Get DRA

TRW
SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

FACILITY FORM 602

N71-20475
(ACCESSION NUMBER)

32
(PAGES)

CR-117042
(NASA CR OR TMX OR AD NUMBER)

G3
(CODE)

31
(CATEGORY)

ENGINEERING MODEL TEST PLAN

SPACE STORABLE PROPELLANT MODULE

ENVIRONMENTAL CONTROL TECHNOLOGY

Report No. 14051-6006-T0-00
Contract NAS 7-750

ENGINEERING MODEL TEST PLAN

SPACE STORABLE PROPELLANT MODULE
ENVIRONMENTAL CONTROL TECHNOLOGY
Report No. 14051-6006-T0-00
Contract NAS 7-750

by

O. O. Haroldsen
R. N. Porter

November 23, 1970

TRW SYSTEMS
One Space Park
Redondo Beach, California

Table of Contents

ENGINEERING MODEL TEST PLAN

SUMMARY

In order to prove the thermal control system design, it will be necessary to test a model of the module. It is not necessary that such testing duplicate the expected module mission. Rather, the testing should be designed to prove the system capability at the hot and cold extremes. Also, such testing should furnish sufficient information to provide guidance in any future analysis or design effort. The recommended test plan for such a test program is listed below. For completeness, the appendix gives the recommended hardware and procedure for passivation checkout when actual propellants are used.

1.0 OBJECTIVES

The objectives of the testing are two:

1. Verify the thermal control system design by testing it under simulated extreme environmental conditions.

2. Provide a basis for any proposed changes in the system, by verifying the validity of the analytical (computer) model.

2.0 TEST ARTICLE

Ideally, the test article should be as described in the Task V drawings. However, as indicated below, some deviations may be tolerated without materially compromising the test objectives.

2.1 Vibration Test

The test article for the vibration test can be one propellant tank, its insulation, radiators, and the internal cooling coil.

2.2 Groundhold Thermal Test

The test article for the groundhold thermal test can be the complete module as described in the drawings, except the engine and engine thrust frame may be deleted. However, lines leading from the various control panels and tanks, together with their prescribed insulation, should be installed. It is not necessary to have the spacecraft or RTG installed.

During this test, the following hardware substitutions may be made. Pressurant and propellant tanks may be made of aluminum if desirable, provided the tank surfaces are properly prepared prior to application of the foam insulation. The hardware of the various control panels and the isolation valve hardware located at the base of each propellant tank do not need to be flight-type hardware. Fiberglass struts may be used in the place of all boron filament struts.

2.3 Flight Thermal Test

The test article for this test is the module as described in Drawing X 122468. In addition, a heated surface covered with multilayer insulation simulating the spacecraft and a simulated RTG is required. The simulated RTG only needs to be a heated surface which "sees" the module with the same view factor as the flight RTG.

The fluid tanks may be fabricated from aluminum and all boron filament struts may be replaced with fiberglass struts. The engine and the bipropellant valve should duplicate in shape, weight, and thermal conductivity the flight hardware as near as possible and it is important that simulated feed and purge lines which attach to the valve be installed. If desirable, the simulated frame may be of carbon steel.

The hardware on the various equipment panels and the isolation valve hardware located at the bottom of each propellant tank must also duplicate in weight and thermal conductivity the flight equipment. It is not necessary for such equipment to be flight equipment.

3.0 SUPPORT EQUIPMENT AND TEST FACILITIES

3.1 Vibration Test

A vibration test fixture, capable of transmitting loads in a rigid manner to the test item, will be required. The fixture should be designed to handle, in a rigid manner, a total load of 2000 pounds during vibration in the axial (Z) and lateral (Y) directions. Vibration levels during test will be as follows:

Sine:	Frequency (Hz)	Level (g_{rms})
	10 - 50	0.7
	50 - 90	1.0
	90 - 110	Increasing from 1.0 to 1.5
	110 - 280	1.5
	280 - 320	Increasing from 1.5 to 2.5
	320 -2000	2.5

Sweep rate is to be 1 octave per minute.

3.2 Groundhold Test

A support and transport fixture will be required for the ground thermal test. The fixture must be capable of supporting the module, 3200 pounds, and maintaining the five spacecraft support plates in a rigid position in the absence of the spacecraft. This fixture must attach to the module at the eight boost vehicle separation assemblies and five spacecraft support plates only.

Provisions must be made for supplying LN_2 to the module at arbitrary rates ranging from 20 to 400 pounds per hour total for 48 hours by way of three separately controlled circuits. Flow rate measuring equipment must be provided for each line.

Provisions must also be made for loading (and unloading) the propellant tanks with the simulated propellants (Freon 12 and Freon 23).

3.3 Flight Thermal Test

A support fixture which attaches to the eight boost vehicle support points and to the five spacecraft support points will be required. This fixture must be capable of supporting the module such that the simulated sun can irradiate the module in the two configurations shown in Figure 1. The support fixture must be thermally isolated from the test article at each of the eight boost vehicle support points by an isolation block having a conductance, KA/X, no greater than 0.1 Btu/hr-^{o}F. In addition, the support fixture at these eight points must be black and uninsulated on the -X side for a distance of two feet away from the mating surface. The remainder of the support fixture should be insulated with one layer of 3 mil aluminized Mylar with the Mylar side out. On each of these eight supports and adjacent to the mating surfaces must be installed a 60 watt heater and a thermocouple. A sketch of this arrangement is given in Figure 2.

Testing must be done inside a vacuum chamber having a capability of 10^{-5} torr. The chamber must be completely lined with a LN_2 coldwall and the facility must have a capability of simulating sun radiation over a ten foot diameter circle at an intensity of 430 $Btu/hr\text{-}ft^2$. As in the case of the groundhold test, provisions must be made for supplying the module with LN_2, but in this case, it will be used only for maintaining module temperatures prior to test and in case of emergency.

4.0 INSTRUMENTATION

4.1 Vibration Test

No special instrumentation for the vibration test will be required on the test article provided the frame is rigid. Accelerometers mounted to the support fixture must be provided wherever necessary to establish that the prescribed vibration levels during the test have been met.

4.2 Groundhold Test

Instrumentation for the groundhold test will consist of LN_2 flow meters for measuring the coolant flow rate into each of the helium and propellant tanks, thermocouples for establishing temperatures of various components and pressure taps for monitoring the pressure of the helium and propellant tanks.

All thermocouples should be Cu/Cn, 24 or 28 gauge. The positions and ranges of these thermocouples are listed in Tables 1 and 2, and Drawing SK 406876. The range of the required pressure gauges are also listed in Table 1.

4.3 Flight Thermal Test

The basic instrumentation on the test article for the flight thermal test is the same as that listed for the groundhold thermal test. However, to monitor the operation within the vacuum chamber and to eliminate the flow of heat from the support fixture, the additional instrumentation listed in Table 2 will be necessary.

All instrumentation lines and fluid lines must have guard heaters located within one foot of the test article and all instrumentation line bundles and fluid lines must be insulated with ten or more layers of aluminized Mylar with the Mylar side out. The location and size of these heaters are listed in Table 2.

Radiometers for monitoring the simulated solar intensity will be required. The exact location of these will have to be determined after the module has been installed inside the vacuum chamber. They must be mounted such that they will view the solar simulator continuously during the test.

5.0 SIMULATED PROPELLANTS

During tests in which simulated propellants are required, Freon 12 should be used as the oxidizer and Freon 23 used as the fuel. Table 3 lists the properties of the fluids. It will be noticed that most of the properties of the simulated propellants are not the same as they are for the actual propellants. However, this will not appreciably effect the validity of the results since the variations may be taken into consideration in the analysis of the results.

6.0 TESTS

6.1 Vibration Testing

The first test to be performed is a vibration test. The sequence of testing is as follows:

1. Install the vibration test specimen in the vibration test fixture.

2. Install accelerometers to the vibration fixture.

3. Load tank to 90% with LN_2.

4. Visually inspect for damage and cracks in the insulation.

5. Vibrate in the X axis as follows:

Sine: Frequency (Hz)	Level (g_{rms})
10- 50	0.7
50- 90	1.0
90- 110	Increasing from 1.0 to 1.5
110- 280	1.5
280- 320	Increasing from 1.5 to 2.5
320-2000	2.5

Sweep rate is to be 1 octave per minute.

6. Inspect for damage and cracks in the insulation.

7. Vibrate in the Z axis at same levels indicated in Step 5.

8. Inspect for damage and cracks in the insulation.

Note: These tests could be performed with water in the tank in place of the LN_2. However, to assure a highly reliable system, LN_2 is recommended.

6.2 Groundhold Thermal Test

The second test to be performed is the groundhold thermal test. Starting with the test apparatus and support fixture as indicated in Section 2.2, the specific steps of the test are as follows:

1. Flow LN_2 through the helium tank and the propellant tanks cooling coils at approximately 50 pounds/hr per tank.

2. During the chilling process of Step 1, monitor the pressure of the three tanks continuously. Maintain the pressure of these three tanks during the chilling process between 15 and 30 psia by bleeding helium into the helium tank and filling the propellant tanks with the simulated propellants. Continue this process until all tanks reach a temperature of a -180 ± 15°F, the propellant tanks are 90% filled with simulated propellant, and helium tanks is at 25 to 30 psia. Adjust the coolant flow rate as necessary to achieve equilibrium at this condition.

