INTEGRATED LIFE SUPPORT SYSTEM STUDY (20-DAY EVALUATION PROGRAM)

PROGRAM COORDINATORS

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Foreword

This research study was initiated by the Life Support Division, Biomedical Laboratory, Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. The study was conducted in support of project 6373, "Equipment for Life Support in Aerospace." The program was initiated and coordinated by Mr. Courtney A. Metzger assisted by Technical Sergeant Eugene Fritz. Principal investigators were Sheldon London, PhD; Milton Alexander; Lloyd L. Laubach, Antioch College; Albert B. Hearld; Arnold R. Slonim, PhD; J. Arthur Brown; Lieutenant Colonel S. J. Borden, PhD, Air Force Institute of Technology; Earl L. Sayre; Ints Kaleps. Additional support was provided by Major V. H. Thaler, Investigating Psychologist; A. E. Prince, PhD; Arselus West; Master Sergeant W. Bigelow; and P. Lachance, PhD, and C. Lutz of the National Aeronautical Space Administration.

The assistance of the following physicians who served on the medical investigator's team is gratefully acknowledged: Lieutenant Colonel Robert H. Lang, Major George C. Mohr, Major Edmund B. Weis, Jr., and Captains Stanley J. Myers, Harold P. Kaplan, James G. Clark, Jerry D. Williams, John A. Godley, Neil Abramson, Thomas E. Piemme. Also acknowledged is the assistance of experiment monitors from Toxic Hazards and Life Support Divisions and from Miami Valley Hospital. Volunteer subjects for this study were: Captain J. M. Dunn, Master Sergeant B. G. McMullen, and Staff Sergeant C. Gailey. This study covers research conducted from April 1965 to December 1965.

This technical report has been reviewed and is approved.

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Abstract

Tests are conducted to define the various problems involved in the maintenance of an acceptable environment, the number of variables concerned with the man-machine concept, the operation, maintenance and evaluation of single units and integrated systems for the support of life in a simulated aerospace mission. The investigation covers primary problems and benefits associated with water recovery, personal hygiene, sanitation, nutrition, instrumentation, atmospheric conditions at various pressures and mixtures, clothing, crew accommodations, waste management and muscle-strength while confined in a chamber simulating an aerospace vehicle, and the facilities and support required to test and evaluate life support systems.

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SECTION I.
Introduction

An experiment was conducted to study life support systems in the areas of atmospheric composition and control, water recovery, waste management, nutritional support, and emergency breathing and suit pressurization for a 20-day mission using selected atmospheric parameters. Specific objectives of this experiment were as follows:

a. Determine the acceptability and potability of atmospheric condensate water for human consumption.

b. Study the coupled effects of an Oxygen-Inert Gas Sensor-Controller unit, a carbon dioxode removal unit, a sensible/latent heat removal unit, and an air reheat unit.

c. Determine the effects of a 14-day exposure of three subjects to reduced atmospheric pressures and controlled gas mixtures.

d. Obtain additional information on a diet supplied by the National Aeronautics and Space Administration (NASA).

e. Evaluate minimal personal hygiene procedures designed for long-term space flight.

f. Study the environmental effects on dental health.

g. Study the accumulated effects of subjects confined in full- or partial-pressure suits (including helmets and gloves) for a period of 14 continuous days.

h. Study the individual changes in performance of strength tests before and after confinement.

i. Determine requirements for monitoring civilian contract subjects on subsequent programs.

The planned pressures and gas composition were as follows:

a. Oxygen partial pressure – 180 mm Hg, ± 15 mm Hg.

b. Helium partial pressure – 180 mm Hg, ± 15 mm Hg.

c. Carbon dioxide partial pressure – 7.5 mm Hg, ± 4 mm Hg.

d. Water vapor partial pressure – 7.5 mm Hg, ± 4 mm Hg.

e. Total pressure – 275 mm Hg, ± 15 mm Hg.

f. Dry bulb temperature – 74 F ± 6 F.

g. Rate of ascent/descent – 30 mm Hg, ± 10 mm Hg/minute except for "wide open" descent in event of an emergency.

The experiment was conducted the total 20 days as planned and results reported herein.

SECTION II.

Chamber Facility and Support Instrumentation

J. Arthur Brown

DESCRIPTION

The Life Support Systems Evaluator (LSSE) utilized during this experiment (fig. 1) (ref. 1) serves as a research facility for determining the technical feasibility of techniques and principles, and for determining the adequacy and performance of systems in the general area of bioastronautics. This broad spectrum includes life support, respiratory equipment, environmental control systems, nutritional support, waste management, and biologistics.

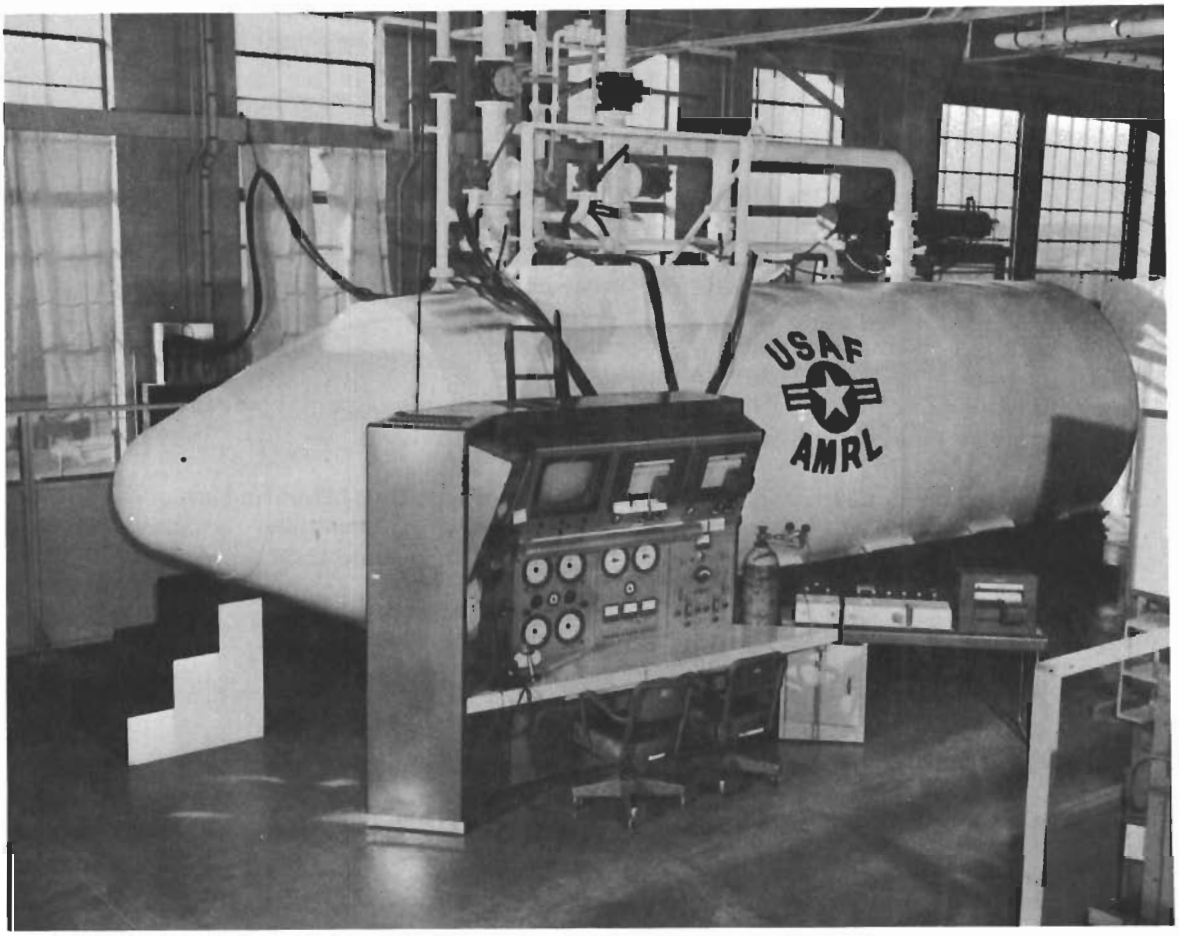

Figure 1. Life Support Systems Evaluator (LSSE).

Viewed from the outside, the Evaluator is cylindrical with a conical forward section. The inside of the Evaluator is divided into two sections. The aft cylindrical section is 19.1 feet long and has a 7.5-foot inside diameter; the conical nose section has a 7.5-foot inside diameter tapering to 3 feet and is 8.5 feet long. These two sections are physically connected, but can be operated

independent of one another. A second wall, 4 inches from the inner wall, encloses the two primary sections (fig. 2).

This doublewalled facility provides a low-pressure environment immediately surrounding the two inner sections. The configuration insures that any leakage of the inner chambers will be outboard, preventing contamination or dilution of the interior atmosphere by the ambient atmosphere. The door designs also adhere to the doublewall feature. When the doors are closed, the low-pressure area between the doors maintains the sealing of the doors.

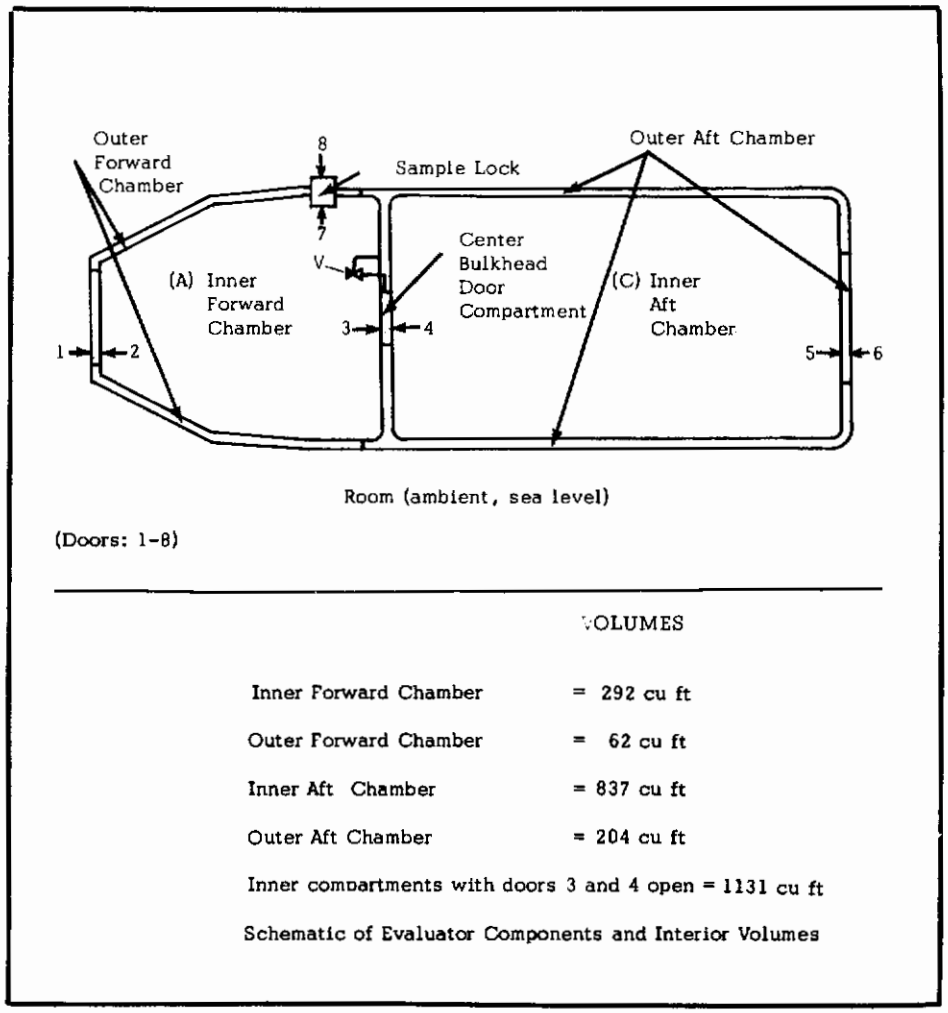

Figure 2. LSSE Components and Interior Volumes.

The Evaluator is fabricated from 6061ST-6 weldable aluminum alloy. All walls are stressed to withstand a minimum of 45-psia pressure differential across the walls from either direction. The inner wall is ¼-inch thick and the outer is $\frac{5}{16}$-inch thick. For additional support, the inner and outer walls are secured on a series of H-beams strategically located longitudinally and circumferentially. One-inch diameter bleed holes are spaced approximately 12 inches apart throughout all bulkheads and horizontal supports. The bleed holes were omitted on the middle door

frame and in the circumferential H-beam separating the outer forward and outer aft chambers. Bleed holes are located in the door frame between doors 1 and 2, and 5 and 6.

A sample lock (see fig. 2) is integrated into the right side of the nose section. It is 65½ inches long and has a 10-inch inside diameter. This lock can be operated independently by using small auxiliary vacuum pumps. The doors are secured by three hand-tightened locks. Each door contains a single O-ring seal. Any item smaller than the sample lock can be transferred through the sample lock without appreciably affecting the habitable atmosphere. The valving and pumping sequence can be established so that the interior chamber atmosphere is unaffected after the sample lock has been used, i.e., ambient atmosphere entrapped in the lock is evacuated to the room.

Primary monitoring instrumentation for the LSSE is incorporated in a single console (fig. 1). (See ref. 2). AIC-18 communications equipment was recently added for coverage while wearing full-pressure suit helmets. Backup communication was provided by a station-to-station telephone system. The gas chromatograph was not operated. However, a hydrocarbon detector was operated continuously. A nitrogen analyzer was also monitored.

OBSERVATIONS

The double-tier bunks provided the necessary capacity for a three-man crew (fig. 3). The padding of the bunk was highly fire retardant. It was not, however, capable of readily conforming to the individual's body contour. Length and girth of padding had to be reduced for the swelling experienced at altitude.

Wearing of the pressure suit helmet in the prone position proved to be very uncomfortable.

The two chairs in the forward cabin were modified aircraft types with full-length adjustable backs, headrests and armrests. These chairs were very comfortable.

The two aft chairs were commercial-type, swiveled, fiberglas chairs with arm rests. They lacked a full-length back with headrest. The contour of the LSSE is such that the sitting subject must step down when stepping out of the aft chairs. The biggest discomfort of the aft chairs was the wide, rearward slope of the seat which made it necessary for the subject to push himself out of the chair.

The most severe monitoring problem was the unsatisfactory performance of the closed-circuit-television cameras. These units were not rated for operation at altitude and performed poorly at the cabin pressure and gas composition maintained during this program.

Eight thermisters were available for monitoring ambient temperatures. At least twice this number are required.

When the subjects were permitted the choice of communicating via telephone or via the headset-microphone H-157/AIC (helmet removed), they unanimously and consistently, chose the telephone.

CONCLUSIONS

Data obtained confirm a capability of these Laboratories to perform research studies utilizing human subjects and experimental systems in an aerospace vehicle cabin simulator in safety, continuous operation, and subject comfort.

The requirement for trained, alert physiological chamber operators and adequately indoctri-

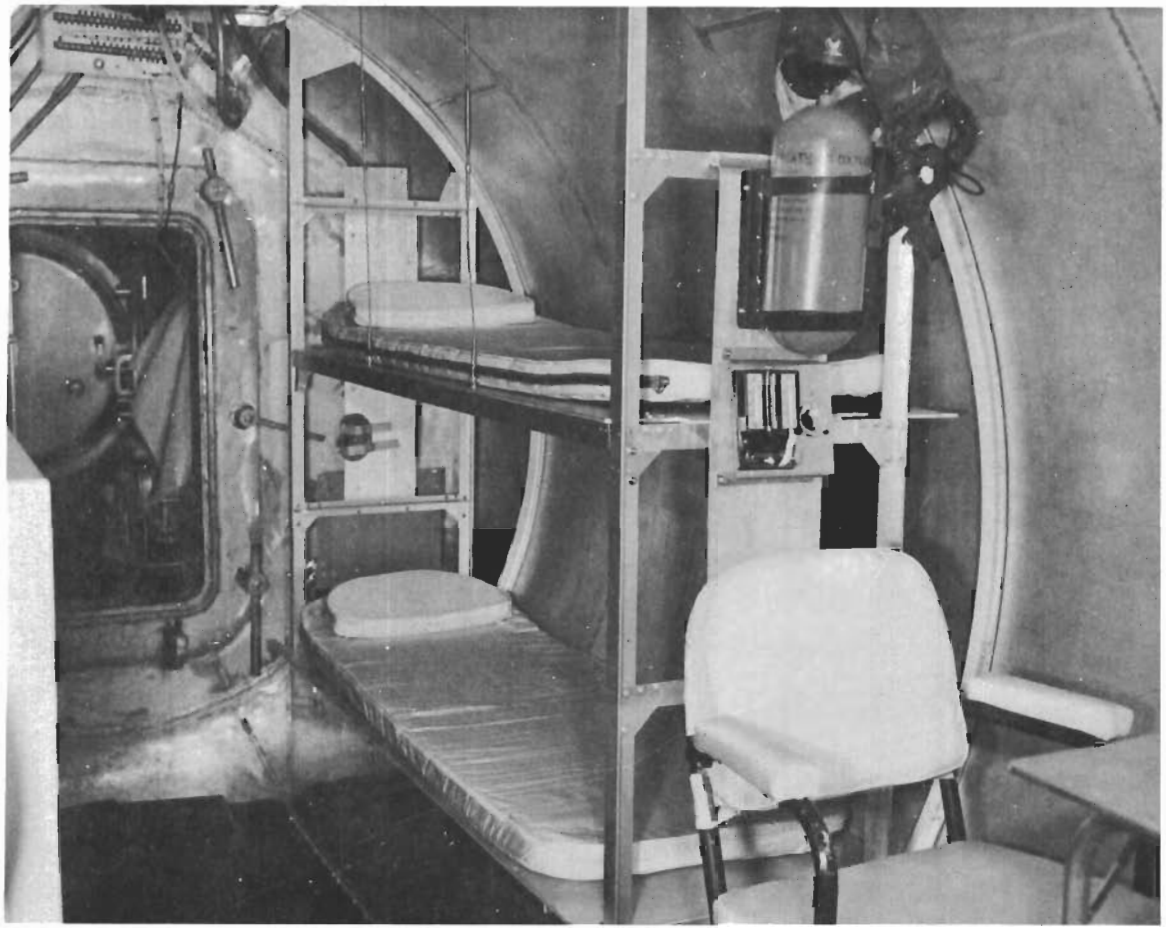

Figure 3. Double-Tier Bunks.

nated motivated subjects were the two primary factors leading to the successful completion of this program.

