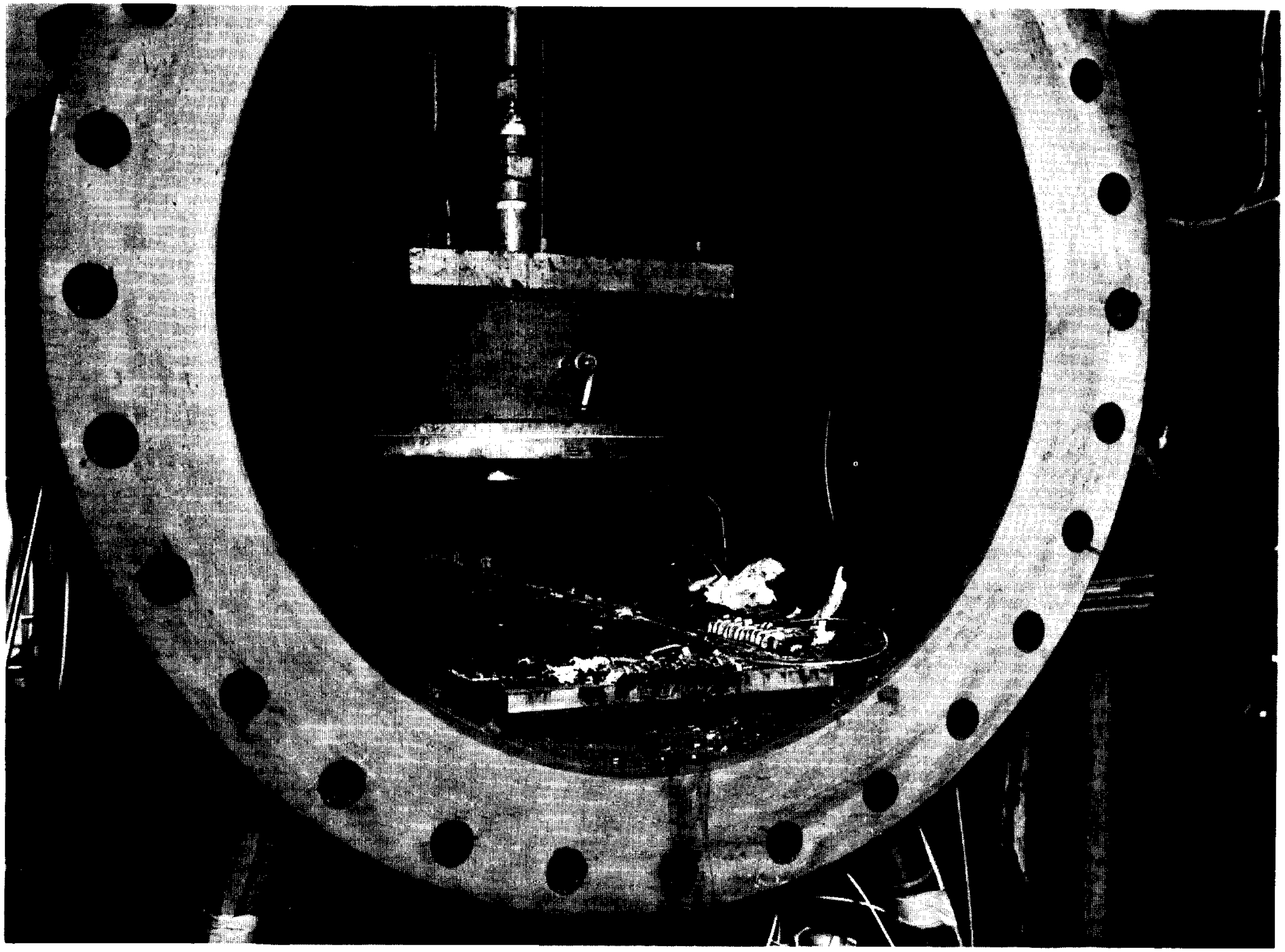


Figure F3.9-5.- View of chamber conditions after test.

PART F3.10

PANEL SEPARATION TESTS

Objectives

The objective of these tests was to demonstrate complete separation of the SM bay 4 cover panel in a manner that could be correlated with flight conditions. The panel failure mechanism and the pressure distribution that resulted in separation were also to be determined.

Approach

An experimental and analytical program utilizing one-half scale dynamic models of the SM bay 4 cover panel was conducted. Panels were attached through replica-scaled joints to a test fixture that simulated pertinent SM geometry and volume. Venting was provided between compartments and to space. A high-pressure gas system was used to rapidly build up pressure behind the cover panel as the input force leading to failure.

Size of the dynamic models (one-half scale) was determined primarily by material availability. The use of full-scale materials and fabrication techniques in the model was dictated by the need to duplicate a failure mechanism. Therefore, similarity laws for the response of structures led to scale factors of one-half for model time and one-eighth (one-half cubed) for model mass. From these scale factors for the fundamental units, some of the derived model to full-scale ratios are as follows:

Displacement = 1/2
Velocity = 1
Acceleration = 2
Area = 1/4
Volume = 1/8

Force = 1/4
Pressure = 1
Stress = 1
Energy = 1/8
Momentum = 1/8

A step-by-step approach to testing led to rapid learning as new factors were introduced. Initial tests were conducted on isotropic panels that scaled only membrane properties while more completely scaled sandwich panels were being fabricated. Testing started in atmosphere while preparations for vacuum testing were underway. In a similar manner, first tests concentrated on determining the pressure input required for separation and deferred the simulation of internal flow required to produce these distributions to later tests.

Analysis of the one-half scale bay 4 cover panel models used two computer programs. Initial dynamic response calculations using a nonlinear elastic finite difference program indicated that panel response was essentially static for the class of pressure loadings expected in the tests. Subsequent calculations used static loadings with a nonlinear elastic finite element representation and the NASTRAN computer program.

Apparatus

Models.- Figure F3.10-1 shows the full-scale and model panel cross sections.

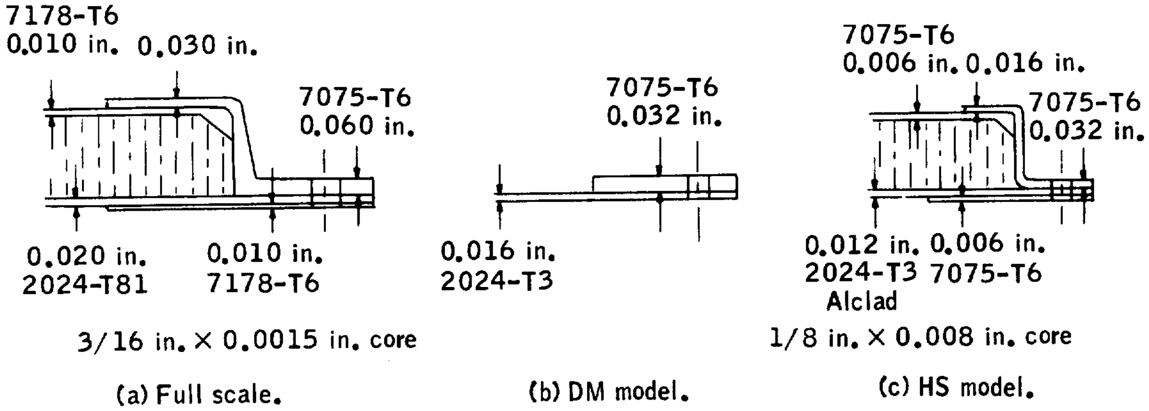
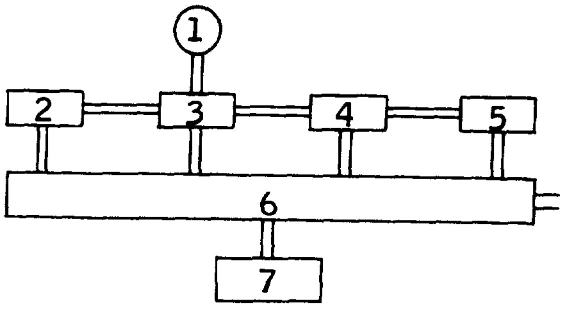


Figure F3.10-1.- Panel designs.

The full-scale panel is a honeycomb sandwich structure with a z-bar edge closeout attached to the SM by 1/4-inch bolts around the edges and to each of the bay 4 shelves. The first one-half scale panel models, designated DM and shown in figure F3.10-1(b), scaled membrane properties of the full-scale sandwich panel inner and outer face sheets with a single isotropic panel having the correct nominal ultimate tensile strength. The z-bar was simulated by a flat bar that represented the shear area of the outer z-bar flange. Fastener sizes, bolt patterns, and bonding material were duplicated from full scale.

One-half size honeycomb sandwich panels, designated HS and shown in figure F3.10-1(c), scaled both bending stiffness and membrane stiffness. Although core density of the sandwich models is slightly high, the dimensions, materials, bonding, and z-bar closeout are scaled. Some alloy substitutions were made but nominal strength requirements were met.

