REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX D

PANELS 19 thru 21

REPORT OF PANEL 19
SAFETY OF INVESTIGATION OPERATIONS
APPENDIX D-19
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

SAFETY OF INVESTIGATION OPERATIONS

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Safety of Investigation Operations Panel, 19. The task assigned for accomplishment by Panel 19 was prescribed as follows:

This group is charged with the responsibility of reviewing all operations performed during the investigation to assure that all personnel safety requirements are adequately maintained.

B. PANEL ORGANIZATION

1. MEMBERSHIP

The assigned task was accomplished by the following members of the Safety of Investigation Operations Panel:

Mr. J. R. Atkins, Chairman, Kennedy Space Center (KSC), NASA
Mr. J. McCaugh, Kennedy Space Center (KSC), NASA
Lt. Col. J. Rawers, U. S. Air Force, Air Force Eastern Test Range (AFETR)
Mr. R. Walker, Bendix Corporation, KSC
Mr. D. Karl, Pan American Airways, AFETR

2. COGNIZANT BOARD MEMBER:

Mr. E. Barton Geer, Langley Research Center (LaRC), NASA, Board Member, was assigned to monitor the Safety of Investigation Operations Panel.

C. PROCEEDINGS

1. The composition of this Panel reflected the incorporation of operations safety as identified in the Kennedy Space Center, Air Force Eastern Test Range (AFETR) Agreements (Enclosure 19-1). Launch Complex 34 is a NASA-KSC owned facility located on AFETR property at Cape Kennedy Air Force Station (CKAFS). Therefore, the Air Force exercises prime responsibility which is normal for the host Commander, NASA exercises safety responsibility for all NASA personnel, facilities and equipment located at AFETR.

2. All hazardous operations performed by NASA and their contractors at KSC and CKAFS by the requirements of Kennedy Management Instruction (KMI) 1710.1 are subject to Safety Office approval. The Uprated Saturn Ground Safety Plan delineates the safety considerations that must be satisfied during the performance of those checkout operations deemed hazardous. In consonance with the policy of KMI 1710.1, the Panel provided a technical safety review of all post-accident procedures employed in the disassembly, handling, storage and testing of Space Vehicle AS-204. In addition, selected operations and tests were monitored by a member of the safety organization. Monitoring of operations included: assuring use of required protective equipment; presence of special support, i.e., fire/medical; presence of only essential personnel; and rigorous adherence to the procedures written by the other Panels in the form of Test Preparation Sheets (TPS).

3. Safety support at Launch Complex 34 was given continuous coverage from January 31 through February 23, 1967. This safety support commenced with removal of launch vehicle ordnance at Launch Complex 34, and concluded with the arrival of the AS-204 Service Module at the Manned Spacecraft Operations Building.

4. The disassembly and removal of the Spacecraft from Launch Complex 34 was performed without incident. Ordnance, toxic materials, high-pressure vessels and structural weakness were typical problem considerations which had to be taken into account during the disassembly, transfer, storage, and clean-up of Launch Complex 34. Periodic spacecraft air samples for beryllium were taken at selected intervals at Launch Complex 34 and the Pyrotechnic Installation Building (PIB). Air samples for beryllium were taken inside the cabin as a precautionary measure due to the indicated presence of beryllium dust from swab tests taken on the exterior of the Spacecraft after the accident. All tests proved to be negative.

5. Concurrent with the activity on Launch Complex 34, the PIB and the Materials Analysis Branch laboratory were utilized in support of the investigation. Special arrangements with regard to exits were required in the PIB once it was established as the area for AS-204 storage. Special tests involving oxygen-enriched atmospheres required establishment of safety requirements and safety support during actual performance. These special tests were performed for the purpose of determining burning rates and ignition characteristics of various materials.

6. Following are items of general interest:

a. There was no indication of beryllium at toxic levels during handling and disassembly at Launch Complex 34 and the PIB.

b. The Environmental Control System (ECS) surge tank was the only pressure vessel activated during the Plugs Out Overall Test and did not present a hazard to disassembly personnel.

c. Hypergolic propellants were present only in the Ground Support Equipment and did not present a hazard over and above that established for Launch Complex operations.

d. No cryogenic propellants were present in the spacecraft. Oxygen was supplied in gaseous form from a source external to the spacecraft.

e. The Launch Escape System did not have initiators installed, thereby negating the need for special de-arming action prior to removal.

f. The ordnance in the forward section under the heat shield was removed as a precautionary measure because of possible damage to the forward bulkhead that may have been weakened by the fire. The remainder of the spacecraft ordnance was identified and did not constitute a hazard.

g. Adequate safeguards for personal protection were taken during test operations.

D. FINDINGS AND DETERMINATIONS

Not applicable.

E. SUPPORTING DATA

Enclosure

19-1 Extract, KSC/AFETR Joint Operating and Support Agreement KMI 1052.1, July 12, 1965 Pages D-8, D-9, 6 and Authority

KMI 1052.1

March 9, 1965
Effective Date

JOHN F. KENNEDY SPACE CENTER, NASA
MANAGEMENT INSTRUCTION

SUBJECT : KSC/AFETR JOINT OPERATING AND SUPPORT AGREEMENT

1. PURPOSE

This Instruction incorporates into the KSC Issuance System an agreement between the John F. Kennedy Space Center and the Air Force Eastern Test Range (Attachment A) concerning the responsibilities for performance of operating and support functions that are intrinsic to the mission assignments of both agencies.

2. AUTHORITY

NMI 1052.31, "DOD/NASA Agreement - Atlantic Missile Range and Merritt Island Launch Area."

3. SUPERSESSION

Administrative Regulation KSC 4-2, dated March 9, 1965.

Simon H. Burttschell
Simon ∂. Burttschell
Chief, Administrative Branch
Administrative and Transportation Services Office

Attachment:
A. Agreement

Distribution "H"

13. Ground Safety

a. Safety policy and operation procedure on the ETR is the responsibility of the Commander, AFETR. DOD and NASA Test Activities are responsible for compliance with these policies and procedures as formulated by the pertinent AF regulations and documents, and by established practices.

b. The Director, KSC, is responsible for:

(1) Designating launch danger areas on MILA, and clearing these danger areas or accepting the risk for persons remaining therein. When deemed necessary by the Director, KSC, and subject to the possible imposition of additional launch or trajectory limitations by the Commander, AFETR, the location of impact limit lines may be jointly agreed upon by the Director, KSC, and the Commander, AFETR.

(2) Protection of life and property that could be endangered:

(a) During the transportation (on MILA), assembly, checkout, static firing, or preparation of launch of all space vehicles/missiles to be launched or intended for launch from MILA.

(b) By propellants or ordnance items during their transportation (on MILA) to and from storage or manufacture in MILA facilities.

(3) Limiting access to MILA areas which are inside designated impact limit lines.

(4) Evaluating hazards to MILA areas and the general public associated with MILA preflight operations.

(5) Providing data on toxicological and radiological materials, systems and procedures governing their use as AFETR may require to develop emergency plans or determine launch restrictions and such static instrumentation on MILA as AFETR and KSC may jointly agree is required for detecting and estimating the behavior of toxicological and radiological hazards.

c. The assignment of responsibilities in paragraphs a and b, above, is not intended to prohibit or discourage the generation of safety policies and procedures which are internal to an organization. However, internal policies and procedures will not circumvent, negate or be less stringent than those prescribed by the agency with the primary safety responsibility.

d. The area between the overlapping 0.4 psi launch danger circles of Complexes 39A (Saturn V) and 41 (Titan III) will be under operational security control of either KSC or AFETR, depending upon which complex is involved in launch operations. Should launch operations on both complexes require simultaneous placement of roadblocks, their points of intersection will be mutually agreed upon.

e. AFETR and KSC safety representatives will keep each other informed of their respective safety practices, policies and procedures. These representatives will, where applicable, prepare uniform safety criteria which are of mutual interest.

