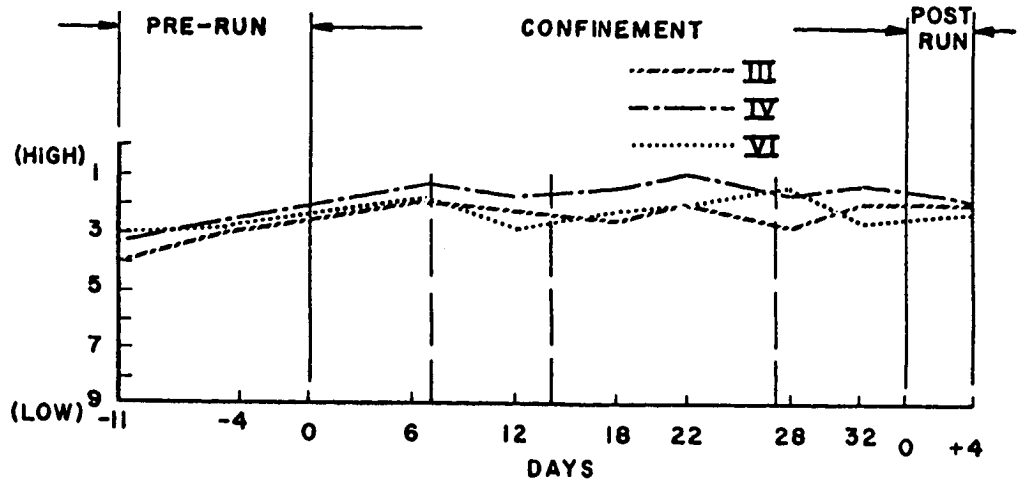


FIG. 10-6 STABILITY INDEX FOR SUBJECTS IN GROUP A

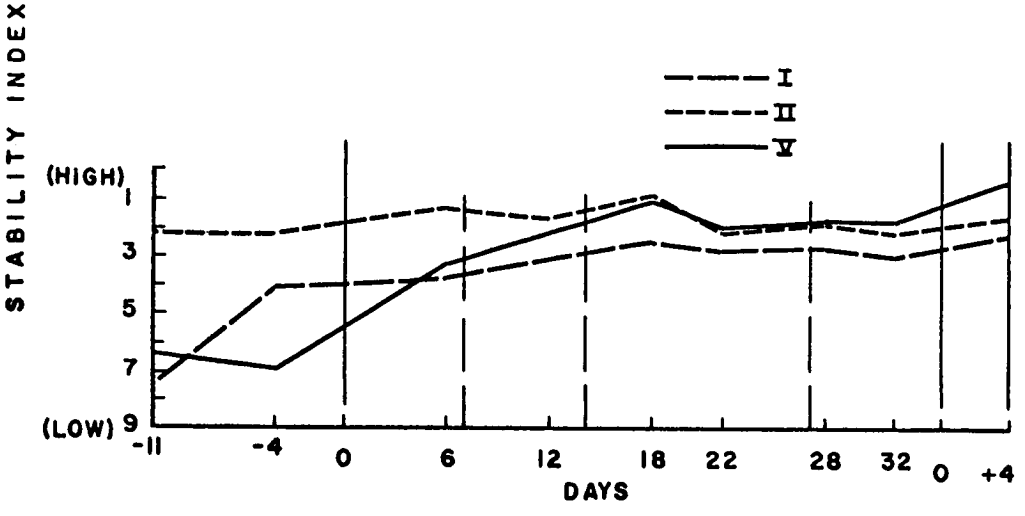


FIG. 10-7 STABILITY INDEX FOR SUBJECTS IN GROUP B

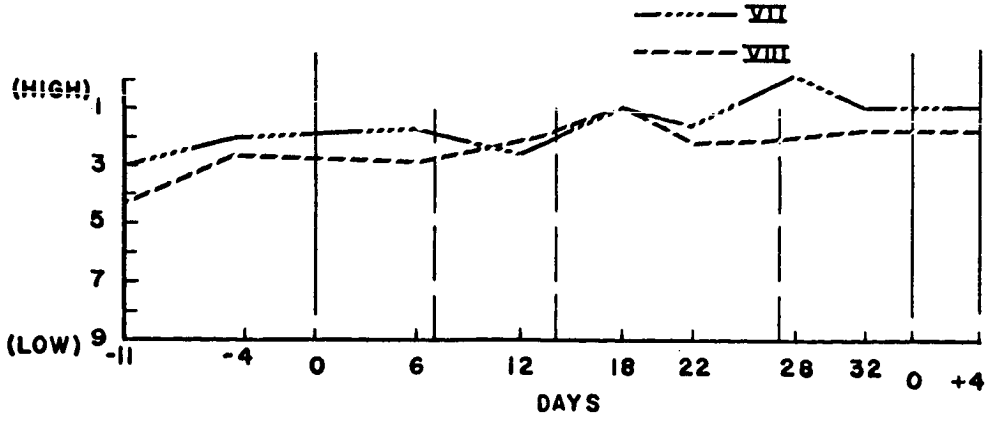


FIG. 10-8 STABILITY INDEX FOR SUBJECTS IN GROUP C

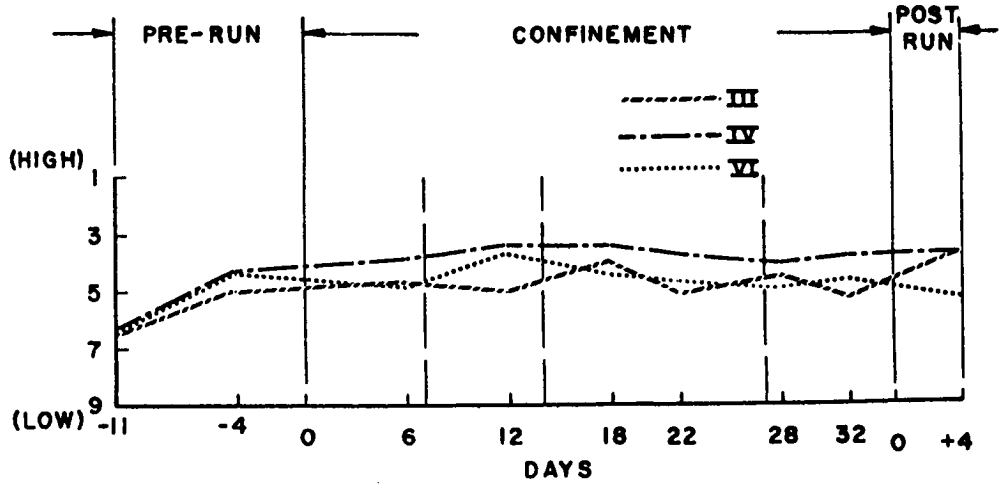


FIG. 10-9 SUBJECTS RATING OF GROUP A

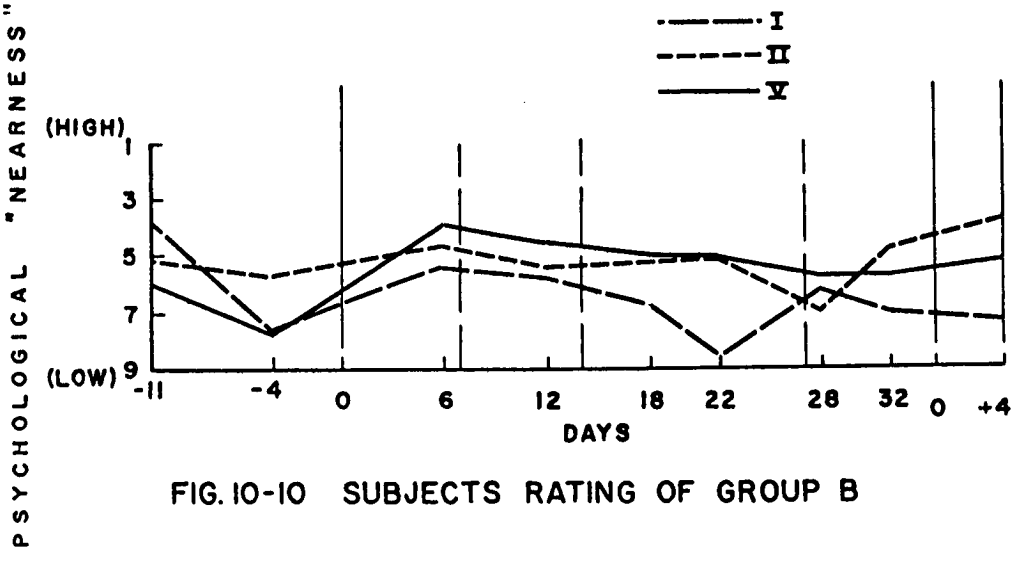


FIG. 10-10 SUBJECTS RATING OF GROUP B

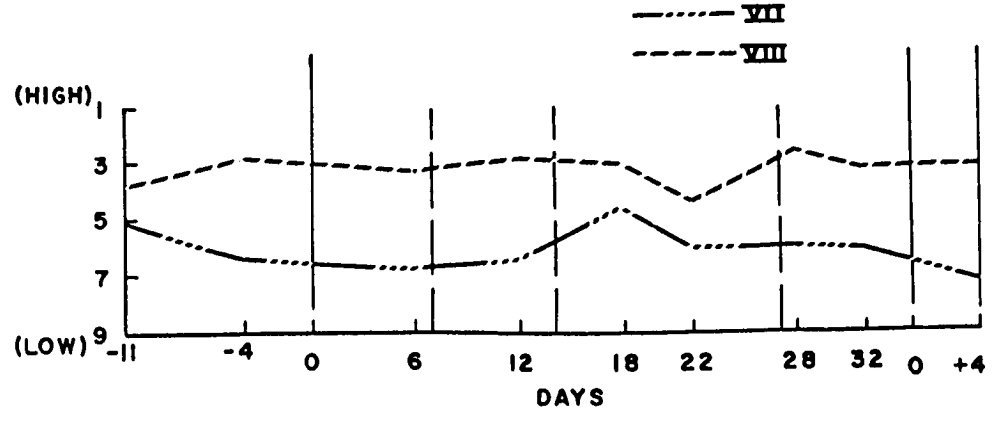


FIG. 10-11 SUBJECTS RATING OF GROUP C

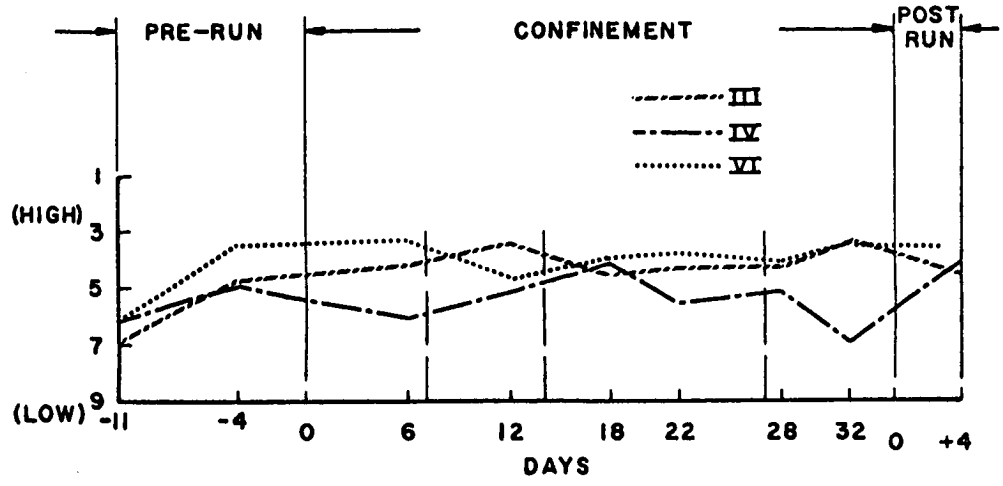


FIG. 10-12. GROUP RATING OF EACH SUBJECT IN GROUP A

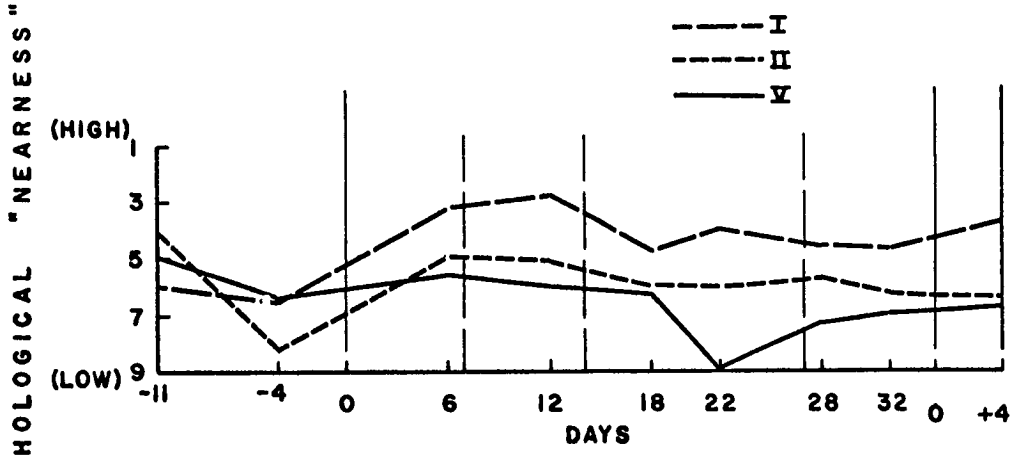


FIG. 10-13 GROUP RATING OF EACH SUBJECT IN GROUP B

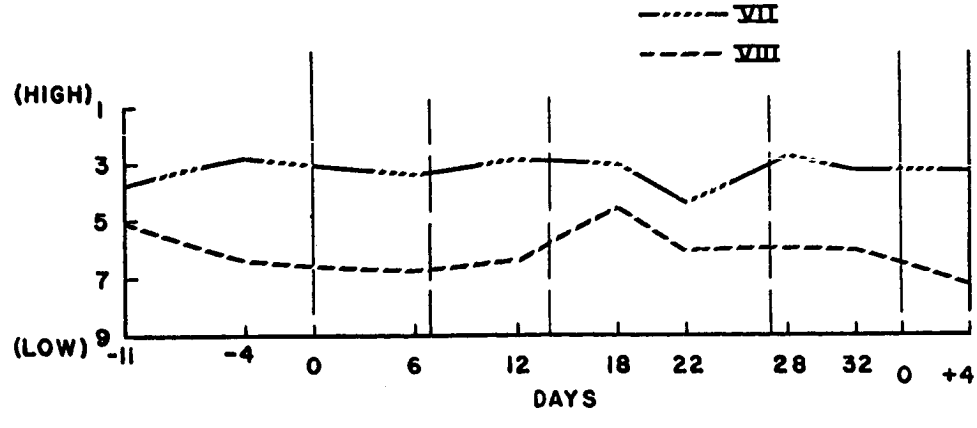


FIG. 10-14 GROUP RATING OF EACH SUBJECT IN GROUP C

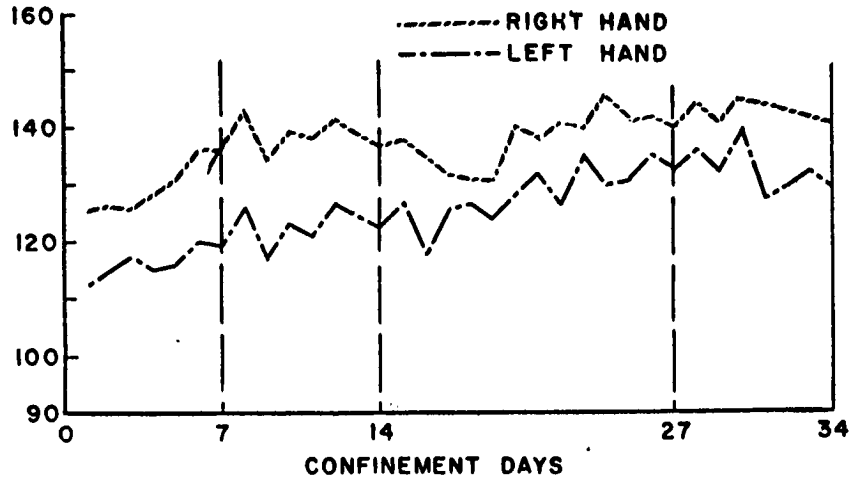


FIG.10-15 HAND DYNOMETER RESULTS FOR ALL SUBJECTS

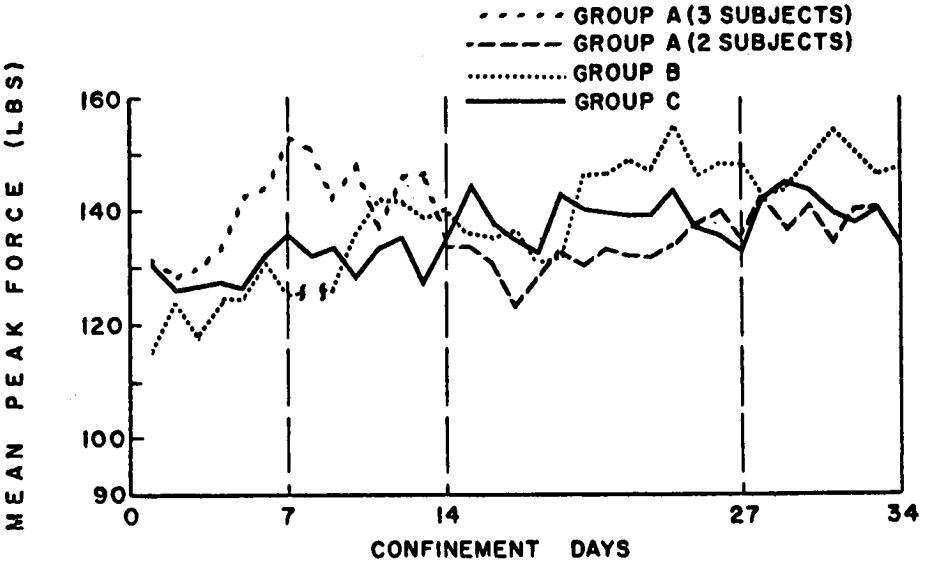


FIG.10-16 HAND DYNOMETER RESULTS, ALL GROUPS (R-H)

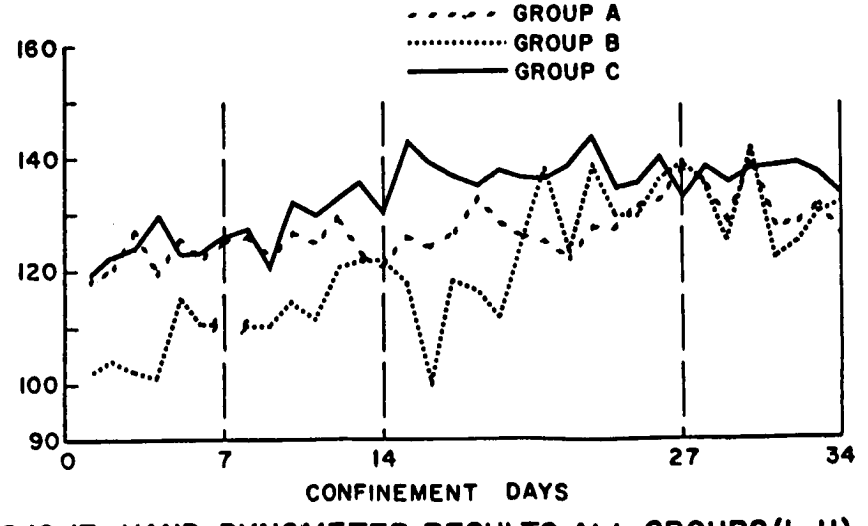


FIG.10-17 HAND DYNOMETER RESULTS, ALL GROUPS (L-H)