Test fixture.- The test fixture shown schematically in figure F3.10-2 and in the photographs of figure F3.10-3 is a one-half size boilerplate mockup of the SM bay 4 and central tunnel. Vent areas connect the bay 4 shelf spaces to the central tunnel and to each other. The tunnel also has vents to space and to a large tank simulating the remaining free volume of the SM. Vent areas were adjusted in initial tests to obtain desired pressure distributions but were scaled from the best available data for final testing. The fixture also holds the pressurization system and instrumentation. True free volume was approached by adding several wooden mockups of equipment.



Volume	Description
1	Pressurization tank
2	Fuel cell space
3	O_2 Tank space
4	Upper H_2 tank space
5	Lower H_2 tank space
6	Tunnel
7	Other SM free volume

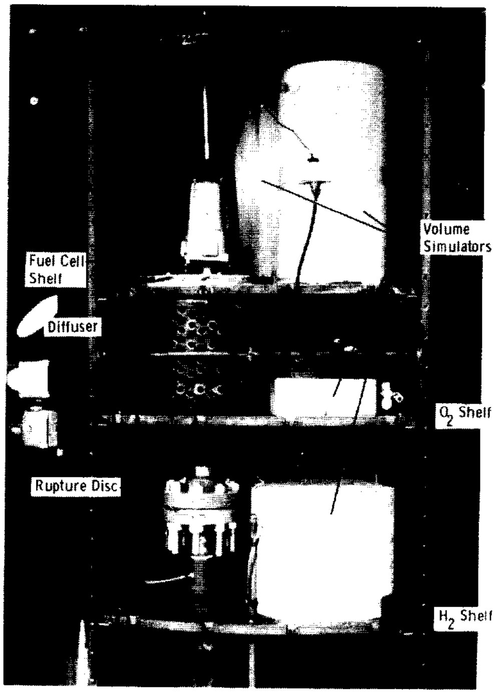
Figure F3.10-2.- Schematic of test fixture.

Pressurization system.- The pressurization system can also be seen in the photographs of figure F3.10-3. A 3000-psi accumulator is discharged on command through an orifice by mechanically rupturing a diaphragm. The gas expands into the oxygen shelf space of bay 4 through a perforated diffuser. In order to obtain uniform pressure over the entire panel for some tests, the diffuser was lowered so that it discharged into both the oxygen and hydrogen shelf spaces. For these particular tests, extra vent area was provided between all shelves to insure uniform pressure throughout bay 4. For most tests, a shield was placed between the diffuser and panel to minimize direct impingement.

Other.- Instrumentation consisted of strain gages, fast response pressure sensors, and high-speed motion picture cameras. Atmospheric tests were conducted in the Rocket Test Cell and vacuum tests at 1mm Hg pressure in the 60-Foot Vacuum Sphere at Langley Research Center.

(a) General view.

(b) Fixture with panel installed.



(c) Internal view.

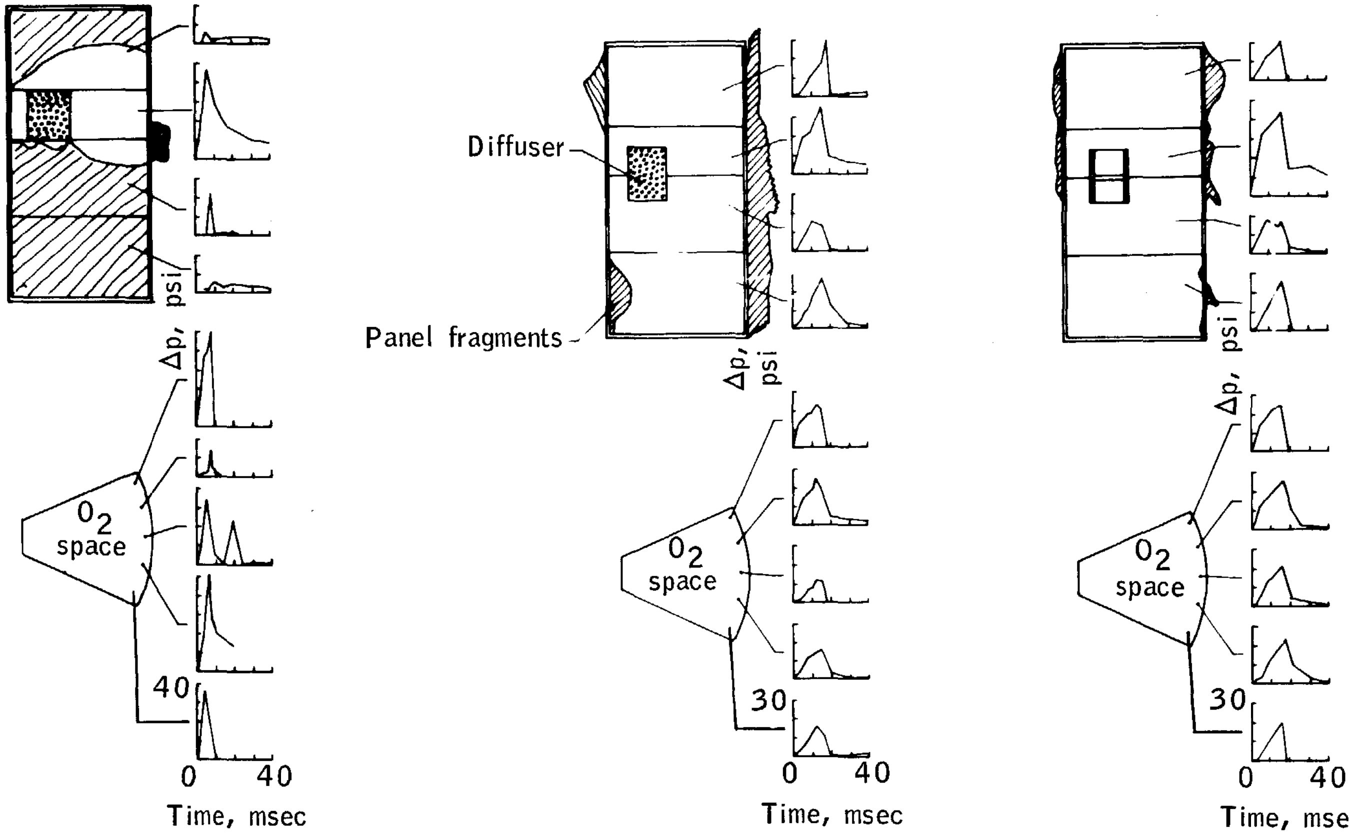
Figure F3.10-3.- One-half size boilerplate mockup of the SM bay 4 and central tunnel.

Results and Discussion

Presentation of results.- The test program is summarized in table F3.10-I. Typical failures and pressure-time histories are illustrated in figure F3.10-4. Figure F3.10-5 is a sequence of prints from high-speed movie cameras that demonstrate separation of the sandwich panel models. Results of NASTRAN calculations on the one-half scale models are presented in figures F3.10-6 and F3.10-7.

Demonstration of panel separation.- Panel separation has been demonstrated with both membrane and sandwich panels. Two sandwich panels separated completely from the test fixture during vacuum tests. Two membrane panels, although less representative of flight conditions, also separated completely in vacuum tests. However, similar tests with membrane panels in atmosphere left portions of panels attached to the test fixture as illustrated in figures F3.10-4(b) and (c). Complete separation in atmosphere could not be achieved due to mass and drag of the air.

Pressure distributions.- Complete membrane panel separation was achieved only with nearly uniform pressure distribution over the entire bay 4 panel cover, shown in figure F3.10-4(d). When just the oxygen shelf space experienced high pressures, membrane panel separation was localized to the area of the panel over the oxygen shelf space as shown in figure F3.10-2(a). This type of local failure occurred in both atmosphere and vacuum. When scaled internal venting was introduced, model DM-10 lost a slightly larger portion of panel due to high pressure experienced by both the oxygen shelf and fuel cell shelf spaces while the rest of bay 4 was at low pressure.

