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UNITED STATES GOVERNMENT

Memorandum

TO : AA/Chairman, Flammability Test Review Board

DATE: FEB 5 1968

FROM : PA/Manager, Apollo Spacecraft Program

In reply refer to:
PD9-8M-88

SUBJECT: Command Module flammability considerations

Purpose - The purpose of this memorandum is to review the major flammability problems encountered during the BP 1224 test program, discuss the actions implemented to resolve the problems, and submit recommendations regarding the next phase of the BP 1224 program.

Introduction - The BP 1224 test program has been conducted in two phases. The first phase evaluated CM (Command Module) flammability at 6.2 psia, 95% oxygen pressure which is the maximum pressure the spacecraft can encounter after injection into orbit. The second phase essentially repeated tests of Phase I with a mixture of 60% oxygen and 40% nitrogen at a test pressure of 16.2 psia which is a possible prelaunch cabin environment for S/C 101. A third phase is also planned to evaluate performance in an environment of 95% oxygen at 16.2 psia.

Thirty-eight tests were conducted at 6.2 psia, 95% oxygen, and 31 were executed at 16.2 psia, 60% oxygen, 40% nitrogen. All were considered successful except for those associated with problems related herein. The results of the BP 1224 tests, including configuration descriptions, are more completely defined in Structures and Mechanics Division's Reports to the Flammability Test Review Board dated January 8 and January 26. These reports provide a detailed understanding of the configurations and conditions described herein.

Discussion - Four significant areas of concern were encountered in the BP 1224 test program. These are as follows:

a. Main Display Console panels

b. Acoustic insulation in the cabin heat exchanger enclosure

c. Circuit breaker panels

d. Guidance and Control eyepiece insulation

In addition, the coaxial cable previously identified as a potential problem (reference my memorandum PA-7-12-43 dated December 19, 1967) did not self-extinguish when ignited during Phase II (16.2 psia, 60% oxygen, 40% nitrogen) conditions.

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Coaxial cable - The coaxial cable used in the CM was determined to be a flammable kynar/polyolefin configuration after fabrication of CSM 101 and 2TV-1 was essentially complete. Considerable testing was executed at the component level to define the ignition and propagation characteristics of the cable assembly. Testing in BP 1224 was conducted to determine if ignition would occur under "realistic" electrical failure modes and to examine propagation if ignition occured. Results show that the cable is extremely difficult to ignite and propagation is unlikely except in vertical runs of the cable. All fires self-extinguished in the 6.2 psia test conditions. The test configuration in BP 1224 differed from the CSM 101 and 2TV-1 configuration. The cable vertical run in the lower equipment bay above the girth shelf was not wrapped with aluminum tape in BP 1224 as it is in CSM 101 and 2TV-1. The following actions had previously been taken to resolve this problem (reference memorandum PA-7-12-43):

a. Vertical runs of the coaxial cable above the girth shelf were wrapped with aluminum tape in CSM 101 and 2TV-1. It was demonstrated in component tests that this tape prevented burning of the cable.

b. Cables in CSM 103, 104, 106, and 107, were completely wrapped.

c. In CSM 108 and subsequent vehicles the kynar/polyolefin cable has been replaced by a nonflammable teflon cable.

These actions are still considered to be adequate.

MDC (Main Display Console) panels - Conformal coating used in the CM is flammable and was therefore covered by a fire-resistant coating to prevent propagation of fire. The coating used in the CM is called Ladicote and was applied to the MDC panels to a minimum thickness of 0.045 inches. Early tests at NR indicated this thickness was adequate for these panels. During the BP 1224 tests at 6.2 psia oxygen, fire propagated during two tests of the MDC panels, Panel 2 and Panel 3. The switch configuration of Panel 3 was the CSM 2TV-1 configuration, plastic covered switches on the back of the panel. Fire propagated on Panel 3 after ignition on the back of the panel and the fire burned through the panel resulting in test termination after 29 minutes and 45 seconds. The switch configuration of Panel 2 was the CSM 101 configuration, metal covered switches on the back of the panel. Fire propagated to a number of switches after ignition on the back of Panel 2. The fire self-extinguished and the test was terminated after 30 minutes. Silicone laminate scuff covers have been placed on the back of the MDC panels and other electrical panels. The scuff covers prevent damage to wiring during manufacturing operations and installation of the electrical panels. The fire did not propagate to or ignite the covers. Component tests of the cover have demonstrated that the covers will not burn in a 6.2 psia oxygen environment. Scuff

cover material sample tests in 60% oxygen, 40% nitrogen at 16.2 psia have shown the material is extremely difficult to ignite but will burn vertically upward. The covers will burn in a 16.2 psia, 100% oxygen environment.