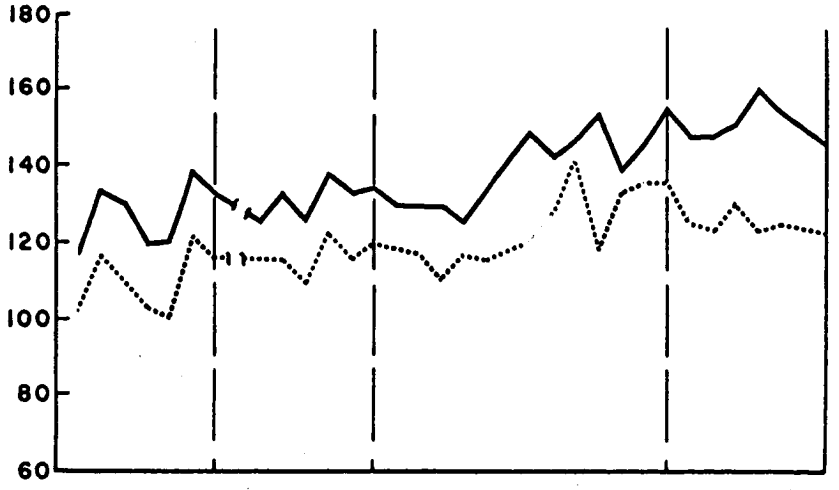


FIG. 10-18 HAND DYNOMETER RESULTS FOR SUBJECT 1

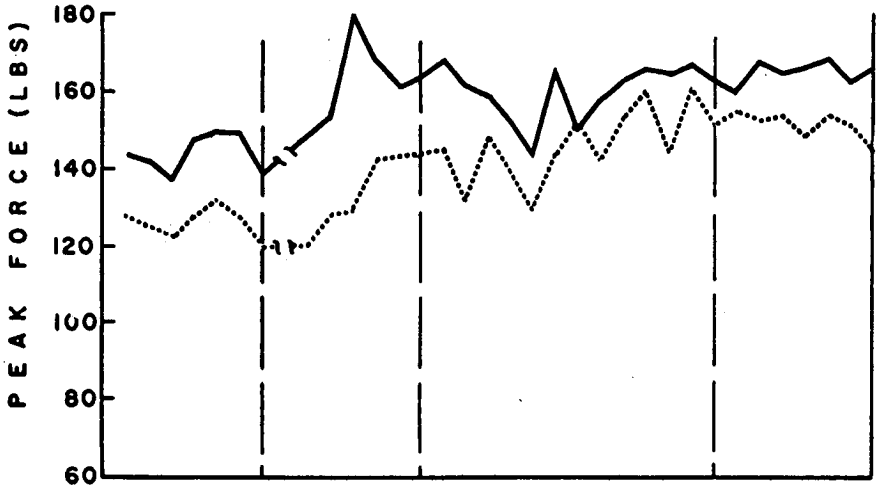


FIG. 10-19 HAND DYNOMETER RESULTS FOR SUBJECT 2

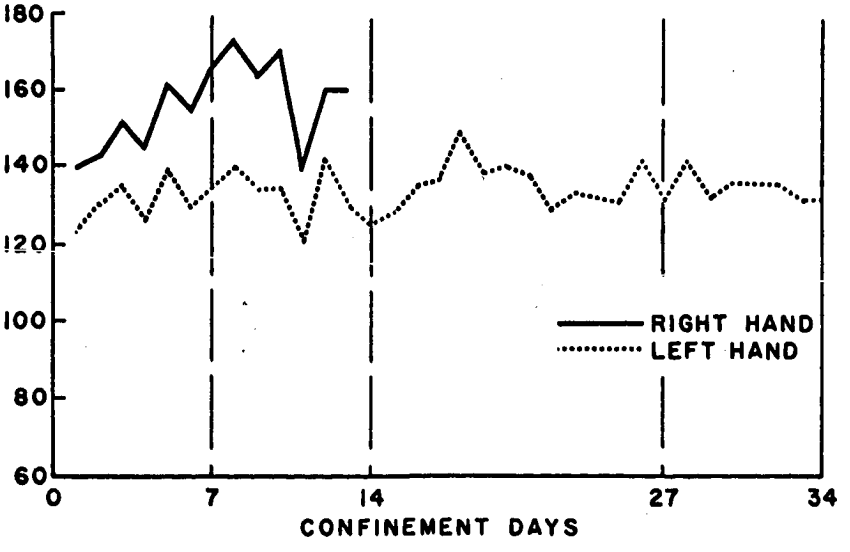


FIG. 10-20 HAND DYNOMETER RESULTS FOR SUBJECT 3

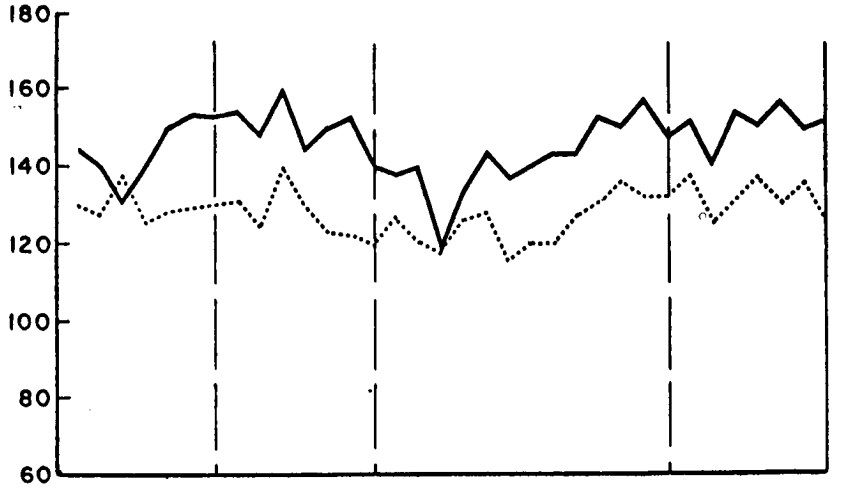


FIG. 10-21 HAND DYNOMETER RESULTS FOR SUBJECT 4

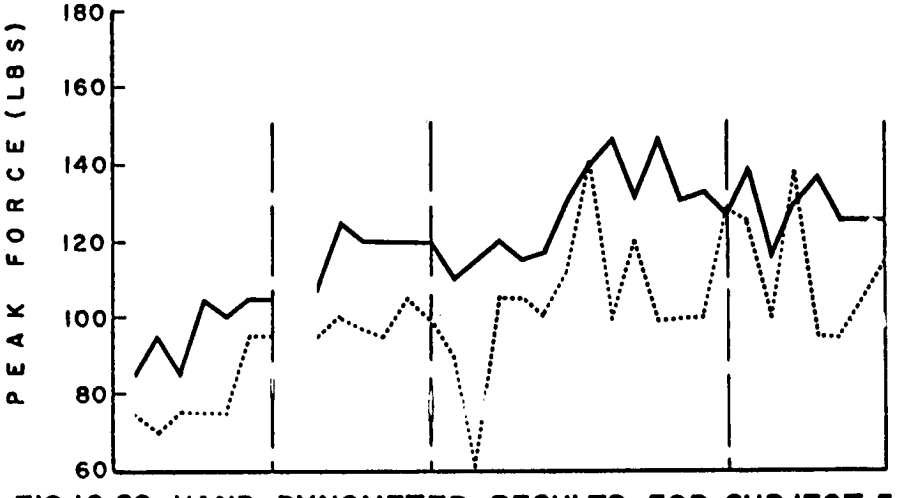


FIG. 10-22 HAND DYNOMETER RESULTS FOR SUBJECT 5

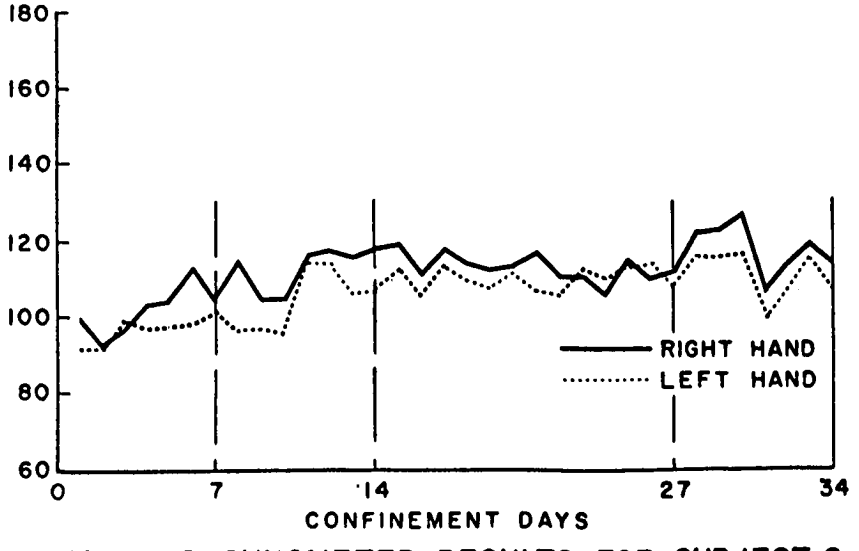


FIG. 10-23 HAND DYNOMETER RESULTS FOR SUBJECT 6

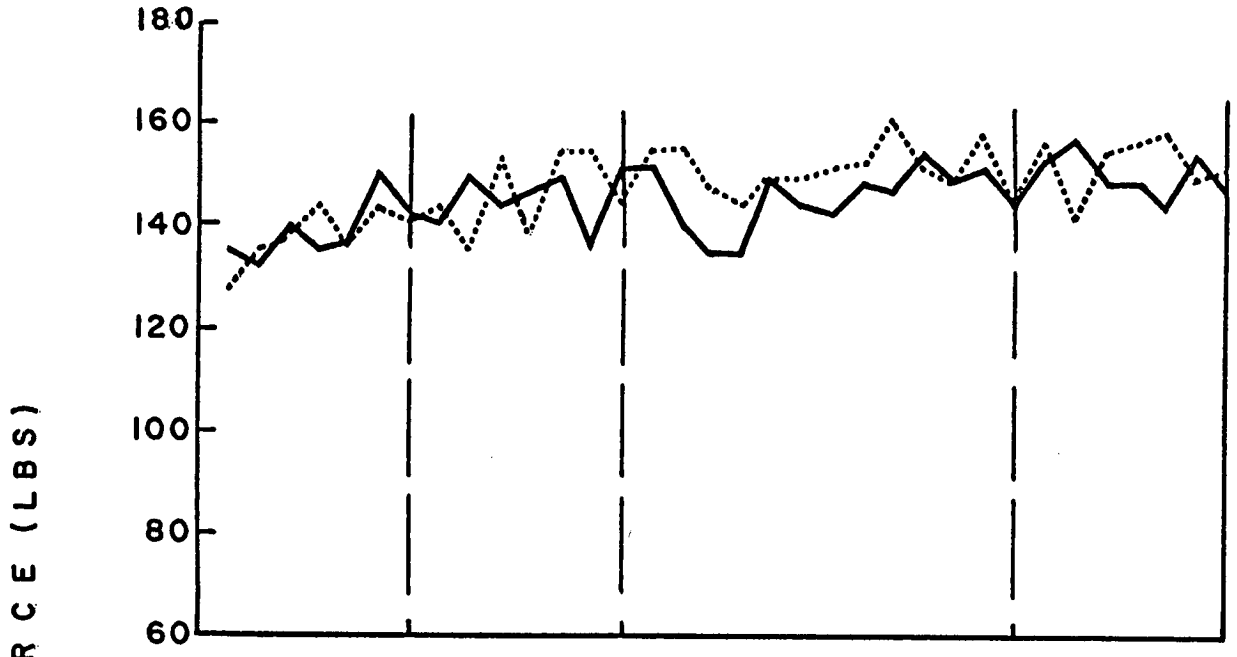


FIG. 10-24 HAND DYNOMETER RESULTS FOR SUBJECT 7

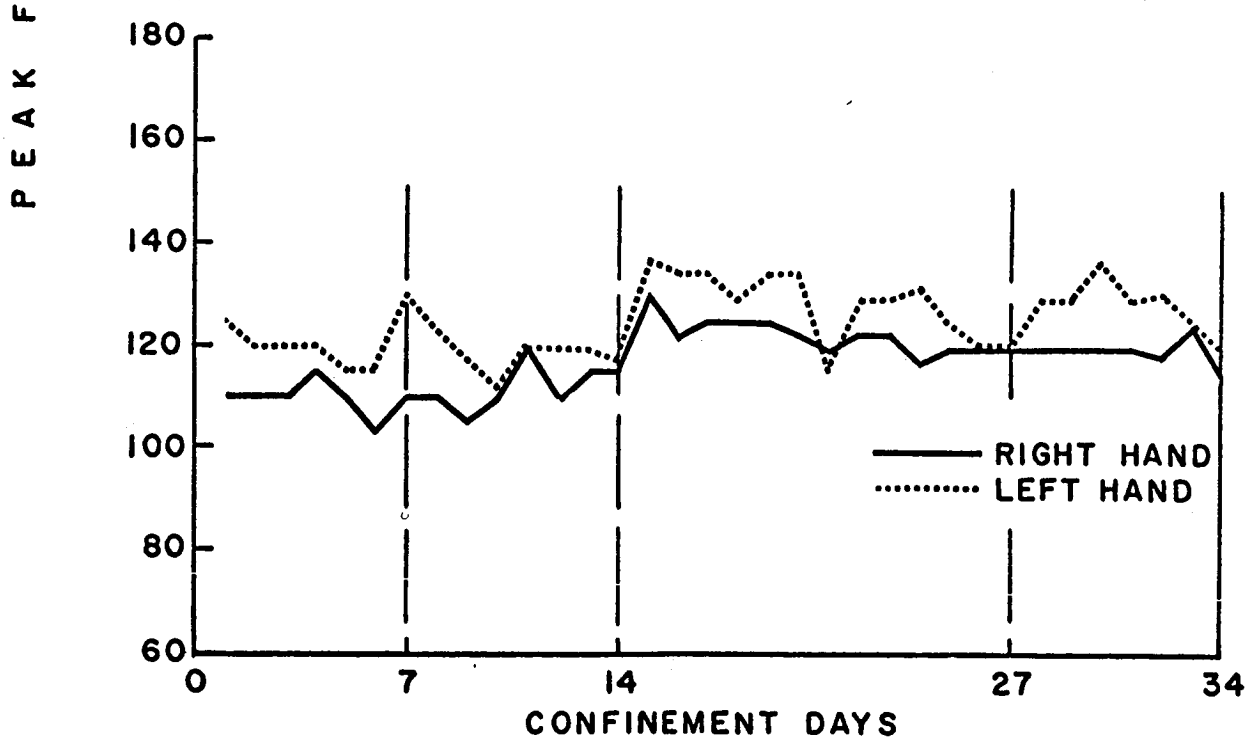


FIG. 10-25 HAND DYNOMETER RESULTS FOR SUBJECT 8

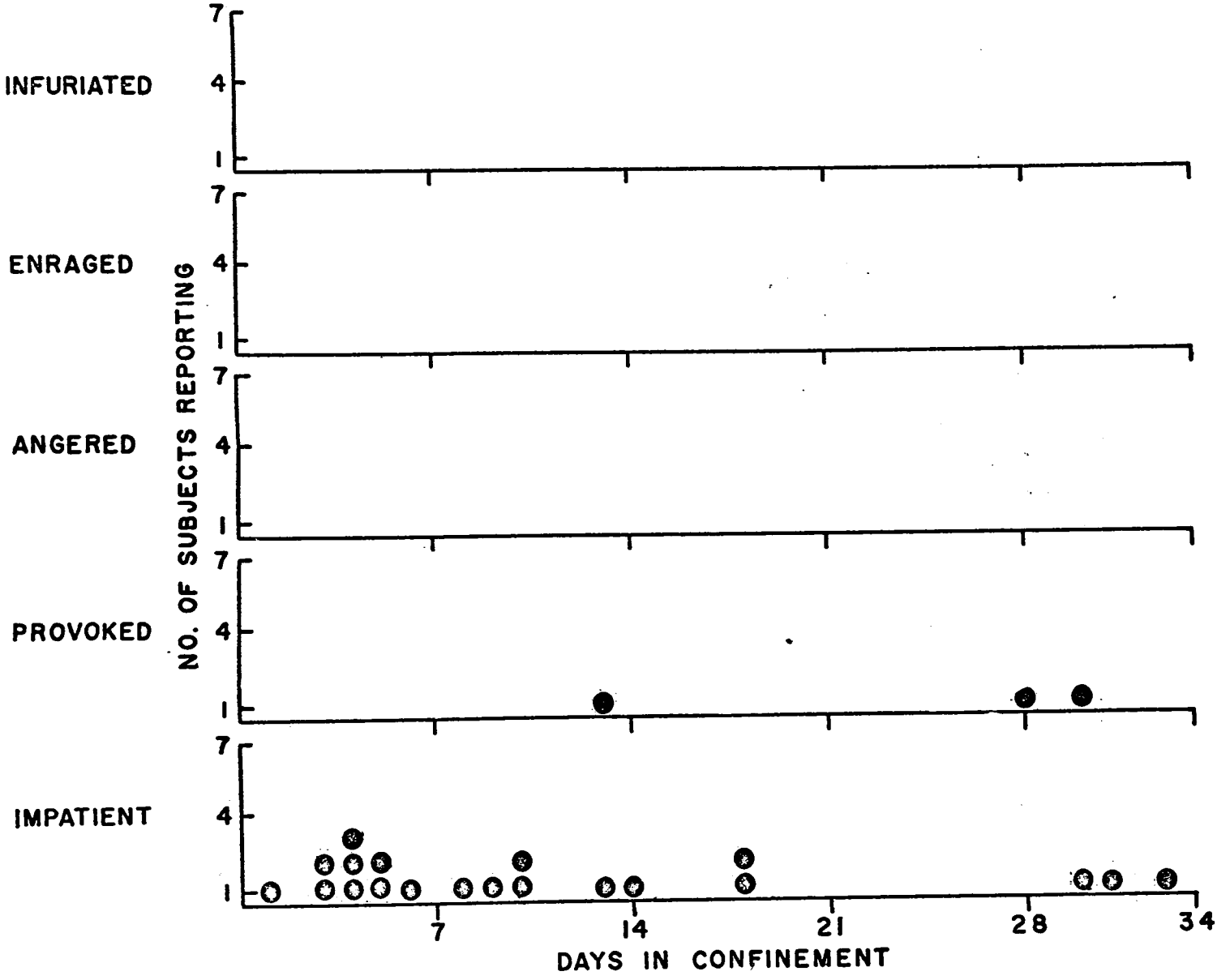


FIG. 10-26 FREQUENCY & TYPE OF IRRITABILITY REPORTED

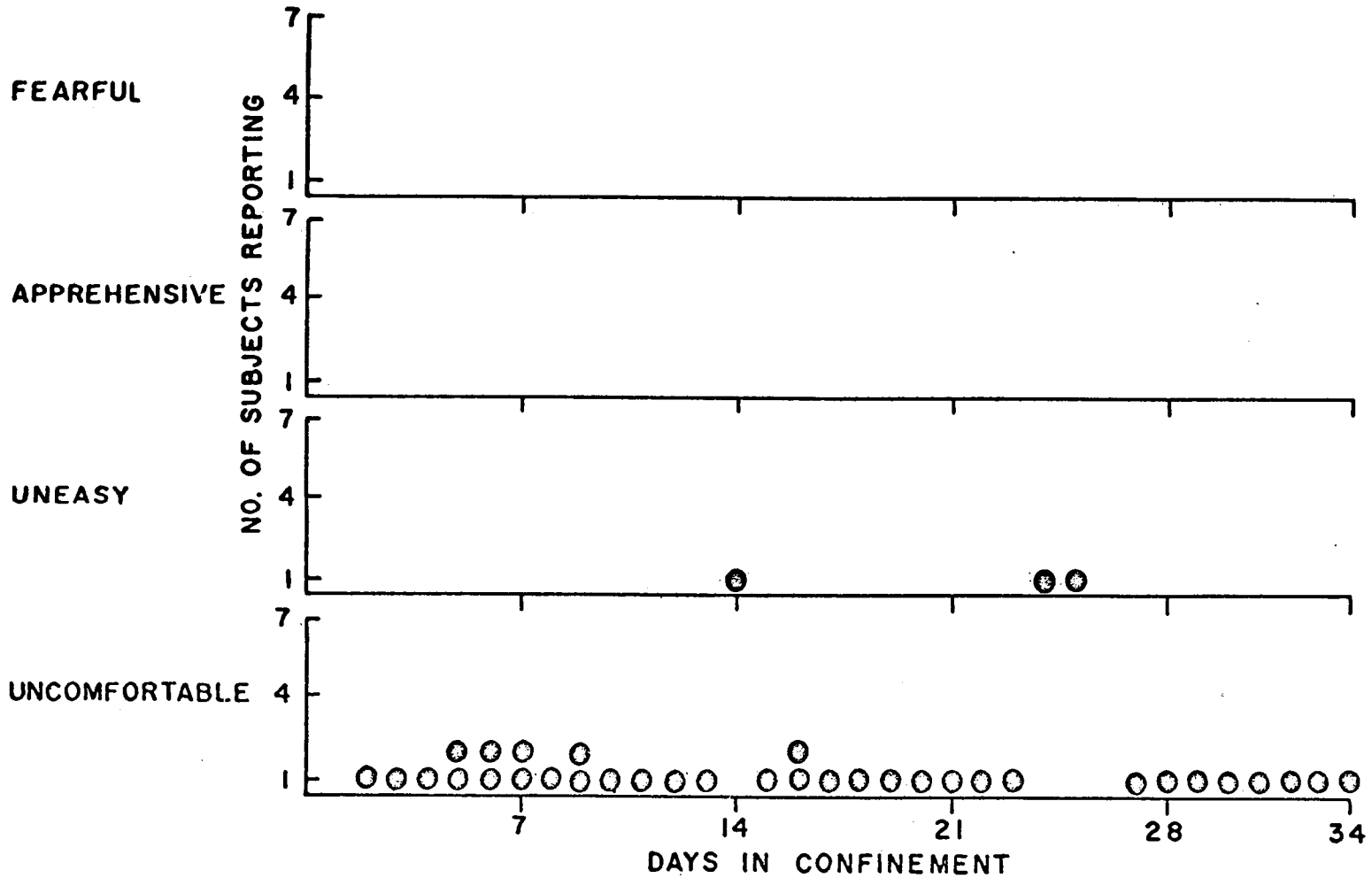


FIG.10-27 FREQUENCY & TYPE OF ANXIETY REPORTED

