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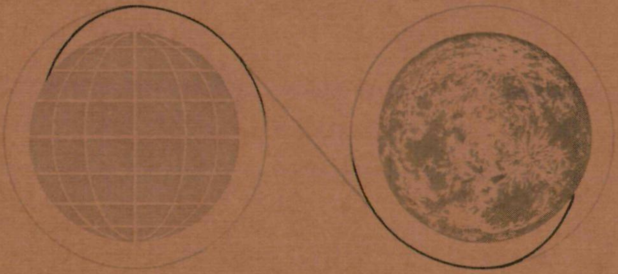

Apollo Extension Systems—Lunar Excursion Module
Phase B Final Report

~~U. S. Government Agencies and Contractors Only~~

Vol. V Shelter Design Analysis Summary (U)

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Apollo Extension Systems — Lunar Excursion Module
Phase B Final Report

to

National Aeronautics and Space Administration
Manned Spacecraft Center
Advanced Spacecraft Technology Division
Houston, Texas 77058

by
Grumman Aircraft Engineering Corporation
Bethpage, New York

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Vol. V Shelter Design Analysis Summary [redacted]

Contract No. NAS 9-4983
ASR 378B

8 December 1965

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Preface

This report presents the results of the Phase "B" Preliminary Definition Study (Contract NAS 9-4983) of the Lunar Excursion Module (LEM) and its modifications and additions, as necessary, for use in the Apollo Extension Systems (AES). This use includes a Laboratory for Earth and lunar orbital missions, and a Shelter, a Taxi and a Truck for extended-stay lunar surface missions. The overall objective of this study was to conduct sufficient analyses to provide a basis for selection by NASA of a single concept for each mission for final definition and development.

The study results are distributed in the volumes listed below in the following manner: Volume I contains a summary of the Preliminary Project Development Plan (PDP) with emphasis on estimates of the program costs and schedules. This volume was submitted on 30 October 1965, one month in advance of the remaining final documentation. Volume II is a brief summary of the overall study. Volumes III through XVI contain the design analyses, preliminary specifications, and operations analyses for each of the AES/LEM vehicle types. Volumes XVII through XXVI contain preliminary project planning data in the areas of management, manufacturing, development testing, and support.

It was necessary to base the preliminary project planning data, including estimated costs, on a single configuration for each of the AES/LEM vehicle types. Since these PDP data were required by the end of October, the configurations had to be selected at the mid-point of the study, before the configuration studies had been completed. These configurations have been called "baseline" configurations. The continuing design analyses in the second half of the study have resulted in recommended changes to the baseline configurations. Volumes III through VI describe the "recommended" configurations, the baseline configurations, and some additional alternates which were studied. It is anticipated that NASA will make a selection from these configurations, and that these selections will then be the new baseline configurations for the next phase of AES definition studies.

The scope of this study included integration of the experimental payloads with the Shelter and Taxi, but did not include study of the integration on individual LEM Laboratory flights. At approximately the mid-point of the study, an addendum was written with the objective of providing support to the NASA Mission Planning Task Force for study of the Phase I Laboratory flights. The schedule for the addendum calls for completion of these mission planning studies in January, 1966. Therefore, the addendum efforts are not described in this report.

The volumes which comprise this report are as follows:

I *Phase B Preliminary Definition Plan (30 Oct 1965)*
II *Preliminary Definition Studies Summary*
III *Phase I Laboratory Design Analysis Summary*
IV *Phase II Laboratory Design Analysis Summary*
V *Shelter Design Analysis Summary*
VI *Taxi Design Analysis Summary*
VII *Truck Design Analysis Summary*
VIII *Phase I Laboratory Master End Item Specification*
IX *Phase II Laboratory Master End Item Specification*
X *Shelter Master End Item Specification*
XI *Taxi Master End Item Specification*
XII *Phase I Laboratory Experimental Payload Performance & Interface Specification*
XIII *Phase II Laboratory Experimental Payload Performance & Interface Specification*
XIV *Shelter Experimental Payload Performance & Interface Specification*
XV *Taxi Experimental Payload Performance & Interface Specification*
XVI *Prelaunch & Mission Operations*
XVII *Manufacturing Plan*
XVIII *AES Modifications to LEM Quality Control Program Plan*
XIX *Ground Development Test Plan*
XX *Support Equipment Specification*
XXI *Facilities Plan*
XXII *Support Plan*
XXIII *Transportation Plan*
XXIV *Training Equipment Requirements*
XXV *Support Equipment Requirements*
XXVI *Management Plan*

Table of Contents

Note: Tables and Figures are grouped at the rear of each major subsection.

[redacted]

1. INTRODUCTION

This volume presents the results of the LEM Shelter design analysis. The LEM Shelter is a modified LEM capable of making an unmanned landing on the Moon, surviving the lunar environment in a quiescent state for periods up to 3 months, and then providing life support and scientific mission capability for the two LEM-Taxi crewmen for periods up to 14 days. The preliminary design data which are provided are intended to permit NASA to select a Taxi configuration.

The following vehicle-level ground rules were observed during this study. Additional subsystem-level ground rules and assumptions are included in this report where applicable.

- Minimum spacecraft modifications
- Maximum utilization of Apollo hardware
- Utilization of other qualified spacecraft hardware (Mercury, Gemini)
- Maximum utilization of and coordination with existing development studies
- Minimum modifications to Ground Support Equipment (GSE), Automatic Checkout Equipment (ACE) and Manned Spaceflight Network (MSFN)
- Where possible, qualification of modifications without flight testing
- Modifications and development to be compatible with spacecraft launch vehicle availability and launch schedules as defined in AES Reference Flight Schedule ML 65-1
- Mission time of up to 3-month storage and 14-day manned operation on the lunar surface
- Consistency in design requirements and commonality of design approaches for the selected configurations for the Lab, Shelter, and Taxi.

Because of the short performance period of this contract, it was necessary to select a single configuration at the mid-study point to form the basis for the preliminary Project Definition Plan (PDP). This configuration was described in the mid-study report and was called the "baseline" configuration. In the latter half of the study, this baseline configuration was modified as a result of NASA direction and/or continuing vehicle design studies. For this report, this more current configuration is called the "recommended" configuration.

The technical discussions in this volume are based upon the recommended configuration. However, any differences between the two configurations are described with appropriate explanations in the individual subsystem discussions. Also included, where applicable, are discussions of alternate configurations considered and potential modifications per flight.

2. CONFIGURATION SUMMARY

2.1. INTRODUCTION

This section summarizes the recommended and baseline Shelter configurations, and the subsystem alternates which were studied during the contract period. The definition of these configurations is based on the following:

- NASA/MSC ground rules as defined in the Work Statement and Blue Book
- Analysis of NASA/MSFC mission descriptions
- Results of Phase A studies, Contract NAS 9-3681
- Subsystem and system studies
- Vehicle design and integration analyses.

The vehicle level ground rules that were observed during the study are defined in the Introduction, Section 1. The mission analysis and supporting studies are described in detail in Sections 3 through 6.

2.2 ASSUMPTIONS

Gross vehicle design assumptions used during the study are summarized by subsystem in Table 2.2-1. These assumptions are based upon the established ground rules and the following mission related requirements:

- Operate in conjunction with the LEM Taxi
- Perform a day or night manned mission.

2.3 RECOMMENDED CONFIGURATION

The recommended Shelter (Fig. 6.1-8) is a LEM with modifications needed to make the unmanned landing on the lunar surface, remain in a stored condition for up to 3 months, and then support two men during an extended exploration period of 14 days. No ascent capability is required. The specific subsystems requiring modification are environmental control, electrical power, and the structural changes associated with these modifications and the integration of the experiment payloads. Relatively minor modifications have been made to all other subsystems. All modifications, or changes, with reference to the present LEM configuration are listed in Table 2.3-1, and are described in detail in Sections 5 and 6. Summary descriptions are presented in the following paragraphs. A Level 1 functional block diagram of the recommended Shelter subsystem interfaces is shown in Fig. 2.3-1.

2.3.1 Environmental Control

The recommended Shelter ECS configuration differs from the LEM as follows: utilization of radiator assemblies for heat rejection during manned mission phases; provisions for managing water produced by fuel cells; capability of providing life support provisions for extended cabin occupancy and surface exploration; and capability for cabin and equipment thermal control during a pre-utilization standby period of up to 90 days. The Shelter ECS is synthesized almost in total from hardware developed for the LEM Program.

Passive thermal control of the Shelter is the same as LEM with the addition of a blanket of insulation to cover the top docking tunnel and insulated reflectors applied to the interior of the windows. The active thermal control system consists of radiator panels totaling 75 ft^2 with a supplemental water evaporator for the 14-day manned phase, and a RTG waste heat transfer system for the 3-month storage period. The RTG waste heat is transferred to the cabin by a heat pipe system. The RTG is carried on the Shelter to supply power during the storage period, and later is removed by the crew and installed in the Taxi for power and active thermal control during the Taxi quiescent storage.

2.3.2 Electrical Power

The electrical power for the Shelter is provided by four distinct primary sources during the different phases of the mission as follows:

- CSM provides 9.5 kw-hr of energy to the Shelter during the translunar flight
- Three modified descent batteries, each having 12-kw-hr capacity and high-rate capability, provide primary power during the unmanned descent and landing.
- 50-w, SNAP 27, Radioisotope Thermoelectric Generator (RTG) is the primary power source during the 90-day storage, with peak loads carried by the energy remaining in the descent batteries
- Two Allis-Chalmers (A-C)fuel cells, remotely started prior to the Taxi launch, provide for the 14-day manned phase; separate EPS radiator to thermally control the fuel cells is located on the aft equipment bay.

The fuel cell reactants are carried in ambient storage tanks. The hydrogen is stored in two 39-in. dia tanks, and the oxygen in one 47-in. dia tank. The oxygen tank also includes the metabolic crew provisions.

2.4 BASELINE CONFIGURATION

The baseline configuration is also summarized in Table 2.3-1 as changes from the LEM configuration. It is essentially identical to the recommended configuration, except that two Pratt & Whitney fuel cells were used, and the ambient reactants were stored in two hydrogen and two oxygen tanks.

