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WORKING PAPER

SMEAT, PART II

FACILITIES

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## SUMMARY

The purpose of the Crew Systems Division (CSD) 20-ft chamber facility was to provide a simulated Skylab Orbital Workshop atmosphere which could be sustained for a period of 56 days to permit evaluation of the Skylab medical experiments.

The ability of the facility to perform satisfactorily for the test duration without test interruption is primarily attributed to built-in system redundancies and to thorough training of test support personnel in all aspects of test operations. The success of a test of this complexity, requiring support throughout the Center, is greatly dependent upon a strong management team. This management was provided by the Test Operations Management Committee which met daily to resolve numerous previous day problems and revise the on-going day activities.

The test provided the opportunity to identify potential hardware problems which could have impact on Skylab flight hardware. Resolution of these problems at this time will provide the time for analysis and resolution prior to Skylab missions. A higher degree of confidence was gained in the ability of the medical hardware to support the Skylab objectives. Skylab Flight Control personnel and principal experimental investigators participated in SMEAT under simulated manned space flight network (MSFN) conditions to evaluate their support for actual Skylab missions. This experience should provide for improved support of Skylab. The control and management of non-metallic materials was aided by a computer program which was highly successful and is recommended for future manned tests and missions.

In so far as the SMEAT application to Skylab, other than the medical experiments which are covered in a separate report, it was determined that the SMEAT shower proved most acceptable to the crew and provided good baseline data for temperature and flow settings for the Skylab shower. Another significant finding was that the Skylab lighting, although satisfactory for routine work, was marginal for conducting medical experiments requiring closeup work. The aforementioned SMEAT determinations are but a few contained in the text of this report, which will contribute in making the Skylab medical flight program and future long-term manned chamber tests successful.

# INTRODUCTION

The CSD 20-ft chamber was modified as required to configure a living area within the chamber to resemble the Skylab Workshop. The existing facility systems were utilized wherever possible and other systems were added where redundancy was deemed necessary to sustain the test, provide for requirements not previously existing, and to provide interface systems for the Skylab medical experiments.

The test was initiated on July 26, 1972, and successfully concluded on September 20, 1972.

The CSD would like to acknowledge the Engineering Division, Technical Services Division, Management Services Division, Logistics Division, Photographic Technology Division, and the Flight Crew Support Division for their excellent support prior to and throughout the conduct of the SMEAT test.

Also, a special acknowledgement to the SMEAT Crew for their inputs into the system designs and modifications which added significantly to the successful operation of the facility throughout the 56 day test.

## DESCRIPTION OF FACILITY

The chamber used for SMEAT is located in the Crew Systems Division (CSD), Building 7 at the Manned Spacecraft Center (MSC) (Figure 1).

The chamber is manrated and has been used to support numerous manned tests prior to the SMEAT test. The main chamber is 20-ft in diameter, 20-ft high and is constructed of stainless steel. There are 15 viewports and seven penetration bulkheads located around its circumference. Connected to the main chamber are two locks in series, each 10-ft in diameter and 9-ft long. The locks also contain viewports and penetration bulkheads. Seven closed-circuit television channels are located in the chamber and locks. The atmosphere circulation system was designed to be used in 100 percent oxygen for pressures ranging from 5.0 to 14.7 psia. (A closed-loop fan system in the chamber circulates, cools, and heats the chamber atmosphere.) Other features of the chamber include: vacuum pumping capacity of up to 15,000 cfm; automatic chamber pressure regulation; backup emergency power systems; emergency repressurization capability from 5.0 to 14.7 psia in 9 seconds; a five channel communications system with six stations in the main chamber; 60 footcandles of lighting with emergency backup, automatic oxygen supply system with emergency backups; fire detection and water deluge systems; analog to digital data recording system; a large stock of instrumentation used in manned testing; and a test control room.

The chamber configuration which simulates the orbital workshop (OWS) crew quarters is depicted in Figure 2. The second level was used as a private desk area and for some stowage and is shown in

Figure 3 and photographs in Figure 4. Two sleep stations were set up in the chamber inner lock. The two doors in the inner lock, not involved in the pressure seal, (previously used for altitude tests) were removed to provide the needed space for the bunks. The 3rd sleep station was located in the main chamber area. The main chamber and the inner lock as combined simulated the first floor of the Skylab OWS with approximately 380 sq ft of floor area (OWS also has approximately 380 sq ft on the first floor). The wardroom and the waste management compartment was partitioned as on the OWS, and the walls and floor were configured so as to have a similar appearance to the OWS. The remainder of the floor area in the main chamber was used for the Skylab medical experiments. An 18-in diameter transfer lock, was attached to an existing bulkhead. This provided for the transfer of food and other items into the chamber and for removal of residues, wastes, etc. The electrical modifications necessary to support this test included oxygen compatible headsets and intercoms; crew caution and warning systems for the environmental control system (ECS); special lighting to simulate the OWS levels and locations; TV cameras for monitoring selected crew activities and medical experiments; a power distribution system for powering the medical experiments; the electrical requirements of the galley, waste management area, ECS, and remaining special support equipment. Modifications to the chamber also included instrumentation for sensing and monitoring the OWS flight equipment, the chamber environment, and for reprogramming the data acquisition system used for recording data in the proper format to allow for computer processing.

The modifications to the chamber atmosphere distribution equipment provided a gas atmosphere simulating that of the OWS. Additional equipment required for the conversion included: a heat exchanger to obtain the desired dewpoint temperature; lithium hydroxide canister assemblies and a $CO_2$ injection system to maintain the desired $CO_2$ levels; a two-gas control system utilizing oxygen analyzers and a cabin pressure regulator; a low flow pressure holding system for maintaining 5.0 psia for the test duration of 56 days; an air distribution system to obtain flow velocities similar to that as specified in Skylab; and gas analysis equipment.

SMEAT medical and environmental test requirements to simulate Skylab are summarized as follows:

| | |
|---|---|
| Chamber atmospheric composition | |
| Total Pressure | 5 +/- 0.15 psia |
| Oxygen (70%) | 3.5 +/- 0.10 psia |
| Carbon Dioxide | 5.0 +.5/-1.0 mmHg |
| Humidity | 8 to 12 mmHg (45 - 57$^{o}$F dewpoint) |
| Nitrogen | 1.5 $\pm$ 0.05 psia |
| Temperature | 67 - 78$^{o}$F |
| Noise | Inchamber audible noise spectrum as similar to Skylab as practical; speech interference level at a minimum or below 55 decibels. |
| Airflow Speed | Velocities of 15-30 fpm with provisions for local control and up to 100 fpm utilizing the Skylab protable fan. |

PRETEST ACTIVITY

The design of systems for the test was accomplished with the following requirements:

a. Full participation design reviews with all organizations represented who were responsible for the results of the test.

b. Materials selected for the oxygen rich atmosphere were from known acceptable materials with sample tests accomplished to re-verify materials in the design as used and for the quantity required. Unknown materials, if required, were completely sampled in flame propagation tests to be found acceptable or to access the hazard if no better fire resistant material was available.

c. All designs were configuration-controlled with Quality Assurance verification that systems were installed as per drawings.

d. All systems were designed to last for the duration of the test. Maintenance procedures were written for those systems which might require changeout by the crew, i.e., TV camera. All crew maintenance procedures were verified at sea level pressure prior to altitude testing.

e. All systems and procedures were verified prior to altitude testing by a dry run lasting for a period of about 30 hours.

f. All emergency procedures were rehearsed by the test subjects with all shifts of the test team to verify each man's role in the emregency functions.

g. A three-day wet run was conducted to verify the modified timeline and to insure operational verification of systems and crew interface.

h. The design, construction, and procedures for the test were reviewed by an Operational Readiness Inspection Committee appointed by the Director.

i. The final test preparations were verified by a Test Readiness

Review Board.

j. All personnel on the test team were required to complete pretest training as prescribed in a training manual. A Training Certification Board verified all training requirements were met.

k. The test personnel supporting the test followed two types of schedules. Civil service personnel, namely, test director, facility engineer, etc., followed the shift schedule shown at the top of Figure 5. As shown, the first shift worked from 0000 to 0715, the second shift from 0700 to 1500, and the third shift worked from 1645 to 0015. This schedule provided for 15 minutes overlap for transfer of needed information and allowed continuous coverage of the crew day by the second shift without shift changes. Personnel were rotated to the next shift after their scheduled days off. The schedule allowed the test to be conducted with four persons for each position. The civil service shift was found not readily acceptable as personnel found changing shifts to be objectionable. Married personnel for instance could not adjust readily to the changing of shifts. The support contractor personnel worked 12-hour shifts as shown at the bottom of Figure 5. The work schedule is shown for personnel such as the chamber operator, environmental control system operator and the mechanical technician. These personnel were cross-trained to work all of these positions. This schedule utilized the shifts of 0000 to 1230 and 1200 to 0030 in order to have overlap for transfer of information and personnel assigned to each shift remained on that shift for the 56-day duration. The 12-hour schedule was preferred by the supervisory personnel conducting the tests because (a) fewer number of key people were required to conduct the test, (b) provided for more backup in case of sickness, (c) did not require rotation of shifts, (d) shift interface was always with the same personnel and (e) allowed some personnel to be free for indirect support.

## SMEAT MANAGEMENT

Prior to the onset and during the buildup of the 56 day test, a Test Management Operations Committee (TOMC) was instituted. The purpose of the committee was to review the progress of the test during the 56 days and to assess realtime problems as they might occur, direct changes to test protocol, release daily reports and to meet with the news media.

The committee was composed of personnel representing the following organizations:

| | |
|---|---|
| Chairman: | Director of Life Sciences |
| Members: | Crew Systems Division, EC |
| | Astronaut Office, CB |
| | Biomedical Research Division, DB |
| | Bioengineering Systems Division, DE |
| | Safety Office, SA |

Typical problems requiring realtime decisions from the TOMC during the 56 days of testing were as follows:

a. Revisions of the timeline to permit reruns on the metabolic analyzer when data appeared questionable.

b. The elimination of the Skylab dewpoint instrument from the test chamber due to erroneous readings.

c. Removing the Skylab vacuum cleaner from the SMEAT due to its poor performance and replacing it with the Apollo vacuum cleaner.

d. Redlining the amount of crew exercise to be performed on the ergometer to preclude additional failures prior to the conclusion of the 56 day test. The ergometer had failed early in the SMEAT test and its importance to the 171 metabolic activities experiment warranted this decision in lieu of crew conditioning. The crew was provided with a laboratory type ergometer which permitted them to maintain their daily exercise routine.

