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EVALUATION OF THE CREW - COMMAND MODULE POSTLANDING INTERFACE

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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EVALUATION OF THE CREW - COMMAND MODULE POSTLANDING INTERFACE

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SUMMARY

Three separate test series were used to evaluate the postlanding interface between the crew and the command module: (1) postlanding-systems qualification tests, (2) water-egress-procedures developmental tests, and (3) flight-crew water-egress training. These tests permitted investigation of all crew and command module postlanding-interface areas which included systems, crew equipment, stowage, and egress.

Crew capability to detect uprighting system failures and in most cases, to take remedial action was demonstrated. Crew reposition, to effect a spacecraft uprighting, was shown to be safe and effective. Further testing is indicated to determine the reasons for uprighting compressor noise-level changes and to determine the desirability of maintaining only the lower noise level during uprighting for reasons of crew comfort.

The Block II forward unified hatch was demonstrated to be capable of permitting a Stable II egress. This lifted a flight constraint from the Apollo 8 mission.

The postlanding ventilation system performed adequately during the high-humidity in-tank test with command module 007A. However, the recent addition of a couch-strut lockout device compresses the airflow duct. Further testing is indicated to determine if air flow is appreciably compromised.

Spacecraft Stable II attitude photographs with one-bag inflations indicate that a side crew-hatch egress may be feasible for a single y-bag inflation. Single z-bag-side crew-hatch Stable II egresses are not recommended because the hatch is partially under water, and immediate flooding would result if the hatch was opened.

Night egress was demonstrated to be feasible for both the Stable I and Stable II attitudes if flight penlights are available. Further

testing is indicated to determine if the new cyclic couch-strut lockout devices interfere with a Stable I egress.

INTRODUCTION

To evaluate the total crew and command module postlanding interface and to permit flight crews to gain valuable operational experience with postlanding hardware, a series of tests was defined which encompassed the postlanding-systems qualification tests, water-egress-procedures developmental tests, and flight-crew water-egress training (fig. 1).

Postlanding-systems qualification tests were conducted in command module 007A. The major portion of the tests consisted of a 48-hour period in which the spacecraft floated freely at sea. Crewmen on this test were astronauts Jim Lovell, Commander; Stuart Roosa, Command Module Pilot; and Charles Duke, Lunar Module Pilot. Although this test qualified spacecraft postlanding systems, it also provided a means of evaluating the postlanding interface between the crew and the command module for a 48-hour postlanding period.

In the water-egress-procedures developmental tests, the water-egress flight checklist was reviewed, updated, and performed by using the training boilerplate 1102A and by using test subjects from the Flight Crew Support Division. These tests presented a means of evaluating the ability of the Block II command module to facilitate a safe and rapid egress for any postlanding contingency. Pertinent details taken into account included loose equipment stowage, acquisition and deployment of survival gear, and proper handling of spacecraft hatches. This test series also included an investigation of crew reposition as a method of effecting an uprighting in the case of a one-bag failure. Test objectives incorporated the determination of crew procedures and the evaluation of crew vulnerability to injury in executing these procedures.

Flight-crew water-egress training is composed of 2 days of testing for each primary and backup crew on any designated mission. The first day includes briefings to the flight crew on postlanding systems, hardware, and procedures. These briefings are followed by two fresh-water training exercises, including both Stable I and Stable II egresses. Also, postlanding procedures are performed in the egress-training boilerplate 1102A. The second day is spent at sea in the Gulf of Mexico, where postlanding procedures and egress procedures are operationally performed. Crew debriefings provide information on hardware and procedures (fig. 2).

TEST VEHICLES AND FACILITIES

Command module 007A — built by North American Rockwell — contains all Block II spacecraft postlanding systems. During the 48-hour sea test, this vehicle was in the command module 101 configuration with the following weight and center of gravity: the weight = 11 779 pounds and x = 38.41, y = 0.27, and z = 4.79. The systems and equipment on command module 007A included the uprighting system, the postlanding ventilation system, spacecraft recovery aids (very high frequency (vhf) recovery beacon, flashing light, sea dye, grappling hook, survival radio, and swimmer interphone), vhf/amplitude modulation (AM) communications, and survival equipment.

Boilerplate 1102A, built by the Landing and Recovery Division at the Manned Spacecraft Center, contains all Block II postlanding systems. These systems closely represent the actual spacecraft — audibly, visually, and tactually. The crew compartment includes flight-item-unitized couches; stowage areas A_1, A_8, U_3, R_4, B_3, B_6, A_2, and B_7; emergency oxygen and repressurization system mockup; pressure-garment-assembly stowage bag; flight-type oxygen umbilicals; postlanding lights, switches, and circuit breakers; main display console with dummy switches, switch guards, and other protrusions; and Block II steam-vent duct mockup. Stowable items in the boilerplate included a flight toolkit, the postlanding ventilation ducts, a grappling hook, and the flight-configured survival kits.

The boilerplate hatches simulate the hatches for command module 101, both in operation and in appearance. The side crew hatch is operated by using a hydraulic gearbox with selector pawls for latching and unlatching. A pressure-actuated counterbalance system aids in hatch operation. Forward hatches are similar in weight to flight items. Actuation torque values were adjusted on the forward hatches to match those of command module 101. A flight-configured forward unified hatch was used for command module 101 post-tests.

The boilerplate contains an uprighting system similar in operation to the flight article but which uses tanks of compressed air rather than a compressor. The airflow to the uprighting bags is adjustable to obtain spacecraft uprighting time. Spacecraft compressors are acoustically duplicated by two motor noisemakers.

Boilerplate 1102A was configured to the following weight and center of gravity: the weight = 11 740 pounds and x = 39.3, y = 0.1, and z = 4.1. Because uprighting characteristics of boilerplate 1102A are slightly different from those of a command module, these values were obtained by matching the boilerplate uprightings to the command module;

thus, the values are slightly different from those of command module 101. The Stable II flotation attitude of boilerplate 1102A is shown in figure 3.

Water Tank Facility

A fresh-water tank is located in building 260 at the Manned Spacecraft Center. The tank is 16 feet in depth and 24 feet in diameter.

Motor Vessel "Retriever"

The "Retriever" is a converted landing craft utility (LCU) which was modified for use as an open-sea test facility. It includes a boom crane capable of placing test vehicles into the water and retrieving them.

DESCRIPTION OF TESTS AND RESULTS

Uprighting

Nominal.- Two stable water attitudes are concomitant with the present location of the center of gravity of an Apollo command module. These are Stable I with the apex up and Stable II with the apex down. The apex-down attitude is undesirable because of a lack of ventilation and a safe-egress capability; thus, bringing the spacecraft from the apex-down attitude to an apex-up attitude and maintaining it in this upright attitude is an important part of the postlanding period. The spacecraft uprighting system includes two 43-inch-diameter bags and one 34-inch-diameter bag located on the upper deck, three bag solenoid switches, three bag solenoid circuit breakers, two air compressors, and two compressor circuit breakers.

The Apollo postlanding-systems qualification test with command module 007A included a normal three-bag uprighting at sea and several failure-mode (two bags) uprightings in the calm-water test facility. These tests demonstrated the capability of the crew to detect failures in the system. The crewmembers can readily determine when a bag has failed. The side-window mirrors allow visibility of the left or right bag approximately 2 minutes after it has begun to inflate. Without using the mirrors, a failure can be determined by a definite roll toward the side of the failed bag. If the center bag fails, there is no roll; but the command module does not upright within the normal time of 7 minutes. Bag failures can also be detected by streams of air bubbles rising near the side windows. Compressor failures were readily detected because of the separate locations — the left side and the right side of the command module. When a compressor fails, noise emits only from one side of the command module. The sound pressure of the air compressors measured in the closed spacecraft varied between 96 and 99 decibels reference 0.0002 microbar. Although this is below the threshold of pain (120 decibels reference 0.0002 microbar) (ref. 1), it is in the region of high annoyance and severely impairs conversation.

During the nominal three-bag uprighting of the postlanding-systems qualification test (at sea), the crew noted that a considerable reduction of compressor noise occurred when the command module reached approximately 90° pitch attitude. During later one-bag failure-mode tests, this noise reduction occurred within 1 minute of the uprighting sequence initiation. This reduction is estimated to be approximately 20 decibels reference 0.0002 microbar and brings the cabin noise down to a level much more conducive to conversation. Although the change in compressor noise appears to be related to system backpressure, further testing is necessary to determine the precise cause. Testing might also determine the desirability and feasibility of maintaining only the lower noise level during uprighting for reasons of crew comfort.