The data provided by the subjects every four hours (oxygen partial pressure, wet bulb and dry bulb temperatures) assured the subjects of adequate metabolic oxygen and supplied data for determining the absolute humidity of the crew cabins via the known wet-dry bulb temperatures and cabin gas composition.

The closed-circuit-television monitoring system should be considerably upgraded to perform adequately at reduced pressures for extended time periods. The cameras should be replaced. Provisions should be made for external pan and tilt control. For monitor comfort, the monitors should be placed at normal eye level.

Temperature sensor-display capacity for ambient conditions should be at least doubled.

Headset-microphone units having improved subject acceptance should be attained.

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SECTION III.

Effects of Pressure Suits/Oxygen-Helium Atmosphere

Eugene Fritz, TSgt, USAF

An objective of the research program was to investigate certain problems associated with the wearing of pressure suits in a 380 mm Hg pressure, 48% oxygen-48% helium atmosphere. Specifically, data on the following were sought:

a. Could a pressure suit, complete with helmet and gloves, be worn unpressurized and ventilated continuously by a subject for 20 days?

b. What ventilation flows would be required using the oxygen-helium atmosphere to keep the suited subject comfortable?

c. Would the emergency breathing system (EBS) installed in the Life Support Systems Evaluator (LSSE) provide the required flow?

The three subjects who were confined inside the LSSE wore, for this study, Type G-2c full pressure (Gemini) suits borrowed from the National Aeronautics and Space Administration, Manned Spacecraft Center (NASA/MSC). Two subjects wore "Large Long" suits; the third wore a suit that had been tailored to fit another individual. Although the suits were not designed specifically to fit the subjects in this experiment, they were considered adequate for the study.

The helmets provided with the suits were donned for several minutes prior to the start of the investigation and were judged to fit satisfactorily. The gloves furnished two of the subjects fit properly, but the glove for the right hand of the third subject would not fit. He started the experiment with only his left hand gloved and with a portion of his ventilating air escaping at the right wrist-glove joint.

Eight hours after the investigation started, two subjects removed their helmets complaining that they were uncomfortable. Neither donned his helmet again during the experiment. Since the helmet liners had not been sized to fit the subjects, pressure points developed after several hours that made wearing of the helmet unbearable. Such points were not apparent the first few hours the helmets were worn.

The third subject removed his helmet 9½ hours after the study began. He complained of being nauseated by body odors inside the helmet. Two hours later he put his helmet on again and wore it for 23 hours (total – 32½ hours) when he removed it for the duration of the experiment because of the odors. It appears that since only one hand was gloved, the ventilation pattern inside the suit assembly was altered such that sufficient air was not circulated to the helmet to remove the body odors that accumulated there.

According to the third subject, his helmet was not uncomfortable and there were no apparent pressure points because of the liner. He did point out that an improper tie-down adjustment to the helmet caused his head to be forced slightly forward.

Each subject complained of body odors flowing up past the face shortly after the helmet had been removed. With the helmet removed, most of the air used to ventilate the suit passed from the neck of the suit up around the head. With time, however, a tolerance to the odors developed and the complaints ceased.

With the helmets off, it was not possible to obtain the required data on the ventilation flows needed to keep a completely suited subject comfortable in the oxygen-helium atmosphere.

Approximately 7 days after the start of the pressure suit study, the blower of the emergency breathing system (EBS) that supplies air to ventilate the suits failed. The study was then terminated and the subjects removed their suits.

Under the conditions of the study, the 380 mm Hg pressure, 48% oxygen-48% helium atmosphere had no adverse effect on the subjects while they were in Type G-2c full-pressure suits with and without helmets. Neither were any benefits noted.

For future studies of this type, it is recommended that (a) all subjects be properly fitted with suits, helmets, and gloves and be completely familiar with the assembly, and (b) all equipment be job-rated to minimize the possibility of breakdown during a test.

SECTION IV.

Atmospheric Condensation as a Potable Water Source

Sheldon A. London, PhD
Albert B. Hearld, M.A.

In a closed or partially closed ecological system, certain substances must be reutilized by the biological components comprising the system or the flow of materials and energy will decrease to the point where the ecosphere becomes nonfunctional. In considering extended manned space missions, one must contend with those mission profiles for which regeneration of water and food becomes mandatory. Water may be made available from several sources and by several techniques, as discussed in references 1 and 2. The ultimate selection of both the source and the technique utilized is dependent upon logistic and technical considerations. Whether or not used as a source of potable water, water is obtained in a space vehicle through condensation of the atmospheric moisture, as part of the environmental control system (ECS). The ultimate source of this water is, of course, the space crew via sensible and insensible perspiration.

The nature of the physical system through which the water changes state is such that the condensator is an effective scrubber of the atmosphere. Significant amounts of dissolved and particulate air contaminants, both organic and inorganic, are entrained in the condensation. Microbial entities removed from the atmosphere find the condensation a favorable milieu in which to grow. The organisms that grow in this water are derived, in part, from the human occupants, i.e., they are not unusual types but rather normal environmental fungi and bacteria. It is significant that some of the microbes isolated from the condensed water (e.g., pseudomonads) have potential pathogenic implications.

To be utilized as a source of potable water in space systems, atmospheric condensation must meet established criteria of acceptability. The Aerospace Medical Research Laboratories (AMRL) has formulated tentative standards (see table I) for aerospace water supplies. These standards are based on criteria that can be readily evaluated and monitored during space missions. They are, in part, dependent on the design of water recovery systems that inherently can produce water of acceptable quality. For ground-based studies, the U. S. Public Health Service (USPHS) Standards (ref. 3) may be applied with certain modifications. The modifications are stringent in that no coliforms or enterococci are permitted and the maximal allowable aerobic count is 500 per ml. Although the USPHS standards permit certain levels of coliform contamination based upon the sample size and frequency of analysis, the nature of reclaimed water sources for space systems necessitates the more rigid approach.

TABLE I.
AMRL TENTATIVE SPACE WATER STANDARDS

Criterion	*Limit*
Specific Conductance	500 μmhos/cm
pH	5.5 to 9.0
Color	15 chloroplatinate units
Turbidity	25 Jackson units
Taste	Acceptable
Odor	Acceptable
Microorganisms	None

One objective of this experiment was the organoleptic evaluation of potable water derived from atmospheric condensation. Preliminary studies were conducted to ascertain the quantitative and qualitative nature of the contaminants appearing in water obtained during previous experiments. Because it was necessary to treat the raw condensation, the water obtained from the condensator was processed as follows:

a. Water condensed on heat exchanger coils was collected in a pan.

b. Water in the pan was gravity fed to an 8-liter aspirator flask containing 2 ml of sodium hypochlorite (approximately 1% available chlorine).

c. When 4 liters of water had collected (in approximately 24 hours), an additional 2 ml of sodium hypochlorite was added (for some samples).

d. Water was transferred to a 4-liter aspirator bottle.

e. A peristaltic pump was employed to pump the water through the following filters, in sequence:

   1. Cellulose acetate fiber filter, #W5A3SNL, Filterite Corp., Timonium, Md.

   2. Acid-washed, distilled-water-rinsed, pecan shell activated charcoal.

   3. Ultipor® 0.15 μ filter, Pall Corporation, Glen Cove, L. I., N. Y.

f. The water was collected in 4-liter glass reservoir and tested for chlorine content. Additional sodium hypochlorite was added to obtain a free chlorine level of 0.2 ppm.

This procedure was considered adequate to reduce particulate and dissolved contaminants to acceptable levels. For this experiment, the condensate was collected in 4-liter amounts, processed as indicated above and, if found potable, made available to the subjects. The chemical and microbiological testing required 48 hours for accomplishment; each batch of water was held in the refrigerator until the tests indicated whether the quality was commensurate with the established standards.

The subjects entered the Life Support Systems Evaluator on 5 November, and the collection of condensate was initiated. The 4-liter collections were removed daily and aliquots subjected to analyses, consisting of determinations performed on the water initially treated with the sodium hypochlorite solution and the water after filtration but prior to final rechlorination. The sample collected and processed on 10 November was tested, considered acceptable, and made available to the subjects on the evening of 12 November. The results of the microbiological and chemical analyses of all the samples tested are shown in tables II and III. These microbiological tests included total viable aerobic counts (determined by spreading 0.1 ml of selected dilutions in Trypticase-Soy Broth (TS) (BBL) on TS agar plates and incubating at 37°C for 48 hours) and coliform analysis utilizing EMB agar (BBL) and Phenol Red Lactose Broth (Difco) in fermentation tubes. The coliform analyses were all negative, with the exception of the first sample collected on 6 November. The chemical analyses were performed according to procedures in reference 4 or modifications thereof.

TABLE II.

REPORT OF CHEMICAL ANALYSIS OF CONDENSATE

	SAMPLE					
Test	*UFC-6*	*FC-6*	*UFC-7*	*FC-7*	*UFC-8*	*FC-8*
pH	7.35	7.85	7.40	7.85	7.70	7.61
Specific Conductance, μmhos/cm	480	1100	560	1200	650	1140
Chloride, ppm	40.0	133.0	37.0	165.0	49.0	172.0
Free Chlorine, ppm	0.04	0.02	0.03	>1.0	0.02	>1.0
Ammonium Nitrogen, ppm	>3.0	>3.0	>3.0	>3.0	>3.0	>3.0

	SAMPLE					
Test	*UFC-9*	*FC-9*	*UFC-10*	*FC-10*	*UFC-11*	*FC-11*
pH	7.50	7.20	7.63	7.86	7.71	7.99
Specific Conductance, μmhos/cm	520	880	500	890	485	780
Chloride, ppm	39.0	83.0	40.0	105.0	40.0	62.0
Free Chlorine, ppm	0.02	0.22	0.02	1.20	0.02	0.22
Ammonium Nitrogen, ppm	39.0	51.0	53.0	45.0	60.0	57.5
Color		Clear		Clear		Clear
Taste		Medicinal, Rubber-like		Medicinal, Rubber-like		Medicinal, Rubber-like
Odor		Rubber-like, Stale		Rubber-like, Stale		Rubber-like, Stale

KEY:

UFC = Unfiltered condensate
FC = Filtered condensate

The number after the sample designation is the date of collection.

TABLE III.

BACTERIOLOGICAL ANALYSIS OF CONDENSATE

Sample	*Count/ml*
UFC-6	TNTC
FC-6	0
UFC-7	TNTC
FC-7	0
UFC-8	TNTC
FC-8	0
UFC-9	77×10^3
FC-9	0
UFC-10	74×10^3
FC-10	0
UFC-11	24.5×10^5
UFC-12	275
F-Pump-12	12.5×10^3
F-Acetate-12	9×10^5
F-Charcoal-12	53.5×10^5
F-Pall-12	30.5×10^5
FC-12	0
UFC-13*	0
FC-13	0
UFC-14*	0
FC-14	0
UFC-15*	0
F-Pall-15	36×10^5
FC-15	0
UFC-16	TNTC
F-Pall-16	TNTC
FC-16	0
UFC-17	9×10^5
F-Pall-17	131×10^5
FC-17	0

KEY:

UFC = unfiltered condensate after initial chlorination
FC = filtered condensate, complete treatment including final chlorination
F-Pump = after circulating pump
F-Cellulose Acetate = after acetate filter
F-Charcoal = after charcoal filter
F-Pall = after Pall filter and prior to second chlorination
* = rechlorinated after collection
TNTC = too numerous to count

The only characteristic of the water samples that remained relatively constant was the pH, ranging from 7.20 to 7.99, well within the established range (see table I) of 5.5 to 9.0. Nine of the twelve samples exceeded the tentative standard of 500 μmhos/cm specific conductance, in some cases (table II, FC-6, FC-7, FC-8) by more than a factor of two. In all samples, the filtered aliquot exhibited a higher specific conductance than did the unfiltered, suggesting that the filtration process contributed to the observed contam nation. The relationship between the values for chloride and specific conductance, although not exactly linear, indicates these criteria are related; the observed differences being due to both errors in the technique and the presence of ions other than chloride. The free chlorine values are quite variable because of variations in the additions of sodium hypochlorite and in the organ c load of each sample. Thus the daily chemical composition of the condensed water was varied, probably due to changes in the environment and perhaps in the activity of the subjects. The marked increase in ammonium nitrogen level is not understood but may have been caused by a change in the bacterial contaminants in the water or an increase in their number at some point during processing (see table III, samples UFC-12 through FC-12).

As shown in table III, the data pertaining to the first five samples (UFC-6 through UFC-10) indicate that the filtration process was successful resulting in a sterile product. On this basis, and the chemical analyses, the water was made available to the subjects. It was subsequently learned that the filtered water was subjected to a final rechlorination. Since the presence of certain organisms (i.e., Enterobacteriacea) even though nonviable, might be harmful, samples of water were obtained from various points during the processing of the 12 November collection and checked for viable organisms. The data in table III definitely show that the filtration process contributed significantly to the contamination. The final chlorination resulted in a sterile product; however, considerable numbers of nonviable bacterial cells were still present. For this reason, the water was not considered potable and was not given to the subjects after 14 November.

Approximately 1⅓ liters of condensate were collected per man per day during the 14 days the three subjects were confined inside the Evaluator. Of this, Subject A consumed 4.2 liters, B consumed 6.2 liters, and C consumed 2.7 liters. Each complained of the strong chlorine taste of the water and Subject B experienced a mild case of diarrhea during the time the water was being consumed. Since Subject A had a similar case 2 days before consumption of the water was started, B's diarrhea may not have been caused by the water he consumed.

This study indicates that considerably more stringent methods for the production of potable water must be utilized.

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SECTION V.

Evaluation of Apollo Block I Diet

Sheldon A. London, PhD

To conserve on the weight and volume of stored food supplies during space missions, consideration has been given to the preparation of nutritionally adequate and organoleptically acceptable diet regimes that are characterized by low levels of water and cellulosic residues. The approaches taken have included both completely dehydrated, i.e., lyophilized items and bite-size, compressed cubes coated with substances such as methyl cellulose. Previous experiments conducted under the joint USAF-NASA R-85 program were concerned with acceptabilities and nutritional balances of various experimental space diets as compared with "normal" equivalent diets (refs. 1 thru 5). These experiments indicated that foods so processed are reasonably acceptable and can be formulated so as to provide a sound nutritional source for space crews.

During the planning phases of this experiment, an experimental diet, termed Apollo Block I, was made available for evaluation. The individual food items comprising this diet were similar to specific items evaluated in previous studies. This study evaluates the organoleptic acceptability and packaging concepts of the Apollo Block I diet. Consideration was not given to nutritional balances. The individual food items were made available to AMRL by NASA Manned Spacecraft Center (MSC), Houston, Texas.

The rehydration of freeze-dehydrated items was accomplished by means of NASA supplied "water guns" which permitted the subjects to introduce hot or cold water into the food packages. The subjects were asked to ingest all meals completely; that this was not accomplished is indicated in tables I thru IV by the large number of "not-rated" items. After each meal was consumed, the subjects were required to rate each diet component with respect to acceptability according to a 9-point hedonic scale. The individual items comprising the 4-meal, 4-cycle menu and the ratings of these items are presented in tables I thru IV. Table V contains a summary of individual food item acceptability; these are grouped according to rating and frequency of consumption. The hedonic evaluation by meal is shown in table VI.

The subjects differed considerably in the amount of food consumed, ranging from very little to all that was offered. This probably reflects both individual differences in eating patterns plus acceptability of specific food items. Tables I thru IV show that Subject C did not rate a large portion of the individual food items, since he consumed only a small portion. The data presented in table V are weighted by these differences; hence, the items appear in groups according to frequency of acceptance. Thus those items in Group I were most acceptable, while those in Group II were rated overall as acceptable but were not consumed 100 per cent of the times offered. The 17 items in Group IV would appear to be unacceptable components of a space diet since they were consumed less than 50 per cent of the times offered and were given an average hedonic rating below 5 (neither like nor dislike). Those items in Group III were, in general, marginally acceptable. The data in table VI suggests that, if consumed (on a meal basis), all meals received a minimum average rating of 6.0 and were rated (consumed) at least 67 per cent of the times offered. Although this suggests that the Apollo Block I diet, based upon these limited observations, is generally acceptable, the data in table VI are biased in that they represent ratings of a preferential sampling, i.e., only those items actually consumed. If one considers the high frequency of food rejection, it could be interpreted as indicating a poor overall level of acceptability. Comparison of these results with previously obtained data (see refs. 1 thru 5) reveals

that the earlier diets were more acceptable. In general, the individual food items were similar in past and present studies; however, changes in the responsible contractor may have resulted in significant differences in processing. This strongly suggests that, when diet compositions are finalized, stringent specifications be formulated to insure a consistent product quality.