## PROCEDURE/TEST OPERATIONS/SPAN TIME AND CREW

The crew activities in the SMEAT chamber were conducted according to a Skylab mission-like flight data file that the crewmen had in the chamber. Chamber test procedures were used for chamber ascent and descent, emergency conditions, and for systems operations external to the chamber. A copy of the chamber test procedures and emergency procedures are included in Appendixes A and B respectively. The flight data file included a timeline book, medical experiments check-lists and malfunction procedures, systems data book, stowage book, crew supplementary activities, experiment emergency procedures and chamber test procedure extractions for crew activity. Changes to the flight data file during the test were handled as in a mission. Test data management practices were similar to Skylab and included daily data reports and crew debriefings.

The chamber atmospheric composition and temperature remained within the specified limits during the entire test. No operational off-nominal conditions were encountered.

Prior to the 56-day test, a 16-hour wet run and a 3-day shakedown altitude run were accomplished. The 16 hour wet run was performed to operate equipment that could not be operated at site pressure or without a crewman in the chamber. The crewmen also made noise measurements with various equipment running for a record of test conditions to verify the background noise was within Skylab specifications. The 3-day shakedown run was made using the SMEAT crew and the same operational protocol as used for the 56-day test, for the purpose of evaluating procedures, medical experiments and off-nominal modes of operation.

The three-man astronaut test crew (Cdr. R. L. Crippen, Plt. K. J. Bobko, Spt. W. E. Thornton) as in an actual Skylab mission, were trained by a series of scheduled training activities for the SMEAT. These activities included medical experiments briefings and hardware operation, chamber briefings and systems operations, storage bench checks, crew compartment fit and functional checks, maintenance briefings, test procedure and flight data file briefings, diagnostic and therapeutic briefings, microbiological training, and emergency procedure training.

Each member of the chamber operations test team attended briefings, on the SMEAT chamber systems and completed a minimum of training as specified in CSD's training manual. Once this training was accomplished, the CSD Training Officer submitted a list of names and respective duty stations for formal certification. A Certification Board, comprised of members from Test Safety, Systems Test Branch, Brown & Root-Northrop (BRN), and Medical Operations reviewed and accepted those submitted for certification. All certified test team members then participated in the scheduled drills and pre-tests to complete their training.

The following test stations required personnel as operators or monitors during the 56-day SMEAT test and comprised the chamber operations test team.

Test Director

Facility Engineer

Capsule Communicator

Checklist

Timeline

Instrumentation Engineer

Instrumentation Technician

Chamber Operator

Quality Assurance (2)

Medical Officer

Medical Technician

Test Safety Officer

Video Technician

Environmental Control System Technician (2)

Mechanical Technician

Facility Coordinator

Communication Technician

Gas Analyzer Operator (2)

Crewmen (3)

## FACILITY OPERATION AND PERFORMANCE

All facility systems performed satisfactorily during the 56-days of testing. A few minor problems were encountered but none of significant magnitude to jeopardize the successful completion of the test.

Environmental Control System (ECS) - An ECS was required to establish and control the SMEAT atmosphere. The ECS consisted of five separate subsystems: (1) air distribution and dewpoint control, (2) two-gas control, (3) $CO_2$ removal, (4) vacuum holding and (5) gas analysis. Each of the subsystems are described in detail as follows and a block diagram shows their integration in Figures 6A, 6B, and 6C.

The SMEAT environment maintained by the ECS was as follows:

| | |
|---|---|
| Total chamber pressure | 4.85 to 5.15 psia |
| Oxygen partial pressure | 175 to 186 mmHg |
| $CO_2$ partial pressure | 4 to 5.5 mmHg |
| Dewpoint temperature | 45 to 57°F |
| Dry bulb temperature | 67 to 78°F |
| Air velocity | 15 to 30 ft/min vertical |

Principles of Operation - As shown in the schematic (Figure 7) the atmosphere gas was circulated by the chamber air-conditioning subsystem blower through ducting into the crew bay. The gas distribution subsystem throughout the chamber provided for pickup of moisture, heat, and carbon dioxide produced by the crew and subsequently mixed with air which had leaked into the chamber. Oxygen was consumed by the crewmen and inboard leakage was pumped from the chamber by the vacuum holding system pumps to maintain the chamber pressure.

The crew bay pressure was sensed by a regulator set to maintain 5.0 ± 0.15 psia. When the pressure dropped below the set point, either oxygen or nitrogen was injected (as required) to bring the crew bay pressure back within the proper limits. The return gas was sampled for temperature, humidity, carbon dioxide, and oxygen concentration. If the oxygen concentration was within the set limits (175-186 mmHg), nitrogen was supplied to the regulator. If the oxygen concentration was low, then oxygen was supplied.

An Apollo suit fan (located in ducting outside the chamber) circulated atmospheric gas through the lithium hydroxide assembly when required for carbon dioxide removal. When the return measured amount of carbon dioxide was at or below 4.5 mmHg, the Apollo suit fan was in the "Off" condition. When the carbon dioxide amount rose above 5.5 mmHg, a valve was automatically opened to allow flow through the LiOH assembly. The Apollo suit fan was placed in ducting outside the chamber to reduce internal chamber ambient noise level.

The return gas then passed over condensing coils, whose temperature was set to obtain the desired dewpoint temperature. The gas then passed over heating elements which were controlled to maintain the desired temperature in the crew bay.

The flow to the vacuum holding subsystem pumps was manually controlled and was set to exhaust slightly more than the inboard chamber leakage plus the amount of oxygen required to enrich the gas to maintain 70 percent oxygen. The two-gas control subsystem functioned as follows: Oxygen was delivered to the two-gas control subsystem from the 20-ft chamber $O_2$ subsystem, which was a part of the existing Building 7 oxygen distribution system. Nitrogen was delivered to the two-gas control subsystem from two of four K-bottles located externally of the 20-ft chamber, through one of two redundant regulators set at 500 psig. Two normally closed solenoid valves, in series, controlled the $N_2$ flow to the crewbay compartment. These valves were operated by control-signals from the oxygen analyzer which opened the valves when $PO_2$ was greater than 186 mmHg and closed them at 175 mmHg. When the nitrogen solenoid valves were open, the two paralleled oxygen solenoid valves were closed. Nitrogen gas delivery quantity was sensed by a flowmeter downstream of the solenoid valves.

Pressure sensing and control subsystems utilized two redundant, subatmospheric pressure regulators, set to 5.0 psia, which delivered the selected gas ($O_2$ or $N_2$) to the crew bay in the return air plenum on demand. No gas was delivered when the crew bay was above 5.15 ~~5.0 ± 1.5~~ psia. When the pressure fell below 5.0 psia, the regulators sensed the pressure drop and opened to allow gas delivery to the chamber. Either $O_2$ or $N_2$ was delivered to the chamber, depending upon the partial pressure of oxygen. Oxygen partial pressure was sensed by an oxygen analyzer, whose sample pickup was in the return air duct of the air distribution system. The sample pickup sensed the average concentration of oxygen in this moving stream to obtain a concentration that would be most representative of the entire crew bay. The gas sample was then subsequently sensed by a carbon dioxide analyzer which controlled the $CO_2$ partial pressure.

Once the nominal $CO_2$ level was reached, the nominal range (4-5.5 mmHg) was maintained as follows:

| $CO_2$ Level | Function |
|---|---|
| 4 mmHg | Inject until $CO_2$ reached 5 mmHg |
| 5.5 mmHg | Remove until $CO_2$ reached 4.5 mmHg |

At test initiation, the $CO_2$ level increased three times as fast as the expected Skylab profile (as per Figure 8) which occurred as a result of the 20-ft chamber volume being approximately 1/3 that of Skylab.

The ambient gas temperature was maintained using a temperature controller on the 20-ft chamber air conditioning subsystem. Return air temperature was sensed and utilized by the controller to operate immersion-type heaters to achieve the desired reading. Chamber ventilation velocity was controlled by the use of a flowmeter in the chamber air conditioning system. The flowmeter output controlled the air conditioning system blower speed to obtain the proper gas velocities throughout the crew bay. The atmospheric gas dewpoint temperature was controlled by use of chilled water circulated through condensing coils upstream of the immersion heaters. The water was delivered at a constant temperature of 45°F. The chilled water system was backed up by a small refrigeration condensing unit which used a thermostat to control water temperature. Redundant water supplies from the chamber cooling system and the Building 7 chilled water system assured continuous control of chamber dewpoint. To remove condensed water, a drain system was installed at the base of the air distribution heat exchanger. The condensate collection tank was open to the SMEAT atmosphere (5 psia) and the drain system allowed the removal of the condensate water without allowing back flow of ambient air. This was accomplished by the use of a valving system, a pressure gage, a drain tank, and a vacuum pump. In use, the tank was evacuated, filled with condensate water, and drained until all the condensate water was removed from the chamber. The total volume of condensate water was then measured and recorded.

ECS System Performance - The air distribution subsystem performed successfully for the complete 56-day test. Near the end of the test, one blower shaft bearing and one pillow block bearing developed flat spots on the rollers causing an increase in noise external to the chamber as the test progressed through the 56-day duration. The noise was not transmitted significantly into the chamber as the crew did not notice the noise increase.

The chamber water condensate removal system was adequate but somewhat cumbersome to operate. This subsystem could be improved with larger internal diameter tubing, improved valving arrangement, and vacuum pump arrangement.

Dewpoint temperature control was adequate but could be improved by a more finely tuned valve. During the test, the chamber dewpoint temperature could be changed several degrees with a small adjustment of the chilled water valve.

The two-gas control subsystem functioned extremely well during the entire test. Oxygen, nitrogen and chamber pressure were maintained within the proper ranges throughout the test duration as indicated in Figures 9A, 9B and 9C. Near the end of the test, one of the two oxygen solenoid valves failed in the open position allowing oxygen to be delivered into the chamber during both the oxygen and nitrogen modes. This problem was corrected without test interruption by replacing the defective component with a new solenoid valve.