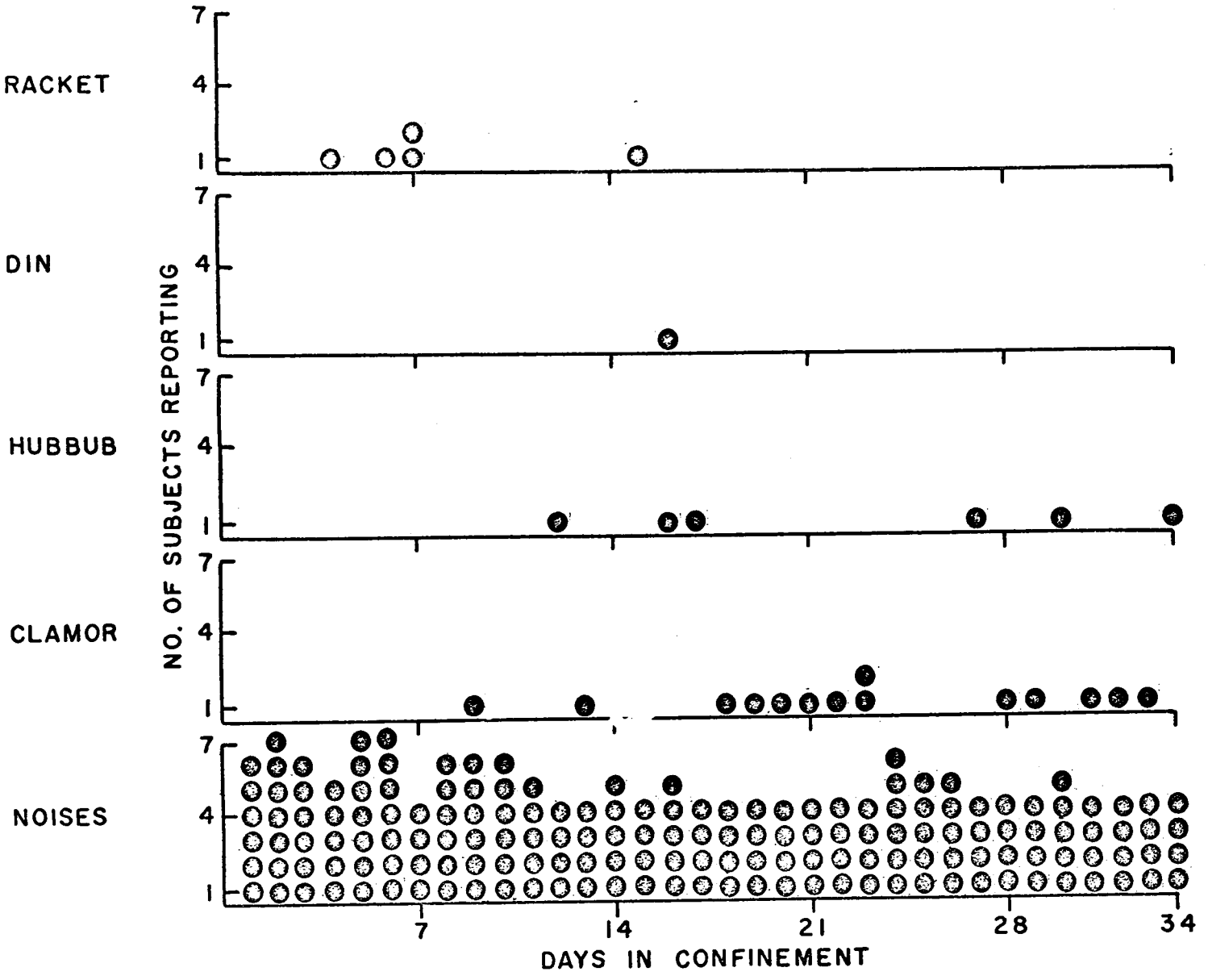


FIG.10-28 FREQUENCY & TYPE OF NOISES REPORTED

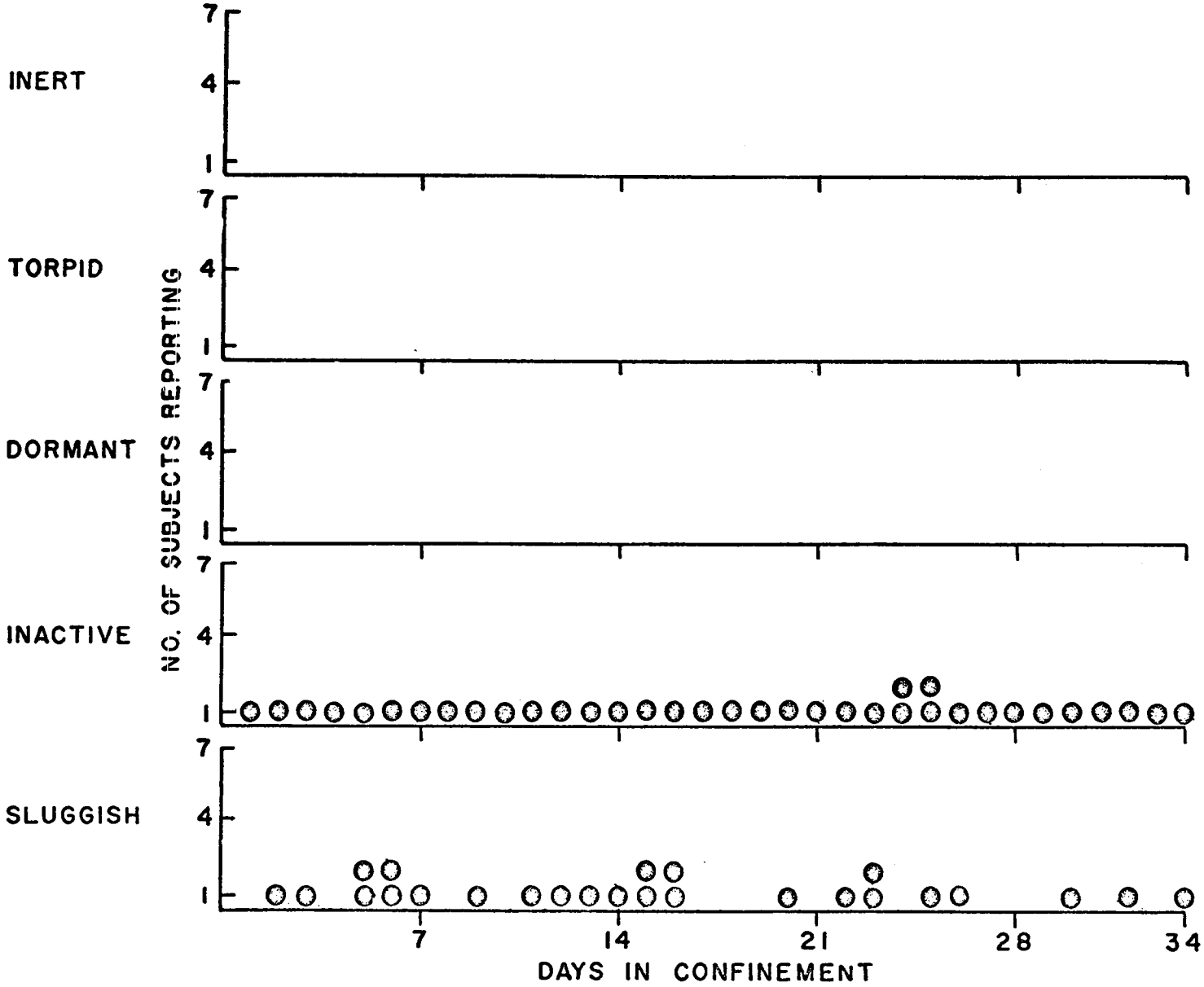


FIG.10-29 FREQUENCY & TYPE OF INACTIVITY REPORTED

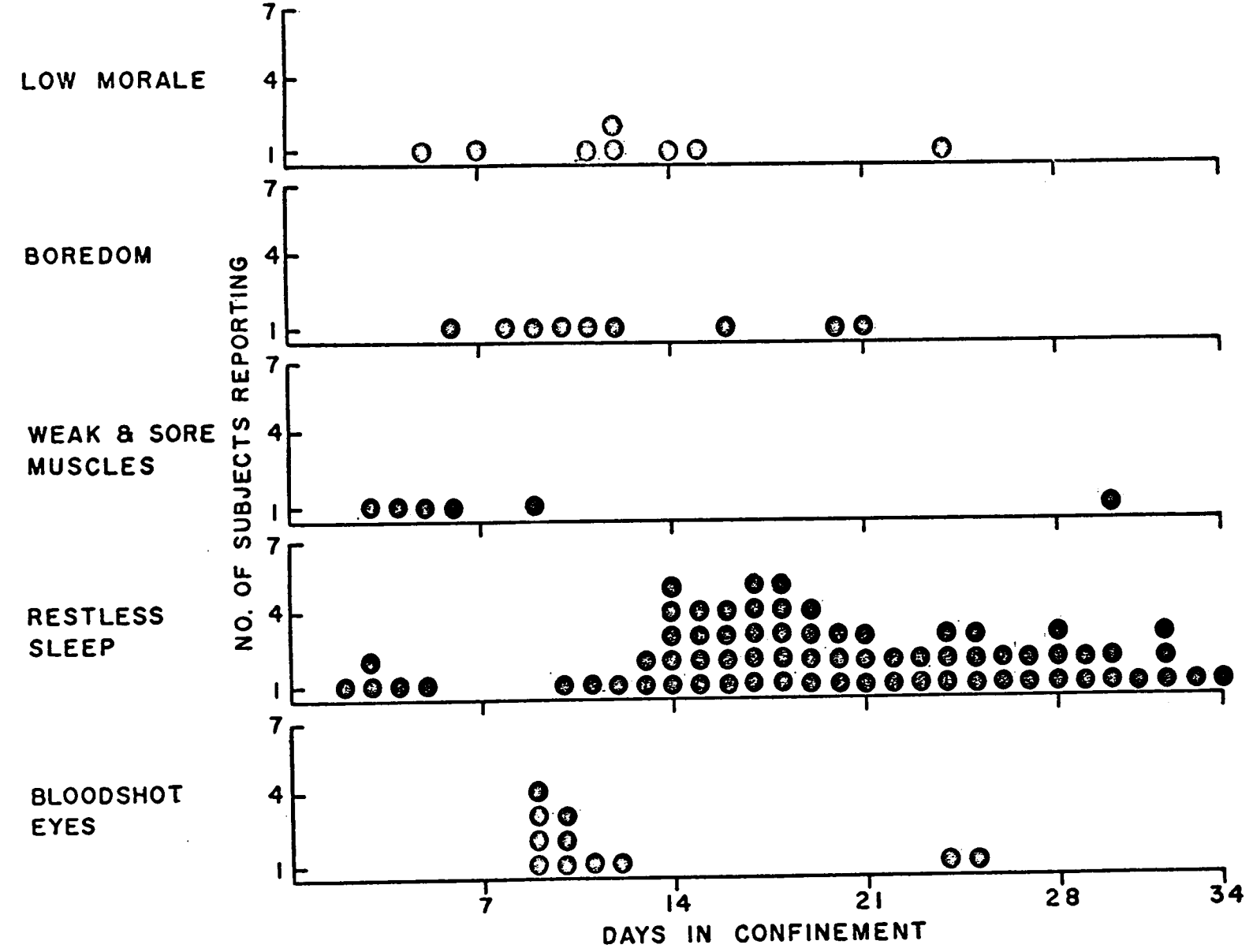


FIG. 10-30 FREQUENCY OF SPECIFIC SYMPTONS OF CONFINEMENT REPORTE

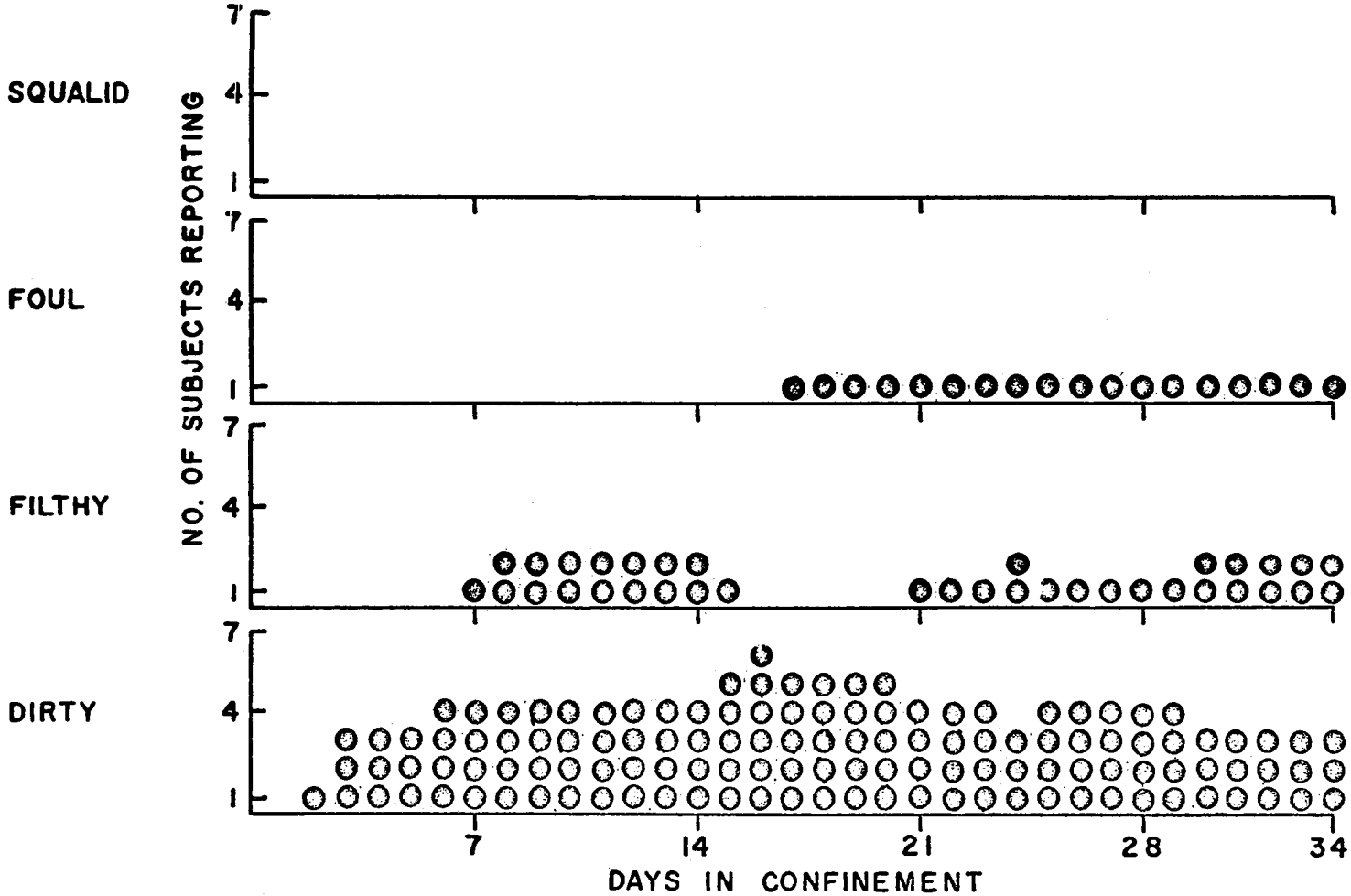


FIG. 10-31 FREQUENCY & TYPE OF DIRTINESS REPORTED

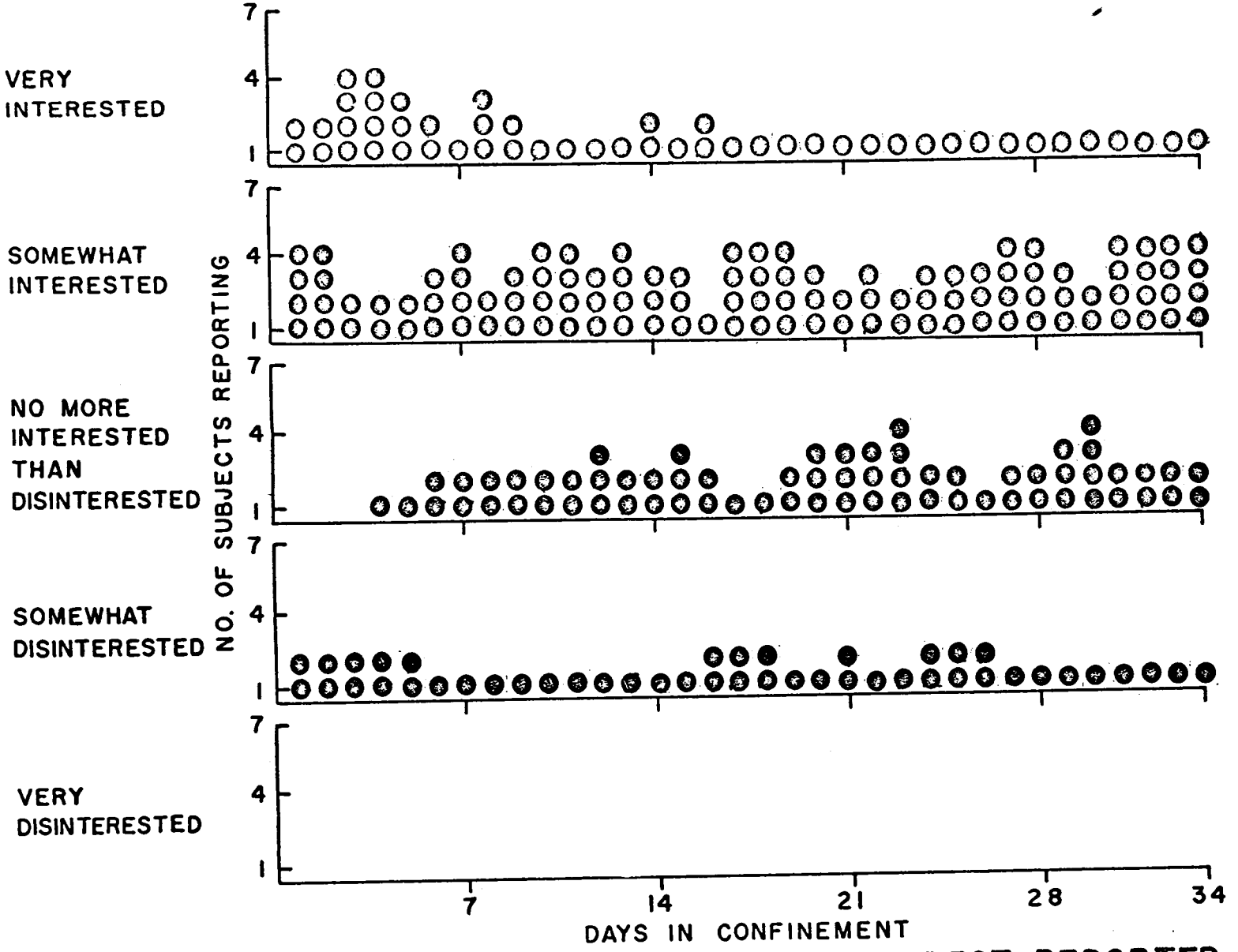


FIG.10-32 FREQUENCY OF DEGREE OF INTEREST REPORTED

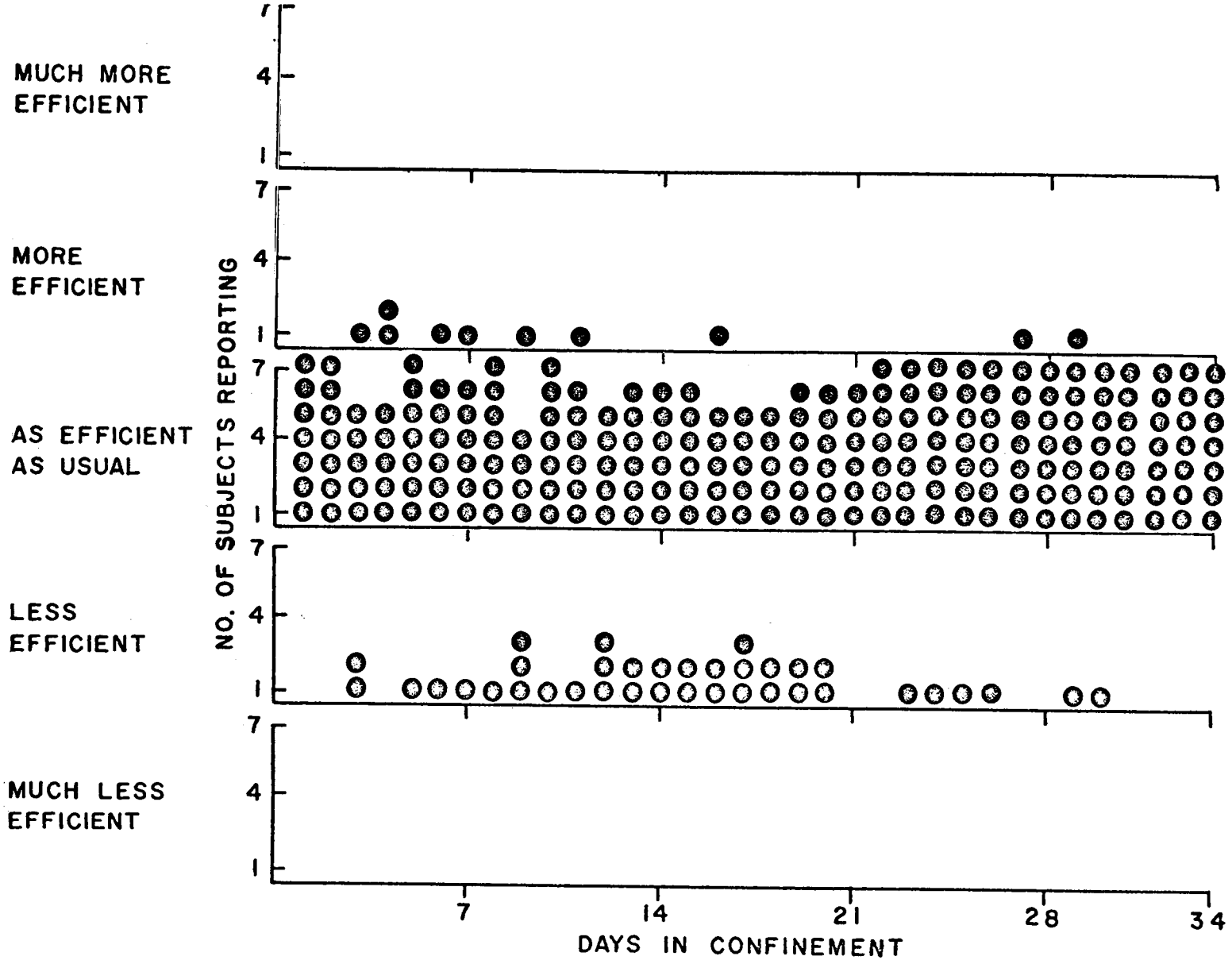


FIG.10-33 FREQUENCY OF DEGREE OF OVERALL EFFICIENCY REPORTED

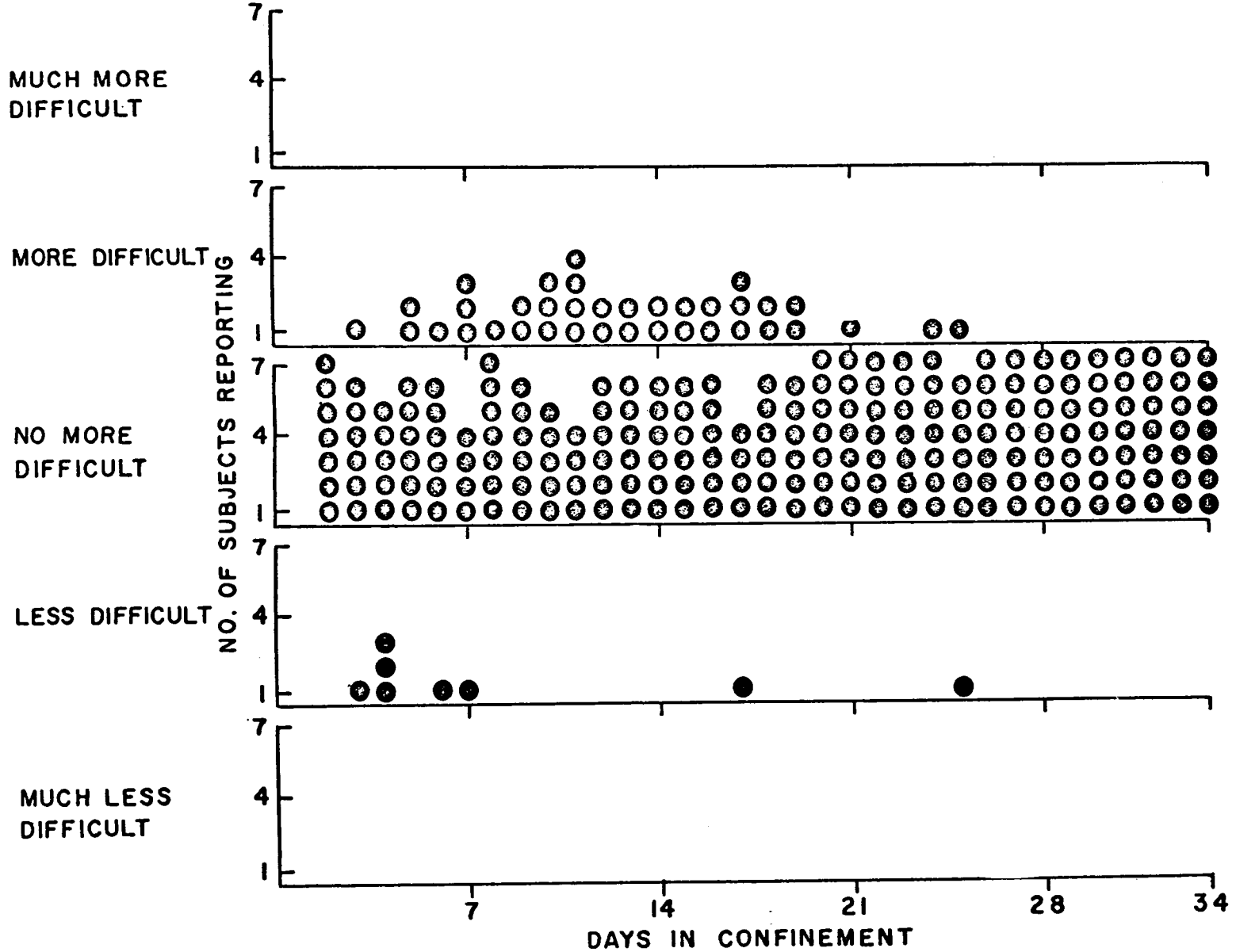


FIG. 10-34 FREQUENCY OF DEGREE OF EASE OF CONCENTRATION REPORTED

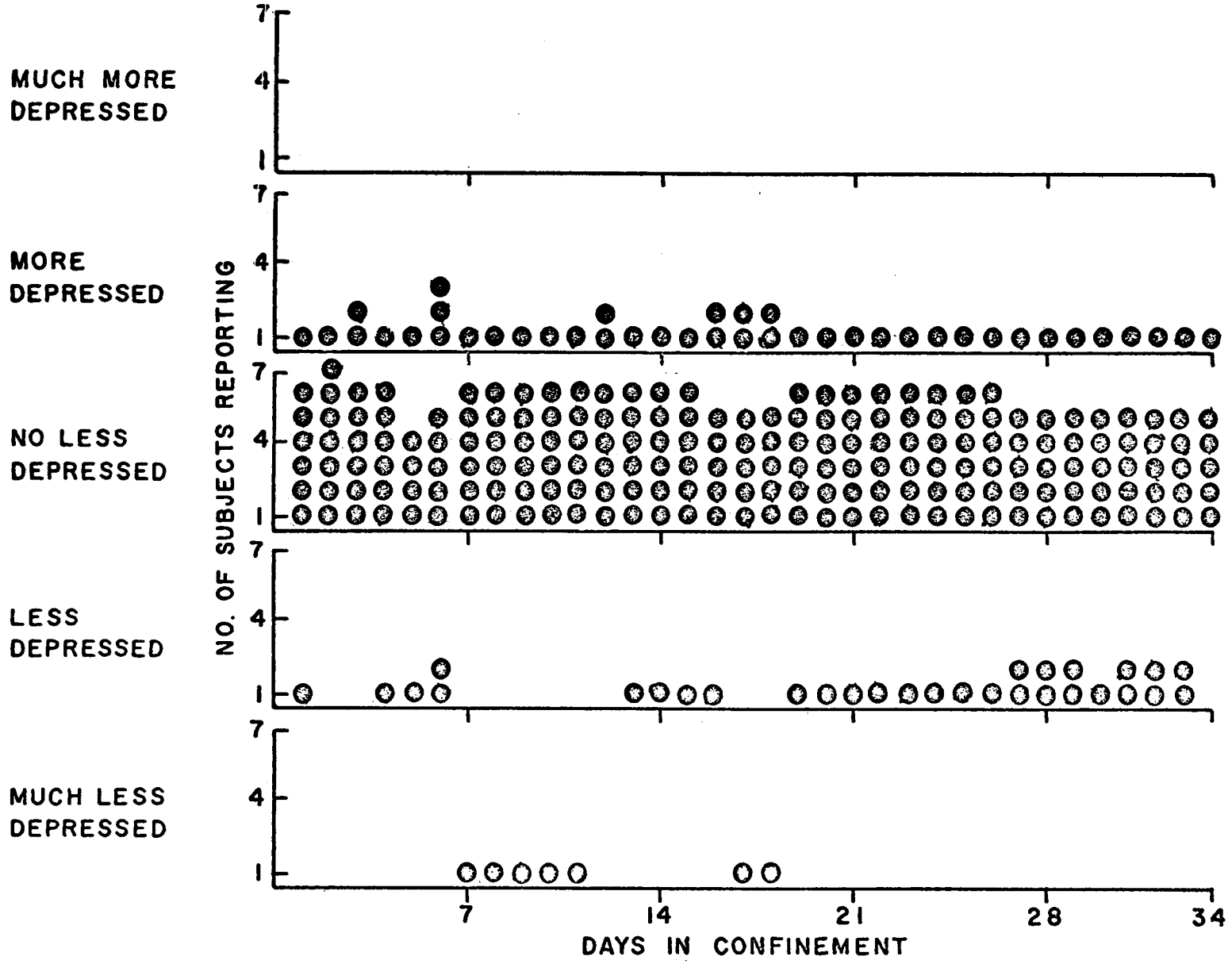


FIG.10-35 FREQUENCY & AMOUNT OF DEPRESSION REPORTED

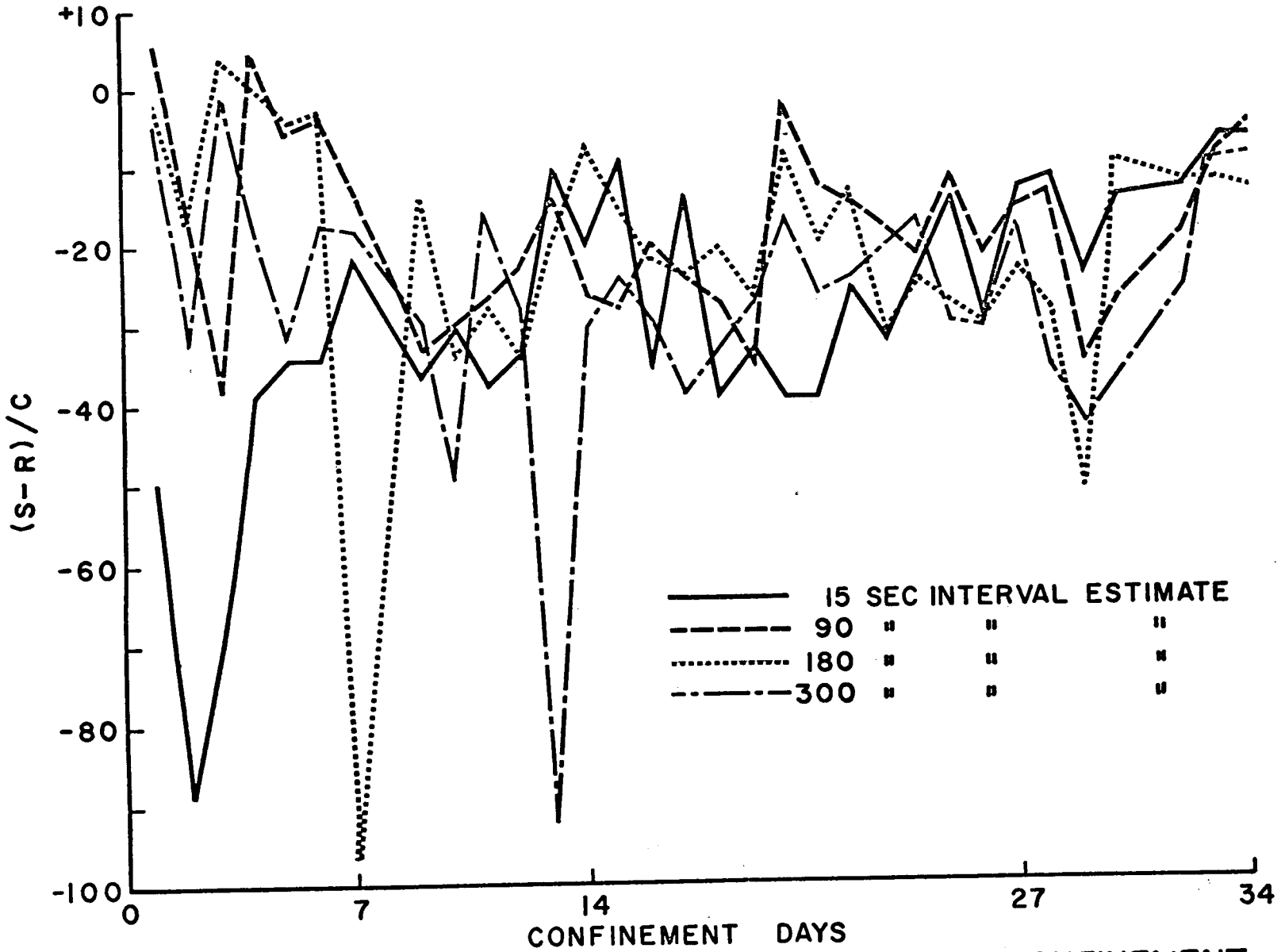


FIG.10-36 TREND OF ALL TIME ESTIMATES DURING DAYS OF CONFINEMENT