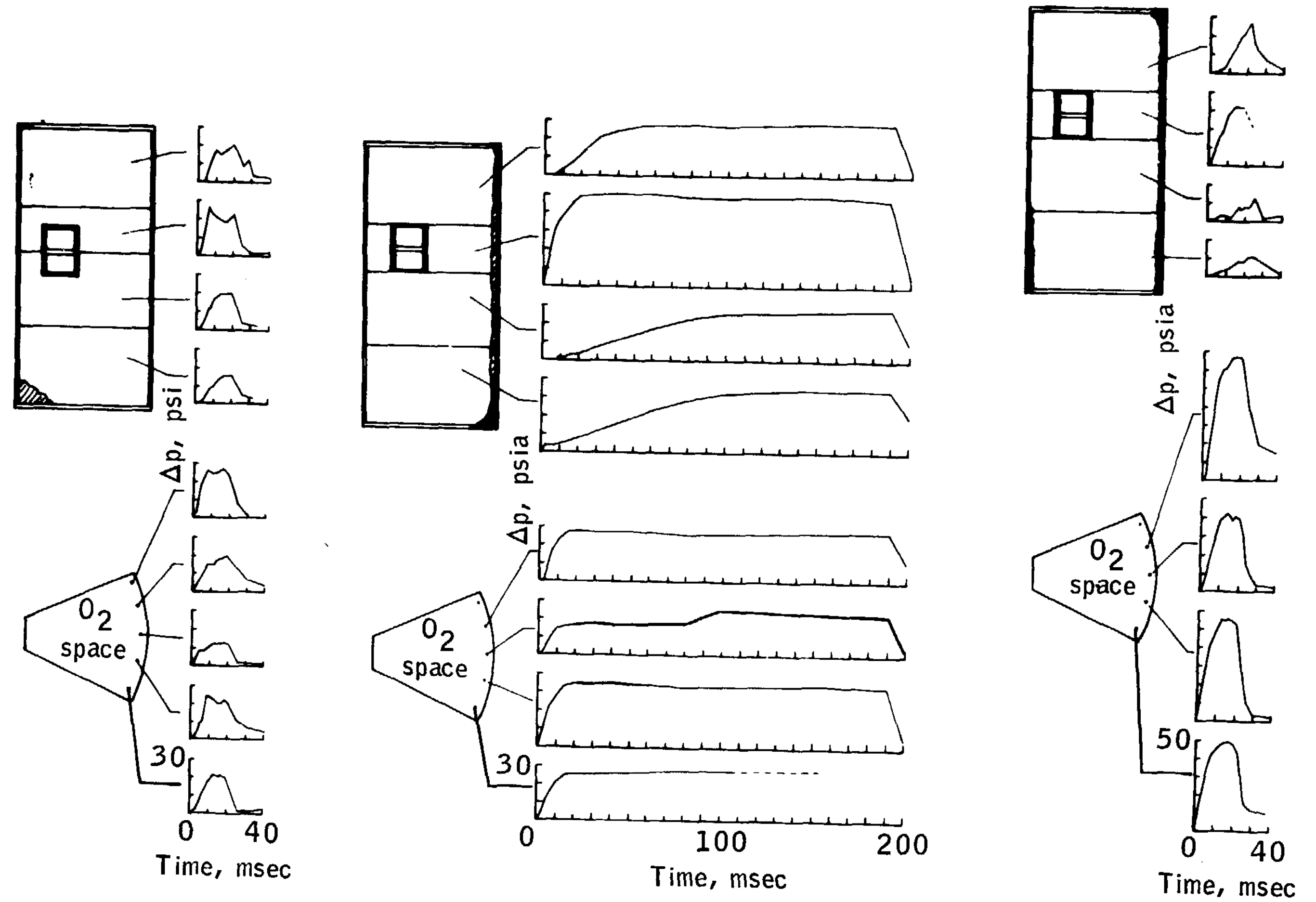


a. Membrane panel DM-2, atmosphere, band load

b. Membrane panel DM-3, atmosphere, uniform load

c. Membrane panel DM-4, atmosphere, uniform load, no direct impingement

Figure F3.10-4.- Failure modes and pressure-time histories.



d. Membrane panel DM-6, vacuum, uniform load, no direct impingement

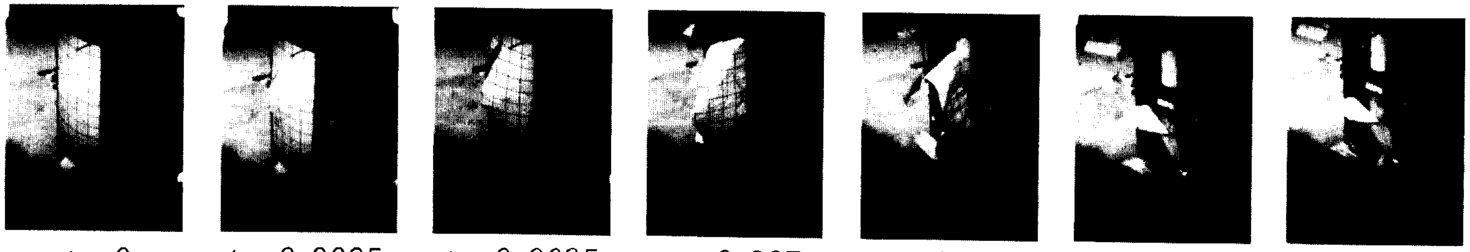
e. Sandwich panel HS-2, vacuum, no direct impingement

f. Sandwich panel HS-3, vacuum, no direct impingement

Figure F3.10-4.- Concluded.

(c) Sandwich panel HS-2.

(b) Sandwich panel HS-3.



(a) Membrane panel DM-6.

Figure F3.10-5.- Sequential failure of two sandwich and one membrane panel (t = time from first observed failure).

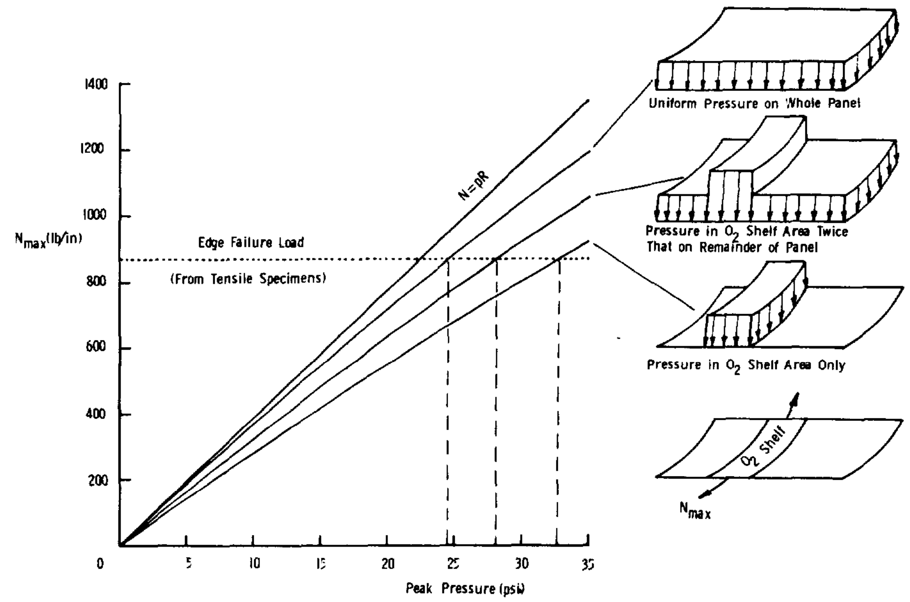


Figure F3.10-6.- Maximum edge load on half-scale honeycomb panel as predicted by NASTRAN.

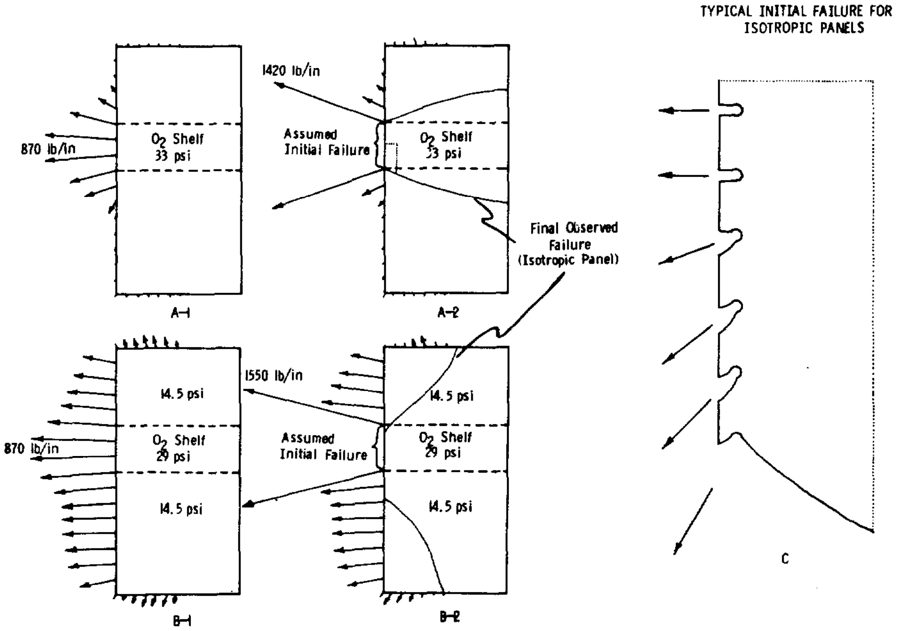


Figure F3.10-7.- Distribution of edge loads on half-scale Apollo 13 honeycomb panel as predicted by NASTRAN.