Adverse comments made by the subjects as indicated in daily diaries were concerned with the following:

1. Coating of the bite-sized items was objectionable and detracted from acceptability of the food.
2. Caloric content (2700 K cal) was too high with respect to the low level of activity during the experiment.
3. Odor emanating from plastic packaging of freeze-dehydrated items was quite objectionable and increased notably when hot water was used to rehydrate.

At the termination of the experiment, the subjects were given a debriefing. A summary of the comments made concerning the packaging and manipulation of the food items is presented in table VII. Generally, the packaging concepts utilized were acceptable. Difficulties were encountered in certain manipulations due to the gloves. Under normal conditions, these may not be worn; however, under contingency conditions, design modifications must be incorporated to insure the rehydration and utilization of food items while the entire pressurized suit is worn. Modifications of rehydration techniques would negate the problem of leaking seals and insertion of the water guns. Improvements are required in the removal of the food from the packaging to insure that space crews utilize the nutritional components fully and to eliminate problems encountered when fermentable waste foods are stored.

The information derived from this effort indicates the need to:

1. Improve the acceptability of specific food items through changes in composition (e.g., lower fat contents) and coating materials.
2. Determine the caloric requirement of the individual space crew members commensurate with his level of activity.
3. Improve seals for rehydration and eliminate material odor.

TABLE I.

MEAL EVALUATION, CYCLE I.

	SUBJECT A					SUBJECT B					SUBJECT C					Mean
Meal A																
Bacon and Egg Bites	5	6	6	7	5	9	7	9	7	7	6	–	–	–	–	6.7
Toasted Bread Cubes	6	–	6	–	–	9	7	8	7	7	9	–	–	–	–	7.4
Toasted Oat Cereal	7	8	8	8	8	9	9	9	8	8	8	9	8	7	7	8.1
Orange Drink	8	9	9	9	9	7	9	9	9	9	7	9	7	7	7	8.3
OVERALL	6	8	7	8	6	8	8	9	8	8	7	–	7	–	–	
Meal B																
Beef and Gravy	8	7	8	7	8	8	8	8	8	7	–	–	–	–	–	7.7
Corn Bar	5	–	–	–	–	7	8	8	8	7	–	–	–	–	–	7.2
Cinnamon Toast	7	–	7	7	7	8	8	8	8	7	–	–	–	–	–	7.4
Date Fruitcake	8	8	8	9	9	8	8	8	8	7	–	–	–	7	7	7.9
Tea and Sugar	1	–	–	–	–	7	7	6	6	6	2	–	–	–	–	5.0
OVERALL	7	8	–	8	7	8	8	8	8	7	–	–	–	–	–	
Meal C																
Pea Soup	3	–	–	–	–	7	6	–	6	–	1	–	–	–	–	4.6
Salmon Salad	7	7	8	7	7	8	8	9	8	8	9	–	–	–	–	7.8
Cinnamon Toast	7	7	7	7	7	8	8	8	8	8	3	–	–	–	–	7.1
Fruit Cocktail	8	9	9	9	9	9	8	9	8	8	9	7	7	7	–	8.3
Orange Drink	8	8	9	9	9	7	9	9	9	9	7	9	7	7	–	8.3
OVERALL	7	8	8	8	8	8	8	8	8	8	8	–	7	–	–	
Meal D																
Chicken Sandwiches	5	6	7	7	4	3	6	6	6	6	1	3	–	–	–	5.0
Peanut Cubes	8	8	6	7	–	7	9	7	7	7	8	8	7	8	7	7.4
Chocolate Pudding	6	9	9	9	9	6	9	8	7	7	8	8	8	8	7	7.9
Orange-Grapefruit Juice	8	9	9	7	9	7	9	9	9	9	8	9	7	7	7	8.2
OVERALL	7	8	7	8	6	7	8	8	8	8	8	8	9	7	7	

SCALE: – not rated

9–Like Extremely	6–Like Slightly	3–Dislike Moderately
8–Like Very Much	5–Neither Like or Dislike	2–Dislike Very Much
7–Like Moderately	4–Dislike Slightly	1–Dislike Extremely

TABLE II.

MEAL EVALUATION, CYCLE II.

	SUBJECT															Mean
	A					B					C					
Meal A																
Bacon and Applesauce	3	–	–	–	–	6	6	6	–	7	6	–	–	–	–	5.7
Apricot Cubes	6	–	5	–	–	7	6	6	–	–	6	–	–	–	–	6.0
Cinnamon Toast	7	7	7	7	7	8	8	8	8	7	–	4	–	–	–	7.1
Cocoa	8	9	9	9	9	7	8	7	9	9	7	8	7	7	7	8.0
OVERALL	5	8	5	4	7	7	8	7	8	8	7	–	–	–	–	
Meal B																
Beef Bites	8	7	6	–	–	4	6	6	6	–	1	–	–	–	–	5.5
Potato Salad	6	4	1	–	–	2	2	2	6	–	1	–	–	–	–	3.0
Pineapple and Fruit Nut Confections	8	8	9	9	9	7	8	7	8	8	7	–	6	7	7	7.7
Orange Drink	8	9	9	9	9	7	9	9	9	9	7	9	7	7	7	8.3
OVERALL	8	6	6	9	7	6	8	8	7	8	4	–	–	–	–	
Meal C																
Beef Sandwiches	8	6	5	5	–	6	6	6	6	–	–	–	–	–	–	6.0
Chicken Salad	7	1	6	5	5	7	3	6	7	6	–	–	–	4	–	5.2
Banana Pudding	8	9	9	9	9	6	7	8	7	7	–	–	–	6	5	7.3
Peach Bar	7	9	9	8	9	9	9	9	9	9	–	–	–	7	7	8.4
OVERALL	7	6	6	6	8	8	8	7	8	8	–	–	–	6	7	
Meal D																
Potato Soup	5	5	4	–	–	7	6	6	–	–	7	4	–	–	–	5.5
Chicken and Gravy	–	7	6	6	5	7	7	6	6	–	7	5	4	–	–	6.0
Cinnamon Toast	7	7	7	7	7	8	8	8	8	8	1	4	–	–	–	6.7
Peanut Cubes	8	8	5	4	–	8	8	8	8	8	9	8	7	8	–	7.5
Tea and Sugar	1	–	–	–	–	6	6	6	6	6	1	–	–	–	–	3.8
OVERALL	4	6	6	4	3	8	8	7	7	7	–	–	–	–	–	

TABLE III.

MEAL EVALUATION, CYCLE III.

	SUBJECT															Mean
	A					B					C					
Meal A																
Sugar Coated Cornflakes	7	7	7	8	7	7	8	8	8	8	9	9	7	7	8	7.6
Pork Sausage Patties	5	4	–	–	–	3	7	4	–	6	4	–	–	–	–	4.7
Cinnamon Toast	7	7	7	7	7	8	8	8	8	8	1	–	–	–	–	6.9
Orange-Grapefruit Drink	9	9	9	9	9	8	9	9	9	9	9	7	7	7	7	8.4
OVERALL	7	7	8	–	7	7	8	7	8	8	8	8	–	–	–	
Meal B																
Cheese Sandwiches	7	8	6	7	6	7	7	7	6	6	–	–	–	4	–	6.4
Tuna Salad	8	8	8	7	7	7	8	8	7	7	–	–	–	4	–	7.2
Apricot Pudding	8	–	7	7	8	7	7	–	6	–	–	–	–	6	–	7.0
Orange Drink	9	9	8	9	9	7	9	9	9	9	–	–	7	7	7	8.3
OVERALL	8	8	7	7	8	7	8	8	7	7	–	–	–	6	–	
Meal C																
Beef Pot Roast	7	8	8	8	7	7	8	7	7	7	–	–	6	–	–	7.3
Pea Bar	–	–	–	–	–	7	7	–	6	6	–	–	–	–	–	6.5
Toasted Bread Cubes	6	7	–	7	–	8	7	7	7	7	–	–	–	–	–	7.0
Pineapple Cubes	6	6	–	–	–	4	7	7	–	–	–	–	5	–	–	5.8
Tea and Sugar	–	–	–	–	–	6	6	6	6	6	–	–	–	–	–	6.0
OVERALL	6	7	6	6	3	7	7	7	7	7	–	–	–	–	–	
Meal D																
Chicken Bites	4	6	–	–	–	–	6	8	6	–	–	–	–	–	–	6.0
Cinnamon Toast	–	7	7	7	7	–	8	8	8	7	–	–	–	–	–	7.4
Applesauce	–	7	5	6	6	–	7	–	–	6	–	7	6	–	–	6.2
Brownies	6	5	7	6	6	–	8	8	7	7	–	7	8	7	7	6.8
Grapefruit Drink	8	9	8	9	9	7	9	9	9	9	–	8	7	7	7	8.2
OVERALL	5	7	7	6	6	–	8	7	7	7	–	7	–	–	–	

TABLE IV.

MEAL EVALUATION, CYCLE IV.

	SUBJECT															Mean
	A					B					C					
Meal A																
Beef Sandwiches	7	7	7	–	x	6	6	6	6	x	–	–	–	–	x	6.4
Strawberry Fruit Cubes	6	5	–	–		4	6	6	–		4	–	–	–		5.2
Bacon Bars	9	9	9	9		7	9	9	8		–	7	9	9		8.5
Orange Drink	8	9	9	9		7	9	9	9		9	8	7	7		7.6
OVERALL	8	8	8	9		7	8	7	8		6	–	–	–		
Meal B																
Beef Sandwiches	–	7	6	–	x	6	6	6	6	x	–	–	–	–	x	6.2
Gingerbread	4	5	6	7		7	7	7	7		4	–	6	7		6.1
Chocolate Pudding	7	9	9	9		7	8	8	8		9	7	7	7		7.9
Corn Chowder Soup	–	–	–	–		6	7	–	–		–	–	–	–		6.5
OVERALL	5	6	6	7		6	8	7	7		6	–	–	–		
Meal C																
Chicken and Vegetables	–	–	4	3	x	6	7	7	6	x	4	2	–	–	x	4.9
Shrimp Cocktail	–	7	8	8		7	8	8	6		–	–	–	4		7.0
Toasted Bread Cubes	–	7	7	–		7	7	8	7		–	–	–	–		7.2
Butterscotch Pudding	8	9	9	8		7	8	8	7		8	8	–	7		7.9
Orange-Grapefruit Drink	8	8	9	9		7	9	9	9		9	7	–	7		8.4
OVERALL	–	8	8	7		7	8	8	7		7	6	–	–		
Meal D																
Spaghetti with Meat Sauce	7	7	6	–	x	7	6	6	7	x	4	–	–	–	x	6.3
Beef with Vegetables	7	7	6	7		6	6	6	–		5	–	6	–		6.2
Apricot Cereal Cubes	–	5	–	–		–	6	6	–		–	–	–	–		5.7
Cinnamon Toast	–	7	7	7		–	8	8	8		–	–	–	–		7.5
Tea and Sugar	–	–	–	–		–	6	6	6		–	–	–	–		6.0
OVERALL	7	7	7	5		–	7	7	7		4	–	–	–		6.4

x = not offered

TABLE V.

ACCEPTABILITY OF INDIVIDUAL FOOD ITEMS

Highly Acceptable

Group I: Foods consumed 100% of times offered
All ratings above 6.0

Item	*x's Offered*	*x's Rated*	*Mean*	*Range*
070—Toasted Oat Cereal	15	15	8.1	6 to 9
060—Cocoa	15	15	8.0	7 to 9
057—Chocolate Pudding	27	27	7.9	6 to 9
069—Sugar Coated Flakes	15	15	7.6	7 to 9

Group II: Foods consumed at least 75% of times offered
All ratings above 6.0

027—Bacon Squares	12	11	8.5	7 to 9
046—Peach Bar	15	12	8.4	7 to 9
045—Fruit Cocktail	15	14	8.3	7 to 9
066—Orange-Grapefruit Drink	42	41	8.3	6 to 9
064—Grapefruit Drink	15	14	8.2	7 to 9
067—Orange Drink	72	69	8.2	7 to 9
056—Butterscotch Pudding	12	11	7.9	7 to 9
047—Date Fruitcake	15	12	7.9	7 to 9
065—Salmon Salad	15	11	7.8	7 to 9
048—Pineapple Fruit and Nut Conf.	15	14	7.7	6 to 9
076—Peanut Cubes	30	27	7.4	4 to 9
055—Banana Pudding	15	12	7.3	5 to 9
033—Brownies	15	13	6.8	5 to 8
059—Spaghetti and Meat Sauce	12	9	6.2	5 to 7
049—Gingerbread	12	11	6.1	4 to 7

TABLE V.—Concluded

ACCEPTABILITY OF INDIVIDUAL FOOD ITEMS

Moderately Acceptable

Group III: Foods consumed at least 50% of times offered
All ratings above 5.0

Item	*x's Offered*	*x's Rated*	*Mean*	*Range*
028—Beef and Gravy	15	10	7.7	7 to 8
042—Chicken Sandwiches	15	12	5.0	1 to 7
030—Beef Pot Roast	15	11	7.3	6 to 8
062—Tuna Salad	15	11	7.2	4 to 8
043—Cinnamon Toast	102	68	7.1	1 to 8
058—Shrimp Cocktail	12	8	7.0	4 to 8
026—Bacon and Egg Bites	15	11	6.7	5 to 9
036—Cheese Sandwiches	15	11	6.4	4 to 8
032—Beef and Vegetables	12	8	6.3	4 to 7
038—Chicken and Gravy	15	11	6.0	4 to 7
031—Beef Sandwiches	39	23	5.6	5 to 8
041—Chicken Salad	15	11	5.2	1 to 7
037—Strawberry Cereal Cubes	12	6	5.2	4 to 6

Unsatisfactory

Group IV: Foods consumed less than 50% of times offered *and/or*
All ratings below 5.0

063—Corn Bar	15	6	7.2	5 to 8
054—Apricot Pudding	15	8	7.0	6 to 8
035—Apricot Cereal Cubes	15	6	6.6	5 to 7
050—Pea Bar	15	4	6.5	6 to 7
044—Corn Chowder	12	2	6.5	6 to 7
051—Applesauce	15	8	6.2	5 to 7
040—Chicken Bites	15	5	6.0	4 to 8
072—Pineapple Cubes	15	6	5.8	4 to 7
034—Bacon and Applesauce	15	6	5.7	3 to 7
075—Apricot Cubes	12	3	5.7	5 to 6
029—Beef Bites	15	8	5.5	1 to 8
074—Potato Soup	15	8	5.5	4 to 7
038—Chicken and Vegetables	12	8	4.9	2 to 7
052—Pork Sausage Patties	15	7	4.7	3 to 7
071—Tea and Sugar	57	24	4.6	1 to 7
073—Pea Soup	15	5	4.6	1 to 7
053—Potato Salad	15	8	3.0	1 to 6

TABLE VI.

SUMMARY OF OVERALL MEAL ACCEPTABILITY

		x's Offered	*x's Rated*	*Mean*	*Range*
CYCLE I.	Meal A	15	12	7.5	6 to 9
	B	15	9	7.7	7 to 8
	C	15	12	7.8	7 to 8
	D	15	15	7.5	6 to 7
CYCLE II.	Meal A	15	11	7.5	7 to 8
	B	15	10	7.5	7 to 8
	C	15	10	6.3	3 to 7
	D	15	10	6.7	5 to 8
CYCLE III.	Meal A	15	11	6.7	4 to 8
	B	15	11	7.0	4 to 9
	C	15	11	7.1	6 to 8
	D	15	10	6.0	3 to 8
CYCLE IV.	Meal A	12	9	7.7	6 to 9
	B	12	9	6.4	5 to 8
	C	12	9	7.3	6 to 7
	D	12	8	6.4	4 to 7

TABLE VII.

SUMMARY OF DEBRIEFING

1. *Man-Meal Packs:*

(1) Was it convenient to open the man-meal packs with scissors?

A. Yes. However, a few packages where the food was packed against the upper end of the package was difficult to open, especially with the pressure suit gloves on. In order to use these, the gloves usually had to be removed.

B. It was convenient in opening the packs with scissors; however, the scissors must be sharp.

C. Yes. However, the scissor finger openings should be large enough to be able to be used with gloves.

(2) Can several items constituting a meal be satisfactorily arranged in the simulator for meal preparation and manipulations?

A. Yes.

B. Several items constituting a meal can be arranged satisfactorily if elevated so the top of the pack is in the upright position. If not, the liquid will leak out. It would be nice if we had a bracket or some type of device to hold the pack requiring liquid.

C. Yes.

2. *Water Dispenser:*

(1) Is the water nozzle probe easily manipulated?

A. Nozzle probe was easy to use.

B. The water nozzle probe was easily manipulated.

C. Yes.

(2) Did the pistol trigger operate, lock satisfactorily?

A. Yes.

B. The pistol trigger and lock worked satisfactorily.

C. Yes.

(3) Were difficulties encontered with probe insertion into food and/or beverage containers?

A. Yes. Especially those without the one-way valve. Again this required the removal of the gloves.

B. Difficulties were encountered when inserting the probe into the pack. Approximately 95% of the packs with valves would leak past the "O" rings. Also, when we were mixing and eating, liquid would come out past the "O" rings.