8. EFFECTIVE DATE:

This Agreement becomes effective upon the date of the latest signature shown below

V. G. HUSTON, Major General, USAF
Commander, AFETR

12 July, 1965

KURT H. DEBUS
Director, KSC

30 June, 1965

REPORT OF PANEL 20
IN-FLIGHT FIRE EMERGENCY PROVISIONS PANEL
APPENDIX D-20
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

IN-FLIGHT FIRE EMERGENCY PROVISIONS REVIEW

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the In-flight Fire Emergency Provisions Review Panel, Panel 20. The task assigned for accomplishment by Panel 20 was prescribed as follows:

> This activity involves an orderly review of planned in-flight fire emergency procedures and other provisions relative to their adequacy, as well as a review to determine that emergency procedures, in fact, exist for all appropriate activities. This review should include recommendations to the Board for changes in existing procedures and other provisions and for the creation of new emergency provisions if deemed necessary.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the In-flight Fire Emergency Provisions Review Panel:

Captain James A. Lovell, Jr., USN, Chairman, Manned Spacecraft Center (MSC), NASA
LCdr. Ronald E. Evans, USN, Manned Spacecraft Center (MSC), NASA
Mr. John L. Swigert, Jr., Manned Spacecraft Center (MSC), NASA
Mr. Richard D. Glover, Manned Spacecraft Center (MSC), NASA
Mr. Thomas R. Loe, Manned Spacecraft Center (MSC), NASA
Mr. Dickie K. Warren, Manned Spacecraft Center (MSC), NASA
Mr. Norman P. Shyken, McDonnell Company

2. COGNIZANT BOARD MEMBER:

Colonel Frank Borman, U. S. Air Force, Board Member, Manned Spacecraft Center (MSC), NASA, was assigned to monitor the In-flight Fire Emergency Provisions Review Panel.

C. PROCEEDINGS

1. In response to the direction of the Apollo 204 Review Board, the Panel derived detailed objectives. These objectives were: determine if in-flight fire procedures were available; determine the severity of and the time available to combat an in-flight fire; determine the adequacy of existing procedures established for Apollo 204 to combat an in-flight fire; recommend the development of new hardware and/or emergency procedures for the Apollo Command Module, if necessary.

2. PUBLISHED PROCEDURES. The in-flight fire emergency procedures in use by the Apollo 204 crewmen are described below.

a. APOLLO CREW ABBREVIATED CHECKLIST, MISSION AS-204, dated January 23, 1967; Fire/Smoke in C/M, page 15-1 (Enclosure 20-1). The procedure is composed of two major steps, seven total, to don the Pressure Garment Assembly (PGA), if applicable, and to vent the main cabin to ambient pressure. The emergency procedure utilizes the orbital PGA donning procedure and the normal cabin depressurization hardware. No other provisions are made for extinguishing or combating in-flight fires. This procedure is the most complete of the group and is as follows:

ASSIGNED CREWMAN	TASK
All three crewmen	Don PGA
Command Pilot	Direct 02 valve - Open
Senior Pilot	Emergency Cabin Pressure - Off
S nior Pilot	Cabin Repress valve - Closed
P.	Suit Fan - Off
Pilc	Cabin Fan - Off
Command Pilot	Cabin Pressure Relief - Dump

As a procedure in donning the pressure suits (Enclosure 20-4), the following Environmental Control System (ECS) controls must be activated or verified:

(1) ECS suit umbilical inlet - Uncapped
(2) Suit circuit return air valve - Closed
(3) Suit demand pressure regulator - 1 and 2
(4) Suit compressors - Compr 1 (or 2) - AC 1 (or 2)

(5) Suit flow control - Suit full flow (3 separate suit flow control levers)

b. APOLLO OPERATIONS HANDBOOK, COMMAND AND SERVICE MODULE, SPACECRAFT 012, dated November 12, 1966, with changes dated November 18 and 30, 1966; Fire/Smoke in C/M, paragraph 9.3.1, pages 9-49. (Enclosure 20-2) The procedure is essentially the same as paragraph 1.a., except that it contains no provisions for turning off the cabin vent fan and suit loop compressor fans. An additional step of closing the suit circuit return air valve as stated in the pressure suit donning procedure is included.

c. FLIGHT MISSION RULES, AS-204, dated January 10, 1967; Section 6, Environmental Control, items 6-21 and 6-22, page 6-6 (Enclosure 20-3), contain references to in-flight fires as follows:

ITEM	MALFUNCTION	RULING
6-12	Smoke or annoying odors in suit circuit	CONTINUE MISSION - Open Direct O_2 to purge suits
6-22	Smoke in cabin	CONTINUE MISSION - Turn off cabin fan. Crew may elect to abort if source of smoke cannot be located and contained. NOTE: Crew may elect to decompress cabin

d. APOLLO AS-204 FLIGHT PLAN dated December 9, 1966; pages 97 and 98. (Enclosure 20-4). The flight plan contains a PGA donning procedure planned for use at 27 hours into the mission. The exercise is scheduled after the initial PGA removal and is included as an evaluation of the suit don-doff task. It is not a complete in-flight fire emergency procedure.

3. CREW TRAINING. Records of specific Apollo crew training lectures on in-flight fire, per se, are not available. However, briefings were held with the prime Apollo crew describing the best PGA stowage configuration and donning procedures which resulted in the minimum suit donning times. These procedures were developed and are available in MSC test report CSD-A-288 (STB-A-015/29). This report also mentions that a well trained test subject accomplished the PGA donning in about 11 minutes at one g. Apollo Mission Simulator (AMS) training records indicate the prime Apollo crew donned the PGA's in the AMS at least twice; even though PGA doffing or donning is not necessarily logged. The crew specifically requested that the donning time be recorded during one PGA donning exercise. This time was about eight and a half minutes.

4. PROCEDURE EVALUATION. On February 5, 1967, two members of the Apollo 204 backup crew and a member from Panel 20 conducted a run-through of the in-flight fire procedures as published in the on board check lists (Enclosure 20-1). The purpose of the exercise was to determine the degree of difficulty and time required to perform the in-flight fire emergency procedure. The check list did not specify any variations of the procedure for the different phases of flight. Therefore, the worst case was assumed; i.e., orbital phase with crewmen in constant wear garments and pressure suits stowed.

The basic concept of the Apollo in-flight fire procedure was to depressurize the cabin to extinguish the fire. This meant that the first step was to don the PGA. The PGA and associated helmets were stowed under the couches in the orbital configuration. Donning procedures as shown in the final flight plan were followed (Enclosure 20-4). The test crew performed the emergency procedure in approximately 12 minutes. It was obvious that the degree of training and peculiar suit donning problems, such as getting zippers caught, could cause a variation in that time. However, for emergency pressure suit donning, with an actual fire condition the crew has the additional hazard of staying clear of the fire. This will add to the donning time. The process of suit donning will increase the air circulation in the cabin by feeding new oxygen to the burning material and increasing propagation of the fire. Pressure suit donning as a first step toward combating an in-flight spacecraft fire requires too much time and adds to severity of the fire. For fires during boost and entry phases of flight, the crewmen are wearing PGA's and this problem does not exist.

All existing in-flight fire procedures center around extinguishing the fire by venting the cabin to remove all oxygen, allowing the fire zone to cool, and repressurizing the cabin. The systems management functions which accompany this vary with mission phase. During launch, entry, and any other time crew is suited, the only operation required is to open the cabin dump valve. (Note that below approximately 28,000 feet alititude, during earth landing sequence, this operation accomplishes nothing since atmosphere is beginning to enter through inflow valves in the cabin pressure relief assembly.) During flight phases where the crew is unsuited, the procedure calls for donning suits as soon as possible, isolating suit circuit from cabin, and venting. Several systems functions are required to assure the most rapid cabin vent after the PGA's are donned, and would normally be done prior to beginning PGA donning. Two of the functions can be done by the Command Pilot from the left-hand couch, and two by the Senior Pilot in the Left Hand Equipment Bay (LHEB). In considering these functions, several comments are in order:

a. DIRECT O_2 - CLOSED. One T-handle is normally installed in this valve and is readily accessible to the Command Pilot. This is the easiest of the four functions to perform, when the handle is installed in the valve.

b. SUIT CIRCUIT RETURN AIR VALVE - CLOSED. This function is required to assure the suit circuit is isolated from any cabin contamination caused by the fire. This valve is located in the space behind the removable attenuation panel covering LHEB panel 311. In orbit, this panel is off and stowed. The valve is closed by hand and can be reached either from the left-hand couch or from below. However, the valve assembly is recessed and difficult to reach.

c. CABIN REPRESS VALVE - CLOSED. This valve is normally closed and must be verified closed by the Senior Pilot while he is in the Lower Equipment Bay preparing to unstow the PGA's. The valve is activated by rotating a three-quarter inch diameter knurled knob on LHEB panel 314. This operation is fairly easy to accomplish in the shirtsleeve environment. However, since this small knob only extends out from the panel about three-quarters of an inch and is located under the left-hand couch, it would be difficult to operate in a fully pressurized PGA.

d. EMERGENCY CABIN PRESSURE - OFF. This valve is located on panel 314 and will normally be open for emergency pressure resulting from meteoroid cabin penetration. This valve must be closed prior to cabin vent to prevent surge tank depletion. The operation requires the Senior Pilot to remove the second T-handle from its stowed position on panel 314, insert in the emergency regulators valve and turn it to Off one-half turn. This valve cannot be moved without a T-handle and if the handle is not in its usual stowage position or if hazardous conditions exist, time could be lost in performing this mandatory function. The Senior Pilot is also responsible for the PGA unstowage.

e. CABIN FANS - OFF. Air movement in the cabin caused by the cabin fans, coupled with the location of the combustible materials, contributes to fire propagation.

