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APOLLO EXPERIENCE REPORT - CREW PROVISIONS AND EQUIPMENT SUBSYSTEM

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16. Abstract

A description of the construction and use of crew provisions and equipment subsystem items for the Apollo Program is presented. The subsystem is composed principally of survival equipment, bioinstrumentation devices, medical components and accessories, water- and waste-management equipment, personal-hygiene articles, docking aids, flight garments (excluding the pressure garment assembly), and various other crew-related accessories. Particular attention is given to items and assemblies that presented design, development, or performance problems: the crew optical alinement sight system, the metering water dispenser, and the waste-management system. Changes made in design and materials to improve the fire safety of the hardware are discussed.

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SUMMARY

A description of equipment and experience gained during development of the crew provisions and equipment subsystem items for the Apollo Program is presented in this document. Details and understanding about the crew-related systems used on the Apollo 11 mission and about the individual equipment and equipment-related problems are presented. The rationale for selection of materials and design philosophy is discussed. Also, several recommendations are presented for future improvement of spacecraft hardware.

INTRODUCTION

This report is a discussion of the Apollo crew equipment items used on the command module (CM) and lunar module (LM). These crew equipment items include the restraint systems, docking aids, water-management systems, waste-management systems, crew accessories, medical components, bioinstrumentation, survival equipment, stowage, and flight garments. System changes have been made for Apollo flights subsequent to the Apollo 11 mission, but only a few are referenced in this document. An alphabetical listing of the equipment discussed in this document is presented in appendix A. Acronyms used are listed in appendix B.

Valuable contributions to this document have been made by Maxwell W. Lippitt, Jr., William L. Burton, Jr., James H. Barnett, Ralph J. Marak, Thomas F. Gallagher, William F. Reveley, and Richard S. Serpas of the NASA Manned Spacecraft Center; and Kevin J. Gravois, Elizabeth W. Gauldin, and Robert C. Hill of the General Electric Company, Houston, Texas.

EQUIPMENT SYNOPSIS

The problems associated with the development of the spacecraft (SC) crew provisions and equipment items were discovered from use and comments by crewmen. The initial design of items often is not discernible in the evolved product. Prior to the approval of a design for flight, the items were subjected to hardware design reviews, bench evaluations, mockup evaluations, zero-gravity water tests, high-fidelity fit and function tests, and finally manned-chamber evaluation under simulated altitude conditions. During the early crew-interface tests, the design remained fluid and changed, as required, with each review.

As experience from tests and mockup reviews increased, changes to the equipment decreased. Designers were better able to anticipate the requirements of the Apollo missions. Eventually, a point of minimum change and maximum efficiency was attained, this being a fine blend of design intuition and crewman participation in the development effort (ref. 1). This same general philosophy of development was applied to the LM restraint system, the docking aids, and the more personal equipment and provision items, such as the waste-management systems.

Crew equipment engineers learned to remain closely involved with the equipment from the time of initial design concept until completion of the postflight analysis. After the Apollo fire, it became mandatory to make SC cabin materials less flammable. This new emphasis completely changed the design philosophy of the crew equipment. The design process (as described) began with new ground rules and new restrictions that required the use of nonflammable materials. Yet, few major crew equipment changes were made after the Apollo 7, 8, and 9 missions. This fact is a credit to the success and efficiency of the design effort.

There have been continuous reevaluations in the categories of waste management and bioinstrumentation. These groups of personal equipment and provision items are used by the crewmen, who offer suggestions for improvement.

CREWMAN-RESTRAINT SYSTEMS

Crewman restraints for all mission modes are provided in Apollo vehicles. The primary systems are the CM couch-harness assembly and the LM "standup" restraint hardware. These systems are designed to provide stability and safety during phases of earth and lunar launch and landing. Handholds, Velcro attachments, and sleep restraints are used also for inflight tasks and general mobility. The sleep-restraint assembly provides the crewmen with a comfortable sleeping enclosure for use in zero-gravity environment. These items, general accessory items, and special equipment designed to allow unsuited entry are discussed in this section.

Headrest-Pad Assembly

The headrest pad, which is attached to the couch headrest in the Apollo CM, is used to create stability and acts as a buffer for the crewman's head during unsuited entry mission modes. The assembly must mate with and enclose the couch headrest. Thus, firm cushioning is provided for the unsuited crewman's head during entry vibration and shock. To satisfy SC flammability requirements, the headrest-pad assembly is made of a firm Fluorel outer case filled with an inner Fluorel-foam cushioning section. Fluorel is used because of its strength, wear, and flammability characteristics. The outer Fluorel case is molded to fit the contours of the couch headrest.

Heel-Restraint Assembly

The heel restraint is used to secure the crewman's feet in a fixed position in the CM during entry. The restraint is designed to be strapped over the coverall boot assembly and is used only during the portion of entry in which the pressure garment assembly (PGA) is not worn by the crewman. A simple design is necessary to allow easy attachment to the foot before entry. The heel must be constructed of a durable material that will mate in a locked position with the SC heel-locking device.

The assembly consists of two subassemblies: an aluminum heel and a strap assembly. The aluminum heel is constructed with three slot openings to permit strap passage. The straps are constructed of polybenzimidazole (PBI) webbing and pass through the aluminum heel and around the ankle. The PBI is used because it possesses desirable structural-strength and flammability characteristics. Velcro strips on the straps fasten around the crewman's ankle to hold the heel firmly in place. The metal heel is slotted to fit directly into the SC heel-locking device (as the PGA boot does). Heel-restraint assemblies have been used successfully on each Apollo flight.

Crewman Sleep Restraints

The "sleeping bag" sleep-restraint enclosure provided in the CM restrains the crewman in the sleep station during zero-gravity environment. The sleep restraints also provide warmth during sleep, and perforated cloth construction provides aeration.

The three sleep restraints (fig. 1) consist of 64-inch-long by approximately 21-inch-wide bags equipped with longitudinal-axis zippers. Each bag has a neck opening and is constructed of perforated Teflon-coated Beta cloth. "Dog leashes" are used to attach one bag under the right couch and another under the left couch. The right couch harness constrains the other bag, which is on top of the right couch. Crewmen enter the sleep restraints through the zipper openings.

Teflon-coated Beta cloth was chosen for the sleeping bags because this material has good abrasion resistance and meets the fire-retardation requirements of the potentially dangerous cabin atmosphere.

Several controlled environment tests were evaluated by crewmen and contractor personnel to determine the number and size of the perforations needed for maximum crew comfort. These tests indicated that perforations which have a 0. 060-inch

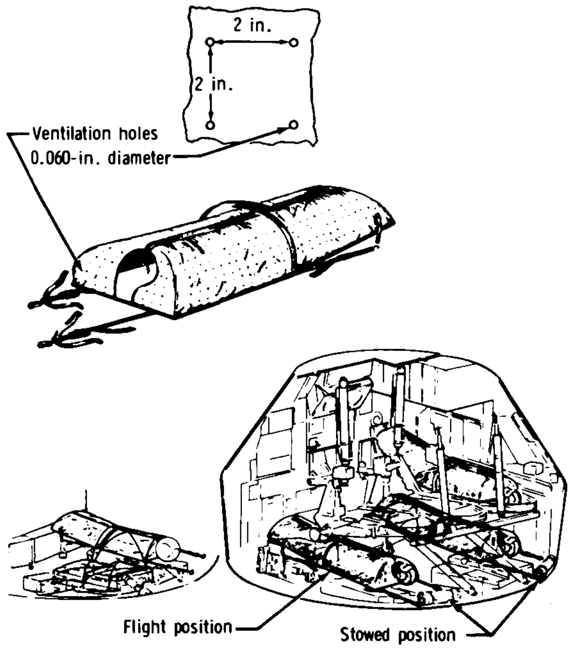


Figure 1. - Sleep-station restraints in the CM.

diameter and are on 2-inch centers provide maximum crewman comfort. Blankets, rather than sleeping bags, were considered but never used. Stiffeners were added, according to crewman recommendations, in the lower-torso area to provide leg support while in the sleep restraints.

Handholds

Handholds are provided to assist crewman ingress and egress from the CM side hatch and for periods of gravity loads. Two aluminum handholds are provided to aid crewmen in the CM. These handholds are located by the side windows, near the main display console (MDC). A handbar is provided on the MDC near the side hatch as an aid to ingress and egress. The handbar can be stowed or extended. Five handstraps, located behind the MDC, plus another handstrap over the environmental control system (ECS) access panel, are maneuverability aids. These handstraps are constructed of Viton material with metal-reinforced interiors.

Velcro

Velcro (H549 hook with P537 pile) provides a simple way to prevent floating of small objects in a zero-gravity environment and is used extensively throughout the crew compartment of the CM for temporary inflight stowage of loose crew equipment items. Patches of Velcro hooks are bonded at convenient locations on the SC structure, and Velcro pile is fastened to most of the loose crew equipment items. Items may be attached, at any location in the SC where Velcro is available, by using hand pressure.

An interface control document (ICD) was originated to establish the Velcro locations within the SC. The ICD is reviewed and updated periodically because crewman preference may dictate many changes in Velcro location.

Lunar Module Crewman-Restraint System

The LM crewman-restraint system restrains the crewmen during powered flight, zero gravity, and the shock of lunar landing. The system must function without seriously reducing the mobility, visibility, or dexterity of the crewmen. The system must also maintain proper pilot orientation, with respect to instruments and controls, during powered flight and zero-gravity environment. During landing, the system must prevent the crewmen from striking adjacent structures and must facilitate absorption of the impact shock.

The development of the restraint system involved three phases: zero-gravity tests using aircraft, ground-based tests using acceleration rigs, and manned drop tests of the lunar test article (LTA-3) vehicle.

The initial landing-acceleration limits at the LM crew station were formulated during October 1965. The landing conditions considered were within 10 ft/sec vertical at a 0-ft/sec horizontal velocity and within 7 ft/sec vertical at a 4-ft/sec horizontal velocity. Landing conditions were limited by the kinematic capability of the landing gear. The landing gear was considered to be elastic and the LM, rigid.

Zero-gravity test planning was conducted (1) to determine the effectiveness of proposed foot restraints and of devices to stabilize the crewmen at the crew station and (2) to determine the best locations and configurations for handholds and handgrips. A KC-135 jet aircraft was used in the zero-gravity tests. The landing-shock test program involved the use of manned shock rigs to simulate the acceleration envelope.

The restraint system that evolved (fig. 2) includes (1) Velcro on the boot soles and the LM floor, (2) restraint cables (from a constant-force reel) attached to the crewman to produce a constant 15-pound downward force on each side of the crewman, and (3) a set of armrests to absorb loads from the crewman's upper torso. The restraint armrests are equipped with hydraulic dampers for energy absorption. Downward forces from the middle and lower torso are intentionally absorbed by the crewman's legs. The panel handholds and the armrests are designed to supply lateral support. The constant-force reel is equipped with a cable lock to restrain the upward motion of the crewman during the lunar landing.

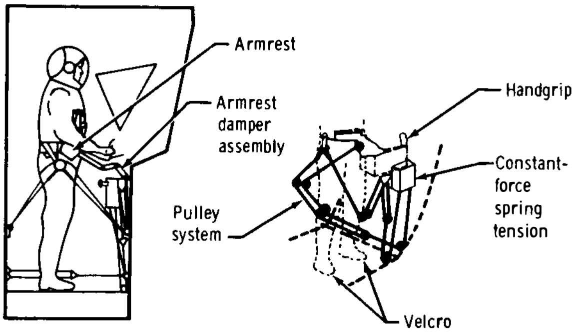


Figure 2. - Crewman-restraint system in the LM.

Difficulties were encountered with the armrest hydraulic damper during component design. The magnesium damper assembly that was developed in a weight-reduction program did not operate properly; the magnesium did not provide adequate piston-chamber surface hardness to protect the sliding seal on the piston. Various corrective approaches, including coating techniques, were tried. Schedule difficulties and lack of success resulted in changing the design to aluminum, and no further difficulties were encountered.

The constant-force reel involved unique design requirements: the unit had to be mobile, lightweight, and lockable. Three negator springs are used to roll and unroll a central (takeup) drum that drives one of two restraint cables operated by the reel.

Changes in material types occurred during hardware development. Flammable plastic parts were replaced with flame-resistant Teflon or metal parts. The synthetic-fiber rope assembly was replaced with a Teflon-coated, braided steel cable. The Velcro was replaced with a better, flame-resistant variety.

The adequacy of the LM restraint design is demonstrated by the flight program. Crewmen indicated that it would be desirable to make the restraint-reel force variable, thereby allowing adjustment for the various mission phases; however, this change is not critical.

OPTICAL DOCKING AIDS

Equipment was developed to enable the crewmen to meet the Apollo Program requirement that the LM and the CM rendezvous and dock in earth and lunar orbits.

Tracking and running lights are on both vehicles; however, the prime docking aid is the crew optical alinement sight (COAS) system (fig. 3) and the respective COAS system targets for the LM (fig. 4) and CM. The COAS system is versatile enough to supply range, range-rate, and attitude information as navigation aids and as a supplement to docking information. The process of rendezvous and docking is a relatively simple series of maneuvers with the use of this system.

Early in the Apollo Program planning stage, the need for a device in the CM to provide range and range-rate data needed by the crewmen for the terminal part of the rendezvous and docking phases of the mission was evident. An aircraft gunsight design concept was modified to meet this requirement. The result, the COAS system, was installed in the CM as a docking aid. Basically, the COAS system is a collimator device consisting of an intensity control, a reticle, a barrel-shaped housing, a combiner assembly, a power receptacle, a clip-on filter, and a mount.

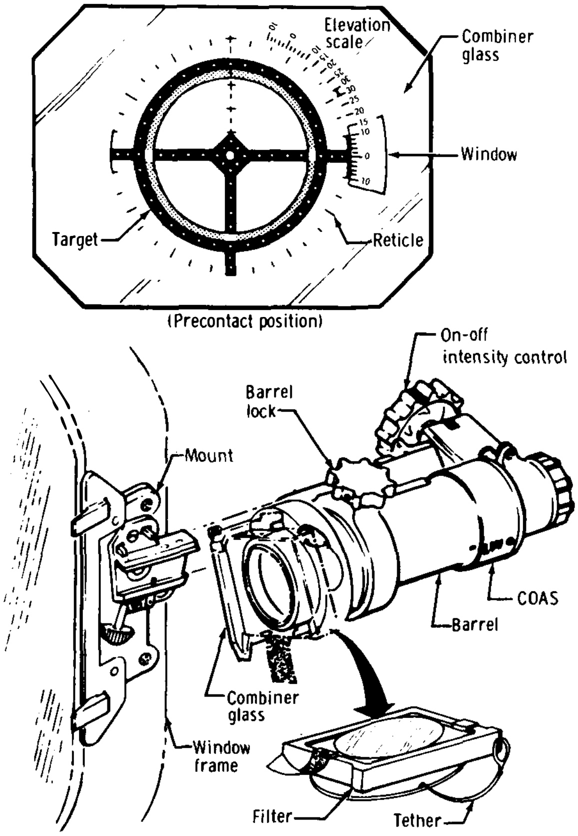


Figure 3. - The COAS docking aid.

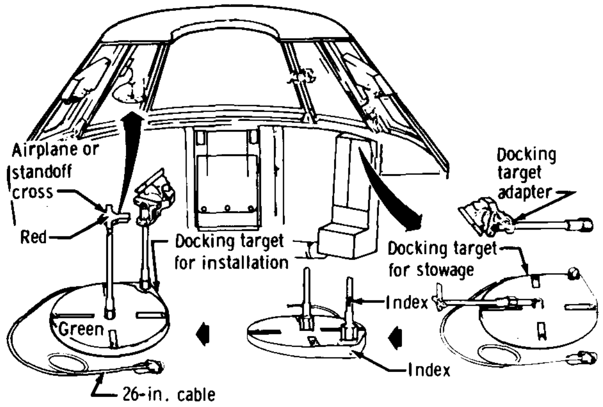


Figure 4. - The LM active docking target.

An active LM mode was required during rendezvous; however, a COAS system was not required for the LM because, in this mode, use of the LM docking port as the forward hatch was sufficient. Thus, the crewmen can directly observe and control the docking operation. No auxiliary devices are needed. In the process of LM development, the docking port was changed to become the overhead hatch, not directly visible to the LM pilot. A device similar to the CM COAS system was obviously needed in the LM; thus, the CM COAS system was modified to be compatible with LM design requirements. The device modified for the LM provides range, range-rate, and attitude information to the LM pilot during docking. A second function of the LM COAS system is to provide the crewmen with a fixed line-of-sight attitude-reference image which, when viewed through the combiner lens, appears to be superimposed on a lighted target located in the CM right rendezvous window. This image is boresighted parallel to the X-axes of the LM and the CM (fig. 5). A similar but larger target is located on the exterior of the LM, adjacent to the overhead hatch, for use with the CM COAS system during the CM active docking maneuver.