Crew reposition.- The one-bag failure-mode tests with command module 007A demonstrated that uprighting was only marginal for this case. To ensure an uprighting with a single-point failure, the technique of crew reposition was developed. In this technique, one or more crewmen must move from the crew couch to a position which causes a favorable center-of-gravity shift and thereby effects an uprighting. When two crewmen reposition, the change in the command module center of gravity can be as great as 1 inch which is a significant change. Crew safety was of major concern in the technique development. Motions of varying magnitude can be imparted to the crewman, depending upon the location of his repositioning. The closer the crewman is located to the pivot point of the uprighting, the less will be his motion. It was determined that a crewman wearing a pressure-garment assembly with its large neck ring and bulky fabric is adequately protected during his reposition movement except when he is caught in a head-down attitude during uprighting. At the completion of the uprighting, the crewman should be sitting in the lower equipment bay or lying on the aft bulkhead. It is highly desirable for the crewman in motion to know the moment when the command module begins to upright. This helps the crewman to avoid a head-down attitude. Repositioning should only be attempted after complete bag inflation because a one-bag failure does not preclude an uprighting. Operational crew training can provide sufficient familiarity with uprighting and crew reposition to ensure crew safety.

Uprighting tests with boilerplate 29 and command module 007A have shown that, unless the failed bag is shut down in an open-line bag failure, the remaining bags inflate at a slower rate and do not completely inflate. To eliminate this problem, the failed bag should be shut down as soon as the failure is recognized. The crew can determine when the remaining bags are inflated by listening for the bag relief valves which produce a gurgling noise when unseated. The center bag which has the smaller diameter is the first to fully inflate. When a crewman recognizes a relief valve unseating, he can turn off that bag, thereby increasing the inflation rate of the remaining bags.

During the development of the repositioning technique, the crewman had to be able to relate a given bag switch to a particular bag to facilitate the shutting down of a failed bag or a completely inflated bag. At that time, the uprighting bag switches were numbered one, two, and three which did not relate a switch to a bag. A change to the spacecraft switch nomenclature was requested — from numerals to left, right, and center of L, R, and C. This change, which would adequately relate a switch to a bag, was accepted and made to command module 101 and subsequent command modules.

Hatches

The changes in the Block II side crew hatch have enhanced a safe and rapid egress capability. Emergency egress times have been cut from approximately 2 minutes to less than half a minute. With crewmen now reentering without pressure garments, egress rapidity has probably been maximized for postlanding. Only an explosive hatch or major structural changes could further reduce the egress time.

Only one minor problem, which was related to the side hatch, arose during the water-egress-procedures developmental test series. This was the accidental unstowing of the extravehicular activity (EVA) D-ring. The EVA D-ring is attached to a line and is used from the inside of the command module to unlatch and to close the side hatch to prevent exposing the crewman to solar radiation. The D-ring is normally stowed in a machined piece of Teflon. After several unstowings, the Teflon becomes stretched and does not adequately hold the D-ring. Several times during tests, when the side hatch was opened by using the counterbalance, the D-ring came unstowed and caught on the inner lip of the hatch frame. This permitted the hatch to open only approximately 70°. The situation is easily remedied by pulling the hatch inboard and by releasing the D-ring. However, in an emergency, this could cut valuable seconds from egress time.

The significant difference in the forward hatches of command module 101 and the unified forward hatch of command 103 necessitated testing with both configurations. Two forward hatches were used in command module 101 — the ablative hatch (50 lb) at the outer extreme of the command module tunnel and the pressure hatch (28 lb) at the inner extreme of the command module tunnel (figs. 4 and 5). S me difficulty was encountered in the unlatching of these hatches. After unstowing the handle, the crewman had to rotate the handle while depressing a lockout button with his thumb. On the ablative hatch (where movement is restricted because of the tunnel diameter and pressure-garment bulkiness), unlatching was a problem, especially for the small-handed crewman. Because this hatch is only removed in the event of an emergency Stable II egress, both hands could be used for the unlatching, and the hatch simply could be permitted to sink (fig. 6).

Emergency Stable II egress is performed by flooding the tunnel area, by removing the ablative hatch, and by exiting through the tunnel and up to the surface of the water. Flooding the tunnel equalizes the pressure across the hatch to permit a safe removal of the hatch. The command module 101 configured forward ablative hatch did not contain a dump valve. To flood the tunnel on command module 101, it would have been necessary to open the postlanding ventilation valves on the upper deck. A test was defined and performed to determine if the command module 101 forward hatches could be opened against 6 feet of water pressure in the event of a postlanding ventilation-valve failure. Also, data were obtained on the torque needed to open these hatches against a waterhead. The latter data were used to adjust the operating force of the mockup hatches in the water-egress trainer, boilerplate 1102A. Results showed that the operating torque of the ablative hatch with a 6-foot waterhead was 93 inch-pounds — well within the specification maximum of 175 inch-pounds. The pressure hatch required 93 inch-pounds under identical conditions — well within its 150-inch-pound specified maximum.

A single forward unified hatch has been adopted to command module 103 and subsequent command modules. This hatch is a combination of the command module 101 ablative and pressure hatches. The operation of the hatch is similar to that of the side crew hatch which is operated by using a gearbox and a ratcheting handle. The single forward unified hatch weighs approximately 81 pounds and includes a pressure equalization valve. A test was defined which constrained the Apollo 8 mission to qualify this unified hatch for a Stable II egress. The increase in hatch weight and bulkiness suggested that a crewman might experience excessive difficulty in lifting and stowing the hatch from the tunnel while suited in an integrated thermal meteoroid garment. Test results showed that the hatch, with its long unlatching handle and short stroke, is significantly easier to unlatch underwater than the command module 101 configured hatch. Because the hatch is under water while inside the tunnel, its weight is reduced to 29 pounds and can be easily lifted. At the top of the tunnel, some interference is encountered with the oxygen umbilicals which protrude slightly into the tunnel envelope. However, by slightly tilting the hatch, it can be lifted past the umbilicals. Outside the tunnel, the hatch can be rolled and stowed in the aft equipment bay next to the couch of the Lunar Module Pilot. If necessary, a second crewman can aid in the hatch removal. The water level inside the tunnel was approximately 3 inches lower than when the postlanding ventilation valves were used to flood the tunnel. The hatch was demonstrated to be adequate for this mode of egress, and the flight constraint for the second manned mission was lifted (fig. 1).

Couches

The couches used in command module 101 differ significantly from those of subsequent command modules. Both configurations were tested, and evaluations were made concerning crew comfort during a 48-hour postlanding period and concerning couch interference during egress.

The 48-hour command module 007A sea test demonstrated the adequacy of the command module 101 unitized hard couch. During the test, couch comfort was enhanced by placing all three seat pa. in the 180° position and by using panels or stowage boxes to extend the couch to the aft equipment-bay wall for lower leg support. With the foldable headrest, these couches allowed some mobility in the area between the head of the couches and the side hatch. The couch struts did cut down on crew mobility during egress by forcing the two side crewmen to move to the center couch to egress from the side hatch.

The foldable crew couch, which is on command modules subsequent to command module 101, was evaluated in a series of tests with the egress trainer boilerplate 1102A. Testing indicated that these couches were significantly easier to operate than the unitized set flown on command module 101. Although the total weight of the sets of couches are approximately equal, the individual foldable couch is significantly lighter and thereby easier to handle. This is apparent in the seat pan of the unitized couch which is difficult to operate in one g because of its weight.

The nonstowable headrest and protruding frame of the foldable couch significantly reduce the working area available between the head of the couch and the side crew hatch. Even the crewman without a pressure-garment assembly finds it difficult to stand in this area to remove the side-hatch dump valve for grappling hook deployment and for normal hatch opening.

The cyclic struts developed for command module 103 and the subsequent command modules include a lockout device which is unlocked on main chutes. Because of the bulkiness of the lockout device, questions have arisen as to possible egress interference. Although any interference is thought to be minimal, mockup units have been ordered; and tests will be initiated to evaluate egress envelope interference.