The descent trajectory for the recommended Shelter is a Hohmann transfer from an 80 n.mi parking orbit which is similar to the present LEM. Updating of the Inertial Measuring Unit (IMU) is made during the descent by the LEM Optical Rendezvous System (LORS). For the baseline configuration, a direct descent to the surface was used. The shorter time duration eliminates the need for updating the IMU alignment and consequently eliminates the need for an LORS. The manual Alignment Optical Telescope (AOT) of the LEM would be used by the astronaut to initially align the IMU prior to separation.

2.5 ALTERNATE CONFIGURATIONS

In arriving at the recommended Shelter configuration, alternate methods of achieving the mission requirements were studied. The candidate systems are summarized by subsystem in Table 2.5-1.

2.5.1 Guidance, Navigation and Control

The only significant alternative considered in this area is the Hohmann vs direct descent described in Paragraph 2.4, with the resulting IMU alignment by auto startracker or AOT, respectively.

2.5.2 Environmental Control

As an alternate to the system of transferring the RTG waste heat to the cabin by an intermediate fluid heat transfer loop (heat pipe), a direct radiation system was studied. With this system, the RTG is mounted on top of the descent stage in an insulated enclosure, one side of which is the ascent stage pressure vessel. The amount of heat transferred to the cabin is controlled by a hinged panel.

The RTG heat pipe system of transferring waste heat to the cabin was recommended, because of the physical consideration involved in transferring the RTG from the Shelter to the Taxi. With the direct radiation system, the RTG must be removed from the top of the descent stage and will require a deployment mechanism. The heat pipe system requires the astronaut, standing on the lunar surface, to remove the RTG from a side bay on the descent stage.

2.5.3 Electrical Power Supply

An alternate EPS configuration was studied which used cryogenic storage for fuel cell reactants and ECS oxygen in lieu of high pressure ambient tanks. The total weights and predicted reliabilities, as well as the operational and performance characteristics of each configuration, were compared.

The cryogenic storage system presents many operational problems which are not thoroughly considered when evaluating the relative reliabilities. The chief problem arises from the long standby period (up to 90 days) on the lunar surface. Off-design heat leak or unexpected thermal environments can cause boil-off loss of usable fluid during quiescent storage. Continuous venting imposes increased duty cycles on pressure relief valves at cryogenic temperature. In addition, since the tanks are just capable of meeting the 90-day storage period and still supply the usable reactant quantities; there is no room for growth, with respect to longer quiescent storage periods, without vehicle and tank modifications. Unlike the cryogenic tanks, ambient tankage is insensitive to standby time. Because of these reasons, as well as the lower reliability of the cryogenic system, the ambient system was selected and a weight penalty of 400 lb was accepted.

Three candidate fuel cell configurations were evaluated during the study; Allis-Chalmers, General Electric, and Pratt & Whitney. The fuel cell configurations were rated on the basis of design and performance, weight, and reliability. After qualitative analysis of endurance test data, which affects confidence in the fuel cell being able to meet the endurance requirements with acceptable degradation, the Allis-Chalmers fuel cell was recommended as the one showing the best prospect of insuring mission success.

2.5.4 Reaction Control System

Since crew safety is not a consideration during the Shelter descent, only one of the two separate and independent RCS systems (System B) is retained. This consists of one set of helium and propellant tanks, and eight thrusters. The deletion of eight thrusters, in addition to minimizing jet impingement problems and Shelter heat losses, make possible an increase in external payload volume.

Mission success reliability of the RCS has been evaluated, considering the complete eight-jet subsystem, and compared with the descent phase of the LEM. For this comparison, a single failure results in a mission failure in either case, and the crew safety abort provisions of the LEM were not considered. The resultant reliability is 0.9757 for the Shelter and approximately 0.96 for the LEM descent phase. This small difference is not considered significant, except to indicate the approximate equality of the LEM and recommended Shelter systems.

As an alternate, a sixteen-thruster RCS was considered, utilizing single pressurization and propellant feed sections with the ascent interconnect valves removed. Retention of all sixteen jets results in minimum hardware and software changes from the LEM. However, the plume of System A jets will impinge on such items as tanks and radiators, and it is not known whether this impingement could be tolerated or whether these components would have to be relocated.

A reliability analysis made of both the eight- and sixteen-jet configurations resulted in mission success reliabilities of 0.9757 and 0.9817, respectively. Both of these configurations have higher reliabilities than the LEM, because of lack of crew safety requirements and elimination of one set of tanks. The increased mission success reliability for the sixteen-jet configuration results from the ability to compensate for certain jet failures. However, it was not obvious that the increased reliability offset the potential plume impingement problem. The eight-jet RCS was therefore selected for the recommended Shelter configuration, since it is capable of providing the required control functions, is a more simplified configuration, and has reduced potential plume impingement problems.

2.5.5 Communications

To receive commands during the storage period, the S-band receiver must be in an active mode. A recent change on the LEM S-band transceiver removed the receive-only capability, and rather than maintain the complete S-band transceiver in an active mode for the entire storage period, a command receiver is added to the existing LEM communication subsystem. As an alternate, the existing transceiver could be modified to provide a receive-only mode of operation with failure detection and correction. The disadvantage of this alternate is that extensive modification is required to the existing LEM equipment. It also requires the receiver to operate for approximately 104 days.

A second alternate to the command receiver approach is to use the LEM-1 Digital Command Assembly (DCA) which operates on UHF, together with a S-band to UHF converter. This alternate was not selected, because it requires more power during the storage period than the recommended system and does not represent a weight saving.

2.6 POTENTIAL MODIFICATIONS PER FLIGHT

The location of antennas on the recommended configuration were assumed to be the same as the LEM. However, the integration of payloads and radiators can cause interferences to these antennas, particularly with the S-band steerable antenna located on the ascent stage along the +Y axis.

On one of the five missions described by NASA/MSFC, two LSSMs are to be integrated with the Shelter. These vehicles would be carried attached to each side of the ascent stage. This would require relocating the S-band steerable antenna on this mission.

Table 2.2-1

SHELTER SUBSYSTEM ASSUMPTIONS

Item	Assumptions
1.0 Structure	● LEM hardware components to be retained in their original locations ● No change to spacecraft LEM adapter (SLA) ● LEM/SLA pickup structure to be preserved ● Additional holes in ascent stage pressure vessel permitted only when required by experiment ● Standardize location of experiments and subsystems
2.0 Stabilization & Control	● Shelter is landed unmanned and automatically to a preselected site by the preprogrammed primary inertial guidance system
3.0 Navigation & Guidance	● Shelter is launched and landed prior to Taxi launch ● IMU is aligned using the automatic startracker prior to separation, and is updated continuously during descent ● The descent trajectory is a Hohmann transfer from an 80 n.mi circular parking orbit ● Post-landing shutdown and pre-Taxi-launch activation is controlled by Earth through the LGC and Program Coupler Assembly ● Transponder provided on the Shelter to aid Taxi landing
4.0 Crew Provisions	● Both crewmen sleep simultaneously in unpressurized soft suits with helmets on ● Two soft suits and two backpacks worn in the Taxi, one hard suit and four backpacks delivered with Shelter; the hard suit will have necessary means to meet crew requirements of water and food for a 6 hr EVA ● A total of 11 rechargeable PLSS batteries to be provided; 6 in backpacks and 5 carried in the Shelter ● Each man to be provided with one liquid cooled garment worn in the Taxi, and seven constant wear garments stored in Shelter ● Waste management system to be same as used in the CSM ● Food required is based on 3200 K cal/man/day.
5.0 Environmental Control	● 115 1/2 hours of EVA life support is provided by the Apollo PLSS; the PLSS is to be recharged by the Shelter, and assumes 3 hr EVA for each recharge ● Heat load rejected by radiator with supplemental water evaporator ● RTG waste heat transferred to Shelter during storage period ● Water management system compatible with FCA ● Windows and hatch covers plus additional cabin insulation required to reduce heat leakage
6.0 Landing Gear	● Landing velocity envelope identical to LEM

Table 2.2-1 (cont.)

Table 2.2-1 (cont.)

Item	Assumptions
7.0 Instrumentation	• Shelter status will be transmitted to CSM at 1600 bps during first part of lunar descent when Shelter is eclipsed by the moon • After occurrence of Earth/Shelter line of sight, and Earth acquisition and lock-on of the Shelter S-band steerable antenna, Shelter status data will be transmitted directly to Earth at 51.2 Kbps in real time • There is no data interface between CSM and Shelter other than the VHF link for the initial descent period
8.0 Electrical Power Supply	• Battery powered during launch, translunar, and landing • RTG provides electrical energy for storage period steady loads; battery provides status monitoring energy for storage period peak loads • Fuel cell assembly, with restart capability, provides electrical energy for operational phase; FCA will be cold stored during storage period • No electrical energy is provided for the mobility aids or other "off-Shelter" payload components
9.0 Propulsion System	• Ascent propulsion system removed • Vent valves added to depressurize propellant tanks after landing • Descent trajectory same as LEM
10.0 Reaction Control System	• One set of helium and propellant tanks removed • Vent valves to be added to depressurize propellant tanks after landing • Remove ascent propellant • Descent propellant requirements similar to LEM
11.0 Communications	• After completion of Shelter checkout and during the time both spacecraft are eclipsed by the moon, Shelter status will be transmitted to CSM for storage and transmitted to Earth when the CSM is in Earth line of sight • Earth transmission via S-band and steerable antenna with automatic lock-on to Earth • Spacecraft status during storage and reactivation of Shelter prior to Taxi launch is controlled by Earth command • Status data will be monitored once per day during storage period; warm up and stabilization is assumed to be 10 min with a nominal 2 min data transmission period
12.0 Controls & Displays	• Preseparation checkout accomplished by an astronaut in the Shelter