5. FIRE PROPAGATION. A review of 100%, 5 pounds per square inch (psi) oxygen fire technical publications was made to determine the time available for crewmen of Apollo 204 to fight an in-flight fire. The review indicates that time available for crewmen to combat an in-flight fire is a function of fire propagation through the spacecraft, the ability to rapidly detect its presence and the span of useful consciousness. Fire propagation in the spacecraft is affected by several factors:

a. Cabin oxygen pressure
b. Presence and proximity of combustible materials
c. Location of the point of ignition energy source
d. Acceleration forces acting on the combustion process

Fire propagation roles of these factors during boost and entry phases of flight would be similar to the ground environment. The cabin oxygen pressure is the exception and will vary directly with ambient pressure changes, as long as ambient pressure is above approximately 5-6 psi. Fire propagation time is a function of the oxygen pressure. Venting the cabin to ambient pressure would reduce oxygen pressure and fire propagation rates during the boost and orbital phase of flight. Because of the high accelerations involved and the requirement for being restrained, fire detection other than by visual means would be difficult during the boost and entry phases of flight.

The crew would be less alert to the danger of fire during these phases of flight because of attention to flight control duties and the environment of maximum dynamic pressure buffet, aerodynamic noise and attention to procedures. The pressure suit circuit would be closed to the cabin with no physiological indications. After detection, any action to combat the fire would be greatly impeded by the high acceleration loads on the crewmen.

Combustion in a zero g environment is affected by the same considerations, except that normal, buoyant, thermal convections are not present. The flame would normally assume a spherical pattern but would be affected by the actual shape of the surface that is burning and air circulation. In addition, any changes to the g field such as thruster firing would affect the pattern. The fire in zero g may propagate along the burning surface or by the omni-directional emission of burning gases generated by pyrolysis of the burning material. The distance such gas jets will extend depends on the configuration and kind of material that is burning. If combustion is confined without an additional oxygen supply, visible flame disappears. However, any disturbance of the surface before it has cooled will introduce additional oxygen causing it to flare up again. Any movements of the spacecraft or crewmen in attempting to combat the fire may be expected to make more oxygen available and thus intensify the fire. Only after sufficient thermal energy has been dissipated will the fire not be kindled by convection currents. Therefore, theoretical considerations and limited experimental evidence indicates that fire propagation may be reduced in zero g environment depending on practical aspects that are not yet fully understood. However, due to other variables, it cannot be concluded that a zero g environment will effectively reduce the spread of the fire in the cabin.

A fire test (Test No. 2-TS47-SMD 3) in an Apollo boilerplate spacecraft was conducted by the Structural and Mechanics Division of the Manned Spacecraft Center under in-flight conditions of 100% oxygen at 5 psi atmosphere and with the flammable materials scheduled to be aboard Apollo 204 for flight. The vent valve was ported to vacuum to simulate orbital flight and opened at approximately 6 psi. The fire was started near the -Y, +Z corner close to the aft bulkhead of the spacecraft with the cabin fan on.

Preliminary results indicate that a fire under 5 psi 100% oxygen is less severe than a fire at Launch Complex conditions of 16 psi. The temperature peak of the fire test at 5 psi occurred approximately 80 to 90 seconds after ignition. This was approximately 50 seconds later than on a similar test at 16 psi. The damage was confined to the left one-third of the cabin and the vent valve was able to control the rise in pressure. It appeared that vent valve operation helped exhaust the oxygen supply and limit the severity of this fire; however, a considerable amount of smoke was generated during the fire indicating a need for crew protection from smoke. The results of these investigations indicate that although an in-flight fire would be less severe than a fire under flight conditions, there was still a high probability of an uncontrolled propagation of fire for all phases of flight with the combustible materials that were on board Apollo 204.

6. CABIN PRESSURE VENTS

a. CABIN PRESSURE VENTS DURING LAUNCH. The cabin is maintained at approximately 1 psi above ambient pressure from the time of cabin oxygen purge until lift-off to prevent ambient flow into the cabin during prelaunch operations. The lift-off cabin pressure is approximately 16 psi absolute (psia), 100% oxygen. The cabin pressure remains at 16 psia until an elapsed time from lift-off of approximately 45 seconds. At this time the spacecraft is at an altitude of 10,000 feet with the ambient pressure at 10 psia. Any attempts to vent the cabin pressure prior to 45 seconds will accomplish no more than reducing the cabin pressure to ambient, somewhere between 14.7 psia and 10 psia. Opening the cabin relief valve at any time during the boost or orbit phases will in no way dilute the oxygen concentration in the cabin. It will serve only to reduce the pressure of the 100% oxygen.

Once the spacecraft has reached an altitude (approximately 10,000 feet) where the cabin pressure exceeds the ambient pressure by 6 psi, the cabin pressure relief valves will open venting cabin pressure. From this point until the ambient pressure has decreased to zero, the cabin pressure relief valves modulate to maintain 6 psi differential, finally sealing the cabin at 6 psia. It is impossible to manually vent the cabin at a rate faster than the relief valves can follow the decrease in ambient pressure. Therefore, cabin pressure vent times to 0.5 psia from lift-off to orbital insertion can vary from 3 minutes 20 seconds to 2 minutes 5 seconds.

To vent cabin atmosphere during the launch phase, the Command Pilot must release the latch on the cabin pressure relief valve and place the handle in the dump position. In the launch configuration, the crew is suited, the emergency cabin pressure selector valve is set to Off, and the suit circuit return air valve is closed.

b. CABIN PRESSURE VENT DURING ORBIT. The venting of cabin pressure was the only method available for Apollo crewmen to use in extinguishing a fire. The procedures and times for venting the cabin are covered in other areas of this report so only the time required to evacuate the cabin to 0.5 psia will be discussed. Based on reference material, it was assumed that 0.5 psi was the maximum pressure that could be utilized to effectively retard an in-flight fire. Figure 2.7-11 of the Apollo Operations Handbook (Enclosure 20-5) shows that the time required to depressurize the cabin from 5 to 0.5 psia is 1 minute and 45 seconds. It can be noted on the referenced figure that due to the relatively higher differential pressures present when the cabin venting is initiated, the initial depressurization rate is quite rapid. As an example, the time required to drop cabin pressure from 5 to 2 psia is only 45 seconds.

The Post Landing Ventilation Valves (PLV) can provide a method for decompressing the cabin more rapidly than the normal method described above. These valves allow cabin pressure to vent in less than 10 seconds; however, this method should not be used in the case of fire since the vent point is under the Apex cover where the parachutes are stowed. The introduction of fire or hot gases to this area could damage or destroy the parachutes.

c. CABIN PRESSURE VENTING DURING ENTRY. Cabin pressure may be vented during the entry with the pressure level dependent on the ambient pressure. It should be noted that venting the cabin to ambient will only serve to lower the total pressure and will not dilute the 100% oxygen concentration. The considerations that applied to orbital use of the PLV valves would also apply. Once the spacecraft has descended to approximately 26,000 feet, it will no longer be possible to lower cabin pressure by opening the dump valve. From this altitude until splashdown, the cabin pressure will be increasing and because of ambient inflow, the oxygen concentration will become diluted to a value of approximately 50%. The length of time from 26,000 feet to splashdown is approximately 6 minutes.

A cabin pressure vent during the entry phase of flight or immediately before will result in an inflated pressure suit entry, since there is insufficient time to repressurize the cabin. The inflated pressure suit limits mobility and complicates the entry portion of the flight.

7. CABIN REPRESSURIZATION. Assuming the crew has been able to perform all necessary tasks and the fire has been extinguished by venting the cabin, the problem of cabin repressurization arises. Provided no further fire hazard exists, cabin repressurization is desirable to make entry preparations and entry easier. When an extended period of time for return is required, repressurization is mandatory for biological functions. The two problem areas which exist in repressurization are: accessibility of repressurization are: accessibility of repressurization controls in inflated suit configuration, and repressurization profile.