C. Yes, the tube had to be cut to open to the valve. Difficulty was encountered in separating the tube with gloves on.

(4) Were leaks associated with the withdrawal of the probe?

A. Yes, in the majority of the cases. Also many of the valves didn't let water in.

B. —

C. Yes.

TABLE VII.—Continued

SUMMARY OF DEBRIEFING

3. *Mixing:*

(1) Were there any difficulties encountered in the mixing; i.e., rehydration of the food items, beverage items?

A. Yes, on some of the foods (i.e., applesauce, potatoes), complete rehydration was never accomplished.

B. I encountered no difficulties in the mixing; i.e., rehydration of food and beverage items.

C. No, although a few of items required quite a bit of time.

4. *Bag Manipulation:*

(1) Did the feeder tubes open out satisfactorily?

A. Yes.

B. The feeder tubes open out satisfactorily; however, on a few bags it was sewed shut. Also on some bags the seams broke while mixing.

C. Yes.

(2) Were any difficulties encountered in eating or drinking from the feeder tube?

A. Yes. Sometimes food could not be pushed through the feeder tube and they had to be cut off down to a larger opening or more water had to be added. Also sometimes too large a bolus would suddenly shoot out.

B. No difficulties encountered in eating or drinking from the tube.

C. No.

(3) Is the feeder tube large enough for the semisolid food items?

A. Most of them.

B. No problem in squeezing food out as the feeder emptied.

C. Yes.

(4) Were the entire contents of a particular feeder tube eaten? If so, was it more difficult to squeeze food out as the feeder emptied?

A. All the food on many of the semisolid ones could not be squeezed out.

B. (Answered in 3.)

C. Yes. It was difficult to squeeze all of the food out of the package.

5. *Bite-size Food Packages:*

(1) Were any difficulties encountered in opening the bite-size servings?

A. No.

B. No difficulties were encountered in opening the bite-size servings. There were only a couple of items that were crumbled, and they were the cheese sandwiches and gingerbread cubes.

C. No.

TABLE VII.–Concluded

SUMMARY OF DEBRIEFING

(2) Were the individual items intact, or was crumbling evident?
A. Intact.
B. Answered in 1.
C. Yes.

(3) Were difficulties encountered in dispensing the bite-size pieces?
A. Yes, especially with gloves on. Sometimes the containers had to be cut completely apart.
B. Difficulties were encountered in dispensing the peanut cubes. The cubes would stick to the plastic and crumble.
C. No.

(4) Did you attempt to drink water along with the mastication of a bite-size piece?
A. Occasionally. This did not help, but then I have overactive salivary glands and this could possibly help someone with little saliva.
B. I had no problem in drinking water along with masticating a bite-size piece.
C. Yes.

(5) If so, were there any difficulties evidenced?
A. Not answered.
B. Not answered.
C. No.

6. *Estimation of Use for Extended Flights:*

A. This could be used for extended periods of time; however, I would expect weight loss due to the unacceptable quality of prolonged use of these foods. The bite-size foods had a wax-like coating that was objectionable. Also, they are unacceptable after a week unless you are quite hungry. This is due to taste. Why could not the beef and chicken bites be processed similar to the bacon so that they are not completely dry and taste more like one would expect? Chipped beef might be tried. Also some seasoning of some of the food would help. Even a little pepper would help the spaghetti and the shrimp cocktail. The fruit cubes were too rich and thus unacceptable (strawberry, pineapple). I would prefer to have orange drink to tea. Some people do not drink tea.

B. Overall I liked the food moderately, but I think the bags need improving.

C. I feel that the biggest factor in consuming this food is how hungry a person becomes. The bite-size sandwiches had a greasy-like coating that was very objectionable. I feel that if the beef and chicken, that were made up into sandwiches, were processed and packaged similar to the bacon bar, they would have been more edible.

The freeze-dried foods in the plastic containers were under-seasoned, and an objectionable plastic odor emitted from the feeder tube. This was more noticeable when hot water was used.

I feel that the problem most encountered with the water insertion tube was the fact that the tube between the valve and the bag was sealed. Some valve leakage was noticed while trying to squeeze food from the bags.

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SECTION VI.

Urine Volume Measuring Device

Marilyn George

The problems involved in the inflight collection, storage, and preservation of biological samples from space crewmen for postflight biochemical analyses are complex and require the design of equipment which not only will function properly under flight conditions but also will conform to limited volume and weight specifications. Because of limited space, total 24-hour samples of urine cannot be collected and stored in space capsules. Therefore, a method was devised whereby an aliquot from each micturition would be collected and stored for postflight analyses and the total urine volume of each micturition determined by an isotope dilution technique. One phase of the experiment described in this report was the evaluation of the Gemini urine collection and volume measurement system which was designed and developed under the direction of the Crew Systems Division, NASA/MSC, Houston, Texas. The urine collection system and the isotope dilution measurement technique are described below.

The urine collection system was designed to inject an exact volume of tritiated water, propylene glycol solution into each urine sample voided. The tritium solution and urine were mixed and an aliquot delivered into a plastic bag for storage. A small sample from each bag was taken for isotope counting and the total volume of urine from each micturition calculated. During the ex-

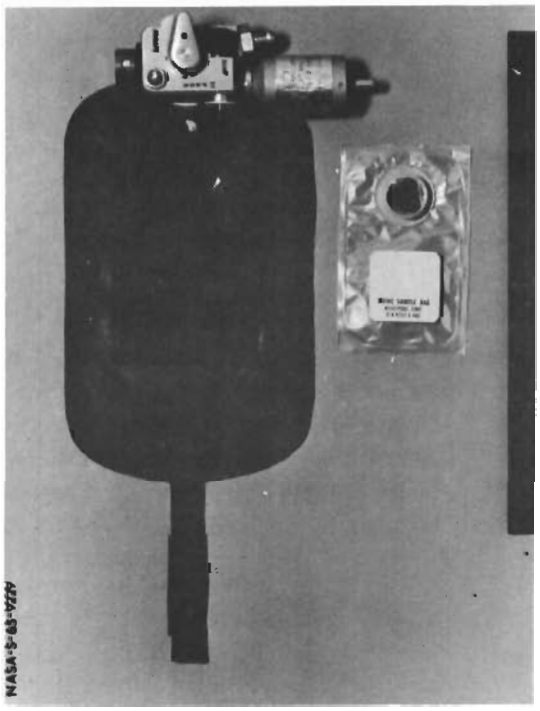


Figure 1. Urine Measurement System.

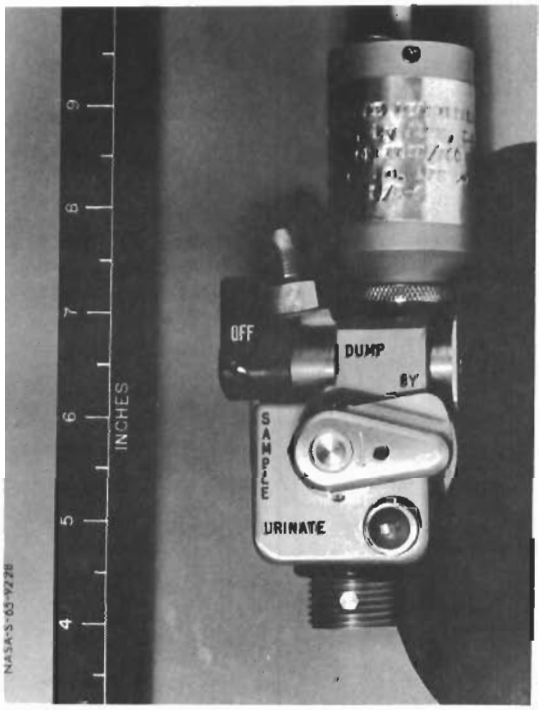


Figure 2. Selector Valve.

periment, the entire urine volume from each micturition was measured by conventional methods and compared to the values obtained by isotope dilution.

The urine collection system consists of the following components (see figures 1 and 2): A condom-type urine receiver is attached to a selector valve. This valve has four positions (Urinate, Sample, Dump, Bypass) which are rotated by a handle attached to a ported center plug. The valve contains a metering pump which is activated by the movement of the handle over a plunger. Prior to use of the system, a tracer storage accumulator containing approximately 20 ml of tritium solution is screwed into the valve body so that the tritium solution is available for delivery by the metering pump. An 800-ml mixing bag and a 75-ml sample bag are attached to the valve. Tubing is attached from the outlet of the valve to a bottle which is connected, in turn, to a pump so that a 5-psi pressure differential is obtained.

When the subjects use the system, they move the selector handle to Urinate position and void into the urine receiver. The movement of the handle to Urinate position activates the metering pump and a constant amount of the tritium solution, 0.3 ml, is dispensed into the urine inlet passageway and is washed into the mixing bag by the urine stream. In the mixing bag the urine and tritium are well mixed by manual manipulation of the bag by the subject. The valve handle is then moved to Sample position and the sample probe introduced into the sample bag. The urine sample bag is filled by squeezing the mixing bag, thus forcing the urine into the valve passageway and into the sample bag. The subjects then move the valve handle to Dump position, switch on the pump, and evacuate the urine remaining in the mixing bag into the bottle attached to the valve outlet.

The sample bags and bottles were stored in the refrigerator and taken to the isotope laboratory every day. The sample bags were agitated, cut open, and the urine collected and measured. The urine collected in the bottle which was attached to the valve outlet was also measured. Six counting vials containing 10 ml Brays Solution were prepared for each sample. Five-tenths ml of urine was added to each vial and 0.01 ml of standard tritium solution was added to three of the vials as a spike. Tritium standards and background solutions were prepared and run daily. All samples were counted in a Packard Tri Carb Liquid Scintillation Spectrometer for 10 minutes. The urine volumes determined by isotope counting and by conventional measurement were compared.

During the first 12 days of this experiment, the urine collection system failed to function properly. The sealant used in the tracer storage accumulator crumbled and particles of the material became lodged in the metering pump valves causing an uneven and inconsistent delivery of tritium into the urine samples. When a new accumulator containing a new sealant material was obtained and the metering pump cleaned, the results improved. However, the metering pump in this particular valve required more sophisticated repair and realignment than could be accomplished in the field during this trial; therefore, the results are not as accurate as desired. One other problem encountered was the freezing of the sample probe when introduced into the sample bag. Although each subject was supplied with a urine receiver, all three subjects used the same valve system. This repeated use by more than one subject may have contributed to the sample probe malfunction. During actual flight each man has an individual urine collection system. During the short period of time when the urine collection system functioned properly the urine volumes measured by the isotope dilution method agreed with the volumes measured by calibrated laboratory glassware within $\pm 5\%$. The method was reproducible; samples held for two weeks and reanalyzed produced the same results. The subjects considered the system acceptable although somewhat difficult to use, particularly when they were wearing pressure suits. Many of the diffi-

culties noted, such as complaints about the weight of the valve, would not be applicable under space conditions of weightlessness.

In summary, the urine collection and volume measurement system was acceptable to the subjects and provided an accurate reproducible technique for measuring total urine volumes from small representative samples.

SECTION VII.
Personal Hygiene and Sanitation

Albert B. Hearld

INTRODUCTION

Personal hygiene and sanitation equipment and technique evaluations made during the 20-day* confinement study were subordinate to the primary objective of the study. The objective was to evaluate the Apollo Block I diet and a urine volume measuring device, at a pressure of 375 mm Hg ± 15 mm Hg with 180 mm Hg, ± 15 mm Hg oxygen and 180 mm Hg ± 15 mm Hg helium.

The hygiene and sanitation equipment was provided to support the primary program, to verify information gained during prior experiments, and to obtain data that would be of value during programed aerospace experiments.

PERSONAL CLEANLINESS AND GROOMING

The three subjects confined during this study were not permitted to bathe, since it had been demonstrated during prior studies that subjects could tolerate up to 36 days in the LSSE without taking a bath. The failure to bathe created some problems. All subjects complained of body odors, especially when the helmet of the pressure suit was worn with the facepiece up: odors from the body passed up and out over the face. Subject C became so nauseated by body odor that he was forced to remove his helmet after wearing it for less than 10 hours. Subjects A and B had already removed their helmets by that time.

With the helmet off, body odors were forced out around the neck of the pressure suit. Subject B described the odors at the end of the fourth day as "absolutely horrible." By the eighth day, he observed that "we are getting more accustomed to our own body odor."

The subjects were furnished wet wipes† for cleaning the face and for washing the hands before eating. Wet wipes were also furnished for cleaning the hands after defecating. Although no restrictions were placed on the number of wipes to be used, they were used sparingly, approximately 5 wipes per man per day. Shaving was not permitted during the confinement.

Prior to the confinement, each subject was instructed to secure a "crew type" haircut. One subject failed to do so and, except for some slight discomfort resulting from dandruff and an itching scalp, suffered no adverse effects. The two other subjects had no complaints. Combing or brushing the hair during the confinement was not allowed.

No provisions were made for nail, eye, nose, and ear care. Oral care was accomplished by brushing the teeth with water and a toothbrush before each meal. The water used was swallowed. A gum (gingival) stimulator was provided on the handle of each brush. A dental examination conducted immediately before and after the confinement revealed no change in the subjects' teeth.

*Three days in a clean room at ambient pressure, 14 days in the LSSE, and 3 days at ambient pressures outside but with access to the Evaluator.

†A lint-free 8 by 5¾-inch loosely woven cloth saturated with a cleansing agent. (Supplied to NASA for use on Gemini flights.)

CABIN SANITATION

No special effort was made to keep the interior of the LSSE clean during the period of the confinement. Spilled liquids and foods were promptly wiped up with single-fold paper towels. Used wipes and towels, empty food packages, wraps, and similar refuse were passed out of the LSSE daily via an airlock.

WASTE MANAGEMENT

Urine

During the portion of the confinement when urine was not being collected by means of the measuring device, it was collected in 1-liter wide-mouth plastic bottles and at times in Piddle-Paks®. The latter are small flexible film plastic bags of approximately 1-liter capacity. Each contains a compressed sponge for adsorbing the urine. Entrance to the urinal is via a flapper-type tube, the top of which is held open by a metal ring. After the urinal is used, the ring is flattened and is used to roll down the "horn" of the urinal to seal the Piddle-Pak.

Feces

Feces were collected in two types of plastic bags. One was a commercial camp stool bag, complete with stool. The second was furnished by NASA/MSC and was of a design proposed for use on Gemini-7 flights. The camp stool bags were used to collect the fecal samples that were required for analyses in the study of the Apollo Block I diet. No germicide or toilet tissue was added to fecal samples collected for analysis. The tissues used were stored in small plastic film bags and disposed of as refuse.

The proposed Gemini bags were of a thin, clear, flexible plastic film and were approximately 6½ inches wide and 12½ inches long. A 7¼-inch wide by 6-inch deep pocket containing toilet tissues, a capsule of blue germicide, and a wet wipe was attached over the closed end of the bag. Around the open end, a 1¾-inch wide by 7½-inch diameter collar of four plies of bag material was attached. The top of the collar was coated with an adhesive for holding the bag against the buttocks of the user. Installed just below collar was a 1-inch diameter tube into which the middle finger was inserted and used to center the bag opening over the anus.

Twenty Gemini bags were used during the confinement study as follows: (a) the capsule of germicide was dropped into the bag, (b) after defecation, the used toilet tissues were added to the bag, (c) the capsule was crushed and the germicide kneaded into the fecal material until the mass was of a uniform blue color, (d) the toilet tissue was mixed with the fecal material, and (e) the bag was rolled to a compact form, secured, weighed, then stored behind a shelf near the rear door of the aft compartment of the Evaluator. The wet wipe was used for cleaning the hands and was disposed of as refuse.

Table I provides data on the feces collected during the 14-day stay inside the LSSE.

TABLE I.

FECES DATA SHEET

Subject	*Number Defecations*	*Feces Weight*		
		Minimum	*Maximum*	*Mean*
A	14	24.00	323.85	138.75
B	10	50.75	329.00	163.80
C	3	47.45	217.90	137.40

All subjects found the proposed Gemini-7 collectors moderately acceptable for use, but the germicide capsules were difficult to crush. Two subjects suggested that a wet wipe be provided for cleaning the anal area. Also, they had difficulty in kneading the fecal mass to mix the germicide and in refraining from urinating while defecating. There were no complaints of the pulling of hair by the adhesive on the collar of bag when it was removed from the buttocks, a complaint which had been made by the majority of subjects on prior tests. There were no complaints of odors from the stored (used) feces bags.

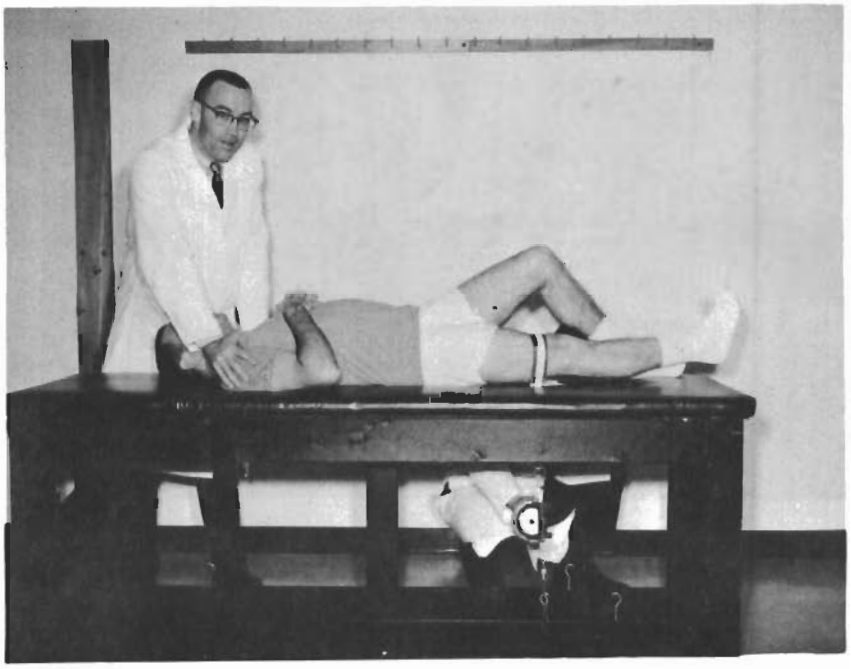
SECTION VIII.