The $CO_2$ removal subsystem performed well and was adequate except during extended periods of high exercise rates by the crew. The $CO_2$ removal subsystem was required to run continuously to prevent the $CO_2$ partial pressure from exceeding the high limit at certain high exercise periods. The blower operated automatically when the $CO_2$ partial pressure reached a pre-set value. The "On-Off" design worked smoothly and minimized the number of operating hours on the LiOH blower motor.

A minor problem of the ECS system was the handling of the LiOH canisters. Throughout the test the LiOH canisters had processing problems such as torn outer bags, fabric cuts on the end caps, surface rusting, excessive moisture of packed LiOH, charcoal spills, and shrinking teflon gaskets. Realtime solutions to these problems were accomplished during the test as follows:

a. Fabric cuts in the LiOH canister end covers were eliminated by redesigning the end covers to include a $\frac{1}{4}$-inch thick pad of durette batt sandwiched between two layers of beta cloth.

b. Since LiOH has a large affinity for water, some of the water vapor absorbed by the LiOH during canister packing was driven from the LiOH bed during the high temperature sterilization process (250°F for 5.2 hours). During cool down, water droplets condensed on the surfaces of the inner bag and the canister. Evacuating the air and water vapor within the confines of the inner bag for an extended period of time prior to sterilization proved to not be successful.

Since attempts to control the moisture proved to be inadequate and since the presence of moisture did not degrade the performance of the LiOH canister, it was decided to accept the condition and use as is.

c. Surface rusting on the LiOH canisters soon became apparent after several use cycles. This was caused by a combination of factors: the oxygen enriched environment, material composition of the LiOH canister shell (304 S.ST.), and high temperature and water vapor present during sterilization. A solution was accomplished by pickling and passivating each canister as it was recycled after use.

d. The LiOH canister outer bags were made of acalar, which became brittle after high temperature sterilization and tended to break. This problem was solved by training technicians to be more careful handling the canister to prevent tearing the outer bags during canister transport.

e. Charcoal spillage was caused by an improper fit of one of the armalon felt pads used to contain the charcoal in the canister. This problem was solved by designing and building a new 14 mil armalon pad to prevent charcoal spillage during usage.

The only minor problem that developed in the vacuum holding system during the test was a failure of the pressure sensor that monitored the inlet pressure to the vacuum holding pumps. This sensor was replaced without test interruption.

The gas analysis subsystem had two deficiencies. (a) the water removal system of the gas analysis subsystem was found to be marginal. For this reason the $O_2/CO_2$ analyzers had to be dried out and recalibrated every 12 hours. (b) Two sets of gas analyzers were used, one set to determine whether $O_2$ or $N_2$ should be supplied by the two-gas control system, and another set to provide primary data to the test team and to initiate crew bay alarms if the gas mixture operated out of specification. This arrangement proved to be awkward since small inaccuracies in the data of both sets of analyzers could create a condition in which the gas mixture might appear to be out-of-limits when it was not out of limit. For instance, when the crew bay environment was either at the high or low-end of the Skylab specification, the analyzers controlling the two-gas system might demand a flow of $O_2$ at a time when the primary data analyzers indicated an $O_2$ concentration within specification. This condition could then exist until the analyzers controlling the two-gas system sensed a high partial pressure of $O_2$ and switched from $O_2$ to $N_2$ flow. This condition, though acceptable, introduced cyclic changes in the gas composition that could have been reduced in number with some other design approach.

## MECHANICAL SYSTEMS

Vacuum System - The 20-ft chamber vacuum pumps used for chamber evacuation consisted of two Roots-Connersville blowers backed by a 1000 cfm Beach Russ pump. These pumps were in existence before SMEAT as originally installed with the chamber in 1968.

These vacuum pumps were controlled from the chamber control console located in the control room. Evacuation rate was controlled by the chamber operator using a Foxboro pneumatic controller which controls valves in the vacuum manifold. The vacuum pumps were used to establish a 5 psia chamber pressure at test startup. These pumps were then isolated from the chamber and secured for standby purposes. The SMEAT vacuum holding system maintained the chamber at 5 psia for the remainder of the 56-day test. The vacuum holding system was added to the system for SMEAT because the capacity of the 20-ft chamber evacuation pumps was far in excess of the 5 psia holding requirement.

The SMEAT vacuum holding system utilized two 300 cfm Beach Russ pumps which evacuate a common manifold. One pump was operated with the other pump on standby for a redundant test capability and to allow maintenance when required.

Gas flow evacuated from the chamber was controlled manually by a small needle valve located at the system control console. The control console also contained a flowmeter which was used in balancing chamber environment and a vacuum gage which was used for monitoring the holding system pumps. The pump vacuum gage was utilized to activate a warning light on the system console and on the facility engineer's console to indicate a vacuum rise above a preselected level (10 torr). A pneumatically actuated vacuum isolation valve was automatically utilized to seal the holding system from the chamber in case of chamber emergency repressurization initiation.

Repressurization System - The chamber repressurization system is shown in Figure 11 - Normal or emergency chamber repressurization was accomplished with systems which were installed with the chamber as originally built. Normal repressurization was accomplished at a variable rate as controlled by the chamber operator, in accordance with the approved test procedures, using filtered air. Emergency repressurization (ER), if required would be accomplished with ambient unfiltered air from the Building 7 Hi-bay area and was independent of normal repressurization. Emergency repressurization is accomplished through ten 6-inch diameter valves located on the chamber lid. Emergency repressurization initiation was manually controlled and could be accomplished at selected areas in the control room. The chamber and innerlock could be repressurized from 27,000 ft (5 psia) to sea level in 9 seconds. The control subsystem compressed air from activation of the chamber repressurization valves was normally supplied from building utilities. In the event of interruption and for redundancy, an auto-start compressor also supplied control subsystem compressed air. Pressure monitors in the control air system as well as the operating mode of the air compressor were displayed to monitoring personnel in the control room.

Fire Suppression System - The SMEAT crewbay compartment was equipped with a water deluge fire suppression system as shown in Figure 12. This system was designed to deliver water at the spray nozzles within 2 seconds of system activation. The water delivery rate was at least 1.3 gpm/ft$^2$ of total surface area within the chamber. Sprays were located to spray water from above, below, and from the sides to wet all surfaces. Care was taken in nozzle layout to insure there were no areas blocked from water spray by installed equipment. Rupture discs sealed the water in the lines from the chamber environment and upon activation would rupture at a water pressure of 35 psi.

In addition to the water deluge system, there were five locally controlled fire hoses for use by the SMEAT crew.

Full scale acceptance testing of the fire suppression system in the chamber was not practical due to the need for maintaining oxygen cleanliness of structures already installed in the chamber. The water delivery system including valve actuation was tested for proper functioning with water diverted from the chamber using the system test diverter valve. In addition, a full scale model was constructed for test and evaluation of water spray patterns, delivery volume, and effect on crew mobility (Figure 13). The model had identical piping, nozzles, and nozzle location as the SMEAT galley which occupied approximately 25 percent of the crewbay.

The model testing results were considered satisfactory, proving the spray pattern coverage was complete, water volume delivered was within specifications, and the effect on the crew during this type of emergency was acceptable. The spray density created limited visibility but allowed normal breathing without protective masks.

Equipment Transfer Lock - A small air lock as shown in Figure 14 and in the photograph of Figure 15, was installed on an existing chamber penetration and was used for transferring items, such as food, clothing, and waste materials to and from the SMEAT environment. A transfer container (basket) was used inside the lock to aid in transferring small items. The lock was 18 inches in diameter by 24 inches long and was sealed from the chamber by a 20-inch diameter air operated gate valve. This gate valve was electrically interlocked to require activation by both technician and crewman to prevent the valve from being opened inadvertently with the lock outer door open and to prevent valve closure without crew concurrence to avoid possible crewman injury. Evacuation and repressurization of the transfer lock was manually controlled at the lock outside the chamber with vacuum provided by the chamber inner-lock vacuum pump.

Medical Experiments Ground Support Equipment (GSE) - The medical experiment vacuum system was designed to provide for all normal and emergency requirements of the metabolic analyzer (MA) and lower body negative pressure device (LB NPD). Vacuum was provided by two high vacuum pumping systems controlled at self-contained consoles. One system was used for normal operation with the other system for backup capability.

A vacuum isolation valve was provided, to automatically seal the vacuum system from the experiments in the event of chamber emergency repressurization.

The metabolic analyzer had a requirement for dumping a calibration gas to vacuum in the event of a control regulator failure. This requirement was provided by an evacuated tank with an independent vacuum pump. The evacuated tank was provided with a pressure sensor which alerted the monitor of rising tank pressure (30 torr or above). Should the tank vacuum pump fail, alternate evaucation could be accomplished by a connection with the normal experiment vacuum pumps.

The metabolic analyzer and experiments support system each required a gaseous nitrogen supply at 150 psig for normal operation. This nitrogen was supplied from a two-bottle bank through a reducing regulator. A relief valve was incorporated in the system outside the chamber to insure that supply lines could not be overpressurized.

Mechanical System Performance - The following mechanical systems operated satisfactorily during SMEAT with no significant problems: Chamber vacuum pumps and vacuum holding system, chamber repressurization system, fire suppression system, and equipment transfer lock.

The medical experiments GSE performed satisfactorily during SMEAT with one minor discrepancy which did not threaten test completion. The vacuum pumps of the medical experiment vacuum system repeatedly overheated and progressively decreased in vacuum capability due to abnormally high gas loads from Experiment M092 (Lower Body Negative Pressure) device. Alternate use of the vacuum systems with changeout of pump fluid allowed the test to continue. Gas loads from the M092 experiment consistently ran above the Skylab specification values provided for the vacuum system design. Replacement of the waist seal used in the experiment during the test decreased the gas load temporarily, but the gas load again progressively increased with use and reached values above the design sepcification.

## INSTRUMENTATION AND CONTROL SYSTEM

The 20-ft chamber pump controls, the 20-ft chamber emergency system and the instrumentation and data handling systems were modified specifically for SMEAT.