Two modes of cabin repressurization exist: (1) a normal procedure requiring 74 minutes to reach 5.0 psia and (2) a minimum time procedure requiring 52 minutes to reach 5.0 psia. In the latter case, the 22 minutes are saved by first venting the contents of the surge tank to achieve 1.9 psia cabin pressure in slightly less than 5 minutes, then followed by the slower rise to 5.0 psia. Both of these procedures require the Senior Pilot to go to LHEB panel 314 and open the cabin repressurization valve using a knurled knob which must be grasped with an inflated glove and turned one-half turn. If the normal repressurization profile is to be followed, no further action is required until the cabin reaches 5.0 psia in 74 minutes when the repressurization valve is closed. The gloves will probably have been removed by this time making the job somewhat easier. For emergencies, 22 minutes may be saved by venting the contents of surge tank from 900 to 150 psia. After the repressurization valve has been opened, the T-handle is removed from its stowage hole, inserted in the emergency cabin pressure regulator valve and turned one-half turn to 1 and 2 position, with inflated gloves. This immediately initiates maximum flow from the system (0.67 pounds per minute) and the surge tank contents begin venting into the cabin. The Pilot, from the right-hand couch, must monitor the surge tank pressure continuously for the remainder of the 52 minutes required to reach 5.0 psia. He must keep the Senior Pilot aware of the pressure to prevent tank pressure from falling below 150 psia, causing main regulator malfunctions. When pressure first falls to 150 psi, the emergency cabin pressure regulator must be turned Off. At this time cabin pressure is approximately 1.9 psia and the elapsed time is approximately 5 minutes. Thereafter, repressurization flow must be modulated to maintain 150 psia until the valve is again full open and surge tank pressure begins to rise slowly. When the cabin reaches 3.5 psia and the main cabin regulators cut in, an additional demand is placed on the surge tank. Surge tank pressure will again fall to 150 psia at which time the repressurization flow must be again modulated to maintain this minimum pressure. When the cabin reaches 5.0 psia, the cabin repressurization valve is closed and surge tank recharging from the Service Module cryogenic oxygen supply begins and requires approximately one-half hour to complete. The continuous attention to surge tank pressure required in this repressurization procedure is not desirable. Enclosure 20-5 shows the cabin pressure histories profiles for the two repressurization modes. The time required for repressurization is too long in either case because of two systems constraints: (1) the total available oxygen within the surge tank is only a fraction of that required for one Command Module repressurization cycle and (2) resupply flow rates from the Service Module cryogenic oxygen tanks to the surge tank are severely limited by flow restrictors (6 pounds per hour nominal). Repressurization is a lengthy process at best, and is hampered by inaccessible Environmental Control Unit management controls. In the case of the minimum time profile, a great deal of voice coordination between crewmen is required since the repressurization valve and the surge tank pressure readout are located in opposite ends of the spacecraft. In addition, possible suit damage due to the fire makes lengthy repressurization times undesirable.

D. FINDINGS AND DETERMINATIONS

1. FINDING

An in-flight fire procedure was published and available to the crew for the Apollo 204 Mission. The procedure was analyzed with reference to the Apollo 204 Command Module 012 configuration.

DETERMINATION

Based on this review, it is the judgment that the existing in-flight fire procedures are deficient in the following areas:

a. The cabin fans should be turned off as the first item of the procedural check list. This may help prevent the spread of a fire by minimizing cabin air currents.

b. The procedure should have specified the length of time to keep the cabin depressurized to insure the fire had been extinguished and that all materials had cooled to below their ignition temperature.

2. FINDING

The Apollo 204 crew had practiced the PGA donning portion of the in-flight fire procedure.

DETERMINATION

No discrepancies were noted.

3. FINDING

Coordination with Panel 8, Materials Review, and Panel 5, Origin and Propagation of Fire, indicates many materials combustible in 100% 5 psi oxygen were on board Apollo 204 Command Module 012.

DETERMINATION

It is the judgment of the Panel that these materials would yield a dangerous propagation rate in case of fire in the Command Module during the boost, orbital and entry phases of flight.

4. FINDING

Lenghty suit donning times were incompatible with fire propagation times.

DETERMINATION

The published in-flight fire procedure was impractical in view of the rapid fire propagation rate expected for an Apollo 204 in-flight fire.

5. FINDING

The Command Module depressurization time from 5 psi to 0.5 psi can vary from 1 minute and 45 seconds to 3 minutes and 20 seconds based on the flight phase ambient pressure.

DETERMINATION

The depressurization time is too slow to effectively combat a cabin fire.

6. FINDING

The emergency cabin repressurization time from a vacuum to 3.5 psi is 35 minutes.

DETERMINATION

The time required to repressurize the cabin to a minimum acceptable pressure is excessive in view of the possible fire damage to the closed loop pressure suit circuit.

7. FINDING

Actuation of the suit circuit return valve, the cabin repressurization valve, and emergency cabin repressurization valve are critical in producing an adequate cabin decompression and subsequent repressurization.

DETERMINATION

The placement of ECS controls and displays complicates the execution of the existing in-flight fire procedure.

E. SUPPORTING DATA

Enclosures

20-1	Apollo Crew Abbreviated Checklist Mossion AS-204, page 15-1, dated January 23, 1967
20-2	Apollo Operations Handbook, NAA SM2A-03-SC-012, dated November 1966, page 9-49
20-3	Flight Mission Rules, AS-204, dated January 10, 1967, page 6-6
20-4	Apollo AS-204A Flight Plan, dated December 9, 1966, pages 97 and 98
20-5	Apollo Operations Handbook, NAA SM2A-03-SC-012, dated 12 November 1966, pages 2.7-40, 2.7-42, 2.7-43
20-6	List of References
20-7	Glossary of Abbreviations

SECTION 15. EMERGENCY PROCEDURES

FIRE/SMOKE IN C/M

CSP	1	DON PGAs	
	2	SET CONTROLS	
C		DIRECT O2 - OPEN (CCW)	
S		EMERGENCY CABIN PRESSURE - OFF	Panel 314
		CABIN REPRESS - CLOSED (CCW)	
		SUIT FAN - OFF	
		CABIN FAN - OFF	
C		CABIN PRESSURE RELIEF - DUMP (Safety latch - off)	Panel 307

Extracted from: APOLLO CREW ABBREVIATED CHECKLIST
MISSION AS-204

January 23, 1967

Sta	Step	PROCEDURE	Panel	STATUS OF SYSTEM
	9.3	EMERGENCY PROCEDURES.		
		INTRODUCTION.		
		Emergency procedures provide the crew with the necessary steps to quickly alleviate situations that have (or will) become both crew hazardous and time critical. These procedures require instant reaction on the part of the crew to prevent the conditions from becoming worse. In most instances the conditions are physically sensed by the crew rather than brought to their attention by the caution and warning system, or voice communication.		
	9.3.1	FIRE/SMOKE IN C/M.		Fire in the C/M cabin is extremely hazardous because of the 100-percent oxygen atmosphere. However, the capability exists to quickly extinguish any fire originating inside the C/M by depressurizing the cabin.
CSP	1	Unsuited crewman don PGAs		
	2	Set controls:		
C		DIRECT O_2 valve - OPEN (CCW)	24	Suit circuit isolated from cabin atmosphere by differential pressure; also commences purge of suit circuit.
S		EMERGENCY CABIN PRESSURE sel - OFF	314	
		CABIN REPRESS valve - close (CCW)		
C		CABIN PRESSURE RELIEF cont (lower) - DUMP	307	Safety latch must be off.
S		Remove attenuation panel		Refer to ECS Systems Management procedures.
		SUIT CIRC RETURN VALVE - close	319	Mechanically isolates suit circuit from cabin atmosphere.
		Install attenuation panel		
C		DIRECT O_2 valve - close (CW)	24	

NASA — Manned Spacecraft Center

MISSION RULES

REV	ITEM	CONDITION MALFUNCTION	RULING	NOTES/COMMENTS SOP S
	6-19	CABIN TEMP $\geq$95°F.	CONTINUE MISSION - TURN OFF CABIN FANS.	AFTER INSERTION, CREW MAY OVERRIDE TEMP CONTROL VALVE AND TURN FANS BACK ON. (PHYSICALLY IMPOSSIBLE TO MANUALLY OVERRIDE CABIN TEMP CONTROL VALVE DURING BOOST.)
	6-20	GLYCOL EVAPORATOR OUT TEMP >55 OR <35°F.	CONTINUE MISSION - AFTER INSERTION MANUALLY OPERATE GLYCOL EVAPORATOR.	NOTE: CAN OPERATE AT LOWER TEMP BUT OPERATION SHOULD BE MONITORED FOR MALFUNCTION. NORMAL OPERATING RANGE 45 ± 5°F.
	6-21	SMOKE OR ANNOYING ODORS IN SUIT CIRCUIT.	CONTINUE MISSION - OPEN DIRECT O_2 TO PURGE SUITS.	
	6-22	SMOKE IN CABIN	CONTINUE MISSION - TURN OFF CABIN FAN. CREW MAY ELECT TO ABORT IF SOURCE OF SMOKE CANNOT BE LOCATED AND CONTAINED.	CREW MAY ELECT TO DECOMPRESS CABIN.