During development of the COAS system, an initial problem was that of obtaining a 28-volt bulb which would survive the required temperature-environment testing. The use of a heat-sink bulb satisfies the requirements.

After production of the COAS system, use in the field revealed a combiner glass-frangibility problem, which was solved by using a toughened Chemcor glass in the combiner. Also, the electrical-connector material (diallylphthalate) used in both the sight and the mount assemblies cracked and otherwise failed mechanically after continued use. This material was replaced with Lexan plastic, and no further failures occurred.

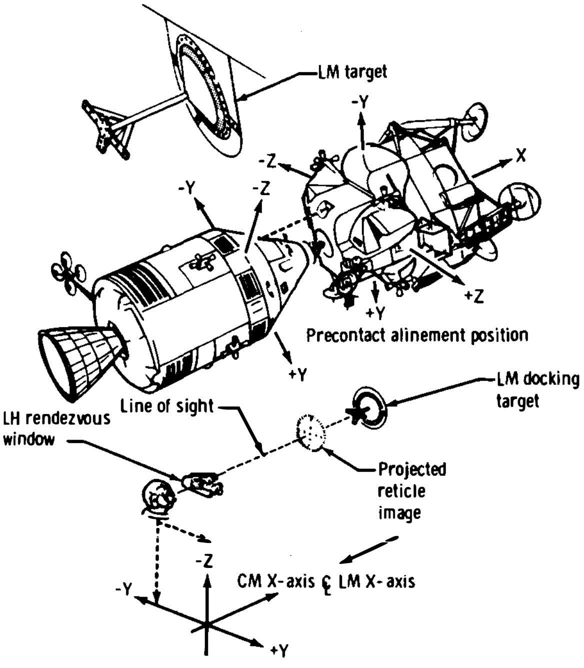


Figure 5. - Predocking condition of the COAS and target.

During the LM-3 crew-compartment fit and function (CCFF) test, an erratic intensity control of the flight COAS system was discovered. Failure analysis indicated that a circuit transistor caused the difficulty. The failure was not restricted to a single unit. The faulty transistor was not compatible with the design of the intensity control; therefore, all COAS system units that were equipped with this transistor in the intensity control were returned to the manufacturer for rework. The defective transistors were replaced with a more satisfactory type, and erratic intensity controls ceased to be a problem.

To establish the appropriate range of reticle brightness, the crewmen visited the manufacturer to view a fifth-magnitude star under laboratory conditions. An internal neutral-density filter was added to the COAS system to reduce the brightness of the reticle. However, severe difficulty was encountered during the Apollo 9 docking phase; high ambient lighting conditions caused a washout of the reticle image on the combiner glass. This problem subsequently resulted in removal of the internal neutral-density filter from the COAS system, allowing the original high-reticle-brightness capability of the COAS system to be used. The ability to sight on a fifth-magnitude star was retained through addition of an external clip-on filter. The Apollo 9 docking difficulty also resulted in the decision that the CM would be the active docking vehicle. Subsequent Apollo missions were flown without docking difficulties. Use of the COAS system in both the LM and the CM has been nominal, and no further design changes are considered necessary or desirable.

WATER-MANAGEMENT SYSTEMS

The metering water dispenser (MWD) and the water dispenser/fire extinguisher (WD/FE) are both pistol-shaped devices that dispense potable water for drinking, food reconstitution, and fire extinguishing.

The initial dispenser was a modified Gemini water metering device (fig. 6). Modification made the device compatible with the Apollo SC requirements. The device metered 15 milliliters (± 10 percent) of water for each trigger cycle and recorded the number of trigger cycles on an integral mechanical counter. The MWD (initial configuration) was cycled 20 000 times more than necessary to meet Apollo qualification requirements. Because an anomaly occurred during the Apollo 7 mission (SC-101), a series of tests was performed to determine the compatibility of the MWD O-rings with the excessive chlorine content of the CM potable water. These tests, in which chlorine concentrations of 2 to 5000 ppm and durations up to 16 days were involved, revealed that a change was required in the material of the forward plunger or metering O-ring of the MWD. This O-ring was changed from neoprene to ethylene propylene, resulting in the 05 configuration MWD, which was used successfully on the Apollo 8 and 9 missions (SC-103 and SC-104).

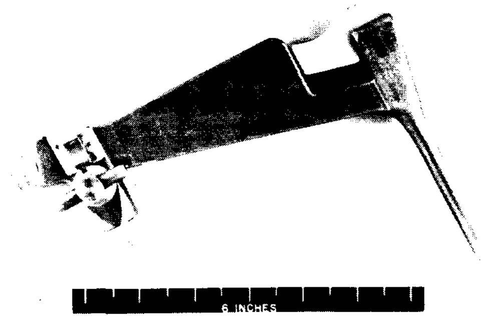


Figure 6. - Gemini water metering device.

The Apollo MWD was intended for use in both the CM and the LM. However, before the first manned Apollo flight, a requirement was included that the water dispenser used in the LM should have the additional capability of dispensing a continuous cone-shaped spray of water for firefighting purposes. To meet this requirement, an early Gemini continuous-flow water dispenser was redesigned. The modified WD/FE unit was selected for LM use on the Apollo 9 (LM-3) and subsequent missions, and for CM use on the Apollo 10 (SC-106) and subsequent missions. Operation of the water/gas separation equipment was simplified significantly by using the modified WD/FE in the CM (fig. 7). The WD/FE also provided the crewmen with drinking water that was relatively free of excess hydrogen.

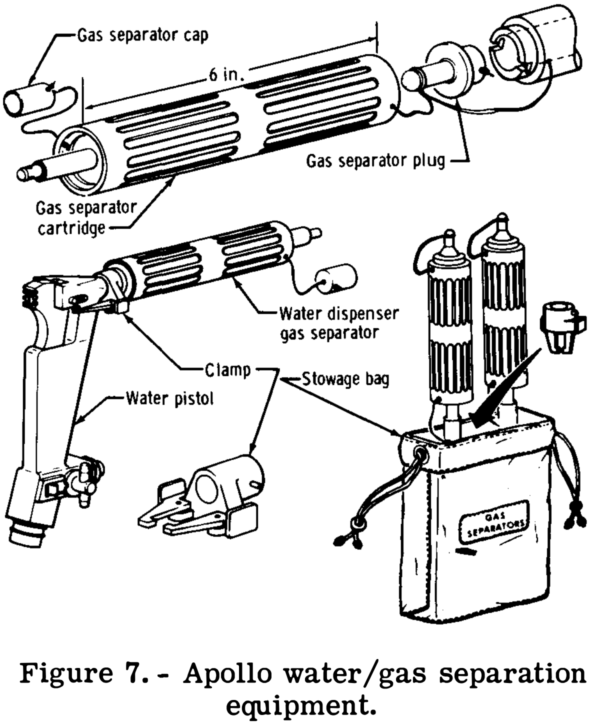


Figure 7. - Apollo water/gas separation equipment.

A bacterial filter has been designed that can be mated to the WD/FE by means of the existing WD/FE water-inlet quick-disconnect fitting. This filter ensures that the drinking and food-reconstitution water dispensed by the unit is free of bacteria. A water-gas separator can be attached to the WD/FE outlet (in the CM) to ensure that the drinking and food-reconstitution water dispensed by the unit is free of entrained gas.

WASTE-MANAGEMENT SYSTEMS

To remove and dispose of crewman waste matter, various waste-management systems were developed for the Apollo Program. Separate systems, for use in both the CM and the LM, were designed for management of feces and urine. The CM waste-management system is shown in figure 8. The LM waste-management system is similar to that of the CM.

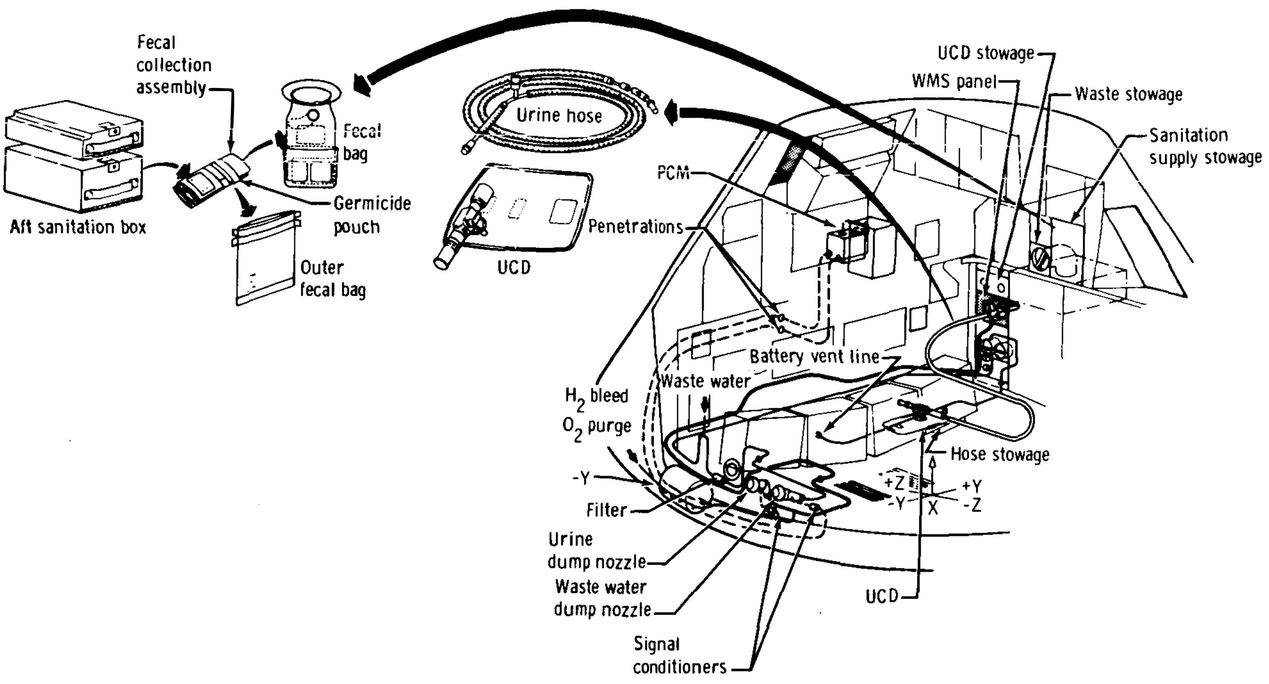


Figure 8. - The CM waste-management system.

Fecal-Collection Systems

The Apollo fecal-collection system consists of the fecal-collection assembly (FCA) on the CM and the defecation-collection device (DCD) on the LM. The design and operation of the DCD are similar to the design and operation of the FCA. The FCA provides a method of collecting, inactivating, and stowing feces for 14-day missions with a minimum of crewman effort. The FCA consists of an inner fecal/emesis bag, a germicide pouch, an outer fecal bag, and a wrapper. A waste compartment with an overboard vent system for odor removal is provided in the SC cabin for stowage of the used fecal bags. The outer fecal bag and the inner fecal/emesis bag are constructed of a heat-sealed laminate film. The germicide is added to the feces to prevent or reduce gas and bacteria.

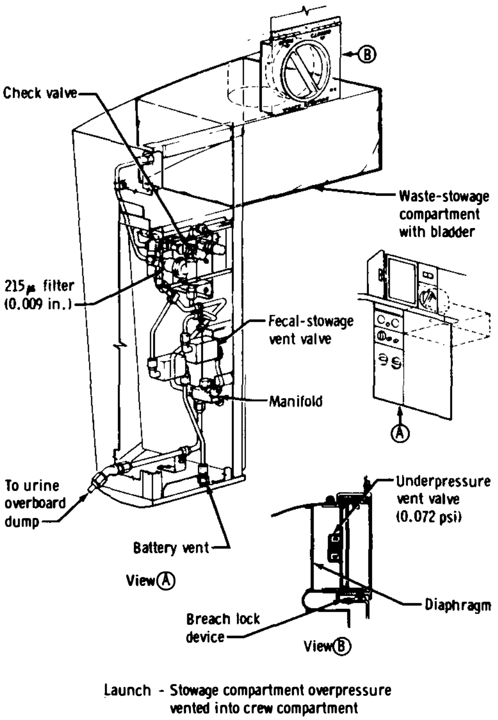
To use the FCA, the crewman attaches the outer fecal bag properly and proceeds with fecal elimination. Upon completion of the action and subsequent sanitary cleansing, the tissues and refuse are placed in the inner fecal/emesis bag. The crewman then removes the germicide pouch, cuts the outer protective seal, and places it in the inner bag. Finally, all items are placed into the outer fecal bag, the bag is sealed, the germicide pouch is ruptured by hand pressure, the bag is kneaded, and the contents are stowed in the waste-stowage compartment.

Although the Apollo fecal-collection system is the same as that used in the Gemini Program, many new concepts and designs were investigated and tested. Various types of canisters, with and without air blowers, were developed with some success. In all cases, the primary problem has been the separation, in a weightless environment, of the fecal wastes from the crewmen. Nothing has proved more effective than the current system, which has proved adequate for all flights, although the crewmen have expressed dislike for it. Other methods are being investigated, and experiments will be conducted on future missions. A better method of collecting fecal wastes must be found for future flights, particularly those of longer duration. Many promising designs are being investigated and may be incorporated into future space vehicles.

Waste-Stowage Vent System

The waste-stowage vent system is shown in figure 9. If any fecal bags were to rupture during the mission, the waste-stowage compartment could emit fecal odors. Therefore, a bladder and an overboard vent system have been placed in the compartment. The system contains a 215-micron filter, a check-relief valve, and a vent valve to the urine overboard-dump line.

During boost, the waste-stowage vent valve is opened to purge nitrogen wastes from the crew compartment. A check valve vents into the crew compartment at a differential pressure of 2 psi. After the vent valve has been closed during a mission, the check valve vents if ruptured fecal bags create a pressure of 2 psi. Then, the crewmen, alerted by the fecal odor, can position the waste-stowage valve to vent the odor overboard at periodic intervals.



Launch - Stowage compartment overpressure vented into crew compartment
Mission - Stowage compartment odors vented overboard
Entry - Crew compartment overpressure vented Into stowage compartment

Figure 9. - Waste-stowage vent system.

Urine Systems

The Apollo urine systems consist of the urine-collection/transfer assembly (UCTA), the LM waste-management system, and the urine-transfer system (UTS).

Urine-collection/transfer assembly. - The UCTA is a flexible container with a 950-cubic-centimeter capacity that is worn by the crewman while he is in his PGA. The UCTA, which is held in place by means of an adjustable elastic harness, consists of a detachable roll-on cuff, a flexible rubber-coated fabric bag, and a quick-disconnect fitting for attachment to the PGA transfer-hose assembly.

The crewman can void the UCTA bag during urination or later. The voiding procedure is to drain the urine into stowage bags (LM) or overboard (CM) through the SC urine hose. The drain operation can be accomplished while the crewman is in either a pressurized or an unpressurized suit.

The UCTA is a design outgrowth of the Gemini in-suit urine-collection device. However, the Gemini device was intended as a one-time-use item for collection and storage of urine during the launch phase, whereas the Apollo requirement was for an in-suit urine-collection and temporary-storage device that could be donned and doffed in flight. The UCTA is designed for use during extravehicular activity (EVA) on the lunar surface. In addition, it is necessary that the UCTA have drainage capability while worn inside the PGA, after launch, or for contingency-mode suit requirements. These requirements were met by redesigning and modifying the Gemini device with the following:

1. A quick-disconnect roll-on cuff and flange at the UCTA/crewman interface

2. A drain hose and quick-disconnect fitting for attachment to the PGA drain fitting

3. An adjustable elastic harness to maintain the device in proper position on the crewman

4. A relief valve to prevent discomfort and physical damage to the crewman as the result of exposure to excessive pressure differentials during urine-transfer operations

In addition, the UCTA is shaped to fit into the space allocated within the PGA, without hampering crewman mobility. The UCTA is qualified as a component of the Apollo extravehicular mobility unit.

Although the performance of the UCTA has been satisfactory, minor problems developed with the cuffs, but these deficiencies were corrected. Each crewman is provided with a variety of cuff sizes, and he may apply a coating of powder to the cuffs to prevent sticking. The UCTA has satisfied the Apollo Program requirement to collect the urine voided by a crewman within a pressure suit.

Lunar module waste-management system. - To prevent contamination on the lunar surface, the LM waste-management system uses a pressure-operated urine-collection system. In accordance with the use of this system, a prime urine-transfer design constraint for the LM was that the crewmen would be protected at all times from pressure differentials. The system uses a direct dump, from the UCTA inside the suit, through the suit wall by way of a quick-disconnect fitting, and then to a pressure-sensitive shutoff valve mounted on the +Z27 bulkhead behind the commander. The urine then passes through another short section of line to a 7-liter collapsible bag. The driving force for transfer of fluid is the inside-outside pressure differential of the PGA. Normally, the pressure differential would be present in a cabin-evacuated condition. However, it can be obtained by pressurizing the PGA from the LM ECS in a cabin-pressurized condition.