SMEAT Chamber Control Room - The SMEAT chamber was controlled and operated from a four bay console adjacent to the main chamber and is shown in Figure 17. The control console was divided into four functional or control areas; outerlock, innerlock parasite chamber and main chamber. Chamber controls, (Figure 18), were arranged for ease of operation and test protocol. As the test progressed the operator controlled from left to right and bottom to the top of the panels. All controls were identified with terms used in the chamber test procedures.

Power for the chamber control system, excepting the emergency repressurization valves, was supplied by the Houston Lighting and Power Co. (HLP). In the event of power failure, power was supplied by an LPG engine driven generator. All AC and DC power for the emergency repressurization system was provided by a battery-redundant generator combination that is unaffected by utility power failure. All the chamber controls were electrical latching-type with the latching signals being provided by relays in parallel with the controlled function. The main chamber pump and blowers were protected by water and oil pressure, flow and temperature sensing devices. All isolation, manifold and pump vacuum valves had fail-safe features and were electrically interlocked to prevent errors in operation. Each chamber operator had emergency repressurization capability at his station. The emergency repressurization controls, in addition to opening the repressurization valves, would automatically stop the vacuum pumps and close all vacuum and isolation valves. There were no problems with this system and therefore no recommended changes are made.

SMEAT Chamber Safety System - The SMEAT chamber safety system provided the test conductor with single switch response in the event of chamber fire, smoke, emergency repressurization or the need for internal power termination. The system logic matrix is indicated in Figure 19. The chamber safety system consisted of the test conductor's switch panel and a relay control cabinet that interfaced with the chamber control and water deluge systems. Redundant methods for activating all control functions were provided throughout the chamber safety system. All functions that must be energized could be turned on from redundant parallel circuits and all operating functions that must be de-energized were turned off from redundant series control circuits. Power for the safety system was normally supplied from the house DC source. In the event of power failure, either house DC or site power, the safety system transferred automatically to battery power.

The test conductor's control panel had switches for main chamber (or outerlock) fire, smoke, emergency repressurization and power termination. The fire switch turned on the water deluge, repressurized the chamber to site pressure, closed all vacuum and isolation valves, stopped the pumping systems, terminated all internal power, turned on emergency external lighting and initiated an alarm to the Fire Department. The smoke switch performed all the functions of the fire switch except water deluge and repressurization. The emergency repressurization switch stopped the pumping system, closed all vacuum and isolation valves and opened the emergency repressurization valves. The power switch terminated all internal power to the chamber and turned on the external emergency lighting. In addition, the test conductor had a fire alarm switch that brought the firemen to the control room. Functions controlled by the test conductor's panel switch could not be cancelled by anyone except the test conductor. Fire, smoke and emergency repressurization indicator lights were provided at the chamber operators and medical officer's consoles. A view of the chamber operating console is presented in Figure 20. The emergency system was never required to be used during the test and was used only in pretest checkout.

Instrumentation and Data - The instrumentation and data system was divided into two categories. The instrumentation that was necessary to monitor the crewbay environment, partial gas pressures, dewpoints, temperatures, etc., was defined as test facility instrumentation and data which were concerned with results from the crew experiments were classed as test instrumentation. Data from the test facility, crew environment, were routed through patchboards, simplified when necessary and terminated in the SMEAT chamber control room and the medical officer's console for display, monitoring and recording. Test instrumentation data from the crew experiments were routed through an analog-digital recording processor unit to Building 36 via co-ax cable for display, monitoring and recording at that location. Test instrumentation data were also available at the outputs of isolation amplifiers in the processor unit for routing through the patchboards to the SMEAT chamber control room and the medical officer's console for display, monitoring and recording without entering the patchboards. A block diagram is indicated in Figure 21 to explain the data flow path.

All analog recordings were on 5-inch strip charts, two pens per chart, and all temperature recordings were on 12-inch charts, 24 data points to a recorder. Both analog and temperature recorders had limit indicator lights mounted directly below the recorders. Facility-stores-type information was monitored by utilizing pressure switches and the status was displayed by indicator lights. Facility power was displayed on analog meters and display lights indicated their "Go-NoGO" status.

Instrumentation and Control System Performance - There was adequate data to insure the safety of the crewmen and to provide monitoring capability for all support systems. Most of the data displayed in Building 7 to test personnel was real-time on meters with strip charts for trend determination.

The only problem with this system was with the crew alarms that notified the crew and the test team an out-of-tolerance condition. These alarms were triggered by any noise or data glitch. For the entire SMEAT test there was never an actual alarm associated with any immediate danger to the crew; however, the alarm went-off spuriously 12 times during the test. These alarms were designed to warn the crew of an out-of-tolerance condition not yet critical to their well-being to allow for corrective action. These alarms were triggered by the close tolerances on the test environments of pressure, percent $O_2$ and percent $CO_2$. For example: The 5 psi pressure environment in the chamber would trigger the alarm if the pressure varied beyond a maximum of 5.2 of below a minimum of 4.8 psi. If this condition triggered the alarm it was simply a warning of out of tolerance and was not to be interpreted as an alarm requiring emergency action. It is recommended for future tests that parameters critical to the well being of the crew trigger the crew's alarm for all test personnel and off-nominal conditions that are not time critical trigger only the test director's alarm. The test director can be responsible to analyze the condition and to notify the crew of the condition when proper to do so.

## SPECIAL SMEAT SYSTEMS OPERATION AND PERFORMANCE

The following systems were configured for SMEAT to be as like Skylab systems as reasonable possible in the absence of available flight hardware.

Potable Water

Lighting and Power

Food Freezer

Food Pedestal

Television Monitoring

Emergency Oxygen Masks

Apollo Vacuum Cleaner

SMEAT Shower

Communications and Recreation

<u>SMEAT Potable Water System</u> - The SMEAT potable water system was designed to deliver water in three separate water loops at 45°, 125°, and 150°F ± 5°F respectively. It was not attempted to duplicate the Skylab potable water system other than delivering the water at these specified temperatures.

The SMEAT potable water system is shown in Figure 22. Water was supplied to all three loops from a 50 gallon supply tank pressurized to 20 psig. A second 50 gallon tank was used to transport water from Building 365 at Ellington AFB (source of Skylab water) to the SMEAT chamber. The water was sampled to verify the quality met Skylab specifications prior to leaving Ellington AFB and also at each transfer into the supply tank. Additional water samples were taken from the supply tank at one week intervals for the entire duration of the test. The Skylab water utilizes iodine to prevent bacteria growth.

The 45°F water loop consisted of a pump, a heat exchanger (supplied by Building 7 chilled water), a relief valve and assorted lines. All components of each loop were 316-stainless steel or teflon. Water at 45° ± 5° was circulated to the cold water drinking guns and cold water reconstitution dispenser at the food pedestal. Cold water from this loop also circulated to the shower cold water fill valve.

The 125°F water loop consisted of a pump, heater, reservoir and relief valve. Water in this loop was circulated only to the wash basin for washing and shaving.

The 150°F water loop was identical to the 125°F water loop with one exception. Hot water at 150° ± 5°F was circulated to the hot water food reconstitution gun at the food pedestal and to the hot water food reconstitution gun at the food pedestal and to the shower hot water fill valve.

The water system operated continuously for approximately 60 days without any problems. The iodine residual level remained in specification throughout the test resulting in no unexpected bacteria growth.

SMEAT Waste Management System (WMS) - The SMEAT WMS was used in conjunction with the Skylab urine system which is described in the detailed test objectives portion of this report. Test protocol called for one crewman to use the Skylab urine system for the entire test and a second crewman to use it for the last 10 days. All other waste management requirements were supplied by the SMEAT WMS.

The SMEAT WMS consisted of the fecal collection stool (FCS), (shown in Figure 23), and the urine and fecal cans. The FCS used was the basic design of Skylab with the following exceptions: (a) the SMEAT unit was mounted in a vertical position (instead of horizontal), and (b) the blower assembly and filter were mounted on the base plate under the chamber floor. These differences were required to operate at normal gravity. The stool lid (cushion) was redesigned just prior to SMEAT because the prototype material used split open during pre-test activity as used in the one-g environment. The replacement lid material was RTV-360 and found to be more acceptable for both usability and for fire retardant criteria. The FCS had two moving parts, the stool lid (which moved up and down), and the fecal blower (Apollo suit fan). The fecal blower maintained a delta pressure of 7 to 8-inches of water across the fecal bag referenced to the SMEAT 5 psia pressure environment. Odor removal was simultaneously accomplished by flowing through a charcoal filter. The filter was 3.5 x 8 inches, packed with Type KE charcoal and located downstream of the fecal blower.

The urine and fecal cans used in SMEAT were not Skylab configuration. They were designed to hold a 1-day void cycle and procedures called for them to be passed out at the end of the cycle day. The urine can assembly was manufactured of 16GA304 stainless steel. All seams were welded and polished. The urine hose assembly was composed of a 5/8" OD x 3/16" ID x 30" convolex tube connected to a teflon funnel. The fecal cans were manufactured of 6061-T6 aluminum. Each can was large enough to nominally contain one Skylab fecal bag and could accommodate two bags for optional use.

The performance of the SMEAT WMS was excellent. A minor discrepancy occurred concerning a urine hose splitting which was attributed to the heat cycle required for sterilization. The filter unit on the FCS was changed out twice by the crew during the test as specified in the timeline without any problem.

The SMEAT lighting system (Figure 24) was designed to simulate the Skylab light levels as nearly as possible. Eighteen 4-ft fluorescent light fixtures were used for area lighting. The lumen output could be varied from the manufacturer specified maximum output to zero. The lighting was controlled from two consoles located at the periphery of the chamber and was adjusted to the Skylab light level before test commencement. All ballasts, fuses, and dimmers were located in these two consoles exterior to the chambers.

The power feeding the two lighting consoles was normal commercial power which was fed through contactors that opened as circuit breakers in the event of a chamber emergency. During an emergency, lights external to the chamber were turned on to provide light in the chamber through portholes.

Control of lighting was provided by a master low voltage control system utilizing 3-position switches which allowed the crew control of light level in most areas from high to dim, and off. Individual controls were provided in each sleeping compartment and in other locations within the chamber for convenience.