3. Inspect the entire system for frost formation and insulation damage.

4. Increase the coolant rate to each of the three tanks by 100%. Hold this condition until equilibrium thermal conditions are achieved. Note: Reduce coolant flow rate if coolant temperatures T/C's number 1 through 4, drop below -245°F.

5. Inspect the entire spacecraft for frost formation and insulation damage.

6. Increase the coolant flow rate to each of the three tanks by 100%. Hold this condition until equilibrium thermal conditions are achieved. Do not allow propellant to drop below -245°F.

7. Inspect the entire spacecraft for frost formation and insulation damage.

8. Stop all LN_2 coolant flow. Monitor all temperatues and pressures at fifteen minute intervals for 12 hours.

9. Reestablish coolant flow rate in each of the three tanks, if necessary, to maintain -180°F.

10. Empty propellant tanks of all simulated propellant 12 hours after initiation of Step 8. Stop all LN_2 coolant flow and allow the module to return to atmospheric temperature. Vent helium tank as necessary to maintain pressure below 45 psia. Inspect the entire spacecraft for insulation damage and water formation.

Note: During all portions of this test, all thermocouples and all pressure gauges must be monitored every 30 minutes. All tank pressures must be maintained above atmospheric pressure.

6.2 <u>Alternate - Groundhold Thermal Test</u>

The steps listed above will provide sufficient basic information concerning the groundhold control system to establish its characteristics and adequacy. If the LN_2 supply system is complete and includes automatic LN_2 flow control, it is recommended that steps 4 through 9 be replaced with the following steps.

4. Set the automatic flow control temperature limits for the oxidizer and helium tanks at -190°F and -240°F.

5. Set the automatic flow control temperature limits for the fuel tank at -190°F to -270°F.

6. Set LN_2 supply pressure at level which will result in an LN_2 flow rate of 250 to 400 pounds/hr per tank when the control valves are open.

7. Initiate automatic operation.

8. Allow test to run continuously for 48 hours or until each tank has cycled at least once. Record times at which each cooling circuit cycled on or off. Record LN_2 flow rates.

9. Inspect continuously for insulation failure.

6.3 <u>Flight Thermal Test</u>

The third test to be performed is the flight thermal test. Starting with the test apparatus mounted to the support fixture the specific steps of this test are as follows:

1. Orient the test fixture to simulate a 20° off-pointing sun angle.

2. Pressurize the helium and propellant tanks to 30 psia with helium.

3. Reduce the pressure of the vacuum facility to 10^{-5} torr or less. The coldwalls may be flooded with LN_2 when a pressure of 10^{-4} torr is achieved.

4. When the temperature on the tanks, thermocouples 1, 3, 76 and 113 reach -240°F, turn the power on to the simulated RTG. Adjust that power to maintain a temperature on the RTG of 500°F.

5. Adjust all guard heaters to maintain temperatures as indicated in Table 4.

6. Maintain these conditions until thermal equilibrium conditions are obtained. Thermal equilibrium may be considered achieved when thermocouples 1, 3, 38, 43, 66, 82, 113 and 125 vary no more than two degrees per hour. Record all temperature and heater power every half hour. Completion of this step constitutes a steady state, 0° off-pointing simulation test.

7. Turn on solar simulation to simulate 20° off-pointing sun angle for near earth condition, that is, solar intensity of 430 Btu/hr. Adjust guard heaters to maintain temperatures as indicated in Table 4. Maintain this condition until thermal equilibrium is obtained. Completion of this test constitutes a steady state, 20° off pointing simulation test.

8. Return facility and test hardware to ambient conditions by warming coldwall and breaking vacuum. Maintain all heater powers on during this phase as necessary including the RTG until temperatures on the module reach 60°F.

9. Inspect all insulation on the module for damage.

10. Orient the test fixture to simulate a 90° off-pointing sun angle.

11. Reduce the pressure of the vacuum facility to 10^{-5} torr or less. Flood the coldwalls with LN_2 when 10^{-4} torr is achieved.

12. When the temperature on the tanks, thermocouples 1, 3, 76 and 113 reach -240°F, turn the power on to the simulated RTG to maintain a temperature of 500°F and turn solar simulation on to simulate a solar intensity of 125 Btu/hr-ft^2.

13. Adjust all guard heaters to maintain temperatures as indicated in Table 4.

14. Maintain these conditions until thermal equilibrium conditions are obtained. Record all temperatures and heater powers every half hour. Completion of this test constitutes a steady state, 90° off pointing simulation test.

15. Turn off solar simulator and RTG. Allow thermocouples 3, 6, and 113 to return to approximately the steady state values obtained in Step 6.

16. Fill propellant tanks to 40% capacity with simulated propellants (Freon 23 for the fuel and Freon 12 for the oxidizer). Use LN_2 cooling and/or RTG as necessary to maintain thermocouples 3, 6 and 113 as indicated in Step 6.

17. Pressurize propellant tanks to approximately 20 psia and the helium tank to 400 psia with helium.

18. Turn power on to RTG to maintain a temperature of 500^{o}F and turn solar simulation on to simulate a solar intensity of 430 Btu/hr-ft^2.

19. Adjust all guard heaters to maintain temperatures as indicated in Table 4.

20. Maintain these conditions for 12 hours or until thermocouple 82 reaches -150^{o}F, whichever is sooner. Record all temperatures every half hour.

21. Turn on auxilliary engine heater to maximum power until thermocouple 125 reaches 1200^{o}F.

22. Turn off auxilliary engine heaters and solar simulator. Record all temperatures and heater power every ten minutes for one hour and every half hour thereafter for two hours.

23. Return facility and test hardware to ambient conditions. Vent propellant tanks as necessary to maintain pressure below 45 psia. Inspect the module for damage.

24. Remove test article and support fixture from vacuum facility and secure vacuum facility.

6.4 Vibration Re-run Test

The last test to be performed is a re-run of the vibration test described in Section 5.1. The specific steps of the test are as follows:

1. Remove the propellant tank which was used in the first vibration test from the module.

2. Repeat the test exactly as indicated in Section 5.1.

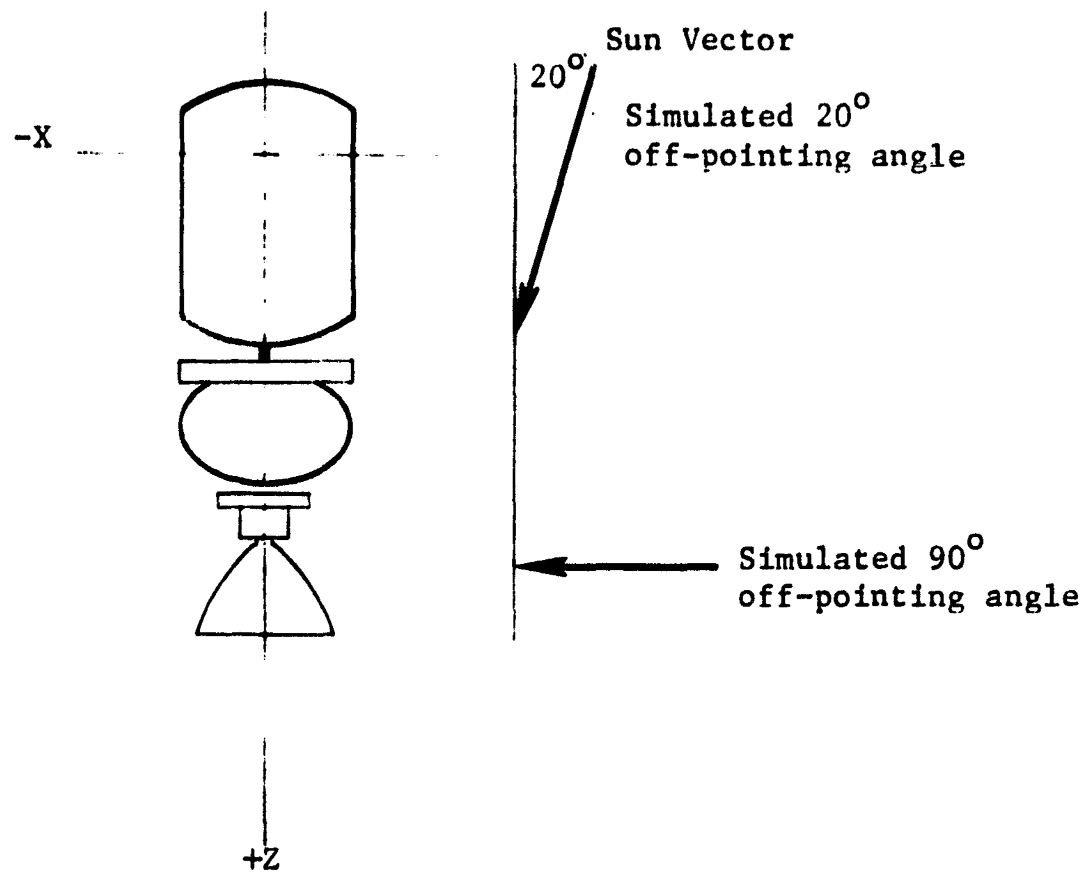


Figure 1 Schematic of Module Position Relative to Sun Vectors for Flight Thermal Tests