Difficulties with valve chatter in the pressure-sensitive part of the shutoff valve were encountered from the outset. This part of the valve was designed to prevent the crewmen from experiencing a vacuum or a reduced pressure on the inside of the UCTA. Although the valve action was much improved, hysteresis was never fully eliminated with the use of the pressure-sensitive part of the shutoff valve. An oxygen-bleed valve was added to the UCTA to provide a pressure-protection function, and the pressure-sensitive part was removed. The shutoff valve now functions properly.

The one-bag urine-collection system was replaced on the Apollo 12 mission (LM-6) by six small 900-cubic-centimeter urine bags designed to connect directly to a PGA by means of a quick-disconnect fitting. Although the transfer valve, the large 7-liter bag, and the drain lines were provided on the Apollo 11 mission (LM-5), the crewmen chose to use small urine-collection assemblies. The change to the use of six small bags was made to achieve lower weight and higher reliability.

Although the small bags have been adequate for the initial LM missions, this design will not be adequate for 2- to 3-day lunar missions. Accordingly, the urine-collection system to be used on the Apollo 15 mission (LM-10) and on subsequent missions will incorporate a large vented tank in the descent stage, into which both urine and portable life support system (PLSS) condensate will be transferred. The use of a tank rather than many small bags provides a weight saving for extended missions. The LM urine-collection system has performed satisfactorily, with all bag sizes and quantities.

Urine-transfer system. - Stowed in the CM, the UTS receives, temporarily stores, and transfers to the CM waste-management system all urine voided by an unsuited crewman. The UTS consists of a roll-on-cuff receiver, a valve, a flexible rubber-coated fabric bag, and a quick-disconnect outlet for attachment to the CM waste-management system by way of the urine-transfer hose. Urine from a crewman can be transferred to the CM waste-management system directly during urination or after temporary storage in the UTS. Three of these systems (one per crewman) and one spare UTS receiver assembly are stowed on each CM; this procedure was used on the Apollo 7 spacecraft (SC-101) and is being followed on all Apollo missions.

The UTS was designed to satisfy the Apollo CM requirement for collection and disposal of urine voided by an unsuited crewman. Basically, this system is a redesign of the Gemini roll-on-cuff-receiver urine-transfer assembly. Two differences between the Gemini and Apollo systems are the addition of an improved and simplified line valve and the addition of a receiver pressure-relief valve. Operation of the Apollo system is identical to operation of the Gemini system, except that the Apollo system provides a capability for the CM crewmen to transfer urine directly to the CM waste-management system during urination.

The performance of the UTS has been satisfactory during all Apollo missions. Minor problems have developed with the UTS cuffs, but these deficiencies have been corrected. Each crewman is provided with a variety of cuff sizes, and he may apply a coating of powder to the cuffs to prevent sticking. The UTS was qualified by a delta-qualification test program. (The system was subjected to a 504-cycle life test and to the expected Apollo mission vibration and shock levels.) This unit was adopted for Apollo Program use as a "stopgap" method when the original system design was found to be unacceptable. The most desirable method for urine collection would be to use a military-aircraft-type pilot-relief tube. Such a system has been designed and is being tested for compatibility with the crewmen and the CM.

Lunar Module Portable Life Support System Condensate-Collection Systems

The LM PLSS condensate-collection systems consist of the feedwater-collection bag and the condensate-transfer assembly.

Portable life support system feedwater-collection bag. - The PLSS feedwater-collection bag is used by the crewmen in the LM to determine the amount of feedwater remaining in the PLSS after EVA. This procedure permits measurement of the crewman's metabolic rate during EVA.

The PLSS feedwater-collection device is constructed of an inner and an outer bag. The inner bag is made of rubberized cloth, and the outer bag, which is used as a restraining cover, is made of Nomex. A vehicle recharge connector, which is attached to the open end of the bags, mates directly with the PLSS to receive the PLSS feedwater. A water-fill connector is attached by a pushbutton indicator lanyard to the vehicle recharge connector to vent the bag when it is not in use.

To determine the amount of water consumption, the PLSS feedwater-collection bag is weighed after termination of lunar-surface operation. The scale used to accomplish the weighing is a standard spring-loaded scale that can be adjusted to obtain tare weights of objects on the lunar surface. When not in use, this scale is stored in a sized pocket on the restraint layer of the bag. The bag and scale were used successfully on the Apollo 11 mission.

Portable life support system condensate-transfer assembly. - During the PLSS-recharge operation in the LM on the lunar surface, vehicle storage provisions for handling condensate drained from the backpack were required. The condensate-transfer assembly was designed to fulfill this requirement. A simple design employed a line, a flexible container with a relief valve, and an enclosing and supporting box. The relief valve was calibrated to open between 2.2 and 2.8 psid and to reseat with less than 1.5 psid. Thus, gas is vented selectively and the system volume is minimized. The system was used first on the Apollo 12 mission (LM-6) and will be replaced by a more integrated waste-management system on the Apollo 15 mission (LM-10) and subsequent missions. No changes to the current system are deemed necessary.

CREW ACCESSORIES

The Apollo Program has generated many items unique to crewman habitability and emergency requirements. These accessories were provided for aid in the performance of designated tasks, for personal hygiene, and for special mission requirements or necessary crewman/SC interfaces. The following items are discussed in this section:

1. The crewman toolset
2. The LM window shades and glare shields
3. The mirrors
4. The CM oxygen umbilicals
5. The communications umbilical
6. The decontamination items
7. The tissue dispensers
8. The utility-towel assembly
9. The penlights
10. The scissors
11. The eye patch
12. The LM ceilings and covers
13. The lunar-equipment conveyor

Crewman Toolset

Multipurpose handtools or attachments for use during mission activities are required for each Apollo crewman. These tools and attachments are designed for use with a PGA glove to make inflight repairs or adjustments. An additional tool is needed for contingency EVA ingress through the CM side hatch. The crewman toolset was designed to meet these requirements. The toolset consists of seven tools, three jackscrews, a tether, and a pouch. Each tool has a tether ring and is designated with a letter of the alphabet. After the Apollo 8 mission, the crewmen requested additional tools for disassembling the SC probe and drogue for contingency operations. Accordingly, five additional items were added to the toolset. Components of the toolset are shown in figure 10. Tolerance-control difficulties were experienced in the early stages of tool production. Particular difficulty was experienced with the B tool, an emergency wrench that is used for side-hatch ingress. Because the tolerances of the tool receptacle and the side-hatch receptacle are quite close, stringent dimensional inspections were required for proper mating.

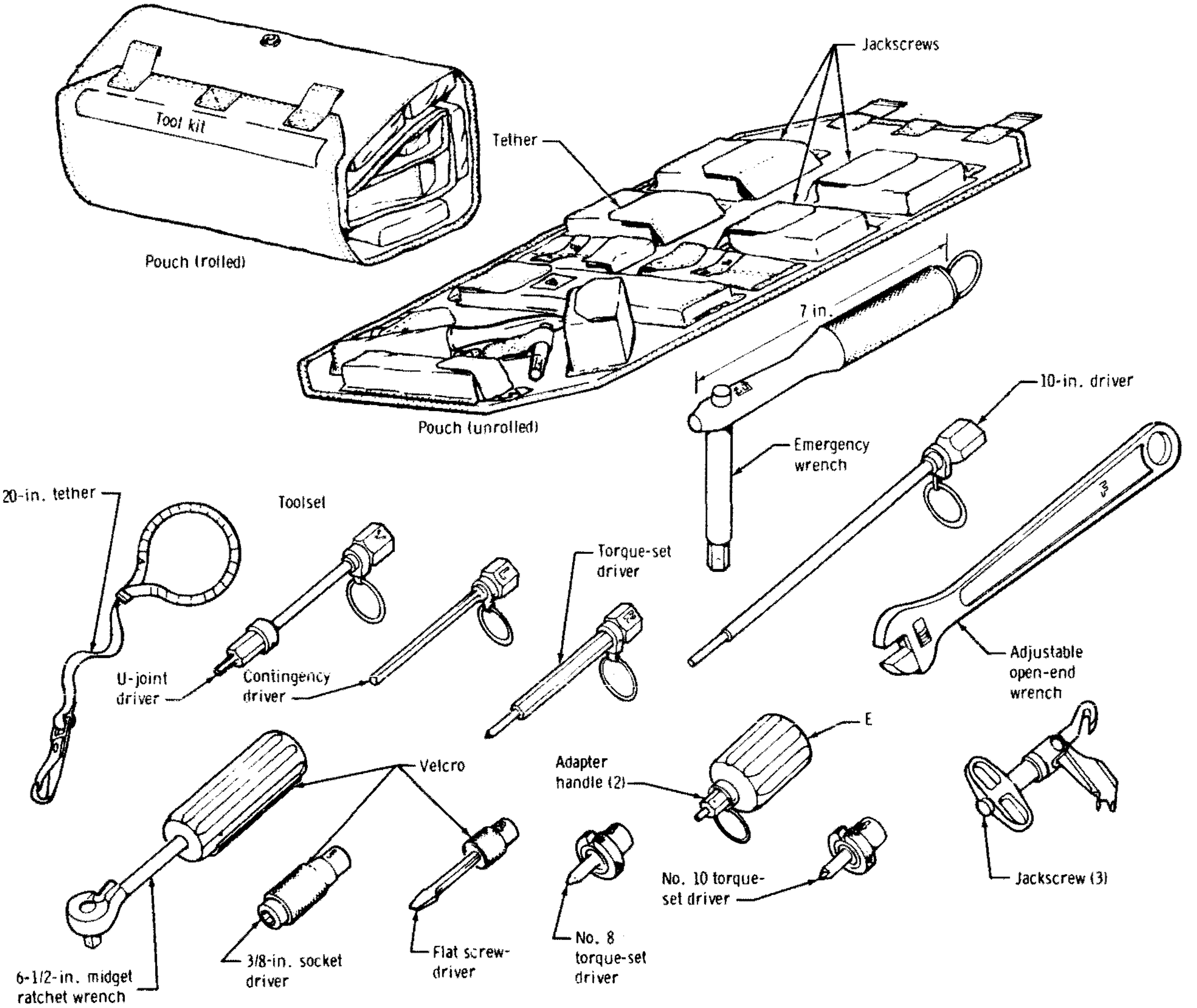


Figure 10. - Crewman toolset components.

Lunar Module Window Shades and Glare Shields

The forward and overhead LM window shades are unique. Special surface materials are required for specific thermal-emissivity characteristics. Requirements for materials are met by the use of a heat-tempered Aclar film that could be formed into a roll. The finished shade can be unrolled, released, and rolled up again. Velcro is used to retain the shade in the unrolled position. A vacuum deposition of Inconel on the outside surface provided the necessary thermal characteristics. Difficulties with light leakage were encountered early in the development cycles. Inconel is susceptible to scratching, and a light streak is produced at each scratch. To minimize scratching, the decision was made to change the shade material.

During the Apollo 9 mission (LM-3), the LM crewmen reported that the integral window heaters caused shade temperatures higher than the forming temperature; thus, the curl in the shades was lost. The situation was corrected by changing the flight procedures for use of window heaters.

During the Apollo 11 mission (LM-5), the crewmen reported that the amount of light which leaked through the shades into the cabin interfered with sleeping. This condition will be corrected for the Apollo 12 mission (LM-6). A layer of carboxy-nitroso rubber (CNR) cloth will be sewn inside the shades, and light leakage will be reduced to an acceptable level.

Two lateral slats, or glare shields, were designed to protect the forward instrument panels from external light impingement. The slats were constructed from layers of Beta material coated with CNR. The slat design has been used successfully, without modification, on all Apollo missions.

Mirrors

Various mirrors are provided throughout the CM to assist crewmen in observing certain crewman activities and events. Originally, the mirrors were designed to aid the crewman in adjusting his couch restraint, in observing the MDC when the crewman is in the lower equipment bay, and in verifying parachute deployment during the entry phase of the mission. The CM was originally provided with five mirrors that were designated as external and internal viewing mirrors. However, after several flights, only three mirrors were deemed necessary. Each mirror assembly consists of a mounting base, a two-segmented arm, and a mirror. The mirror is 4.25 by 3.5 inches and is constructed of flat steel with an aluminized surface.

The mirror-qualification program disclosed some problems. Sometimes, the mirror did not possess the desired reflectivity (at least 75-percent reflectivity), and at other times, the mirror would not pass the corrosive-contaminants, oxygen-and-humidity tests. However, after several modifications, the aluminized-surface steel mirror proved highly effective and has been flown on all Apollo missions.

A single metal mirror assembly was used in the LM. This mirror assembly differed from the CM design in that the mirror was nickel-plated aluminum with the reflecting surface formed by aluminum vacuum deposit. During the polishing operation, difficulties arose because the blank material warped. The lightweight design of the mirror caused the warping, which was eliminated by changing the polishing technique.

Command Module Oxygen Umbilicals

Three oxygen umbilical assemblies are used in the CM to conduct pressurized oxygen to PGA-suited crewmen (fig. 11). The ECS provides the oxygen, and exhaled or odor-causing products are returned to the ECS. The umbilicals may be used to direct oxygen to localized cabin areas when the PGA suits are doffed.

The umbilicals (two separate hoses) have (1) individual interfaces at the PGA inlet, (2) outlet connectors, and (3) a common DD-type connector at the wall panel. The hoses are constructed of silicone rubber with convoluted wire reinforcement coils. Each hose has a smooth bore of 1.25 inches (inside diameter). The left, center, and right assemblies measure 72, 72, and 119 inches in length, respectively. Two layers of Teflon-coated Beta cloth provide fire-retardation protection for each hose assembly. Straps are used at 12-inch intervals to fasten the two hoses of each assembly together.

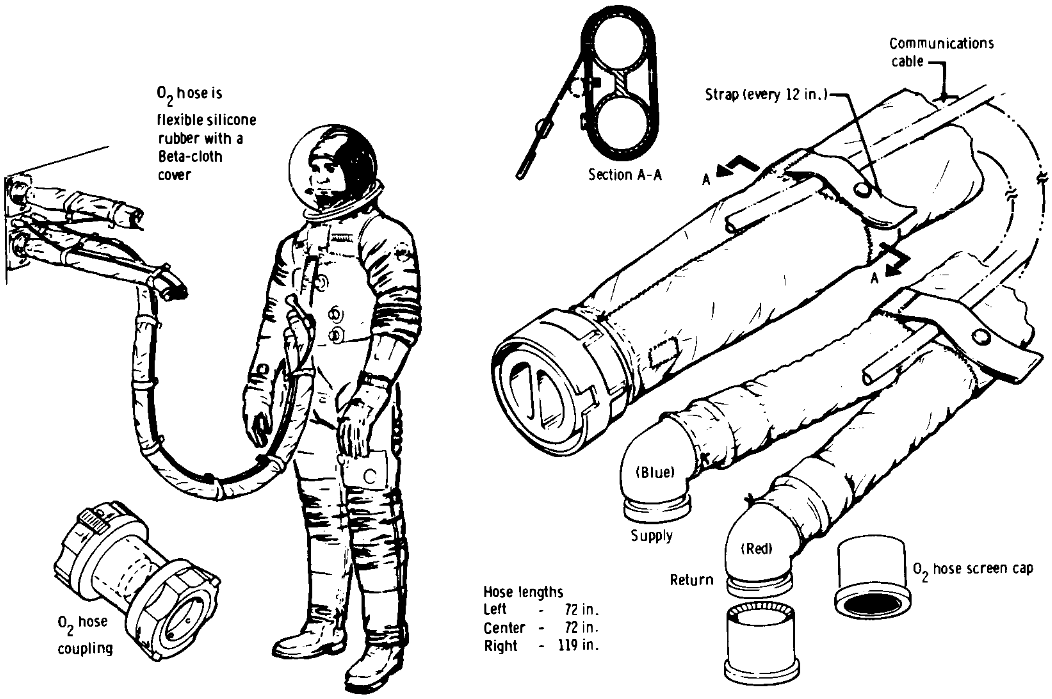


Figure 11. - Oxygen-hose assembly and accessories.

The umbilicals — which are flexible, strong, nonrestrictive, nonflammable hoses — provide sufficient oxygen at a proper temperature and within a proper pressure range. Silicone material is very flexible at low- and medium-range temperatures; however, the material is highly flammable in the presence of pure oxygen. Two other materials, Viton and Fluorel, have been developed to reduce the fire hazard, but both restrict the hose flexibility; further development to increase the flexibility of materials at low temperatures is in progress. Fluorel was used in hose assemblies on SC-103 (Apollo 8) and LM-3 (Apollo 9).

Current experimentation involves use of a different convolute construction that includes a Teflon-impregnated outer cover of Beta cloth. Present investigations may lead to a more flexible, stronger hose that has better fire-retardation qualities.

The hose assembly (including hardware) will withstand a 200-pound compression load and a 250-pound tension force. These loads required Nomex reinforcement sleeves in the hoses and tie wires at the cuff-to-hardware flange interface; also, a DD-type connector flange has been reinforced. The hose assembly is illustrated in figure 11.