Table 2.3-1

SHELTER RECOMMENDED/BASELINE CONFIGURATIONS

Vehicle	Recommended			PDP Baseline		
Change with respect to LEM / Item	Removed	Modified	Added	Removed	Modified	Added
1.0 Structure	• Ascent Engine Cover • Engine Blast • Ascent Propellant Deflector & Helium Tanks	• Food Storage • Additional Insulation • Increase Micrometeorite Shielding • Water Tank Mounting Supports (conductivity change)	• Window covers • Top Hatch cover • Battery Supports • Canister for Waste • Radiator Supports • Supports for Crew Provisions	• Ascent Engine Cover Engine Blast Deflector • Ascent Propellant & Helium Tanks	• Food Storage • Additional Insulation • Increase Micrometeorite Shielding • Water Tank Mounting Supports (conductivity change)	• Window covers • Top Hatch cover • Battery Supports • Canister for Waste • Radiator Supports • Supports for Crew Provisions
2.0 Stabilization & Control	• Rate Gyro Assembly • Abort Guidance Sys		• S-band antenna X-Y Scanner • Program Coupler Assembly	• Abort Guidance Sys.		
3.0 Navigation & Guidance	• Rendezvous Radar • Alignment Optical Telescope (AOT)		• Transponder • Auto. Star Tracker Assembly	• Rendezvous Radar		• Beacon • Mission Programmer (less paper tape reader)
4.0 Crew Provisions	• Soft Suits • Radiation Dosimeters • Liquid Cooled Garments • Bio-Instrumentation • Thermal/Anti Meteoroid Protect. Garments • Suit Repair Kit • Crew • Crew Restraints • LEM Waste Management		• Airlock • One Hard Suit • Additional PLSS Batteries • Two Additional PLSS • Additional PLSS Spare Parts • 14 Constant Wear Garment • Exercise, Recreation & Hygienic Equipment • Two Bunks • Work Stations • Dome & Work Toplights • Additional Food • Additional PLSS LiOH • Medical Equipment • CSM Waste Management • External flood lights (150W)	• Soft Suits • Radiation Dosimeters • Liquid Cooled Garments • Bio-Instrumentation • Thermal Garment • Meteoroid Protect Garments • Suit Repair Kit • Emergency O_2 System • Crew • Crew Restraints • LEM Waste Management		• One Hard Suit • Additional PLSS Batteries • Two Additional PLSS • Additional PLSS Spare Parts • 14 Constant Wear Garment • Exercise & Recreation Equipment • Two Bunks • Work Stations • Dome Light • Additional Food • Additional LiOH • Medical Equipment • CSM Waste Management

Table 2.3-1 (Cont.)

Vehicle	Recommended			PDP Baseline		
Item / Change with respect to LEM	*Removed*	*Modified*	*Added*	*Removed*	*Modified*	*Added*
5.0 Environmental Control	● LEM GOX Tanks (3) ● LEM GOX Plumbing ● Ascent Water Tanks ● Ascent Water Tank Plumbing ● LEM GOX ● Redundant Glycol Loop	● Glycol Pump ● Cold Plates	● PLSS Supplementary GOX Tank ● Tanks for AC Fuel Cell Water Management ● Plumbing Assoc. with Fuel Cell Water Management* ● 12 Cabin LiOH Cartridges ● GOX for PLSS Supplement ● 75 ft^2 Radiator ● Heat Pipe for Use with RTG	● LEM GOX Tanks (3) ● Ascent Water Tanks ● Ascent Water Tank Plumbing ● LEM GOX ● Redundant Glycol Loop	● Glycol Pump ● Cold Plates	● PLSS Supplementary GOX Tank ● Tanks for Fuel Cell Water Management ● Plumbing Assoc. with Fuel Cell Water Management ● 12 Cabin LiOH Cartridges ● GOX for PLSS Supplement ● 75 ft^2 Radiator ● Heat Pipe for Use with RTG
6.0 Landing Gear						
7.0 Instrumentation	● LEM Scientific Equip	● Sensors	● (1) Additional Voice Storage Recorder Cartridge	● Data Storage ● LEM Scientific Equip	● Sensors	
8.0 Electrical Power Supply	● Ascent Batteries ● Descent Batteries ● Control Assy-Ascent		● Three Modified Descent Batteries (12.0 kwh) ● Battery Charger ● Two AC Fuel Cells ● FCA Radiator and glycol pump ● Oxygen Tank (47 in. D.) (1) ● Hydrogen Tanks (39 in. D) (2) ● Plumbing ● Oxygen (Ambient Storage) ● Hydrogen (Ambient Storage) ● RTG Unit	● Ascent Batteries ● Descent Batteries ● Control Assy-Ascent ● Two Descent Control Assembly		● Two Modified Descent Batteries ● Battery Charger ● Storage Battery ● Two P&W Fuel Cells ● Oxygen Tanks ● Hydrogen Tanks ● Plumbing ● Oxygen (Ambient Storage) ● Hydrogen (Ambient Storage) ● RTG Unit

Table 2.3-1 (Cont.)

Vehicle	Recommended			PDP Baseline		
Change with respect to LEM / Item	Removed	Modified	Added	Removed	Modified	Added
9.0 Propulsion System	● Ascent Prop-Usable ● Ascent Prop-Trapped ● Ascent Fuel Tanks ● Ascent Oxid. Tanks ● Ascent Prop Plumbing ● Ascent Helium Tanks ● Ascent Helium ● Ascent Helium Plumbing ● Ascent Engine		● Vent Valves (3) to Descent Plumbing	● Ascent Prop-Usable ● Ascent Prop-Trapped ● Ascent Fuel Tanks ● Ascent Oxid. Tanks ● Ascent Prop Plumbing ● Ascent Helium Tanks ● Ascent Helium ● Ascent Helium Plumbing ● Ascent Engine		● Vent Valves (3) to Descent Plumbing
10.00 Reaction Control System	● Ascent Propellant ● One Fuel Tank ● One Oxidizer Tank ● One Set Plumbing ● One Helium Tank ● 50% Helium ● 50% Press. Plumbing ● 8 Thrusters Assy. ● 50% Cluster Hardware		● Vent Valves to Prop. tanks	● 336 lb. Propellant ● One Fuel Tank ● One Oxidizer Tank ● One Set Plumbing ● One Helium Tank ● 50% Helium ● 50% Press. Plumbing ● 8 Thrusters Assy. ● 50% Cluster Hardware		
11.0 Communications	● Television	● S-Band antenna Electronic Control Assembly. (to work with X-Y scanner) ● S-Band Transceiver bandwidth (70 kc output)	● Command Decoder & assoc. electronics ● Antenna switching matrix ● Command Receiver	● Television		● Command Decoder
12.0 Controls & Displays	● Flight Controls ● Abort Guidance ● Propulsion displays ● ACA (1) TTCA (2) ● RCS displays (1/2) ● S & C displays (some)	● Waste Management ● Environmental Control ● Instrumentation	● Electric Power (FCA)	● Flight Controls ● Abort Guidance ● Controllers ● Ascent Propulsion	● Waste Management ● Environmental Control ● Instrumentation	● Electric Power