Measurements of Muscle Strength

Lloyd L. Laubach, Antioch College
Milton Alexander

The research described in this section was designed to determine the effect of long-term confinement on human muscle-strength capabilities. Twelve strength tests were administered to two of the participating subjects immediately prior to their entry, and upon their emergence from a 20-day confinement period in the Biological Testing Chamber.

CABLE TENSION STRENGTH TESTS*



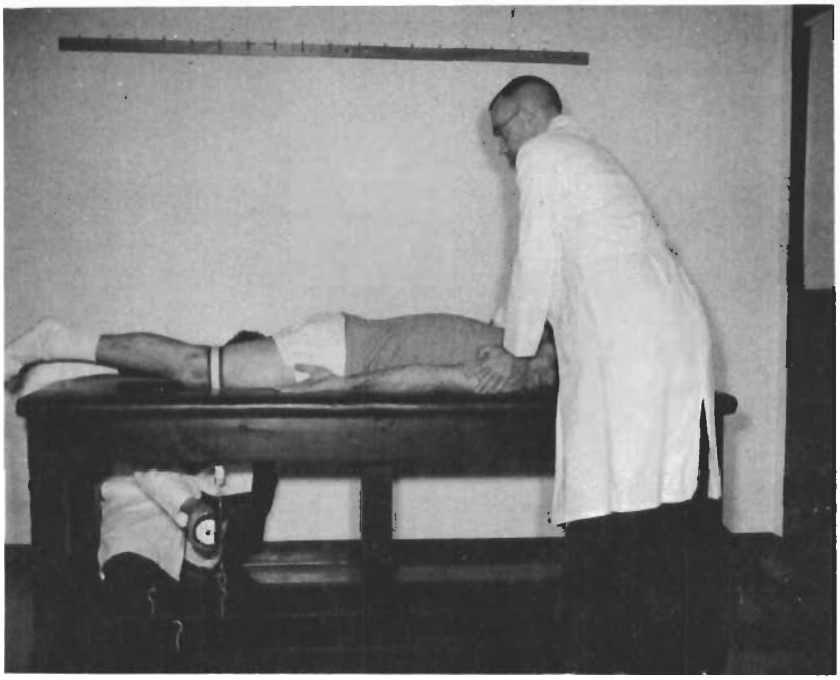
HIP FLEXION

Technique: Starting position – (a) subject in supine lying position, hip and knee of free leg flexed comfortably with foot resting flat on table, arms folded on chest; (b) hip and knee of leg being tested fully extended over table slit. *Attachments:* (a) regulation strap around thigh, lower third between hip and knee joints; (b) pulling assembly attached below leg. *Precautions:* (a) prevent lifting shoulders by bracing; (b) be sure leg below strap is free of table when lifting.

Subject A		Subject B	
Pre-test†	53.6	Pre-test	81.8
Post-test	71.4	Post-test	75.0

*Descriptions of Techniques are from: Clarke, H. Harrison and Clarke, David H., *Developmental and Adapted Physical Education*, Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1963, pp 79-93.

†Test scores are in kilograms.



HIP EXTENSION

Technique: Test is performed the same as hip flexion except subject is in prone lying position with arms along sides. Prevent lifting of hips by bracing.

Subject A		Subject B	
Pre-test*	50.9	Pre-test	49.1
Post-test	60.0	Post-test	54.5

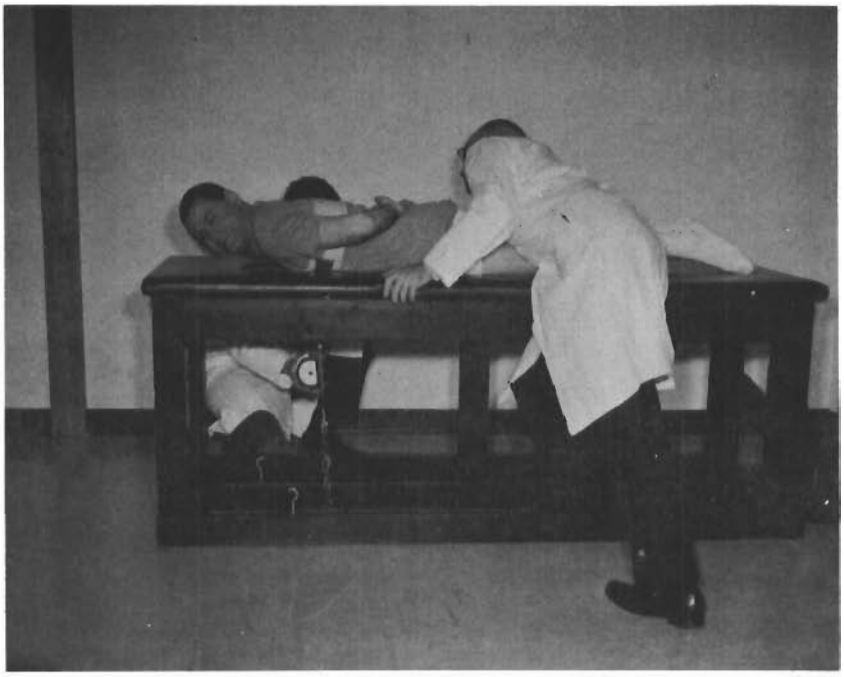
*Test scores are in kilograms.

TRUNK FLEXION

Technique: Starting position – Subject in supine lying position with legs fully extended, arms folded on chest. *Attachments:* (a) trunk strap around chest, close under armpits; (b) pulling assembly attached beneath subject. *Precautions:* Prevent raising legs by bracing.

Subject A		Subject B	
Pre-test*	78.6	Pre-test	86.4
Post-test	72.7	Post-test	83.2

*Test scores are in kilograms.

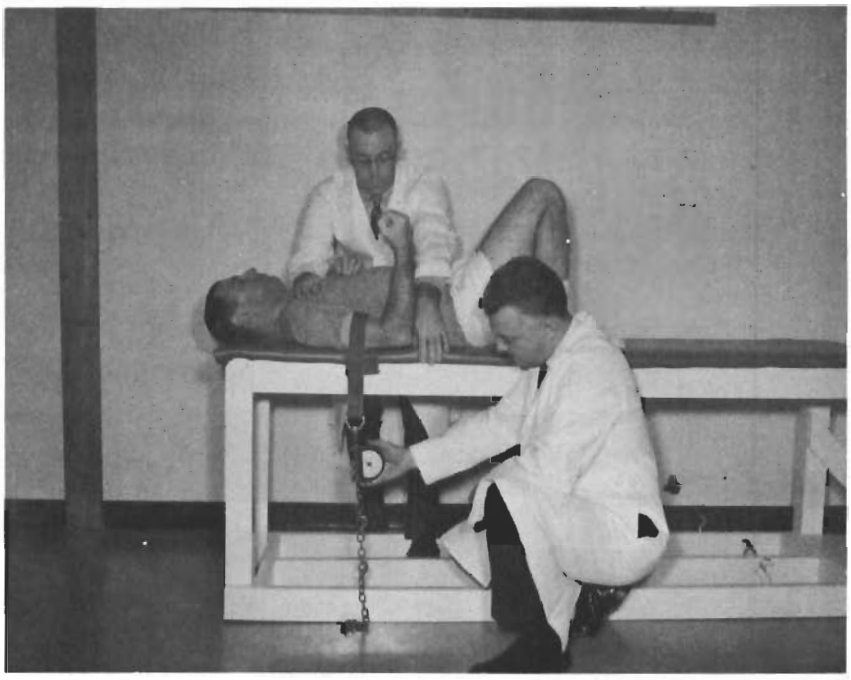


TRUNK EXTENSION

Technique: This test is performed in the same manner as trunk flexion except subject is in prone lying position with hands clasped behind his back.

Subject A		Subject B	
Pre-test*	52.3	Pre-test	112.7
Post-test	96.4	Post-test	86.4

*Test scores are in kilograms.

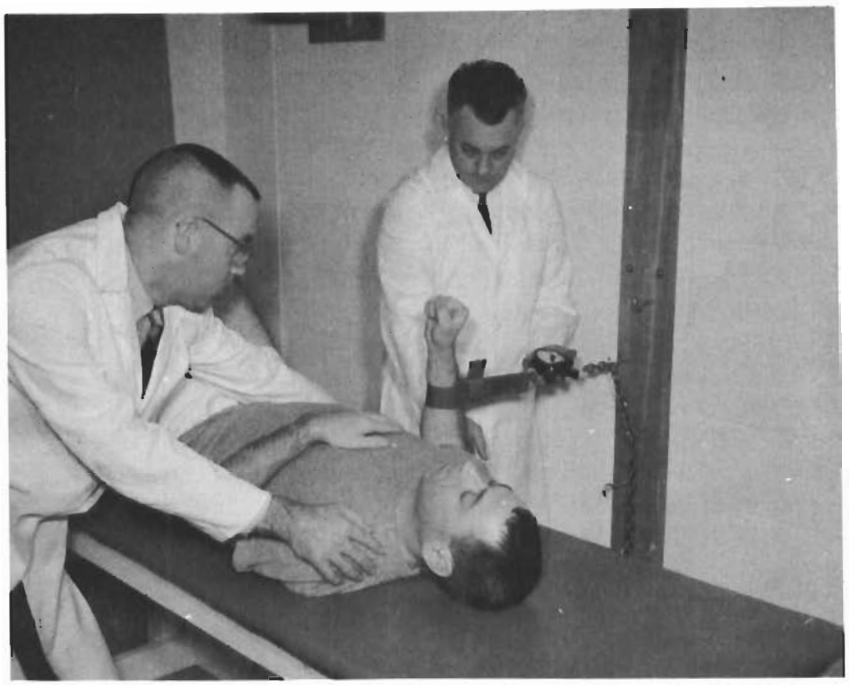


SHOULDER FLEXION

Technique: Starting position – (a) subject in supine lying position, hips and knees flexed comfortably, free hand resting on chest; (b) upper arm on side tested close to side, shoulder flexed to 90°, elbow in 90° flexion. *Attachments:* (a) regulation strap around upper arm midway between elbow and shoulder joints; (b) pulling assembly hooked to table runner below subject's arm. *Precautions:* Prevent shoulder and hip elevation by bracing.

Subject A		Subject B	
Pre-test*	41.8	Pre-test	50.0
Post-test	45.5	Post-test	60.9

*Test scores are in kilograms.

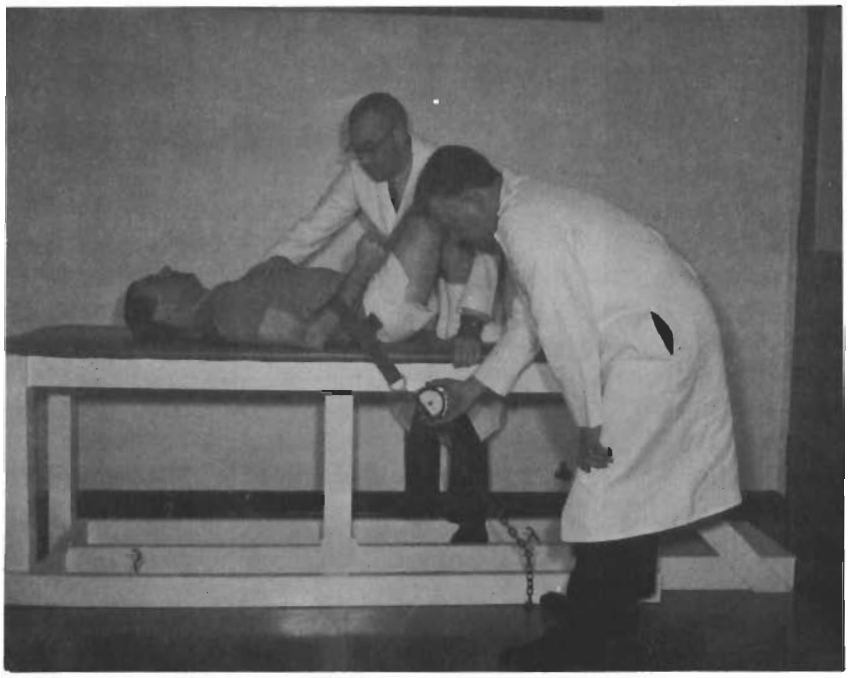


SHOULDER INWARD ROTATION

Technique: Starting position – (a) subject in supine lying position, hips and knees flexed comfortably, free hand on chest; (b) upper arm on side tested close to side, elbow in 90° flexion, and supported by pad to bring upper arm into position parallel with table, forearm in mid-prone-supine position. *Attachments:* Regulation strap around forearm midway between elbow and wrist joints; (b) pulling assembly attached to wall next to side being tested. *Precautions:* (a) adjust forearm so that it is vertical at height of pull; (b) prevent "cupping" shoulder by bracing with hand; (c) prevent raising elbow and abducting upper arm by bracing elbow; (d) stabilize trunk by bracing hips.

Subject A		Subject B	
Pre-test*	43.2	Pre-test	50.9
Post-test	50.0	Post-test	52.7

*Test scores are in kilograms.

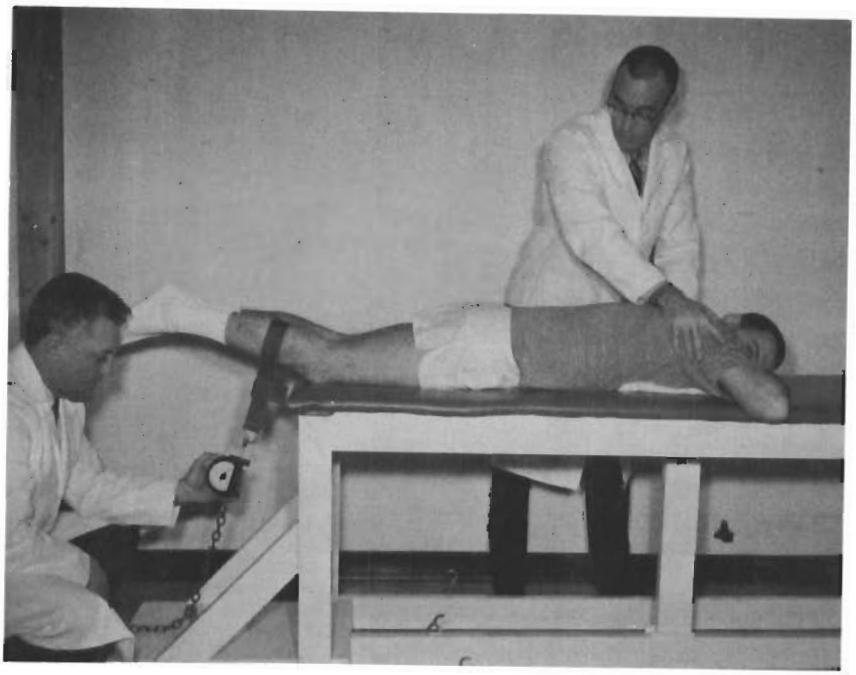


ELBOW FLEXION

Technique: Starting position – (a) subject in supine lying position, hips and knees flexed comfortably, free hand resting on chest; (b) upper arm on side tested close to side, elbow in 115° flexion, forearm in mid-prone-supine position. *Attachments:* (a) regulation strap placed around forearm midway between wrist and elbow joints; (b) pulling assembly hooked toward subject's feet, hook on table runner. *Precautions:* (a) prevent bracing elbow and abducting shoulder by bracing at elbow; (b) stabilize subject on table by bracing legs.

Subject A		Subject B	
Pre-test*	69.5	Pre-test	58.2
Post-test	72.7	Post-test	75.0

*Test scores are in kilograms.



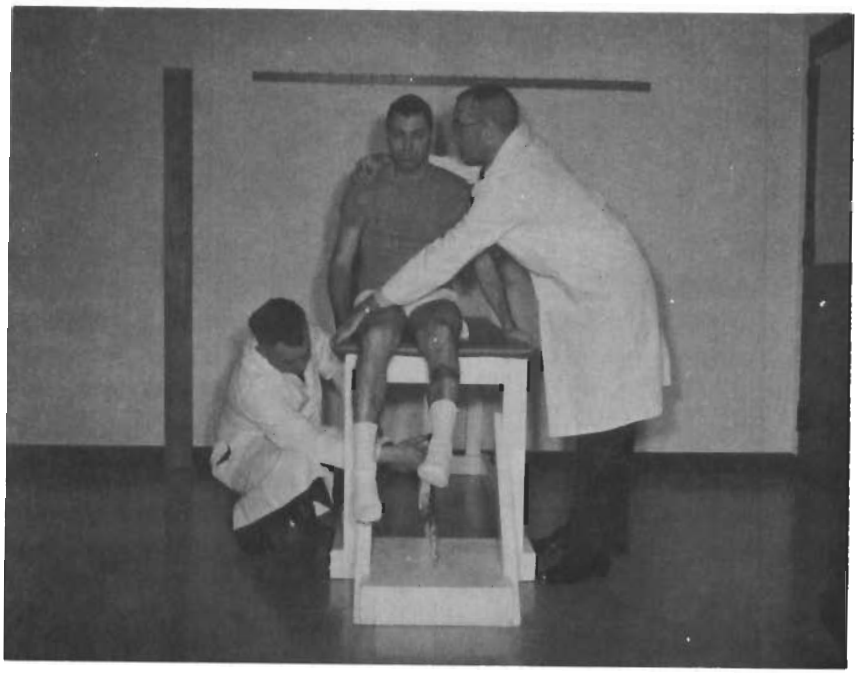
KNEE FLEXION

Technique: Starting position – (a) subject in prone lying position, patella just at edge of table, head resting on folded arms; (b) knee on side tested flexed at 165°. *Attachments:* (a) regulation strap around leg midway between knee and ankle joints; (b) pulling assembly attached to hook below and at lower end of table. *Precautions:* Prevent extension of spine by holding chest on table (flexing of hips permissible).