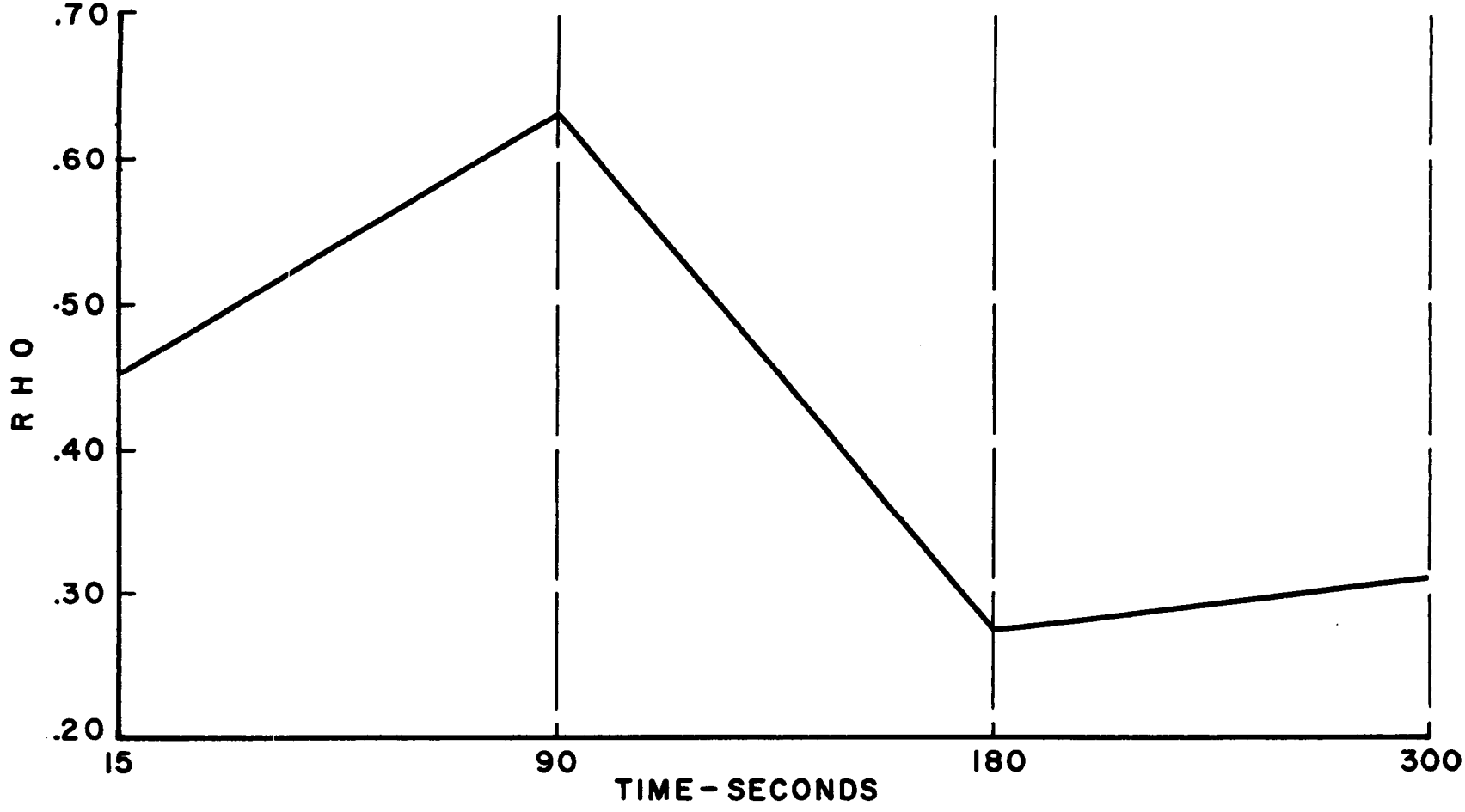


FIG.10-37 CORRELATION BETWEEN MEAN TIME ESTIMATES AND MANIFEST ANXIETY SCORES

APPENDIX A

PAIRED-ASSOCIATE LISTS

LIST #1	LIST #2	LIST #3
WOM-chamber *	WIS-cigarettes *	WIL-shower *
BEL-beaver	BER-fan	BEV-wide
VIF-bored *	VIN-liberty *	VIK-irritable *
BAL-cheap	CEN-to	CIN-ought
VIS-sleep *	TIG-home *	TEX-isolate *
BUR-border	BAS-circuit	BEC-shed
VAC-clean *	WAT-female *	WAK-wife *
COL-class	BOL-lion	BUL-irrigate
BIV-sky	VIC-time *	VES-outside *
WEV-beer *	CUS-hope	DAR-ivory

* affective words

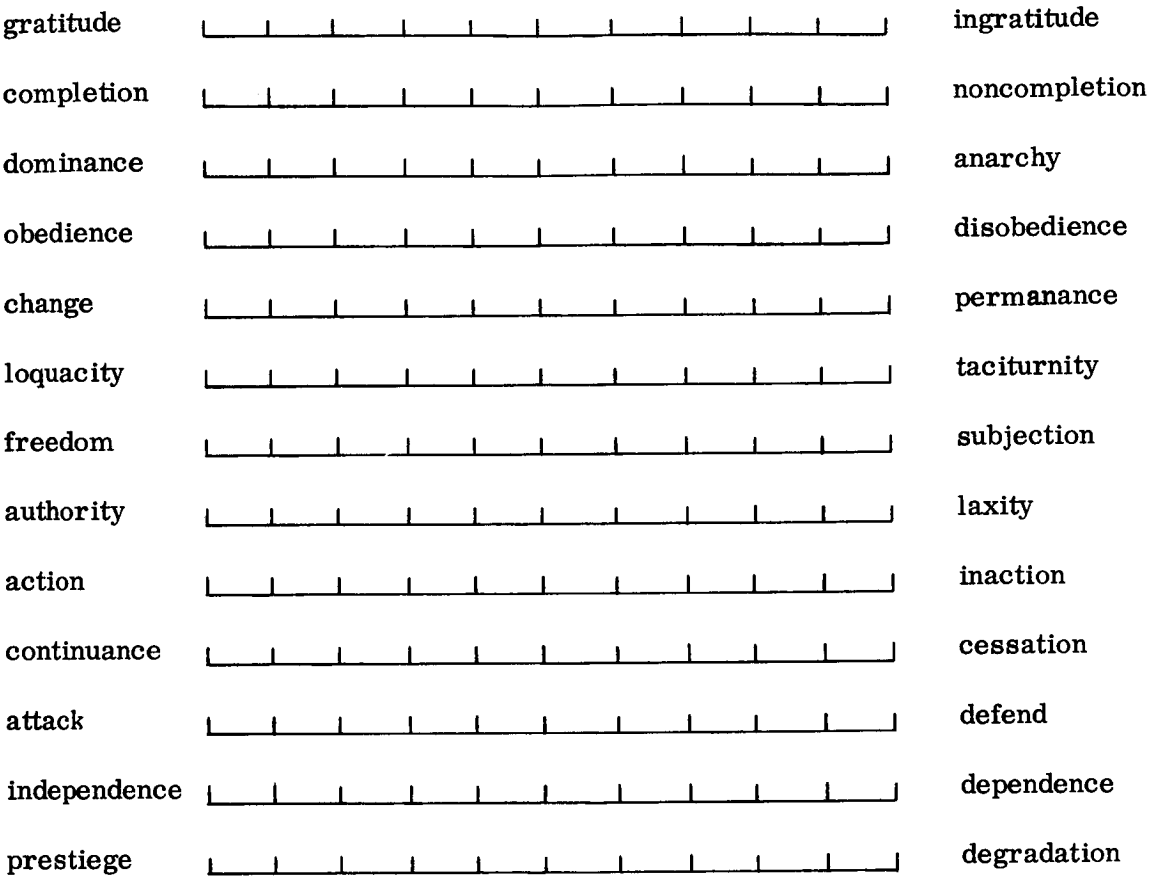
APPENDIX B

Cognate Nonsense Syllables and their Corresponding Words

Cmpastn-Compensation	Astna-Astronaut *
Desr-Dresser	Comdr-Commander *
Explan-Explain	Flgt-Flight *
Imslv-Impulsive	Grp-Group *
Intd-Intend	Hotr-Hotrod *
Inad-Inward	Ledr-Leader *
Mrn-Morn	Pil-Pilot *
Nd-Nod	Sed-Speed *
Rver-Rover	Sovpi-Stovepipe *
Tid-Told	Tig-Tiger *