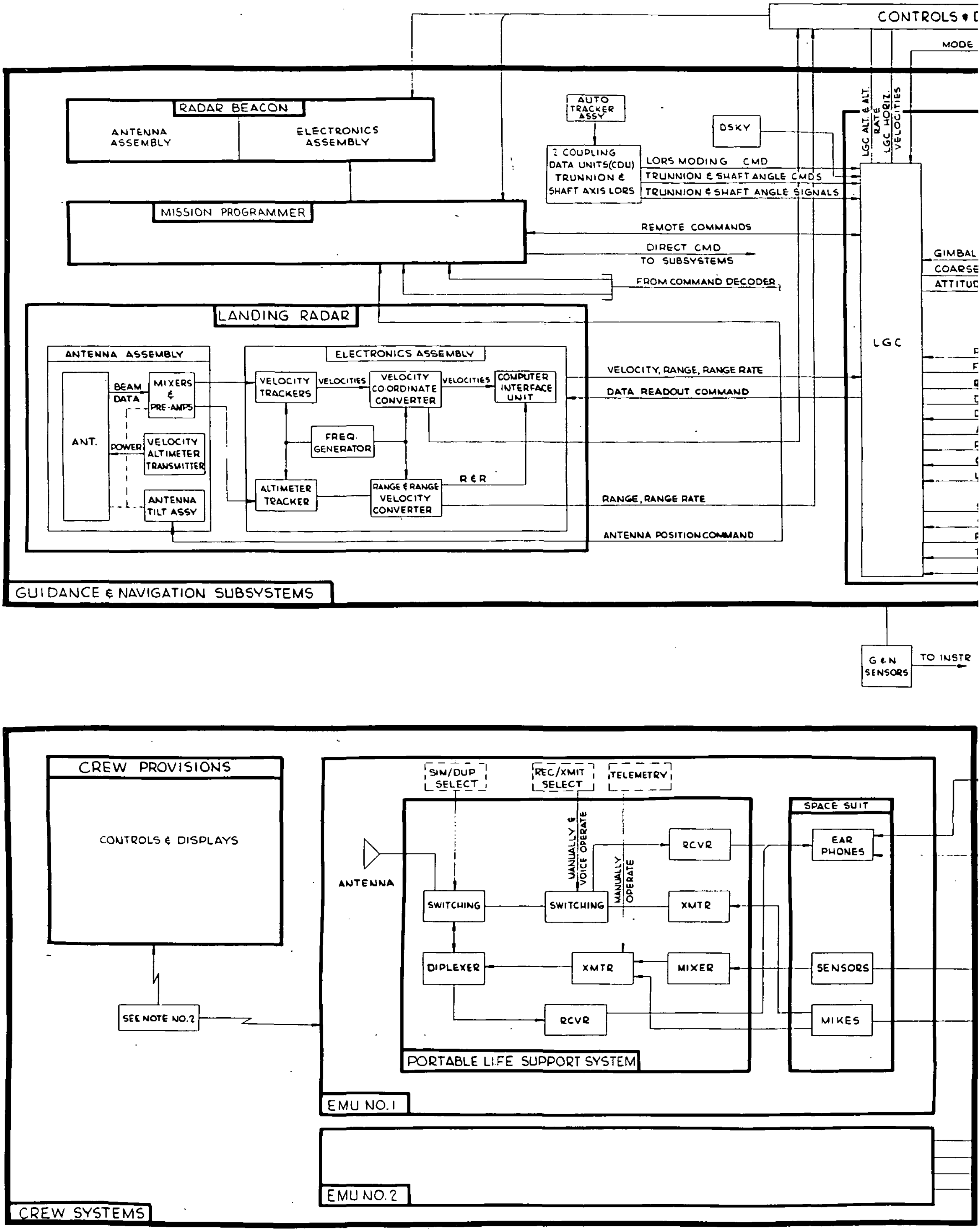
Table 2.5-1

SHELTER SUBSYSTEM ALTERNATIVES

Table 2.5-1

SHELTER SUBSYSTEM ALTERNATIVES

Item	Candidates
1.0 Structure	• Structural provisions to accommodate alternates
2.0 & 3.0 Stabilization & Control and Navigation & Guidance	• Provide landing aid for Taxi with transponder vs beacon • Steer S-band antenna with X-Y scanner vs LGC control • Auto up-date of IMU with LORS (Hohmann descent) vs pre-separation alignment with AOT (direct descent)
4.0 Crew Provisions	• Ingress/egress through airlock vs no airlock • Alternate airlock configurations • EVA operation with one hard suit vs two hard suits • Internal PLSS charging station vs internal and external charging stations • Waste management of urine by dump vs storage • Transfer experiment samples through front hatch vs pass-thru airlock
5.0 Environmental Control	• O_2 management of airlock by dump vs pump-down • Water management for alternate fuel cell assemblies • Transfer RTG excess heat to cabin via heat pipe vs direct radiation • Thermal control of water tanks with RTG excess heat vs electric heaters • Alternate radiator size and location • Reduce heat leakage through RCS clusters by addition of cluster covers
6.0 Landing Gear	
7.0 Instrumentation	
8.0 Electrical Power Supply	• Alternate fuel cell assembly; A-C vs P&W or GE • Ambient storage vs cryogenic storage of reactants • Alternate ambient storage tank size, number and location
9.0 Propulsion System	
10.0 Reaction Control System	• 8 vs 16 thruster configuration
11.0 Communications	• Use of separate command receiver vs modifying S-band transceiver for a receive-only mode of operation or add an S-band to UHF converter for use with LEM-1 DCA • S-band Ommi antenna switching vs coupling antennas
12.0 Controls & Displays	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ELECTRONICS ASSEMBLY
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LORS MODING CMD
TRUNNION & SHAFT ANGLE CMDS
TRUNNION & SHAFT ANGLE SIGNALS
LGC ALT. & ALT. RATE
LGC HORIZ. VELOCITIES
MISSION PROGRAMMER
REMOTE COMMANDS
DIRECT CMD TO SUBSYSTEMS
FROM COMMAND DECODER
GIMBAL
COARSE
ATTITUD
LGC
LANDING RADAR
ANTENNA ASSEMBLY
ANT.
BEAM DATA
MIXERS & PRE-AMPS
POWER
VELOCITY ALTIMETER TRANSMITTER
ANTENNA TILT ASSY
ELECTRONICS ASSEMBLY
VELOCITY TRACKERS
VELOCITIES
VELOCITY CO-ORDINATE CONVERTER
VELOCITIES
COMPUTER INTERFACE UNIT
FREQ. GENERATOR
ALTIMETER TRACKER
RANGE & RANGE VELOCITY CONVERTER
R & R
VELOCITY, RANGE, RANGE RATE
DATA READOUT COMMAND
RANGE, RANGE RATE
ANTENNA POSITION COMMAND
GUIDANCE & NAVIGATION SUBSYSTEMS
G & N SENSORS
TO INSTR
CREW PROVISIONS
CONTROLS & DISPLAYS
SEE NOTE NO. 2
SIM/DUP SELECT
REC/XMIT SELECT
TELEMETRY
ANTENNA
SWITCHING
MANUALLY & VOICE OPERATE
SWITCHING
MANUALLY OPERATE
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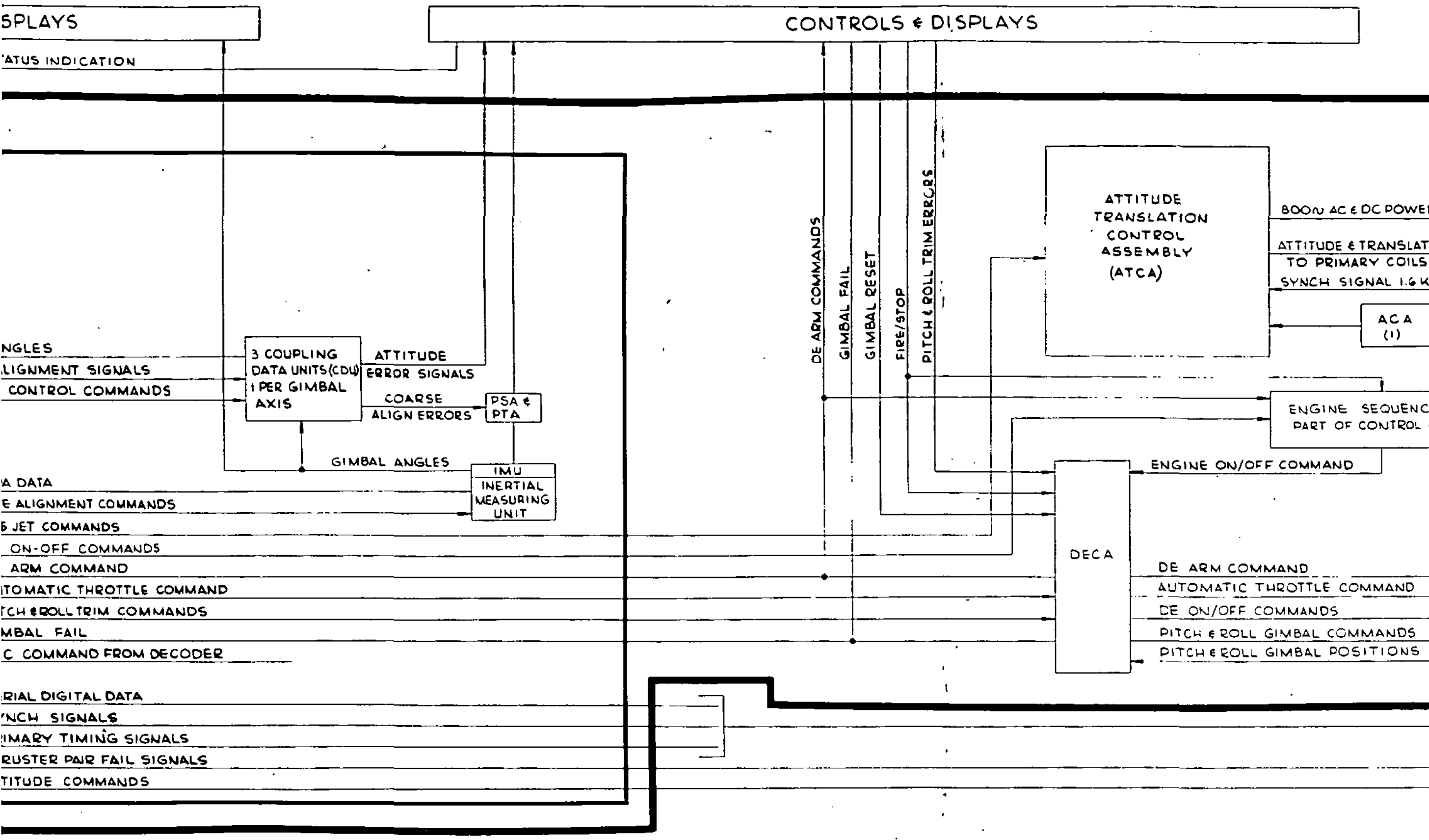
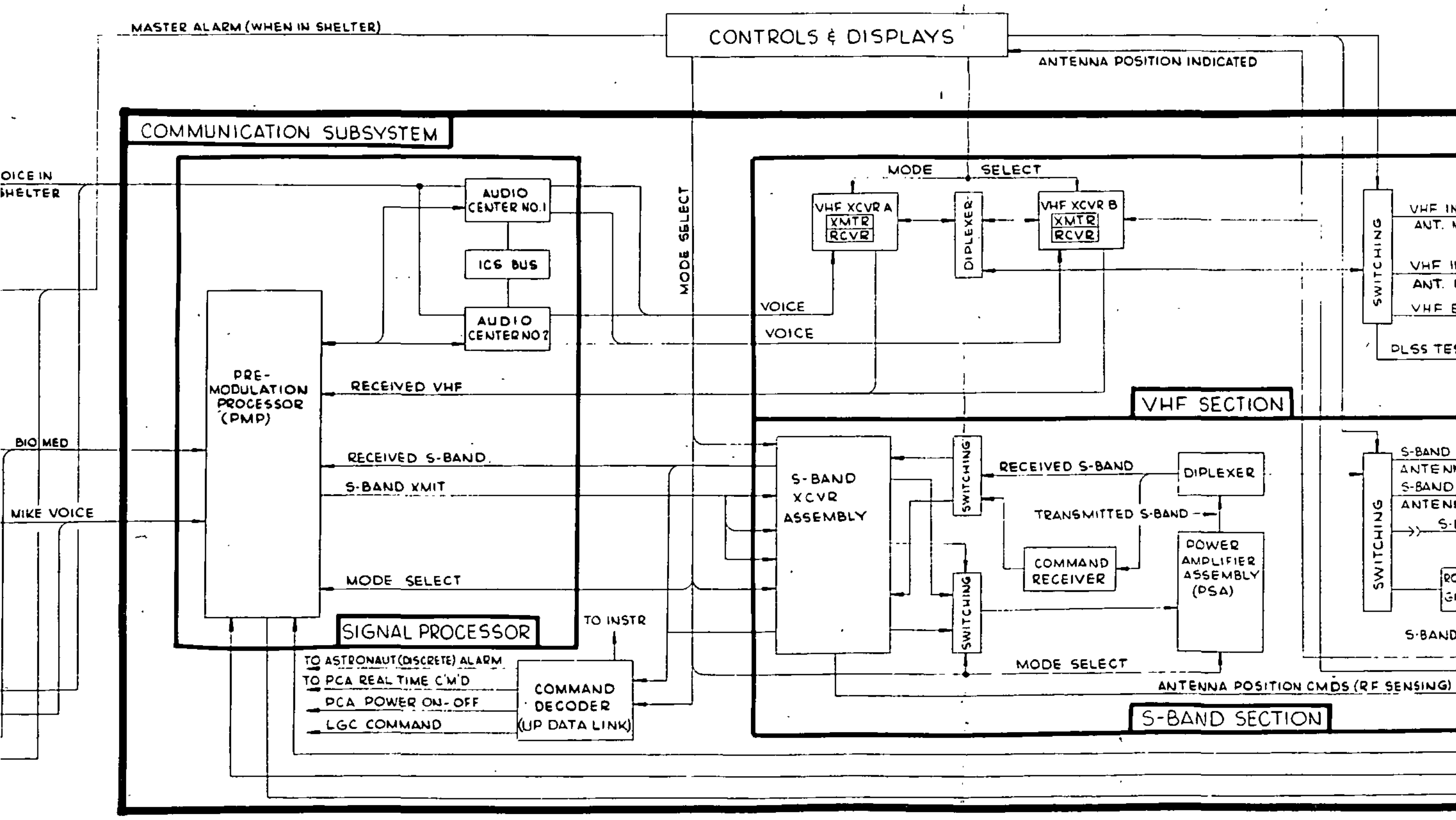
XMTR
DIPLEXER
XMTR
MIXER
RCVR
PORTABLE LIFE SUPPORT SYSTEM
SPACE SUIT
EAR PHONES
SENSORS
MIKES
EMU NO. 1
EMU NO. 2
CREW SYSTEMS