The oxygen-hose interconnect and the screen cap constitute the hardware interfaces. The interconnect (a double assembly) has two purposes: to prevent fresh oxygen from returning to the ECS by way of the umbilical while the suit-circuit return valve is open, and to seal both nozzles during cabin depressurization, when the hose assembly is not in use. The oxygen-hose screen caps (fig. 11) provide a filter for the return-hose nozzle. This assembly can be used as a vacuum for collection of any small cabin debris. The interconnect is made of aluminum, and the caps are made of Fluorel with a Monel screen of 30 mesh.

Crewman Communications Umbilical

The crewman communications umbilical (CCU) consists of a cable and a control-head assembly, which transmits voice communications, bioinstrumentation signals, and the warning-system alarm signals to and from the suited or unsuited crewmen. When the crewman is in the PGA, the CCU assembly interfaces with the PGA suit connectors. When the crewman is out of the PGA, the CCU assembly interfaces with the constant-wear garment (CWG) electrical adapter. The umbilical assembly lengths are 74, 74, and 121 inches for left, center, and right positions, respectively. A 121-inch spare assembly is provided in the CM. The electrical umbilical assembly is shown in figure 12.

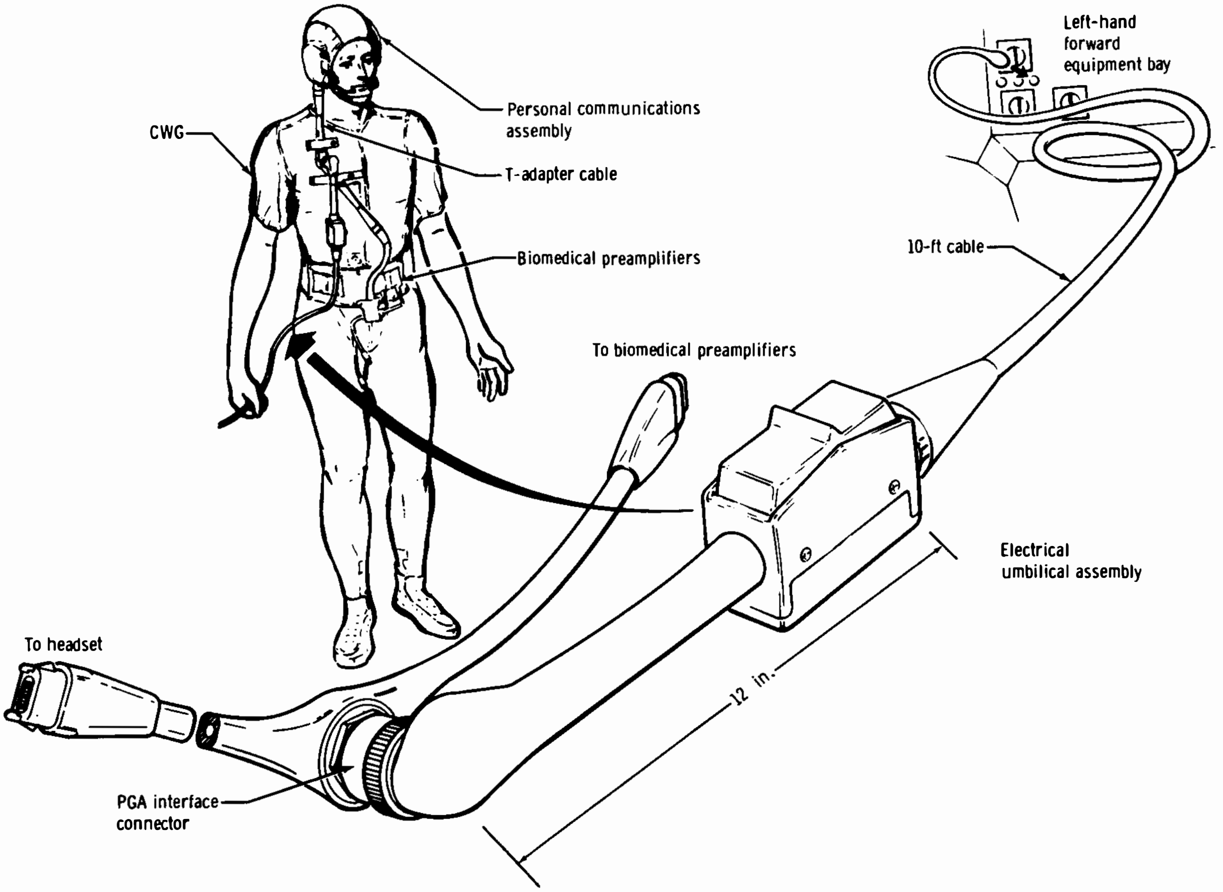


Figure 12. - Electrical umbilical assembly.

Originally, both the CCU cable and the control head were fabricated from silicone material with Teflon-coated Beta-cloth sleeves for fire retardation. Fluorel replaced the silicone-extruded outer cover of the CCU. The design was changed to provide a more flexible, flame-resistant cable. Because the head is of molded construction, fabrication of the control head is restricted to silicone.

Control heads are constructed of 21 wires (22 gage), encapsulated in molded silicone for flexibility and wear. Microdot (61-pin) and Airlock housing connectors interface with the PGA and the CCU. The control head has an electrical rocker-type switch that may be used to select either internal or external vehicle transmission. The switch housing is made of aluminum. The control head has a Teflon-coated Beta-cloth sleeve.

The requirement for the use of twisted wires in construction of the CCU control head and cable is very important for the following reason. When straight wires are used, fractures result from repeated flexing. A minimum of two twists per inch of wire is required. The CCU cable is constructed of twisted wire, but the outer cover is made of an extruded Fluorel material. The connectors are potted in silicone and have a Fluorel outer covering.

In addition to wire breakage, bent pins and separation of materials at the metal connectors have been CCU design problems. The connector installation at the CM panel is unique. An Airlock connector housing (a lock-lock device) is combined with a Microdot female connector insert to form the connector. Basic requirements stipulated that no electrical power be on exposed pins, and because no female-type connector with proper bulkhead attachment was available to meet Apollo Program requirements, this unique connector was developed. However, extreme care was necessary to avoid pin damage. The Microdot connector with the compatible Airlock housing is designed to preclude pins touching the block in the mating half prior to keying. However, not all connectors are in tolerance, nor is the pin height always correct. Separation of material at the metal connectors was caused by improper bonding techniques and by tension stresses fabricated into the material. These difficulties were avoided either by adjusting the tolerance specifications or by reworking defective connectors.

Decontamination Items

Decontamination items were provided for the Apollo 11 mission to prevent the contamination of SC hardware by lunar dust. These items will be provided for all subsequent Apollo missions.

Vacuum-brush assembly. - The vacuum-brush assembly (fig. 13) is a molded housing with attached bristles. When connected with the vacuum cleaning hose, the vacuum brush removes lunar-surface contaminants from lunar equipment. Therefore, the bristles must be strong and flexible and must remain firmly attached to the housing during use. A filter is provided to prevent entry of large particles into the LM ECS, which provides the vacuum.

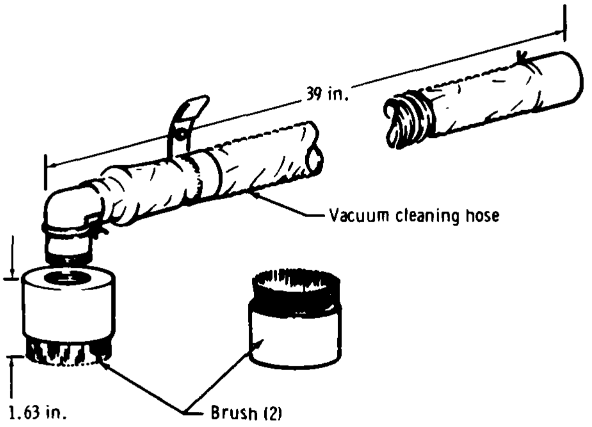


Figure 13. - Vacuum-brush assembly.

Bristle type and arrangement are prime factors in the vacuum-brush design. Teflon bristles were arranged in a concentric ring around a Fluorel elastomer housing in a manner to satisfy flammability requirements. A 20-mesh filter screen is positioned into the molded housing and held in place by epoxy cement. A metal ring containing the Teflon fibers is attached to a Teflon ring, and the integrated ring section is inserted into the brush housing. Care was taken to avoid sharp edges or burrs that might damage delicate equipment. The vacuum brush interfaces directly with the vacuum cleaning hose, which is attached to the LM ECS. The vacuum brush performed satisfactorily during the Apollo 11 mission, removing loose particles and contaminants from equipment to be transferred from the LM to the CM.

Decontamination containers. - Prior to the Apollo 11 launch, the requirement to clean and bag all equipment exposed to the lunar surface was established. This requirement was to prevent any contamination of the earth environment by lunar material. Beta-cloth bags were provided to cover each item exposed to the lunar environment (fig. 14). The vacuum hose and brush were used to remove any loose dust or lunar particles from the items to be bagged.

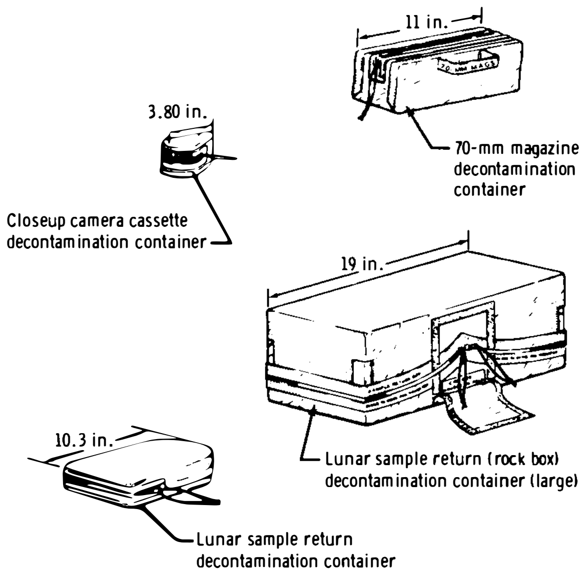


Figure 14. - Decontamination containers.

Tissue Dispensers

Seven tissue-dispenser assemblies are provided in the CM, one of which is transferred to the LM. The assembly includes a woven Teflon-coated Beta-cloth-layup bag that is 5 by 3 by 8 inches. This bag contains 55 nonlinting tissues. (Each tissue is 7-1/2 by 17-1/2 inches.) The tissue dispenser, which was designed during the Gemini Program, was fabricated from nylon and had an exposed opening in the top for the removal of the tissues. To preclude the possibility of fire, the Apollo model was changed to a Teflon-coated Beta-cloth-layup bag that had a cover over the opening. The tissue dispenser is a very functional item and will continue to be used in future missions.

Utility-Towel Assembly

The utility-towel assembly provides the crewmen with absorbent hand towels. The assembly requirements are to provide absorbent, lint-free towels in a fireproof container. There are three color-coded utility-towel assemblies in the CM, one for each crewman. Each assembly contains seven towels. The LM has one assembly containing two towels. The towel container is composed of two layers of Teflon-coated Beta cloth and holds 12-inch-square towels made of rayon polynosic terry cloth.

The towel assembly, which was first used on the Gemini missions, dispensed 12- by 24-inch towels for the first two Gemini flights. On the remaining Gemini missions and on all Apollo flights, 12-inch-square towels were used. On the Apollo missions, the containers were made of Teflon-coated Beta cloth instead of plain Beta cloth, thereby increasing abrasion resistance. The utility-towel assemblies, in both the CM and the LM, have performed as designed and have met all crewman requirements.

Penlights

Five penlights are stowed in the CM, one on each PGA and two within an SC cabin container. The penlights are used (1) for illumination of poorly lighted areas of the CM and LM, (2) for normal operations and maintenance work, and (3) for a source of light in the event of a cabin lighting failure. The penlight provides a pocket-sized light with a minimum continuous operating life of 7 hours and a minimum illumination of 8 ft-c.

The penlight was originally designed for use during the Gemini Program. The first type of penlight, flown on the Gemini VI to XII missions, consisted of two batteries and a bulb completely encapsulated in Butyrate. The penlight was changed to an all-brass model with a Lexan lens to reduce the chance of fire and to provide interchangeable components for the Apollo Program. The penlight has proved to be an extremely versatile high-performance item of personal equipment that also provides a light source for television transmissions originating in the SC.

Scissors

Three heavy-duty scissors are carried on each mission. Scissors stowed in the PGA are used by crewmen to perform varied tasks: the opening of food packages, the opening of pillstrips, and other purposes, including some that contribute to crew survival (such as cutting the couch restraint harness, if necessary). Except for the modified serrated edge, the scissors have undergone little change since they were first used during Project Mercury. The serrated edge allows the crewmen to cut heavier and larger items. The scissors have performed satisfactorily on Apollo missions.

Eye Patch

The eye patch serves two purposes: It enables a crewman to maintain night vision in one eye during earth and lunar orbits, and it is used by a crewman to cover one eye while sighting through the navigation eyepiece. The eye patches are made of room-temperature-vulcanizing rubber. One eye patch is stowed in the CM and another is kept in the LM. The eye patch has not been changed since it was first used on the Apollo 9 mission.

Lunar Module Ceilings and Covers

A special nonflammable lightweight material was developed for use as fairings and protective covers to protect critical components within the LM from inadvertent damage caused by crewman movements. A protective ceiling was required for the electrical cabling on the underside of the upper pressure bulkhead; Trevarno F-130, a moldable silicone fiber glass laminated with an epoxy resin, was used successfully for this purpose. The Trevarno F-130 has performed well, with two exceptions: Minor configuration changes have been made to afford a better fit, and, occasionally, a cracked fairing (caused by installation operations) in the cabin has needed replacement. No further changes in materials or configuration are planned.

Apollo Lunar-Equipment Conveyor

Late in 1967, the MSC Lunar Operations Panel investigated a proposed method for transferring cargo in and out of the LM ascent stage. This method involved a single line to be used by a crewman standing on the LM ladder and proved to be unacceptable.

An endless belt concept was proposed. A rough mockup was constructed, the method looked promising, and in-house development studies were started to provide qualified hardware for flight use. Such an in-house project afforded close cooperation between user and designer. In addition, changes resulting from flight experience could be made quickly. This arrangement worked successfully with the Gemini XII waist tethers. The conveyor could conceivably have two uses: first, as a conveyor device; second, as a contingency lifeline for EVA return to the CM, following a hard-dock failure.

Recommendations were made, following mission-profile studies, that the LM be provided with a kit containing a lunar-equipment conveyor and two pairs of waist tethers. Crewman evaluations indicated the desire (1) for the tether kits to be tailored for specific missions and (2) for separate lifelines, rather than a two-purpose conveyor. Two kit configurations were recommended: the first, designed for the Apollo 9 and 10 (LM-3 and LM-4) missions (a lifeline equipped with two sets of waist tethers); the second, a 30-foot lunar-equipment conveyor, a lightweight lifeline, and two pairs of waist tethers. Both kits were used successfully on the Apollo 9 to Apollo 11 missions (LM-3, LM-4, and LM-5). During the Apollo 12 (LM-6) training, the crewmen requested that the lunar-equipment conveyor be changed to a single-strap design. This change was used for the Apollo 12 (LM-6) and subsequent missions and will be used until such time that other changes are authorized.

Since the inception of the Apollo Program, many minor changes have occurred to hardware designs. These changes and the overall success of the Apollo missions justify the decision to conduct the program in-house.

MEDICAL COMPONENTS AND ACCESSORIES

As space flights are completed, the medication criteria for crewmen change; experience transforms speculation into known requirements. Flight and training experiences of the crewmen dictate medical component and accessory needs.

The medical-accessories kit (MAK), stowed in each SC, provides the crewmen with sufficient medical supplies and medications to treat any foreseeable ailment that might occur during their stay in the CM or on the lunar surface. The MAK consists of a Teflon-coated Beta-cloth-layup container with the equipment required to perform several functions.

1. To monitor, as required, crewman oral temperature and the pH level of the SC potable water (within the pH range of 1 to 11)

2. To provide spare biomedical harnesses, electrode paste, Stomaseal washers, and micropore disks for inflight bioinstrumentation-sensor replacement or repair

3. To provide spare UCTA roll-on cuffs for periodic replacement of cuffs during the mission

4. To provide both injectable and ingestible medicants for treatment of a variety of physiological ailments that might affect the health of the crewmen during a mission

5. To provide bandages, eye drops, skin cream, and antibiotic ointment for crewman use

The LM medical kit is a double-layer Teflon-coated Beta-cloth package containing components required to perform the following functions.