A reading light was provided in each sleeping compartment with local control. A trouble light with local control was provided with sufficient cable length to reach any area in the test area. The individual light fixtures were designed to be readily changed out by the crewmen.

When the SMEAT design was initiated, an attempt was made to obtain Skylab lighting fixtures to use for area illumination. The fixtures were not available for use and the cost to have additional Skylab units made for SMEAT was prohibitive. The alternative chosen was a standard 4-ft, 40 watt, rapid start, cool white fluorescent lamp sealed in a pyrex pipe and mounted in a metal fixture (guard) to preclude physical damage. Prototype lighting fixtures were subjected to comprehensive tests at 5 psi and approximately 100 percent $O_2$ to determine heat rise and estimated lamp life and to verify safety features. Tests were also conducted to determine radio frequency interference (RFI) output of an individual fixture at maximum lumen output, and for the entire system after the chamber was in test configuration with acceptable results. The frequency spectrum of the standard cool white lamp very closely approximated that of the Skylab fixture.

Light level measurements were measured in a Skylab high fidelity mockup. In order to match the light level closely a system was designed for SMEAT with dimming capability. The SMEAT chamber was divided into areas best suited for group lamp dimming. To simulate a low light level option available in the Skylab system, controls were included which would turn off selected fixtures in the area desired so that those remaining on would approximate the Skylab low level illumination. To make the light sources more "Skylab" in appearance, simple cloth wraps were designed to cover any third of the SMEAT fixtures to make it appear as two 12-inch sources by covering the center section, or one 12-inch source by leaving the center third exposed.

The light levels were adjusted in all areas of SMEAT to within $\frac{1}{2}$-ft candle of the Skylab mockup readings. Once set, the rheostats were not adjusted during the conduct of the test.

In an attempt to assure an adequate light output control span, and uniform illumination level over the whole test area, 27 lamps were utilized in the system. Testing during wet runs prior to SMEAT found there was a problem in that with a very low lumen output (low voltage on the lamp) there is a tendency toward mercury starvation and pooling due to the lamp wall temperatures being too low. Several lamps failed due to this problem. To correct the situation, lamps mounted directly in the chamber cold air stream were either relocated or removed. In all, nine lamps were removed, allowing higher voltage to be placed on the remaining lamps with accompanying higher lamp wall temperature. As a result, there were no area lamp failures during the 56-day manned test.

The three reading lamps and the troublelight utilized 400 Hertz white fluoresent lamps made as early prototypes for use in Apollo. One reading lamp failed during the SMEAT test and was replaced with a spare.

Electrical Systems - The normal electrical power for the SMEAT chamber was supplied by Houston Power & Light Company. In the event of a power failure, critical power supply would have been automatically transferred to a natural gas-driven generator that is rated for continuous operation for the SMEAT load imposed on it. If primary power could not be restored, procedures would have been follwed to start up a trailer-mounted diesel-engine-driven generator with adequate power rating to supply all power requirements for the SMEAT including necessary building support facilities. The trailer power supply was connected to the Building 7 power system for the duration of the test. The 28V DC and 400 Hertz power requirements for convenience outlets, food preparation center and other ancillary needs was provided by redundant systems with a manual transfer capability if required standby units.

Power for emergency repressurization was provided by battery-driven redundant DC/AC converters with automatic transfer feature to the standby unit in case of failure of the primary unit.

Within the chamber, zero-G type convenience outlets were placed at optimum locations to provide power for experiment requirements. Figure 25 indicates the location of the SMEAT power receptacles.

SMEAT Food Freezer - The SMEAT food freezer was designed to provide a storage space for frozen food at a temperature of $-10 \pm 10^{\circ}F$. No attempt was made to duplicate the Skylab freezer. Differences between the SMEAT freezer and Skylab freezer are the orientation of the freezer locker, door latch, coolant, and the quantity of food storage. The useful storage space in the freezer measured 9.5 inches side, 20 inches high, and 13 inches deep. This allowed space for 6 Skylab overcans. The freezer system consisted of a chiller unit and coolant circulation pump outside the chamber and the insulated storage locker inside the chamber.

The coolant fluid, a fluorinated hydrocarbon, was chilled in the chiller unit reservoir and circulated through tubing coils inside the storage cabinet.

The freezer maintained the proper food temperature throughout the test. The crew reported that there were no problems in using the freezer and that frost buildup was minimal and did not require removal during the test.

A small leak developed at the coolant circulation pump shaft seal during the test. Coolant was added externally as required and system operation was not affected. If the leak had become worse, replacement of the pump would have been required. A replacement pump was available but was not utilized.

SMEAT Food Pedestal - The SMEAT food pedestal is indicated in Figure 26. It was designed to be the supporting structure for Skylab food heating trays, Skylab food reconstitution water dispensers, and drinking water dispensers. The configuration of the SMEAT food pedestal was similar to the Skylab food pedestal.

The Skylab food heating trays were clamped to three Skylab configuration heat sinks attached at three equally spaced locations around the top of the SMEAT food pedestal. The top of the food pedestal was at a comfortable sitting height for the chairs used in the SMEAT. The drinking water dispensers consisted of two Apollo dispensers and one Skylab dispenser and were held in brakets on the sides of the food pedestal between the tray. The Skylab food reconstitution water dispensers were mounted in a recess in the top of the pedestal. A cover was provided for the recess when it was not in use. This cover with the three food tray covers in place provided a convenient desk-like work surface for crew activity between meals.

There were no problems encountered in the use of the food pedestal, trays or water dispensers during the test. The SMEAT crew found that they liked the pedestal concept for eating.

Television (TV) Monitoring - The SMEAT closed-circuit TV system provided TV monitoring and recording of activities inside the chamber for experimental and safety purposes. The basic system was composed of five cameras in the crewbay chamber area and one camera in the outer-lock, the Building 7 video control console (Room 114), the MSC video control center (Building 8), and approximately nine monitors in the SMEAT test control areas of Building 7. Four fixed mounted cameras in the crewbay monitored the wardroom, the experiments area, and the second level. The fifth camera in the crewbay was portable with a tripod. The basic camera was a Cohu Model 2000 environmentally sealed camera. The camera housing design was certified to the following explosion resistance specifications: MIL-E-5272C, Procedure IV, paragraph 4.13.5 and MIL-STD-810, Method 511, Procedure 11. Camera locations inside the chamber are indicated in Figure 27. Three cameras, (E2, F1, and P1) were equipped with a 20 to 80 mm zoom lenses. Cameras E1, L1, and W1 utilized fixed 10 mm wide-angle lenses. The zoom lenses were remotely controlled by an operator at the control room console. The portable camera (P1) was normally stowed when not in use. The cameras on the pan and tilt mounts could be manually repositioned by the test crew. The output from each crewbay area camera (E1, E2, F1, W1) was "hardlined" to a monitor in the SMEAT chamber control room. In addition, the output from each of the cameras was switchable for recording and display. Cameras E1 and F1 were designated as the cameras to be recorded during emergencies.

Procedurally, the crewbay area mounted cameras were kept operating at all times with the target voltage turned down when TV reception was not scheduled. When the target voltage was turned up, an instant picture was received from the camera which permited a fast response in the event of an emergency situation. The lock camera L1 was kept on continuously. Two video tape recorders (VTR) located at the Building 8 video control center were used for recording. Routinely, one VTR machine ran continuously with the second in a standby mode. At any time the console operator was required to be absent from his station, both machines were turned on. This operational method permitted video recording to be initiated by the Building 7 console operator when he switched the camera output to the VTR. A Greenwich Mean Time (GMT) timing signal and a test intercom audio track was also recorded on the video tape. The GMT was superimposed on one of the TV monitors in the SMEAT chamber control room and was continuously available to the test subjects for viewing on their recreational TV monitors.

The SMEAT closed-circuit TV system operated satisfactorily during SMEAT with no problems jeopardizing video coverage. Initially noise problems were encountered during movement of the portable TV camera. The source of noise was found to be a slight movement between the mating electrical connectors used on camera housing and cable. The problem was resolved by installing a thin teflon ring around the base of the camera connector to restrict this movement.

Emergency Oxygen Mask System - Oxygen was supplied from the chamber oxygen system at 100 psig to manual oxygen shutoff valves inside the crewbay. From the shutoff valve, the oxygen passes through an umbilical of sufficient length to allow the crewmen to egress the chamber while breathing from this source. The umbilical is connected to the input of a mask-mounted regulator. The mask is a quick-don, full-face type incorporating a smoke-protecting lens.

Eleven mask assemblies were installed in the chamber as follows: 3 near the fire suppression switches in the wardroom, 2 near the fire suppression switches on the second level, 2 near the fire suppression switches in the medical experiments area, and 2 near the fire suppression switches in each of the innerlock sleep areas.

The emergency oxygen mask system was never required to be used during this test and subsequently was never used in an emergency. Pre-test training activity use indicated satisfactory performance with desirable quick-don features and proper capability in the event an emergency had occurred.

Apollo Vacuum Cleaner - The Apollo vacuum cleaner was used during the SMEAT because the Skylab unit did not generate enough suction to pick up the debris in the chamber. Prior to the start of SMEAT the Apollo vacuum cleaner was intended to be used as the backup unit.

The Apollo vacuum cleaner was designed to be used on the lunar missions. It is powered with an Apollo suit compressor with a 3-ft suit hose connected to the inlet side of the 110 volt, 400 cycle 3-phase motor. A bristle brush is attached to the end of the hose and a catch bag is connected at the rear of the unit to hold the particles picked up by the vacuum.

There were no problems with the Apollo vacuum cleaner during the entire test. The unit became clogged with shedding debris during the test but after it was emptied, the unit was fully restored to operation.

SMEAT Shower - The SMEAT shower system was incorporated into the facility to simulate at earth gravity conditions the proposed Skylab shower system. The configuration resembled the Skylab shower in appearance and served the specific need for a crewman shower for cleanliness. The drain tank is shown in Figure 28, the shower in Figure 29, the shower deployed for use in Figure 30, and the hot and cold water supply system in Figure 31.