Switches and Circuit Breakers

Testing in boilerplate 1102A and command module 007A has shown that the center (Command Module Pilot) and right-hand (Lunar Module Pilot) crewmen are unable to reach the uprighting bag switches when strapped in their couches. However, crew reposition tests have demonstrated the capability of a crewman to control his movements inside a spacecraft in nominal sea states (3 to 5 ft). Because reentry is now performed without pressure garments, a crewman has the mobility and capability to unstrap, to move across the spacecraft, and to operate the uprighting system while in the Stable II attitude.

Cabin Lighting

Postlanding cabin lighting is supplied by two floodlights. One floodlight is located above the head of the Commander near the rendezvous window; the other floodlight is located at the head of the crew couches between the Commander and the Command Module Pilot. These lights provide excellent illumination for the majority of postlanding switches, namely the main display console panels numbers 8 and 15. Only one of the areas containing the postlanding circuit breakers is poorly illuminated. This is panel number 250 which is located in the lower right-hand equipment bay and contains the following circuit breakers: circuit breaker pyrotechnic A sequence A, circuit breaker pyrotechnic B sequence B, battery A power entry and postlanding, battery B power entry and postlanding, and battery C power entry and postlanding (appendixes A and B). Although illumination in this area is poor, it is felt that the appropriate crewman is familiar enough with these circuit breakers to know their location, or the flight penlights may be used to overcome difficulties.

Prior to the Apollo 8 mission, two tests were conducted to determine problem areas associated with night egress. Both Stable I and Stable II emergency egresses were performed from boilerplate 1102A in the test tank facility. All building lights were turned off.

The Stable I test demonstrated the adequacy of the cabin lighting for emergency night egress. Slight problems were encountered when deploying the raft and when egressing into the raft because of loss of night vision when looking back into the cabin. Cabin penlights were useful particularly in raft deployment and raft ingressing. A penlight taped to the side hatch would aid the crewmen when entering the raft and when observing hatch movement.

The Stable II test demonstrated the adequacy of cabin lighting for this mode. The crew did obtain some minimal lighting on the surface from cabin lighting through spacecraft windows. However, it was determined that penlights are necessary for raft deployment. It was recommended that penlights be taped to the wrist of the crewmen to preclude loss of the penlights during surfacing and raft inflation.

Handholds

Except for the tendency of the handholds on the lower edge of the main display console to pinch fingers, all other handholds are sufficient for postlanding crew movement. Although no handholds are located in the lower equipment bay and aft stowage area, crew reposition for uprighting was readily performed by using the z-z struts as handholds, when necessary.

Postlanding Ventilation

Command module 007A was used for qualification tests of the postlanding ventilation system. Tests were conducted at sea and in the Apollo environmental test chamber for the design limit case. Specific test results are available in the Landing and Recovery Division System Test Report 68-219. The tests demonstrated the adequacy of the postlanding ventilation system in maintaining a habitable environment throughout the postlanding phase of a mission.

The first two manned missions have demonstrated the need for a change in procedure in the postlanding ventilation operation. Following both missions, the ventilation valves were left open after powerdown and after crew egress because the main power circuit breakers were pulled before the ventilation switch was turned off. The ventilation valves are motor driven and require a current pulse to close. The procedure should call out the closing of the ventilation valves before powerdown. This problem was pointed out to the Apollo 9 flight crew in a premission recovery briefing. Tests with boilerplate 1102A and command module 007A and mission results have shown that, following an uprighting, sea water is trapped on the upper deck between gussets 3 and 4. When postlanding ventilation valves are opened, this water drains through the valve openings and is either blown on the crew through the inlet valve or runs down the rear of the main display console through the exhaust valve. Although the quantity is small, the problem of salt water corrosion could compromise cabin components for future reuse.

A new type of couch strut has been installed on command module 103 and subsequent command modules which incorporates a lockout device. This device is located on the plus-Z side of the struts and does not appear to pose any restriction to command module egress. However, because the right-hand x-x head strut interfaces with postlanding-ventilation blower ducts, the addition of the lockout device compresses the center duct and appears to restrict flow. The specific effect of the strut change to postlanding-ventilation flow rates has not yet been determined. The use of duct extensions has been shown to aid the cooling effects of the postlanding fan. However, stowage of these three ducts beneath the Commander's couch appears inappropriate. Because the ducts are necessary only during periods of high heat load, the work needed to unstow and to connect the ducts appears to partially defeat the purpose of the ducts. The possibility of attaching the extensions to the molded fan duct (as in Block I) should be reevaluated.

Sea Water Pump

During the postlanding-systems qualification tests with command module 007A, water gushed from the steam-vent line when the steam-vent plug was removed for insertion of the sea water pump. Because command module 007A had a Block I configured steam-vent line, a test was defined by using a Block II configured steam-vent line to determine whether the sea water pump was needed for water ingestion. Test results showed that, even in moderate sea states, water collected in the Block II steam-vent line. This water was easily transferred into the desalting bag without the use of the sea water pump.

During egress training of the Apollo 7 flight crew, an alternate means of deploying the sea water pump was demonstrated. By opening the side-hatch dump valve, the pump line can be deployed between the valve and the valve seat. The pump-line length is adequate to reach the water. This method is much easier than moving beneath the couches, using tool E to remove the steam-vent-line access panel, and using tool B to remove the steam-vent-line plug. Use of the side-hatch dump valve provides an easily accessible penetration and relatively large working area; whereas the working area beneath the couches was confined. If the sea water pump is retained as a stowage item on the spacecraft, it is recommended that it be used through the dump valve rather than the steam-vent duct. For further information, see Landing and Recovery Division System Test Report 69-06.

Grappling Hook

The grappling hook is a device deployed through the side-hatch dump valve to snag a line and to slow the drift rate of the command module. Two problems were encountered in hook deployment during egress training exercises. During removal of the spacecraft dump valve, the torque set screws were extremely difficult to withdraw; and in two cases, the heads of the screws were stripped, which prevented removal. This was remedied by backing off the dump valve one or two turns to reduce the tension on the screws. No problem has been encountered when this procedure was followed. The second problem involved the "captive" screws on the anchor plate of the grappling hook. The anchor plate is mated to the spacecraft by two screws after removal of the dump valve. On two occasions, when flight-item grappling hooks were used, one of the captive screws dropped out of the anchor plate prior to spacecraft attachment. It has not been determined whether loss of these screws was caused by faulty design of the washer retainer, improper handling, or excessive use of the hooks.

Egress

Because of command module changes from Block I to Block II, an egress-procedures-verification test series was conducted, as in Block I (ref. 2). Stable I egress remained essentially the same as in Block I with differences relating mainly to the opening of the new unified side hatch. Stable II egress was significantly altered by removal of the postlanding ventilation valves from the forward hatch in Block I to the upper deck on Block II, by the inclusion of the double forward hatch on command module 101, and by inclusion of the forward unified hatch with integrated pressure equalization valve on command module 103 and subsequent command modules (figs. 7 to 10).

Although Stable I and Stable II egress procedures had been investigated and verified, questions remained concerning the procedure to be used in the case of a partially uprighted spacecraft. Several tests were performed (by using boilerplate 29A) to determine the position of spacecraft hatches in relation to water levels. In each test, only one bag was inflated. Photographs show that a Stable II egress is necessary if only the z-bag inflates because the side hatch remains below the water level. However, in the case of a single y-bag inflation, it appears that a side crew-hatch egress could be performed because in this case, the side hatch is above the waterline. Some questions remain as to whether an uprighting can be effected with one inflated y-bag and with three crewmen repositioning. Further tests would clarify these questions and would determine whether two or three modes of egress are necessary. The boilerplate 29A single-bag attitude is shown in figure 11.

During egress testing, flight-configured survival kits were used. These kits contain survival items such as water, flashing light, sunglasses, raft, radio, sunbonnet, signal mirror, fishing apparatus, and knife. Some difficulties were encountered with lanyard entanglement. This problem is felt to be one of crew inexperience and not a design deficiency of the survival equipment system. Another problem involving loss of carbon dioxide during raft and lifevest inflation was rectified by a design change in the carbon dioxide cylinder plunger-inflation mechanism.