23.1 A ①


SPLAYS
ATUS INDICATION
CONTROLS & DISPLAYS
NGLES
LIGNMENT SIGNALS
CONTROL COMMANDS
3 COUPLING DATA UNITS (CDU) 1 PER GIMBAL AXIS
ATTITUDE ERROR SIGNALS
COARSE ALIGN ERRORS
PSA & PTA
GIMBAL ANGLES
IMU INERTIAL MEASURING UNIT
A DATA
E ALIGNMENT COMMANDS
S JET COMMANDS
ON-OFF COMMANDS
ARM COMMAND
TOMATIC THROTTLE COMMAND
CH & ROLL TRIM COMMANDS
MBAL FAIL
C COMMAND FROM DECODER
RIAL DIGITAL DATA
NCH SIGNALS
IMARY TIMING SIGNALS
RUSTER PAIR FAIL SIGNALS
TITUDE COMMANDS
DE ARM COMMANDS
GIMBAL FAIL
GIMBAL RESET
FIRE/STOP
PITCH & ROLL TRIM ERRORS
ATTITUDE TRANSLATION CONTROL ASSEMBLY (ATCA)
800~ AC & DC POWE
ATTITUDE & TRANSLAT
TO PRIMARY COILS
SYNCH SIGNAL 1.6 K
ACA (1)
ENGINE SEQUENC
PART OF CONTROL
ENGINE ON/OFF COMMAND
DECA
DE ARM COMMAND
AUTOMATIC THROTTLE COMMAND
DE ON/OFF COMMANDS
PITCH & ROLL GIMBAL COMMANDS
PITCH & ROLL GIMBAL POSITIONS


MASTER ALARM (WHEN IN SHELTER)
CONTROLS & DISPLAYS
ANTENNA POSITION INDICATED
COMMUNICATION SUBSYSTEM
OICE IN
HELTER
AUDIO CENTER NO. 1
ICS BUS
AUDIO CENTER NO 2
PRE-MODULATION PROCESSOR (PMP)
RECEIVED VHF
RECEIVED S-BAND
S-BAND XMIT
MODE SELECT
SIGNAL PROCESSOR
BIO MED
MIKE VOICE
TO INSTR
TO ASTRONAUT (DISCRETE) ALARM
TO PCA REAL TIME C'M'D
PCA POWER ON-OFF
LGC COMMAND
COMMAND DECODER (UP DATA LINK)
MODE SELECT
MODE SELECT
VHF XCVR A
XMTR
RCVR
DIPLEXER
VHF XCVR B
XMTR
RCVR
VOICE
VOICE
VHF SECTION
SWITCHING
VHF IN
ANT.
VHF I
ANT.
VHF E
PLSS TES
S-BAND XCVR ASSEMBLY
SWITCHING
RECEIVED S-BAND
DIPLEXER
TRANSMITTED S-BAND
COMMAND RECEIVER
POWER AMPLIFIER ASSEMBLY (PSA)
SWITCHING
MODE SELECT
ANTENNA POSITION CMDS (RF SENSING)
S-BAND SECTION
SWITCHING
S-BAND
ANTEN
S-BAND
ANTEN
S-
RC
GI
S-BAND

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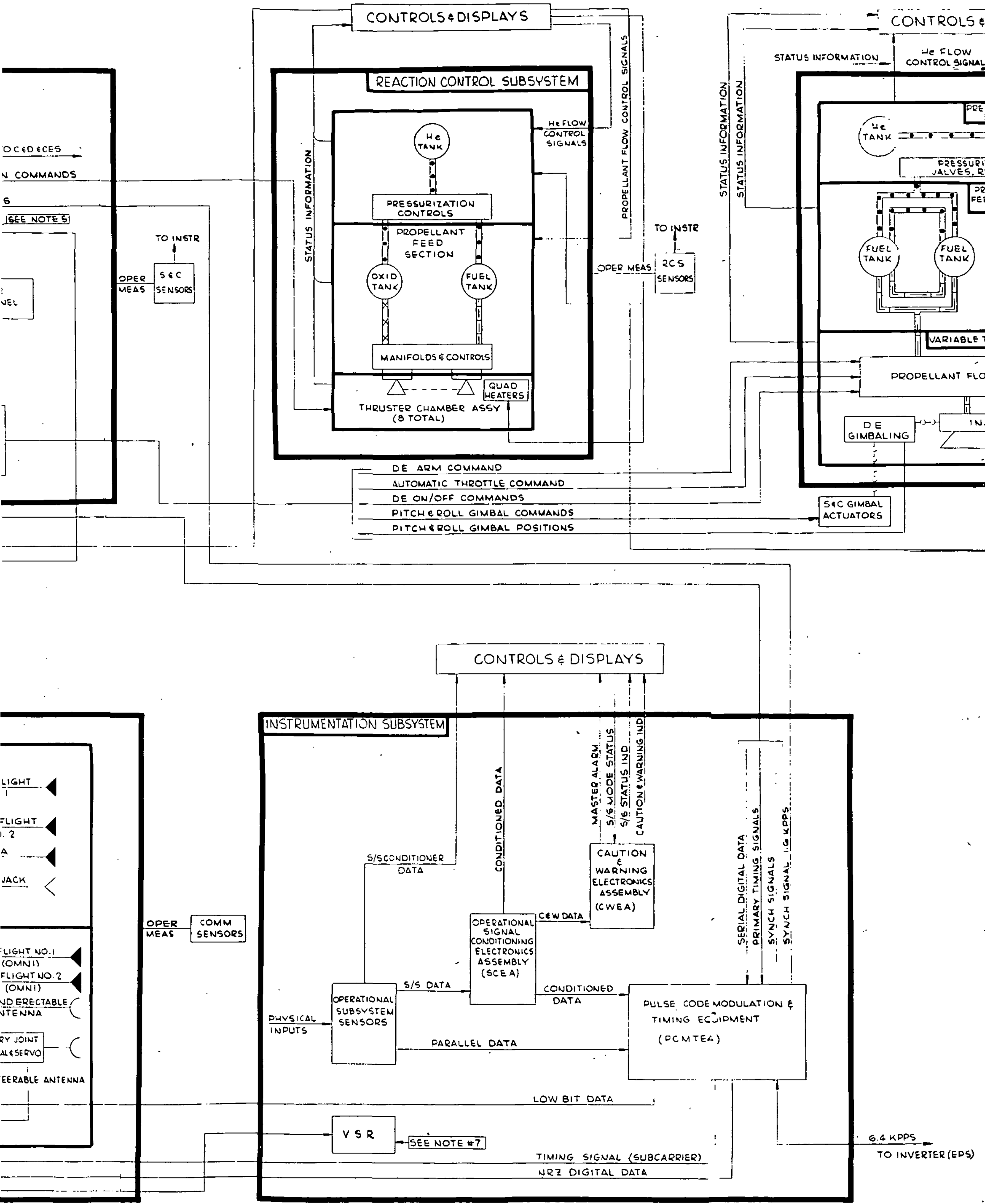