* words thought to reflect motivations of these subjects

TIRED


gratitude
ingratitude
completion
noncompletion
dominance
anarchy
obedience
disobedience
change
permanance
loquacity
taciturnity
freedom
subjection
authority
laxity
action
inaction
continuance
cessation
attack
defend
independence
dependence
prestiege
degradation

APPENDIX D

DAILY QUESTIONNAIRE

Your Number_____

APPENDIX (Cont'd)

DAILY QUESTIONNAIRE

1. How irritable have you been in your relations with the other men in the chamber in the last 24 hours as compared to other days in the chamber? (check one)

Days-	1	5	10	15	20	25	30	35
infuriated								
enraged								
angered								
provoked								
impatient								

2. In the last 24 hours, how anxious would you say you were in comparison to other days in the chamber? (check one)

Days-	1	5	10	15	20	25	30	35
fearful								
apprehensive								
uneasy								
uncomfortable								

3. The worst noises that you noticed in the last 24 hours, would you classify them as: (check one)

Days-	1	5	10	15	20	25	30	35
a racket								
a din								
a hubbub								
a clamor								
noises								

4. In comparison to other days in the chamber, choose whether today you have been more active or less active and how much more: (choose one in either of two categories)

Days-	1	5	10	15	20	25	30	35
INACTIVE-choose:								
inert								
torpid								
dormat								
inactive								
sluggish								
ACTIVE-choose:								
strenuous								
vigorous								
energetic								
active								
busy								

5. In the last 24 hours, have you noticed any of the following in yourself: (Choose one)

Days-	1	5	10	15	20	25	30	35
BLOODSHOT EYES	/	/	/	/	/	/	/	/
RESTLESS SLEEP	/	/	/	/	/	/	/	/
WEAK AND SORE MUSCLES	/	/	/	/	/	/	/	/
BOREDOM	/	/	/	/	/	/	/	/
LOW MORALE	/	/	/	/	/	/	/	/

6. Would you say that now (in the last 24 hours) your reason for completing this study was to: (check at least one)

Days-	1	5	10	15	20	25	30	35
satisfy an inner urge that prompts me to complete this study	/	/	/	/	/	/	/	/
realize the contemplated result of completing this study	/	/	/	/	/	/	/	/
take advantage of the opportunities offered by acceptance of the conditions of this study	/	/	/	/	/	/	/	/
receive a reward that will show you as better than those that you feel are your competitors	/	/	/	/	/	/	/	/
stimulate your emotions and/or your imagination in this study	/	/	/	/	/	/	/	/
none of the above	/	/	/	/	/	/	/	/

7. How dirty would you day that you felt or you felt your surroundings were in the last 24 hours as compared to other 24 hour periods in the chamber? (check one)

Days-	1	5	10	15	20	25	30	35
squalid	/	/	/	/	/	/	/	/
foul	/	/	/	/	/	/	/	/
filthy	/	/	/	/	/	/	/	/
dirty	/	/	/	/	/	/	/	/
none of the above	/	/	/	/	/	/	/	/

8. How interested were you in the duties that you have performed in the last 24 hours? (check one)

Days-	1 5 10 15 20 25 30 35
very interested	/ /
somewhat interested	/ /
no more interested than disinterested	/ /
somewhat disinterested	/ /
very disinterested	/ /

9. How would you say your overall efficiency has been in the past 24 hours? (check one)

Days-	1 5 10 15 20 25 30 35
much more efficient than usual	/ /
more efficient than usual	/ /
as efficient as usual	/ /
less efficient than usual	/ /
much less efficient than usual	/ /

10. How difficult have you found it to concentrate on a task in the past 24 hours? (check one)

Days-	1	5	10	15	20	25	30	35
much more difficult than usual	/	/	/	/	/	/	/	/
more difficult than usual	/	/	/	/	/	/	/	/
no more difficult than usual	/	/	/	/	/	/	/	/
less difficult than usual	/	/	/	/	/	/	/	/
much less difficult than usual	/	/	/	/	/	/	/	/

11. How depressed have you felt in the last 24 hours as compared to previous days? (check one)

Days-	1	5	10	15	20	25	30	35
much more depressed than usual	/	/	/	/	/	/	/	/
more depressed than usual	/	/	/	/	/	/	/	/
no less depressed than usual	/	/	/	/	/	/	/	/
less depressed than usual	/	/	/	/	/	/	/	/
much less depressed than usual	/	/	/	/	/	/	/	/

APPENDIX E

SYMBOL CANCELLATION
Page # 2

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Part III

SECTION 11

EFFECT OF DIET AND ATMOSPHERE ON INTESTINAL AND SKIN FLORA: (SUMMARY REPORT)*

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SECTION 11

GENERAL DISCUSSION OF RESULTS AND CONCLUSIONS

INTRODUCTION

The health and welfare of the astronaut is of prime importance during space flight so that he is capable of rendering peak performance at all times during his mission. One factor that can impair the health of the astronaut is related to the microbial flora which live in or on his body or which are present in his environment. For this reason it is necessary to study the effect of conditions of space flight upon these indigenous microorganisms, since knowledge of the alterations in the occurrence, and metabolism of individual microorganisms, or in the balances of organisms under these conditions is necessary in maintaining the health and welfare of these astronauts.

Certain conditions of space flight such as personal hygiene procedures, wearing of space suits, atmospheric composition and pressure, confinement and a space-type diet are particularly apt to influence the microbial flora of the astronaut. For example, the type and frequency of personal hygiene procedures such as bathing, brushing of teeth, shaving and toilet routines play an important role in the establishment of the resident flora of the exposed areas of the human body. A requirement of space travel is the minimal use of personal hygiene procedures, which often are limited to the use of face cloths without a cleansing agent and brushing the teeth without a dentrifrice. The effect of the less complete hygiene methods on the resident microflora of men living under these conditions is important. Microbial studies underway at Wright-Patterson under contract AF33(615)-1814, Biomedical Criteria for Personal Hygiene (1), where men have been confined to a chamber under ambient conditions for four weeks and have used minimal personal hygiene procedures indicate that certain bacterial populations tend to buld up in some body areas, particularly in areas of heavy perspiration; but that no serious health problems have developed in these men. However, potentially pathogenic bacteria have been isolated, and further study superimposing certain space stresses are needed to evaluate this finding as related to space flight.

The wearing of a closely fitting space suit, with air or oxygen circulating through it for prolonged periods, will create an altered environment for the microorganisms on the skin of the astronaut. Problems may arise both with respect to possible areas of contact irritation and to the effects of humidity. The close-fitting suit may rub a certain body area, creating an abrasion ideal for microbial infection. Areas of the body where perspiration is normally heavy may remain damp, while areas near the air intake may be abnormally dry. The variable humidity plus the altered atmospheric flow may well influence the bacterial population. In fact the high oxygen atmosphere itself coupled with reduced atmospheric pressure may also influence the character of the bacterial flora.

The close confinement imposed by space flight will cause considerable interaction between the microbial flora of the several astronauts with each other and with their environment. The spread of potentially pathogenic microorganisms from a "well" carrier to another astronaut directly or by way of the common environment presents a problem and microbiological studies conducted on men in simulated space chamber experiments under contracts NASr-92 (2) and AF33(615)-1814 (1) have shown the probable transfer of pathogenic bacteria from one subject to the others. The mode and frequency of such transfer of potential pathogens is of importance in maintaining the flight crew efficiency.

Diet is known to influence the intestinal flora of animals and recent studies conducted under Wright-Patterson contract AF33(615)-1748 (3) at Republic Aviation Corporation have shown that a space-type diet affects the human fecal flora, especially with respect to the increased occurrence of a group of gas-forming, proteolytic anaerobes. Since flatulence and odors from intestinal gas may be a problem in space flight, the influence of diet on the intestinal flora must be clarified.

From this discussion it is evident that several questions remain to be answered relating to the microbiological aspects of space flight. Specifically, does the bacterial population of the astronaut or his environment build-up during space flight and if so, with respect to which type of organisms? Do any of the factors of space flight favor this buildup? Is this buildup harmful to the health and well-being of the astronauts? Do any of the pathogenic organisms present a problem during space flight? Are the astronauts healthy carriers of potentially pathogenic organisms and do they transfer these organisms to fellow crew members? If so, does this create a health hazard? If any of the foregoing considerations create problems, what can be done to alleviate them? Only a comprehensive microbiological study on humans under simulated space conditions can offer the answers to these questions.

For these reasons an extensive study was done on the types and numbers of microorganisms present and the frequency of their occurrences in six body areas of six young men subjected to certain conditions of space flight and their two controls for a 34 day period in a recent study in the Aerospace Crew Equipment Laboratory chamber at the Naval Air Engineering Center, Philadelphia, Pa., 19112. Under contract NAS-9-4172, samples for microbiological culturing were taken at the start of the trial and at frequent intervals during the test, and the kinds and numbers of bacteria isolated in each sampling period were studied. The bacteria present in their environment were also determined in the same manner.

The experiment was designed in such a way that the six experimental subjects and their controls used the same minimal personal hygiene procedures and ate the same dehydrated foods throughout the entire experiment. Both the test subjects and their controls lived in confinement which in the case of the controls was maintained at ambient conditions. This was in contrast to the test subjects who were

maintained at an altitude of 27,000 feet under 100% oxygen for a total of three weeks and wore space suits during the last two weeks at altitude and for one week post-altitude. The control subjects wore space suits during the last three weeks of the trial.

Since the microbiological determinations were carried out throughout the entire experimental period, the effect of the various experimental conditions can be evaluated in terms of their influence on the various members of the microbial population.

The scope of the work can probably be best appreciated by quoting several figures: 1378 samples were taken from the body areas and the environment as well as from the urine bottles, wash water and the suits, which resulted in 18,500 odd primary cultures. To study these cultures, over 150,000 plates and tubes of media were used in secondary culturing and over 10,000 slides were made and observed. The results of these studies have been summarized in table form (reference 11) and present the total numbers and occurrences of aerobic and anaerobic bacteria found on the various body areas tested and in the environmental areas of the chamber and cottage.

METHODS

Eight young men from the United States Armed Forces were subjects in a chamber trial to determine the effect of a pure oxygen atmosphere at altitude combined with the wearing of space suits, minimal personal hygiene procedures, and eating a space-type diet upon their health and well-being. Six men were confined to the Aerospace Crew Equipment Laboratory chamber for a period of 34 days and two men served as controls in a nearby installation termed the "cottage". The exact experimental conditions have been defined elsewhere, but in brief the subjects in the space chamber were under ambient conditions for one week, at altitude with no space suits for one week and with space suits for two weeks, after which the chamber was maintained under ambient conditions, but the subjects wore the space suits. The men in the cottage were under ambient conditions at all times but wore space suits for the last three weeks of the trial. All eight men ate the dehydrated food and used the minimum personal hygiene procedures of washing only the face and hands with a face cloth with no cleanser and brushing the teeth with no dentrifrice for the entire experimental trial.

The microbiological samples were taken according to the schedule indicated in Table 11-1. All eight men were scrubbed thoroughly, as were the chamber and cottage, prior to the first sampling. The exact details of the collection and processing of the samples are contained in Appendix A, but in brief two swabs-- one for aerobic and one for anaerobic culturing, were taken from the following body areas: throat, buccal area, axilla, groin, glans penis, and eye (first sampling only) for a total of 10 samples from each area and fecal samples were obtained

approximately twice a week as indicated in Table 11-2. Fourteen samples were taken from each of several environmental areas in both the chamber and the cottage as indicated in Table 11-1, by means of sedimentation plates or swabs. In addition cultures were made from the urine collection bottles, water squeezed from face cloths and from certain areas of the suit prior to donning and from the suit vents after donning at stated intervals indicated in Table 11-1.

The detailed anaerobic and aerobic experimental procedures for obtaining each sample and the technique and media used for the primary culturing for each of the body areas is included in Appendix A. The culturing of the samples from the body areas was done at the site of the Aerospace Crew Equipment Laboratory chamber and the culturing was done immediately following the collection of the samples by the subjects. The fecal samples were cultured immediately following elimination on an individual basis. After proper incubation the primary cultures on solid media were then transferred to Republic Aviation Corporation laboratories for processing according to the schema set forth in Appendix A. Selected broth cultures from the anaerobic series were transferred into agar shakes at the primary culturing site for transport to Republic Aviation Corporation's laboratories. The cultures that were made from the environmental areas and from the miscellaneous items were treated in the same manner as the cultures from the body areas.

Slides were made from all aerobic and anaerobic cultures showing growth and slides were also made of all original samples at the time of primary culturing. None of the samples collected appeared to be abnormal in character.

The data from both the aerobic and anaerobic culturing (when done) for each body area sampled, from the feces, the environmental areas, and the miscellaneous items are recorded in tabular form and are considered both with respect to the microflora of each subject or environmental area and with respect to each sampling period which reflects the effect of the various test conditions.

The data recorded in the tables refers to the subjects by number as shown in the following list:

Subject Number	Area
1	Chamber
2	Chamber
3	Chamber
4	Chamber
5	Chamber
6	Chamber
7	Cottage
8	Cottage

RESULTS

1. The total number of colonies on aerobic blood plates in all body areas and in the environment increased as the experiment progressed. The buildup in the axilla, groin, glans penis, and buccal area reached a plateau by the mid-point of the experiment and then stayed relatively constant or decreased, while the buildup in the throat flora was more variable. Although the counts from all body areas fluctuated, consideration of the colony counts from the blood plates incubated under CO_2 from the skin areas would eliminate many of these fluctuations. Bacterial buildup was larger and more irregular in the chamber than in the cottage.

2. The types of microorganisms found in each of the body areas and feces were in good agreement with those regarded in published reports as normal body microflora for that area of the body. Whereas the same types of bacteria usually grew under both the aerobic and anaerobic conditions used in this experiment, several predominating types grew better under CO_2 incubation on primary isolation. The kinds of microorganisms found in the environment reflected the hardier types of body microorganisms isolated from the subjects.

3. The bacteria involved in the buildup of microflora in the axilla, groin and glans penis were staphylococci or micrococci and corynebacteria, with the corynebacteria predominating in the groin and glans penis of the subjects and in the axilla of four of the subjects in the last sampling periods. Streptococci, and to some extent staphylococci or micrococci, were involved in the increase in microorganisms in the throat and buccal area. The buildup of corynebacteria in most instances represented a relative increase of the rod over the cocci toward the end of the trial while the increase of streptococci seemed only to indicate an increase in the numbers of the type of bacteria that had predominated throughout the experiment. The buildup was most marked in the body areas where sweat is a factor. The strict anaerobes peptococcus and veillonella may have built up in the glans penis and throat, respectively. The bacteria involved in the buildup in the environment were largely staphylococci or micrococci, gram negative rods and, to a lesser extent, streptococci.

4. The buildup of bacteria on the body areas occurred in such a pattern that it appears to be the result of the minimal personal hygiene procedures with the subjects in a confined area and the increase in bacteria was of such a nature that it does not appear harmful for a 34 day period.

5. In the feces strict anaerobes represented over 95 percent of the predominating bacteria and outnumbered the aerobes by more than 1000 to 1. In general, the types of fecal anaerobes isolated, as well as the frequency of their occurrence, agreed well with the distribution of the bacteria described as FA types on the basic NASA study with one significant exception. After the subjects had been on the experimental diet for about two weeks, the type of fecal anaerobes designated as

GD started to increase and continued to be isolated frequently for the remainder of the trial. These GD types of organism which form gas, black-slime and are proteolytic, were previously found associated with a space-type diet eaten by subjects on a study conducted by Wright-Patterson Air Force Base under contract AF33(615)-1748(3). This change in fecal anaerobes probably is diet connected. Another interesting finding was an increase in the diversity of fecal anaerobes, starting about a week after the men changed to the experimental diet and continuing for about two weeks, after which the variety of fecal anaerobes decreased to the original level, a finding similar to that observed in primates when their diet was shifted on a nutrition study conducted by 6571st Aeromedical Research Laboratory at Holloman Air Force Base under contract AF33(600)-4124(7).

6. Other experimental conditions, such as the 100% oxygen at 5 psia and the wearing of space suits did not seem to affect the body flora materially, as there was no marked difference in the microflora of the subjects when these experimental conditions prevailed.

7. The potentially pathogenic bacteria, Shigella Poly B, Bethesda-Ballerup and coagulase-positive phage typable staphylococci were isolated from certain subjects during the experiment; but these bacteria did not cause overt illness and did not appear to transfer readily from one subject to another.

8. Only one apparent transfer of a bacterium from one subject to another occurred when Bethesda-Ballerup was isolated from Subject 4 after having been isolated from Subject 6 previously. The organism did not seem to implant well, as it was isolated only once from the second subject. The Shigella Poly B and phage typable staphylococci did not transfer to other subjects.

9. The types and numbers of bacteria found in the wash water from the "space" sink contributed to the abandonment of the use of these sinks. The microbiological examination of the wash water from the wash cloths used in the latter part of the experiment indicated they were unsatisfactory also when used continuously.

10. The kinds and numbers of bacteria isolated from the neck of the urine bottles indicated that these bottles could serve as a source of undesirable contamination of the environment.

11. The method of cleaning the space suits left a sizeable residual contamination of typical body organisms which could be transferred to the body of the wearer. The air coming from the vent of the space suits during wearing is contaminated, but not excessively with body microflora.

DISCUSSION

The microbiological determinations carried out in this study were designed to detect the effect of various conditions typical of space flight including minimum personal hygiene procedures, confinement, space type diets, space suits and 100% oxygen at 5 psia upon the microflora of the subjects and their environment. To do this both aerobic and anaerobic cultural procedures were used to study the kinds and numbers of bacteria present in several body areas including the axilla, groin, glans penis, throat and buccal area as well as the feces and in several areas of the chamber and cottage. The samples were taken frequently throughout the experimental period, at intervals planned to reflect the changing conditions of the experiment, especially the effect of 100% oxygen at altitude to which the six men in the chamber were subjected. Two men living in the cottage served as controls with respect to the 100% oxygen at altitude.

The first question involved the effect of the minimal hygiene procedure coupled with confinement on the numbers of bacteria on the man and his environment, and both plate counting and serial dilution techniques were employed to determine whether the total numbers of bacteria increased during the trial. Both methods showed that there was a buildup of bacteria in all body areas and in both environments as the experiment progressed. The buildup was greatest in the body areas where sweating occured, the axilla and groin, and was also pronounced in the buccal cavity where the effects of minimal oral hygiene probably were felt. The buildup was greater in the chamber where six men lived than in the cottage, and the numbers of microorganisms in the chamber fluctuated more than in the cottage for an unexplained reason. This buildup usually occurred gradually and then tended to plateau or even to fall off somewhat rather than to continue rising at each testing period. This suggested that more prolonged confinement per se probably would not result in a much greater buildup of microorganisms.

The next important factor to be considered is the types of bacteria involved in the buildup in each body area and the environment. To do this, it is first necessary to establish what bacteria are present initially in these areas and then to follow the increase or decrease of each type of microorganism.

To establish the types of microorganisms present, appropriate microbiological procedures were employed to identify the various bacteria cultured from the body areas and environment. The results of these studies showed that the aerobic microorganisms found on the various body areas were in general in good agreement with those reported in the literature for normal adults and that the microflora of the chamber and cottage reflected to a certain degree the more hardy microorganisms such as staphlococci, or micrococci, streptococci and gram negative rods present on the body of the occupants. Certain types of bacteria such as neisseria and hemophilus often reported as part of the normal flora were isolated infrequently from these subjects, as were certain fungi such as Pityrosporum ovale.