CONCLUDING REMARKS

The Apollo postlanding interface between man and machine has been tested and has been demonstrated to be adequate. Uprighting system failures are detectable by the crew. The crew repositioning technique has been demonstrated to be safe and has shown that the crewmen are capable of controlling their motions in a dynamic command module. Crewmen in the process of repositioning should be warned when the spacecraft begins to upright.

No significant problems were encountered with the hatches. In removing the dump valve for grappling hook deployment, it is advisable to back off the valve one or two turns to ease the tension on the screws.

Foldable couches were more easily operated than the unitized couch of command module 101; the comfort level was equal. Protrusion of the foldable couch frame toward the side hatch restricts movement near the hatch. Further testing is necessary to determine any interference problems — egress or postlanding ventilation — caused by the new cyclic strut lockout devices.

Several postlanding switches are inaccessible to the crewmen when they are strapped in their couches. However, crew reposition tests demonstrated the crew's mobility and capability to control movement in a dynamic situation.

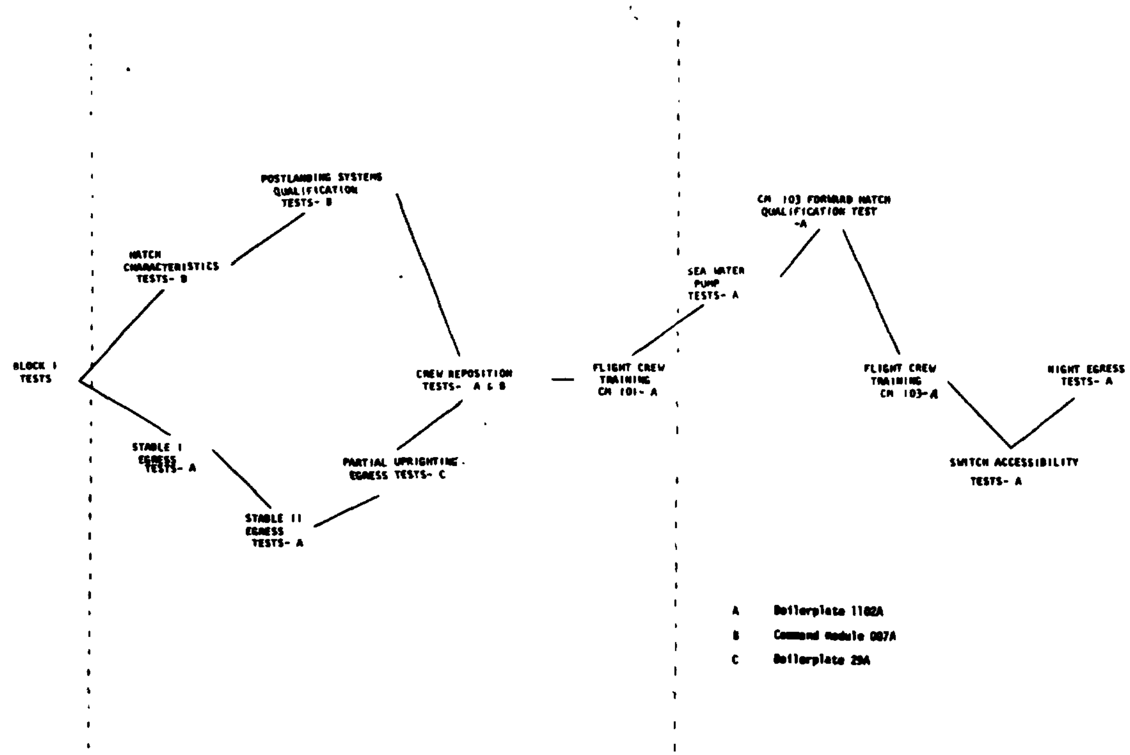
Cabin lighting is excellent for night interior sight. Flight penlights should be made available for possible nighttime egresses.

The sea water pump is not needed to obtain sea water when maintaining cabin integrity because the steam-vent duct acts as a water trap. However, if it is used, the cabin ventilation valve in the side hatch is a more accessible opening.

REFERENCES

1. Bonney, Thomas B; et al.: Industrial Noise Manual. American Industrial Hygiene Assoc., 1966, p. 2.

2. Clancy, Harold J.; and Dailey, Reed M.: Crew Egress Procedures for Apollo Block I Command Module at Sea. NASA Program Apollo Working Paper No. 1213, 1966.



(a) Command module 101 configuration.

(b) Command module 103 configuration.

Figure 1.- Test flow diagram.

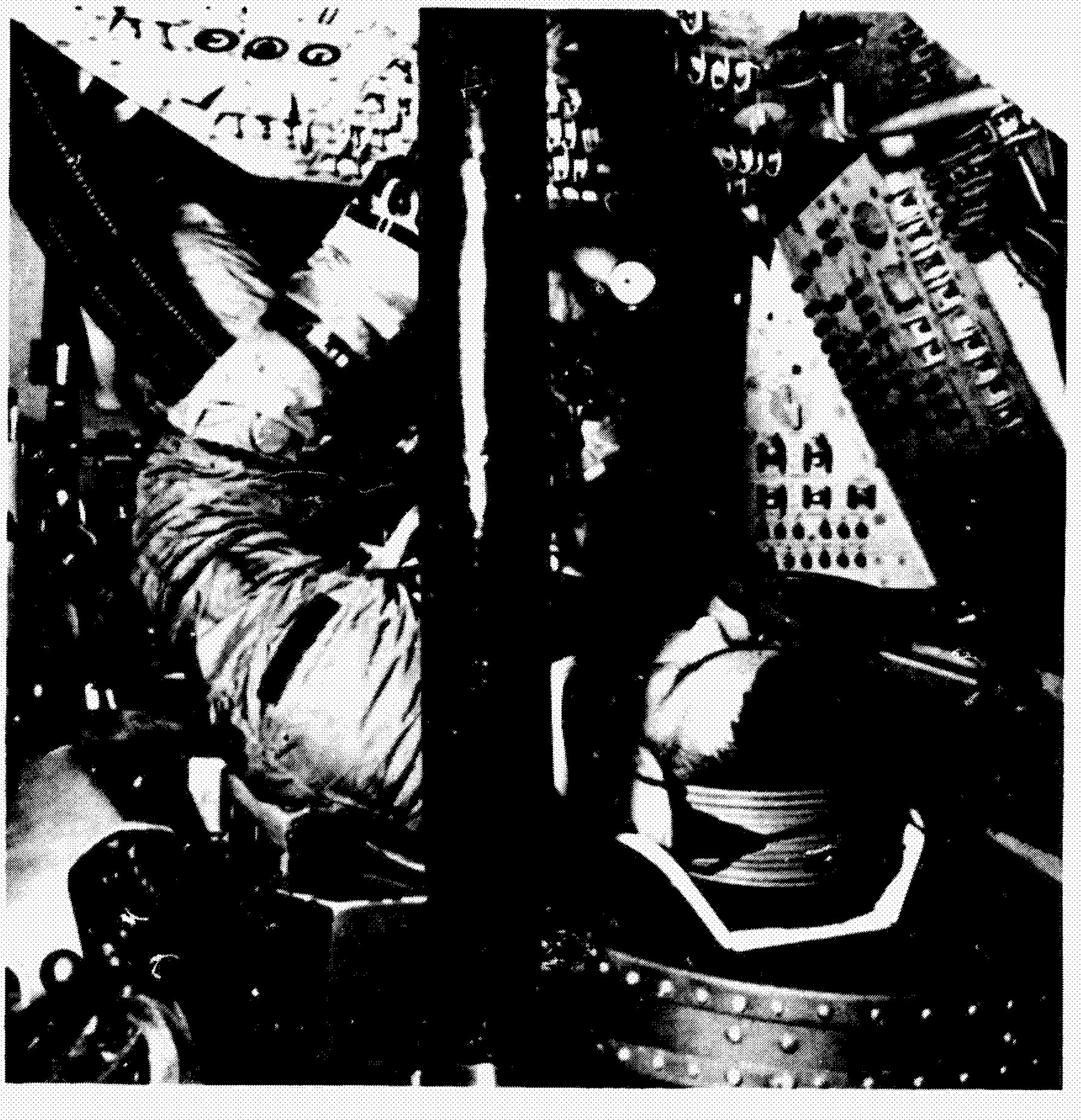


Figure 2.- Boilerplate 1102A interior flight-crew egress-training test.