CONTROLS & DISPLAYS
REACTION CONTROL SUBSYSTEM
He TANK
He FLOW CONTROL SIGNALS
PRESSURIZATION CONTROLS
PROPELLANT FEED SECTION
OXID TANK
FUEL TANK
MANIFOLDS & CONTROLS
QUAD HEATERS
THRUSTER CHAMBER ASSY (8 TOTAL)
STATUS INFORMATION
PROPELLANT FLOW CONTROL SIGNALS
TO INSTR
OPER MEAS
RCS SENSORS
S&C SENSORS
OC&D&CES
N COMMANDS
S
SEE NOTE 5
NEL
DE ARM COMMAND
AUTOMATIC THROTTLE COMMAND
DE ON/OFF COMMANDS
PITCH & ROLL GIMBAL COMMANDS
PITCH & ROLL GIMBAL POSITIONS
CONTROLS &
STATUS INFORMATION
He FLOW CONTROL SIGNAL
STATUS INFORMATION
STATUS INFORMATION
He TANK
PRE
PRESSURI VALVES, R
PR FEE
FUEL TANK
FUEL TANK
VARIABLE T
PROPELLANT FLO
DE GIMBALING
IN
S&C GIMBAL ACTUATORS
CONTROLS & DISPLAYS
INSTRUMENTATION SUBSYSTEM
CONDITIONED DATA
MASTER ALARM
S/C MODE STATUS
S/C STATUS IND
CAUTION & WARNING IND
S/S CONDITIONER DATA
CAUTION & WARNING ELECTRONICS ASSEMBLY (CWEA)
C&W DATA
OPERATIONAL SIGNAL CONDITIONING ELECTRONICS ASSEMBLY (SCEA)
SERIAL DIGITAL DATA
PRIMARY TIMING SIGNALS
SYNCH SIGNALS
SYNCH SIGNAL 1.6 KPPS
S/S DATA
CONDITIONED DATA
PHYSICAL INPUTS
OPERATIONAL SUBSYSTEM SENSORS
PARALLEL DATA
PULSE CODE MODULATION & TIMING EQUIPMENT (PCMTEA)
LOW BIT DATA
VSR
SEE NOTE #7
TIMING SIGNAL (SUBCARRIER)
NRZ DIGITAL DATA
6.4 KPPS
TO INVERTER (EPS)
OPER MEAS
COMM SENSORS
LIGHT
FLIGHT
2
A
JACK
FLIGHT NO. 1 (OMNI)
FLIGHT NO. 2 (OMNI)
ND ERECTABLE NTENNA
RY JOINT AL & SERVO
EERABLE ANTENNA

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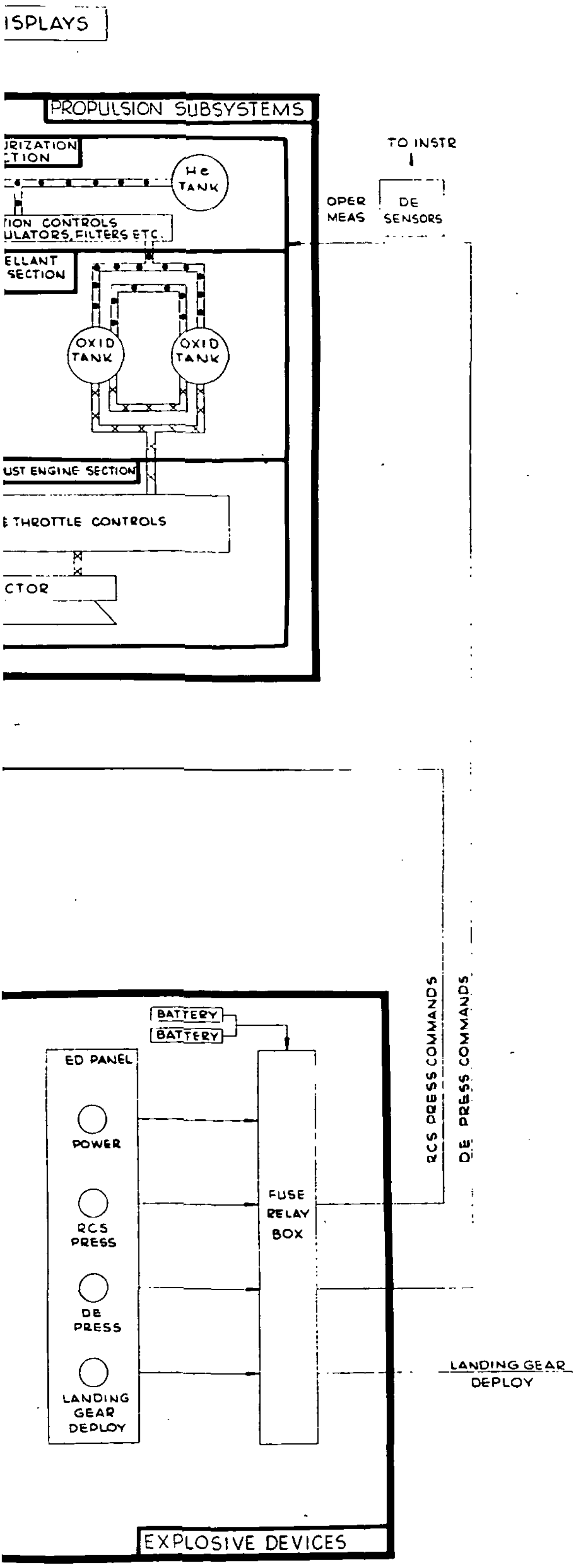
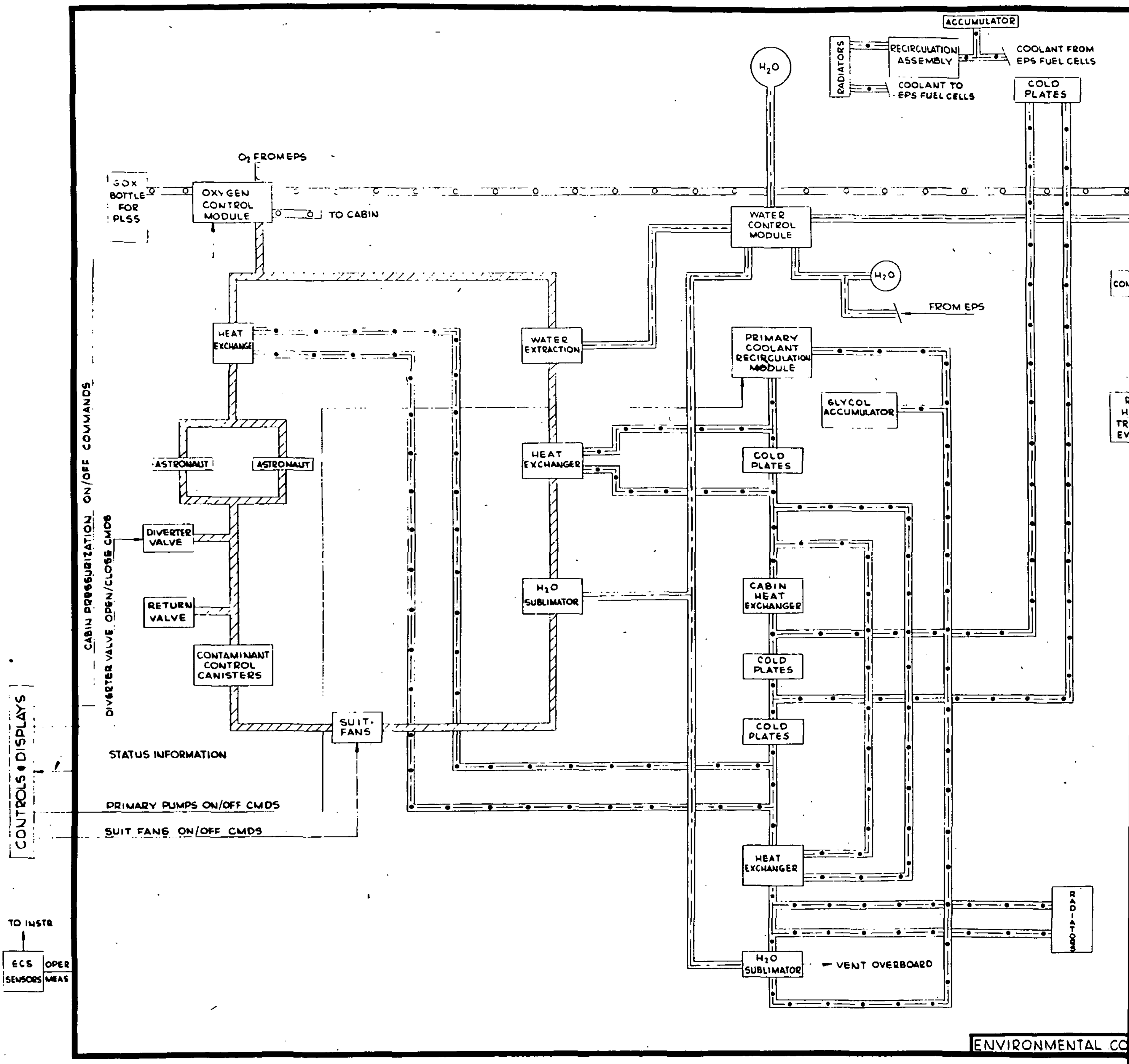


Fig. 2.3-1 Shelter Level I Functional Block Diagram (Sheet 1 of 2)