The failure to culture P. ovale was probably due to the deficiency of an essential oil in the medium. Corynebacterium acnes was not identified among the isolants in this study, probably because the definition of this organism as an obligate anaerobe was strictly adhered to. Of interest also was the lack of yeasts in the axilla, although these organism were isolated from other body areas.

To determine which of the types of bacteria were involved in the buildup of microorganisms two procedures were used. The characteristics of distinctive colonies found in the greatest numbers on the blood plates were linked to bacteria selected for identification, and using this as a basis, estimates were made of the predominating organism on each plate. To check this estimate, microscopic observations were made to determine the morphological types of bacteria occurring in the highest broth culture in the dilution series of each sample. Excellent agreement was obtained between these two methods and from these observations, it was evident that staphlococci or micrococci and corynebacteria were the organisms involved in the buildup of bacteria in the axilla, groin and glans penis, with corynebacteria being the most predominant in the latter part of the experiment in the groin and glans penis and on four subjects in the axillar area. Streptococci with some staphylococci or micrococci were principally involved in the buildup in buccal area and the throat.

The organisms which built up in the chamber and to a lesser extent in the cottage were staphylococci, gram negative rods and streptococci, probably from the bodies of the occupants.

Because of the aerobic techniques used in enumerating the bacteria, no strict anaerobes were specified as being involved in a bacterial buildup on any of the body areas, excluding the feces and during the studies on strict anaerobes, only the peptococci isolated from the glans penis offer any evidence of increasing in prevalence as the experiment progressed. However, since strict enumeration of the obligate anaerobes is difficult, the increased incidence of this type of bacterium in the glans penis area of several subjects during the last few sampling periods may not indicate a true numerical buildup.

From the data presented and discussed, it is evident that the minimum hygiene procedures employed in this experiment coupled with confinement did bring about the buildup of microorganisms both in the body areas tested and in the environment, which reached a plateau about midway in the experiment and remained on this plateau or declined. This increase in bacteria seemed to be associated with the microflora usually found in that area of the body and did not seem to harm the subjects. The bacteria in the environment also reached a plateau, after which no further substantial increase occurred and the most numerous bacteria in the environment apparently came from the subjects.

These findings are strengthened by their general agreement with the results of the series of similar tests conducted at Wright-Patterson Air Force Base (1).

The strict anaerobessisolated in this study were principally from the feces, where they comprise over 95% of the predominating flora. Anaerobes were shown to outnumber aerobes by about 1000 fold and for this reason the work on fecal bacteria in this study emphasizes the strict anaerobes. The techniques for isolating these organisms and the key for grouping similar bacteria has been devised under NASA contract NASw-738(4), and the discussion of the results involving the fecal anaerobes will be based on the data from the NASA study on normal males.

In general the fecal anaerobes isolated during this experiment correspond well both with respect to kinds and frequency of distribution to the NASA study. Most of the FA types defined in the NASA experiment were found in this study and the most and least prevalent types were similar on both studies. There was more variation between individuals than between sampling periods in the occurrence of the FA types.

There was one notable point of divergence between the two studies in the increased occurrence on this experiment of strict anaerobes of the GD type, a group of black slime, gas forming proteolytic bacteria that were seldom found in the NASA study. The GD types occurred more frequently in the latter part of the trial in a pattern similar to, but not as marked as that which was found in subjects fed a space-type diet at Wright-Patterson Air Force Base (3). The pattern in both of these trials suggests that diet was involved in the increase in isolations of the GD types.

Also worthy of comment is the increase in diversity of the fecal anaerobes after the men had been on the space type diet for about a week followed by a decrease in the diversity about two weeks later. This increase in the variety of fecal anaerobes present in a group of subjects has been noted before, during a nutrition study conducted with primates under contract AF29(600)-4555(5) which occurred whenever there was a shift from one diet to another.

Thus the findings with respect to the fecal anaerobes in this study are in good agreement with other similar studies and indicate that diet is the most important factor influencing the fecal anaerobes.

The effect of 100% oxygen at altitude and the wearing of space suits during certain periods in the trial were other experimental variables. There was little, if any evidence that either of these factors influenced either the body, fecal or environmental microflora. The possible exception was the seemingly smaller fluctuations in the bacterial counts of the axilla and groin of the cottage inhabitants as well as in the environmental bacterial counts in the cottage itself. This may have been due

to the smaller number of men in the cottage with the resultant quieter conditions or to a more careful sampling technique practiced by these men.

An important microbiological consideration in the confined environment of a space capsule is the presence of potential or frank pathogens which could affect the well-being of the space travelers. During the course of this study particular attention was paid to the isolation of any such bacteria, and three types of potentially dangerous bacteria were isolated. From the first fecal sample from Subject 6, as well as from the seventh fecal sample, the potentially disease-producing Bethesda-Ballerup was isolated and typed, and this same subject repeatedly showed the pathogen, shigella, during the most of the experiment. The shigella was not found in any other subject, but the Bethesda-Ballerup was isolated from Subject 4 in the second fecal sample. Neither subject appeared to be ill.

The other incident involved the isolation of several coagulase positive, phage typable staphylococci from the bodies of several of the subjects as well as from their environment. One subject developed staphylococcus-infected pustules, but the potentially pathogenic staphylococci were not involved. Thus dangerous bacteria were present throughout the experiment but fortunately in no instance did the possibly dangerous bacteria cause an overt illness in the subject, and these bacteria did not build in the subject's bodies or their environment. However, a microbiological examination of the subjects prior to the experiment, would have revealed the presence of these bacteria and proper treatment could probably have been instituted to eliminate the possibility of trouble from these bacteria.

Another important microbiological consideration is the transference of bacteria, particularly pathogens, from one subject to another. In this experiment there were three good opportunities to determine whether bacteria are transferred, two of which involved the fecal bacteria, Bethesda-Ballerup and Shigella Poly B. There was no transfer of the shigella, but it appears that one instance of the transfer of the Bethesda-Ballerup did occur. However this bacterium apparently did not implant firmly, as it was isolated from the second subject only once.

All coagulase positive staphylococci were studied for phage type and among eight typable cultures, five different phage types were found. No instance of transfer of a typable staphylococci from one subject to another was demonstrated.

Another possible instance of transference involved the peptococci. Peptococcus 1 was found only once (in Subject 5) prior to the fifth sampling period, after which this type of organism was isolated in several subjects. However, this "spread" of Peptococcus 1 from a subject confined in the chamber to two men living in the cottage weakens the transference concept in this instance unless the transfer was effected in the two weeks prior to the start of the experiment by a light inoculum of Peptococcus 1 that required several weeks to implant firmly.

From these data, it would appear that transference can occur under certain circumstances, but it did not seem to occur frequently nor to have lasting effect in this trial.

Additional studies were made on the bacterial content of the wash water coming from the face cloths of the subjects. During the initial week of the experiment two men shared each of four "space sinks" for washing purposes. When the wash water from these space sinks was tested microbiologically, the numbers of bacteria found coupled with the presence of many coliform organisms contributed to the decision to abandon this method of washing. The substitution of clean face cloths twice during the trial which were rinsed in the regular wash bowl temporarily cleared up this undesirable situation, but as soon as the wash cloths were used continuously, the same unsatisfactory condition developed, although not quite as acutely.

CONCLUSIONS

The experimental conditions imposed on the subjects in this trial did not appear to create a microbiological situation that would be harmful to the subjects for the length of time encompassed in this test. A buildup of bacteria did occur both with respect to the various body areas examined and to the environmental areas in the chamber and cottage, but the increase in bacteria appeared to have plateaued or decreased before the end of the trial and most of the bacteria involved in the buildup are generally not considered to be pathogenic. Pathogenic bacteria were brought to the experimental site in or on the subjects, but these bacteria did not cause a frank illness and with one possible exception did not appear to be transferred from one subject to another.

The predominating fecal flora was affected to some extent apparently by the diet eaten, and the types of bacteria that occurred after the subjects had been eating the experimental diet for several days were heavy gas-formers which might produce increased flatulence.

The bacterial buildup in the wash water and on the neck of the urine bottle was caused by generally undesirable types of bacteria, and the suits showed many residual microorganisms of the type associated with the human body.

As the result of these studies, recommendations for consideration in future studies include a thorough microbiological study to be done on future subjects to detect carriers of potentially pathogenic bacteria prior to the experiment, better methods of cleaning the face and hands, collecting uring and cleaning the suits to prevent microbiological contamination.

APPENDIX A

TECHNIQUES

Collection of Samples

The procedure for the collection of samples from the body areas, feces, environmental and miscellaneous areas are described for each class of samples.

Body areas. - Two swabs from each body area were collected by subjects in the chamber and cottage at 7-8 AM on specified sampling days (see Table 11-1). One swab was placed in 10 ml of Gall1s broth plus cysteine for anaerobic culturing and one was placed in 10 ml of heart infusion broth for aerobic culturing. Collection was made by swabbing a 1" x 1/2" area as follows:

(1) Eye (first sample period only) - Evert lower eyelid and swab confunctiva gently, following contour of eyelid with swab.

(2) Groin - Swab from front toward rear.

(3) Axilla - Swab with care to get specimen from skin below hair area.

(4) Throat - While depressing tongue, swab tonsillar area.

(5) Buccal Area - Swab gingival margin adjacent to the last upper right molar.

(6) Glans Penis - Swab specified area of skin of glans, or between glans and foreskin.

For purposes of approximate quantitation each swab was considered to contain about 0.01 gm of sample.

Feces. - Fecal samples were eliminated into sterile containers and were cultured immediately. Composite samples were taken by inserting a standard loop into five separate areas of the fecal mass, and the 0.01 gm sample was placed into 10 ml Gall's broth plus cysteine, representing a 10^{-3} dilution of the feces. Samples were received as indicated on Table 11-2.

Environmental areas. - Aerobic cultures were made from several room areas, using two procedures:

(1) Sedimentation plates of blood, MacConkey's actinomyces agar, and

phytone yeast were made from the following room areas as indicated on Table 11-1 by exposing the plates for thirty minutes.

TV
Table
Bed
Personal hygiene area

(2) Swabs were taken from the following areas of the chamber and cottage, placed into 10 ml broth and incubated aerobically as indicated in Table 11-1.

Telephone (chamber only)
Filter (cottage only)
Toilet seat
Transfer lock handle
Two buttons (chamber only)
Table top (cottage only)
Water faucet
Bed post
Floor area
Chair

Miscellaneous items. - Cultures were made from the lips of the urine collection bottles, water squeezed from face cloths, from three areas of the suit prior to donning and from the air coming from the suit vents after donning. Samples were taken at the intervals indicated in Table 11-1.

(1) Urine Bottles - The urine bottles were cultured by swabbing around the outside rim of the urine bottle and placing the swab into 19 ml of Gall's broth plus cysteine, which represented a 10^{-3} dilution of the original samples.

(2) Wash Water - The wash water was cultured by taking 0.5 ml of the squeezed water from the wash cloth and adding it to 10 ml of Gall's broth.

(3) Suit Areas - The suit areas were sampled at the axilla, crotch, and right boot prior to donning by taking two swabs, one of which was placed in 10 ml of Gall's broth plus cysteine for anaerobic culturing and the other in 10 ml of heart infusion broth for aerobic culturing.

(4) Suit Vent - Forty-eight hours following the donning of the suit, samples were taken by holding a blood plate approximately one foot from the vent of each suit for about fifteen seconds. This was done subsequently two more times at approximately weekly intervals.

Primary Culturing

Primary culturing of body areas (other than feces).

Aerobic: The aerobic swab collected by each subject for each body area was emulsified in 10 ml of broth into which it had been placed when collected and serial dilutions in 4-6 tubes were made in heart infusion broth diluting by 1:10, 1:20, or 1:40 depending upon the numbers of organisms expected to be present in the sample based on previous experience. The exact procedure for culturing is shown in Figure 11-1. The heart infusion broth series was incubated aerobically and observed for growth at 24 and 48 hours. All cultures showing growth were smeared. Aerobic plates were made on the media listed in Table 11-3, for each of the body areas by spreading 0.1 ml of broth from the lead tube plus one on the plate using a glass spreader, and additional blood agar plate was made in the same manner from the lead tube. Aerobic count was taken from a blood plate.

Anaerobic: The anaerobic swab from each body area collected by each subject in the chamber or cottage was emulsified in 10 ml of broth into which the swab was placed when collected and the sample was then serially diluted through 4-6 tubes of Gall's broth containing cysteine by making dilutions of 1:10, 1:20, or 1:40 depending upon the numbers of organisms expected to be found in that particular sample. The procedure is essentially the same as the aerobic method is depicted in Table 11-1. The cultures were then incubated in a CO_2 anaerobic incubator at 37°C and were observed after 24 and 48 hours for growth. Agar shakes in Gall's agar were made from the top 2 or 3 dilutions showing growth and slides were made on all cultures that showed growth. The agar shakes were then transported from the site of primary culturing to Republic Aviation Corporation's laboratories where the cultures were further studied. Anaerobic Brewer plates were made with 1.0 ml of the appropriate dilution of the throat, buccal and glans penis samples using Gall's agar with cysteine. A blood agar plate, and where indicated a chocolate agar plate, was inoculated with 0.1 ml from the lead tube plus one and spread over the surface of the plate with a sterile, bent-glass rod. A pour plate of Rogosa's agar, when appropriate, was inoculated with 1.0 ml of the lead tube plus one. These plates were incubated in the CO_2 anaerobic incubator. Deep blood agar shakes were made from the buccal sample only by placing 1 ml of blood into a cooled Gall's agar shake and inoculating with 0.2 ml of the lead tube plus one of the buccal sample.

Primary culturing of feces.

Aerobic: The aerobic plates from the fecal sample were taken from the anaerobic broth series. One-tenth ml from the lead tube plus one was spread on one blood plate, and all other aerobic plates listed in Table 11-3 under media for feces including the second blood plate were made by spreading - .1 ml of the lead tube plus two on the plate with a glass rod. 0.1 ml of the lead tube plus two was

also used as inoculum for a pour plate for aerobic count. One ml of the lead tube plus two was used as inoculum for the Rogosa's pour plate.

Anaerobic: The anaerobic broth series for the primary culture of the fecal sample was essentially the same as that used previously by Gall, et al. (8) for culturing rumen anaerobes, and which has been recently successfully adapted in the Republic laboratories to the culture of human feces. (9) This is a technique that can be adapted easily for work under field conditions. Figure 11-3 gives a schematic representation of the primary culturing technique, which is modified to culture from a standard loopful (0.01 gram) of freshly eliminated fecal material. Samples were cultured within fifteen minutes of elimination.

The fecal material on the standard loop was placed directly into a tube containing 10 ml of Gall's broth prepared with two drops of cysteine and one drop of sodium bicarbonate. This tube was considered to represent roughly a 10^{-3} dilution to the fecal contents. Serial dilutions were made into 11 additional tubes containing 9 ml of Gall's broth prepared as above by transferring 1 ml from the inoculated tube into the next tube, etc. The top 10 tubes were labeled 1 to 10 and were incubated anaerobically in a CO_2 incubator until growth occurred usually within 48 hours. Observations were made at 16 and 24 hours and daily thereafter. These ten tubes were considered to approximate a dilution of the sample from 10^{-4} to 10^{-13}. No dilution blanks were used, as each tube containing broth acts as a dilution blank for the next tube in the series. From tubes 5 and 6 pour plates were made into anaerobic Brewer dishes using Gall's medium with cysteine and bicarbonate added.

The top three tubes showing growth were subcultured into agar shakes using Gall's medium to observe the anaerobic or aerobic character of the growth and to preserve the cultures for transport and for purification and study. Each culture was stained by Hucker's modification of the Gram stain and the slide was observed microsopically.

In addition, blood plates were made from the 10^{-3} and 10^{-4} dilution of the fecal sample by the same technique as the aerobic plates from the other body areas and were incubated in the same manner as the anaerobic broth series. Growth was recorded after 24 hours and the plates were treated in the same manner as the aerobic blood plates to be described below.

Primary culturing of environmental areas. - The sedimentation plates made from the several room areas indicated above were exposed for 30 minutes, incubated at 37°C and were observed for growth at the end of 24 hours. The swab cultures taken from the various environmental areas were placed in broth, incubated aerobically at 37°C and smears were made of all broths that grew.

Primary culturing of miscellaneous items.

Urine Bottles: Using the 10^{-3} broth dilution containing the swab, serial dilutions representing 10^{-5} and 10^{-7} dilution were made by taking 0.1 ml from the previous tube into 10 ml of Gall's broth. In addition 0.1 ml from the 10^{-3} tube was streaked by the usual procedure on MacConkey's plates, Mitis salivarius and two blood plates, one of which was incubated aerobically and one under CO_2. Pour plates using Gall's agar were made using 1 ml of the 10^{-3} and 10^{-7} dilutions are inoculum.

Wash water: Using the lead tube containing the wash water as inoculum, 0.5 ml was transferred serially into three more tubes containing 9 ml of broth. These broths were incubated aerobically. Pour plates were made using Gall's agar inoculated with 1 ml of the first and third tube in the series with Gall's broth.

Suit areas: Using the lead tube as inoculum one more serial dilution was made from each suit area and blood plates were streaked from this dilution from each suit area and incubated aerobically.

Suit vent: The exposure plates made by holding the blood plates 1 foot for 30 seconds were incubated aerobically and were observed for growth.

Subject 4: Approximately one week after donning the suit Subject 4 noticed a bloody discharge near the area of the buttocks and at that time several other pustules were noted on his upper torso near the vent in the suit. Swabs for culture were taken from the pustules in both areas and placed on blood plates.

Secondary Culturing

Aerobic. - All the cultures from the Petri dishes incubated aerobically and under CO_2 from all body areas, feces, environmental areas and miscellaneous items, were returned to the Republic Aviation Corporation laboratories and selected colonies were picked into broth. Cultures picked from the anaerobically incubated plates were incubated in the CO_2 incubator while all other colonies from the aerobic plates were processed by the usual aerobic methods. The cultures were smeared, stained, observed microscopically, separated according to morphological types, and processed according to the schema if applicable.

(1) Staphylococci and Micrococci

Mannitol salt agar
All positives confirmed with coagulase test
Phage typing on selected cultures

(2) Streptococci

Alpha hemolysis
Beta hemolysis
Gamma hemolysis
Differential sugars
Typing

(3) Pneumococci

Pneumococcus broth - bile solubility

(4) Haemophilus

Identified with typing antisera

(5) Neisseria

Sugar screen test

(6) Lactobacillus

pH in glucose broth

(7) Gram Positive Rods

Loeffler's
Ziehl Neelsen
Sporulation
Gelatin
Sugar screen
Hydrolysis of starch
Detection of hyphae (Proact. or Nocardia groups)
Tellurite
Catalase
Hemolysis on sheep blood
CO_2 requirement

(8) Gram Negative Rods

TSI
Indol
Methyl red
Voges-Proskauer
Simmon's citrate
Urease
Nitrate
Litmus milk
Motility
Gelatin
KCN
Phenylalanine

(9) PPLO

Dienes' stained agar technique

(10) Fungi and Actinomyces

WET mount
Lactophenol cotton blue
Corn meal agar
Fermentation series

(11) Spirochetes

Blood broth (morphology)
Darkfield when indicated
Vincent's stain

(12) Protozoa

Identification by selective stains

Phage typing: Phage typing of staphlococci isolated in the course of this contract were done by Dr. John E. Blair, Head, Department of Microbiology, Chairman International Subcommittee of Phage Typing of Staphylococcus. The Roosevelt Hospital, Long Island, New York.

The cultures of staphylococci submitted for examination were isolated from various body surfaces of the test subjects or from environmental sources in the chamber and the cottage. The 33 cultures received included 25 coagulase-positive strains and 8 coagulose-negative strains. One culture proved unsuitable for study because of poor growth.

For typing, the 22 standard phages recommended by the International Subcommittee on Phage Typing of Staphylococcus were used. (10) The phages are: 29, 52, 52A, 79, 80, 3A, 3B, 3C, 55, 71, 6, 7, 42E, 47, 53, 54, 75, 77, 83A, 42D, 81 and 187. In addition, four "experimental" phages from Dr. Blair's personal collection were used which sometimes have proved useful for the identification of certain strains that are not typable with the standard phages; these phages were B5, D, 77ad and UC18.

The methods recommended by the Subcommittee were employed. Cultures were typed first with the routine test dilutions (RTD) of the phages. Those cultures which showed no significant lytic reactions at RTD were then retyped with the phages in concentrations 10000 times stronger than RTD. The phage pattern, or "type", of a culture is reported by listing those phages that produced significant lysis. Cultures showing no significant lysis at either RTD or 1000 x RTD were recorded as nontypable.

Although it is well known that coagulase-negative strains of staphylococci are not susceptible to lysis by the typing phages, the seven viable coagulase-negative cultures nevertheless were submitted to typing together with the coagulase-positive cultures because these strains had been isolated from Subject 4 who had pustules and from Subject 7 because of the high frequency of isolation of staphylococci from this subject. None of the coagulase-negative cultures was typeable.