1. To provide crewmen with the proper ingestible medications to treat any of a variety of physiological ailments that might affect the health of the crewmen while they are in the LM or on the lunar surface

2. To provide bandages and eye drops for crewman use

Basically, the medical kits are a continuation of the Mercury and Gemini design. However, the Apollo kits contain increased quantities and types of medications. The basic kit material was changed from nylon to a Beta-cloth layup to reduce or eliminate fire hazards. Various ailments suffered by the crewmen during the Apollo 7 to Apollo 11 missions have necessitated 13 changes. One change involved stowing the kits in larger volumes. The medical kits are considered adequate to cope with any medical problems that the crewmen might encounter.

BIOINSTRUMENTATION SYSTEM

The bioinstrumentation system is used by ground-based medical personnel to monitor the health of the crewmen. At MSC, development of the bioinstrumentation system and related hardware is primarily mission oriented in order that the following functions may be performed.

1. Operational inflight safety monitoring

2. Inflight medical experiments

3. Ground-based operations safety monitoring

The Apollo operational system is composed of one electrocardiograph (ECG), one impedance pneumograph (ZPN), one dc/dc converter, one sternal-electrode harness, and one axillary-electrode harness.

The ECG signal conditioner and the associated electrodes are designed to provide inflight measurements of the ECG activities of crewmen and to develop a signal wave ranging between 0 and 5 volts peak to peak. (The signal wave is representative of crewman ECG activity.) The unit is designed to permit preflight adjustments, and it is worn in a pocket on the biobelt attached to the underwear inside the space suit (fig. 15).

The ZPN signal conditioner and the associated electrodes are designed to measure transthoracic impedance changes to a low-level current at a frequency of approximately 50 kilohertz. Measurements are made by using a pair of electrodes approximately placed on the crewman or other test subject. The signals range from 0 to 5 volts peak to peak. The signals, which correspond to a wide range of respiratory activity, designate the respiration rate of a particular subject. The unit is designed to permit preflight changes in circuit gain, accommodating the characteristics of the individual subject. The unit is located in a biobelt pocket inside the space suit.

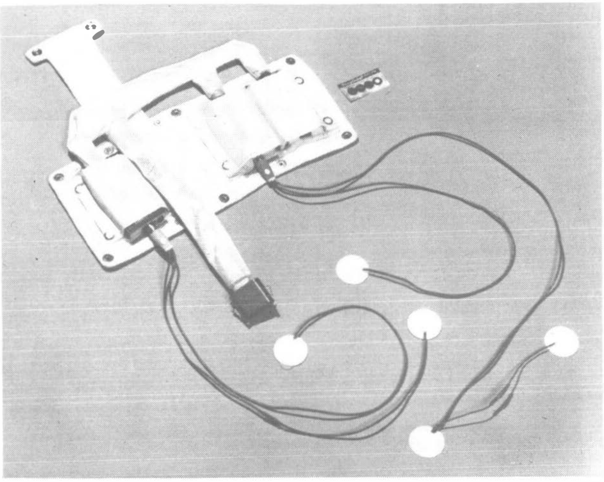


Figure 15. - Bioinstrumentation belt assembly.

The dc/dc power converter delivers a regulated positive 10- and negative 10-volt power to each signal conditioner. The component is powered from the unipolar nominal 16.8 volts available for suit electronic equipment. The unit receives the voltage and converts it to the isolated and balanced bipolar supply required by the bioinstrumentation system. The design characteristics of the power converter incorporate features for reverse-polarity protection, load-current limiting, and electrical isolation of the input/output ground systems. There are no adjustments associated with the unit. The converter is worn in a biobelt pocket inside the space suit.

The axillary-electrode harness is a small cable used in conjunction with the ZPN signal conditioner. The cable provides the electrical interface between the crewman's electrodes and the ZPN signal conditioner.

The sternal-electrode harness is a small cable that is used in conjunction with the ECG signal conditioner. The harness provides the electrical interface between the crewman's electrode and the ECG signal conditioner. The cable also contains the system ground electrode, which is a high-impedance ground primarily used to remove the static charge from the test subject.

During flight, physiological data are received from each crewman. As a result, three complete, separate bioinstrumentation systems are required. There are three spare sternal harnesses and one spare axillary harness on board the SC. However, there are no spare signal conditioners.

Use of the bioinstrumentation system inside the suit is a design compromise, since for personal comfort, it would be preferable for the system to be outside the suit. The inconvenience of the inner bioinstrumentation system is more than compensated for by the improved signal-to-noise ratio obtained. Also, the electrical isolation provided by the signal conditioners affords maximum protection against accidental electroshock. The placement of the system inside the suit provides another advantage. The gain settings differ for each crewman, and use of a central set of instruments would involve additional switching problems in the low-level signal lines.

The bioinstrumentation system has provided satisfactory and useful data for the space program; yet, there have been a few mechanical and electrical problems associated with the system. The first problem was to determine the nature of the fire hazard inside the space suit. Extensive testing revealed that, by shorting the output leads of the dc/dc converter, a spark could be produced which would ignite cotton in the presence of oxygen under conditions of 19 psia. This ignition source was traced to output capacitor energy storage in the dc/dc power converter and to the ability of the output capacitors to produce a high-current pulse in a short-circuit condition (even though the output current would go to 50 milliamperes in a steady-state condition). The high-current pulse and the associated ignition hazard were eliminated by installing resistors that limit the current in the positive 10- and negative 10-volt output leads of the dc/dc converter.

There were additional major problems during the first manned Apollo flight (Apollo 7). The single pin disconnects in both the electrode harnesses inside the suit separated, and the data were lost until the suit was removed and the connection remated. There was a lead breakage at the connectors of the electrode harnesses that added to the overall problem. Also, during the Apollo 7 mission, one crewman reported a heated signal conditioner, and he was instructed to remove and stow the biomedical hardware.

Solution of this problem was difficult. As a first step, the electrode harness was redesigned to eliminate the pin disconnect that had come loose during flight. Then, electrodes were wired as a permanent part of the harnesses, which are custom fitted to the crewman. A series of meetings was held to review the test results obtained on various materials; also, the use of various materials to solve the fatigue problem was discussed. As a result, the wire insulation was changed from Teflon to polyvinyl chloride (PVC), and the strain-relief boot was changed from epoxy to silicone rubber. Data from subsequent qualification tests indicated this combination to be superior to the original concept. The new system has been used on all subsequent flights. An investigation of the heated signal-conditioner problem revealed (1) the dc/dc converter runs warm to the touch under normal operation, and (2) if the series voltage-dropping resistor in the SC power system develops a short and applies 30 volts to the converter, it will become uncomfortably warm. The converter has not been redesigned, but prior to any mission, each crewman is briefed on what to expect under both normal and abnormal conditions. In addition, a temperature-recording label is affixed to each signal conditioner. There has been no further problem.

Continued testing revealed a sneak ground path in the input circuit of the ECG signal conditioner (which provides a current path to ground if the crewmen should contact a voltage source). The solution to this problem required increasing the input lead impedances by adding series current-limiting resistors to the sternal-electrode harness. Also, a ground electrode with a series resistor was added to reduce noise and artifact on the ECG data.

The ECG and ZPN electrode systems include a sternal harness and an axillary harness. The electrodes are silver/silver chloride anodized disks in an acrylic housing. The wiring is a highly flexible PVC-insulated cable with a silicone-rubber bend relief at the connector.

The electrodes are filled with electrode paste and attached to the crewmen by double-back adhesive tape. Then, the electrode is covered with porous surgical tape that permits normal skin respiration. The electrochemical activity that occurs at the electrode surface is degraded if the anodizing is damaged. This problem occurs after many use cycles and may be eliminated by replacing the anodized disk with a pressed pellet of powdered silver/silver chloride. The pressed pellet technique is currently undergoing development. Hopefully, this technique will provide a homogeneous electrode that will not be affected by surface damage.

The attachment technique is limited by safety and comfort. Reliable contact is difficult to maintain under conditions of minimal discomfort and skin damage. Because an electrode may be dislodged under such severe effort as suit doffing and donning, a kit is provided to replace electrodes (if necessary) during unsuited periods.

If the existing bioinstrumentation system is redesigned, several problems warrant serious consideration. These problems are listed as follows:

1. The rise time on the dc/dc converter switching must be considered. The fast rise time now used has caused some electromagnetic-interference problems.

2. The frequency of the dc/dc converter oscillator and the ZPN oscillator should be controlled so that a harmonic of the dc/dc converter does not fall at the same frequency as that of the ZPN. When this happens, the ZPN signal is affected. Although the data obtained are usable, an undesirable noise is produced.

3. The current-limiting resistors now used in the sternal-electrode harness should be placed in the ECG signal conditioner, or other means should be used to eliminate a possible hazard.

4. A bias control should be added to both the ZPN and the ECG signal conditioners to allow proper level adjustment of the zero signal.

5. A method should be devised to protect biomedical sensors against electromagnetic fields that might occur in the near field of an antenna.

6. A system should be developed to replace the high resistance in the ground-electrode circuit. The ideal system would offer a low-resistance path for small signals; however, the system would provide current limiting during electrical overload situations (such as contacting an external voltage source).

7. A considerable improvement in usable ZPN data could be obtained by making a near-logarithmic output signal.

8. The low-frequency response of the ECG signal conditioner should be reduced to 0.05 hertz, and circuitry should be employed to provide a rapid electrical overload correction.

Further attention should be focused on a radio link between crewmen and SC or on signal-conditioning equipment for each crewman in the SC.

The bioinstrumentation belt (fig. 15) is a band of cotton-duck fabric, to which three pockets with elastic inserts are sewn. The belt provides a compact means for placement and stowage of the bioinstrumentation signal conditioners and the dc/dc converter. Snap fasteners are used to mate the biobelt to the midriff section of either the CWG or the liquid-cooling garment. The signal conditioners and the dc/dc converter must be available for easy connection to the biomedical harness and the sensing equipment. The pockets must contain the contents securely, yet fulfill flexibility and interface requirements.

The original biobelt concept included conventional box-type pockets on a cotton belt. Redesign provided a different method for securing the signal conditioners and the dc/dc converter. Elastic straps are used to maintain the contents in a fixed position, and an overflap snaps over the contents of each pocket. The overflaps are fabricated of Teflon-coated Beta cloth to satisfy flammability requirements. This biobelt has been satisfactory throughout all Apollo missions. Some wear has been noted during severe testing exercises, particularly of the Teflon-coated Beta cloth around snap locations. However, such wear is acceptable; this is a one-mission-use item.

Although the biobelt (as now constructed) meets the requirements for Apollo flights, redesign may be necessary (1) for longer-duration missions, (2) for those missions that involve extensive use of the belt, or (3) for relocation of the biobelt assembly.

SURVIVAL EQUIPMENT

For emergency landing conditions, certain survival equipment is provided to support the crewmen for a 3-day period. The items are contained in two rucksacks. In addition, three lifevests are provided for launch-abort and postflight water landings. Neck and wrist dams, located in the PGA, are also used during water survival to provide water seals. Components of the survival kit are shown in figure 16.

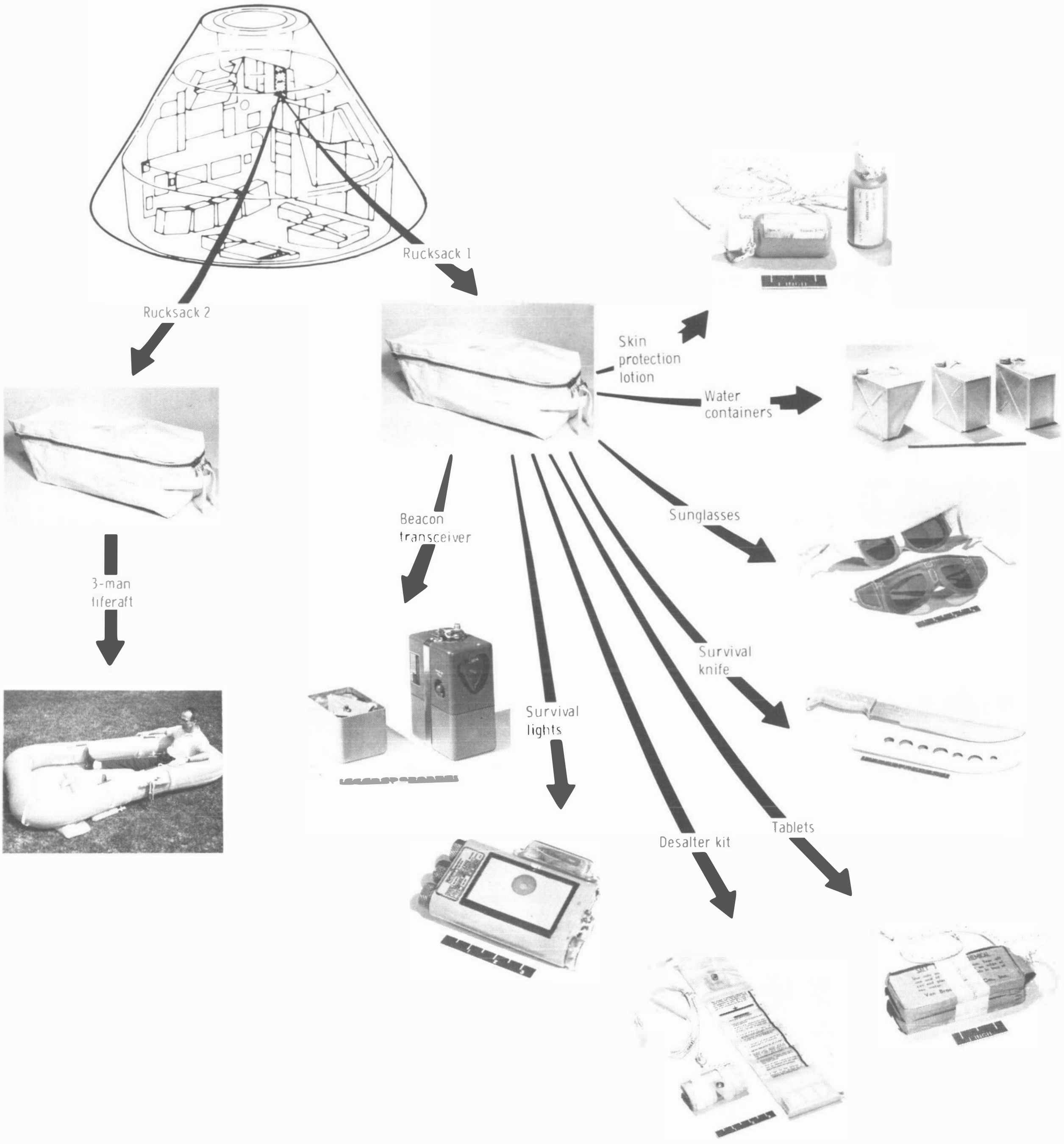


Figure 16. - Components of the survival kit.

Rucksacks

The rucksacks are rectangular-shaped bags made of Armalon, a Teflon-coated glass fabric. Each bag is equipped with a zipper opening and a strap handle. There are two rucksacks stowed in the CM right-hand forward equipment bay. Items contained in the rucksacks include a raft, a radio and beacon transceiver, three water containers, a machete, a desalter kit, sunglasses, and combination survival lights.

The rucksacks fulfill the requirements for a survival-equipment system with a stowage container that is capable of allowing rapid egress from the SC in the event of a postlanding emergency; also, the rucksack design precludes possible loss of the contents after deployment.

The shape of the rucksacks was controlled by the location of available stowage space. Armalon, selected to be used in fabricating the rucksacks, fulfilled the criteria of being nonmetallic and abrasion resistant. A strap was attached to enable rapid removal of the rucksack from stowage and to allow handling by one crewman. A D-ring is attached to each handle to facilitate mooring the rucksack to the three-man liferaft (to prevent loss).

The rucksack has never been needed on Apollo missions. However, the rucksack receives small cuts and abrasions during installation and removal from the stowage location. Despite the small cuts and abrasions, Armalon is the best material available at the present time.

Combination Survival-Light Assembly

The combination survival-light assembly meets the requirement to provide the crewmen with adequate survival components that would provide the most effective means of survival and yet have a minimum weight and volume. The assembly is a hand-held unit that is primarily used for visual signaling, which is accomplished by means of a strobe light, a flashlight, or a signal mirror. Additionally, the unit contains a siren whistle, a compass, fire starters, cotton balls, halogen tablets, a water receptacle, knife blades, needles, nylon cord, and fishhooks.

The combination survival light was developed for use in the Gemini Program. It satisfies the Apollo postlanding requirements. This item, intended for use during an emergency postlanding situation, has not been required during any mission. However, postflight testing demonstrated that the units remain functional.

Desalter Kit

The desalter kit is a standard off-the-shelf Department of Defense (DOD) item. The kit has been modified slightly to meet the NASA requirements. The kit consists of two processing bags, eight chemical packets, and mending tape. Each chemical packet is designed to produce 1 pint of potable water. The water is processed by mixing sea water and a chemical packet for a certain period of time. The mixture is then filtered to produce the drinking water. The DOD item has been modified by replacing the mending tape with fiber-glass tape and by removing the stowage container; without modification, this container would not meet the Apollo Program requirements. Eight chemical packets will produce 1 gallon of potable water.