The shower enclosure consisted of a cylindrically shaped, 79-inches high, 35-inches diameter, two pass beta cloth wall with four ring stiffeners. The enclosure was open at the top with an aluminum pan at the bottom. The unit was normally stored as a collapsed unit under the chamber bunk. The nozzle assembly consisted of a bete fog nozzle No. 5080F plumbed to 76-inches of 3/8 inch diameter convolex flex tubing with a quick-disconnect fitting at the ceiling level. In use, the nozzle was hand-held by the crewman using the unit.

To use, the water tank was filled with hot and cold water to arrive at a mixed "use" temperature of 107° to 110°F. The temperature was measured at a point 3-4 inches from the nozzle. The water tank was pressurized initially with nitrogen to 35 psia which decreased to approximately 10 psia at the completion of each shower. Each crewman used 6 lbs. of water per shower (as in Skylab). Each crewman took a total of seven showers. Showers were taken on mission days 8, 14, 20, 26, 35, 41, and 49 respectively. At the end of three showers, the drain tank was passed outside the chamber through the transfer lock. The SMEAT crew found the temperature range adequate but preferred the showers hot (upper part of available range). The 6 lbs of water per shower was found to be minimum but adequate. The use of the shower was operationally workable, trouble-free, and free of fungus or bacterial growth.

Test Communications - The SMEAT intercom system provided two-way audio communications between test team members. The basic system was composed of seven speaker intercom stations (SIS) in the crewbay area, four $O_2$ mask communication connections in the innerlock, four $O_2$ mask communication connections in the outerlock, and approximately 24 intercom stations located outside of the chamber in the test team areas. The system had five normal channels and an emergency "all call" channel, enabling simultaneous conversations on different channels. The intercom stations exterior to the chamber were used with headsets. The SIS inside the chamber could be used with or without the Skylab headset. Locations of units within the chamber are shown in Figure 32 and a typical SIS unit is shown in Figure 33.

The intercom was a modified Carter Engineering CE 2000/AIC intercommunication unit. This basic system has been utilized with the CSL altitude chambers for approximately seven years. Modifications for the SMEAT included the addition of the seven SIS units, adding monitor speakers, isolating the SMEAT chamber system from the other chambers of Building 7, and adding audio recording equipment.

Each intercom station had the capability of being switched to any one of five channels during normal use. On stations external to the chamber this channel selection was done by the user. The test director switched channels for the SIS units and $O_2$ mask intercom connections inside the chamber. The five channels available to the SIS units were configured as follows:

Channel 1 - common with intercom system Channel 1

Channel 2 - common with intercom system Channel 2

Channel 3 - common with intercom system Channel 3

Channel 4 - private to "Capcom Station" and "Guest Com Station"

Channel 5 - private to "Capcom" and "Telephone Coupler".

In the event of an emergency, predesignated stations were configured to switch to the "all call" audio channel. The stations which were switched to the "all call" channel also had certain previously selected stations could transmit as well as receive. The intercom system could be switched to the "all call" mode by either the test director or automatically by the chamber emergency control system.

"Capcom-Test Subject" audio was provided to Building 36 for the medical experiment monitoring station. This output was controlled at the "Capcom" station in the event of an emergency "all call" initiation, the output would have been muted to prevent the station from interferring with vital communication.

The test director's audio channel and the "Test Subject-Capcom" audio channel were continuously recorded for the full duration of the test. An "IRIGB" coded GMT time reference signal was recorded on the same tapes. The emergency "all call" audio channel would have been recorded during "all call" initiation if used. Additionally, the "Test Subject-Capcom" audio was provided to the video studio for recording purposes. The output to the video studio was controlled at the "Capcom" station on normal use and was automatically switched on during the "all call" mode. A warning tone was initiated on the "Test Subject-Capcom" audio channel whenever a previously designated critical parameter exceeded its tolerance.

A private channel available to only the subjects and "Capcom" was acoustically coupled to a telephone receiver. The "Capcom" station controlled the telephone coupler equipment. In case of emergency "all call" initiation, the subject using the phone tie was automatically switched to the emergency "all call" audio channel.

The Speaker Intercom Station (SIS) (Figure 33) unit was similar to the Skylab intercom assembly (SIA). Each SIS contained a fixed microphone and speaker as well as provisions for connecting two umbilical/headset assemblies. The fixed speaker/microphone could be used only in a "push to talk" mode. During an emergency "all call" initiation, the SIS was switched automatically to the emergency audio channel and the speaker was turned to maximum volume. A "message notifier light" could be turned on at the "Capcom" station to notify the crew when conversation was desired.

Three Skylab lightweight headsets and "Snoopy Hat" communication carriers were available inside the chamber. Skylab lightweight communication umbilicals and control head assemblies were used with the headsets.

The $O_2$ mask assemblies (used by the crewmen during ascent) contained earphone receivers and microphones. These assemblies and their umbilicals were utilized with the four $O_2$ mask intercom connections in the inner and outerlock areas.

Recreational Electronics - The SMEAT recreational electronics system provided both TV and radio entertainment to the test crew. The physical arrangement of the system is shown in Figure 34. The basic system was composed of two remotely controlled TV monitors located outside two chamber viewports, two remotely controlled AM-FM radios (outside the chamber), and three speaker entertainment stations (SES) inside the chamber. The SES units contained radio controls, TV monitor controls, speakers, and provisions for listening with Skylab headset/umbilical assemblies. The TV monitors displayed both commercial network TV and closed-circuit TV from either cameras or video tape. The system provided television and radio listening capabilities for entertainment during off-duty hours. In addition, the system provided for educational classes using either video tapes or a live instructor outside the chamber. To minimize costs, the system was designed similar to the intercom (where applicable) and used the same Skylab headset/umbilical assemblies for audio capability. A SMEAT SIS and SES station is shown in Figure 35.

The three SES units inside the chamber were used for listening and controlling the radio and TV signals. Of the three, two units (designated SES-1 and SES-2 as shown in Figure 36) controlled one TV monitor and one AM-FM radio. The third SES unit (designated SES-3 and shown in Figure 37) was used only for listening to either the SES-1 and SES-2.

Power to the SES units was fused and current limited with resistors outside of the chamber using as guidelines existing MSC standards and McDonnell-Douglas Report MDC E0065 - Design Requirements, Airlock Speaker Intercom Assembly.

Whenever the intercom system was switched to the emergency "all call" mode, the SES units monitored the emergency "all call" audio channel.

Closed circuit TV was used in the conduct of elective study classes by the crewmen. A temporary TV camera was located in Room 114, Building 7, which viewed the instructor, and video signals from this camera were displayed on the test crewman TV monitor. Two-way audio communications were available via the SMEAT intercom system. When video tapes were used, the video and audio signals were originated from the television facility located in Building 8. These signals were monitored at the test crewman TV monitor and SES.

The two radio units, exterior to the chamber were AM-FM automobile radios, of the automatic station-seeking type, modified with relays for remote control. The audio signals from the radios were conditioned using the same type of equipment as used in the intercom system.

The TV monitors were modified with servo controls and relays to permit remote operation from inside the chamber. Multiple video and audio signals, originating from Building 8, were routed to remotely controlled switchers (i.e., subject controlled at SES units) where the signals were selected for display and listening.

The SMEAT communication and recreational radio systems operated satisfactorily during SMEAT with no problems jeopardizing communications within the test chamber. Communications to the chamber were interrupted only for pre-planned maintenance procedures as required for normal repairs. Two crewman communication control heads had failures of the convolex tubing cable sheath (reference IDR IS260389 and IDR 1260405). One of the lightweight crewman communication umbilicals had a loose shell on an electrical connector (ref. IDR IS260396). The PLT noted that the crewman communication control head would be easier to use if the length of the flexible portion was increased.

The original telephone tie was an acoustical coupler which interfaced with a phone headset. This coupler operated satisfactorily except for two characteristics. When utilized with a degraded outside phone connection, the acoustical coupler required a relatively critical adjustment of incoming and outgoing volume levels. Also, there was always some background control room noise due to the exposed microphone in the coupler device. In response to the crew's request for improved telephone service, a telephone company owned "hardwire" coupler device was installed. This device improved the overall performance but decreased the volume on the intercom systems "Phone" channel due to loading characteristics. The phone company was unable to further improve the performance and the "hardline" coupler was utilized "as is" for the remainder of the test.

## NONMETALLIC MATERIALS CONTROL

The high inherent danger associated with nonmetallic materials (NMM) in oxygen-rich environment required that a rigid NMM control procedure be imposed at the beginning of the SMEAT program. The NMM used in SMEAT were in two approximate classes: (a) flight or flight prototype hardware and experiments, (b) and all other support materials. Control of these materials was accomplished by the use of four different Boards which operated as a system of checks and balances to assure maximum attention to every material accepted for use.

The control procedure will be discussed from the point of view of controlling the physical flow of materials as well as control from an acceptability standpoint. Some of the materials which were substituted to increase the fire safety will be discussed briefly.

Over 1800 NMM usages were reviewed by the CSD Materials Usage Control Board (MUCB) in addition to the NMM accepted by the Skylab Program Office and a SMEAT waiver review committee. Of these, slightly over 200 were initially rejected and required additional evaluation. The number of NMM initially rejected was minimized by close coordination between SMEAT engineers and the MUCB in the area of materials selection prior to formal submission of the materials for review.

Materials Control Organization - The materials control organization used to support the SMEAT is outlined in Figure 38. As noted, hardware materials which had been unconditionally approved for flight by the Skylab Program Office was accepted for use in the SMEAT without further review. Evidence of such approval was required for each test item. Skylab experiment materials or test articles which were not flight-configured were reviewed by a special SMEAT waiver review committee. This committee, which was chaired by the Director of the Life Sciences Directorate, was empowered to review the status of Skylab medical experiments and to accept those items which, through different from flight configuration, would not constitute a hazard in the SMEAT facility.

All other NMM were submitted, through the Systems Test Branch, to the MUCB. One Board member was designated as materials engineering specialist (MES) with responsibility for screening all submitted materials and making recommendations to the other Board members. Incoming non-metallic materials master log sheets or waiver requests were logged and reviewed for acceptability. The MES contacted requesting organizations for clarification of data, conducted chamber walk-through for personal evaluation, examined components, requested samples of marginal NMM for additional testing, and otherwise obtained sufficient information to verify the safety of each material in its particular usage application.