MISSION	REV	DATE	SECTION	GROUP	PAGE
AS-204		1/10/67	ENVIRONMENTAL CONTROL	LAUNCH INSERTION	6-6

MSC Form 364A (May 65)

PGA DONNING

GET 27:30
GET 325:00

1. Configuration:

   A. Cabin humidity taken prior to doffing PGA
   B. ECS suit umbilical inlet capped
   C. Normal ECS shirtsleeve configuration
   D. Three men in couches, wearing light coveralls, sandals, and communications carrier.
   E. Helmets stowed in bags under center couch.
   F. Commander's (C) PGA stowed in bag under LH couch.
   G. Senior Pilot's (S) PGA stowed in bag under LH couch.
   H. Pilot's (P) PGA stowed in bag under RH couch near headrest
   I. TV and seq. CAM - Setup
   J. Interior lights - All ON

2. Unstow PGAs
   A. C,S,P - Release couch restraints
   B. S - Drop center couch to 180° position, ingress LEB, fold couch to 270° position.
   C. C,S,P - Remove light coveralls, restraint sandals, bioinstrumentation, and communication connectors.
   D. C,P - Pass Light coveralls, etc, to S
   E. S - Retrieve C's PGA and pass to C
   F. P - Roll over, drop couch headrest and retrieve suit from RH bag.
   G. S - Stow light coveralls, etc, in LH suit bag
   H. S - Retrieve three helmets in bags from aft bulkhead, stow on center couch.
   I. S - Retrieve S's suit

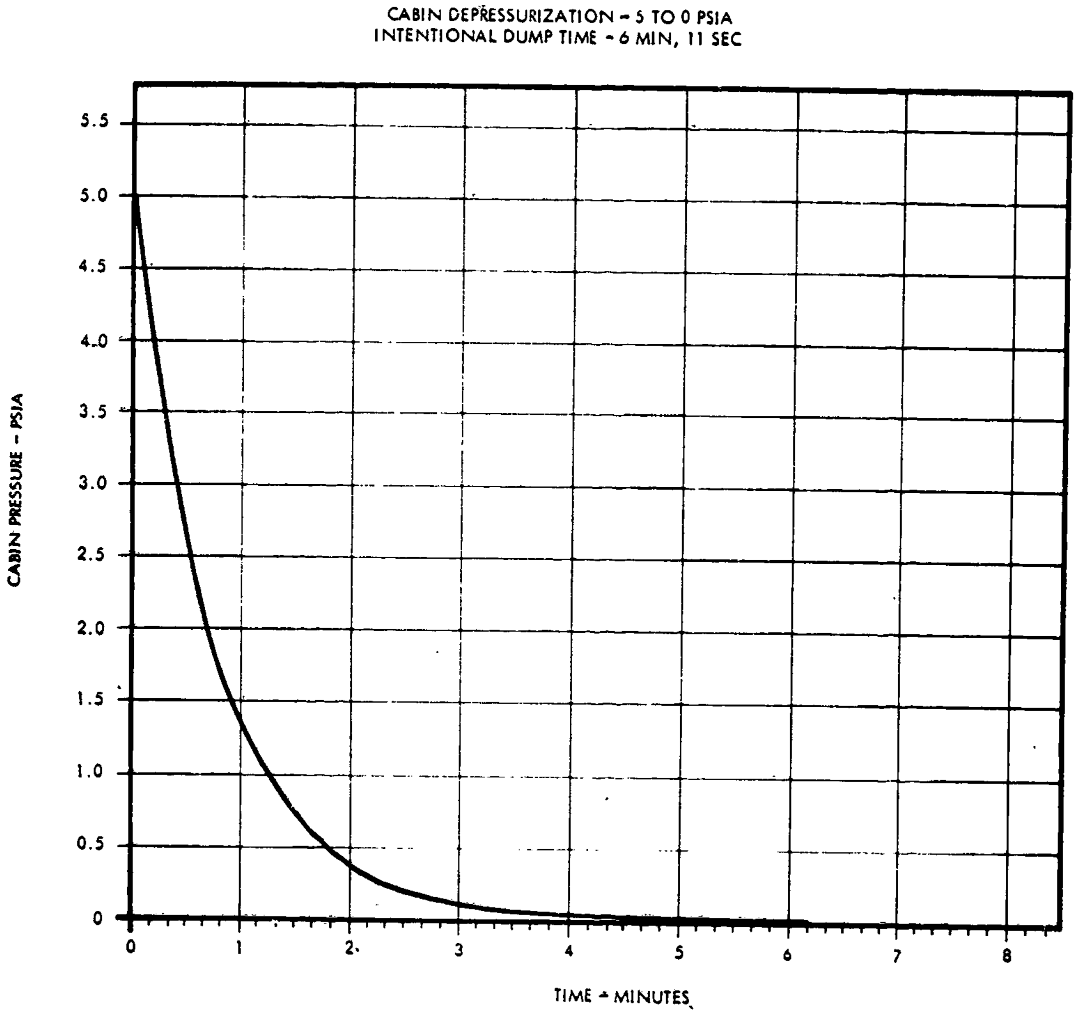
3. Prior to donning PGAs verify:
   A. ECS suit umbilical inlet - UNCAPPED
   B. SUIT CIRCUIT RETURN AIR VALVE - CLOSED
   C. SUIT DEMAND PRESSURE REGULATOR 1 & 2
   D. SUIT COMPRESSORS - COMPR 1 (or 2) - AC1 (or2)
   E. SUIT FLOW CONTROL - SUIT FULL FLOW

4. Don PGA's
   A. C - Don PGA in LH couch
      P - Don PGA in RH couch
      S - Don PGA in LEB
   B. C,P,S - Remove helmets from bags and stow bags under respective couches
   C. UCD donned
   D. Bio-med connector from underwear to suit attached.
   E. Restraint zipper closed and lanyard stowed
   F. Pressure sealing zipper closed, snap secure
   G. Don helmet: helmet comm. disconnect attached to suit disconnect and stowed
   H. Helmet attached to neckring and locked in position.
   I. Glove wrist disconnect locked
   J. Glove straps snagged down
   K. Boot zippers secure
   L. Helmet tie down - front and back - (slack takeup) and locked
   M. ECS inlet nozzle attached to suit and locked in position
   N. ECS outlet nozzle uncapped, attached to suit, and locked in position
   O. Cobra cable connected
   P. Bio-med cable attached to suit and locked
   Q. Close visor and secure double lock