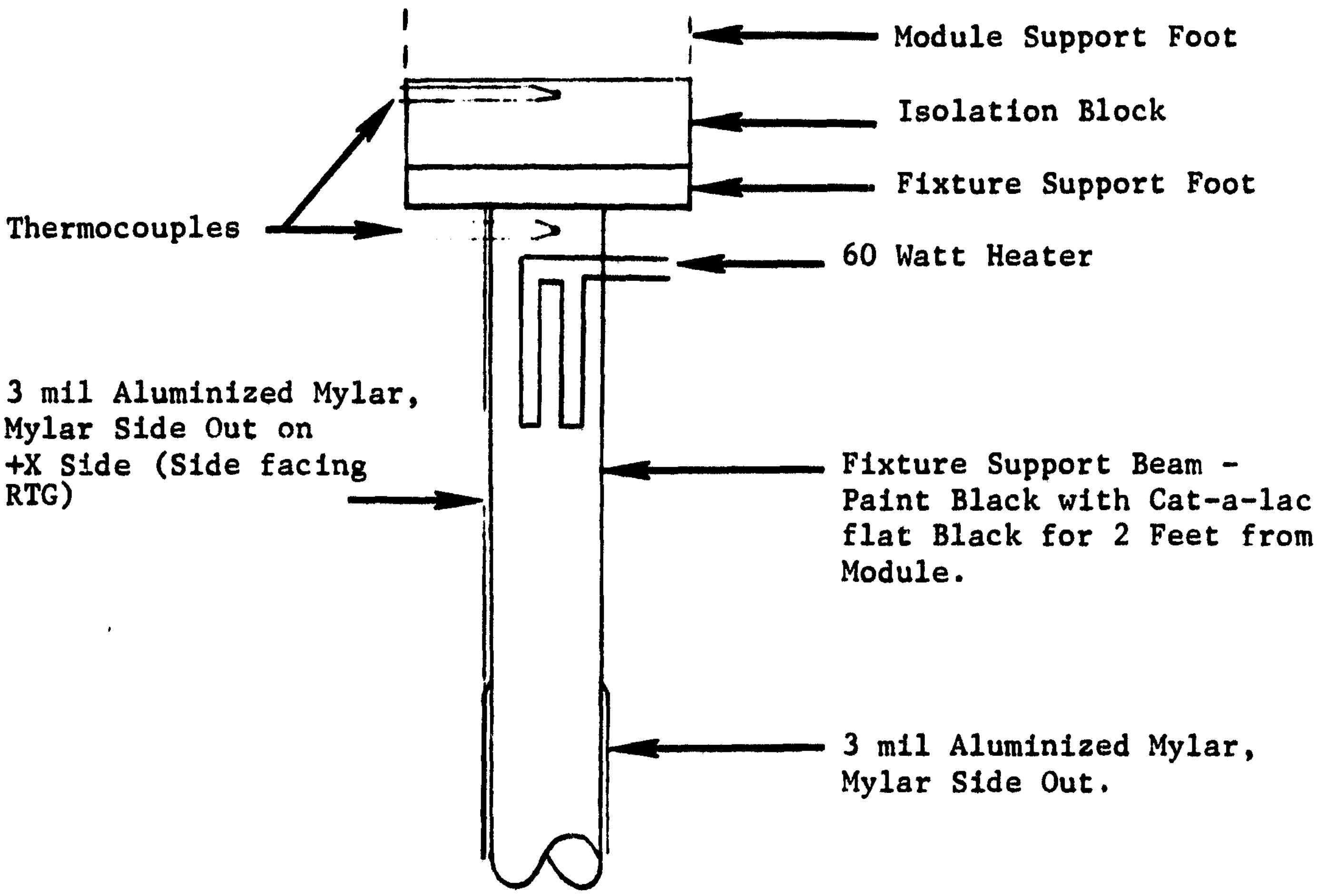


Figure 2 Schematic of Typical Support Foot of Vacuum Test Fixture

Table 1 Module Thermocouple List

T/C No.	Description
1	B_2H_6 Tank, bottom
2	B_2H_6 Tank, top
3	OF_2 Tank, bottom
4	OF_2 Tank, top
9A, B, C, D, E	Spacecraft Support (each support)
16	OF_2 Center Strut
24	Diagonal Strut, +X, center
38	Frame, -X, +Y
43	Frame, +X, +Y
49	Helium Control Panel
52	Insulation Exterior, B_2H_6, -X
55	Insulation Exterior, B_2H_6, +X
59	Insulation Exterior, OF_2, +X
61	Mating Foot, +X, +Y
63	Mating Foot, +X
66	Louver, B_2H_6, +X
67	Louver, B_2H_6, -X
68	Louver, OF_2, +X
69	Louver, OF_2, -X
76	Propellant Valve
80	OF_2 Feed Line, middle
82	Bipropellant Valve
88	Mating Foot, +X, -Y
89	Mating Foot, -Y
90	Mating Foot, -X, -Y
91	Mating Foot, -X
92	Mating Foot, -X, +Y
93	Mating Foot, +Y
95	Aluminum Beam

Table 1 (Continued)

T/C No.	Description
108	Cross Beam
112	Helium Tank, top
113	Helium Tank, bottom
125	Thrust Cone
145	Shield +X
146	Aft Shield
154	Spacecraft Insulation, -X
156	Spacecraft Insulation, +X
157	RTG
181	B_2H_6 Coolant Coil, bottom
182	OF_2 Coolant Coil, bottom
183	He Coolant Coil, bottom

Note: Thermocouple numbers are chosen to correspond to node numbers of computer analysis program.

Table 2 Support Thermocouples and Heaters

T/C No.	Description
201	Isolation Block, top, +X, +Y
202	+X
203	+X, -Y
204	-Y
205	-X, -Y
206	-X
207	-X, -Y
208	+Y
211	Adjacent to Heater No. 1
212	2
213	3
214	4
215	5
216	6
217	7
218	8
219	9
220	10

Heater No.	Size	Description
1	100 watt	Fixture Support Beam, +X, +Y
2		+X
3		+X, +Y
4		-Y
5		-X, -Y
6		-X
7		-X, +Y
8		+Y
9	10 watts	T/C Cable Guard Heater
10	20 watts	Fluid Line Guard Heater
11	14 KW	Engine Bell Heater
12-16	100 watts ea.	Spacecraft Support (Each Support)

Table 3 Fluid Properties

Property	B_2H_6	Freon 23	OF_2	Freon 12
Boiling Point at 1 atm ^oR	-	345.0	300.0	438.0
Freezing Point at 1 ATM ^oR	190.0	213.0	-	208.0
Liquid Density lbs/ft^3	30.2	32.8	91.0	81.8
Specific Heat of Liquid Btu/lb-^oF	0.65	1.55	0.348	0.232
Thermal Conductivity Btu/hr-ft-^oF	0.72	0.008	0.175	0.006

Table 4 Thermocouple Set Points During Flight Test

T/C No.	Temperature, °F
9A, B, C, D, E	60 to 95
157	500
201	T/C 61 ± 10
202	T/C 63 ± 10
203	T/C 88 ± 10
204	T/C 89 ± 10
205	T/C 90 ± 10
206	T/C 91 ± 10
207	T/C 92 ± 10
208	T/C 93 ± 10
219	Match Closest Module T/C ± 10
220	T/C 2 ± 5

APPENDIX

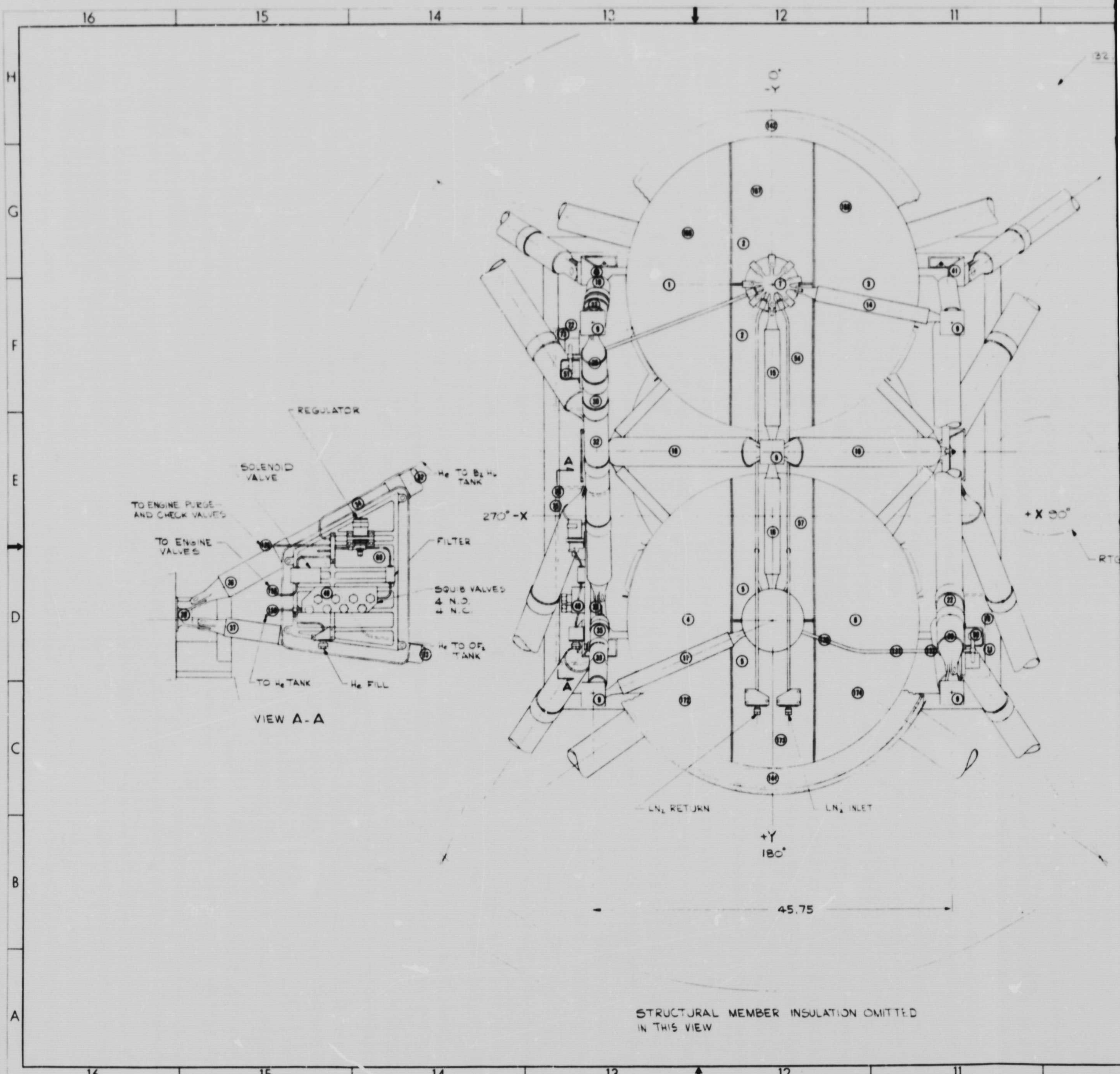
The following is a preliminary recommendation for a procedure to passivate the oxidizer circuit of the SSPM and to fill it with oxidizer (OF_2). This procedure is based on a philosophy of conservatism. Conservatism is warranted because of the extreme reactivity and toxicity of the oxidizer, the lack of flight system operational experience with it and the necessity of completing the operation on time so launch operations are not perturbed.