All materials accepted by the MUCB and the SMEAT waiver review committee were forwarded to the Test Readiness Review Board (TRRB). The TRRB was chaired by CSD's Assistant Chief for Test and Development and its membership included personnel from the Safety Office, the Reliability and Quality Assurance Office, the Life Sciences Directorate, and the Systems Test Branch. The Board was responsible for reviewing the condition of readiness of all facilities, test buildup, and Skylab equipment. The condition of materials acceptance was made a major part of this review. The TRRB was empowered to reject materials which had previously been approved by either the MUCB of the SMEAT waiver review committee if in their judgement such action was required, thereby assuring that MSC management had final control on materials acceptability. In fact, no such materials rejection action was taken.

The TRRB also had authority to accept materials or waivers which had been previously rejected by the other Boards.

After all NMM problems had been resolved and all individual materials had been accepted, a final integrated waiver review was held at the MUCB and the TRRB on all materials which had been conditionally accepted or accepted on waiver. The purpose of this review was to assure that any marginal materials did not, as a result of their proximity to other materials or power sources in the test chamber, constitute a hazardous condition which could not have been anticipated when the materials were reviewed individually. No unanticipated interactive problems were found.

The documents developed to aid in the control of the SMEAT NMM are described briefly in Appendix F and are shown in Figures 38 through 45.

Materials Acceptance Criteria - Document MSC-PA-D-67-13 was used as a point of departure, with considerable engineering judgement to determine the acceptability of each NMM used in the SMEAT. MSC-PA-D-67-13 was written as a materials control document for spacecraft and as such does not consider mitigating circumstances such as the presence of a water deluge system, the proximity of external assistance for rescue, or the ability to return to an ambient (relatively benign) environment in a fraction of a minute.

The ground rules used by the MUCB in determining the acceptability of NMM for SMEAT were as follows:

1. If a flammable NMM could be replaced it was replaced.

2. The water deluge and short emergency-repressurization time were not considered in ascertaining the acceptability of NMM, but rather were thought of as contributing a margin of safety to manned tests in an otherwise hazardous environment.

3. The nonavailability of an ignition source was normally not considered in determining the acceptability of exposed materials.

4. The offgassing criteria of MSC-PA-D-67-13, though conservative for chamber testing, were used as guidelines for acceptance of NMM.

5. All materials accepted for use in the chamber were required to be either self-extinguishing as used or be nonhazardous in the event that they were ignited. The single exception to this policy was those flammable materials which were totally nonreplaceable and which were exposed

to the chamber environment in small quantities for only short periods of time. Considerations included the location of the item within the chamber, proximity of other NMM and the extent of protection afforded by the enclosure.

6. Materials review did not formally include materials properties as they related to mechanical performance or physical configuration.

These criteria, with some flexibility, were enforced by the MUCB in reviewing all SMEAT NMM. The criteria were obviously unnecessarily conservation and in any final consideration, a realistic cost-benefit analysis must be made between cost and scheduling considerations and the actual probability of risk involved. Accordingly, after all practical avenues for complying with these criteria were investigated, the mitigating circumstances alluded to above were taken into consideration. Becuase of the nature of the final judgement required, all decisions of this type were deferred to the more senior TRRB.

<u>Control of Materials Flow</u> - Though the various Boards described above were responsible for determining the acceptability of the NMM used in the SMEAT, the Systems Test Branch was responsible for controlling the actual flow of NMM into the test chamber. The governing document for materials control into the chamber was the MSC-CSD-STB Altitude Chamber Facilities Standard Operating Procedure Manual, CSD-X-109.

To provide additional assistance in monitoring materials status and providing increased visibility in possible materials interaction, a computerized materials control program for SMEAT was instituted. A typical computer printout is shown in Figure 39. The computer listing included all items from the chamber materials-control log and gave the status of each. The listing was used as a control of status in determining which materials had been submitted to a Board for review and which Board did the review. Every NMM which was rejected, accepted conditionally, or accepted on waiver, was compiled on a separate listing. The program provided a printout by material, condition of approval, system, responsible engineer, and was updated periodically for status. Attempts were initiated, but not completely implemented to obtain from the program the cumulative total quantity of each material used.

In addition to listing the materials which were most likely to cause potential problems, the computer provided a 3-dimensional display of the locations of the materials as they existed during the SMEAT. A plan view of the chamber, such as that shown in Figure 40 gave the location of every NMM listed. A separate display was provided for each 12-inch elevation of the chamber.

The computer printout was found to be a most valuable method of controlling the status of NMM in preparation for the SMEAT. Copies were forwarded at frequent intervals to each responsible engineer and supervisor and assisted the TRRB in monitoring potential problem areas.

Concluding Remarks - A major portion of the MUCB materials control activity in preparation for the SMEAT was recommending alternate solutions when materials were considered unsafe as submitted. This support ranged from recommending fire-resistant coverings to conducting short-term development programs to obtain new or improved materials where existing materials appeared nonexistant.

It was found that very satisfactory flexible nonflammable coverings could be formed from alternating layers of Beta fabric, aluminum foil, and Asbeston fabric. Where greater durability under flexure and where greater scuff resistance was required, a layup including Teflon fabric and polyimide film was found quite suitable.

The Skylab heating food tray is one example of a substitute materials recommendation. This item was originally designed utilizing polycarbonate as the plastic material adjacent to the heating elements. The program manager for the tray submitted the material to the MUCB representative well in advance of SMEAT and as a result of the evaluation was advised to replace the polycarbonate with polyimide. The recommendation was accomplished and subsequently the trays as modified were used in SMEAT.

A short-term development program was initiated in response to a request for an acceptable paint for the SMEAT interior. A paint was required which was vacuum compatible, fire-resistant, had acceptable offgassing properties, would adhere to various metals, and was available in a variety of light pastel colors. An inorganic ethyl silicate based paint was obtained, evaluated, found to accept dramatone pigments, passed odor and toxicity tests, and resulted in a paint meeting all objectives.

Some materials problems were encountered which, though solved for SMEAT, should be viewed as possibly problematic in general. The large amount of reading material required to entertain a crew for such a long period of time is an example. This problem was minimized in SMEAT by storing the books in metal lockers, by limiting the number of books allowed out at any one time, and by initiating and enforcing good housekeeping procedures. It is highly desirable that similar actions be taken on future tests and manned flights, particularly if water deluge or other fire extinguishment is not available. Another appreciable fuel source within the SMEAT was the use of cotton towels.

Cotton, contrary to the synthetic fibers, has high moisture absorption properties and hence is unsurpassed as a towelling material, but is very flammable. This problem was similarly controlled in SMEAT by storing the towels in a metal locker and limiting the number of towels exposed at any time. More ideally, because of the extreme flammability of cotton, it is recommended for future chamber tests and flights that if cotton towels are used, the daily ration be hung to dry behind a vented metal grill when not actually in use. Such a device would minimize the resulting fire potential without inhibiting the evaporation of moisture.

## SAFETY, RELIABILITY, AND QUALITY ASSURANCE

Pretest Support - Safety, Reliability, and Quality Assurance (SR&QA) provided real-time support to the SMEAT test team for ensuring that all facility/experiment hardware was adequately certified, installed, pretested, and controlled. All discrepancies were documented and resolved either prior to test or documented as failures for later analysis and resolution depending on hardware support requirements.

Certification - Prior to the start of the SMEAT Manned Testing, considerable effort was expended by SR&QA representatives to obtain configuration status and in initiating a system which would control certification of the medical experiments.

In an effort to preclude any incidents of equipment being stowed with an unknown status, the SR&QA Office established hardware review teams consisting of engineering personnel from the three disciplines to participate in the review of equipment/documentation, with the technical monitor responsible for supplying the various equipment for the SMEAT. It was the responsibility of these hardware review teams to certify the equipment listed in the SMEAT Stowage List. Also, it was their responsibility to identify by submitting Review Item Dispositions (RID's) on any significant problems or questionable areas which would require resolution by the SMEAT Review Committee. In certain instances, these problems were resolved through issuance of waivers reviewed and approved by the SMEAT Waiver Review Committee.

Since flight medical hardware was not always available to support SMEAT, flight-like hardware classifications were substituted such as: Design Verification Test Unit (DVTU); training hardware; and prototype hardware. As such, only a minimal amount of documentation/information was available to the review team for certification prior to the start of SMEAT manned testing.

All hardware and supporting documentation was reviewed to ensure that test reports, data, waivers and deviations, hardware design versus as-built configuration, anomalies, and previous test conclusions were adequate to support the test objectives of SMEAT. Individual certification sign-off sheets were generated for each review item.

Acceptance Data Packages (ADP's) were reviewed to determine: present configuration of hardware, differences between test and flight hardware, and open items which required resolution in order that the SMEAT hardware would meaningfully support the test objectives.

Resultant review deficiencies automatically required the initiation of the following documentation:

RID's: Generated to document deficiencies and ensure adequate resolution prior to final certification unless waivered by the SMEAT Review Committee. The RID index is included as Appendix C to this report.

Waivers: Documented existing hardware and/or documentation deficiencies; authorized use of uncertified hardware to support SMEAT. Waivers required review and signatures of the SMEAT Waiver Review Committee. The Waiver Index is included as Appendix D to this report.

The hardware review team during their subsequent reviews of the available documentation and hardware generated a total of two hundred and fourty-five (245) RID's requiring additional information/resolution prior to certifying the hardware as ready for test.

Positive corrective action was not feasible on 47 RID's and required SMEAT waivers. SMEAT waivers were submitted with adequate engineering rationale to the SMEAT Waiver Committee for their consideration and subsequent approval.

Special Hardware Testing - Special testing was conducted and supported by Quality Assurance. Tests were initiated where certification/recertification was required in certain areas of concern (i.e., $O_2$ compatibility and preinstallation acceptance tests prior to chamber installation).

TRRB - TRRB summary sheets were reviewed to ensure proper status of hardware. The TRR sheets were then submitted to the TRRB for review in order to assess the current status of the facility and experiment hardware.