Anaerobic

Body areas other than feces: The agar shakes made from the dilution series and the colonies picked from the Brewer plate (when made) were separated into two groups depending upon the degree of anaerobiosis. The obligate anaerobes were processed in the same way as the fecal anaerobes described below with the exception that many of the cultures particularly from the buccal area, throat and glans penis were identified from Bergey's manual (6) rather than from the anaerobic "key". The facultative anaerobes were grouped according to morphology and were processed as indicated for the aerobes of similar morphology.

Feces: The agar shakes from the top three tubes of the cultural series were processed in the following manner. The agar shake cultures were transferred to Gall's broth plus cysteine and incubated anaerobically until growth occurred. Gram stains were made, and if the cultures were pure, they were immediately screen tested as described below. Cultures showing two or more distinct morphological types of bacteria were purified by plating using the following anaerobic technique. A needle of the impure broth culture was spread on a bed of Gall's agar which was then covered with a layer of Gall's agar with added cysteine. The plates were incubated anaerobically in a Torbal jar with hydrogen

and 10% CO_2 and discrete colonies were picked. Selected colonies on the anaerobic Brewer dishes originating from tubes 5 and 6 were picked and treated like the subcultures from the agar shakes as described above. The physiological studies of the pure cultures isolated from the feces included the following screen tests:

(1) Gram stain to observe morphology
(2) Final pH in 0.1% glucose broth
(3) Fermentation of the following sugars in Gall's media with glucose omitted (Glucose, Sucrose, Lactose, Dextrin - sugars added at 0.1% level aseptically after autoclaving)
(4) Growth in Gall's broth with no carbohydrate added
(5) Liquefaction of 12% gelatin in Gall's media minus carbohydrate
(6) Growth and reaction in litmus milk (to which 0.05% bovine albumin and 0.1% of peptone have been added)
(7) Growth in agar shake containing Gall's Media

All media contained bicarbonate and all media except the agar shake contained cysteine to produce an Eh of about -200 mv. The results of the screen tests on each anaerobic culture were compared with a "key" derived from tests done on NASA study (4). This "key" consists of the results of the screen tests from the most frequently occurring fecal anaerobic cultures and is designed to group similar bacteria. Each different screen test pattern is assigned an FA, FN or GD number. The GA and GD types are used to designate obligate anaerobes.

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TABLE 11-1

SCHEDULE OF SAMPLES FROM THE BODY AREAS AND THE ENVIRONMENT

	TEST CONDITION																																			
	AMBIENT								ALTITUDE-NO SUITS							ALTITUDE PLUS SUITS												AMBIENT PLUS SUITS							
DATE	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T
AREAS	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ALL BODY AREAS	1							2			3				4			5				6		7				8			9					10	
ENVIRONMENTAL CHAMBER 8 CONTROL COTTAGE	1							2		3		4			5		6		7			8		9		10		11		12		13		14		
MISCELLANEOUS SAMPLES WASH WATER OR CLOTHS								1							2							3						4								
URINE BOTTLES										1								2						3												
SUIT	SAMPLES TAKEN FROM SUITS AFTER CLEANING AND PRIOR TO DONNING																																			
SUIT VENT																		1								2						3				

NUMBERS REFER TO SAMPLE NUMBER
CONTROLS WERE AT AMBIENT AT ALL TIMES

TABLE 11-2

SCHEDULE OF THE FECAL SAMPLES

SUBJECT NUMBER	DATES																																				
	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1		2					3		4					5		6					7					8							9		10	
2	1			2				3			4				5			6				7		8						9	10					
3	1		2					3 *								4					5				6				7		8				9	10 *
4	1		2					3				4			5		6							7		8			9						10 *	
5	1 *				2			3		4						5				6		7		8							9			10			
6	1		2						3			4			5		6						7					8			9				10	
7	1		2					3		4						5		6				7			8					9			10			
8		1		2				3		4							5		6			7		8					9			10				

SUBJECTS ON DEHYDRATED SPACE-TYPE DIET THROUGHOUT ENTIRE EXPERIMENT
NUMBERS REFER TO SAMPLE NUMBER
* NO SAMPLE OBTAINED

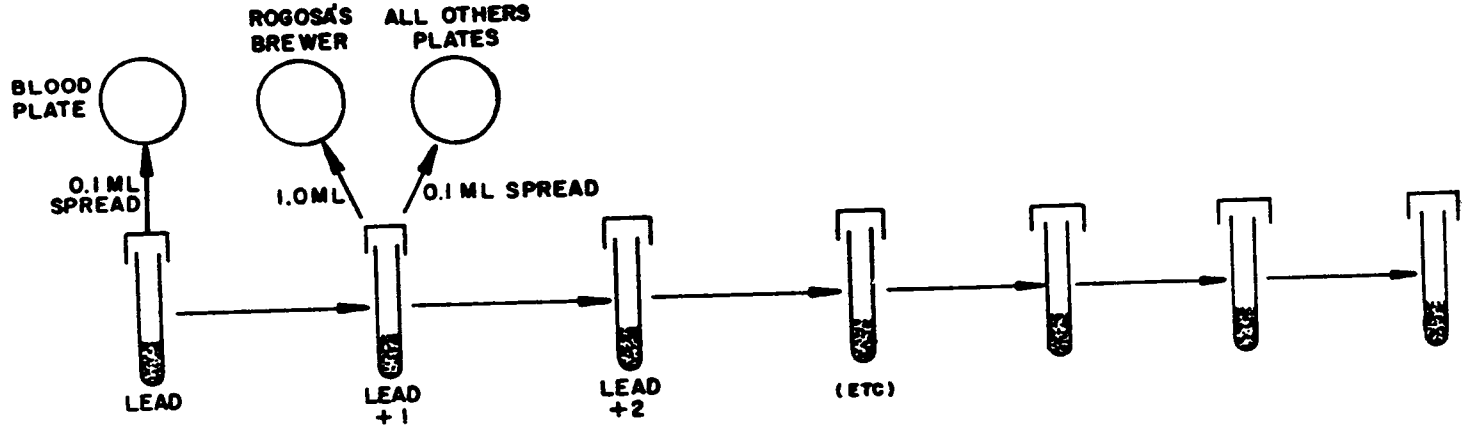
TABLE 11-3

LIST OF PRIMARY CULTURE MEDIA FOR EACH BODY AREA

AEROBIC AND ANAEROBIC

	Eye	Throat	Buccal	Axilla	Groin	G. P.	Feces
			Aerobic Samples				
Actinomycete Agar	x	x	x	x	x	x	x
Blood Agar (2)	x	x	x	x	x	x	x
Desoxycholate Agar	x	x	x				
PPLO Agar	x	x	x	x	x	x	x
Fungi Media Agar		x	x	x	x	x	x
Mitis Salivarius Agar		x	x	x	x	x	x
MacConkey's Agar				x	x	x	x
			Anaerobic Samples				
Anaerobic Blood Agar	x	x	x	x	x	x	x
Chocolate Agar	x	x	x			x	
Rogosa's Agar		x	x				x
Deep Blood Agar Tubes			x				
Dilution Series	1-4	1-6	1-6	1-4	1-5	1-4	1-12*
Agar Shakes	x	x	x	x	x	x	x**
Brewer Plates		x	x			x	x**
Counting Plates							x**

* Gall's Broth
** Gall's Agar



Plates made from Lead tube + 1 listed for each body area in Table 47.

All plates except fungi incubated at 37°C. Fungi incubated at room temperature.

Sample No. 1, 2, 3 - amount transferred - 1 ml
Sample No. 4 - amount transferred - 0.5 ml
Sample No. 5 and thereafter - amount transferred 0.5 ml first tube;
0.25 ml thereafter.

Number of tubes in culture series:

Eye	1 - 4	Buccal	1 - 6	Groin	1 - 5
Throat	1 - 7	Axilla	1 - 4	G. P.	1 - 4

Figure 11-1 Aerobic or Anaerobic Cultural Series for All Body Areas

SECTION 12

NUTRITION AND BALANCE

LT Gary L. Kellett, MC, USN

SECTION 12

NUTRITION & BALANCE

INTRODUCTION

It was decided to evaluate the diet for ease of preparation, taste, acceptability and as many nutritional balance studies as feasible to show if any trend existed toward metabolic imbalance. The diet, supplied by NASA, had previously been evaluated in similar studies. Speckmann, at al[1] noted that their study indicated "that a four-day cycle menu with four meals per day and consisting only of pre-cooked freeze-dehydrated and bit-size compressed food items was highly acceptable and rated equally with a matched diet consisting of fresh, frozen and heat-processed foods." In another study by Vanderveen et al,[2] it was found "that a freshly-prepared diet or a diet composed of pre-cooked freeze-dehydrated foods is equally efficient in supplying the nutrient requirements of the experimental subjects." From these statements it is obvious that, within the scope of their investigations, the food seemed to be acceptable. In the nitrogen balance studies which were carried out in both of the above cited experiments, the Vanderveen study showed a positive nitrogen balance, however no imbalance was seen in the other. Although there is reference to excretory products being analyzed for calcium, sodium, potassium, and phosphorus content, no results were listed. It is assumed from this that no significant abnormalities along these lines were noted. Also, the positive nitrogen balance noted in the Vanderveen report represents between 1.8 to 4.2 gram/day and the nitrogen balance in the Speckmann study is shown as 15 mg/kg/ day which for a 70 kg man would be slightly over 1 gram/day. These data would tend to indicate that very little change would be noted by using the NASA supplied diet.

Our basic aims in this study were to examine the metabolic picture and to extend the evaluation of overall food acceptability.

METHODS AND MATERIALS

The food was supplied by NASA in a freeze dehydrated state and packaged in plastic bags suitable for use in a weightless situation. This food had been carefully weighed and analyzed for caloric, water, protein, fat, carbohydrate, calcium and iron content. Since our interests were in the water, nitrogen, and calcium balance, the individual intakes were determined. This was done by having the subjects weigh each food package before and after adding water and after eating. Knowing the weight of the container, the percentage of each food eaten could be determined. This could then be multiplied by the amount of protein and calcium in the package thus leading to the daily intake of these substances. The nitrogen intake was determined by multiplying the protein by the constant 0.16, which is the average part of protein made up of nitrogen. The calcium was calculated directly.

The urine output was determined by collecting twenty-four hour urine samples each day on every subject. The urea nitrogen content was measured by auto-analysis. The calcium was determined by titration. Since urea nitrogen represents approximately 85% of all nitrogen output, it was multiplied by 1.18 to get an approximate total body output of nitrogen. Daily electrolyte output was followed for shifts. These consisted of sodium, chloride and potassium which was done by auto-analyser.

Body weights were taken daily by the subjects and recorded in individual log books each morning after urination and prior to eating.

Preparing the food for consumption was left to the individual subjects, who, after a few days, developed a system by which one man did the weighing while another added water and mixed it.

RESULTS

The majority of subjects were highly satisfied with the tastiness and general esthetic properties of the food. There was a general consensus that it tasted better as they became used to it. Although the food was supplied in daily rations and had to be eaten at prescribed times, the subjects were permitted to eat what they wanted and trade food packets among themselves to suit their individual tastes. This was found to be very advantageous to morale as well as increasing acceptance of the food. Some subjects stated that such a small selection of food might become monotonous and that lack of something with resistance for chewing was felt to be a significant complaint.

Water was added to the packets according to instruction but many foods were found tastier if more was added. This was also done to some juices to give more flavored liquid as the stipulated amount was felt to be inadequate. Again, individual tastes dictated.

The preparation of the food gave no difficulty. Although weighing was a necessary part of preparation, it was found to be a pleasurable task and was actually looked forward to. Some of the packages were found to leak, but this was felt to be due to injuries to containers incurred during shipping or occasionally a plastic bag being stamped when the covering aluminum foil was sealed.

The averaged caloric intake for all subjects was 2,283 (Fig. 12-1). This remained fairly constant throughout the entire study. Most individual variation was within expected limits except for subjects 3 and 4. Subject 3 was well below pre-run weight and upon questioning, he revealed that he had undertaken a self-imposed diet without consulting outside observers. Subject 4 had a steady increase in calcoric intake and during the last week was consuming in excess of 3,000 calories daily.

There was an average weight loss among the eight subjects of 2.0 Kgm. over the thirty-four days of the study (Fig. 12-2). One subject gained 3.2 Kgm., two maintained their weight and four lost between 1.7 Kgm. and 4 Kgm. each. Subject 4, on his diet, lost 7 Kgm. If his weight loss were eliminated from the figures, there would be an average weight loss of only 1.6 Kgm. As noted in the Vanderveen study in which subjects over 66 Kgm. tended to lose weight while those under 66 Kgm. tended to gain, our only subject weighing less than 66 Kgm. gained while the rest either maintained or lost weight.

There was moderate variation in nitrogen balance in all subjects from day to day, both positively and negatively (Fig. 12-3). Overall nitrogen balance studies on individual subjects gave a range of 20.37 gms/day negative balance to 29.24 gms/day positive balance Table 12-1 with a combined average negative nitrogen balance of approximately 6 gms/day. Because of a technical malfunction, nitrogen balance studies were not carried out during the first three weeks of the study.

Twenty-four hour calcium intake and urinary calcium output (Fig. 12-4) was measured every third day throughout the run. Intake was noted to be uniformly adequate (over 500 mg/24h) in seven of the eight subjects Table 12-2. The dieting subject had an average calcium intake of only 329 mg/24h. The calcium output of all subjects remained essentially constant throughout the run averaging 225 mg/24h. Urinary output of calcium ranged from 21% to 34% of intake in individual subjects for the duration of the run except for Subject 3 who because of low intake, averaged 65%.

Urinary electrolytes showed expected day to day variation of twenty-four hour samples (Fig. 12-5). Again, by averaging, all subjects gave almost constant values across the chart for sodium, chloride and potassium. The only large deviation from the norm occurred in all subjects in all three electrolytes on the 21st day of the run. Because this occurred so uniformly in all subjects and controls with no dietary or environmental changes, it is likely that this was a result of a variation in chemical analysis.

DISCUSSION

The primary aim of the preceding studies was to evaluate in as many reasonable parameters as possible, the freeze dehydrated diet supplied by NASA. Although no change in dietary metabolism was expected because of pressure or atmosphere variation, this was also taken into account and evaluated both by comparing subjects to controls as well as the subjects themselves in the different environments of the study.

A most important aspect of food evaluation is the acceptability rating. This was done by having the subjects rate their acceptance of each food on a scale from

one to nine. These forms were chiefly for use by NASA in comparing the different foods used and will not be discussed. It is evident; however, both from interviews, written comments and the acceptability forms, that the food was well accepted by the subjects. Comments to the effect that food was often better than that freshly made were often made. Also, it was almost universally felt that the food tasted better as the men became used to it.

A slight average weight loss was expected since prior reports using the same diet showed that weight changes were a function of initial weight.[2] The average loss of 1.6 Kgm. as well as all individual weight changes are felt to be acceptable except for the subject who lost weight purposely. It is expected that weight changes, as noted in the prior studies would tend to be toward 66 Kgm. and they would stabilize at various points along the way. The required exercise for our subjects consisted of ten sit-ups, ten push-ups and ten deep knee bends twice per day. This was meant only to help general fitness and was not felt to be sufficient to maintain weight control.

The general impression gained from the metabolic studies is good. Although nitrogen balance was negative, individuals varied both positively and negatively. It would seem, then, that these results, along with the electrolyte findings, give no evidence of serious metabolic biochemical changes.

CONCLUSIONS

The NASA supplied, freeze-dehydrated diet was found acceptable for a period up to at least thirty-four days. The acceptability as to ease of preparation and taste was very good with complaints stemming primarily from variation in individual taste. Biochemical analysis of excretory products along with balance studies show variations felt to be within acceptable limits.

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TABLE 12-1

AVERAGED NITROGEN INTAKE AND CALCULATED NITROGEN OUTPUT

Subject	Nitrogen Intake	Calculated Nitrogen Output	
I	236.42 gm/24 hr	228.95 gm/24 hr	7.47 pos
II	236.37 "	239.01 "	2.64 neg
III	120.96 "	126.68 "	5.72 neg
IV	269.41 "	258.67 "	10.74 pos
V	248.26 "	237.28 "	10.98 pos
VI	165.36 "	185.73 "	20.37 neg
VII	195.46 "	166.22 "	29.24 pos
VIII	196.58 "	175.57 "	21.01 pos

TABLE 12-2

AVERAGED CALCIUM INTAKE AND OUTPUT

Subject	Calcium Intake	Urinary Calcium Output	%
I	720 mg/24 hr	211 mg/24 hr	29
II	721 "	247 "	34
III	329 "	215 "	65
IV	766 "	317 "	21
V	708 "	179 "	25
VI	632 "	195 "	31
VII	529 "	227 "	23
VIII	652 "	179 "	27

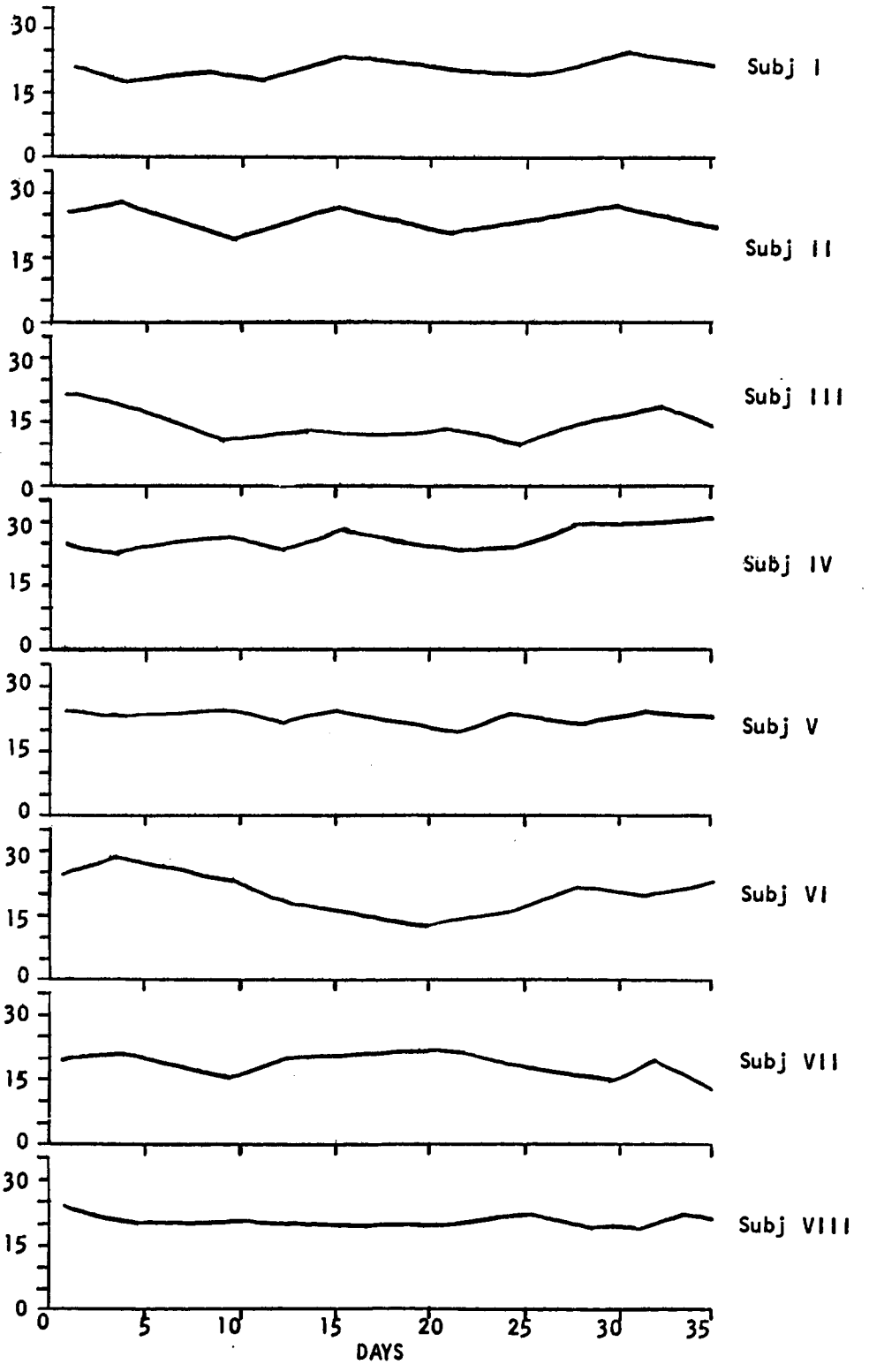
Cal/24 Hr (X100)
30
15
0
Subj I
Subj II
Subj III
Subj IV
Subj V
Subj VI
Subj VII
Subj VIII
0
5
10
15
20
25
30
35
DAYS