Subject A	
Pre-test*	67.3
Post-test	74.1

Subject B	
Pre-test	76.4
Post-test	49.1

*Test scores are in kilograms.

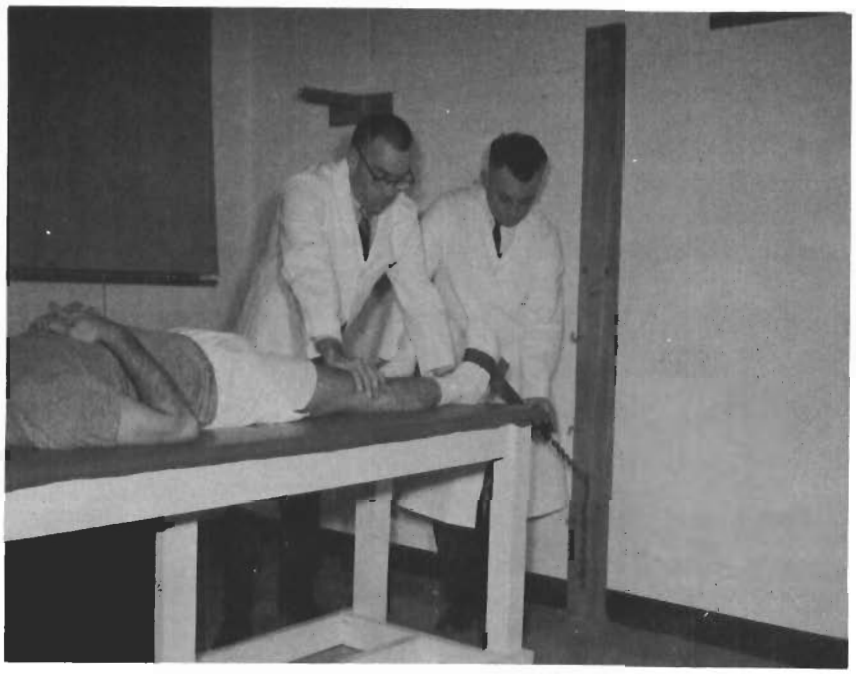


KNEE EXTENSION

Technique: Starting position – (a) subject in sitting backward-leaning position, arms extended to rear, hands grasping sides of table; (b) knee on side tested in 115° extension. *Attachments:* (a) regulation strap around leg midway between knee and ankle joints; (b) pulling assembly attached to hook at lower end of table. *Precautions:* (a) prevent lifting buttocks; (b) prevent flexing arms.

Subject A		Subject B	
Pre-test*	85.0	Pre-test	80.5
Post-test	103.6	Post-test	110.9

*Test scores are in kilograms.



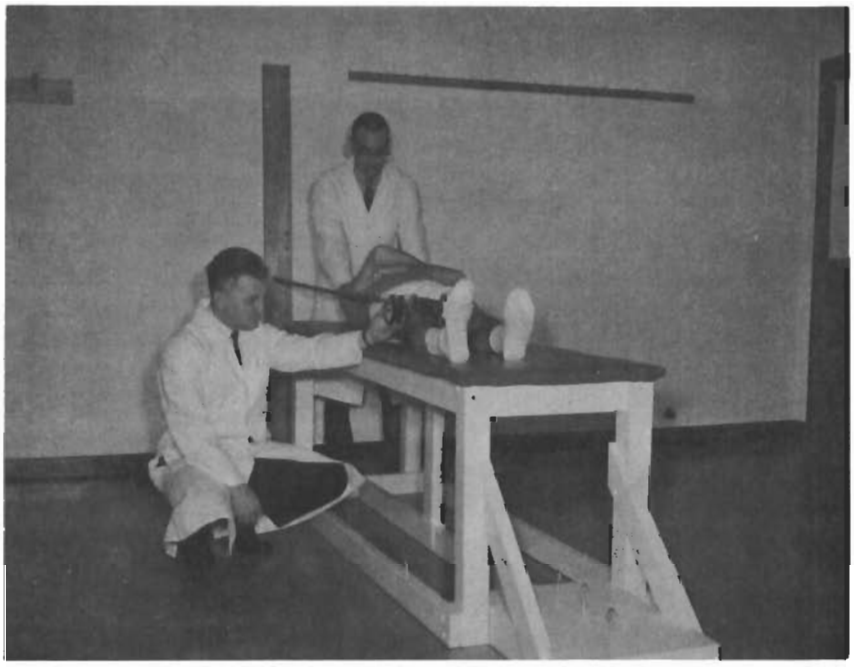
ANKLE DORSI FLEXION

Technique: Starting position – (a) subject in supine, lying position with legs fully extended, arms folded on chest; (b) ankle on side tested in 125° dorsal flexion. *Attachments:* (a) regulation strap around foot above metatarsal-phalangeal joint; (b) pulling assembly attached to wall at subject's feet. *Precautions:* (a) prevent inversion or eversion of foot; (b) prevent flexion at metatarsal-phalangeal joint; (c) prevent flexion at knee by holding leg against table

Subject A	
Pre-test*	50.9
Post-test	47.7

Subject B	
Pre-test	40.0
Post-test	45.5

*Test scores are in kilograms.

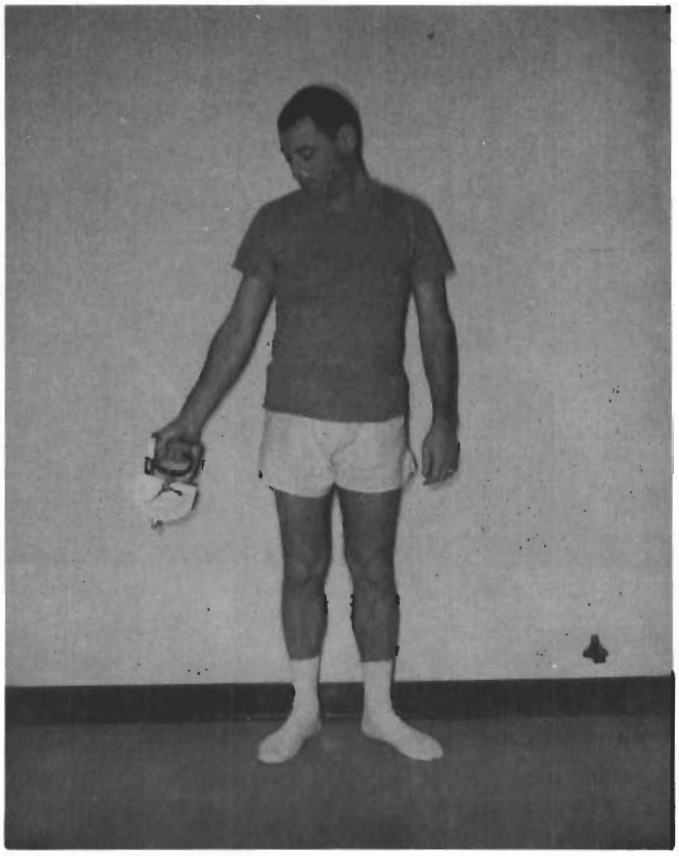


ANKLE PLANTAR FLEXION

Technique: The position for the subject on this test is the same as for ankle dorsi flexion, with the following exceptions: (a) use stirrup strap for this test; (b) ankle on side tested is in 90° flexion; (c) the pulling assembly is attached to the wall at the subject's head; (d) brace behind shoulders to hold the subject in place when pulling.

Subject A		Subject B	
Pre-test*	61.4	Pre-test	77.3
Post-test	68.2	Post-test	79.5

*Test scores are in kilograms.



HAND GRIP STRENGTH

The Smedley Hand Dynamometer was used to measure grip strength. The subject adjusted the grip distance of the dynamometer to "fit" his dominant hand. The subject then squeezed the dynamometer with his dominant hand and the recording was taken.

Subject A		Subject B	
Pre-test*	61.8	Pre-test	44.0
Post-test	63.2	Post-test	50.0

*Test scores are in kilograms.

Results*

The results of the twelve muscle strength tests that were administered to the two subjects on 2 November and 22 November 1965 are summarized below. Also included are age, weight and stature for the two subjects.

	Subject A			*Subject B*		
	Test	*Retest*	*Diff.*	*Test*	*Retest*	*Diff.*
Hip Flexion Strength	53.6	71.4	17.8	81.8	75.0	6.8
Hip Extension Strength	50.9	60.0	9.1	49.1	54.5	5.4
Trunk Flexion Strength	78.6	72.7	5.9	86.4	83.2	3.2
Trunk Extension Strength†	52.3	96.4	44.1	112.7	86.4	26.3
Shoulder Flexion Strength	41.8	45.5	3.7	50.0	60.9	10.9
Shoulder Inward Rotation Strength	43.2	50.0	6.8	50.9	52.7	1.8
Elbow Flexion Strength	69.5	72.7	3.2	58.2	75.0	16.8
Knee Flexion Strength	67.3	74.1	6.8	76.4	49.1	27.3
Knee Extension Strength	85.0	103.6	18.6	80.5	110.9	30.4
Ankle Dorsi Flexion Strength	50.9	47.7	3.2	40.0	45.5	5.5
Ankle Plantar Flexion Strength	61.4	68.2	6.8	77.3	79.5	2.2
Hand Grip Strength	61.8	63.2	1.4	44.0	50.0	6.0
Total Strength	716.3	825.5	109.2	807.3	822.7	15.4
Mean Total Strength	59.7	68.8	9.1	67.3	68.6	1.3

*Test scores are in kilograms.

†When Subject A was first tested (2 November 1965) he complained of back pain. This probably explains the large discrepancy in test-retest results.

	Subject A	*Subject B*
Age†	34	30
Weight (Pre-test)†	86.4	76.1
Weight (Post-test)†	85.6	71.2
Stature†	178.7	174.5

†Age in years; weight in kilograms; stature in centimeters.

CONCLUSIONS

The results of the strength tests were inconclusive. It is not known at this time whether or not the changes observed can be attributed to confinement, motivation, lack of a controlled regimen of activities, or the subjects' pre-test and post-test physiological condition.

SECTION IX.
Carbon Dioxide Removal Systems

J. Arthur Brown

DESCRIPTION

Two systems were utilized to control the crew cabin carbon dioxide partial pressure.

The principal system being evaluated was supplied under contract. The system utilizes regenerable solid adsorbents in two canisters, silica gel in two additional canisters, coupled by piping and switch valves to result in the familiar configuration of (1) silica gel adsorbing moisture, (2) molecular sieve adsorbing carbon dioxide, and (3) silica gel desorbing moisture, with (4) isolated molecular sieve canister desorbing carbon dioxide. Timers, heaters, coolant, heat exchangers, blowers, pump, vacuum subsystem, and control panel complete the system.

The backup system consisted of Baralyme pellets (4 to 8 mesh) in screen surface canisters utilizing the passive adsorption technique.

The Emergency Breathing and Suit Pressurization System (ref. 3) was used to cool, dehumidify, and circulate cabin air to the full-pressure suits worn by the three subjects in the first phase of the program. In this mode, the system was an open circuit (suits not pressurized) and was not used to remove carbon dioxide.

OBJECTIVE

The regenerable solid adsorbent system had been designed to maintain a maximum of 7.6 mm Hg pp of carbon dioxide for a four-man crew having a total daily output of 10.6 pounds of carbon dioxide at 7.7-psia (400 mm Hg) or 14.7-psia cabin pressure, 160 ± 20 mm Hg pp of oxygen (balance of gas assumed to be nitrogen, water vapor, carbon dioxide, and trace gases), 44 to 51% relative humidity at crew cabin temperatures of 72° ± 2° F. The profile specified for this specific test program included: crew cabin pressure of 375 mm Hg, oxygen partial pressure of 180 mm Hg, water vapor partial pressure 7.5 mm Hg, carbon dioxide partial pressure 7.5 mm Hg, balance Helium (~180 mm Hg) and trace gases at cabin temperatures of 74° ± 3° F with a three-man crew.

FACTUAL DATA

The regenerable carbon dioxide system was used solely during the first day of the program. Twenty-four hours after the program had begun, the carbon dioxide partial pressure had risen to 5.9 mm Hg and the decision to add Baralyme was made. Baralyme was kept aboard for the balance of the program.

During the balance of the program, several attempts were made to regenerate the system and to restart. On one occasion, a burned out heater was replaced. An attempt was also made to determine whether sufficient vacuum was available to desorb the molecular sieve bed by vacuum alone (ref. 1). However, vacuum applied on 1-hour cycles failed to produce a system vacuum under 1 mm Hg during a 24-hour period. No check was made on the silica gel adsorbtion bed exit frost point at any time during the program. Also, the carbon dioxide partial pressure at the exit of the adsorbing molecular sieve bed(s) was not checked at any time during the program (ref. 2).

The Baralyme backup system utilized 32 pounds of chemical per day. This can maintain the carbon dioxide partial pressure below 7.0 mm Hg. Other sources indicate approximately 28 to 30

pounds Baralyme per three-man crew per day is required. This organization has found on past programs that 32 pounds Baralyme per four-man crew per day can maintain an average carbon dioxide partial pressure of 7.6 mm Hg.

CONCLUSION

Systems selected for optimization into flight hardware for cabin atmospheric control will require extensive performance and reliability testing. Also, subjects must be thoroughly indoctrinated.

A larke factor in the adequate performance of a regenerable carbon dioxide removal system is the establishment, and assured control, of the maximum cabin air water vapor partial pressure.

References

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2. Hypes, W. D., and Brown, J. A., *Study of An Inorganic System for the Recovery of Oxygen (30-Day Evaluation Program),* Section I, AMRL-TDR-64-30, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, (AD 606 665) July 1964.

3. Miller, R. A., and Withey, D. J., *Emergency Breathing and Suit Pressurization System,* AMRL-TDR-64-60, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, (AD 608 088) September 1964.

SECTION X.

Sensible/Latent Heat Removal and Air Reheat Units

J. Arthur Brown

DESCRIPTION

Crew cabin air is dehumidified at a single location utilizing a finned heat exchanger and glycol cooling media circulated to a reservoir external to the LSSE where the glycol is in turn cooled by a Freon refrigeration unit (ref. 1). The glycol circuit and controls are simplified to the current test configuration by the elimination of the moisture freeze out assembly and its associated switch valve. The finned heat exchanger is maintained at the desired dew point and the condensate allowed to collect by gravity flow at the bottom of the cabinet. A high capacity 5-speed centrifugal blower has replaced the original two each 28-volt, d-c vaneaxial blowers, permitting the elimination of brush motors and reduction in noise level. A solid particle filter has been incorporated. The glycol lines to the heat exchanger are in the main duct between the heat exchanger cabinet and the aisle overhead air-lighting duct. Therefore, the air reheaters are distributed inside the overhead duct in locations free of glycol lines. Air reheaters are quartz heat lamps capable of adjustment by external powerstats.

Previous programs had revealed that the forward cabin temperature would average 6° to 8° F higher than corresponding temperatures in the aft cabin. This was attributed to having only one penetration between the forward and aft cabins and the resultant failure to move air between cabins. To overcome this, a 2½-inch-diameter tube was coupled to the forward end of the aft air duct which incorporated a $\frac{1}{125}$-hp, 3030-rpm centrifugal blower. The tube was then passed through the door sill. Temperatures in the forward cabin then averaged 1 to 2° F lower than the aft cabin. The air reheaters for the forward cabin are located at the exit of the extension tube.

The temperature of the glycol in the external reservoir and the coupled internal Evaluator circuits is solely a function of the Freon refrigeration control limits. The glycol circulating pumps to the individual internal Evaluator circuits run continuously. (This has since been corrected. Each circuit now has its individual temperature sensor and relay control.)

OBJECTIVE

Dry bulb temperatures desired were 71° to 77° F with 68° to 80° F temperatures being acceptable. The coolest location was to be the sleeping area. Drafts on personnel were to be avoided while maintaining a fan speed equivalent to 800 cfm at S.T.P. Water vapor was designated in terms of partial pressure (ref. 4); 5.5 to 9.5 mm Hg objective, 4.5 to 12.5 mm Hg acceptable. This corresponds to 36° to 51° F dewpoint objective, 32° to 58.5° F dewpoint acceptable.

DATA

Subjects wore the full-pressure suits for the first 7 days (171 to 173 hours) of the program. (See Pressure Suit section.) During this time, several adjustments were made both internal and external to the LSSE to increase the subject's comfort. During one adjustment, the control limits of the refrigeration unit were lowered to provide more cooling to the heat exchanger of the Emergency Breathing and Suit Pressurization System which provided vent air to the full-pressure suits. Therefore, due to the lack of individual circuit temperature sensor and relay control, both the crew cabin dry bulb temperatures and water vapor partial pressures were decreased markedly.