A 4



ENVIRONMENTAL CO

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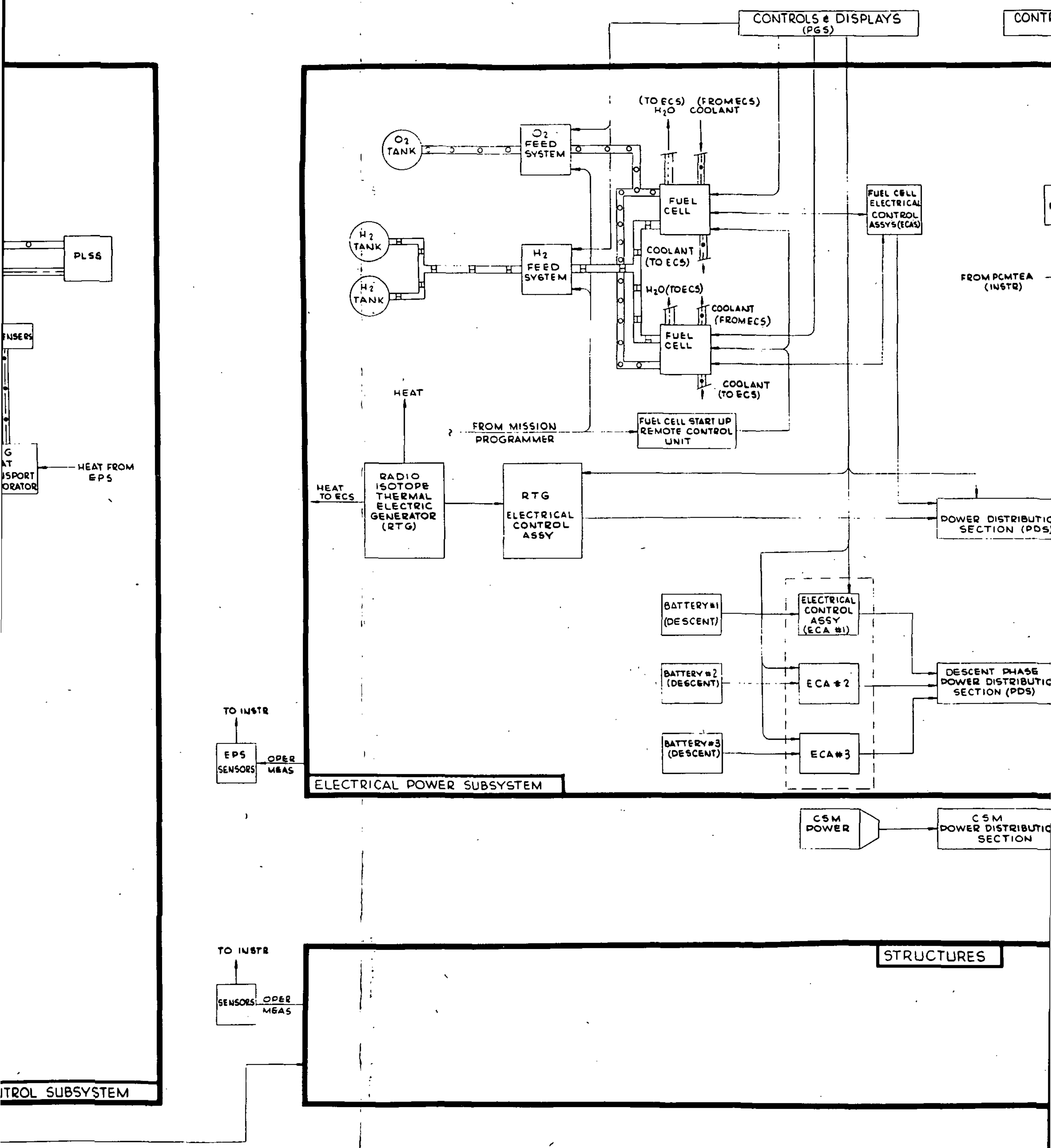
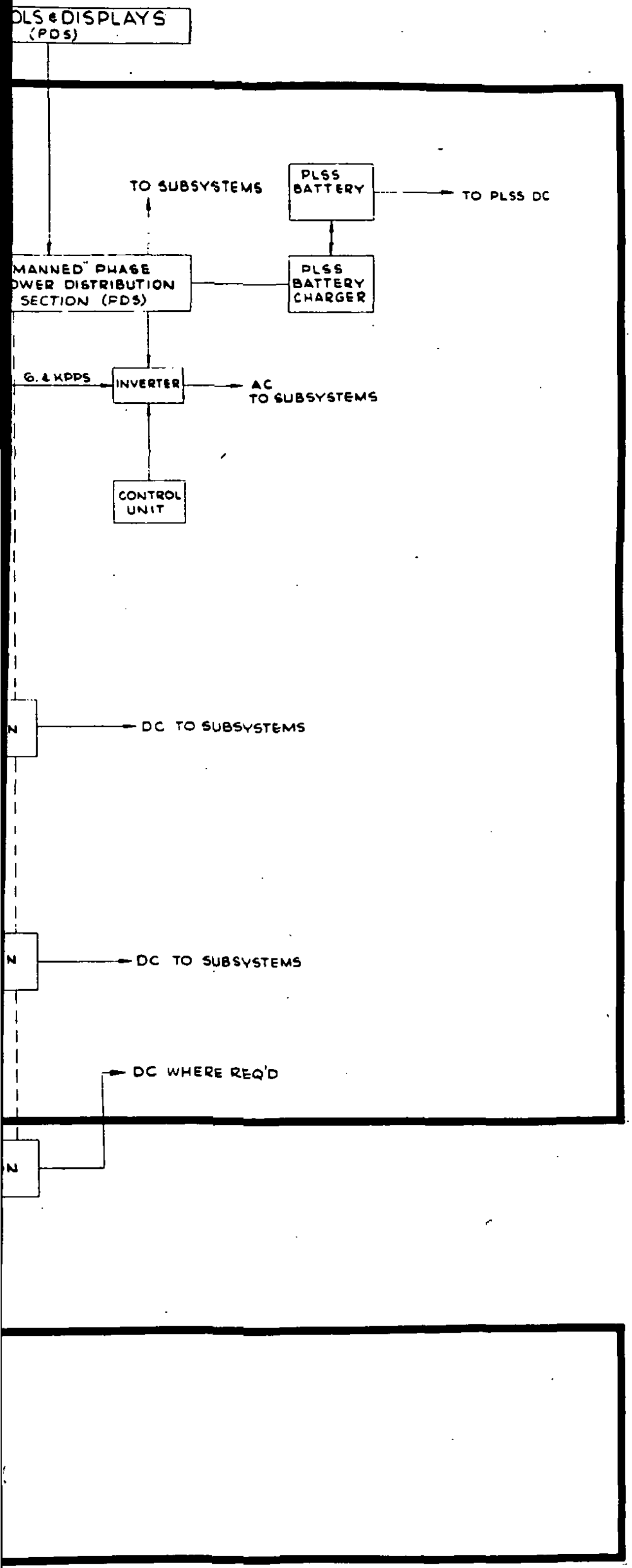

CONTROLS & DISPLAYS (PGS)
CONT
(TO ECS) H$_2$O
(FROM ECS) COOLANT
O$_2$ TANK
O$_2$ FEED SYSTEM
H$_2$ TANK
H$_2$ TANK
H$_2$ FEED SYSTEM
FUEL CELL
COOLANT (TO ECS)
H$_2$O (TO ECS)
COOLANT (FROM ECS)
FUEL CELL
COOLANT (TO ECS)
FUEL CELL ELECTRICAL CONTROL ASSYS (ECAS)
FROM PCMTEA (INSTR)
PLSS
NSERS
G
AT
SPORT
ORATOR
HEAT FROM EPS
HEAT
FROM MISSION PROGRAMMER
FUEL CELL START UP REMOTE CONTROL UNIT
HEAT TO ECS
RADIO ISOTOPE THERMAL ELECTRIC GENERATOR (RTG)
RTG ELECTRICAL CONTROL ASSY
POWER DISTRIBUTIO SECTION (PDS)
BATTERY #1 (DESCENT)
ELECTRICAL CONTROL ASSY (ECA #1)
BATTERY #2 (DESCENT)
ECA #2
BATTERY #3 (DESCENT)
ECA #3
DESCENT PHASE POWER DISTRIBUTIO SECTION (PDS)
TO INSTR
EPS SENSORS
OPER MEAS
ELECTRICAL POWER SUBSYSTEM
CSM POWER
CSM POWER DISTRIBUTIO SECTION
STRUCTURES
TO INSTR
SENSORS
OPER MEAS
TROL SUBSYSTEM

23.1 B
②



NOTES

1. GENERAL:
   THIS IS A TENTATIVE FUNCTIONAL DIAGRAM OF THE AES SHELTER.
2. ADDITIONS TO THE BASIC LEM CONFIGURATION:
   - A) 2 PORTABLE LIFE SUPPORT SYSTEMS (TOTAL 4).
   - B) 14 CONSTANT WEAR GARMENTS
   - C) A DOME LIGHT
   - D) WORK STATIONS
   - E) 2 BUNKS
   - F) TOTAL FOOD CAPACITY 78 POUNDS
   - G) THE WASTE MANAGEMENT SYSTEM WILL BE REPLACED WITH THE CSM SYSTEM
   - H) ADDITIONAL MEDICAL, RECREATIONAL, EXERCISE & MISCELLANEOUS EQUIPMENT.
3. REMOVALS FROM BASIC LEM CONFIGURATION:
   - A) RADIATION DOSIMETERS
   - B) LIQUID COOLED GARMENTS
   - C) BIO-INSTRUMENTATION
   - D) THERMAL GARMENT-EXT
   - E) SUIT REPAIR KIT
   - F) EMERGENCY OXYGEN SYSTEM
   - G) CREW & THE RESTRAINTS
4. 34 LIOH CARTRIDGES HAVE BEEN ADDED (TOTAL 38)
5. ATTITUDE CONTROLLER ASSEMBLY (ACA) WILL BE USED FOR PRIMARY PATH ALIGNMENT & RCS CHECKOUT
6. ADD AIRLOCK
7. THERE ARE TWO VSR'S (ONE SPARE)

ABBREVIATIONS

RCVR - RECEIVER
XMIT - TRANSMITTER
XCVR - TRANSMITTER/RECEIVER
SIM/DUP - SIMPLEX/DUPLEX
ATCA - ATTITUDE TRANSLATIONAL CONTROL ASSEMBLY
DECA - DECSENT ENGINE CONTROL ASSEMBLY
DC - DIRECT CURRENT
AC - ALTERNATING CURRENT
KPPS - KILO PULSE PER SECOND
DE - DESCENT ENGINE
FM - FREQUENCY MODULATION
PM - PHASE MODULATION
PCM - PULSE CODE MODULATION
AM - AMPLITUDE MODULATION
ANT - ANTENNA
NRZ - NON RETURN TO ZERO
INSTR - INSTRUMENTATION SUBSYSTEM
RGA - RATE GYRO ASSEMBLY
AOT - ALIGNMENT OPTICAL TELESCOPE
DSKY - DISPLAY KEYBOARD ASSEMBLY
DEDA - DATA ENTRY DISPLAY ASSEMBLY
OPER - OPERATIONAL
MEAS - MEASUREMENT
ACA - ATTITUDE CONTROL ASSEMBLY
PRESS - PRESSURIZATION
LORS - LEM OPTICAL RENDEZVOUS SYSTEM
VSR - VOICE STORAGE RECORDER
S/S - SUBSYSTEMS

SYMBOLS

o o o - OXYGEN
– – – - WATER
–•–•– - COOLANT
▨ - CONDITIONED OXYGEN
-o-o-o-o- - MECHANICAL LINKAGE
• • • HELIUM
H H H HYDROGEN
X X X OXIDIZER

Fig. 2.3-1 Shelter Level I Functional Block Diagram (Sheet 2 of 2)

C 3

3. MISSION ANALYSIS

3.1 GROUND RULES

The following NASA ground rules are unique to the mission analysis:

- Characteristics of the Shelter and Taxi missions shall be assembled and summarized in coordination with NASA/Marshall Space Flight Center
- NASA will define the experiments which shall be integrated with the Shelter/Taxi.