Sunglasses

The light-polarizing sunglasses have soft fabric frames and are adjustable to head size and face contour. They are held against the face by lengths of elastic braid, which are fastened in back of the head with hook and pile fasteners. The sunglasses were designed specifically for the Apollo Program, as a part of the survival equipment, to satisfy criteria for resistance to breakage and for compactness and to provide the crewmen with protection from harmful sunrays and glare.

Machete and Sheath

The survival machete is a 17-inch long, all-metal knife that has an aluminum handle and a high-quality stainless steel blade with a cutting edge on one side and a sawing edge on the opposite side. The machete sheath is fabricated from aluminum sheeting with a Teflon spacer (to protect the blade). The machete may be used for cutting or sawing if jungle-type terrain is encountered after an emergency landing. The nylon handle (flammable) used on the Gemini missions was replaced by an aluminum handle (nonflammable) for the Apollo flights.

Although the machete has yet to be needed on a mission, it has proved to be a very useful item during the training exercises. The blade is of high-quality stainless steel, but is brittle and will break if used for prying. A more desirable material for the blade should be considered for further development.

Water Containers

Three water containers are included in the Apollo survival kit. Two of the containers are rectangular in shape; the third is triangular. Each water container holds 4.5 pounds of deionized water, with access to the water provided by a metal cap.

The survival water containers used in Project Mercury and in the Gemini Program were made from PVC plastic film with a nylon or neoprene-coated-nylon restraint layer. However, the Apollo water containers were made from aluminum to (1) create rigid components in the survival kit and maintain dimensional integrity, (2) meet outgassing and flammability requirements imposed upon the Apollo Program, and (3) provide sufficient physical strength to pass the 78g shock load required to qualify this item for SC use.

During development of the metal water containers, two significant problems were encountered. The largest side of the water containers would deflect considerably because of pressure differential. A 1/4-inch-radius indention forming an "X" on each of the two largest sides of the water containers solved this deflection problem. The other problem encountered was the result of depressurization. The first aluminum water containers had a press-fit stopper, which blew out during a chamber decompression test and which was replaced by an externally threaded drinking port with a screw cap. This item has yet to be used during a mission. The water containers have proved to be satisfactory during training use; however, a few crewmen have stated that the aluminum causes the water to have an undesirable taste. A suitable film liner for the water containers will eliminate any taste complaints.

Skin Protection Lotion

Protection against sunburn is provided by two plastic squeeze bottles containing approximately 2 ounces each of skin protection lotion. The lotion is water repellant. It has been used only during training and has been satisfactory.

Three-Man Liferaft

The three-man liferaft is a triangular-shaped flotation tube with a reversible inflatable baffle, an inflatable floor, three ballast buckets, a carbon dioxide system, a sea anchor, and an oral inflation system. It is designed to support three crewmen in a stable condition for an extended time period by using an initial inflation pressure of 2 psig.

The three-man liferaft is used only if an emergency mode develops, in which normal rescue practices cannot be used. It was designed specifically for use on the Apollo missions. The inflatable baffle was developed to provide a backup flotation system if a portion of the liferaft failed to hold pressure. The baffle chamber can be inflated orally. The raft was designed to be inflated by carbon dioxide. Two activated carbon dioxide cylinders, each charged with 375 grams of carbon dioxide, are used for inflation of the raft. Approximately 25 seconds are needed for full inflation of the raft. Two carbon dioxide cylinders are required because the inflatable baffle forms two separate chambers out of the main flotation tube.

Sea-Dye Markers

Two sea-dye packets are stored in the raft. The dye, capable of turning the sea water to yellow green, is a visual aid for locating a raft. It is a standard DOD-developed item that was procured to meet NASA requirements. The dye is activated by pulling a nylon tab loose and lowering the dye into the water. The dye can be recognized from an altitude of 5000 feet at a range of up to 10 miles.

Radio Beacon

The survival radio is a hand-held, dry-cell-battery-powered, electronic signal-and-voice communications device. The radio can be operated within the SC by using a connector cable to the SC antenna. A constant emergency-signal and voice-contact device is required to aid rescue teams if postlanding recovery is delayed; the survival radio meets this requirement. It operates on a frequency of 242 megahertz for training and 243 megahertz (the international distress frequency) during flight. Broadcast and reception are limited to line-of-sight transmissions. Although the Gemini radio was used in the SC for the Apollo 7 to Apollo 11 missions, improved capabilities can be obtained by replacing this radio with a unit developed especially for the Apollo Program. Voice reception will increase from approximately 30 to 120 miles. Voice modulation will be improved and radio weight will be reduced from 6 pounds to 4 pounds. Beacon range reception will also increase to 120 nautical miles, for search aircraft operating at 10 000 feet. The radio beacon has yet to be required in any mission; nevertheless, each flight radio is tested functionally with the SC prior to each flight.

Lanyard System

Crewmen, the SC, and the survival liferaft must be connected during emergency postlanding egress from the SC. This is accomplished by the use of a lanyard system composed of a 25-foot mooring lanyard and three manlines. The mooring lanyard, which has a snap on each end for quick attachment and detachment, is designed for use in securing the three-man liferaft to the SC. An 8-foot manline is provided for the first crewman to egress, and 4-foot manlines are provided for the second and third crewmen. The 8-foot manline is attached directly to the raft. The 4-foot manlines are attached to two metal rings that can slide along the entire length of the mooring lanyard. Each crewman attaches a manline to himself prior to SC egress to prevent separation from the liferaft.

Lifevest

Each crewman wears a lifevest during launch, entry, SC egress, and recovery. The lifevest consists of two inflatable underarm flotation tubes and a harness to attach the lifevest to the crewman. The flotation tubes are packed in fabric cases that fit under each arm. If, during entry, SC egress, or recovery, the crewman should be rendered unconscious, the lifevest would furnish flotation to keep the mouth and nose above water. The flotation tubes used in the Apollo lifevest are the same as the ones used in the Gemini Program. A different harness and case, using nonflammable material, were developed for use in the Apollo Program. Each flotation tube is made from neoprene-coated nylon and is inflated through activation of a 16-gram carbon dioxide cylinder. An oral inflation valve located on each tube provides a backup inflation system. Partial inflation of the flotation tubes has occurred at times during training exercises. However, no problems with the lifevests have occurred during missions.

Utility Netting

The utility netting is 60 by 52 inches and is made of a standard fine-mesh nylon material. The netting was installed in the survival kit for the Apollo 12 (SC-108) and subsequent missions. The netting is intended primarily for protection from insects, but also serves as a filler material for the survival kit.

Survival Blanket

Three pieces of nylon-Mylar material that are 60 by 42 inches are provided for the Apollo missions. The material can be used for thermal protection and for signal purposes. This item will be included in the redesigned, smaller-volume survival kit. For packing purposes, a material is needed to fill the void in the survival kit; the blankets can be used for this purpose, and the requirement for a nonfunctional filler thereby avoided.

Sunbonnet

The sunbonnet is a triangular-shaped nylon-Mylar material approximately 30 inches on each side. The sunbonnet has a Teflon bib and is used for sunburn protection. This item is identical to the sunbonnet developed for use in the Gemini Program.

Survival Knife

Two survival knives are provided for each Apollo survival kit. These are standard three-bladed all-metal knives developed by the U. S. Navy. These items are stowed in the space provided through the use of a smaller kit and serve as functional filler material.

CREW EQUIPMENT STOWAGE

Crew equipment stowage locations are keyed to need and availability, so that crewmen may quickly find and use an article, when it is needed, with minimum interference to the piloting task. Equipment items must be located to efficiently support the primary systems with which each is associated (such as lenses for optical-guidance gear and umbilical interconnects for oxygen hoses). Quick removal without interference from loose flaps or tangled ties is necessary. These factors dictate the locations of crew-provision stowage items.

After the locations have been determined, the next most important requirement is the protection of the equipment from possible fire damage. The present configuration includes overlaps and multilayers in the Beta-cloth containers, the metal snaps, and the all-metal CM containers. Modularization (to allow packaging on the bench), versatility in equipment selection, and ease of ground access are the remaining engineering considerations.

Command Module Stowage

The variety of crewman activities demands stringent housekeeping. All equipment is stowed at times of launch and entry, and provisions are made to restrain loose equipment during missions. Patches of Velcro hook are located conveniently on the CM interior panels, on bulkheads, and on other structural elements, for attaching loose equipment. The equipment items have patches of Velcro pile. Mechanical fasteners (snaps, straps, and clips) are also used to restrain loose articles.

Movable or loose equipment is stowed in compartments and lockers located in the equipment bays, on the crew couch, on the aft bulkhead, or on side bulkheads. Load-bearing compartment doors, internal foam blocks, or metal boxes aid in retaining and positioning the equipment. On the aft bulkhead, rigid aluminum boxes or reinforced bags are provided for stowage. Each SC is stowed in accordance with field installation stowage drawings (figs. 17 to 19). Stowage differs from one SC to another because of different crewman desires and requirements. The locations of the items stowed in SC-107 are presented in figures 20 and 21.

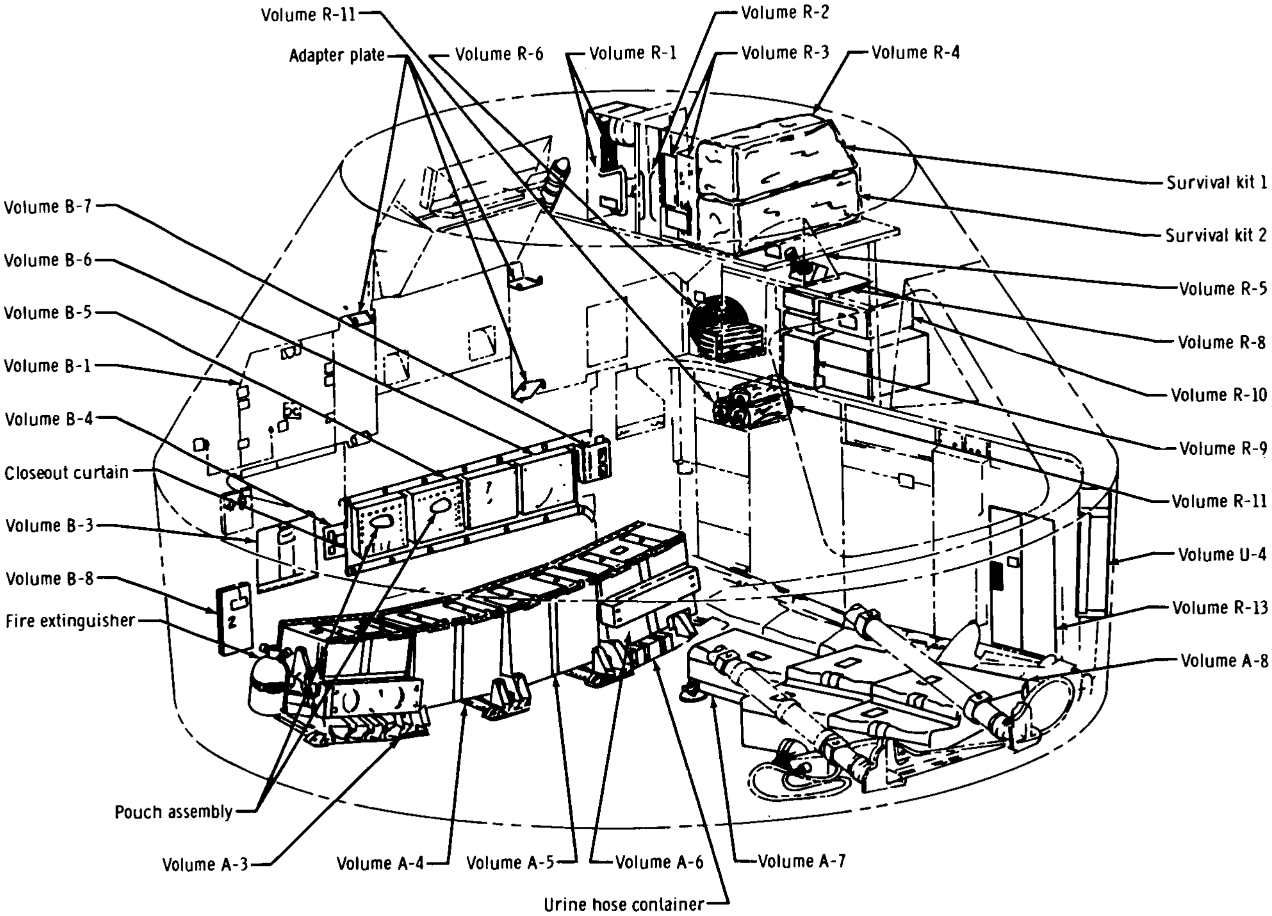


Figure 17. - The CM stowage for aft bulkhead, lower equipment bay, and right-hand equipment bay.

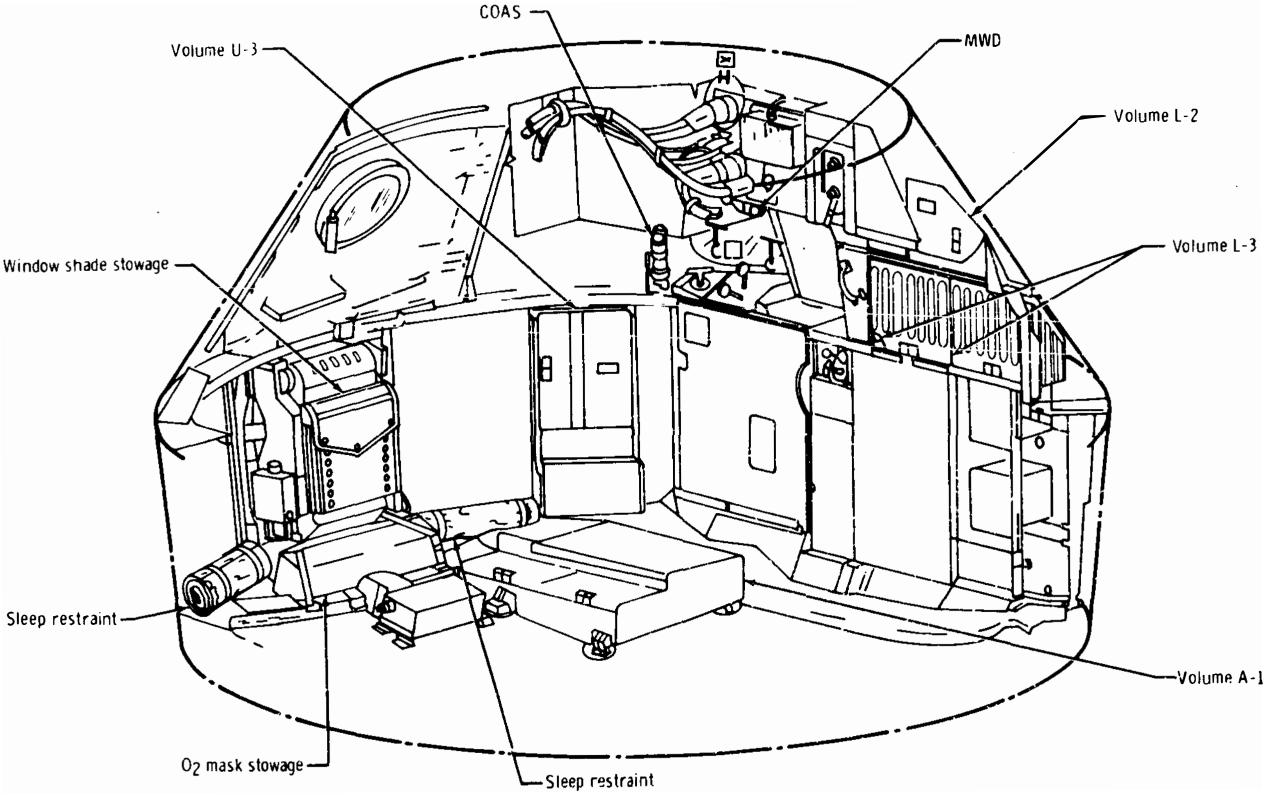


Figure 18. - The CM stowage for aft bulkhead, upper equipment bay, and left-hand equipment bay.