At present, there is no standard procedure for passivation. Essentially all programs to date, using either OF_2 or F_2, have dealt with heavyweight systems in which thick wall sections have provided substantial heat sinks and conduction paths for dissipating locally generated heat. The SSPM, however, will have thin wall parts so it is essential that heat-producing reactions are minimized and, when inevitable, are slow so local temperatures are kept as low as possible. At the same time, it is important that the probability of latent hazards is reduced to negligible levels by thorough cleaning and passivating. To assure as complete a reaction as possible, the reactivity of the passivating gases should not be too inhibited by low temperatures; hence, the need for controlling the gas temperature to keep it at or slightly above ambient.

To achieve reliable, but safe operations, a number of procedural and design concepts are suggested.

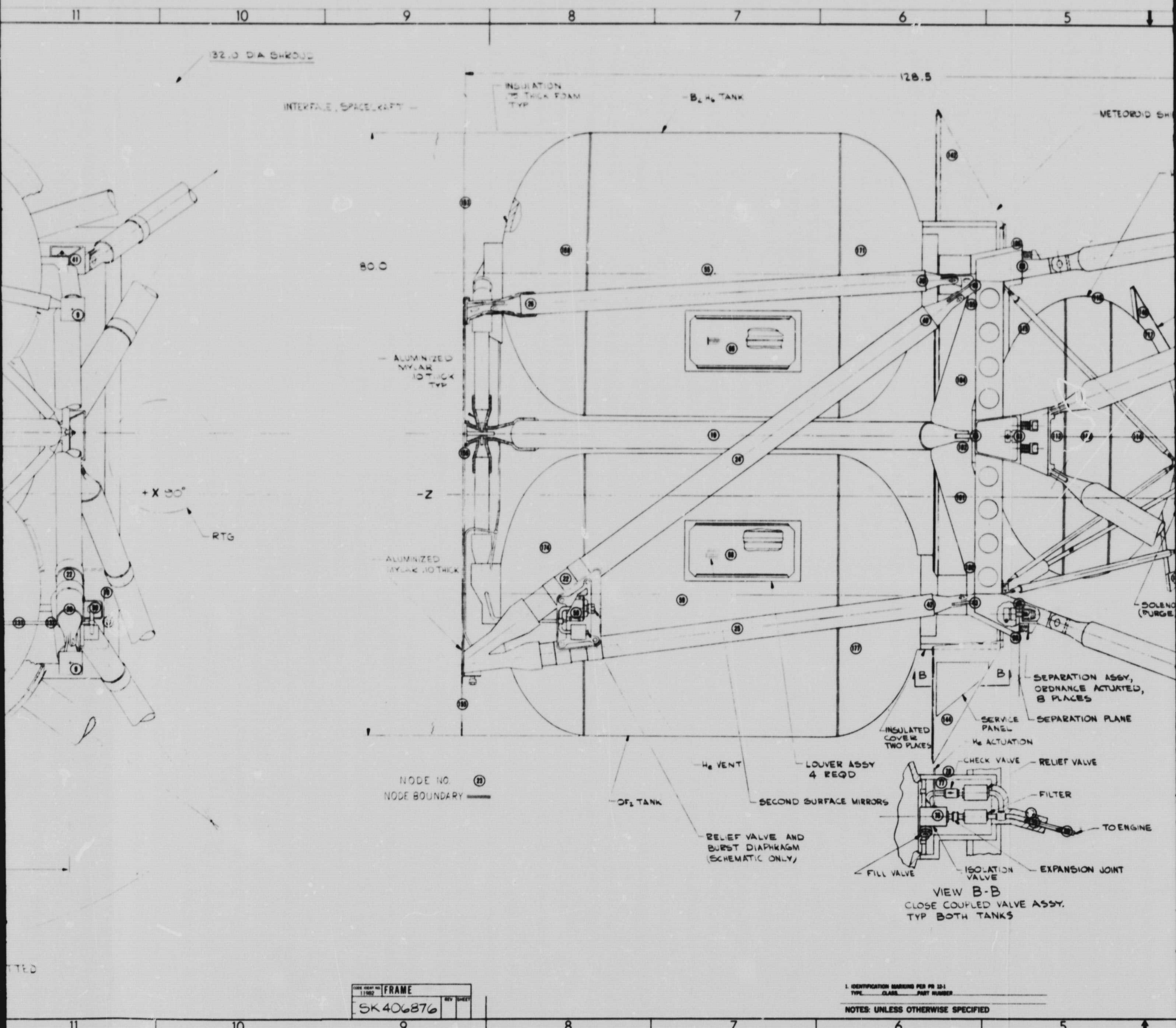
1. The system must always be under control, regardless of the problems encountered. Series redundant valves are probably in many locations. One of each pair should be normally closed, remotely operated, so that the system can be secured by sensing malfunctions or by a "panic" switch in a safe location. Water spray provisions for cooling should cover the entire area. All liquid and vapor should be easily and quickly removable in case reactions cause unsafe temperature rises. Adequate inert gas supplies should be available to thoroughly purge the system.