This situation was returned to the normal mode after approximately 166 hours when the pressure suits were removed, with improvements in both dry bulb and dewpoint temperatures.

A temporary sensor used to cycle the dehumidifying glycol pump (installed after the first 55 hours of reduced temperatures) provided an improved (higher) water vapor partial pressure for the balance of the cool period until the pressure suits were removed. This cool period resulted in no complaints because of drafts external to the suits.

Although the subjects did not complain of drafts during the time they did not wear the pressure suits, they needed blankets in their bunks. Flame-retardent curtains were drawn across the individual bunks to shield light and forced air.

The air reheaters were not operated at any time during the program. This can be attributed, in part, to the facility capability of heating the air surrounding the LSSE thereby causing the cabin air to warmup as it passes over the cabin walls.

The water vapor partial pressure was monitored by three indirect techniques:

a. A thermister was located at the glycol return fitting of the dehumidifier (finned heat exchanger). This provided a visual display of the air temperature immediately downstream of the dehumidifier.

b. Four gold-grid humidity sensors with integral temperature compensation. One each sensor forward and aft may be read directly on individual panel display meters. One each sensor forward and aft provided multipoint recorder input which was noted every hour.

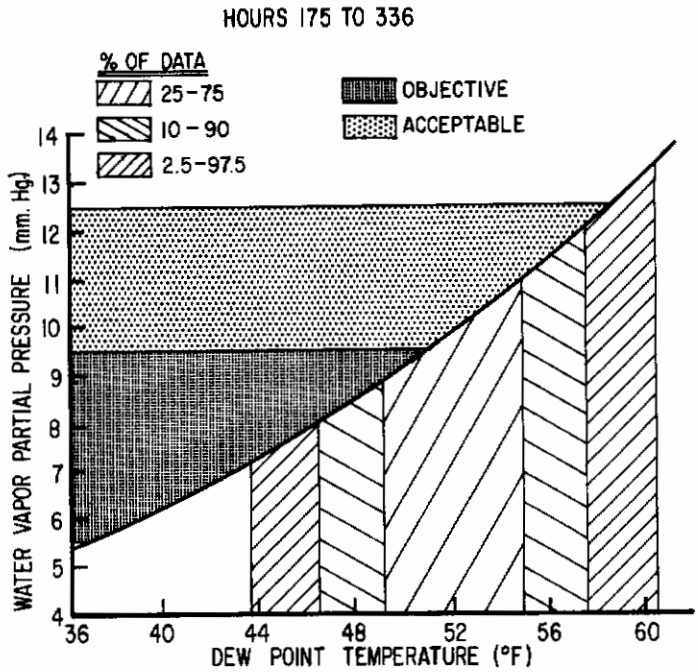

Figure 1. Water Vapor Partial Pressures as Measured by Dewpoint Temperatures.

c. Subjects noted dry bulb and wet bulb temperatures, forward and aft, once every 4 hours, by utilizing a packaged psychrometer with a battery operated air fan.

Figures 1 thru 3 indicate the general accord of the various data noted with respect to the desired water vapor partial pressure. However, all of the techniques employed are indirect. The dry bulb-wet bulb technique can be adapted to altitude chamber applications by psychrometric tables or charts corrected to the programmed crew cabin pressure (refs. 2, 3) and the anticipated cabin gas composition.

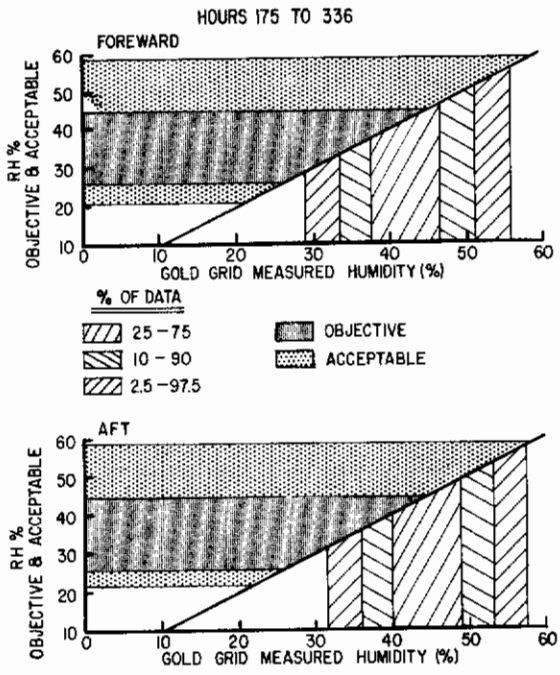

Figure 2. Forward and Aft Humidities.

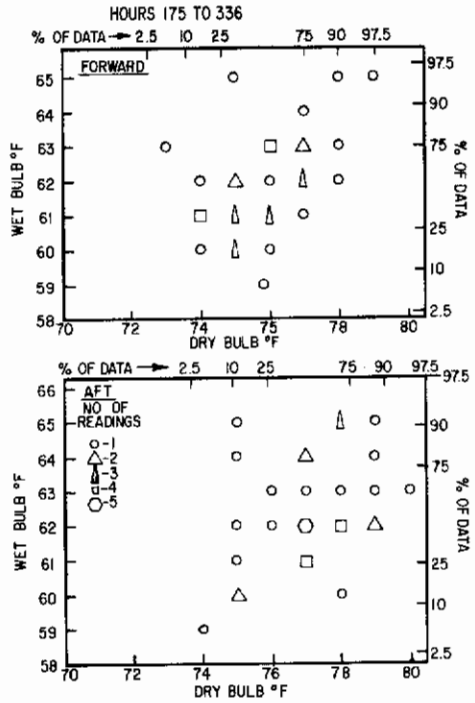

Figure 3. Forward and Aft Wet Bulb-Dry Bulb Temperatures.

Figure 1 shows the water vapor partial pressures obtained as measured by the dewpoint temperatures. Variations are indicated by the average and ranges of 50%, 80%, and 95% of data distribution. Reflection pertaining to the choice of objective and acceptable limits for water vapor partial pressure dictates the selection of limits more in line with those actually experienced during the last 7 days of this study. This is based on complaints by the subjects during the first days of the study, i.e., of dry throats, etc., when the partial pressure was in the range of 4.5 to 6.5 mm Hg; whereas there were no complaints during the final week.

Figure 2 illustrates the humidities as measured by the gold-grid sensors. These sensors have a thin film containing lithium chloride laid over gold-grid electrodes on a plastic base. Variations are indicated by the average and ranges of 50%, 80%, and 95% of data distribution. The objective and acceptable limits again illustrate that these initial values were set too low.

Figure 3 illustrates the data provided by the subjects' wet bulb-dry bulb observations. Average and ranges of 50%, 80%, and 95% of the data distribution are again noted. Note the somewhat

higher dry bulb temperatures read with the mercury thermometer vs the temperatures read with the thermistors in table I (Thermisters No. 12 aft and No. 15 forward). Apparently crew comfort is better at 76° to 77° F dry bulb than at 74° F, as originally anticipated. As measured with the mercury thermometer in a cabin atmosphere of 48% 0_2 + 48% He + 2% CO_2 + 2% Water Vapor at an absolute pressure of 375 mm Hg.

The crew cabin temperature profile displayed in table I illustrates the variation in dry bulb temperatures at various locations and the slight variation attributed to the subjects' change in activity during various segments of the day.

TABLE I.

CREW CABIN TEMPERATURE PROFILE

Time	*Date*	*Thermister* No.*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
2000	13 Nov.		44	—	81	74	71	69	71	72
0400	14 Nov.		47	--	79	71	69	68	72	71
1900	14 Nov.		56	—	84	75	72	70	73	74
0100	15 Nov.		55	—	84	76	74	73	74	74
1700	15 Nov.		57	—	81	74	69	72	74	75
1000	16 Nov.		48	—	79	71	66	70	71	72
2100	16 Nov.		52	—	81	73	66	68	71	72
0200	17 Nov.		56	84	84	75	69	71	71	72
0800	17 Nov.		53	91	85	75	71	71	71	73
1300	17 Nov.		54	88	85	75	70	73	72	74
1800	17 Nov.		52	87	86	76	70	72	72	73
2300	17 Nov.		51	—	85	77	70	71	72	73
0600	18 Nov.		47	—	82	74	69	71	72	74
1300	18 Nov.		52	—	83	75	69	72	74	74
		°F Hi	57	91	86	77	74	73	74	75
		Low	44	84	79	71	66	68	71	71
		#Sample	14	4	14	14	14	14	14	14

*9. Dewpoint temperature at dehumidifier (Aft cabin).
10. Cabin air outside end of air duct at rear-most door; left overhead (Aft cabin).
11. Cabin air outside air duct across from bunks; left overhead (Aft cabin).
12. Cabin air above table between chairs; right horizontal (Aft cabin).
13. Cabin air at head end of top bunk (Aft cabin).
14. Cabin air at head end of bottom bunk (Aft cabin).
15. Cabin air above and behind pilot's chair (Forward cabin).
16. Cabin air above and in front of copilot's chair (Forward cabin).

CONCLUSIONS

The existing system has sufficient capacity to move, dehumidify, and reheat the cabin air for pressures down to 250 mm Hg absolute and of various gas compositions for four subjects over extended time periods.

To recondition the cabin air at a central location, means must be provided to move the air thru bulkheads, preferably by separate penetrations and duct work.

Adequate filters are essential to entrap particles, principally dust, capable of suspension in moving cabin air. Extensive deposits in the dehumidifying heat exchanger had escaped the upstream solid particle filter.

Care must be taken to assure air movement across the bunks. Flow quantity is perhaps more important than precisely controlled temperature.

Water vapor partial pressure, being the ultimate measure of crew comfort with respect to atmospheric water vapor, should be sensed, displayed, and controlled by measuring the cabin air dewpoint temperature. To determine relative humidity, dry bulb temperature should also be monitored.

Air reheaters should be provided immediately downstream of the dehumidifier and upstream of the branching air duct.

Each heat exchanger should be coupled to an independent sensor-controller-reaction system for maximum overall flexibility. For the operation of ground simulators, it appears desirable to have only the sensor located inside the simulator when the subjects do not have sufficient indoctrination on specific equipment or where the failure of this equipment could cause an abort. This approach should be extended to such items as power switches, fuses, etc. Individual system control panels could be equipped with a single indicator light which remains ON should only one circuit of the system be open.

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SECTION XI.

Oxygen-Inert Gas Sensor Controller Unit

J. Arthur Brown

DESCRIPTION

This system was procured, tested, and evaluated to determine its capability to sense, display, and control a two-gas, crew cabin atmosphere (refs. 1, 2). The oxygen is to be controlled within acceptable physiological limits. The sensor employed here is an oxygen polarographic sensor with an incorporated attenuation circuit on the oxygen amplifier input to compensate for oxygen sensor aging when employed over extended time. The total pressure is sensed by a total-pressure transducer which will actuate the delivery of the makeup gas as the crew cabin pressure decreases, but only if the oxygen partial pressure is adequate; thus a master-slave relationship is provided between the oxygen-total pressure sensors.

The oxygen control loop accepts a 0- to 5-volt, d-c input signal from the oxygen partial pressure sensor and compares it to the d-c voltage level output from the oxygen controller potentiometer in a difference amplifier. The difference amplifier activates a solenoid valve to admit more oxygen to the chamber if the sensor voltage is lower than the oxygen control potentiometer output. The solenoid valve is deenergized when the preset pressure is reached. The difference amplifier and solenoid valve of the total pressure circuit are identical to the oxygen channel. However, the preset voltage level for control of total pressure is derived by summing the setting of the oxygen and makeup gas potentiometer setting. This is accomplished by referencing the negative end of the makeup gas control potentiometer to the output of the oxygen control voltage level.

Redundency is provided by switching to one of two oxygen sensors and to one of two total pressure sensors available. Also, the monitor is provided with an enclosed unit having parallel display meters and indicator lights identical to the subjects' unit. The subjects' unit (figs. 1, 2) also incorporates the main 28-volt d-c and 115-volt, 60-cycle, a-c power inputs, oxygen and total pressure turns counter, switches to actuate solenoids for delivery of oxygen sensor calibration gases (zero and span), and the double-throw switch which transfers control from subjects' unit to monitors' unit, viz. The gas regulating unit, including solenoid valves, is located near the subjects' unit.

OBJECTIVES

It was desired to determine the delivery rate and span of the individual gases in terms of rate-of-descent and "pressure-on" to "pressure-off". The interaction of the master-slave arrangement as well as the capability of the oxygen sensor to perform for extended time periods were also to be determined.

Calibration was performed by reference to the instrumentation of the main console. The total pressure transducers were compared to the crew cabin total pressure gauge. The oxygen sensors were compared to the oxygen paramagnetic analyzer. Actuation of the sensors-solenoids was accomplished by initiating a slow rate-of-climb of approximately 10 mm Hg per minute.

FACTUAL DATA

Several attempts were made to use this system as the primary controller for the crew cabin oxygen partial pressure and minimum total pressure. During these attempts, the oxygen sensors were found capable of recalibration for continued use for periods in excess of three days.

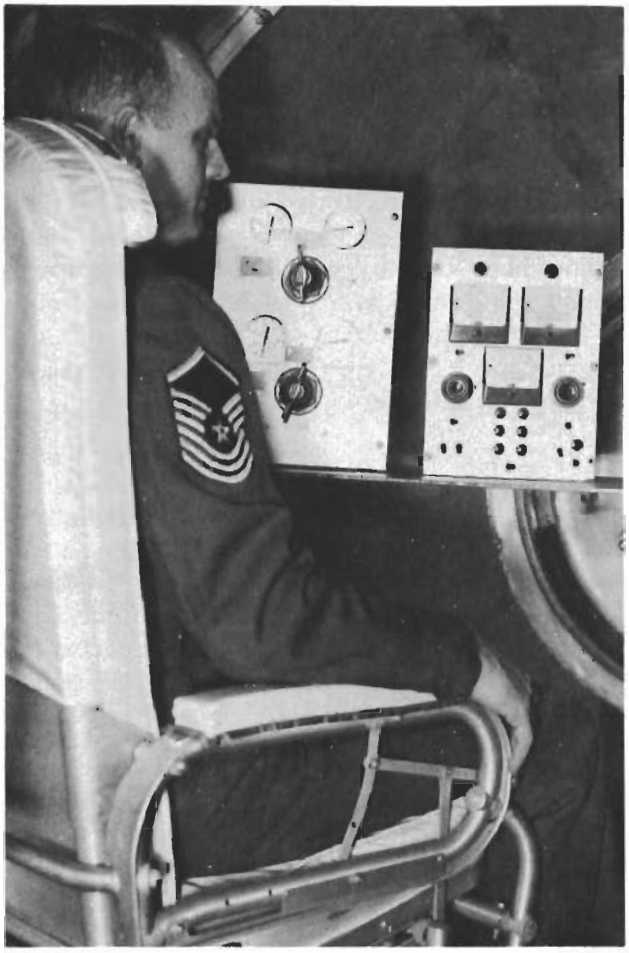

Figure 1. Monitoring the Oxygen-Nitrogen Indicator Controller, see Figure 2.

Figure 2. Oxygen-Nitrogen Indicator Controller.

In approximately half of the attempts to actuate the system, the total pressure decreased to the level where the makeup gas indicated readiness to deliver helium. However, the oxygen circuit would also indicate readiness to deliver and would suppress the makeup gas circuit past the minimum desired level for total pressure. The oxygen delivery might begin as much as 20 mm Hg lower than the minimum desired total pressure. The oxygen delivery would continue over a span of 10 to 15 mm Hg pressure. The helium delivery would then take over on many occasions. Whenever the helium delivered without prior oxygen delivery, the helium delivery would continue over a span of 25 to 35 mm Hg pressure. On several occasions, the combined delivery was over a span of 40 to 45 mm Hg pressure at a rate in excess of 30 mm Hg per minute. This rate was sufficient to cause discomfort to the subjects and to awaken them from sleep.

On several occasions there was a wild fluctuation of the oxygen indicator when the oxygen solenoid actuated. This would be followed immediately by the total pressure indicator reacting to match the oxygen indicator action, resulting on many occasions in push-push opening of the helium and oxygen solenoids. Attempts to discover the cause of this erratic action (following this program) revealed that the 28-volt, d-c power supply had a poor regulation of approximately 5.5 percent. Followup checks with a power supply having a 0.9 percent regulation resulted in no apparent improvement in the interacting circuitry.

CONCLUSIONS

The master-slave relationship between the separate gas systems should be eliminated and the rate-of-descent of the separate gas deliveries limited at the same time to 5 to 8 mm Hg per minute. However, a manually actuated bypass could be supplied for emergency-type increased flow requirements.

The delivery of both the oxygen and helium from "pressure-on" to "pressure-off" should be capable of performing within a span of 12 to 18 mm Hg differential.

Sensors, meters, and controllers requiring better than 1% regulation should incorporate separate regulation subsystems and be isolated from basic power requirements.

References

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SECTION XII.

Operating Characteristics of NASA Prototype Infrared Carbon Dioxide Sensor

Ints Kaleps

DESCRIPTION

Operating characteristics of a miniaturized flight-type, infrared absorption carbon dioxide sensor in a space chamber simulator were observed. The sensor was used continuously for 11 days, and hourly readings were taken.