The Ladicote thickness has been increased to 0.090 inches minimum on all electrical panels in CSM 103 and subsequent vehicles. Tests of circuit breaker panels indicate that this will prevent any propagation of the fire at 6.2 psia oxygen. A component test of Panel 3 to verify the effectiveness of this fix will be conducted at NR on February 7, 1968. Fire extinguisher access holes have been provided in the MDC panels in CSM 101 and 2TV-1. Considering the propagation rate of the fire during the BP 1224 tests, the crewman would have adequate time to extinguish the fires that were observed in BP 1224. This will be verified during fire extinguisher tests planned at NR.

Cabin heat exchanger acoustic insulation - The fluorel acoustic insulation in the cabin heat exchanger enclosure burned rapidly in the BP 1224 test. The material was known to be flammable but the burning rate was considerably increased by the high gas velocity resulting from cabin fan circulation of oxygen through the heat exchanger.

Acoustic tests have revealed that the insulation can be deleted with no adverse effects on cabin noise level. It was removed from CSM 101 and subsequent vehicles. Tests conducted in BP 1224 show that the crew could safely egress CSM 2TV-1 if a fire should occur; therefore, the material will be retained in this ground test vehicle. Tests at NR have also demonstrated that the fire can be extinguished with the foam fire extinguisher agent provided in 2TV-1 in approximately 5 seconds.

Toxic? Tru?

Circuit breaker panels - All circuit breaker panels and terminal strips were coated with Ladicote to a minimum thickness of 0.090 inches. Initial tests indicated that this thickness was adequate to self-extinguish fires even at the 16.5 psia, 95% oxygen "worst case" environment. Later tests at NR showed that fire can propagate very slowly at this "worst case" condition when the breaker panel is tightly packed into the CM equipment bays. Age of Ladicote may also contribute to this slow propagation. The BP 1224 tests showed that this slow propagation also occurs at the 16.2 psia, 60% oxygen, 40% nitrogen environment. No fire propagation has ever occurred at the 6.2 psia oxygen condition with the 0.090 inches Ladicote thickness. This protection is adequate for all spacecraft. The only propagation that could occur is during prelaunch operations at 16.2 psia, 60% oxygen, 40% nitrogen. The crew has adequate time to egress. We also believe this protection is adequate to limit propagation during the launch phase of the mission while the cabin pressure is above 6.2 psia.

In addition, NR is investigating the provision of holes to allow access of the fire extinguishing foam to all electrical panels. Beta bag overwrap of circuit breakers has been demonstrated by test to prevent fire propagation in all environments. Panel fabrication problems using the Beta bags indicated they may be unacceptable.

Guidance and Control eyepieces - Fluorel insulation over the heater on the Guidance and Control eyepiece was ignited and burned with considerable dripping of flaming particles which resulted in secondary ignition of mylar covered maps on the work table. The insulation has been replaced by a metallic strap. Teflon film is under investigation as a substitute for the mylar. Housekeeping procedures will be developed to reduce any hazard associated with the crew flight data file to a minimum.

Additional Board actions - During the Board meeting held on December 11, a request was made to evaluate replacing the crewman communications umbilical ("cobra cable"). A fluorel umbilical is being evaluated and will be used if it proves to be acceptable. In addition, it is planned to cover the silicon with a Beta sleeve if this proves to be feasible during mockup evaluation.

Conclusions - The results of the BP 1224 and associated flammability test programs result in the conclusion that adequate fire protection has been provided to assure crew safety at both 6.2 psia, 100% oxygen, and 16.2 psia, 60% oxygen, 40% nitrogen environmental conditions.

Recommendations

a. Approve CSM 2TV-1 and 101 for manned test and flight at the 6.2 psia oxygen pressure orbital and 16.2 psia, 60% oxygen, 40% nitrogen pre-launch environmental conditions.

b. Authorize conduct of the next BP 1224 tests of the CSM 101 and 2TV-1 "worst case" configuration at 16.2 psia, 95% oxygen.

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Write up items or results --
① Reg NAA Test results
② Toxicity Review.
③ 60-40 decision + follow up
our needs as regards testing to
find when & 60-40.