FOLDOUT FRAME 1

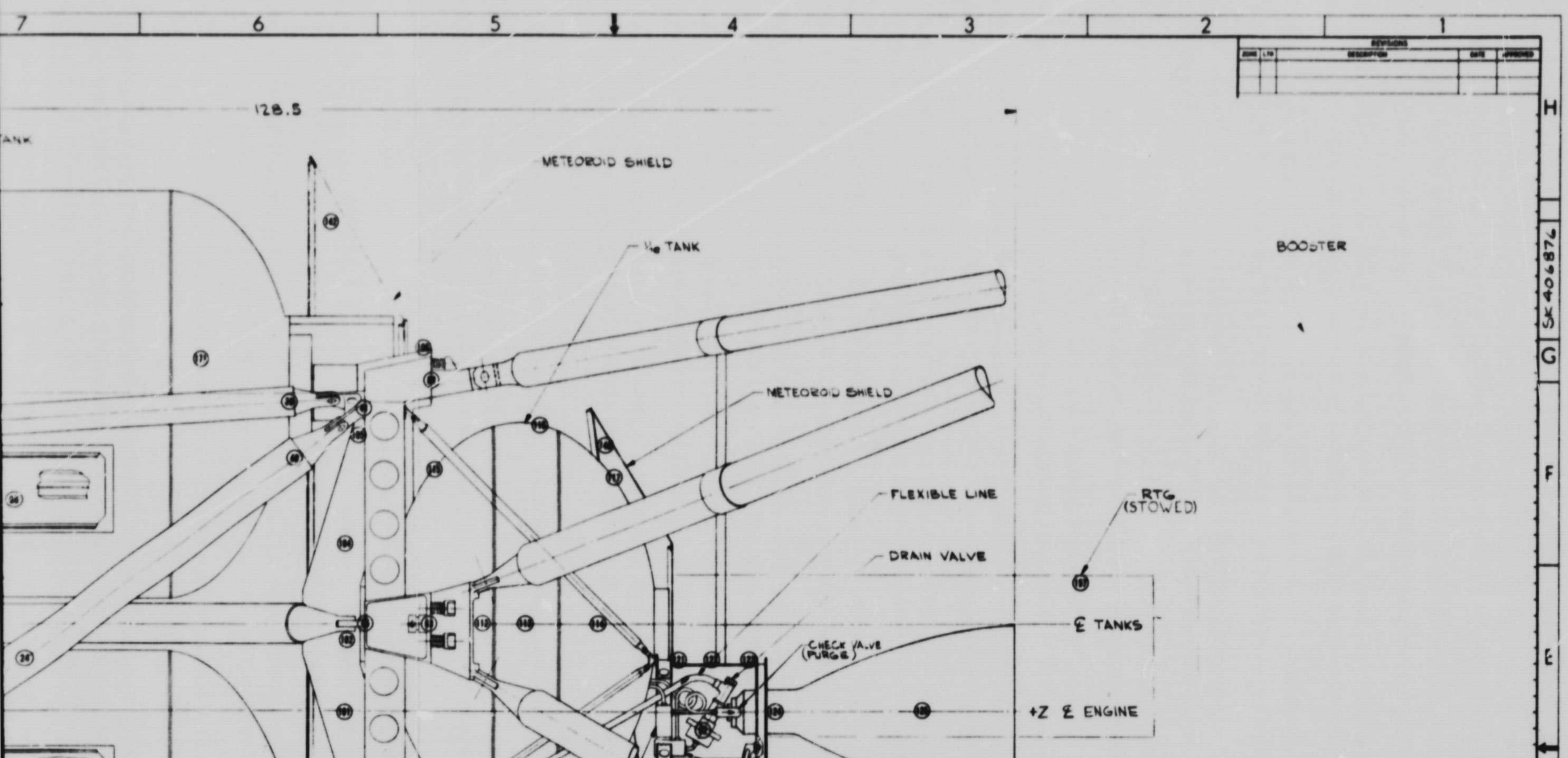


STRUCTURAL MEMBER INSULATION OMITTED IN THIS VIEW

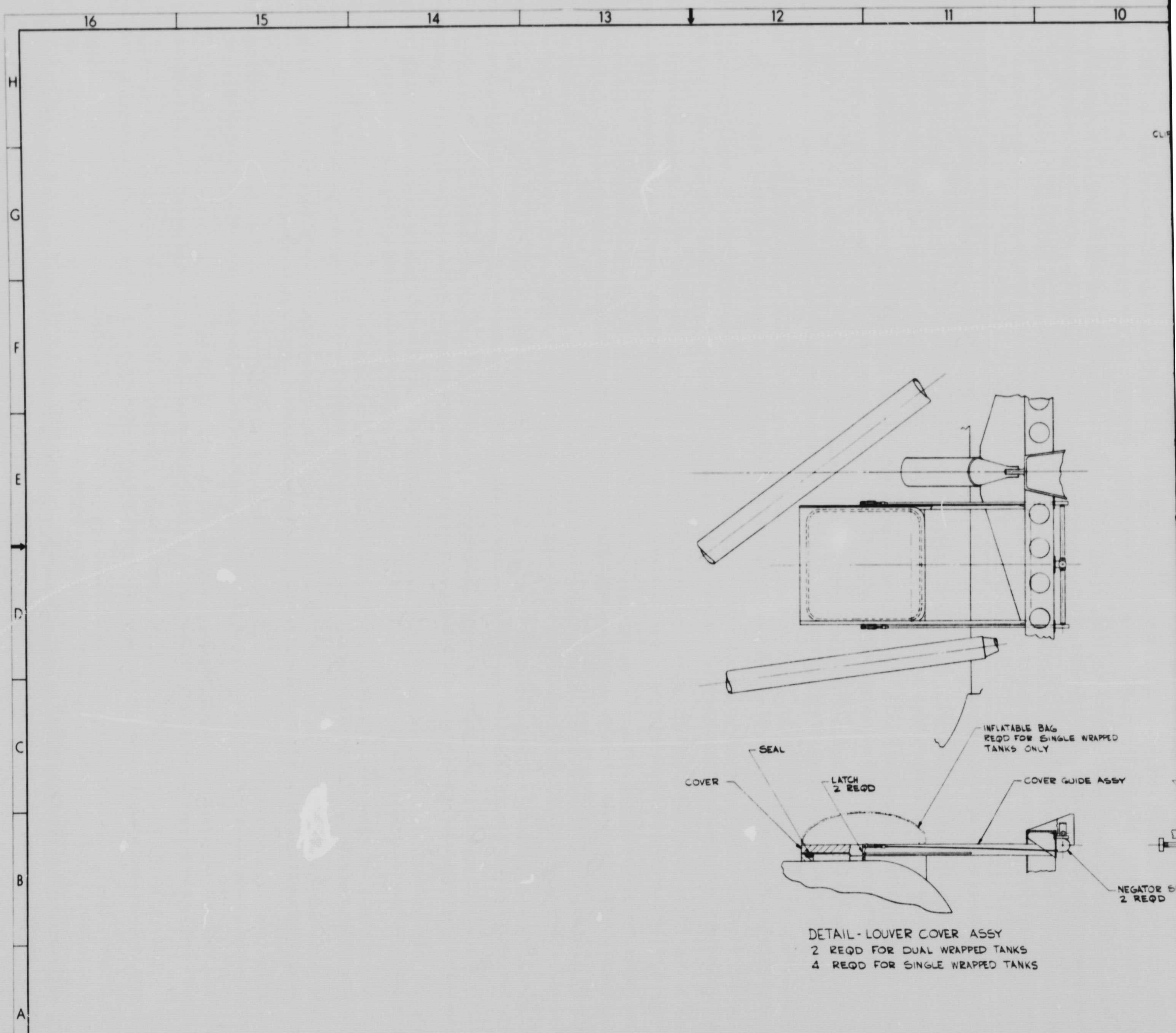
FOLDOUT FRAME 2



[redacted]LDOUT FRAME 3

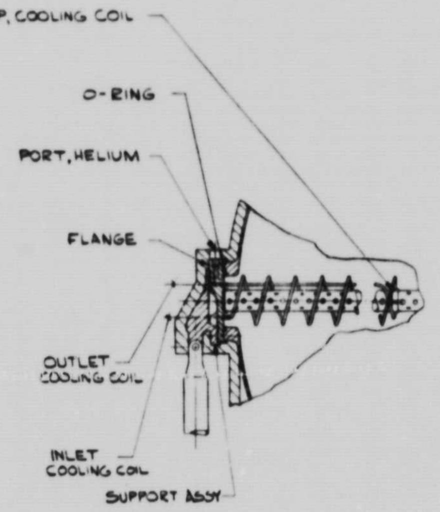


FOLDOUT FRAME 1

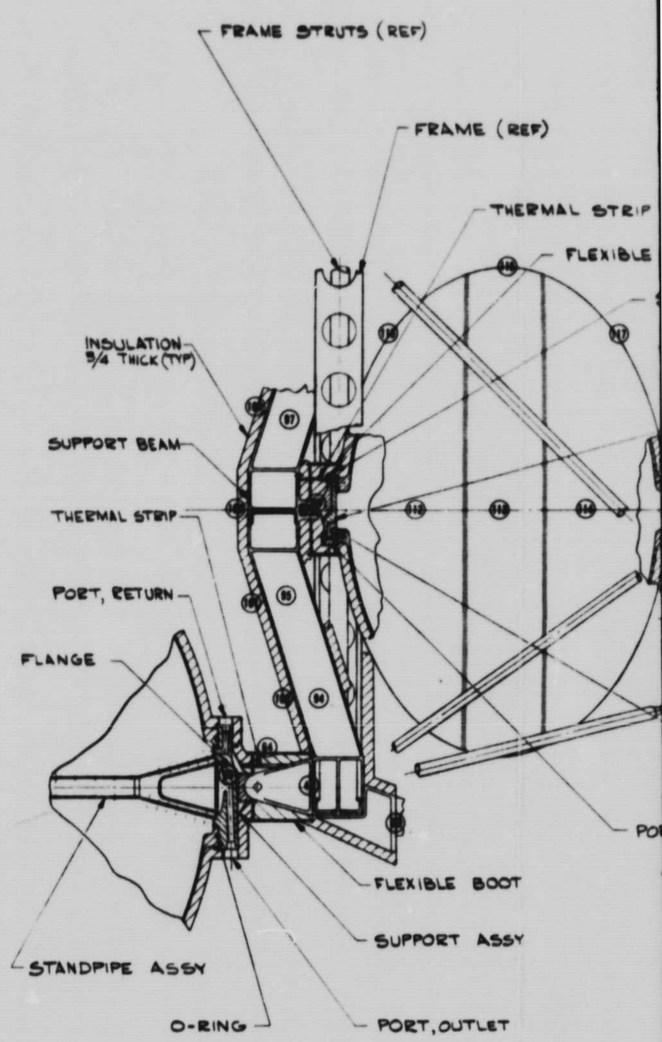


FOLDOUT FRAME 2

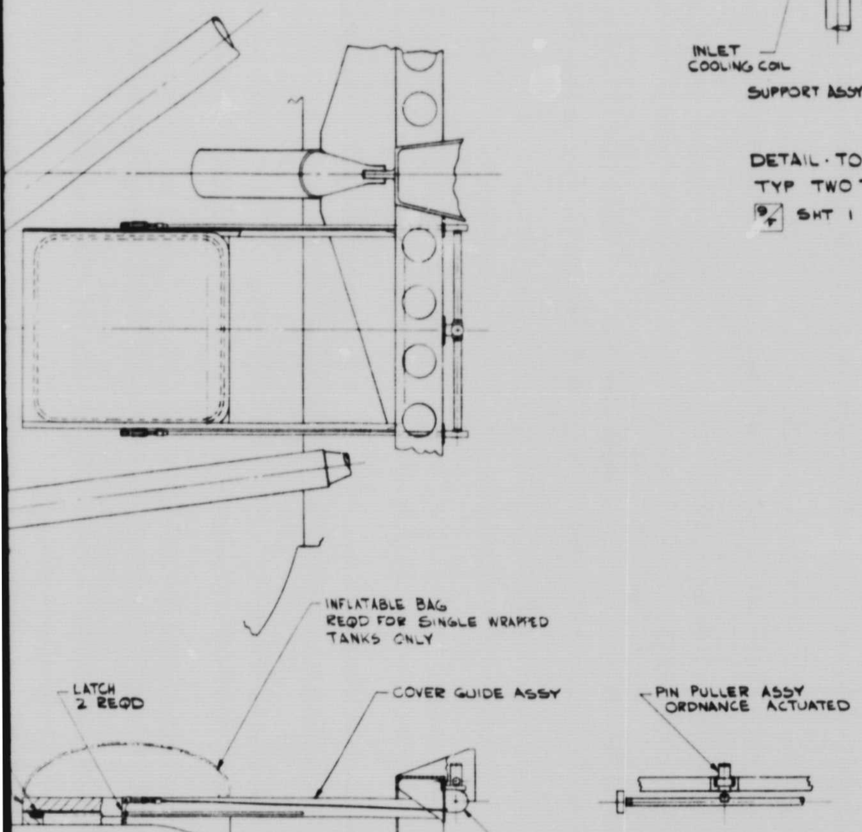
11	10	9	8	7	6	5



DETAIL - TOP FLANGE ASSY
TYP TWO TANKS
SHT 1



DETAIL
SEPARA

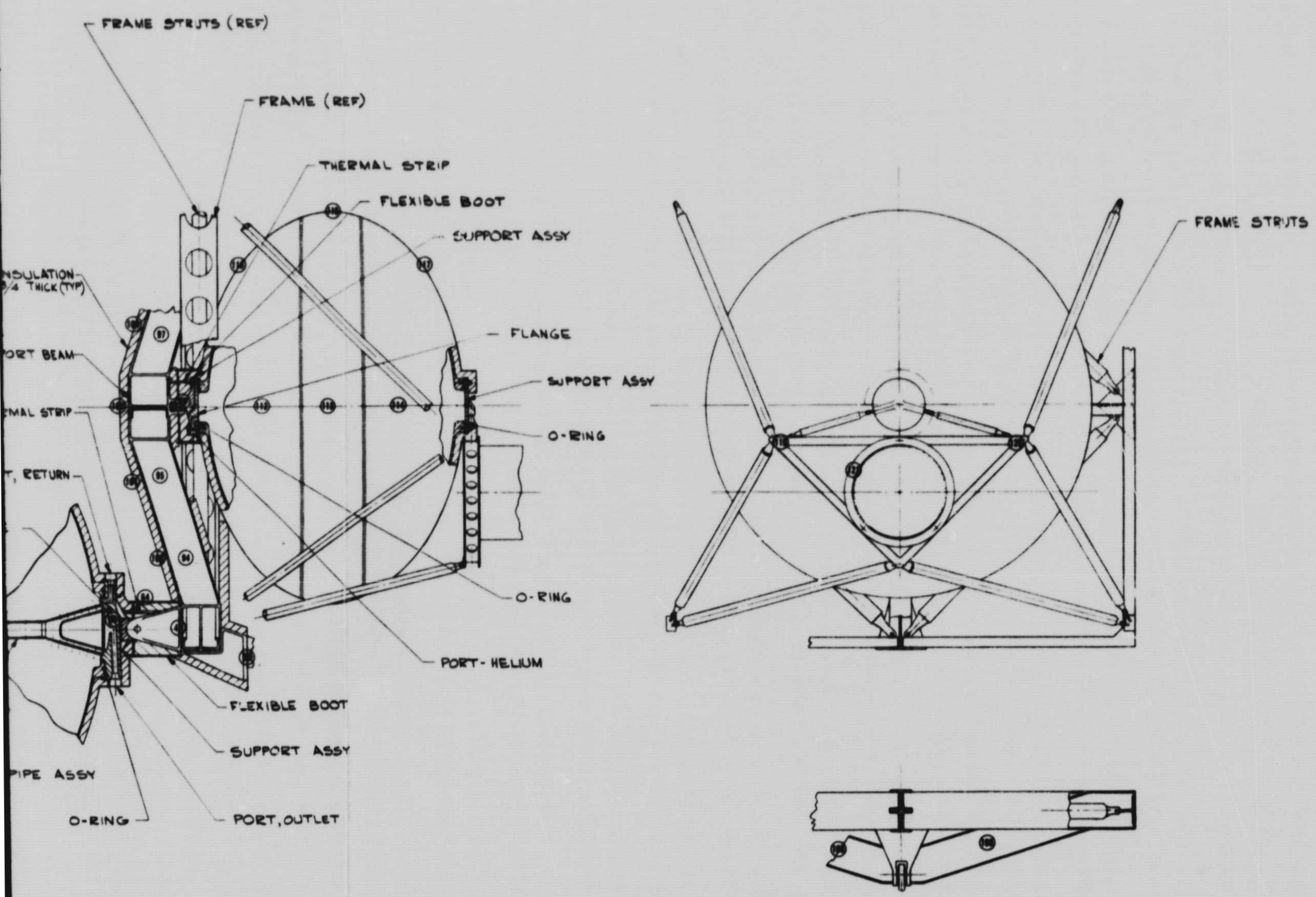


DETAIL - LOUVER COVER ASSY
2 REQD FOR DUAL WRAPPED TANKS
4 REQD FOR SINGLE WRAPPED TANKS

TRW
FRAME
SK 406876

11	10	9	8	7	6	5

FOLDOUT FRAME 3



DETAIL - ENGINE MOUNT AND BEAM ASSYS
SEPARATION ASSYS OMITTED

TRW
SINGLE TANK CONFIGURATION-
DUAL WRAPPED

J	11982	SK 406876

1173-15

2. More than adequate facility for disposing of the entire supply of fluorine and OF_2 should be available. F_2 and OF_2 which has circulated in the system should be condensed and stored (under LN_2) for later disposal in another area whenever feasible. Re-use should be discouraged due to the chance of contamination with reaction products. Mobile tankage (e.g., General Chemical trailers) should be preferred for all storage because this allows easy removal to a remote location when the ground system is to be worked on. Sufficient empty capacity must be provided to catch all condensate from the entire operation (passivation, fill and perhaps a second fill in case the initial load must be drained).

3. Reliable means of cleaning and drying and keeping the system clean and dry must be incorporated into its design. Generally, it should be assumed that flow is necessary to effectively clean, dry and passivate; hence, deadend volumes should be reduced to a very minimum. Sensing methods to detect hydrocarbons and moisture will be necessary. One nearly universal rule is to keep a pad pressure (approximately 20 psig) of clean, dry inert gas in the system at all times possible. An exception to this is when vacuum is pulled to dry the circuit, remove inert gas, or to remove the F_2 or OF_2 vapor, whenever the circuits must be opened for repair or cleaning. Unfortunately, this vacuum may draw moisture-laden air into the system if there are any leaks; therefore, leak-tightness is essential to dryness if the system is to be evacuated.