OBJECTIVES

The sensor was operated continuously for 11 days in a helium and oxygen atmosphere at about 380 mm Hg total pressure. Readings were taken throughout the run at hourly intervals. A Beckman® (Beckman Infrared 15A Carbon Dioxide Analyzer) infrared absorption carbon dioxide sensor was used on the chamber to monitor carbon dioxide partial pressure and to provide a standard for comparison with the experimental sensor.

Data from both sensors were assembled graphically and their responses compared.

FACTUAL DATA

Graphical comparisons of the two sensor readouts were made every hour, but a more comprehensive comparison was obtained by comparing average daily carbon dioxide concentration levels. Figure 1 shows the average daily concentration of carbon dioxide as measured by the

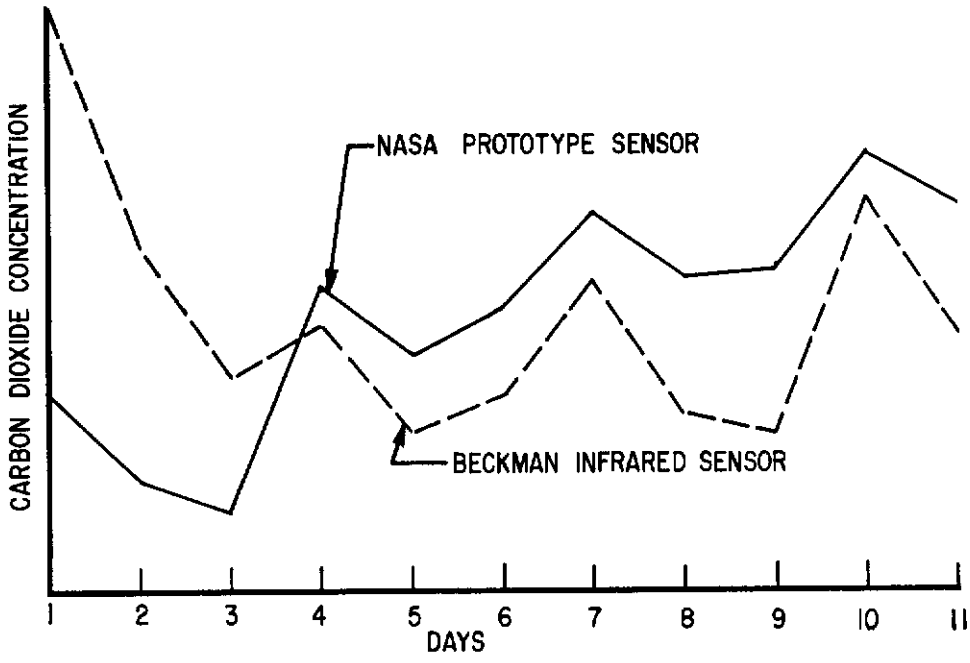

Figure 1. First Comparison of Sensor Readouts.

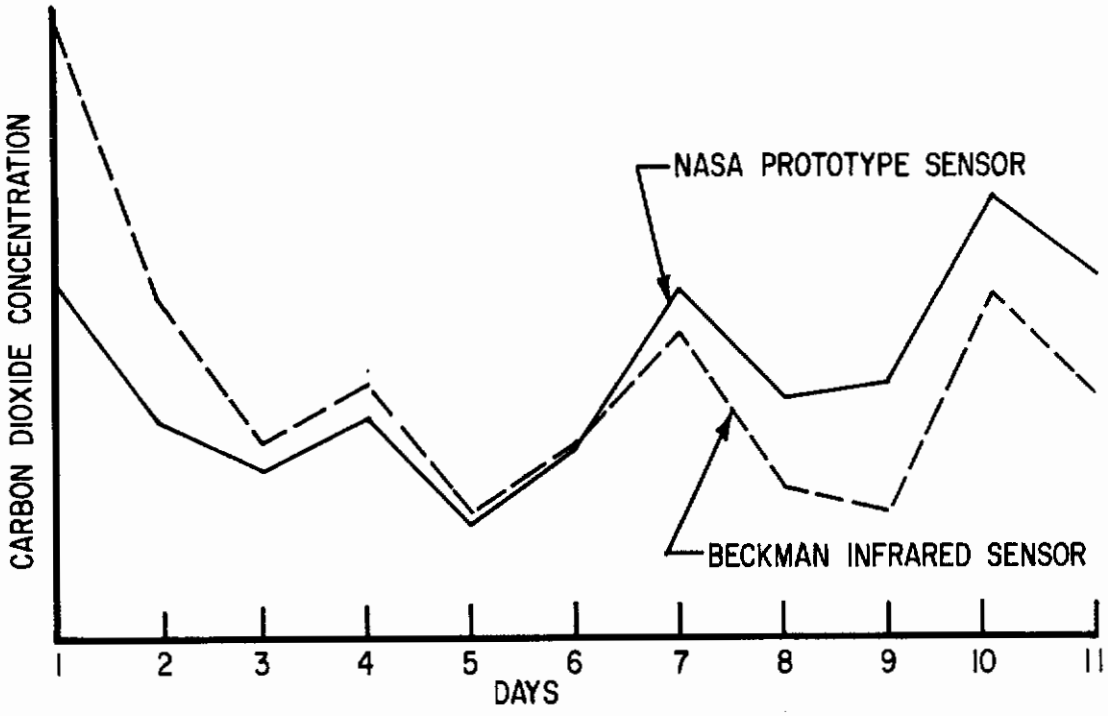

Figure 2. Second Comparison of Sensor Readouts.

NASA prototype and the Beckman infrared sensor. These values were normalized to show di-dectly proportional concentrations in arbitrary units.

On the fourth day of operation, a shift occurred in the level of output of the prototype sensor. This anomaly is clearly visible in figure 1. For a better comparison of the data, this anomaly was corrected and is replotted in figure 2. Figure 2 shows that the prototype instrument responded properly to absolute carbon dioxide concentration levels.

A comparison of the hourly readout (which is not shown here) shows a shorter reaction time for the prototype instrument. It also shows the shift in operating level to have occurred in less than 1 hour.

CONCLUSIONS

The operation of the NASA prototype carbon dioxide sensor during an 11-day test in a manned sealed cabin appeared satisfactory. Comparison of the prototype instrument readout against a Beckman infrared carbon dioxide analyzer was used as a basis for the instrument evaluation.

Except for a shift in the signal output level on the fourth day, the two instrument readings corresponded closely. Inasmuch as the prototype instrument was inside the chamber and, thus, subject to all the variations in total gas pressure, changes in constituent gas concentrations, temperature variations, and possible interference from the buildup of trace contaminants, the long-term stability was excellent. The shift in the signal output level was not considered a serious defect as it was nonreoccurring and appeared to have been caused by a loose lead or connection.

Possibly the best indication of the instrument reliability is the close correspondence of the changes from day to day in carbon dioxide concentration as shown by the two sensors. Only for one change in ten, from the eighth to the ninth day, was the correspondence poor.

SECTION XIII.
Cabin Gas Analysis
(COMPARISON OF TECHNIQUES)

Jared M. Dunn, Captain, USAF

INTRODUCTION

Monitoring of crew cabin atmospheres centers around the accurate, reliable sensing and measuring of the basic gaseous constituents of oxygen, carbon dioxide, water vapor and makeup gas (which is nominally assumed to be total pressure minus the sum of the three previously listed gases. Trace gases come into prominence as the length of mission is increased and the variety of activities and materials are increased. Laboratory analyzers are used in monitoring simulators such as the LSSE. However, the reliability of commercially available portable analyzers is questioned from time to time.

OBJECTIVES

Portable analyzers are viewed as aids in determining when gas chromatographs should begin monitoring for trace contaminants. Also, as analyzers for gases not detected by the gas chromatograph. The ability to accurately monitor oxygen in a two-gas atmosphere is highly desirable coupled with sealed storage and ability to be utilized in a zero-g force field. The sealed glass vial detector tubes discussed herein may be considered major contenders for this assignment.

FACTUAL DATA

Glass vial detector tubes were provided to the subjects for monitoring oxygen, carbon dioxide, carbon monoxide, and ozone three times daily. Oxygen data were compared to a console paramagnetic analyzer and a portable paramagnetic analyzer also utilized by the subjects. See table I. As noted under the manufacturer's data in table I, the value of oxygen detected requires a correction for the quantity of carbon dioxide present. Generally, this meant a correction of up to 1% above that noted on the detector. The console analyzer loop contained a silica gel tower ahead of the oxygen-carbon dioxide analyzers. The gas sample was compressed to 1 atmosphere prior to passing thru the analyzers. This resulted in considerable moisture being found in the silica gel. Also, the console analyzers were calibrated at ambient pressures (724 to 746 mm Hg); the cabin gases were then monitored at analyzer pressures of 749 to 810 mm Hg. Both of these factors could cause the corrected console analyzer readings to be lower than those noted in table I by as much as 4 to 5 percent.

The portable oxygen analyzer has been reliable in the past, and results here indicate good correlation with the glass vial detector.

The carbon dioxide detector tube results showed poor, if any, correlation with the data supplied by the console infrared analyzer. This console analyzer, however, suffered from the same errors discussed for the console oxygen analyzer. The variance of the detector tube data is roughly that experienced by others when utilizing carbon monoxide detectors (ref. 1).

Data indicating a trace of methyl bromide may actually be a freon compound as indicated under the manufacturer's data in table II. Freon compounds are not utilized inside the LSSE; however, they have been detected in the LSSE atmosphere on previous occasions (ref. 2).

During the entire program, two charcoal canisters, complete with individual blowers, operated continuously. Each charcoal canister contained approximately 1450 grams of 4 by 6 particle-size, activated coconut charcoal. Other programs have shown a net increase in charcoal weight in the order of 12 to 17.5 percent plus considerable surface dust-like particles. A flame-ionization hydrocarbon analyzer also operated continuously. The calibration hydrocarbon used was 100-percent methane. However, inadequate sample flow renders this data invalid.

CONCLUSIONS

The validity of the stated detection values of the glass vial detectors should be subjected to more rigorous laboratory controlled bench tests utilizing calibration-grade gases.

The oxygen detector tubes may be used to monitor cabin gaseous oxygen within safe physiological limits.

Although several gases may be detected by the same detector tube, they do serve as a useful indication of the "cleanliness" of the cabin atmosphere.

TABLE I.

CONCENTRATIONS DETERMINED WITH DETECTOR TUBES
(Three Times Daily)

		← OXYGEN % →							
65 Date	*Time*	*Detector*	*Detector Corrected*	*Console Para-magnetic*	*Portable Para-magnetic*	*Carbon Dioxide % Detector*	*Console*	*Carbon Monoxide ppm*	*Ozone ppm*
8 Nov.	0030	44	41	43	37	1.6	1.2	10	0
8 Nov.	1330	40	39	47	40	.8	1.4	10	0
9 Nov.	0400	40	40	42	39	.8	1.3	10	0
9 Nov.	0900	40	41	47	43	1.2	.9	10	0
10 Nov.	0500	45	44	50	49	.9	.8	<10	0
10 Nov.	1200	42	43	48	47	1.0	1.2	<10	0
10 Nov.	1900	44	45	49	46	.6	.6	<10	0
11 Nov.	0830	42	42	43	43	.5	.6	<10	0
11 Nov.	1830	42	43	46	43	1.2	1.2	<10	0
11 Nov.	2300	38	39	49	44	1.2	1.5	<10	0
12 Nov.	0900	42	43	48	44	1.4	.7	<10	0
12 Nov.	1600	38	39	48	43	1.4	1.0	<10	0
12 Nov.	2300	40	41	46	44	1.4	.3	<10	0
13 Nov.	0830	44	45	46	43	.6	.6	<10	0
13 Nov.	1200	42	44	50	46	1.0	.7	0	0
13 Nov.	2000	36	37	46	44	1.2	1.0	<10	0
14 Nov.	0900	42	44	49	46	1.6	.6	<10	0
14 Nov.	1800	42	43	47	44	1.2	1.2	<10	0
14 Nov.	2300	40	41	45	42	1.0	.8	<10	0
15 Nov.	0800	50	51	47	44	1.0	.7	10	0
15 Nov.	1500	44	45	47	44	1.2	.9	<10	0
15 Nov.	2300	42	44	47	45	1.2	.7	<10	0
16 Nov.	0800	46	47	48	45	1.0	.5	<10	0
16 Nov.	1230	44	45	49	46	.8	.7	<10	0
16 Nov.	2300	44	45	48	42	.8	1.0	<10	0
17 Nov.	0830	40	41	48	44	.8	.7	10	0
17 Nov.	1200	46	47	49	38	1.2	.9	<10	0
17 Nov.	1900	38	39	47	42	1.2	1.4	<10	0
18 Nov.	1200	46	47	48	44	1.4	.9	<10	0
18 Nov.	1630	42	43	49	43	.8	.7	<10	0
18 Nov.	2300	36	38	47	44	.8	.8	<10	0
19 Nov.	0900	44	45	49	45	1.0	.8	<10	0
		42	43	47	44	1.1	.9		

SPECIAL INSTRUCTIONS: For oxygen and carbon dioxide, use the number of strokes recommended by the manufacturer, then double the reading to compensate for usage at approximately one-half atmospheric pressure.

For all others, and carbon dioxide when possible, double the number of strokes recommended by the manufacturer to compensate for usage at approximately one-half atmospheric pressure.

TABLE I.—Concluded

Data, including Manufacturer's Instructions:

1. *Oxygen*

   Measuring range 5 to 25% volume. Discoloration may also be caused by halogenated hydrocarbons and hydrogen sulfide. Carbon monoxide in concentrations above 100 ppm may simulate excessive oxygen content. Carbon dioxide present in large concentrations will simulate too low an oxygen concentration; 1% volume CO_2 reduces oxygen indication by approximately 1% volume.

   One stroke (at 760 mm Hg) to read % volume directly.

   Indication based on reaction between oxygen and alkaline pyrogallol solutions; carbon monoxide formed is measured in the indicating layer and is in indirect indication of the oxygen content.

2. *Carbon Dioxide*

   Measuring range 0.1 to 1.0% volume. Five strokes (at 760 mm Hg) to read concentration directly.

   Indication based on reaction with a hydrazine compound.

3. *Carbon Monoxide*

   Measuring range 10 to 300 ppm. Ten strokes (at 760 mm Hg) to read concentration directly.

   Indication based on reaction with a mixture of iodine pentoxide and sulphuric acid.

4. *Ozone*

   Measuring range .05 to 1.4 ppm. Ten strokes (at 760 mm Hg) to read concentration directly.

   Indication based on the cleavage of an organic dyestuff by oxidation.

TABLE II.

CONCENTRATIONS DETERMINED WITH DETECTOR TUBES
(Once Per Day)

65 Date	Time	Chlorine Cl_2	Methyl Bromide CH_3Br	Carbon Tetrachloride CCl_4	Hydrogen Sulfide H_2S	Ammonia NH_3
8 Nov.	0200	0	5	0	0	0
9 Nov.	0400	0	3	0	0	0
10 Nov.	0500	0	5	0	0	0
11 Nov.	0830	0	3	0	0	0
12 Nov.	0900	0	5	0	0	0
13 Nov.	0830	0	5	0	0	0
14 Nov.	0900	0	5	0	0	0
15 Nov.	0800	0	5	0	0	0
16 Nov.	0800	0	5	0	0	0
17 Nov.	0830	0	8	0	0	0
18 Nov.	1200	0	3	0	0	0
19 Nov.	0900	0	5	0	0	0

Special Instructions: Double the number of strokes recommended by the manufacturer to compensate for usage at approximately one-half atmospheric pressure.

Data, including Manufacturer's Instructions:

1. *Chlorine*
   Measuring range 0.2 to 3 ppm (Chlorine or Bromine).
   Ten strokes (at 760 mm Hg) to read concentration directly.
   Indication based on color reaction with an aromatic amine.

2. *Methyl Bromide*
   Measuring range 5 to 55 ppm (Methyl Bromide, Freon 113 or Trichloroethane).
   Five strokes (at 760 mm Hg) to read concentration directly.
   Indication based on oxidative scission of the hydrocarbon halide.

3. *Carbon Tetrachloride*
   Measuring range 10 to 100 ppm (Carbon Tetrachloride or Freon 11).
   Three strokes (at 760 mm Hg) to read concentration directly.
   Indication based on decomposition of carbon tetrachloride by fuming sulphuric acid, producing phosgene which is quantitatively determined in the indicator.

4. *Hydrogen Sulfide*
   Measuring range 1 to 60 ppm.
   Ten strokes (at 760 mm Hg) to read concentration directly.
   Indication based on color reaction with heavy metal salts.

5. *Ammonia*
   Measuring range 25 to 700 ppm (Ammonia or Monoethanolamine).
   Ten strokes (at 760 mm Hg) to read concentration directly.
   Indication based on ammonia forming a complex with heavy metal salt.

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13. ABSTRACT

Tests are conducted to define the various problems involved in the maintenance of an acceptable environment, the number of variables concerned with the man-machine concept, the operation, maintenance and evaluation of single units and integrated systems for the support of life in a simulated aerospace mission. The investigation covers primary problems and benefits associated with water recovery, personal hygiene, sanitation, nutrition, instrumentation, atmospheric conditions at various pressures and mixtures, clothing, crew accommodations, waste management and muscle-strength while confined in a chamber simulating an aerospace vehicle, and the facilities and support required to test and evaluate life support systems.

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Security Classification

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Life support						
Physiology						
Space simulation chamber						
Cabin atmospheres						
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Waste management						
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