TABLE F3.10-I.- PANEL SEPARATION TEST SUMMARY

Model	Internal vents	Volume first pressurized	Diffuser	Load character	Pressure*		Failure
					Peak, psi	Rise time, sec	
Atmosphere tests							
DM-1-1	Not scaled	Oxygen shelf	Open	Band	24-30	0.020	None
DM-1-2	Not scaled	Oxygen shelf	Open	Band	30-58	0.005	Oxygen shelf area
DM-2	Not scaled	Oxygen shelf	Open	Band	34-52	0.006	Oxygen shelf area
DM-3	Not scaled	Bay 4	Open	Uniform	15-35	0.015	Nearly total (folded back)
DM-4	Not scaled	Bay 4	Shielded	Uniform	20-26	0.016	Nearly total (left edges)
Vacuum tests							
DM-5-1	Not scaled	Bay 4	Shielded	Uniform	14-20	-	None
DM-5-2	Not scaled	Bay 4	Shielded	Uniform	20-28	0.016	Total
DM-6	Not scaled	Bay 4	Shielded	Uniform	19-27	0.018	Total
DM-7	Not scaled	Oxygen shelf	Open	Band	25-40	0.005	Oxygen shelf area
DM-8	Not scaled	Oxygen shelf	Shielded	Band	20-37	0.012	Oxygen shelf area
DM-9	Not scaled	Oxygen shelf	Shielded	Band	18-23	0.040	None
DM-10	Scaled	Oxygen shelf	Shielded	-	21-39	0.070	Upper 2/3 of panel
HS-1	Scaled	Oxygen shelf	Shielded	-	-	-	None
HS-2	Scaled	Oxygen shelf	Shielded	-	23-32	0.190	Total
HS-3	Scaled	Oxygen shelf	Shielded	-	30-67	0.020	Total
HS-4	Scaled	Oxygen shelf	Shielded	-	30-44	0.020	None

*Range of peak pressures in the oxygen shelf space is indicated. Time from pressure release to peak pressure is rise time.

Complete separation of sandwich panels has been obtained with both uniform and nonuniform pressure distributions. Figure F3.10-8 shows the type of pressure time histories experienced by various sections of the panels. The pressure predictions are based on the internal flow model

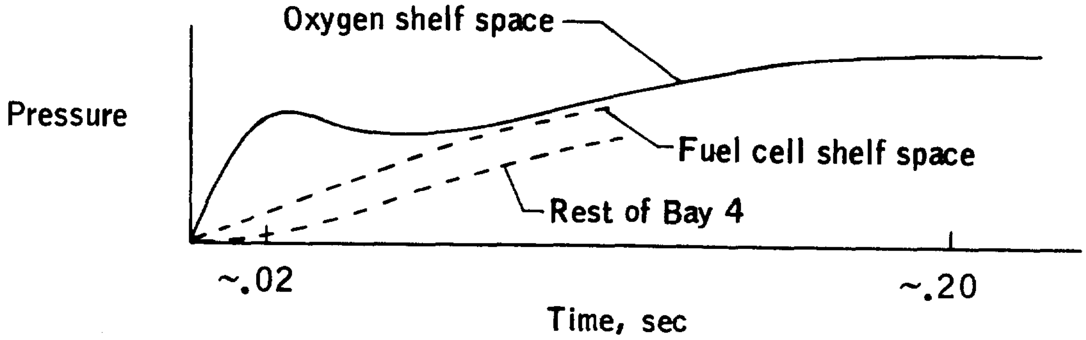


Figure F3.10-8.- Pressure build-up in bay 4.

of the Apollo 13 SM shown in figure F3.10-2 and have been verified in these experiments. Peak pressure levels were varied from test to test but the curve shape was always similar. One sandwich panel separated after about 0.02 second during the initial pressure rise in the oxygen shelf space, while overall panel loading was highly nonuniform as shown in figure F3.10-4(b). The other sandwich panel did not separate until about 0.19 second after all bay 4 compartments had time to fill with gas and arrive at a much more uniform loading, as shown in figure F3.10-4(e).

The effect of pressure distribution on peak pressures required for failure is shown by the NASTRAN calculation in figure F3.10-6. Included for reference is the linear membrane result, $N = pR$. The load required for edge failure was determined from tensile tests on specimens of the DM model joints. The peak uniform pressure at failure initiation is only 75 percent of peak pressure at the failure load with just the oxygen shelf space pressurized.

Failure mechanism.- The failure mechanism for complete separation of a membrane panel is demonstrated by the photographic sequence in figure F3.10-5(a). Failure is probably initiated by a localized high pressure near the edge of the oxygen shelf space. A crack formed where a shelf bolt head pulled through and rapidly propagated through the panel. Expansion of the pressurizing gas through the openings accelerated panel fragments to very high velocities. Inertia loads from the high acceleration completed the separation. Membrane panels were observed to separate in three pieces--one large and two small fragments.

The failure of a sandwich panel under uniform loading in vacuum is shown in the picture sequence of figure F3.10-5(c). Failure started at the edge of the oxygen shelf space by pull-through of the edge bolts through the upper sandwich face sheet. Very rapid tearout along three edges followed, primarily by tension in the face sheets and tearing of the core material from the z-bar at the edge. The panel then rotated like a door and separated from the test fixture in one piece.

Nonuniform loading of a sandwich panel led to the failure shown in figure F3.10-5(b). Initial failure was at the panel edge near the fuel cell shelf. Tearout along one edge and the top rapidly followed, similar to the previous failure. However, the edge tear stopped before reaching the bottom and became a diagonal rip that left the lower third of the panel attached to the fixture. The upper two-thirds of the panel then rotated door-like and separated. Finally, a vertical tear propagated through the center of the remaining fragment, the bottom tore out, and rapid rotation separated the remnants in two pieces.

Figure F3.10-7 relates NASTRAN calculations to the observed failures. Predicted edge load direction and magnitude are illustrated for two pressure distributions. In figure F3.10-7, parts A-1 and B-1, panel edges are assumed fixed, while in figure F3.10-7, parts A-2 and B-2, the panel edge joint along the oxygen shelf space is assumed to have failed. Also shown in figure F3.10-7, parts A-2 and B-2, are typical observed failure patterns for these types of loadings on membrane panels. An enlargement of the dotted section of figure F3.10-7, part A-2, is shown in part C of the figure to indicate the type of edge failure observed. Arrows indicate the direction of force required to cause the pullout failures. The NASTRAN edge force patterns are consistent with these failures. In addition, figure F3.10-7, parts A-2 and B-2, indicates that tears into the membrane panels tend to remain normal to the direction of the edge forces.

Correlation with flight.- Tests with sandwich panels more closely similate flight conditions than tests with membrane panels due to initial failure characteristics and post-failure separation behavior. The separation behavior of sandwich model HS-3, figures F3.10-4(f) and F3.10-5(b), is also believed to be more representative of flight than the separation behavior of model HS-2, figures F3.10-4(e) and F3.10-5(c), for two reasons. First, although model HS-2 was tested with scaled internal venting between the compartments of bay 4 and the SM tunnel, the rest of the SM free volume had been closed. In the HS-3 model test, this vent area had been opened to a realistic value of 60 square inches. Second, the slow pressure buildup before separation of model HS-2 allowed SM tunnel pressure to rise well above the 10-psi limitation required to prevent CM-SM separation. Pressurization leading to model HS-3 separation was so rapid (20 milliseconds) that SM tunnel pressure remained below the 10-psi limit. The time to failure would scale up to 40 milliseconds for the flight configuration.

Tests with models HS-3 and HS-4 have bracketed the most likely separation conditions. For both tests, internal venting was scaled and diffuser configuration and accumulator pressure were identical. Model HS-3 separated due to an initial air flow of 190 lb/sec through an orifice of 2.85 square inches. Separation was not achieved on model HS-4 when initial air flow was 135 lb/sec through a 2.0-square inch orifice, even though peak pressures of over 35 psi occurred in the oxygen shelf space after 20 milliseconds.

As a part of this study, an analysis has also been carried out at the Langley Research Center to estimate the distribution and time history of pressures within the Apollo 13 service module. Based on these calculations and the experimental results on panel separation, it appears that additional combustion outside the oxygen tank or rapid flashing of ejected liquid oxygen may have occurred to produce panel separation. A report of this analysis can be found in the official file of the Review Board.

Conclusions

Complete separation of one-half scale honeycomb sandwich models of the bay 4 cover panel in vacuum has been demonstrated. Separation was achieved by rapid air pressurization of the oxygen shelf space. Internal volumes and vent areas of the SM were scaled. Separations were obtained with both uniform and nonuniform pressure distributions. The separation resulting from a nonuniform loading that peaks 20 milliseconds after start of pressurization (40 milliseconds full scale) correlates best with hypotheses and data from flight. This particular panel separated in three pieces after an initial tear along the sides that allowed it to open like a door. Inertial loads are a major factor in obtaining complete separation after initial failure.