4. Personnel safety requires a leak-tight system. OF_2 vapor is highly toxic; so slight leaks pose a serious hazard, especially if air changes are not rapid enough to keep the concentration below the MAC.

The system schematic diagram, Drawing SK 407052, has not been subject to careful scrutiny; nevertheless, it shows a number of features which enhance operational safety and flexibility. Among these are flow passivation of all facility parts which see F_2 or OF_2, thermal control of the passivating gas and condenser for returned vapor. The relative complexity is a potential problem as is the determination of just where temperatures should be monitored.

Abbreviated Procedure

1. Supplies - The following supplies shall be available:

    1.1 Clean, dry helium

    1.2 Liquid nitrogen

    1.3 Gaseous fluorine

    1.4 Liquid fluorine if the supply of gaseous fluorine is limited

    1.5 Water, for general cooling in the event of a fire or leak, and for the disposal system

    1.6 Propane to the burner

    1.7 Oxidizer

2. Cleaning - All parts contacted by F_2, OF_2 or helium shall be cleaned to fluorine service level. No hydrocarbons, silicon compounds or other non-metals shall be detectable by standard clean room inspection techniques. No water (dew point at least $-100^{o}F$), no solvents or other volatile substances shall be detectable. Special care shall be taken to assure that no non-approved metals or polymers are present (i.e., cleaning procedure shall leave essentially no solid particles of non-compatible materials, such as chips of metal, flakes of coatings or bits of plastic or polymer). This includes lines downstream of the relief and disposal system valves (#16 and 18). Particle contamination shall conform to that level specified for the propulsion system. After cleaning, all sections of the system upstream of the relief and disposal valves shall remain pressurized to 20 psig with clean, dry inert gas at all times except when charged with F_2 or OF_2.

3. Functional Tests and Calibrations - The entire system and its components shall be functionally tested to assure that all valves

function, all relief valves open at appropriate setpoints and no gas is bypassing the filter elements. All gauges and transducers shall be calibrated; this must be done without introducing contamination.