Figure 3.- Boilerplate 1102A in Stable II.

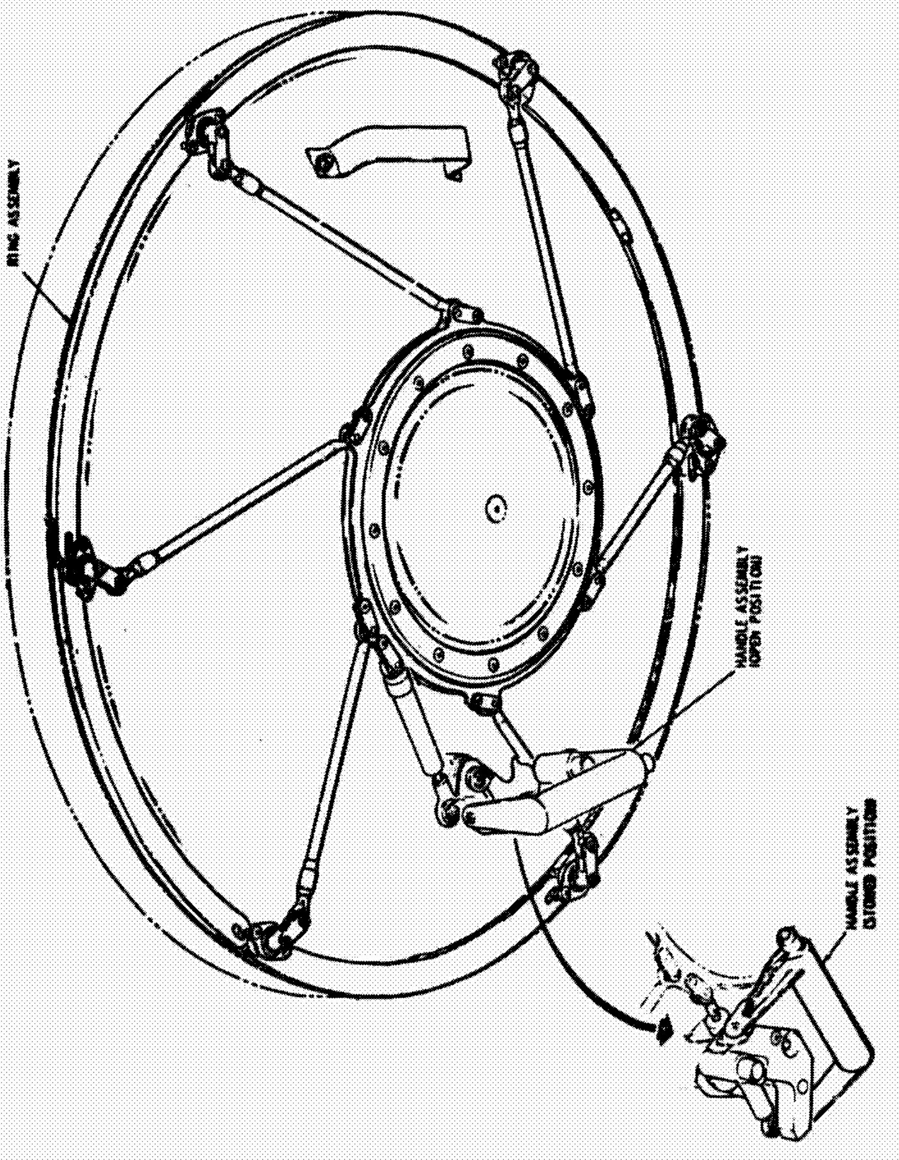


Figure 4.- Ablative hatch (command module 101).

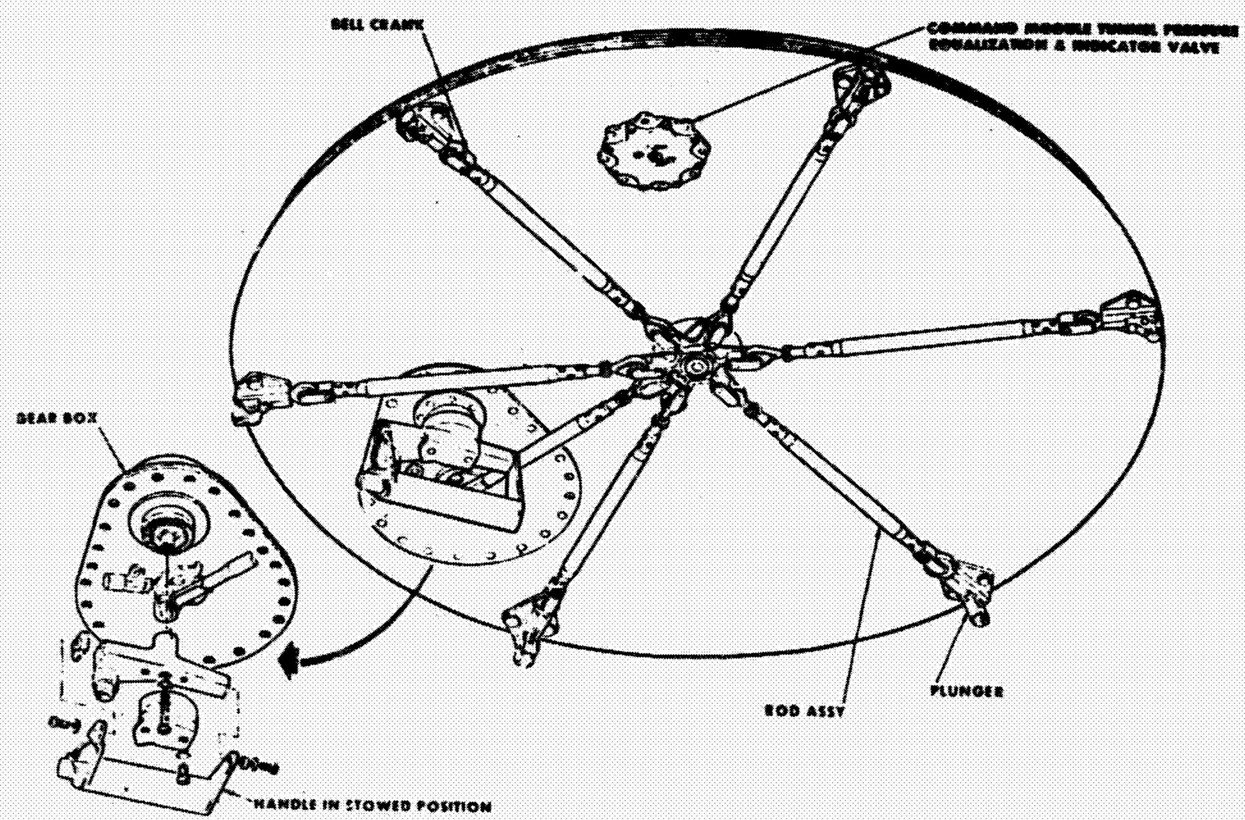


Figure 5.- Forward pressure hatch (command module 101).