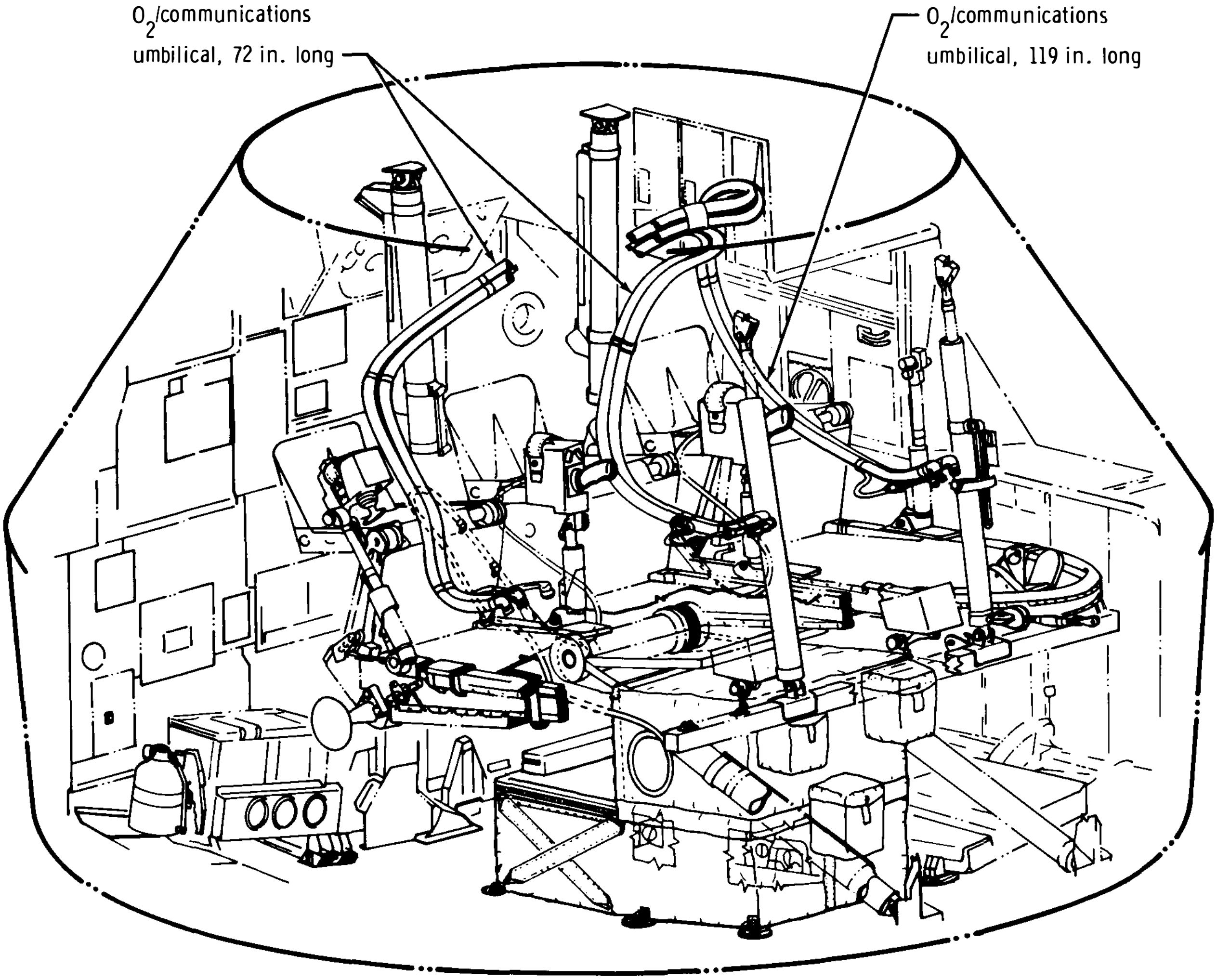
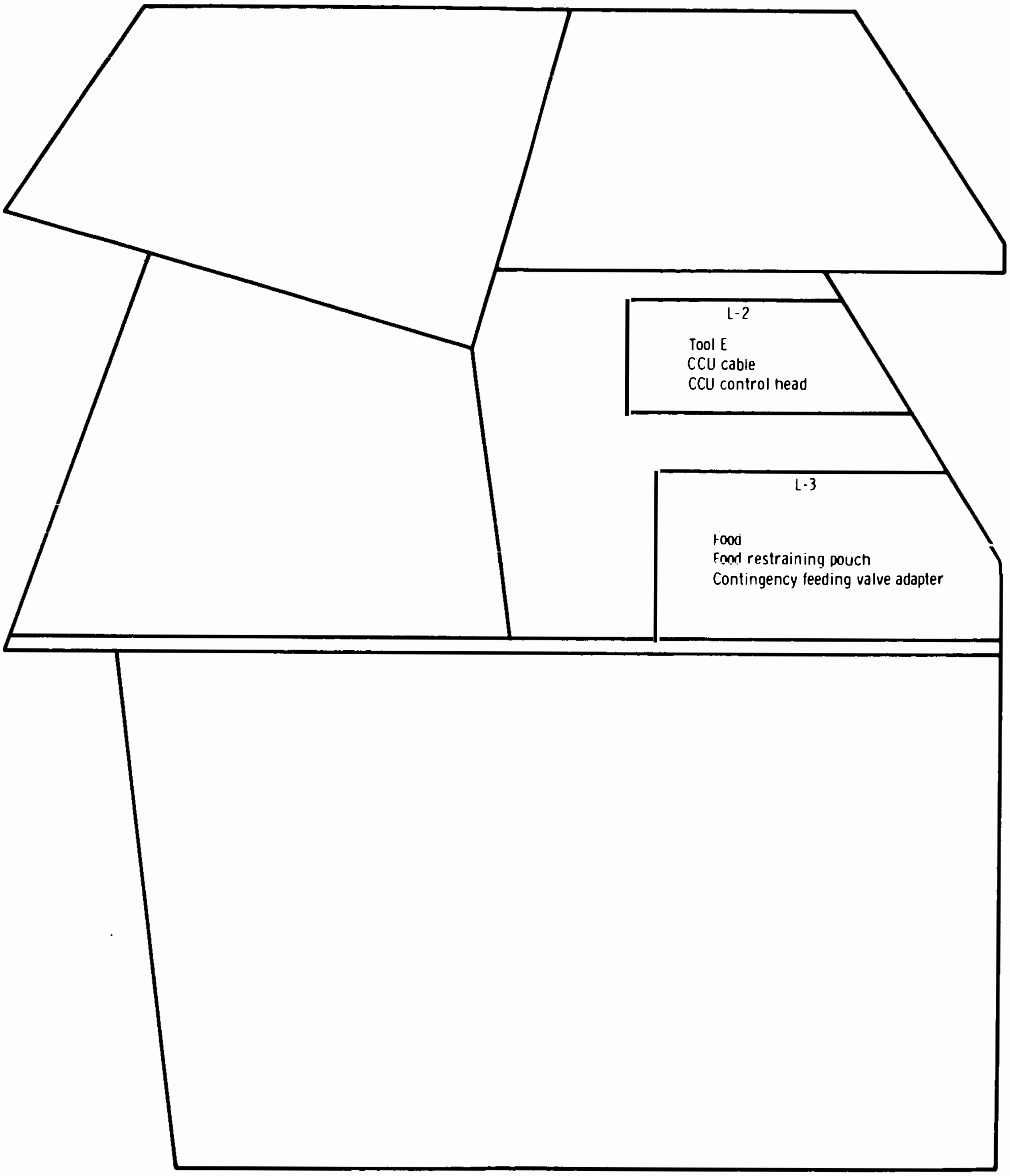
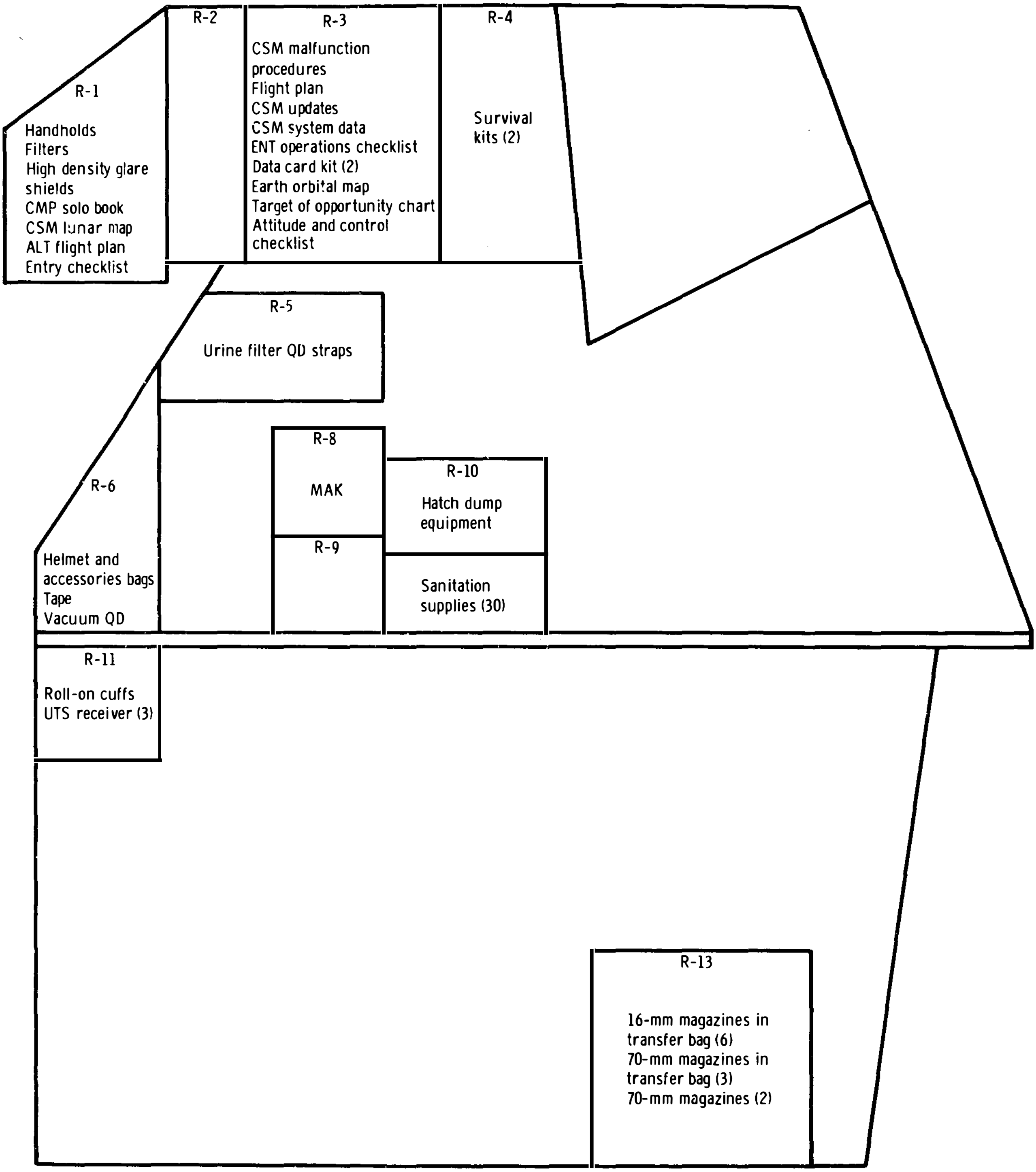


Figure 19. - The CM stowage for crewman couches and associated equipment.



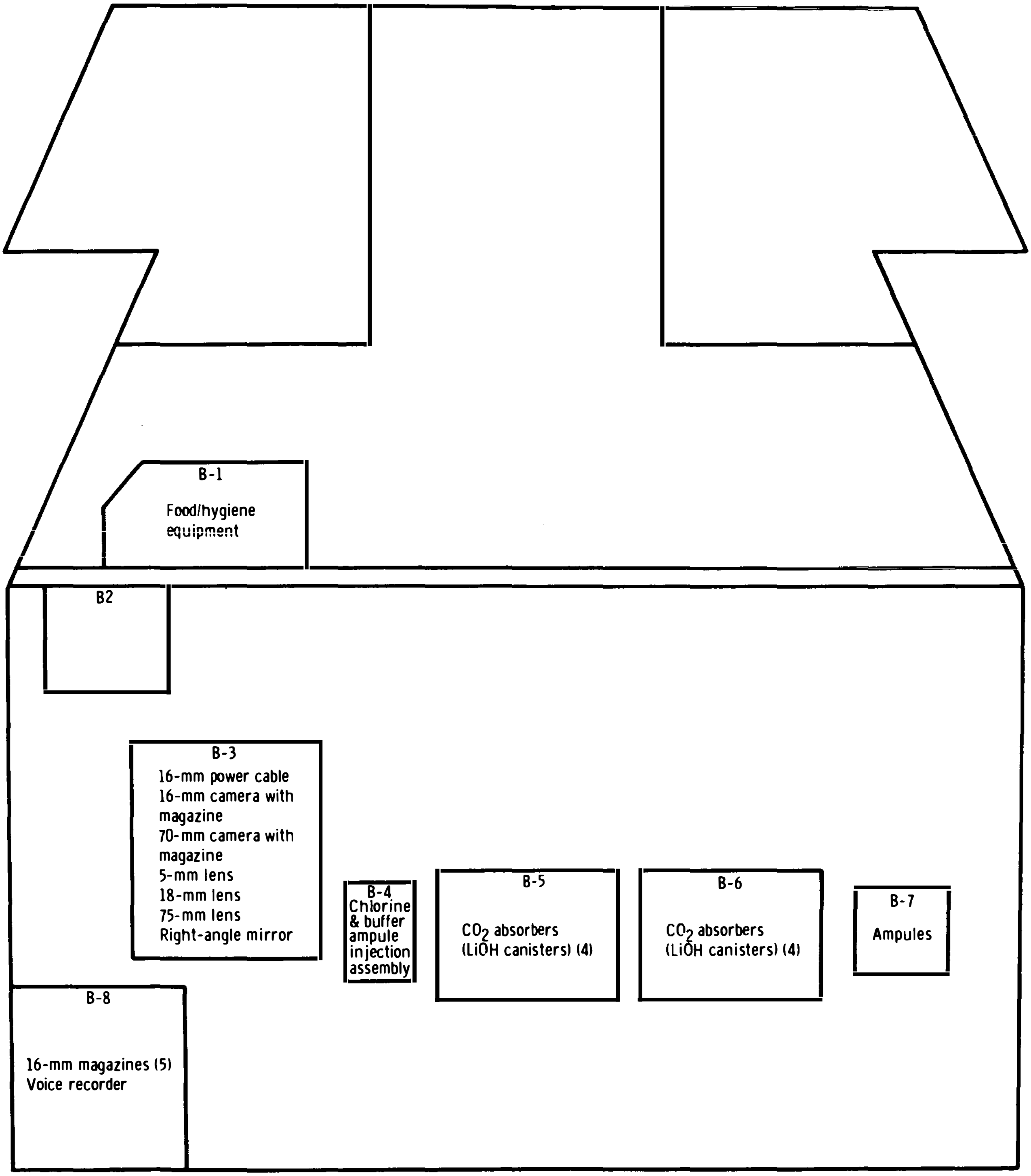
(a) Left-hand equipment bay.

Figure 20. - Location of SC-107 stowed items in left-hand and right-hand equipment bays.



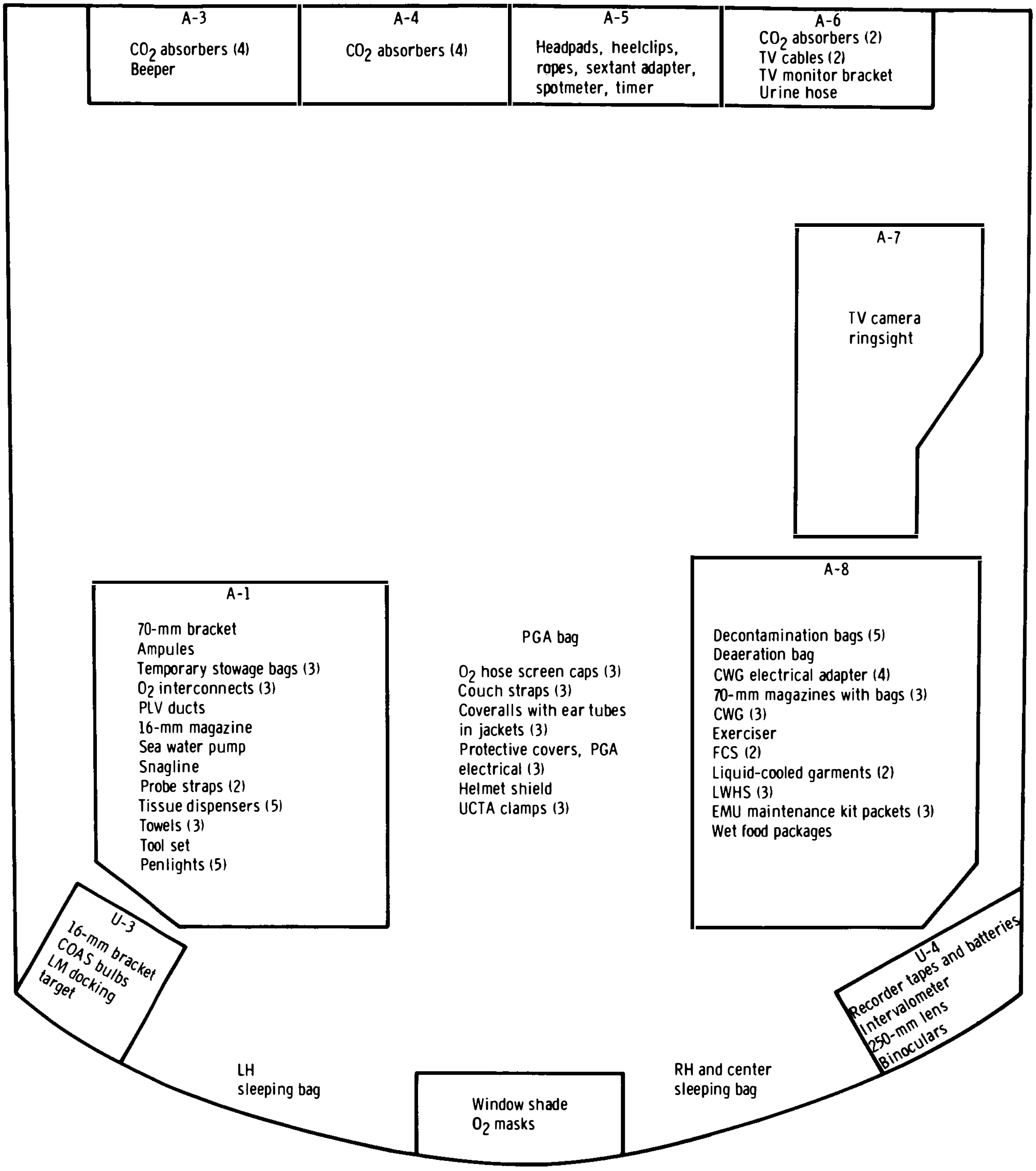
(b) Right-hand equipment bay.