4. Leak Check - The entire system shall be leak checked.

   a) Fluorine/OF_2 Systems - All components and lines which carry F_2 or OF_2 liquid or vapor shall be leak tight to helium gas at rated working pressure and ambient temperatures, as indicated by soap solution (a Snoop) bubble test or mass spectrometer. Valve seat leakage on critical shutoff and relief valves shall be checked by helium flow out special test taps. This check must be made in a manner which reliably precludes the entry of contaminants into the system via the test taps.

   b) Helium system shall be reasonably leak tight at operating pressures.

5. Passivation - The entire circuit shall be passivated by contact with warm mixtures of helium and fluorine gases of increasing fluorine concentration before any pure fluorine gas of OF_2 is allowed to enter. Flow rate increases through valves are to be controlled by very slowly opening the valves. Critical/typical parts and the return flow shall be monitored for temperature increase to detect reactions. Temperatures above critical limits (to be specified) are to be lowered by immediately decreasing the fluorine concentration. Continuous monitoring is essential to avoid overheating and fires.

   a) Ground System Passivation - Clean connecting pieces are used to interconnect C_1 to C_2 and C_3 to C_0. Connectors C_4 and C_5 are to be joined together as are C_6 and C_7. The purge tank is then filled with a 20% (by weight) mixture of fluorine in helium. To do this, all valves and regulators are closed except valves 7, 10, and 28. Then regulator R1 is gradually opened until a pressure of *__ psig is built up in the surge tank. Valves 7 and 10 are then closed. Valves 8 and 9 are slowly opened to admit fluorine gas to the surge tank until a pressure of *__ psig is attained, then valve 9 is closed. The helium gas should be warmed by the heater so that the resulting mixture in the surge tank will equilibrate at a temperature of 20 to 40 degrees above the maximum atmospheric ambient temperature. If the system is definitely known to be

---

*Pressures depend upon tank volume.

able to withstand vacuum and fully leak-tight, it may be evacuated by pump via valve 16. By metering the gas with valve 10 and sequentially opening valves throughout the system, all parts except the helium system are gradually pressurized to 50 psig with this mixture. During this process, pertinent temperatures are monitored to detect heating due to reaction. If sustained temperature increases are noticed, the mixture should be diluted with helium by closing valve 10, opening valve 7 and all intervening valves, increasing the regulator outlet pressure and drawing off the mixture through the disposal system by opening valve 18. Once the mixture is diluted sufficiently to begin reducing the temperature, the inflow of helium and outflow to the disposal system should be stopped so the diluted mixture can slowly react with the contaminant. After the temperature has returned to near ambient, the mixture should be flushed out with helium and the system vented via the disposal system down to 20 psig. Then the process is repeated by admitting more of the 20% mixture from the surge tank. If excessive temperature rises are repeated, the system must be purged with helium (and evacuated, if possible) until the detector reads "0" fluorine concentration and the offending section must then be recleaned, leak checked and passivation attempted again. If the process results in acceptable temperature rises, then a new mixture of 50% fluorine is made up in the surge tank and the procedure of sequencing the valves is repeated. After successful passivation to the 50% fluorine mixture, the process is repeated with pure fluorine gas. When the entire system has contained pure fluorine gas at 50 psig for 30 minutes and all temperatures are essentially constant, the pressure should be slowly increased to the maximum pressure at which the system will operate plus a margin of 20 psi. Care must be taken to avoid actuating relief devices. If different parts of the system operate at different pressures, the valving must be used to isolate the lower pressure sections while the pressure is raised in the other parts of the system. The purpose of this step is to be sure all parts of the system are exposed to fluorine at pressure and temperatures slightly in excess of the maximums to be encountered in service. Successful operation of all the above steps should be followed by replacement of the fluorine with helium at 20 psig.

b) Propulsion System Passivation* - When the module oxidizer system is ready to be passivated, Valve 7 is opened so helium pad pressure is maintained by regulator R1. Valves 2, 4, and 5 should be closed then opened a slight amount to allow a continuous purge as the connectors are separated. Then the interconnecting lines between C_0, C_1, C_2 and C_3 must be removed and the connectors attached to the spacecraft relief,

*It must be confirmed that the entire oxidizer circuit of the module is clean and leak-tight.

fill and pressurization ports. It is most vital that this be accomplished without any contamination or moisture entering the fittings. The slight pad pressure in the spacecraft should be used as a gentle purge by opening the fill and pressurization valves slightly before the module connections are uncapped. After connection has been secured, these connections must be carefully leak checked. Helium is then flowed through the module system and out the pressurization valve to the disposal system so a moisture detector can be used to be sure the module is dry inside. Then the spacecraft system is passivated with fluorine/helium mixtures just as the ground system was passivated. Note, however, that there are at least three deadend volumes within the oxidizer circuit (cross-hatched on the drawing) and two volumes that cannot be readily passivated at this stage (the injector and the tank relief module shown dotted cross-hatched). The former must be passivated by pumping action; that is, repeated variations in pressure must be imposed to push the passivating gas into the deadend volumes. The latter should be cleaned and passivated <u>before</u> arrival at the propellant loading facility and then carefully sealed up to prevent entry of contamination. In order to fully passivate the feed and relief return lines, it will be necessary to actuate the oxidizer isolation valve and the relief valve so passivating gas can be flowed through these two lines. Evacuation of the propulsion system may not be possible (it depends upon the buckling strength of the lines and tank under external pressure), so venting down to nearly ambient pressure via the disposal system plus helium purging may be the only means of removing the fluorine gas. After exposure to the 20%, 50%, and pure fluorine has been successfully accomplished, the normal pad pressure of helium should be left in the spacecraft system.

6. Chilling the System - When the oxidizer loading operation is ready to commence, the ground and module circuits must be chilled to as near the specified oxidizer ground storage temperature as possible -- most likely this will be in the range of 210 to 240°R. To do this, the fill lines jackets are filled with liquid nitrogen and a preliminary chilling is accomplished with helium flowing through these cold sections, through the propulsion system, and out the pressurization port to the disposal system. During this period, the propulsion ground hold thermal conditioning system operation is started by flowing coolant (LN_2) through the internal coils of the oxidizer tank.

Appropriate temperature sensors are monitored to gauge the childown progress. When suitable temperatures have been reached, the flow rates are varied as necessary to maintain the temperature.

7. Oxidizer Loading - Due to the toxicity and reactivity of the OF_2, a completely closed system is highly desirable but some provision for emergency disposal is necessary. This may be done with the same equipment used for the fluorine. To minimize the amount of OF_2 passing out the disposal system, a liquid nitrogen chilled condenser is used. Furthermore, if at all feasible, the module tank and feedlines should be as near to the liquid OF_2 storage temperature as possible to minimize vaporization.

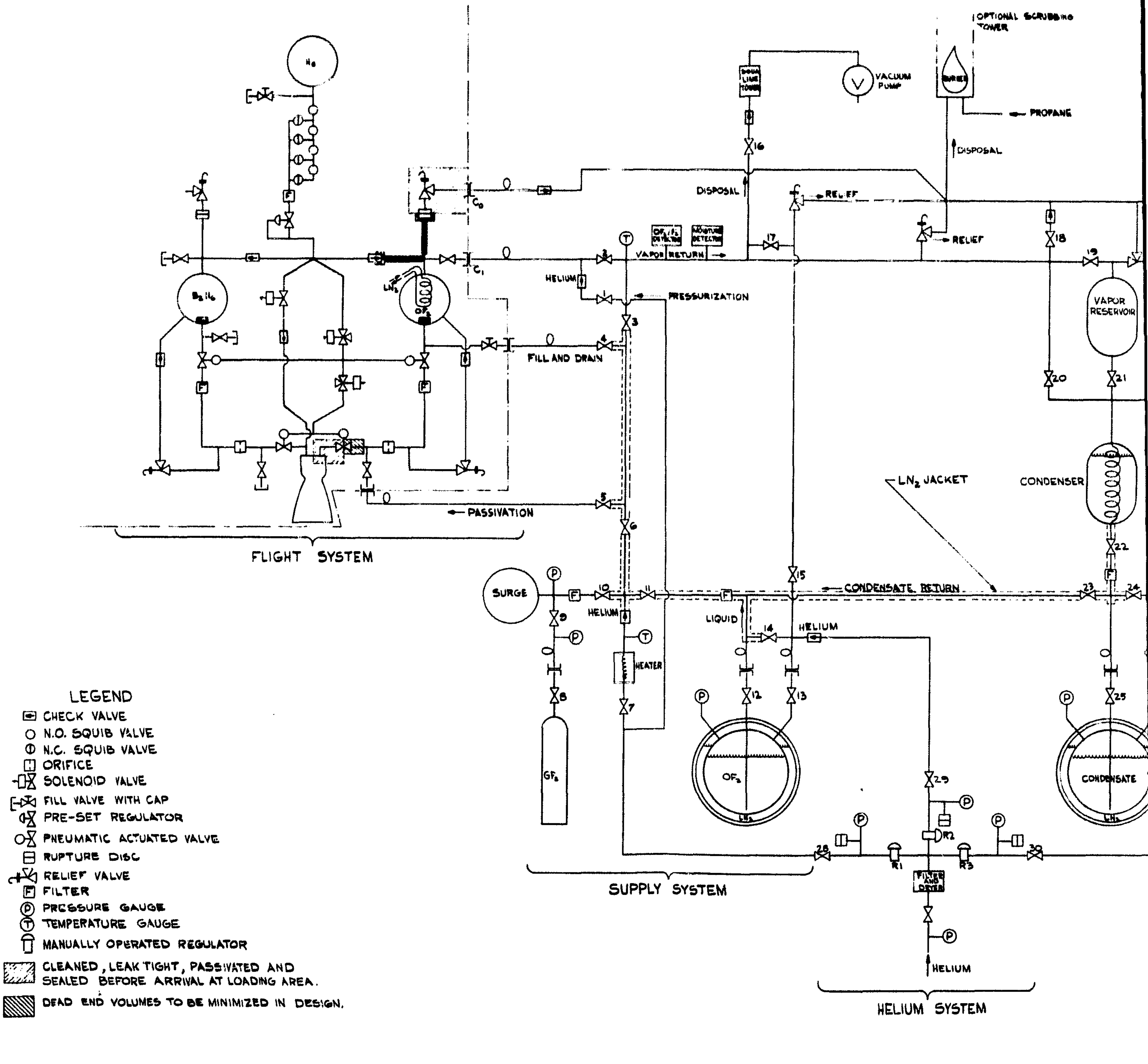
   a) Metering - A weighing system seems most preferable. This is not shown on the diagram. Probably it will consist of a set of load cells within the mount holding the SSPM.