PART F4

MASTER LIST OF TESTS AND ANALYSES

This part presents a listing of tests and analyses grouped according to the following event categories:

Shelf Drop

Detanking

Quantity Gage Dropout

Short Generation

Ignition

Propagation of Combustion

Pressure Rise

Temperature Rise

Pressure Drop

Final Instrument Loss

Telemetry Loss

Tank Failure

Oxygen Tank No. 1 Pressure Loss

Panel Loss

Side Effects

Miscellaneous

MASTER LIST OF TESTS AND ANALYSES

[By Event]

Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
"SHELF DROP"			
13-T-55(T) MSC P. Glynn R. Lindley	Tank Impact Test	Determine energy required to produce a dent in tank dome and determine the approximate input g level to tank.	C - May 26, 1970. A load of 7g was required to produce a dent in the tank shelf.
13-T-60 MSC P. Glynn S. Himmel	Quantity Gage Rivet Test	Apply incrementally increasing force to the load rivet supporting the quantity probe concentric tubes until the rivet fails. X-ray the rivet during significant failure stages to show the failure mechanism.	C - April 27, 1970. Shortly after a load of 105 lb was applied, a decrease to 90 lb was noted, indicating a failure. When the load was increased to 120 lb, the rivet failed by bending and subsequently pulling through the probe tubing.
A-92(T) LRC R. Herr R. Lindley	Shock Load Failure Test of Fan Motor Mounting Screws	Determine by test the shock load at which the four 4-40 x 1/4-inch steel fan mounting screws fail.	C - May 8, 1970. The four machine screws started yielding between 2000g and 2500g with complete failure in tension between 4000g and 4200g with an attached 0.875-lb mass.
DETANKING			
13-T-07R3(T) Beech A/C S. Owens K. Heimburg	Apollo 13 Oxygen Detanking Simulation	Determine the effects on the tank wiring and components of the detanking sequence with the Inconel sleeve and Teflon block displaced in the top probe assembly.	ECD - June 18, 1970. Test in progress.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined

MASTER LIST OF TESTS AND ANALYSES

[By Event]

Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
		DETANKING	
13-T-08R1(T) MSC C. Propp K. Heimburg	Bench Test of Oxygen Tank Conduit	Determine whether the electrical loads and pressure cycling during KSC detanking raised the wire temperature in the conduit to damaging levels.	C - May 15, 1970. Maximum temperature of the conduit (at the midpoint) reached 325° F. Pressure cycling of the tank did not raise the temperature significantly. Inspection showed no degradation. Test results will be confirmed by TPS 13-T-07R3(T).
13-T-19(T) NR J. Jones K. Heimburg	Ground Support Equipment Filter Analysis	Identify contaminants (oil and glass beads) found in GSE filter pads during Apollo 13 oxygen tanking at KSC and determine if the filter material could be responsible for the failure to detank.	C - April 20, 1970. This test showed that the filter assembly did not contribute to the system malfunction. Oxygen-compatible lubricant was found on filter.
13-T-20(T) KSC H. Lamberth K. Heimburg	Heater Cycle Test at KSC	Determine if the oxygen tank heater cycled during the 7-hour period of prelaunch detanking at KSC.	C - May 1, 1970. Test results indicate that heater cycling would cause voltage drop on other channels. The prelaunch records during detanking show that the heaters did not cycle but remained continuously "on."
13-T-53(T) MSC C. Propp K. Heimburg	Heater Assembly Temperature Profile	Determine if the heater temperatures could have been high enough during the KSC detanking to degrade the fan motor lead wire insulation. Tests are to be carried out using nitrogen.	C - May 26, 1970. Tests indicate heater surface could reach 1000° F. Wire conduit could reach 750° F. Teflon insulation was damaged. A second detanking test resulted in thermal switch failure in the closed position with 65 V dc applied.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined

MASTER LIST OF TESTS AND ANALYSES

[By Event]

Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
DETANKING			
13-T-80 MSC C. Propp H. Mark	Thermostatic Switch Failure Tests	Determine the voltage and current levels at which the thermostatic switches weld shut in the closed position when they attempt to open in response to temperatures exceeding 80° F.	C - June 5, 1970. The thermostatic switches fail to open where currents exceeding 1.5 amps at 65 V dc are passed through them. The heater current used in the special detanking procedure at KSC was 7 amps at 65 V dc, well in excess of the measured failure current.
A-15(T) KSC T. Sasseen E. Baehr	Blowdown Characteristics of Oxygen Tanks	Determine the bleeddown time from 250 psig using GSE at KSC with the proper configuration for one tank and the fill tube completely disconnected for the other tank.	C - May 15, 1970. The test proved that both tanks did depressurize in practically identical times considering the difference in vent lines and back pressure. The test refuted the earlier assumption of a time difference between the different tank configurations. The significance is that blowdown data are not sensitive enough to determine the fill tube configuration.
QUANTITY GAGE DROPOUT			
13-T-30(T) MSC R. Robinson R. Wells	Quantity Gage and Signal Conditioner Test	Determine the signal conditioner response under extreme transient conditions of ambient temperature, determine quantity gage failure indications, and define transient and steady-state energy levels supplied to every possible fault condition.	C - May 22, 1970. The quantity gage signal conditioner deviated less than 0.85 percent under extreme temperature excursions, the response of the gage to various electrical faults was catalogued, and an analysis of the energy level of faults was made. The significance of this test is that it permits interpretation of abnormal quantity gage readings at the time of the accident and eliminates the gage as a probable source of ignition.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined

MSC Form 343 (OT) NASA — MSC

MASTER LIST OF TESTS AND ANALYSES

[By Event]

Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
SHORT GENERATION			
13-T-11(T) MSC R. Robinson R. Wells	Fan Motor Inductive Voltage Discharge and Electrical Energy Release	Determine the amount of stored energy released from the fan motor when one power lead is opened.	C - May 7, 1970. The test showed a power release of 0.02 joule. Transient peak voltage of 1800 volts and current of 0.7 amp were measured. These data establish the energy potential from an open circuit failure of a fan motor.
13-T-22(T) MSC G. Johnson R. Wells	Inverter Operational Characteristics	Determine the operating characteristics of the spacecraft ac inverter when operated with three-phase, phase-to-phase, and phase-to-neutral step loads and short circuits.	C - April 20, 1970. Generally, faults introduced on a particular phase gave a voltage reduction on that phase and a voltage rise on the other phases. Clearing the faults gave the opposite response. This information assists in interpretation of flight data.
13-T-23(T) MSC J. Hanaway R. Wells	AC Transient Voltage Signal Duplication	To determine whether bus 2 transients are capable of producing the type of response seen in the SCS auto TVC gimbal command servo signals just prior to the oxygen tank failure.	C - April 22, 1970. This series of tests applied transients to the ac bus that dipped the bus voltage to 105, 95, 85, and 80 volts for durations of 50, 100, and 150 milliseconds. The transient that dipped the voltage to 85 volts for 150 milliseconds, caused a transient of 0.16 degree per second in the SCS signals, which matched the largest transient observed in the flight data. The significance of this is that it allows more precise timing of the duration, and estimation of the magnitude, of possible causes of ignition.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined

MASTER LIST OF TESTS AND ANALYSES

[By Event]

Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
IGNITION			
13-T-01(T) MSC L. Leger I. Pinkel	Ignition of Fan Motor Winding by Electrical Overload	Determine if overloaded fan motor winding will cause ignition and combustion of the insulation in supercritical oxygen. Initial conditions were 115 volts, 1-amp fuse, current initially 1 amp and increased in 0.5-amp increments.	C - April 24, 1970. Windings were not fused by 400 Hz-5 amps; 8 amps dc fused winding wire. Ignition did not occur. Results were the same in nitrogen and oxygen at 900 psia, -180° F. NR test shows same result.
13-T-13(T) MSC C. Propp I. Pinkel	Spark Ignition Energy Threshold for Various Tank Materials	Determine if an electrical spark generated by tank wiring can ignite selected nonmetallic tank materials.	C - May 30, 1970. A single Teflon insulated wire may be ignited with energies as low as 0.45 joule with a spark/arc.
13-T-15(T) ARC L. Stollar H. Mark	Spark Source Ignition in Supercritical Oxygen	Determine if Teflon can be ignited with 115 V ac spark under various conditions in oxygen atmospheres.	C - April 30, 1970. Three tests in oxygen of 50 psig, 500 psig, and 940 psig at ambient temperature showed insulation ignited and burned in all cases. In oxygen at 940 psig and -190° F the Teflon insulation ignited and burned with a 138-psig pressure rise and no noticeable temperature rise.
13-T-21(T) MSC G. Johnson I. Pinkel	One-Amp Fuse Test	Determine the time/current characteristics to blow the 1-amp fuses in the tank fan circuit.	C - April 20, 1970. The fuses blow at the following currents and times: 4 amp - 0.05 second, 8 amps - 0.025 second. These values give approximately 16 joules.
13-T-24(T) MSC C. Propp I. Pinkel	Tank Materials Ignition Test	Exploratory test with electrical overloads and nichrome heaters to determine the ignition and combustion possibilities of tank materials in low and high pressure gaseous oxygen and ambient pressure liquid oxygen.	C - May 30, 1970. Drilube 822 and all of the different types of tank wiring ignited. Nickel wire was only partially consumed in LOX and solder could not be ignited. The power levels required to get ignition were far in excess of the amount available in the tank.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined

NASA — MSC

MSC Form 343 (OT)

MASTER LIST OF TESTS AND ANALYSES

[By Event]

Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
IGNITION			
13-T-25(T) MSC P. McLaughlin	Locked-Rotor Motor Fan Test	Determine motor behavior in a locked condition and check possibility of ignition and propagation.	C - April 19, 1970. Two motors were tested in LOX and powered for 2.3 and 1.0 hours, respectively. There was no indication of malfunction such as heating, arcing, or sparking. Posttest measurements showed no degradation of motor wire insulation.
13-T-28(T) MSFC R. Johnson I. Pinkel	Liquid Oxygen Impact Test of Tank Components	Obtain the impact sensitivity data on Ag-plated Cu wire (two sizes), nickel wire, 822 Drilube, and Pb-Sn solder.	C - May 22, 1970. Teflon insulated wire showed no reaction, Drilube 822 had one reaction of 20 tests, 60-40 solder ignited in 7 out of 20 tests. These results indicate that in one-g, Teflon and Drilube are acceptable in LOX from an impact sensitivity standpoint and that 60-40 solder is not acceptable.
13-T-33(T) NR B. Williams I. Pinkel	Spark/Electric Arc Ignition Test	Determine the spark/electric arc ignition characteristics of Teflon and other nonmetallic materials in a LOX/GOX environment by simulating specific component failures which could serve as possible ignition sources.	C - April 19, 1970. There was no ignition of the Teflon in the LOX at 1 atmosphere. This test was superceded by later tests.
13-T-34(T) NR B. Williams I. Pinkel	Closed Chamber Spark Ignition Test	Determine the possibility of igniting Teflon on a motor lead wire when the Teflon is penetrated by a grounded knife edge in pressurized LOX while the motor is running.	C - April 20, 1970. This was an early test designed for a quick appraisal and the desired test conditions were not realized.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
IGNITION			
13-T-35(T) NR G. Johnson I. Pinkel	One-Amp Fuse Test	Determine the time/current characteristics of the 1-amp fuses in the tank fan circuit using a spacecraft regulator and inverter.	C - April 19, 1970. Fuses blow at the following times and currents: 0.010 second -7.3 amps, 0.012 second - 5.0 amps, 0.100 second - 3.1 amps, and 1.00 second - 2.0 amps.
13-T-36(T) NR R. Johnson I. Pinkel	Hot Wire Test of Nonmetallic Tank Materials	Determine if Teflon materials in the tank will ignite with ohmic heating at simulated tank environment.	C - April 20, 1970. This test shows that Teflon sleeving in supercritical oxygen can be ignited by the burn-through of a nichrome wire with 7 to 18 joules.
13-T-41(T) MSC R. Bricker I. Pinkel	Failed Wire Overload Ignition	Determine if a failure or defect in a wire could produce an overload condition with eventual ignition of wire insulation.	C - June 1, 1970. No ignition was obtained where fan motor wire was reduced to one strand with electric current ranging up to 5 amperes. Current-time duration was fixed by quick-blow 1-amp fuse used in fan motor circuit. In a separate test, a 3-amp current was held for 1 minute without ignition.
13-T-42(T) MSC C. Propp I. Pinkel	Ignition Capability of Quantity Gage Signal Conditioners	Determine if the quantity gage signal conditioners can supply sufficient energy to cause ignition in supercritical oxygen.	C - May 18, 1970. Test with signal conditioner showed that it is incapable of generating enough electrical energy to cause ignition of Teflon.
13-T-44(T) WSTF A. Bond I. Pinkel	High Pressure LOX Sensitivity of Metallics with Surface Oxide Penetrations	Determine if a freshly scored or abraded surface of tank metal would provide an environment suitable for initiation of fire under typical LOX tank operating conditions.	ECD - TBD. Tests to start June 5, 1970. Metallic materials will be 1100Al, 2024T-3Al, and 3003Al. Tests will be extended to include Alcoa AMS-3412 brazing flux.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
IGNITION			
13-T-62(T) ARC T. Canning H. Mark	Ignition Test of Teflon Submerged in LOX	Determine the ignition potentiality of Teflon submerged in LOX from an electrical short.	C - May 4, 1970. This test shows that Teflon can be ignited by a low energy electrical spark (5 ± 3 joules) and gives sustained temperatures great enough to melt through the test fixture, ceramic feed-throughs and cause pressure increases.
13-T-68(T) ARC J. Parker H. Mark	Flow Reactor Test	Determine the effect of flowing oxygen over a heated polymer.	C - May 4, 1970. The initial stage of degradation follows a first-order process. The temperature at which spontaneous ignition occurs is 500° C.
13-T-69(T) ARC J. Parker H. Mark	Arc Test of Tank Materials Submerged in LOX at One Atmosphere	Determine ignition energy required from a short circuit to cause ignition in atmospheric oxygen.	C - May 4. 1970. All materials could be ignited but burning was very marginal. Ignition energy under these conditions was not determined.
13-T-70(T) ARC J. Parker H. Mark	Ignition Test on Tank Materials in High-Pressure LOX	Determine the ignition energy required from a short circuit to cause ignition in high-pressure LOX.	C - May 4, 1970. The test indicated that spark energies of 2.5 joules would ignite Teflon and initiate a metal-Teflon reaction.
PROPAGATION OF COMBUSTION			
13-T-04R2(T) NR/MSC/KSC E. Tucker I. Pinkel	Sample Analysis of Residual Oxygen in S/C 109 Surge Tank	Determine the contaminates present in the residual oxygen in the surge tank as an aid in identifying the possible source of combustion.	C - May 30, 1970. Tests showed trace contaminate level had not changed from that or original tank fill.

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
PROPAGATION OF COMBUSTION			
13-T-06(T) MSC R. Bricker I. Pinkel	Ignition of Oxygen Tank Metals by Burning Teflon	Determine if burning Teflon can ignite metals at cryogenic conditions and attempt to ignite quantity probe aluminum tube by igniting the probe wires.	C - May 27, 1970. Iron, Inconel, and aluminum were ignited by burning Teflon in a series of tests. A separate test showed that a flame propagating along Teflon insulation will enter the quantity probe insulator. Posttest examination showed that about a 2-inch diameter hole had burned through the 3/8-inch thick stainless steel tank closure plate.
13-T-12(T) MSC R. Bricker I. Pinkel	Propagation Rates of Ignited Teflon Wire Insulation and Glass-Filled Teflon	Determine the flame propagation rate of various forms of Teflon used in the oxygen tank.	C - May 15, 1970. Flame propagation rate for Teflon insulation in 900 psia/-180° F oxygen was 0.2 to 0.4 in/sec downward. In 900 psia/75° F oxygen, Teflon gives 0.4 to 0.9 in/sec downward and 2 to 10 in/sec upward, and glass-filled Teflon gives 0.09 to 0.17 in/sec downward.
13-T-18(T) NR E. Tucker I. Pinkel	Inspection and Contamination Analysis of CM Oxygen System Components - S/C 109	Determine the contaminates present and damage incurred in components of the oxygen system as an aid in identifying the source and extent of the anomaly.	ECD - TBD. Work in progress. Laboratory analysis of contaminants in oxygen system components is to begin June 18, 1970.
13-T-48(T) MSC A. Bond I. Pinkel	Comparison of Uncolored and Color-Filled Teflon Flame Propagation Rates	Determine the electrical conductivity and the flame propagation of colored, uncolored, and fingerprint-contaminated Teflon.	C - May 15, 1970. This test was done under TPS 13-T-12. The fingerprint portion will be done at a later date.