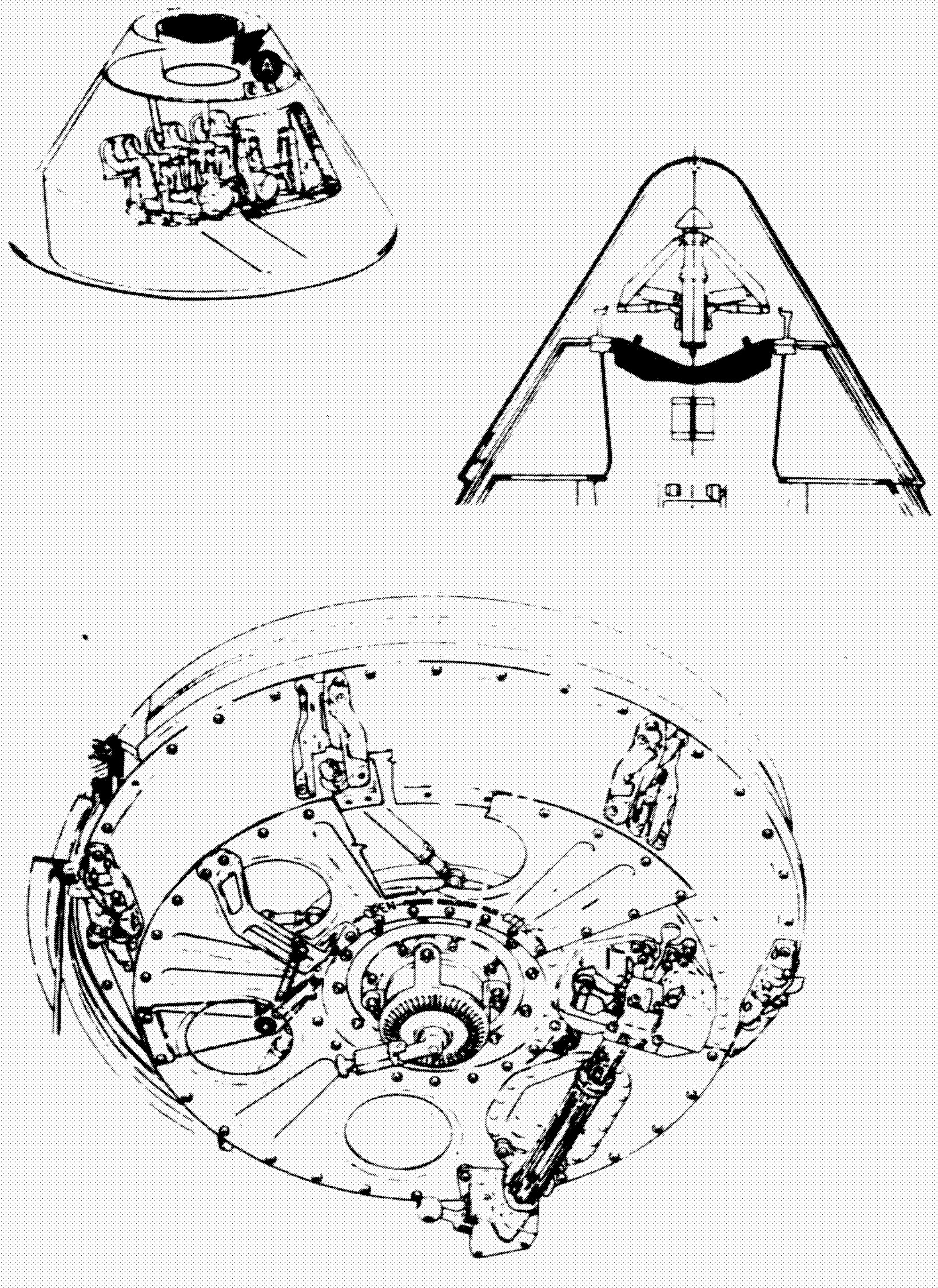


Figure 6.- Combined tunnel hatch.

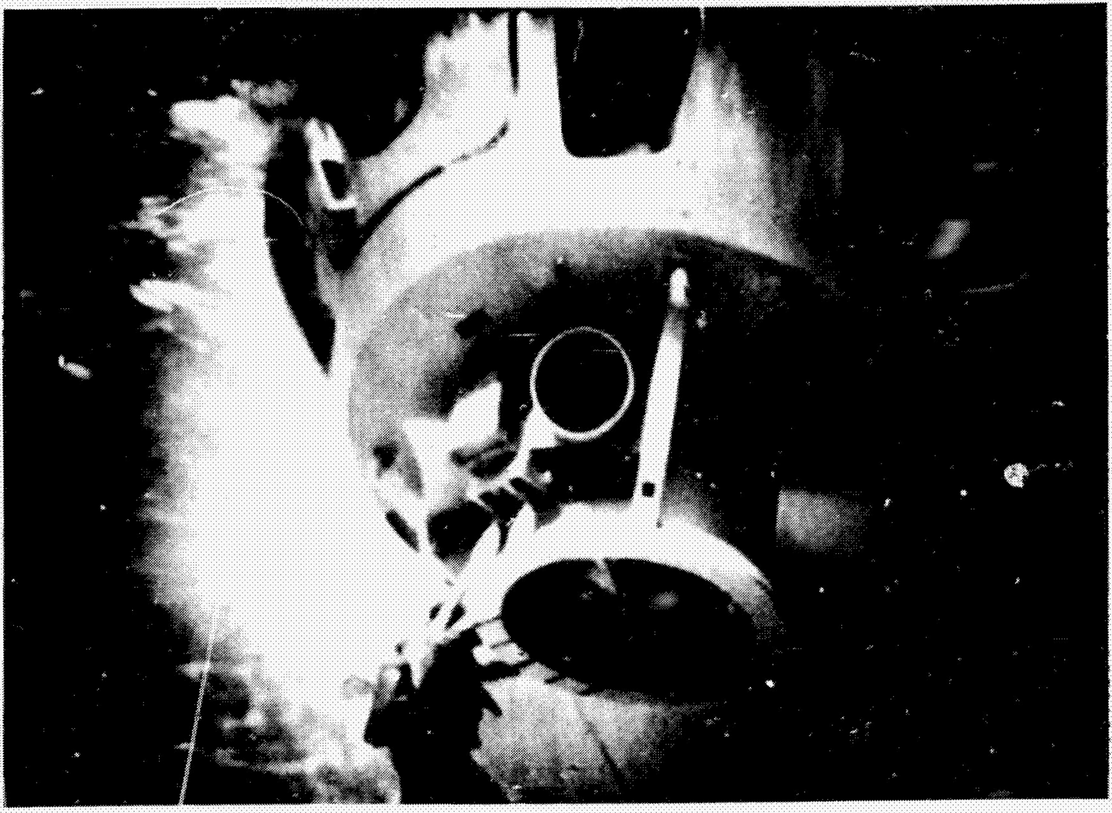


Figure 7.- Command Module Pilot standing in tunnel
(Stable II egress test).

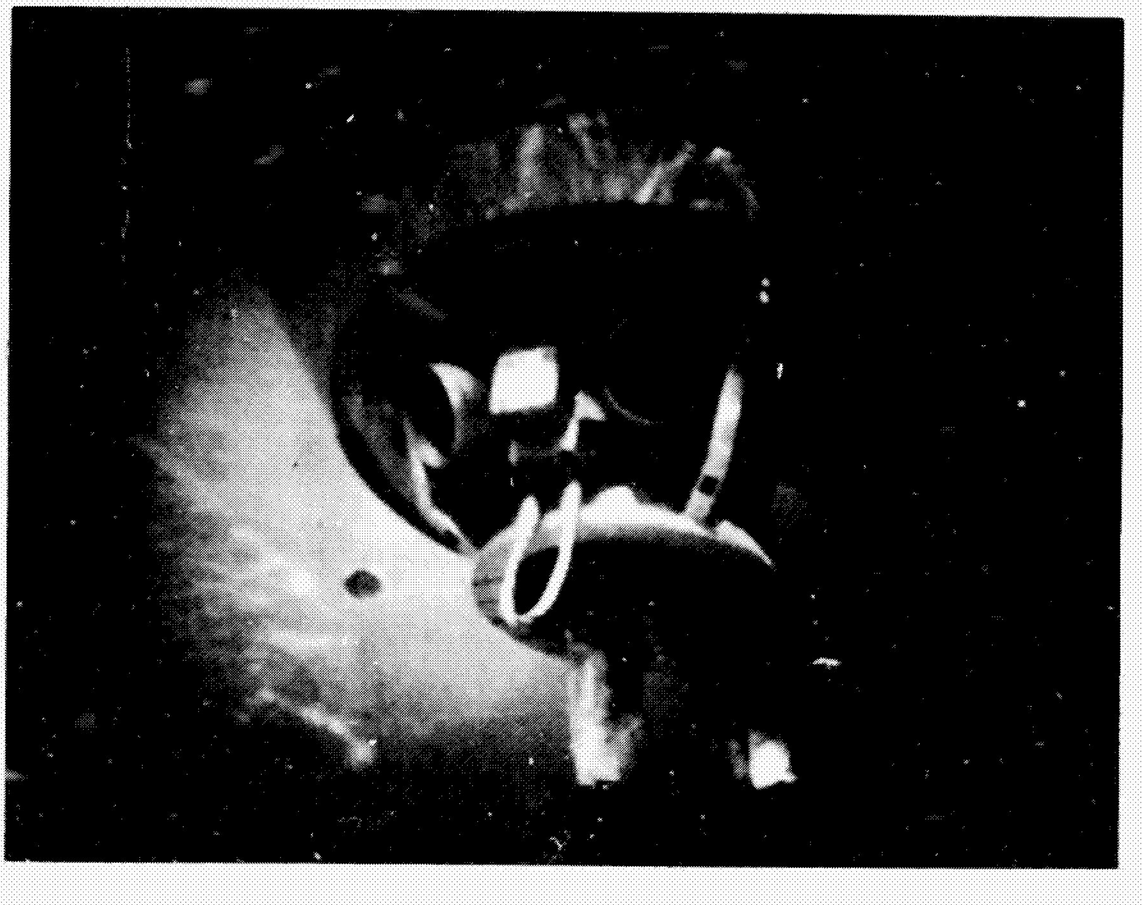


Figure 8.- Hardware rucksack has been dropped; the Command Module Pilot is egressing (Stable II egress test).