   b) Filling - Pressurization of the OF_2 supply tank is the preferred means of transferring the liquid to the module. (Seal leakage and the potential for fire makes pumps undesirable.) Since the recommended working pressure of the tanks is low, very good control over the pressure is required to avoid cracking the relief valve while supplying sufficient head to force OF_2 into the module system. The condenser and condensate tank are used as a low pressure receiver downstream of the module into which vapor generated in the flight system will be drawn. To establish this low pressure sink, the liquid nitrogen jackets are filled and the internal volume bled down to about 2 to 5 psig via valve 18 with valves 2, 3, 16, 20, 23, 24, 27, and 30 closed and valves 19, 21, 22, and 25 open. Helium regulated to the desired working pressure is admitted to the ullage of the supply tank by opening valve 29 and regulator R2. With valves 1, 3, 5, 7, 10, 14, 16, 17, 18, 20, 23, 24, and 30 closed, valves 6, 11, and 12 are opened. Valves 13 and 15 have been open in the relief path for the supply tank. Valve 2 is opened, then the module oxidizer isolation valve is opened. Next, valve 4 is gradually opened to permit OF_2 to flow and valve 26 is opened to provide a relief path from the condensate tank. Cold OF_2 vapor will chill the fill line and then fill it with liquid. Boil-off vapor flowing out the module tank to the condenser will be liquefied and flowed under gravity head to the condensate tank. If sufficient head is not developed due to the volume of boil-off, then valves 26 and 27 should be slowly opened to decrease the back pressure by venting off some of the vapor through the b burner; this should be done only if necessary. As the module tank is chilled to liquid temperature, it will be filled with liquid OF_2. Filling should proceed slowly to minimize the amount of sub-surface boiling in the module system. Since the refrigeration system is sufficiently effective, there will be very little vaporization even at the low filling pressures. When the weigh system indicates a full load is onboard, valves 4 and 19 are closed.

c) Securing the Ground System - To empty the liquid fill line, valves 3 and 17 are opened. If this line does not drain due to gravity, valve 17 is closed, then pressurant is slowly introduced through valve 1 to force the liquid OF_2 out of the fill line. When the line is empty of liquid, valves 2, 12, 13 and 15 are closed, valves 14, 18 and 29 are opened and helium pressure is used to purge the line. Next, valves 3, 14, 18 and 29 are closed and 2, 13 and 15 are opened again.

8. Emergency Draining - The system must, of course, be able to safely drain the module tankage. To do this, valves 3, 5, 7, 10, 12, 14, and 24 are closed. Valves 6, 11, 2, 25, and 26 are opened. The line jackets are chilled with LN_2. Then valves 1 and 28 are opened and regulated helium pressure is slowly applied to the tank while valve 4 is slowly opened. This forces liquid OF_2 out of the module tank, through the fill and condensate return line and into the condensate tank. Since pressure will build up in the condensate tank, it may be necessary to carefully vent this vapor pressure through valve 27 to the burner. When the liquid has been completely drained, valve 23 is closed. If necessary, the entire transfer system and spacecraft circuit can then be purged with helium (or evacuated through valve 18 by the vacuum pump if this is necessary).

FOLDOUT FRAME 1



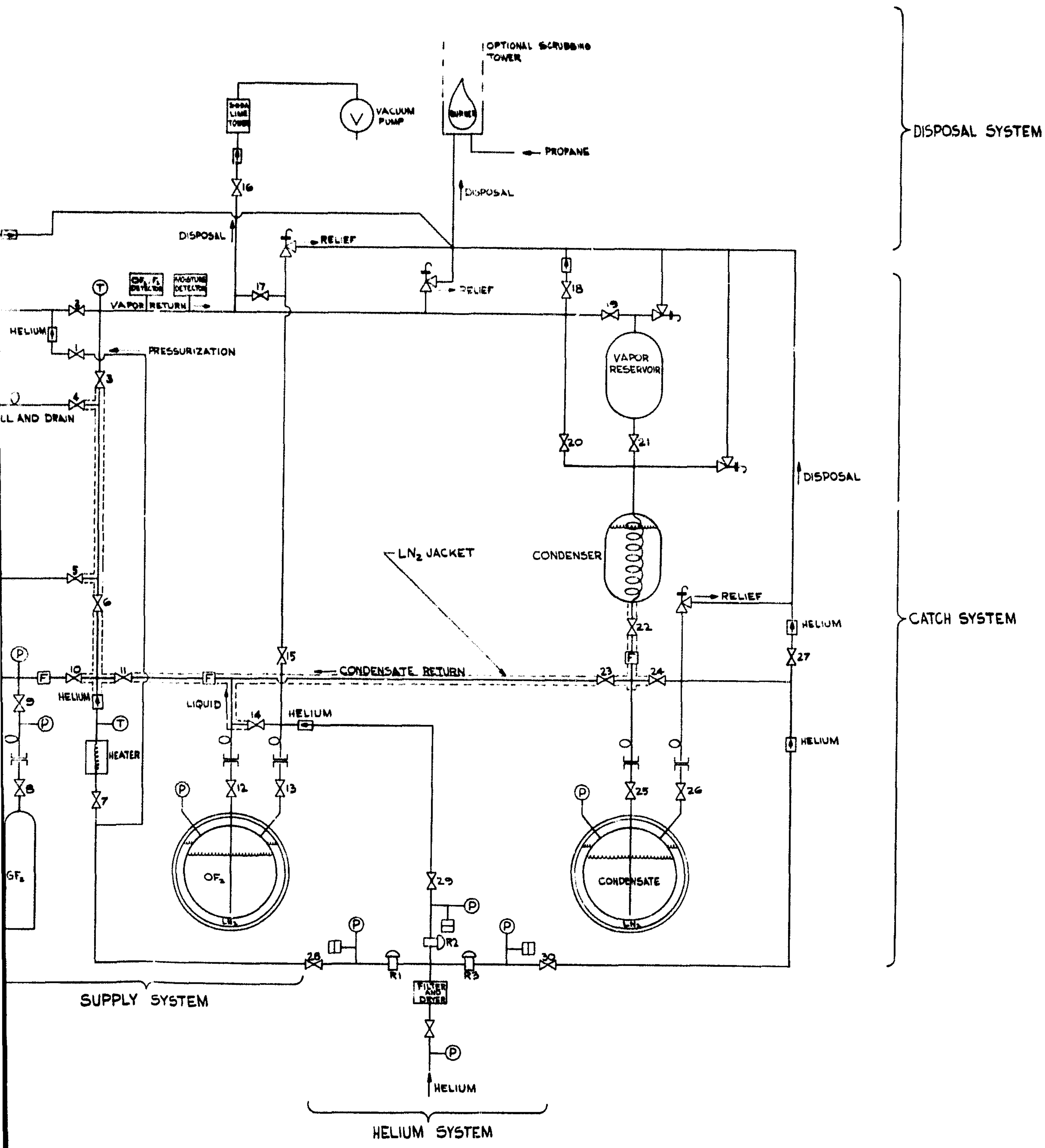
2. SUPPORTING SYSTEM DETAILS, (PRESSURIZATION, LN_2 ETC) ARE NOT SHOWN.

1. REDUNDANCY NOT SHOWN BUT IN PRACTICE REDUNDANCY IS DESIREABLE FOR SAFETY AND SECURING SYSTEM IN EVENT OF A MALFUNCTION.

~~1. IDENTIFICATION MARKING PER~~

NOTES: UNLESS OTHERWISE SPECIFIED

FOLDOUT FRAME 2



DETAILS, (PRESSURIZATION,
SHOWN.

WN BUT IN PRACTICE
REAKLE FOR SAFETY
IN EVENT OF A MALFUNCTION.

SPECIFIED

PARTS LIST

DO NOT SCALE DRAWING

J. WEDGBURY

TRW

SCHEMATIC, OF_2 PASSIVATION, FILL AND DRAIN SYSTEM - S.S.P.M

E 11982 SK 407052

SK 407052