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PROPAGATION OF COMBUSTION			
13-T-49(T) LeRC A. Bond I. Pinkel	Teflon Flame Propagation in Zero-g	Determine the propagation rates for fan motor and temperature sensor wire bundle at zero-g for comparison with data from tests performed at one-g.	ECD - June 17, 1970. Zero-g flame propagation rate over fan motor wire bundles in clear Teflon sleeving is 0.12 in/sec and in white pigmented sleeving 0.15 to 0.32 in/sec. Measurement of zero-g flame propagation rate along wire in oxygen tank conduit to start June 10.
13-T-56(T) MSC R. Bricker I. Pinkel	Teflon Spark Ignition	Determine the ignition energy of a variety of Teflon materials not associated with Apollo 13.	ECD - August 1, 1970.
13-T-57(T) MSC R. Bricker I. Pinkel	Teflon Propagation Rates	Determine the bounds of Teflon propagation rates in supercritical oxygen.	ECD - August 30, 1970. Tests to start end of June. Tests will establish flame propagation rates for Teflon insulation formulations which differ from present Apollo insulations; to provide possible candidate insulations of reduced fire hazard.
13-T-58(T) MSC C. Propp I. Pinkel	Ignition and Flame Propagation Tests of Fan Motor Lead-Wire System	To determine whether lead wire flame will propagate into fan motor and ignite the interior when immersed in oxygen at 900 psi and -180° F.	C - May 22, 1970. Flame propagates into fan motor house without ignition of any metals or stator windings.
13-T-59(T) MSC C. Propp B. Brown	Oxygen Tank Combustion Propagation Test	Determine the pressure time history curve of an oxygen tank if the lower motor lead wires are ignited between the entrance to the motor and the exit from the heater assembly.	C - June 4, 1970. Ignition point was located at lower fan motor. Flame propagated along wire insulation to tank conduit approximately 1-1/2 as fast as observed in Apollo 13 flight oxygen tank. Tank failure occurred in conduit close to tank closure plate.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
PROPAGATION OF COMBUSTION			
13-T-63(T) ARC J. Parker H. Mark	Products of Combustion of Teflon in LOX	Determine the principal products of combustion of Teflon in oxygen.	C - May 4, 1970. The principal product of combustion was COF_2 with an energy release of 121 kcal/mole.
13-T-64(T) LRC J. Hallisay W. Erickson	Propagation Rate of Teflon Combustion in Supercritical Oxygen	Determine the propagation rate of combustion along a wire in supercritical oxygen.	C - June 2, 1970. Test gives downward propagation rate of 0.25 in/sec for a single black wire.
13-T-67(T) ARC J. Parker H. Mark	DTA on Motor Components	Perform a differential thermal analysis on aluminum and Teflon in air.	C - May 4, 1970. This test shows that approximately 793 kcal/mole of heat are released when Teflon, aluminum, and oxygen react.
A-86(A) LRC G. Walberg W. Erickson	Computer Prediction of Products from Oxygen/Teflon Combustion	Compute the flame temperature and major combustion products for a range of oxygen/Teflon ratios and assumed heat losses.	C - May 19, 1970. The maximum flame temperature is 4360° F and the major products of combustion are COF_2, CF_4, and CO_2. F_2 mole fraction is 0.10 at highest temperature.
13-T-17R1(T)			See Pressure Rise.
13-T-25(T)			See Ignition.

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
PRESSURE RISE			
13-T-17R1(T) MSC C. Propp W. Erickson	Oxygen Tank Wiring Conduit Propagation Rate and Pressure Buildup	Determine the propagation rate of combustion and the pressure increase in the tank conduit filled with supercritical oxygen when the wiring is ignited at the electrical connector end of the conduit.	C - May 17, 1970. Ignition started in conduit behind electrical connector. Conduit ruptured approximately 2 to 3 seconds after ignition.
13-T-26(T) MSC P. McLaughlan F. Smith	Flowmeter Test	Determine the effects of oxygen pressure and temperature variations on flowmeter output to analyze why the flowmeter behavior led the remaining instrumentation in the timeline prior to failure.	C - April 27, 1970. During the ambient temperature test a step pressure increase would result in a spike in the flowmeter output but the flowrate indication would not show any other change. At low temperatures an increase or decrease in pressure would give an indicated corresponding change in flow. At constant pressure a temperature change would give an indicated flow change. All of these effects were known and the data do not have to be corrected for any unexpected behavior of the flowmeter.
13-T-46(T) ARC A. Bond F. Smith	Filter Clogging by COF_2	Determine if the oxygen tank filter can be clogged by COF_2 snow.	ECD - TBD. This test has not yet been conducted.
B-62(T) MSC C. Propp E. Cortright	Simulated Tank Fire	Investigate pressure-temperature profiles and propagation patterns within a closely simulated oxygen tank with various ignition points.	This test was conducted under TPS 13-T-59.

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
PRESSURE RISE			
A-87(A) MSC/LRC R. Ried G. Walberg W. Erickson	Energy Required to Account for Observed Pressure Rise	Determine the energy required to explain the observed pressure rise in oxygen tank no. 2. An isentropic compression of the oxygen is considered as well as a constant density process with heat addition.	C - May 19, 1970. The minimum energy required (isentropic) is about 10 Btu and the maximum (constant density) is about 130 Btu.
13-T-37(T)			See Final Instrument Loss.
TEMPERATURE RISE			
13-T-38(T)			See Final Instrument Loss.
B-62(T)			See Pressure Rise.
PRESSURE DROP			
13-T-02(T) MSC C. Fropp V. Johnson	Relief Valve Blowdown Investigation	Determine the differential pressure between a simulated oxygen tank and the flight pressure transducer as a function of a mass flow through the relief valve. Also determine the response of the flight transducer to a step pressure stimulus.	C - April 27, 1970. The maximum pressure difference between the tank and the flight transducer was 9 psig at a flow rate of 182 lb/hr. The pressure stimulus of 75 psi was transmitted to the flight transducer in 24 milliseconds and reached 100 percent of the step pressure in 57 milliseconds. This test shows that the flight transducer will follow the system pressure under high flow rates and step pressure increases and will not introduce significant errors in the TM data.

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
		PRESSURE DROP	
13-T-16(T) Parker A/C W. Chandler V. Johnson	Relief Valve Flow Tests	Determine the flow rate of the relief valve at temperatures from 360° R to 1060° R.	C - May 15, 1970. The flow rate at these temperatures ranged from approximately 0.016 to 0.034 lb-m/sec. This is greater than is required to produce the observed pressure drop.
13-T-27(T) MSC P. Crabb N. Armstrong	Oxygen Relief Valve System Simulation at 80° F	Determine the pressure drop between the filter and the relief valve, and the flight pressure transducer response to a step pressure increase.	C - April 21, 1970. The maximum recorded pressure drop between the simulated tank and pressure transducer was 18 psi. A 500-psi step increase in the "tank" was measured by the pressure transducer with a delay of about 100 milliseconds. This test indicates that under conditions of warm gas and an open filter, the pressure transducer will follow actual tank pressure with reasonable accuracies in magnitude and time.
13-T-31(T) Parker A/C L. Johnson S. Himmel	Relief Valve Flow Rate	Determine flow rate through a fully open relief valve.	C - April 21, 1970. The crack pressure of the valve was 1005 psig and it was fully open at 1010 psig. The maximum flow rate of GOX was 34.5 lb/hr and 108 lb/hr for LOX.
A-24(A) MSC W. Chandler F. Smith	Oxygen Tank Filter	Determine flow rates and pressure drops through lines and filter to account for those pressure measurements noted during the flight. Consider the case of a completely clogged filter.	C - May 14, 1970. The analysis showed that if the filter had been clogged, the rate of pressure drop would have been much greater than that observed in the data. Analysis shows that the pressure relief valve can reduce the oxygen tank pressure at the rate shown in the telemetry data.

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PRESSURE DROP			
A-55(A) MSC W. Rice N. Armstrong	Premature Relief Valve Opening	To determine if a premature relief valve opening would account for the 15 seconds of constant tank pressure after the initial pressure rise, assuming several gas temperatures.	C - May 14, 1970. This analysis showed that the relief valve flow would have caused a pressure drop, not a plateau.
13-T-71(T)			See Tank Failure.
FINAL INSTRUMENT LOSS			
13-T-37 Beech A/C R. Urbach R. Wells	Pressure Transducer Test	Determine the pressure transducer output characteristics at extremely low temperatures.	C - April 21, 1970. The pressure transducer gives erratic readings below -250° F. Temperatures in the oxygen tank were always above -190° F.
13-T-38(T) Beech A/C W. Rice	Temperature Sensor Response	Determine the temperature sensor response time in a rapidly changing temperature environment.	C - April 18, 1970. This test gave sensor response rates of 3° to 12° F per second over a range of +60° to -317° F.
A-3(A) MSC G. Johnson J. Williams	Time Tabulation of Alarms	To determine times and causes for caution and warning alarms during the mission.	C - May 14, 1970. These data were used by Panel 1 in their analyses of mission events.