5. EMERG CABIN PRESS Valve - ON

6. Perform PGA verification check (Ref. AOH)

7. Record on flight log donning times, problems encountered, comments, etc.

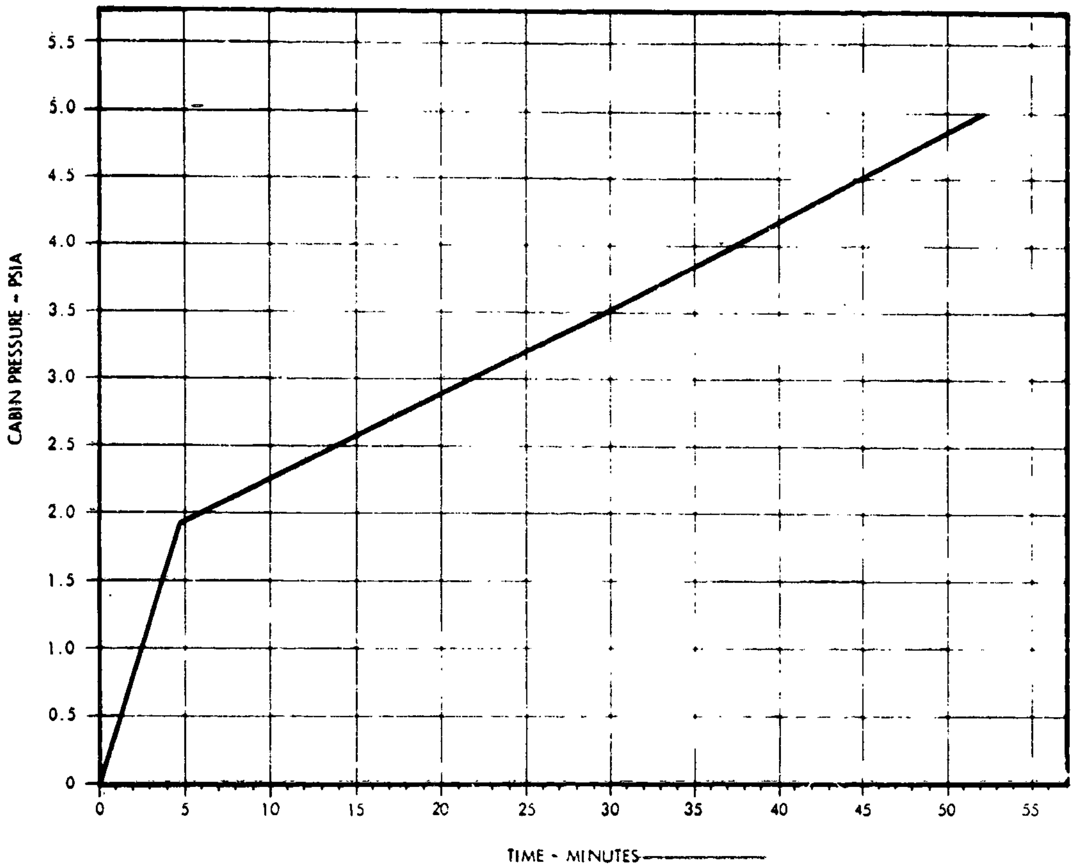


CONDITIONS:
1. EMERGENCY CABIN PRESSURE selector valve set to OFF.
2. CABIN REPRESS manual valve set to close.
3. CABIN PRESSURE RELIEF valve set to DUMP.
4. Normal cabin pressure regulators automatically close at 3.5 psia.

SM-2A-890

Figure 2.7-11. Cabin Depressurization Rates (Sheet 1 of 2)

CABIN REPRESSURIZATION - 0 TO 5 PSIA *
MINIMUM TIME - 52 MIN, 22 SEC



CONDITIONS 1 EMERGENCY CABIN PRESSURE selector valve set to NORMAL.

2. CABIN REPRESS manual valve set to OPEN.

3. When surge tank pressure indicator decreases to 150 psia, EMERGENCY CABIN PRESSURE selector valve set to OFF, surge tank minimum pressure (150 psia) maintained by regulating CABIN REPRESS manual valve until valve is full open and surge tank pressure starts to increase

4 Normal cabin pressure regulators automatically open at 3.5 psia

5 When surge tank pressure again decreases to 150 psia, CABIN REPRESS manual valve regulated to maintain this minimum surge tank pressure.

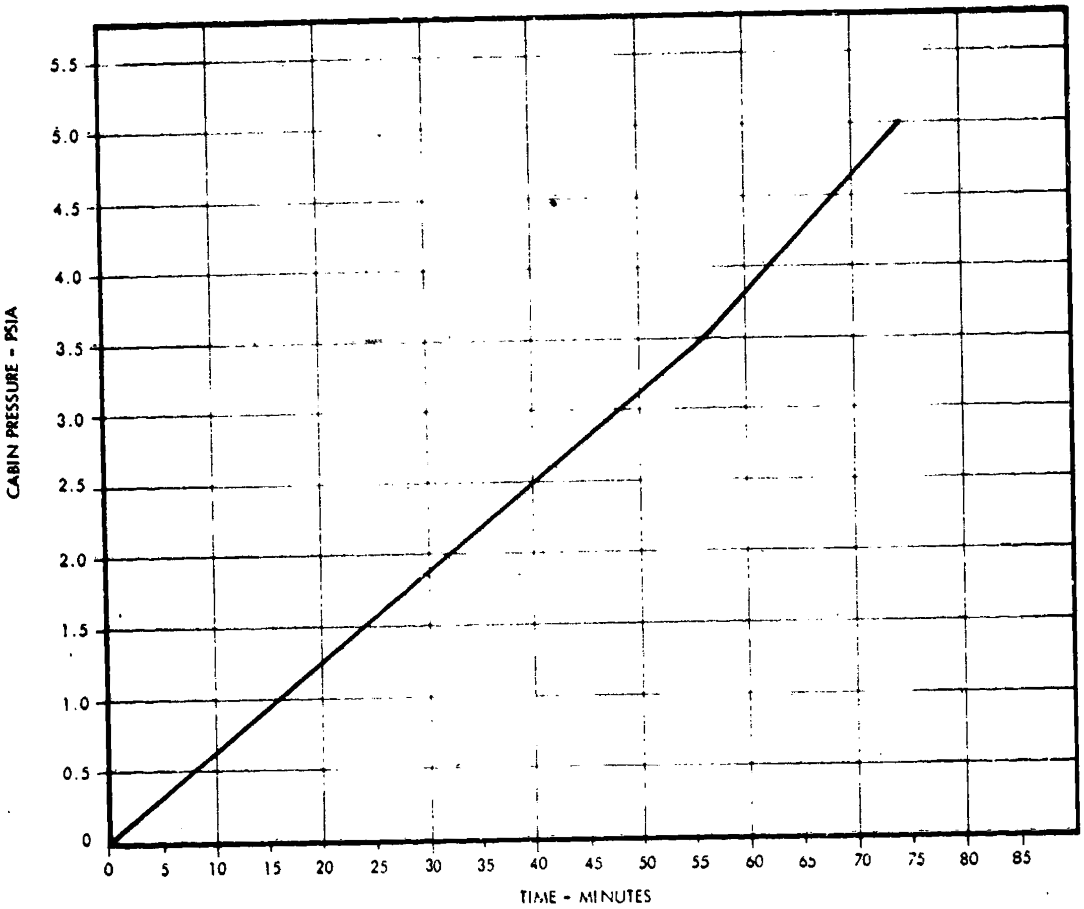
6 When cabin pressure indicator reaches 5.0 psia, normal cabin pressure regulators automatically close and CABIN REPRESS manual valve set to close

* Requires 9.1lb oxygen at [illegible]°F cabin temperature

M-2A-[illegible]A

Figure 2.7-12. Cabin Repressurization Rates (Sheet 1 of 2)

CABIN REPRESSURIZATION - 0 TO 5 PSIA *
NORMAL TIME - 74 MIN, 25 SEC



CONDITIONS: 1. EMERGENCY CABIN PRESSURE selector valve set to OFF.

2. CABIN REPRESS manual valve set to OPEN.

3. Normal cabin pressure regulators automatically open at 3.5 psia

4. When cabin pressure indicator reaches 5.0 psia, normal cabin pressure regulators automatically close and CABIN REPRESS manual valve set to close

* Requires 9.1 lb oxygen at 70°F cabin temperature

SM-2A-887A

Figure 2.7-12. Cabin Repressurization Rates (Sheet 2 of 2)

LIST OF REFERENCES

20-1 Mumma, G. B. and Olson, R. E.: Report of Spacecraft Fire Hazards. Martin Company, Denver, Colorado, February 1967

20-2 Huggett, Clayton, PhD: The effects of 100% oxygen at reduced pressures on Ignitability and Combustibility of Materials. SAM-TR-65-78, USAF School of Aerospace Medicine, Brooks AFB, Texas, December 1965, pages 1, 2, 4, 7 and 8.

20-3 National Aeronautics and Space Administration, Manned Spacecraft Center, S67-71 Film of Zero-G Inflammability.

20-4 Anon: Investigation of Aerospace Vehicle Crew Station Criteria. FDL-TDR-64-86 AD452187, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, page 64.

20-5 Staklis, A.A., PhD: Fire Control for Spacecraft with 5-psia Oxygen Atmospheres. Preliminary NASA TN S-136, 1967, pages 1-5, 11, 17, 18, 27, 36, 37 and 40-42.

20-6 Henderson, Edward M., Lunde, Alfred N., and Newman, Samuel R.: Spacecraft Operational Trajectory for AS-204, S/C 012. NASA-MSC Internal Note 66-FM-113. Vol. I and II, Part B, page 33, October 17, 1966.

20-7 Anon: AS-204 CSM S/C 012 Subsystem Operating Logic Schematics. General Electric Company, ASD-MSCCO, Houston, Texas, January 1967.