Fig 12-1

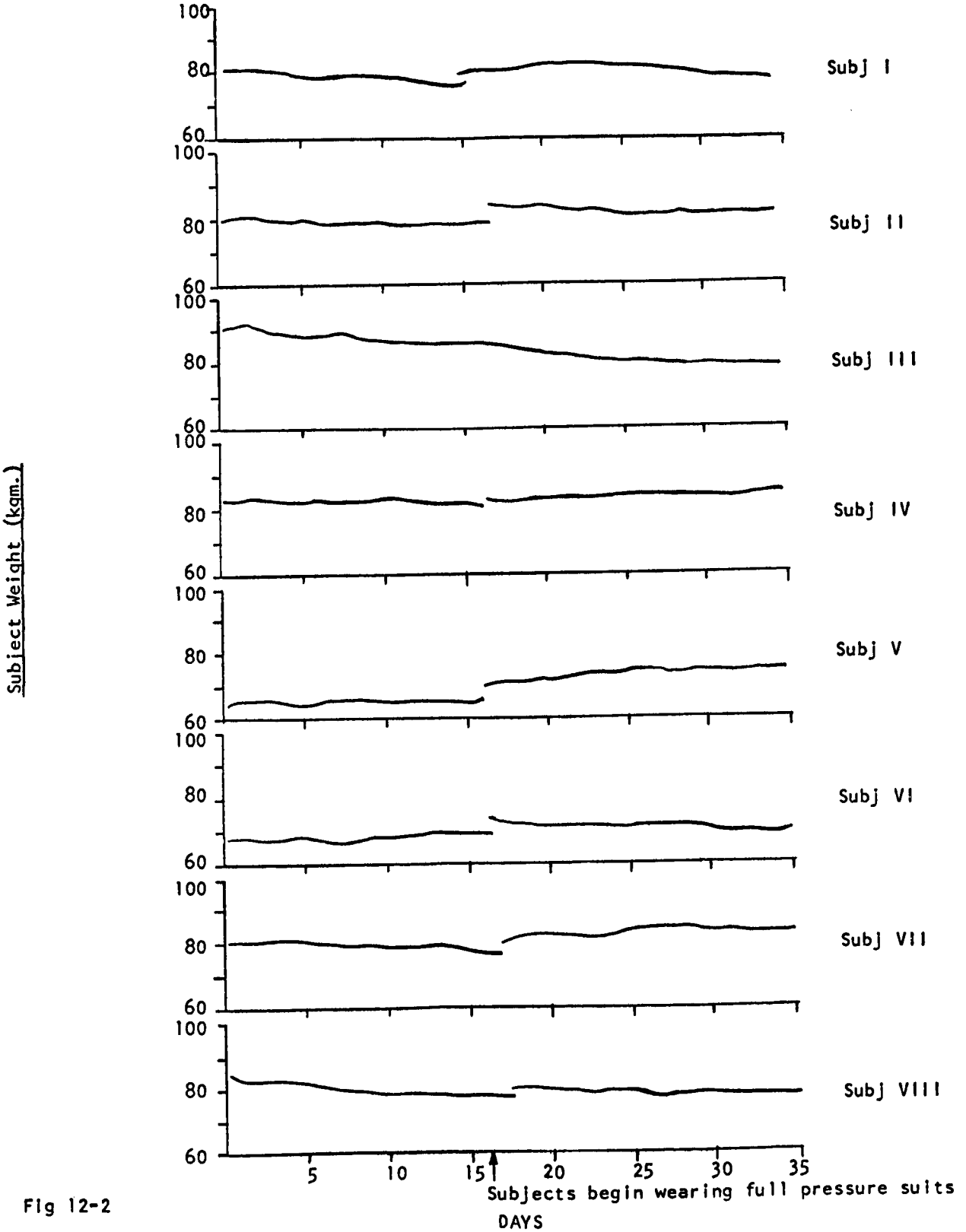
Subject Weight (kgm.)
100
80
60
Subj I
Subj II
Subj III
Subj IV
Subj V
Subj VI
Subj VII
Subj VIII
5
10
15
20
25
30
35
Subjects begin wearing full pressure suits
DAYS

Fig 12-2

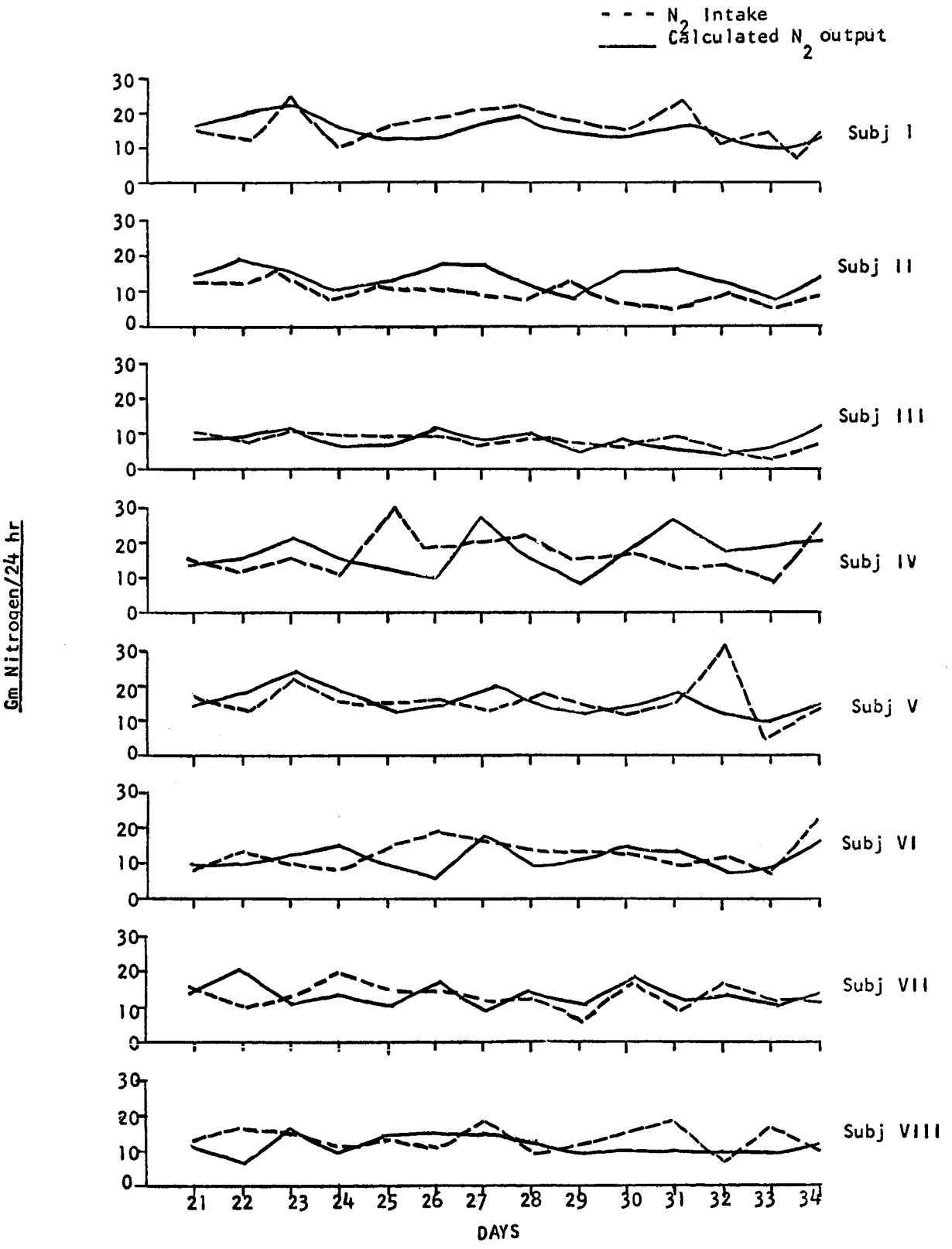
- - - N_2 Intake
——— Calculated N_2 output
Gm Nitrogen/24 hr
Subj I
Subj II
Subj III
Subj IV
Subj V
Subj VI
Subj VII
Subj VIII
30
20
10
0
21 22 23 24 25 26 27 28 29 30 31 32 33 34
DAYS

Fig 12-3

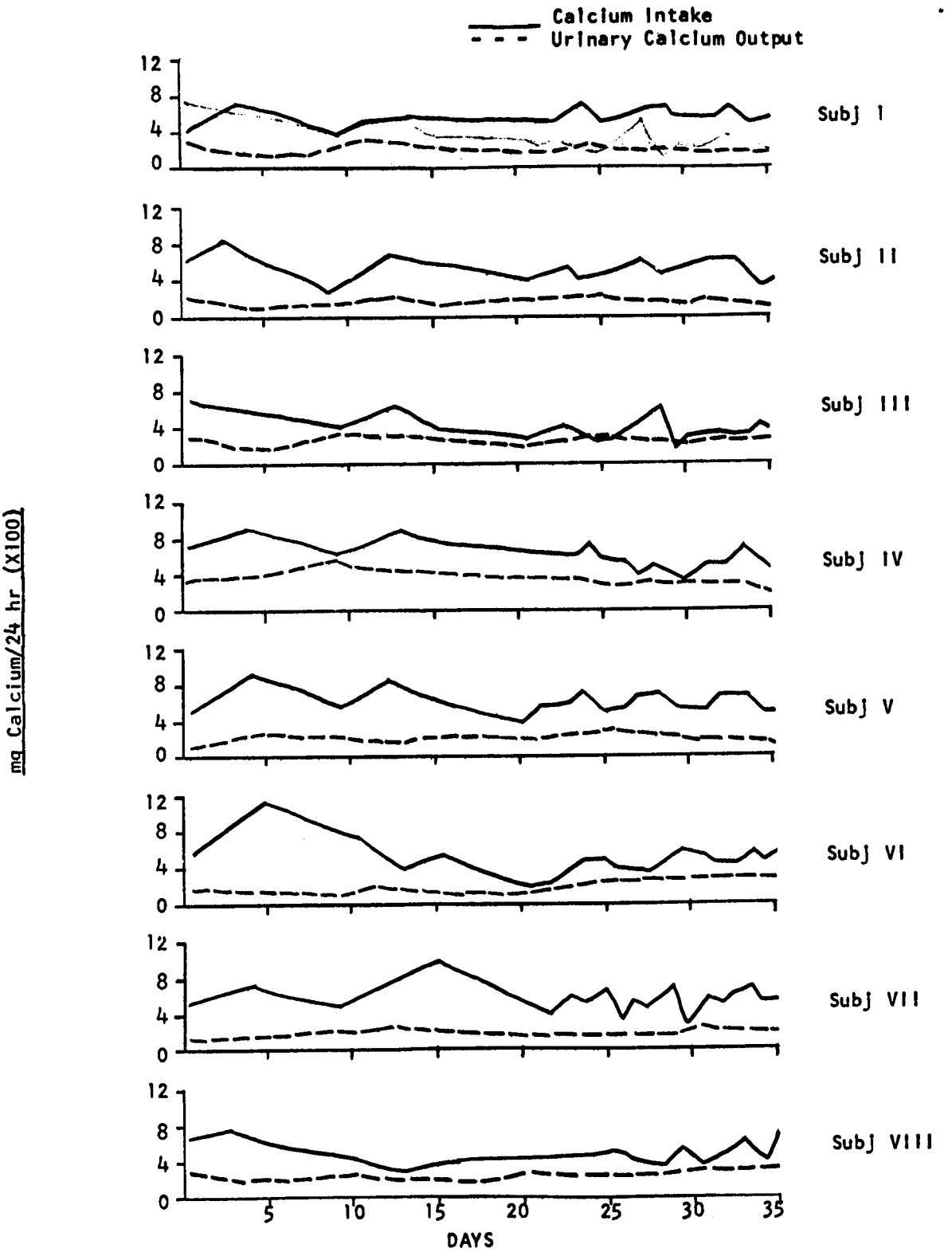
Calcium Intake
Urinary Calcium Output
mg Calcium/24 hr (X100)
Subj I
Subj II
Subj III
Subj IV
Subj V
Subj VI
Subj VII
Subj VIII
12
8
4
0
5
10
15
20
25
30
35
DAYS

Fig 12-4

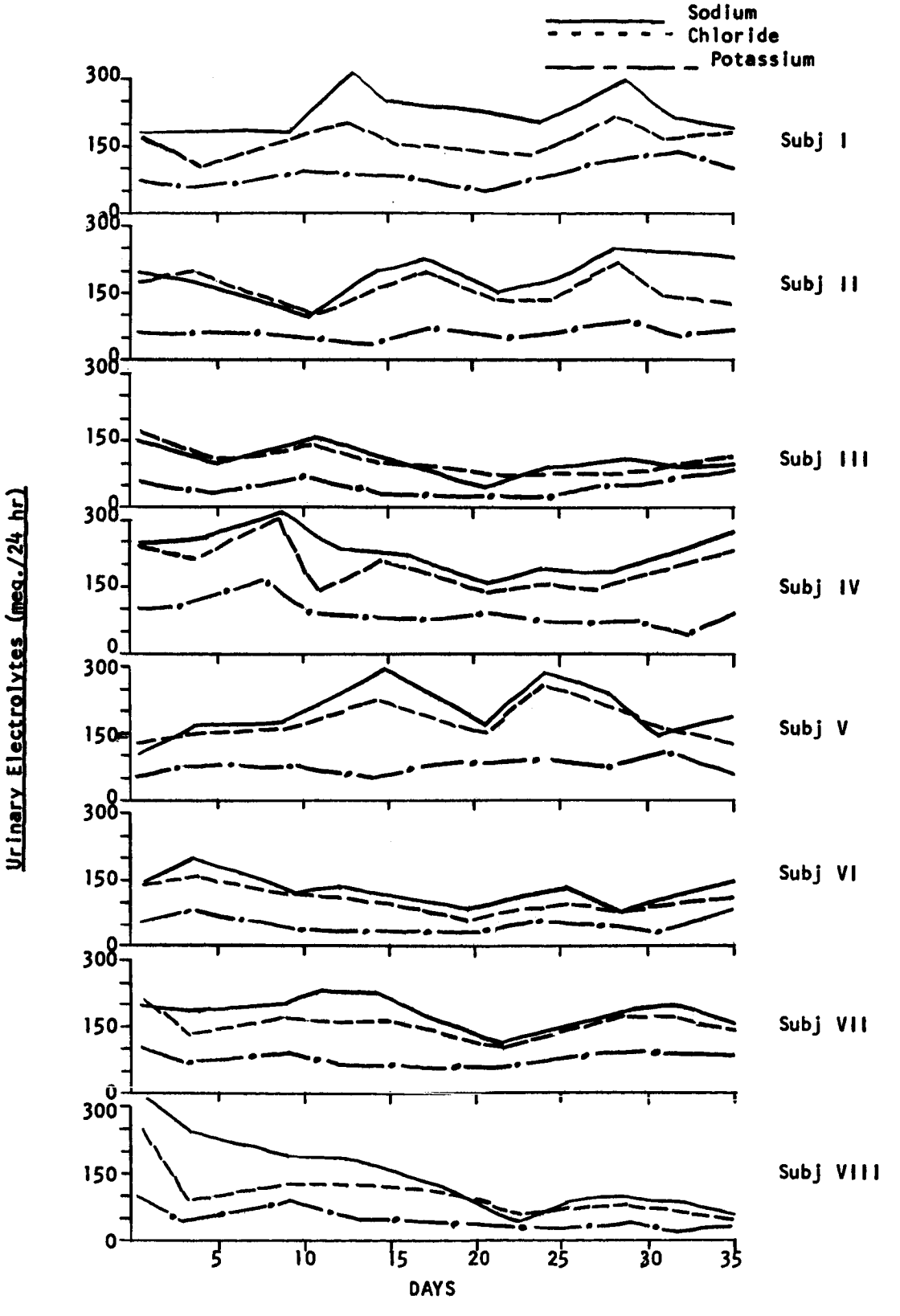
Sodium
Chloride
Potassium
Urinary Electrolytes (meq./24 hr)
300
150
0
Subj I
Subj II
Subj III
Subj IV
Subj V
Subj VI
Subj VII
Subj VIII
5
10
15
20
25
30
35
DAYS

Fig 12-5

SECTION 13

FULL PRESSURE SUITS AND PERSONAL HYGIENE

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SECTION 13

FULL PRESSURE SUITS AND PERSONAL HYGIENE

The subjects put on full pressure suits on the 15th day of the study and wore then continually for the last 20 days of the experiment. Ideally, suits like those used on an actual mission would have been preferable, however these were of limited supply and individually sized. From the suits supplied by NASA, only two could be fitted to the men in this study. The rest of the subjects were dressed in U.S.N. full pressure suits. The suits worn are listed below:

Subject	1 - Apollo
	2 - Mark IV
	3 - Mark IV
	4 - Mark IV
	5 - Mercury Suit X
	6 - Mark V
	7 - Mark IV
	8 - Mark IV

The subjects were observed and questioned as to the effects of wearing this type of garment for extended periods of time. Of particular interest was individual comfort, problems of elimination, sleeping, odor, bacteriological contamination, and emotional reactions to living in a relatively uncomfortable body covering.

In an effort to substitute conditions found in the NASA supplied suits, the naval suits were fitted loosely. All suits were constantly ventilated at 60°F with individual adjustments to regulate flow up to 12 liters/minute.

The subjects were required to wear helmets and gloves for a minimum of three hours each day with the times to be chosen by individual preference. Most of the subjects preferred to wear the complete pressure suit during periods of sleep because the helmet was cumbersome when moving about and gave better ventilation for sleeping. It was necessary to partially remove the suits for defecation, but they were worn continually otherwise.

The suits varied greatly in their design and purpose. Hence, no general conclusion can be made concerning comfort. However, some common problems were found which presumably would have been inherent in all heavy, airtight garments.

Body odor became noticeable after approximately three days. Although individuals had different opinions about this inconvenience, the odor was not found

to be objectionable as to become incapacitating. It was more prominent with the suit partially removed. When the helmet and gloves were worn, ventilation was reversed through the neck region and flowed away from the face giving more freedom from odor.

Most subjects noted a lack of adequate ventilation to the feet, especially those wearing the Navy Mark IV. This resulted in constant dampness of the socks from perspiration. On day 23 it was decided to cut away the forward half of the rubber booty on all Mark IV suits which greatly improved the situation. Subject 1 was also allowed to change his socks and Subject 4 was found to have developed slight "Athlete's foot".

Subject 5 was bothered early in the study by dampness in the groin area and subsequently developed a small area of irritation on the right side of the scrotum.

A common complaint concerned the pressure suit neck ring. This caused some discomfort to the neck during sleep, but became less bothersome as the subjects grew accustomed to it.

On the 23rd day of the run, Subject 5 noted some peeling or flaking of the superficial skin layer of both arms. Over the next few days it spread over his entire body and became pronounced. Eventually, all subjects developed the same symptom. It became quite marked during the last few days of the study and a shower of then dry flakes could be produced by brushing one's body or hair. After termination of the study, a fine layer of powdery scales was found to cover the floor of the chamber.

Subject 4 developed two small pustules over the coccygeat area on day 23. On further examination, 15 - 20 pustules 1-2 mm in diameter, were found on the left chest wall. Cultures from several of these pustules were negative. The rash cleared completely after washing the involved areas with Dial soap (Armour Co.) for two days.

There was no problem with elimination. A toilet was located in a corner of the chamber under an exhaust port. Subjects were allowed to doff their suits sufficiently to permit the normal manner of elimination into the collecting containers provided.

It would seen that a full pressure suit, as worn in this study, is acceptably comfortable when the wearer has a period of time to become accustomed to it. All suits lacked adequate ventilation with the helmet and gloves off. This in turn Aggravated skin irritation in areas where moisture and dirt accumulated which probably caused development of "athlete's foot" in one subject, pustules in another, and probable tinea cruris in a third. These skin reactions cleared rapidly with minimal treatment. However, if constant wearing of the suits would have been

necessary and no treatment were instituted, more serious skin reaction may have resulted. Shedding of superficial skin layers may be the result of lack of body hygiene and probably would have occurred even without the use of full pressure suits.

Personal hygiene articles consisted of a wash cloth and toothbrush for each subject. The subjects had available an unlimited supply of hot and cold water for washing their hands and face and for brushing their teeth (without toothpaste). Soap was not used except as treatment for skin irritations as described earlier. All subjects indicated that, contrary to their expectations, body hygiene did not prove to be a problem. They stated that as long as they could wash their face and brush teeth, they felt relatively comfortable. However, most would have also perferred to wash the armpit, genital, and perineal areas. In addition, all subjects developed itching and oily scalps. They stated that they would have felt miserable if they could not have been able to remove their helmets and scratch to their satisfaction.

The wash cloths became dirty and malodorous after a few days of use. It was found necessary to wash them thoroughly each day in hot water. They were passed out of the chamber twice during the study to be laundered. Nevertheless, all subjects preferred wash cloths to chemically treated hygiene pads.

Small, hard toothbrushes were preferred. However, most subjects thought that, without toothpaste, their teeth became more yellowed toward the end of the study.

The growing beards posed no problem; they were a great morale booster instead. The beards were compared daily as to their length, bushiness, and beauty.

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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