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
TELEMETRY LOSS			
A-2(A) MSC M. Kingsley J. Williams	High Gain Antenna Signal Loss	To explain the difficulties associated with acquiring high-gain antenna operation at 55 hours 5 minutes into the mission.	C - May 14, 1970. This was not a specific antenna problem which could be isolated to this mission. Previous missions have encountered similar problems. This difficulty is not considered significant to the Apollo 13 incident.
TANK FAILURE			
13-T-29(T) Boeing S. Glorioso B. Brown	Fracture Mechanics Data for EB Welded Inconel 718 in LOX	Determine the fracture toughness and LOX threshold of electron beam welded Inconel 718 tank materials.	C - June 3, 1970. Test results show that a through fracture greater than 3 inches long would be required to cause rupture of the pressure vessel.
13-T-40(T) MSC S. Glorioso B. Brown	Torch Test of Inconel 718	Determine the burn-through tolerance of Inconel 718, by prestressing the specimen to tank operating pressure and burning through the specimen with an oxyacetylene torch.	C - May 18, 1970. The significant result of this test is that fairly large holes must be burned through Inconel 718 to cause catastrophic failure.
13-T-61(T) MSC S. Glorioso B. Brown	Crack Growth of Cracked Inconel EB Welds	Weld specimens (0.125 inch thick) containing cracks will be tested in liquid nitrogen and subjected to a mean stress corresponding to a relief valve pressure in the supercritical oxygen tank with a superimposed cyclic stress equal to that caused by heater operation.	ECD - July 15, 1970.
13-T-71(T) LeRC W. Chandler S. Himmel	Supercritical Oxygen Blowdown Test	Determine the transient thermodynamic process involved in sudden venting of supercritical oxygen to a hard vacuum.	ECD - June 16, 1970. Apparatus being assembled for this test.

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
		TANK FAILURE	
A-38(A) MSC P. Glynn B. Brown	Stress Analysis of Oxygen Tank Neck Areas	To determine whether failures of the oxygen tank neck area might be initiated by the combined effects of pressure and thermal stresses.	C - May 19, 1970. The analysis was performed using three assumptions on thermal inputs. In all cases analysis showed that the conduit would fail rather than the vessel.
A-39(A) MSC P. Glynn B. Brown	Complete Tank Stress Analysis	To provide information on the complete design stress analysis and on the assumption of membrane stress made in the fracture mechanics analysis with particular emphasis on low discontinuity areas.	C - May 13, 1970. Received two cursory stress analysis reports. Factors of safety acceptable for all conditions analyzed.
A-40(T) Boeing Co. P. Glynn B. Brown	Fracture Test on Oxygen Tank	Carry out fracture mechanics tests and analysis of the oxygen tank.	C - June 3, 1970. Test shows that the failure mode of the tank would have probably been leaking and not a rupture.
A-57(T) MSC/Boeing P. Glynn B. Brown	Tensile Test at Low and Elevated Temperatures	Determine the tensile strength of Inconel 718 and EB weld in the temperature range from -320° to +1800° F.	C - May 20, 1970. All information furnished on typical ultimate and yield strength data showed adequate safety margins for pressures reached in tank.
A-59(A) MSC/Boeing J. Kotanchik B. Brown	Fracture Mechanics Review of All Apollo Pressure Vessels	To assess the adequacy of previous fracture analyses and to identify areas where additional data are needed.	ECD - June 19, 1970. Analysis is underway.

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
		OXYGEN TANK NO. 1 PRESSURE LOSS	
13-T-39(T) Beech A/C W. Rice H. Mark	Oxygen Tank Blowdown	Determine the rate of pressure decay from oxygen tank XTA 00041 through simulated delivery and vent line fracture starting at 78 percent density level, and 900 psig and ending at ambient pressure.	C - April 20, 1970. Vent through delivery line (0.1870D x 0.015W) reached 350 psia in 25 seconds and 160 psia in 600 seconds. Vent through vent line (0.3750D x 0.015W) reached 415 psia in 3 seconds and ambient in 360 seconds.
A-36(A) MSC W. Chandler E. Baehr	Hardware Damage - Tank 1	Determine what hardware damage would be required to explain the loss of pressure from oxygen tank no. 1.	C - May 18, 1970. The analysis shows that a hole from 0.076 inch to 0.108 inch in diameter would be required to explain the pressure loss in tank no. 1.
		PANEL LOSS	
13-T-50(T) MSC R. Bricker W. Erickson	Oxygen Impingement Test on Mylar Insulation	Determine if Mylar insulation can be ignited by a jet of hot oxygen.	C - June 5, 1970. The lowest pressure at which the Mylar will burn in a static oxygen atmosphere with flame ignition is 0.5 psia. Impingement of 1000° F and 1200° F oxygen at 80 psia did not ignite the Mylar blanket. (A test is being prepared to attempt to ignite Mylar in the configuration of the oxygen tank area.)
13-T-54(T) NR D. Arabian S. Himmel	Fuel Cell Radiator Inlet Temperature Response Test	Determine thermal response of temperature sensor installed on EPS water-glycol line.	C - May 20, 1970. Results indicate that under no-flow conditions the flight profiles could not be reproduced. Initial response of the temperature sensor occurred in 0.25 second after heat application.

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
		PANEL LOSS	
13-T-65(T) LRC H. Morgan W. Erickson	One-Half Scale Panel Separation Test	Determine the pressure impulse necessary to cause complete panel separation and determine the mode of failure. A 1/2-scale model of SM bay 4 is used with structurally scaled test panels. Tests are to be run in vacuum with appropriate vent areas. Panel loading is simulated by a rapid pressure pulse.	C - June 2, 1970. Complete separation of 1/2-scale honeycomb panel models in vacuum was demonstrated for a rapid band loaded pressure pulse and for uniform pressure. Separation for nonuniform loading occurred within about 20 milliseconds. Peak pressures that occur in the oxygen shelf space are near 50 psia, 25 psia in fuel cell shelf, and somewhat less than 10 psia in tunnel volume.
13-T-66(T) LRC M. Ellis W. Erickson	Hot Oxygen Impingement on Mylar Ignition Test	Determine if the Mylar insulation blanket will be ignited by a jet of hot oxygen and estimate the rate of combustion.	C - May 18, 1970. Mylar blanket can be ignited by a hot oxygen (1500° F) jet at pressures above 10 psia. Combustion of a 1-foot square sample requires about 15 seconds. More rapid combustion occurs with 70° F at 10 psia oxygen when Mylar is ignited with Pyrofuse.
13-T-75(T) MSFC J. Nunelley W. Erickson	Heats of Combustion of Teflon, Mylar and Kapton	Determine the heats of combustion of Teflon, Mylar, aluminized Mylar, and aluminized Kapton.	C - May 27, 1970. Heats of combustion were: Teflon - 2200 Btu/lb, Mylar - 9850 Btu/lb, Kapton - 10,700 Btu/lb.
13-T-76(T) MSFC C. Key W. Erickson	Threshold Oxygen Pressure for Mylar & Kapton Flame Propagation	Determine the threshold oxygen pressure for flame propagation of Mylar and Kapton films.	C - May 27, 1970. Ignition threshold oxygen pressure ranged from 0.5 to 1.5 psi for both aluminized Mylar and Kapton under static conditions.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined

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Number (T/A) Location Monitors	Title	Objective - Description	Status - Results - Remarks
PANEL LOSS			
A-65(A) MSC P. Glynn V. Johnson	CM-SM Heat Shield and Attach Fittings Analysis	Determine if there is any reasonable possibility of estimating the pressure loads applied to the bay 4 panel by reviewing the design of the CM heat shield structure and the CM-SM attach fittings.	C - May 22, 1970. Visual inspection of the bolt assembly between the CM-SM interface revealed no thread damage. It is improbable that the bulkhead experienced any structurally significant pressures during the event.
A-68(A) MSC M. Windler W. Hedrick	Panel Trajectory	To determine if the bay 4 panel is in lunar or earth orbit; if so, to investigate the possibility of getting photographs of the panel on some future manned space flight.	C - May 15, 1970. Analysis revealed that the most probable trajectory led to an impact of the panel on the Moon.
A-88(A) LRC G. Walberg W. Erickson	Prediction of Combustion Products from Oxygen/Mylar Oxidation	Compute the flame temperature and major combustion products for an oxygen/Mylar reaction over a range of oxygen/Mylar ratios.	C - May 25, 1970. Flame temperature is 4750° and 5400° F for stoichiometric combustion at 1.5 and 60 psia. For oxygen/Mylar molar ratios of 10, the flame temperature is 2350° and 2400° F at 1.5 and 60 psia. Combustion products are CO_2 and H_2O below 3500° F and include CO and O at the higher temperatures.
A-93(A) LRC R. Trimpi W. Erickson	Calculated Pressure Rise in Bay 4 Due to Combustion	Calculate the pressure rise in the oxygen tank shelf which could result from various modes of tank rupture. Consider cases with and without combustion.	C - June 8, 1970. A maximum pressure rise of about 9 psia is achieved in the oxygen shelf space for no combustion based on initial tank conditions of 900 psia/-190° F and a 2-inch diameter orifice. This pressure occurs at 180 milliseconds after rupture. An estimate with combustion of 0.2 lb_m of Mylar indicates a pressure rise of about 33 psia.

LEGEND: (T) - Test (A) - Analyses C - Completed ECD - Estimated Completion Date TBD - To Be Determined