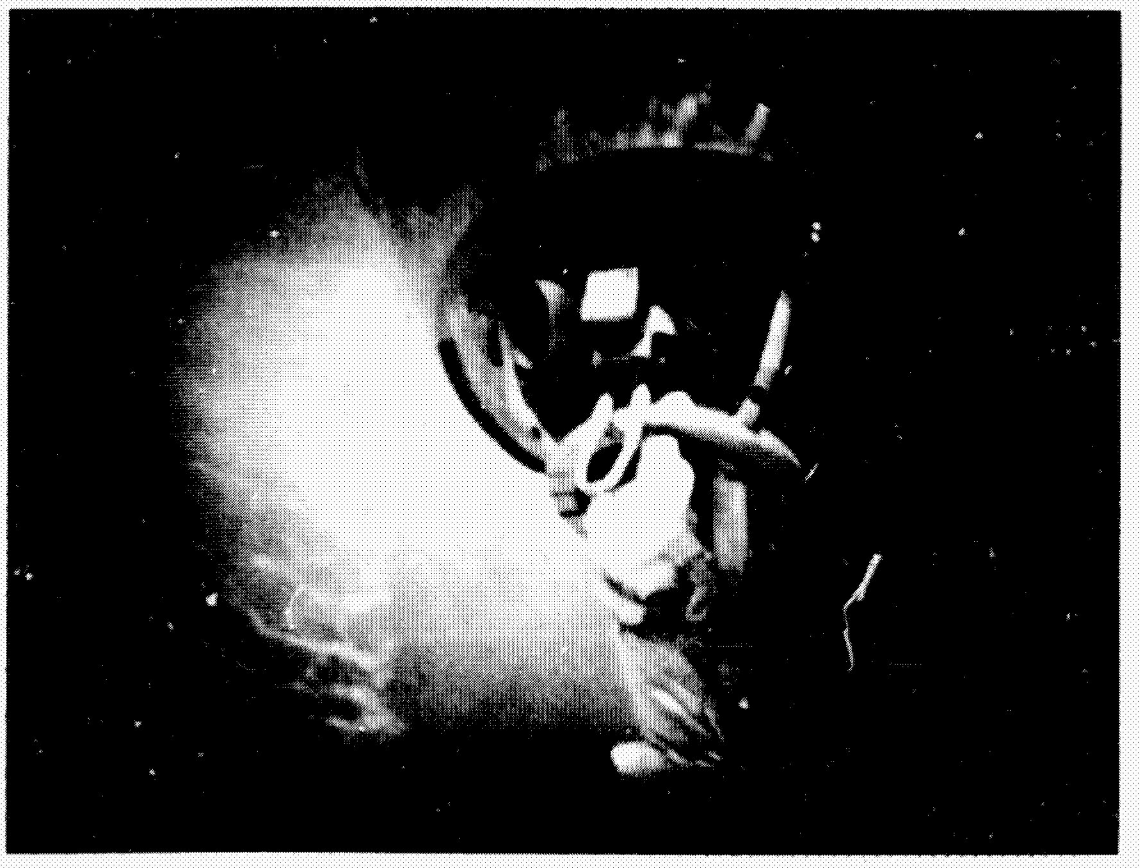


Figure 9.- Command Module Pilot with liferaft rucksack
(Stable II egress test).

Figure 10.- Command Module Pilot rising to surface with liferaft rucksack (Stable II egress test).

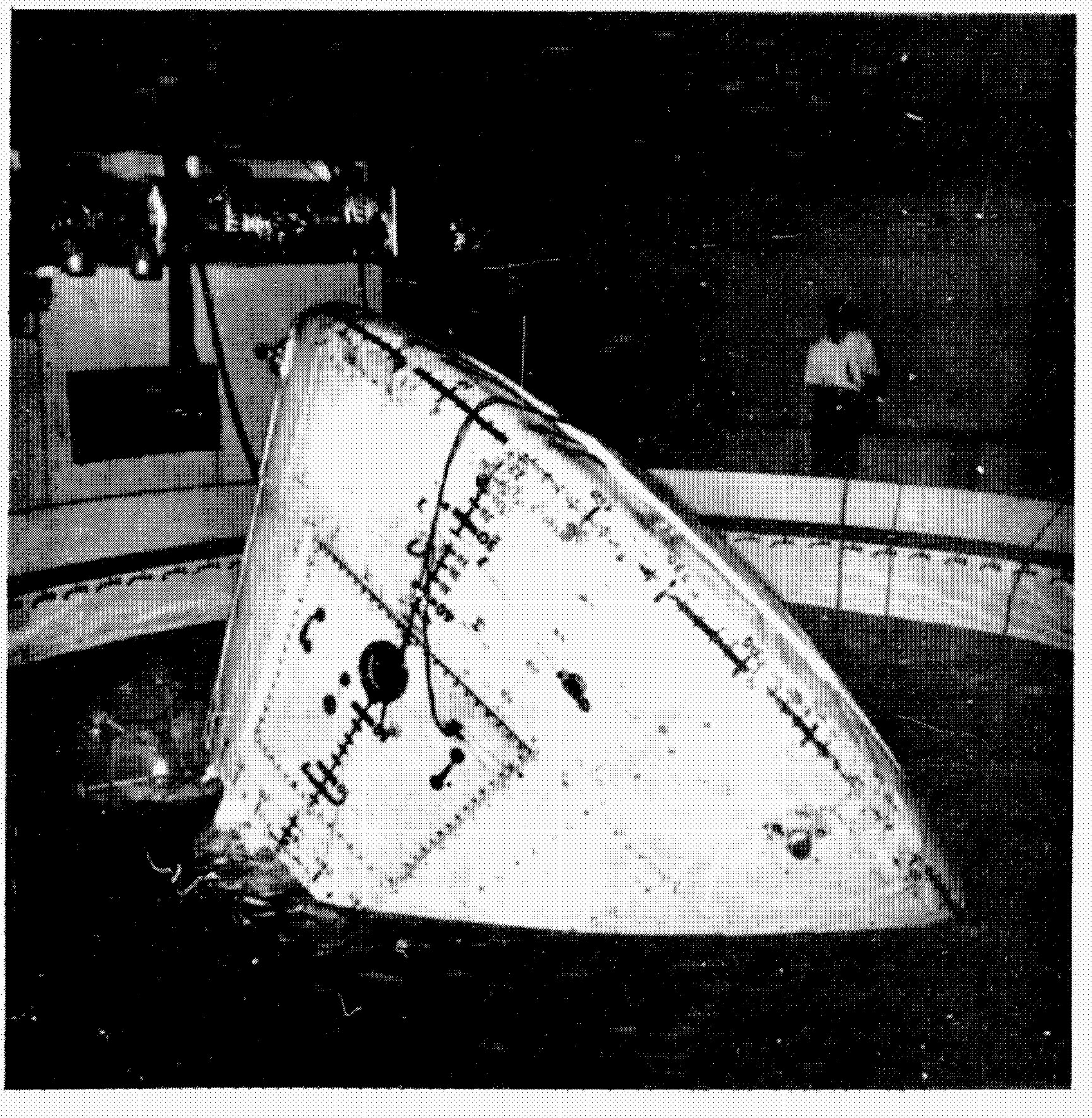
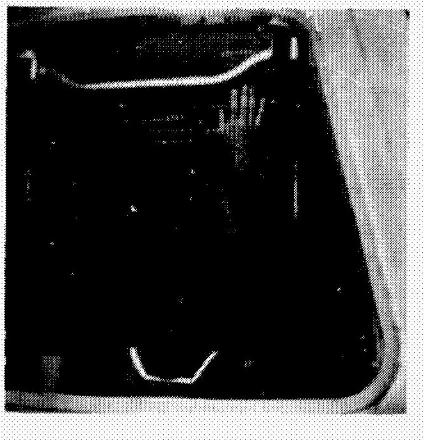


Figure 11.- Single y-bag, partial uprighting; hatch above waterline.