20-8 Anon: MSC Test Report CSD-A-288 (STB-A-015/29) Manned Spacecraft Center, Houston, Texas, July 29, 1966, pages 6 and 7.

GLOSSARY OF ABBREVIATIONS

AC	Alternating Current
AOH	Apollo Operations Handbook
C	Command Pilot
CAM	Camera
CCW	Counterclockwise
CIRC	Circuit
CM	Command Module
COMM	Communications
COMPR	Compressor
CONT	Control
CW	Clockwise
LEB	Left Equipment Bay
LH	Left Hand
MAX Q	Maximum Dynamic Pressure
O_2	Oxygen
P	Pilot
PRESS	Pressurization
RH	Right Hand
S	Senior Pilot
SEL	Selector
SEQ	Sequence
TV	Television
UCD	Urine Collection Device

REPORT OF PANEL 21
SERVICE MODULE DISPOSITION
APPENDIX D-21
TO
FINAL REPORT OF
APOLLO 204 REVIEW BOARD

A. TASK ASSIGNMENT

The Apollo 204 Review Board established the Service Module Disposition Panel, 21. The task assigned for accomplishment by Panel 21 was prescribed as follows:

This task involves the planning and execution of necessary S/M activity beginning at the time of Board approval for Command Module (C/M) demate. This task will be performed mainly by appropriate Apollo line organizational elements in accordance with a Board approved plan which identifies the Board requirements for documentation and control of this activity.

B. PANEL ORGANIZATION

1. MEMBERSHIP:

The assigned task was accomplished by the following members of the Service Module Disposition Panel:

Mr. W. W. Petynia, Chairman, Manned Spacecraft Center (MSC), NASA
Mr. R. D. Carothers, Kennedy Space Center (KSC), NASA
Mr. B. R. Haight, North American Aviation (NAA), KSC

2. COGNIZANT BOARD MEMBER:

Mr. John J. Williams, Kennedy Space Center (KSC), NASA, Board Member, was assigned to monitor the Service Module Disposition Panel.

C. PROCEEDINGS

1. The Panel discharged its responsibilities to the Board by planning and executing the following major S/M activities:

a. Demated the Service Module/Service Module Lunar Module Adapter (SM/SLA) from the Launch Vehicle (LV) and moved the SM/SLA to the Manned Spacecraft Operations Building (MSOB).
b. Performed a detailed inspection of both the exterior and interior areas of the S/M.
c. Performed detailed systems tests of all S/M systems mechanically or electrically connected to the C/M at the time of the accident.

Following demate of the C/M at Launch Complex 34 (LC34), the activities to demate the S/M and perform detailed systems tests were in accordance with a board approved plan (Board Action 0163). Specific tasks performed in executing this plan were conducted in the following general areas:

(1) INSPECTION AT LC 34. Following demate of the C/M, a visual inspection was made on February 17 and 18 by structural engineers to verify the structural integrity of the S/M and determine the handling method to be utilized to lower the SM/SLA from the LV and transport to MSOB.

(2) DEMATE AND MOVE TO MSOB. The SM/SLA combination was demated from the LV and moved to the MSOB on February 23, 1967. The SM/SLA was positioned in MSOB Integrated No. 1 stand in preparation for separation of S/M and SLA.

(3) DEMATE SM/SLA. Following demate of the S/M and SLA all pyrotechnic devices were removed from the SLA. Electrical continuity tests of the S/M and SLA interface wiring were made. The S/M was positioned in the H14-134 stand to remove the Service Propulsion System (SPS) nozzle extension and then moved to the H14-124 stand for access to perform the detailed inspections and systems tests. The SPS nozzle extension was reclassified to Category "C" by the 204 Review Board on March 3 (Material Release Record No. 0140) and placed in storage. The SLA was reclassified to Category "C" by the 204 Review Board on March 4 (Material Release Record No. 0142) and returned to the Apollo line organizations for storage.

(4) DETAILED INSPECTION IN MSOB. A detailed inspection was made of both the exterior and interior areas of the S/M (See Enclosure 21-2). The inspection was carried out in two phases by two different groups. The first phase was conducted with the S/M Reaction Control

System Panels (RCS QUAD) open and the top deck Mylar insulation in place. The second phase was made with the top deck Mylar removed. In order to provide access and visibility during the inspections, the following hardware was removed:

(a) Sector I access door.
(b) Sector IV access door.
(c) SPS flame shield.

The two groups inspecting the S/M were composed of both NASA and NAA personnel. The first group consisted of Quality Control Inspectors. The second group consisted of systems engineers and representatives of Apollo 204 Review Panels. Both groups included the following areas in their detailed inspection:

(a) Top deck of S/M (Mylar on).
(b) Top deck of S/M (Mylar off).
(c) Exterior areas.
(d) Sector 4 areas.
(e) Cryogenic areas.
(f) SPS engine compartment.
(g) Bottom of S/M
(h) Quad A and Quad A access area.
(i) Quad B and Quad B access area.
(j) Quad C and Quad C access area.
(k) Quad D and Quad D access area.

During the detailed inspection, appropriate photographs were taken and summary findings written. All hardware items removed for the inspection were reinstalled.

(5) SYSTEMS TESTS. Following the detailed inspection, specific detailed systems tests were made for the following systems:

(a) ELECTRICAL POWER SYSTEM

The Electrical Power System (EPS) tests consisted of the following:

(1) Selected resistance checks through the CM/SM umbilical, and the flyaway umbilical were performed prior to removal of DC Power Distribution Box (DC PDB).

(b) ENVIRONMENTAL CONTROL SYSTEM

The Environmental Control System (ECS) tests consisted of the following:

(1) The water/glycol remaining in the S/M was drained and transferred to the Pyrotechnic Installation Building (PIB) and placed in bonded storage to be included with that from the C/M.

(2) The integrity and condition of the water/glycol system was determined by leak check with dry nitrogen.

(c) PROPULSION SYSTEM

The Propulsion System tests consisted of the following:

(1) The operation and condition of the Propellant Utilization Gaging System (PUGS) controller was determined in the EPS Laboratory. The tests of the controller were made using the SPS PUGS Bench Maintenance Equipment. After completing the tests, the PUGS controller was reinstalled in the S/M.

(2) The operation and condition of the SPS Flight Combustion Stability Monitor (FCSM) amplifier and relay box were investigated.

(3) Samples of all foreign material found in the upward pointing RCS engine nozzles (-X thrust) for all four engines was collected. These samples were sent to the Material Analysis Branch laboratory for quantitative analysis.

(d) INSTRUMENTATION SYSTEM

The Instrumentation System test consisted of the following:

(1) Resistance measurements of the SM/SLA separation monitor circuits were made.

(2) The SM/SLA separation monitor was removed and sent to the PIB for component analysis.

(e) FUEL CELL/ECS OXYGEN SYSTEM

The Fuel Cell/ECS Oxygen System tests consisted of the following:

(1) The integrity of that portion of the cryogenic system used to supply breathing oxygen to the astronauts at the time of the accident was determined. The oxygen line was pressurized to 500 psi with dry helium and the pressure decay over a thirty-minute period was measured.

(2) The operation and condition of the fuel cell reactant valves was determined. The continuity between the contacts on the shut-off valves was determined. Resistance to ground through the solenoids of each of the valves was made to determine any grounding of any of the coils.

(3) The continuity through the fuel cell switch used to control the individual fuel cell heaters was determined. With the switch disconnected, the resistance through the coil of the motor switch to S/M ground point was measured.

(4) The continuity through the holding current switch contacts was determined. With the switch disconnected, the resistance through the coil of the motor switches to S/M ground point was measured.

(5) The continuity through the tank heater control switch contacts was determined. With the motor switches disconnected, the resistance through the coil of the motor switch to S/M ground was measured.

D. FINDINGS AND DETERMINATIONS

1. FINDINGS

Detailed inspections of the S/M interior and exterior areas by Quality Control Inspectors, systems engineers and 204 Panel Members (References 21-1 thru 21-4) found the S/M suffered minor damage by fire. (See Enclosures 21-3 and 21-4.)

DETERMINATION

a. There is no indication that the S/M was the origin of the fire.

b. The fire damage to the S/M resulted from a source located above the S/M.

2. FINDINGS

Test results indicate S/M motor switch S-6 in the DC PDB was transferred to the closed position resulting in fuel cell No. 2 harness being connected to Bus B (Reference 21-5). The control switches in the C/M were found in the off position.