All TRR sheets that were facility and/or medical hardware oriented were finally signed by the Board assuring the state-of-readiness in support of SMEAT.

Hardware Installation/Removal and Checkout - The SR&QA organization provided surveillance buildup of all facility systems including installation/removal of medical experiments hardware. All work was accomplished using the MSC Test Preparation Sheet (TPS) system as outlined in MSCM 5312. Any discrepancies noted during this time required the initiation of a DR/MRR. IDR's, by mutual consent, were generated only after the commencement of the 56-day manned test.

Since all TPS's were controlled by QA, the associated index was utilized at daily meetings to assess the quantity of open items. Significant problems were identified and specific action items were assigned to responsible personnel for resolution in a scheduled manner.

## Configuration/Control

SMEAT configuration is broken into the following categories:

Configuration - Medical Hardware - The overall medical equipment required to support SMEAT was delineated in the "SMEAT Stowage List". This document was updated (listing additional equipment required) via the Stowage List Change Notice (SLCN). This document provided a single point control for configuration of medical hardware in the chamber and required periodic programmed chamber inventories of this hardware to verify status. All hardware was installed via a TPS and required Quality Assurance buy-off.

Control - Medical Hardware - Quality Assurance formulated and implemented the SMEAT Program Chamber Medical Hardware Installation and Certification Plan (Figure 46) which allowed Quality Assurance to control and track hardware installation as well as ensure installed hardware certification.

Configuration - Facility Chamber - The facility configuration is comprised of basic chamber hardware and associated loose equipment required to interface the medical experiments to the chamber facility. The SMEAT facility top drawing defines and authorizes installation of this hardware. Any hardware installations not in accordance with the top drawing required initiation of formal engineering documentation. The formal MSC TPS system was utilized as the vehicle for authorizing actual hardware installations.

Control - Facility Chamber - Control of hardware configuration was accomplished by the aforementioned top drawing and engineering changes. In addition, the TPS's generated to install the hardware were tracked and periodically inventoried against the SMEAT facility top drawing.

Nonconformance Reporting - The documenting of SMEAT nonconformances was accomplished utilizing the MSC Discrepancy Report/Material Review Board (DR/MRB) system as delineated in MSCM 5312.

Since the supporting medical experiments are comprised of flight, qualification, training, prototype, and Design Verification Test Unit (DVTU) type hardware, some nonconformances were unique to that particular unit and did not affect flight hardware. Therefore, only RID's and/or waivers were generated, rather than Failure Investigation Action Report (FIAR's).

Any major nonconformances which effected flight hardware were transferred to a FIAR which was submitted to Problem Assessment Engineering (PAE) and for inclusion in the Open Problem List (OPL) for formal tracking and closeout.

Management Visibility Support - Quality Assurance supplied management visibility by maintaining and publishing the following documents:

Chamber Hardware Tracking Book, which provided up-to-date inventory of all hardware installed in the 20-ft chamber.

SMEAT Hardware Status (published weekly), which reflected chamber configuration and support required, by discipline (Safety, Reliability, Quality Assurance - Technical Monitors), to complete hardware certification.

Progress Report (weekly), which appraised management of current activity, special milestone schedules, behind-schedule reviews, and significant pending problems.

Maintained/status of open DR's and TPS's for the daily SMEAT meeting.

## TEST SUPPORT

SR&QA provided real-time support to the SMEAT test team ensuring that MSC Reliability, Safety, and Quality Assurance protocols were adhered to during the test phase. To accomplish this, the following responsibilities were assumed by Quality Assurance and Safety in the Facility area (Building 7), Medical Experiments area (Building 36), and Data Review area (Building 36).

Test Team Participation - Quality Assurance and Safety personnel participated as test team members during the entire SMEAT Program. Specific responsibilities included: control of all hardware removal/ installation; surveillance of all associated testing; verification of chamber lock transfers; initiation of IDR's/DR's, review of resolution and recurrence control of problems identified by IDR's/DR's with responsible engineering personnel; and support of the various daily test management meetings.

Since the SMEAT test was conducted in Building 7 and all real-time data was displayed in Building 36 at the Medical Experiments Officer (EO) console, it was also necessary to provide Quality Engineering coverage to support this test station during the conduct of all major medical experiment activities. Quality Engineering supporting this station initiated IDR's as outlined in the "Discrepancy Reporting" paragraph of this section.

Safety also periodically (programmed) monitored all internal chamber compartments via the portable TV system operated by a crew member. This coverage provided Safety the opportunity to examine any area suspected of becoming a hazard or potential hazard to the crew or facility.

Discrepancy Reporting - SMEAT test anomalies and IDR's, were documented from the following sources: as incidents were reported over the communications network, visual monitoring of displays, review of strip charts and other readouts, discussions with responsible engineering organizations, daily test crew debriefing reports, and morning status meetings. Upon initiation, the IDR's were forwarded to the SMEAT test facility for tracking and assignment to responsible engineering groups for disposition and corrective action. IDR's initiated on the medical experiments hardware were assigned to the EO in Building 36 for cognizance and reassignment to the respective responsible Project Engineers. Copies of the IDR's and IDR indexes were forwarded to the Skylab Program Office for their assessment of impact on future Skylab missions. When the IDR, through engineering analysis and/or troubleshooting, had been isolated to a major system or component, it was then transferred to a DR for subsequent hardware problem resolution. Quality Assurance, during the conduct of the SMEAT, also maintained a tabulation of the IDR's generated on the major medical experiments. This tabulation described the problem and status on a weekly basis.

A description and status for each IDR are compiled in Appendix E, "SMEAT Medical Hardware Problem List."

Failure Reporting - Failure reports were generated on medical hardware problems where SMEAT hardware configuration was similar or identical to flight hardware. There was a total of 46 failures reported during SMEAT testing. For a description of the failures and their status, refer to the "SMEAT Medical Hardware Problem List" included in this test report (Appendix E). All FIAR's were sent to the Problem Assessment Engineer (PAE) for formal distribution to responsible personnel and for tracking via the weekly Open Problem List (OPL) which was published and reviewed by the Program Office weekly.

Problem Assessment Meeting/Support - Test Operation Management Committee - Convened daily to discuss: previous day's anomalies (IDR/DR) and activities; unresolved concerns that might impact test schedules; test support problems; changes to test configuration resulting from current anomalies; and timeline changes required to facilitate special unscheduled tests.

Special Engineering Hardware Committee - Convened when anomalies occurred that could impact further testing of specific facility and/or medical experiment supporting systems.

## POST-TEST SUPPORT

ADP's - All hardware ADP's will be reviewed and updated by the Quality Assurance Records Center. Inclusion of all anomalies and nonconformances incurred during the SMEAT Program will be ensured.

Hardware - Utilizing the SMEAT Hardware Stowage List (Revision F) as a baseline for chamber-installed equipment, Quality Assurance will establish a "Chamber Deactivation Scheme" to ensure that all hardware is removed and routed to the appropriate designee, as defined in the stowage list.

All hardware will be removed utilizing the MSC TPS system, as defined in MSCM 5312. All TPS numbers will be issued and tracked by the Quality Assurance Record Center in Building 7 in order to maintain single point control. All TPS's will be signed by Quality Assurance and the Technical Monitor.

IDR/DR/FIAR's - SR&QA will review all open anomalies, IDR's, DR's, and FIAR's with responsible hardware technical monitors for technical resolution and nonrecurrence control, as required. SR&QA will review all anomalies for flight impact and will ensure the generation of formal FIAR's, if required.

Anomaly Tracking - Quality Assurance will maintain "SMEAT Hardware Problem List" status to ensure final disposition of all SMEAT anomalies.

Formal Test Reports - Generation of the Safety, Reliability, and Quality Assurance Test Reports were required by September 29, 1972. These test reports reflected test team support activities, test conduct, and anomalies encountered. In addition, Quality Assurance will integrate these reports to form the overall SR&QA SMEAT Test Report which will then be integrated into the formal NASA/MSC SMEAT Test Report.

## CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations for future tests are summarized as gathered from the system.

a. The test facility provided the desired environment for the full 56-day period without any major problem.

b. Operational problems with facility systems were of a minor nature and were corrected during the test without test interruption.

c. Apollo suit fans used for moving the chamber environment through the lithium hydroxide canister and for odor removal were noisy inside the chamber. Pre-test activity corrected this problem by removing the lithium hydroxide blower from inside the chamber and locating it in a duct with sound deafening baffles outside the chamber. The odor removing fan was used intermittently and was found acceptable to remain inside the chamber.

d. Potential hardware problems were recognized which could have had impact on Skylab flight hardware. Recognition of these problems at this time afforded time for analysis and resolution prior to Skylab use.

e. A higher degree of confidence was gained in the ability of the medical hardware to support the Skylab objectives.

f. Skylab Flight Control personnel and Principal Experiment Investigators participated in SMEAT under simulated MSFN (Manned Space Flight Network) conditions to evaluate their support required for actual Skylab missions. Areas of improvement were noted and will be incorporated in supporting Skylab missions.

g. Safety, Reliability, and Quality Assurance were exposed as a team to the integrated performance of Skylab medical hardware and as a result, have a better understanding to develop their overall plan to support actual Skylab missions.

h. Nonmetallic materials computer control program proved highly successful and is recommended to be utilized in all future manned tests.

i. Good housekeeping controls were found to be a workable method for limiting the amount of exposed nonmetallic materials in the oxygen-enriched environment.

j. Personnel participating in 12-hour shifts without rotating duty hours proved most satisfactory. It is recommended that this duty cycle be considered for future long-term manned tests especially when personnel availability is limited.

k. For future tests the following improvements are recommended for the SMEAT chamber:

(1) Improve water removal from gas analysis system.

(2) Replace blower shaft bearings with an improved life bearing.

(3) Rearrange support systems to improve logistics of bottle changeout.

(4) Provide for additional redundancy pump in the freezer coolant pumping system or cycle the coolant pump rather than operate continuously.

(5) Improve the interface connection for telephone use by test subjects in the oxygen environment.

(6) Further improvement is recommended in an instructional program for craftsmen who accomplish the electrical wiring in the chamber to impress on them the requirement for quality workmanship to avoid hazards in the oxygen-rich environment.