Figure 20. - Concluded.



(a) Lower equipment bay.

Figure 21. - Location of stowed items in lower equipment bay and aft bulkhead.



(b) Aft bulkhead.

Figure 21. - Concluded.

Lunar Module Stowage

Because the crewmen spend significantly less time in the LM than in the CM and because the LM weight limitations are much more critical than those of the CM, stowage design in the LM emphasizes accessibility of equipment and lightweight, nonflammable construction. The initial construction was a framework of riveted sheet aluminum (with nylon covers and nylon Velcro closures) built into the lower right-hand cockpit and the left-hand midsection areas of the LM crew compartment.

Initial developments to meet flammability requirements resulted in a change of the container cover construction to a multilayer of Beta cloth, aluminum foil, Aclar (Teflon film), aluminum foil, and Beta cloth. Weight was reduced by changing the multilayer to a layer of Teflon-coated Beta cloth (Armalon), which has better abrasion resistance and meets fire hazard requirements. This material has been used successfully on all Apollo missions. The LM crew provisions and equipment and their typical locations in the ascent stage are shown in figures 22 and 23. The disposable bag assembly located in the lower left cockpit is removable, and it is normally off-loaded to the lunar surface. No fundamental change in container design, other than an increase in modularization to allow late stowage changes to be implemented, is planned. Each LM is stowed in accordance with field installation stowage drawings.

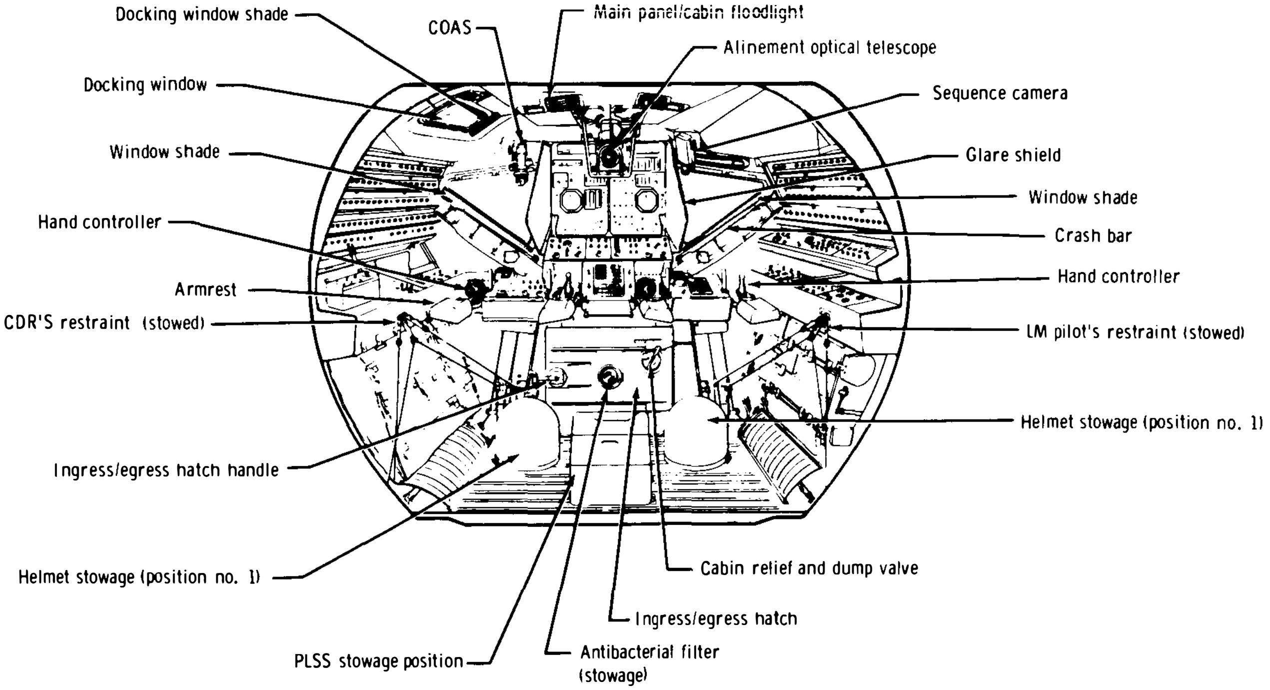


Figure 22. - Location of stowed items in LM, looking forward.

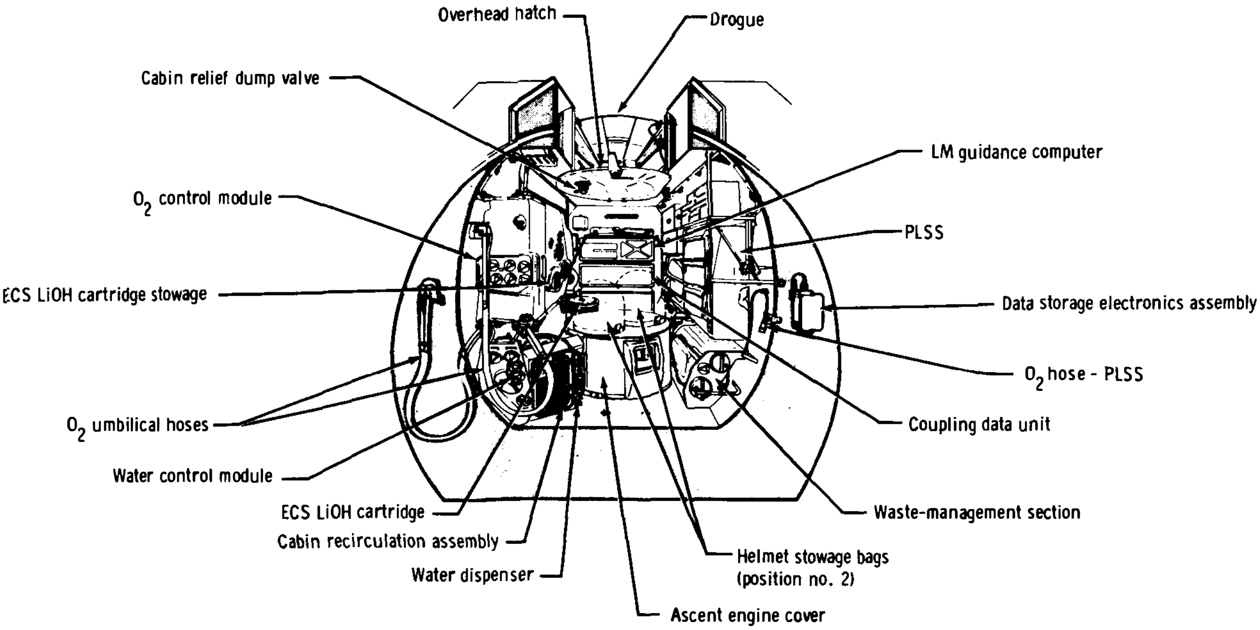


Figure 23. - Location of stowed items in LM, looking aft.

FLIGHT GARMENTS

The inflight coverall garment (ICG), the CWG, the biological-isolation garment (BIG), and the PGA represent a crewman's wardrobe. The design of these items is a successful compromise of comfort requirements and materials compatibility with the SC environment. Discussion of the PGA is not included in this report.

Inflight Coverall Garment

The ICG is a three-piece flight suit consisting of a jacket, trousers, and a pair of boots. The ICG is designed to be worn over the CWG whenever the PGA is not worn. The wearing of this suit has become the normal mode during extended Apollo missions.

Because the ICG is worn extensively, it must satisfy these requirements: (1) to provide comfort, (2) to have a pleasing appearance, (3) to be fabricated from nonflammable materials, (4) to be designed so that conventional equipment can be used to fabricate the garments, (5) to be physiologically compatible with the crewmen, (6) to interface with the CWG, and (7) to provide passthrough and attachment for the bioinstrumentation systems. The basic concept of the ICG has not changed substantially throughout the Apollo Program; however, fabric changes have been numerous. The first garments designed for Apollo flight were constructed of 4190B Beta cloth; however, for reasons of durability, the material was changed to Teflon-coated Beta cloth. When the crewmen reported discomfort caused by skin irritation, the jackets were lined with Nomex. The problem of skin irritation persisted, and the material was again changed — this time to woven Teflon fabric. Teflon inflight coverall garments have been used on every Apollo mission.

To facilitate bioinstrumentation compatibility, the earliest ICG designs incorporated "passthroughs" for the bioinstrumentation, mating with passthroughs on the CWG. A later modification incorporated an opening to accommodate redesign of the lightweight headset. The boots, also fabricated of Teflon fabric, are designed to incorporate a circle of Velcro hook in the sole to facilitate walking in zero gravity.

The Teflon three-piece ICG has performed well. The only suggested change is related to the Velcro-fastened front flap in the box-type leg pocket. Replacement of the Velcro closure with a zipper is being considered.

Constant-Wear Garment

The CWG is a one-piece cotton-knit garment that provides cover for the torso and feet, but leaves the lower arms bare. It is designed to be worn under either the PGA or the ICG. Worn next to the skin, the CWG must be snug but comfortable, must provide warmth, and must provide for absorption and transpiration of skin wastes. Two garments are provided for each crewman. Design of the CWG includes provision for attachment of the bioinstrumentation leads and skin sensors. Slit openings provide for elimination of body wastes, whether the crewman is suited in the PGA or in the ICG.

The CWG is fabricated from cotton knit and has a biobelt attachment sewn to the midriff of the undergarment. The CWG buttons up the front. The sleeves are short to prevent bunching. Socks are attached to the CWG for warmth and to prevent the CWG from "riding up" when the PGA is donned.

Minor modifications to the original design relate to biobelt snap locations and accommodations for bioinstrumentation passthrough. These garments meet all Apollo Program requirements for comfort and wearability. The only inflight problem was an insufficient opening of the back flap. A complete front-to-back opening, secured with Velcro, snaps, or a button, depending upon the crewman's preference, provided the solution. This simple but effective garment has been used successfully throughout the Apollo Program.

Biological-Isolation Garment

The BIG — a nonflight garment — is a one-piece, completely integrated garment that incorporates shoes, gloves, and hood. The garment is designed to contain the crewman and to prevent any possible contamination of the outside environment by lunar materials. Isolation garments are worn by the crewmen and the recovery teams until the crewmen are safely within the recovery van.

The BIG is required to contain or prevent contamination by 98 percent of all particles 0.45 micron or larger. It must maintain thermal balance at a work rate of 500 Btu/hr at sea-level ambient conditions. It is fabricated of lightweight, porous material and requires no ground-support cooling. Filters to screen out particles are provided in the BIG mask design.

Following extensive materials evaluation, a high-density cotton fabric was used to fabricate the BIG because it (1) meets the requirements for microbiological containment,

(2) swells when wetted, thereby waterproofing the suit, and (3) has good breathing properties, essential to a completely closed garment system.

Two BIG types have been fabricated. One type, worn by the returning lunar crewmen, filters the air breathed out; the other, worn by the recovery team, filters the air breathed in. Because the integrated gloves are fabricated of latex, fabric overgloves are provided with the BIG to preclude tearing or snagging, thereby maintaining the biological isolation.

The BIG was used successfully after splashdown of the Apollo 11 spacecraft. The crewmen donned the garments in the recovery raft with a minimum of difficulty. No difficulties were encountered with breathing, excessive body heat, or mobility. The BIG, as designed, is adequate to meet Apollo mission requirements for biological containment.

EQUIPMENT MANAGEMENT AND CONTROL

The Apollo Program control guidelines are used for design, development, testing, and delivery of crew equipment. All standard reviews are incorporated in the Apollo Spacecraft Program Office planning; additional disciplines, unique to crew equipment, are used to derive and ensure flight-ready hardware. Basically, these disciplines use hardware interfaces to verify mission requirements. Specific, sequential steps are included in design and verification.

Interface Control Document

The ICD contains the requirements for mating-equipment compatibility, the stowage envelope, the special restrictions for installation and environment, and the electrical and functional constraints. The ICD is the controlling document for the equipment suppliers. The interfaces described by the ICD are contractual, and, by this method, each supplier is assured of notification or negotiation if later changes are necessary.

Equipment functional verification is accomplished by using KC-135 jet aircraft zero-gravity parabolas and water-tank controlled buoyancy. This type of testing allows study of the equipment performance in a simulated zero-gravity environment. Each medium is necessary and complements the other. The flights are restricted to approximately 25 seconds, but allow sequence demonstration. However, the water-immersion tank allows uninterrupted sequence training by using controlled buoyancy of the crewmen and equipment, thus providing for hardware confirmation.

Mockup Reviews

Each item of crew equipment, stowed or installed, is verified for fit and function by using a simulated SC (a mockup). The mockup is continually updated to reflect mission requirements. Any stowage or operating problem will be revealed by using this method. The mockup must reflect the configuration precisely and must be "full up" at the time of each review.

Bench Checks

The flight equipment is reviewed by crewmen and support-team engineers in a clean room before installation in a flight vehicle. The review comprises an accountability of each item by part and serial number, based on a controlled stowage list; visual inspection for damage; and a briefing of the crewmen on any peculiar aspects of an item.

Crew-Compartment Fit and Function Review

The CCFF review in the flight vehicle is the most significant review prior to vehicle chamber tests. The CCFF is the first review with all flight equipment installed and stowed in the flight vehicle. The test, a vehicle-controlled checkout test, is conducted by the suited prime and backup crewmen and is performed in accordance with an operational checkout procedure. All equipment is reviewed for fit and function and then compared to the enveloping vehicle constraints. Equipment discrepancies that must be closed out before SC shipment and before flight are recorded during the CCFF review.

CONCLUDING REMARKS

Crew equipment items are continually changing. Design concepts of the early Apollo Program have become obsolete with the development of new materials and manufacturing techniques. In addition, mission requirements have necessitated minor changes, as well as some complete redesign, in most crew equipment items. Technology developments will continue to change hardware design to provide more reliable and economical crew equipment.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, October 15, 1971
914-50-80-04-72

REFERENCE

1. Anon.: Apollo Operations Handbook, Block II Spacecraft. Vol. I, Spacecraft Description. Document No. SM2A-03-Block II-(1), Contract NAS 9-150, Jan. 1970.

APPENDIX A

ALPHABETICAL LISTING OF EQUIPMENT

APPENDIX B

ABBREVIATIONS AND ACRONYMS

BIG	biological isolation garment
CCFF	crew-compartment fit and function
CCU	crewman communications umbilical
CDR	commander
CM	command module
CNR	carboxy-nitroso rubber
CO_2	carbon dioxide
COAS	crew optical alinement sight
CWG	constant-wear garment
DCD	defecation-collection device
DOD	Department of Defense
ECG	electrocardiogram
ECS	environmental control system
EMU	extravehicular mobility unit
EVA	extravehicular activity
FCA	fecal-collection assembly
FCS	fecal-collection system
ICD	interface control document
ICG	inflight coverall garment
LEB	lower equipment bay
LH	left hand
LHEB	left-hand equipment bay
LM	lunar module

LWHS	lightweight headset
MAK	medical accessories kit
MDC	main display console
MSC	Manned Spacecraft Center
MWD	metering water dispenser
O_2	oxygen
PBI	polybenzimidazole
PGA	pressure garment assembly
PLSS	portable life support system
PLV	postlanding vent
PVC	polyvinylchloride
QD	quick disconnect
RH	right hand
RHEB	right-hand equipment bay
SC	spacecraft
UCTA	urine-collection/transfer assembly
UTS	urine-transfer system
WD/FE	water dispenser/fire extinguisher
ZPN	impedance pneumograph

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