DETERMINATION

It was determined by examination of resistance checks of the C/M wiring made at the CM/SM umbilical connector P/J 12 that the control wiring in the C/M was shorted causing the S/M motor switch to transfer.

3. FINDINGS:

Fuel Cell No. 2 hydrogen shut-off valve was found in the open position (Reference 21-6).

DETERMINATION:

It was determined by examination of resistance checks of the C/M wiring made at the CM/SM umbilical connector P/J 12 that the control wiring in the C/M was shorted causing the valve to open. Telemetry data up to loss of signal (LOS) from the C/M show the valve closed indicating opening was a result of the accident.

4. FINDINGS:

Test results indicated that the hydrogen tank No. 2 heater wiring circuit was open (Reference 21-7).

DETERMINATION:

It was determined that the S/M wiring was proper and that the open circuit existed in the heater circuit (containing thermal switches) inside the tank. This condition is not considered abnormal because the thermal switches in series with the heater element open at 80°F (±10°) (Reference 21-8). Ambient temperature was well within this range of temperatures.

5. FINDINGS:

No shorts or open circuits were found in the wiring for the SM/SLA separation monitor (SS0120X) wiring, but the fuse in the S28A7 fuse box was found to be open (Reference 21-9).

DETERMINATION:

Prior to moving the S/M to LC 34 the separation monitor tape was inadvertently pulled out of its case and subsequently pushed back in. It was determined by investigation (Reference 21-10) that pushing the tape back in would cause the tape to short-to-case and thus blow the fuse.

6. FINDINGS:

Test results failed to show any S/M anomalies due to the S/M systems (Reference 21-5 thru 21-16).

DETERMINATION:

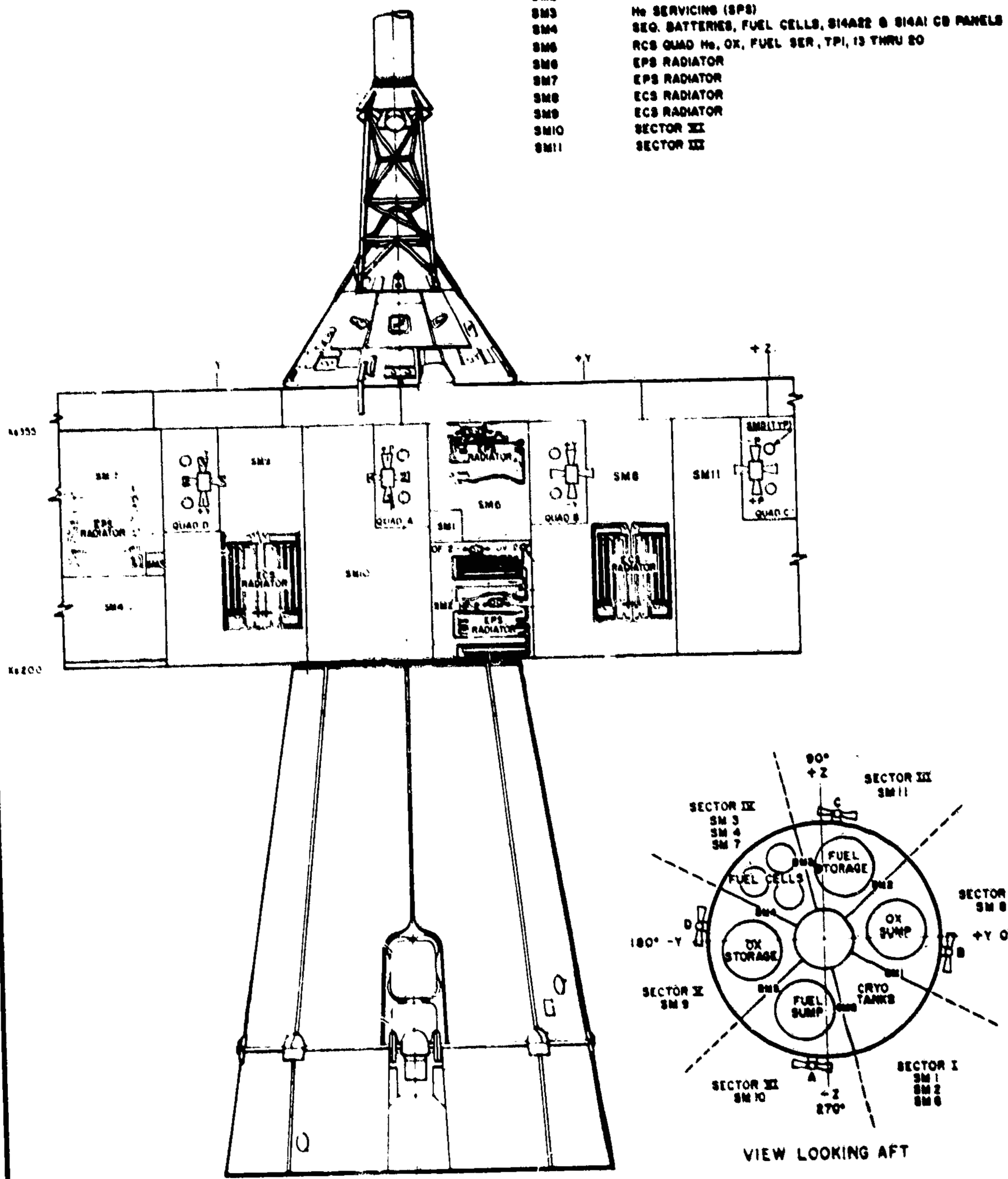
There is no indication the S/M systems were responsible for initiating the accident.

E. SUPPORTING DATA

Enclosures	Description
21-1	Not Used.
21-2	General arrangements of S/M and sectors
21-3	Top deck of S/M with Mylar installed
21-4	Top deck of S/M with Mylar removed
21-5	List of References

S/M CODE

SM1	CRYO TKS, PROPULSION
SM2	EPS RADIATOR
SM3	He SERVICING (SPS)
SM4	SEQ. BATTERIES, FUEL CELLS, 814A22 & 814A1 CB PANELS
SM5	RCS QUAD He, OX, FUEL SER, TPI, 13 THRU 20
SM6	EPS RADIATOR
SM7	EPS RADIATOR
SM8	ECS RADIATOR
SM9	ECS RADIATOR
SM10	SECTOR VI
SM11	SECTOR III



GENERAL ARRANGEMENT OF SM SECTORS

ENCLOSURE 21-2

REFERENCES

REFERENCE 21-1: Inspection of S/M top deck after CM demate. TPS No. S/C 012-S/C 099, dated February 16, 1967.

REFERENCE 21-2: Quality Control Inspection of S/M. TPS No. 012-SM-IV-003 dated February 27, 1967.

REFERENCE 21-3: Engineering Inspection of S/M. TPS No. 012-SM-IV-004 dated February 27, 1967.

REFERENCE 21-4: Dry and Clean –X RCS Engines. TPS No. 012-SM-008 dated March 1, 1967.

REFERENCE 21-5: S14A1 Motor Switch Analysis. TPS No. 012-SM-CA-001 dated March 8, 1967.

REFERENCE 21-6: Fuel Cell and CGSS Investigation. TPS No. 12-SM-IV-012 dated March 2, 1967.

REFERENCE 21-7: Continuity Check - Specific S/M Circuits. TPS No. 12-SM-IV-007 dated March 1, 1967.

REFERENCE 21-8: Hydrogen Tank No. 2 Heater checkout. TPS No. S/C 012-SM-IV-016 dated March 11, 1967.

REFERENCE 21-9: Separation Monitor Investigation (SS0120X). TPS No. 012-SM-IV-002 dated February 24, 1967.

REFERENCE 21-10: Separation Monitor Investigation. TPS No. S/C 012-SM-CA-002 dated March 9, 1967.

REFERENCE 21-11: SM Water Glycol Deservicing. TPS No. 12-SM-IV-013 dated March 4, 1967.

REFERENCE 21-12: PUGS Control Unit Test. TPS No. 012 SM-IV-005 dated February 27, 1967.

REFERENCE 21-13: FCSM Checkout. TPS No. 012-SM-IV-009 dated March 2, 1967.

REFERENCE 21-14: Remove Liquid from Quad B Engine No. 3 for Analysis. TPS No. 12-SM-MA-001.

REFERENCE 21-15: Leak Check of ECS Supply Lines. TPS No. 012-SM-IV-010 dated February 15, 1967.

REFERENCE 21-16: SLA Wiring Resistance Check. TPS No. 12-SLA-IV-002 dated March 2, 1967.