(a) Uprighting bag switch.

(b) Uprighting compressor circuit breaker.

(c) Crew station audio circuit breaker.



(d) Postlanding ventilation-valve lockout T-handle.

Figure 12.- Switch accessibility, nominal water landing.

(a) Postlanding ventilation switch.

(b) Main parachute release pyrotechnic circuit breakers.

(c) Postlanding ventilation-valve lockout T-handle.

Figure 13.- Switch accessibility, land landing.

APPENDIX A

ACCESSIBILITY OF POSTLANDING SWITCHES AND CIRCUIT BREAKERS

The following table lists the postlanding switches and circuit breakers and their accessibility to the crewmen for both a worst-case land landing (50 ft/sec horizontal velocity — x-struts stroke approximately 11 inches and z-struts stroke approximately 17 inches) and a nominal water landing. The test subject was 5 feet 7 inches tall and weighed 145 pounds (figs. 12 and 13).

Postlanding circuit breaker or switch	Nominal water landing (harness on)		Worst-case land landing (harness on)	
	Crewman	Accessibility	Crewman	Accessibility
ELS — AUTO	CDR[a]	Easy	CDR	Difficult
CB — MAIN REL PYRO	LMP[b]	Easy	LMP	Easy
SECS PYRO	CDR	Easy	CDR	Easy
SECS LOGIC	CDR	Easy	CDR	Easy
CB BAT RELAY BUS	LMP	Easy	LMP	Difficult
DIRECT O_2	CDR	Easy	CDR	Easy
VHF AM B	LMP	Easy	LMP	Easy
FLOAT BAG — (3)	CDR	Easy	CDR	Easy
CB PL VENT	CDR	Easy	CDR	Easy
CB FLOAT BAG	CDR	Easy	CDR	Easy
VHF AM BCN	CMP[c]	Easy	LMP	Easy
VHF AM A	LMP	Easy	LMP	Easy
PL VENT LOCK HANDLE	CMP	Impossible	CMP	Impossible
PL VENT SWITCH	CDR	Easy	CDR	Impossible
CB MNA BAT BUS A AND BAT C	LMP	Easy	LMP	Easy

[a]Commander.

[b]Lunar Module Pilot.

[c]Command Module Pilot.

Postlanding circuit breaker or switch	Nominal water landing (harness on)		Worst-case land landing (harness on)	
	Crew-man	Accessibility	Crew-man	Accessibility
CB MNB BAT BUS B AND BAT C	LMP	Easy	LMP	Easy
CB FLT AND PL BAT C	LMP	Easy	[illegible]	Easy
CB PYRO A SEQ A	LMP	Impossible	LMP	Impossible
CB PYRO B SEQ B	LMP	Impossible	LMP	Impossible
CB FLT AND PL BAT BUS A AND B	LMP	Easy	LMP	Easy
CB FLT AND PL BAT C	LMP	Easy	LMP	Easy
PL BCN LT	CDR	Easy	CDR	Impossible
PL DYE MARKER	CDR	Easy	CDR	Impossible
VHF ANT — RECY	LMP	Difficult	LMP	Impossible
PL FIXED FLOOD	CDR	Easy	CDR	Easy
CB BAT A, B, C PWR ENT/PL	LMP	Impossible	LMP	Impossible

APPENDIX B

A SECTION OF THE FLIGHT CREW CHECKLIST

Crewman	POSTLANDING AND WATER EGRESS	Panel
	1. Stabilization after landing	
CDR	ELS - AUTO (verify)	2
LMP	CB MAIN REL PYRO (both) - CLOSE	
CDR	MAIN RELEASE - on (up)	
	SECS PYRO (both) - SAFE	8
	SECS LOGIC (both) - OFF	
LMP	CB BAT RLY BUS (2) - OPEN	
ALL	Helmet off (if suited)	
CDR	DIRECT O_2 - CLOSE (CW) (if suited)	
LMP	VHF AM B - OFF (center)	3
CDR	CB PL VENT - CLOSE	8
	CB FLOAT BAG (3) - CLOSE	
	If Stable II	
	FLOAT BAG (3) - FILL till 2 min after upright, then - OFF	
	VHF AM A - OFF while inverted	
	VHF AM BCN - OFF while inverted	
	If Stable I	
	After 10 min cooling period,	
	FLOAT BAG (3) - FILL 7 min	
	FLOAT BAG (3) - OFF	
	2. Post Stabilization and Ventilation	
	PL Vent vlv handle - PULL	
	Remove PL vent exhaust cover	
	PL Vent - High or Low	
	PL DYE MARKER - ON	
	Release restraints (if suited)	
LMP	CB MNA BAT BUS A and BAT C(2) - OPEN	275
	CB MNB BAT BUS B and BAT C(2) - OPEN	
	CB FLT and PL BAT C - OPEN	
CMP	CB PYRO A SEQ A - OPEN	250
	CB PYRO B SEQ B - OPEN	

Crewman		Panel
	EACH HR - CHECK DC VOLTS 27.5 V	3
	If Not:	
	CB FLT and PL BAT BUS A AND B (2) - OPEN	
	CB FLT and PL VAT C - CLOSE	
	GO TO LOW POWER CHECKLIST pg 2	
	Unstow and install POSTLANDING VENTILATION DIRECTIONAL AIRFLOW DUCT	
	Deploy grappling hook and line if req.	
	3. Postlanding Communications	
	VHF ANT - RECY (verify)	
LMP	VHF BCN - ON (verify)	
	If no contact with recovery forces	
	MONITOR VHF BEACON Transmission with Survival Transceiver	
	VHF Beacon not operating - connect Survival Transceiver to ANT Cable and place radio in BCN mode	
	LOW POWER CHECKLIST	
LMP	VHF BCN - OFF	3
	VHF (3) - RCV	
	FLOOD FIXED - OFF	8
	VHF AM B off (center)	
CDR	VHF AM REC ONLY - A (verify)	3
CDR, LMP	COUCH LIGHTS - OFF	8,5
CDR	POSTLANDING VENT SYS: minimize use	8
CMP	SURV RADIO - plug into VHF BCN ANT cable CONN and turn radio on in BCN mode	
	EGRESS PROCEDURES	
	STABLE I	
ALL	Disconnect umbilicals (if suited)	
	Neck dams on (if suited)	
CMP	Center couch - 270° position	
CDR, LMP	Armrests folded	
CMP	Unstow survival rucksacks	
LMP	Open side hatch	
CDR	PL Vent fan - OFF	
CMP	CB BAT A, B, C, PWR ENT/PL (3) - OPEN	

Crewman		Panel
CDR	Connect raft to S/C, if desired, with green lanyard	
ALL	Connect raft white lanyards to water wings and inflate water wings when egressing	
CMP	Egress with liferaft	
LMP	Put hardware kit out	
LMP, CDR	Egress	
	STABLE II	
LMP	CB CREW STA AUDIO (3) - OPEN	225
ALL	PWR (3) - OFF	9,10,6
	SUIT PWR (3) - OFF	
	Disconnect umbilicals (if suited)	
	Release restraints (if suited)	
	Couch seat pans (3) - 170° position	
	Neck dams on (if suited)	
CMP	Arm rests folded	
	Survival kits removed from stowage	
CDR	Connect liferaft mainline to CDR	
CMP	Connect first white lanyard from liferaft to water wings	
LMP	Connect second white lanyard from liferaft to water wings	
CDR	Connect third white lanyard from liferaft to water wings	
CMP	PRESSURE EQUALIZATION VLV - OPEN	
CMP, LMP	Remove and stow fwd hatch	
CMP	Exit feet first with rucksacks; when clear of S/C inflate water wings and raft	
LMP	Exit feet first; when clear of S/C inflate water wings	
CDR	Exit feet first; when clear of S/C inflate water wings	