3.2 ASSUMPTIONS AND BACKGROUND DATA

The mission related assumptions used in the Shelter/Taxi mission analysis are as follows:

- Shelter is landed and stored on the lunar surface for a period of up to 3 months before the Taxi is launched
- Shelter capability to support the lunar mission will be verified by Earth command before the Taxi is committed to a lunar landing
- Taxi will land within 1000 ft of the Shelter
- All Extra Vehicular Activity (EVA) is supported by the Apollo Portable Life Support System (PLSS)
- Only one crewman will be permitted on the lunar surface at a time, except for emergency situations
- All EVA will be monitored by the crewman remaining in the spacecraft (Taxi or Shelter)
- All critical Taxi subsystems will be monitored by MSFN during the quiescent storage; caution and warning alarm will be transmitted to the crew in the Shelter by the Earth station
- Shelter shall be capable of supporting up to a 14-day manned mission on the Moon, during either lunar day or night.

3.3 RECOMMENDED CONFIGURATION MISSION REQUIREMENTS

3.3.1 Analysis of NASA/MSFC Missions

Five Shelter missions were provided by NASA/MSFC for use in developing the Shelter configuration. The names, locations, and characteristic payload are:

1.	Hyginus Crater	7°45'N,6°18'E	MFS/100-ft Drill
2.	Alphonsus Crater	13°13'S,1°12'W	LSSM/100-ft Drill
3.	Alphonsus Crater	13°13'S,1°20'W	2 LSSM
4.	Alphonsus Crater	13°13'S,1°20'W	LSSM/MFS
5.	Alphonsus Crater	13°13'S,1°20'W	LSSM/ESS

A comparison of the five missions to determine Shelter configuration sensitivity to experiment mission profiles, is given in Table 3.3-1. Except for utilization of the 100-ft drill, the Shelter configuration appears to be insensitive to the experiment payload or the site selected. (The primary effect of the site selected is on the stay time - return payload - anytime abort relationship of the Taxi.)

The number of ingress-egress cycles is less than the number of repressurizations because of some astronaut ingress-egress exchanges. At the end of each ingress-egress cycle, PLSS backpacks that were used will be recharged. The number of PLSS recharges is less than the number of repressurizations because the extra PLSS are left empty at the end of the mission. Missions 3 and 4 need an extra PLSS backpack because of crew rescue capability with two mobility aids.

Table 3.3-2 is a summary of the mission equipment for the Shelter defined by NASA. The table describes the weight, volume, size, power required, duty cycle, and the location of each experiment. The last column indicates which mission the equipment is used on.

Tables 3.3-3 through 3.3-7 contain power requirements of the scientific equipment utilized in, or in the vicinity of, the Shelter for the five missions. The power requirements of the LSSM and/or the MFS scientific equipment complements are not included in these tables, since it is assumed that the LSSM and MFS vehicles will supply their own power.

Tables 3.3-8 and 3.3-9 illustrate the ingress-egress time lines for the five missions. The ingress-egress exchange is a concurrent exchange of astronauts; an example of it is seen on Day 2 from 0430-0500.

Tables 3.3-10, 3.3-11, and 3.3-12 list the extravehicular activity (EVA) for the five missions. The EVA function and its duration are given for each day with the total EVA hr/day and total EVA hr/mission noted.

3.3.2 Shelter Timeline

The timeline for the Shelter mission to the crater Alphonsus with 1 LSSM, a 100-ft drill, and an ESS is shown in Table 3.3-13. The timeline has been divided into four phases:

- Phase A: Prelaunch to Lunar Touchdown
- Phase B: Lunar Storage
- Phase C: Taxi Prelaunch to Taxi Lunar Touchdown
- Phase D: Lunar Surface Activities.

The information presented is based upon the "Design Reference Mission, Apollo Mission Planning Task Force," 30 Oct 1964, and Bendix Report BSR-1153 "Scientific Mission Support Study Apollo Extension System," July 1965.

3.3.3 Mission Programmer

The Shelter operates in different modes, submodes, and subsystem configurations. Switching between modes is required during several phases of the mission. During unmanned phases, a mission programmer will be used to perform these switching functions. It is assumed that an astronaut will perform as much manual switching as is possible prior to Shelter/CSM separation.

There are two groups of switching functions to consider. First, there are the functions that occur at a specified time and in a fixed sequence. These functions may be preprogrammed in the LEM Guidance Computer (LGC). The second group consists of those functions for which it is mandatory or desirable to have an option on occurrence, timing or sequencing. These functions will be initiated from Earth A preliminary list of the switching functions that must be performed during the unmanned phases of the Shelter mission is presented in Table 3.3-14.

It is anticipated that the LEM Mission Programmer (LMP) can be used to perform the command functions for the Shelter. The main elements of the LMP are the LEM Guidance Computer (LGC), the Digital Command Assembly (DCA), and the Programmer Control Assembly (PCA). The LGC provides the means for storage of preprogrammed information. The DCA is the uplink receiver and decoder for Earth commands. The PCA provides the relay switching for the execution of commands.

The PCA, containing a 16 by 16 relay matrix, is capable of handling 127 on-off functions, and is used for commands from the LGC. Each set of two relays provide a complete on-off function with latching. A 16 by 6 matrix is provided to operate with the DCA. This allows 48 functions to be performed by Earth command.

The minimum number of relay pairs needed to perform the functions listed in Table 3.3-14 was estimated. The count of functions that are to be performed by preprogrammed commands is 43, and the count for Earth command is 33. Comparing these numbers with the number of switching operations available, it appears that the PCA has the functional capacity to handle the Shelter mission. It is possible that detail design requirements may dictate some redesign of the PCA. Such design factors as internal rewiring of the relay matrix and current carrying capacity of the relays must be considered.

3.4 BASELINE CONFIGURATION MISSION REQUIREMENTS

The mission requirements for the baseline configuration are the same as for the recommended configuration.

3.5 ENVIRONMENTAL PROTECTION REQUIREMENTS

3.5.1 Meteoroid Hazard Evaluation

The meteoroid environment used is that defined by LEM Specification LSP-470-1. The sporadic flux is presented as an average isotropic flux that is constant throughout the regions of space applicable to the AES missions. It is modified only by the planetary shielding factor determined by each mission trajectory. Shower meteoroids are not included.

The secondary meteoroid flux ejected from the lunar surface by the sporadic meteoroids is defined only for vehicles resting on the surface. Vehicles in descent or ascent or in low lunar orbits do not encounter secondary meteoroids.

3.5.1.1 Approach

LEM Specification LSP-470-1 presents criteria for defining the meteoroid protection provided by single and double skin areas against both primary (sporadic) and secondary meteoroids. It does not contain criteria for handling multi-skinned configurations and double skins with small separation distances. Such situations were conservatively analyzed by omitting the thinnest skins until the configuration fit the LEM specification. The analysis was performed for the recommended Shelter configuration with no meteoroid shielding assumed in addition to that provided by LEM.

Approximations were made to estimate the meteoroid protection provided by the Shelter structure that is composed of spherical and cylindrical shapes enclosed by flat surfaces. Since the penetration mechanics are very sensitive to the distance between the bumper skins, the critical areas exposed to meteoroids by spherical and cylindrical tanks were divided into two sections: the cap area which is an area of the tank closest to the bumper, and the doughnut area which is a section of the tank area adjoining the cap (Fig. 3.5-1). The distance from the bumper to the point of closest approach in each area was used to ensure conservative calculations. The critical areas were also sized by their cone of exposure to the isotropic flux. A very conservative 2π solid angle was applied in most cases. A nominal critical area was added to include the effect of such miscellaneous items as black boxes, wiring, and tubing. Though the ascent and descent stages were utilized for reciprocal shielding, the SM was not included in the calculations because of the long durations in the mission profile where the Shelter and CSM are separated.

3.5.1.2 Computer Program

The Shelter basic design was described in terms of critical areas, exposure periods, skin thicknesses, and skin separation distances, and the information fed into a computer program which contained the LEM protection criteria. When a particular combination of skin thickness and separation distance for a specified critical area resulted in a bumper skin too thin to melt the meteoroid, the size of the meteoroid was reduced to the melting point, and the probability of such a particle impacting during the mission was determined.

The program evaluated the existing LEM structure for the probability that it will not be damaged by meteoroids during its mission, and determined those locations where shielding would be most profitably applied.

3.5.1.3 Micrometeoroid Hazard Results

The Shelter mission profile of 3-day transit, 90-day storage, and 14-day manned operations resulted in the following probabilities of no penetrations:

	Primaries	Secondaries	Total
Crew Safety	0.99940	0.99824	0.99765
Mission Success	0.99507	0.96758	0.96266

Crew safety was defined as the probability that no fatality would occur among the crew, and mission success was defined as the probability that the mission will not be aborted by a micrometeoroid penetration. Events that are specified as causes of a crew fatality are:

- Puncture of a manned, pressurized cabin
- Penetration of more than 25% of a high-pressure tank wall thickness

It was assumed that the descent stage propellant tanks would be vented after the landing is accomplished, and therefore they would not constitute an explosion hazard. The cabin was considered to be a crew safety item during the 14 days it is manned.

Events that are specified as cause for aborting the mission are:

- Puncture of the cabin while manned, whether pressurized or not
- Penetration of more than 25% of a pressure tank wall thickness.

The cabin was given full term for the mission success calculations because any puncture of the cabin, prior to preparation for the Taxi's Earth launch, would be discovered when the cabin is pressurized and cause the mission to be aborted.

The major contributor to the total unreliability estimate is the secondaries. Sixty percent of their contribution is caused by the descent stage water tank and the bottom panel of the cabin. The hatches are the next major contributors.

Further gains can be made in reliability by multi-sectioning the effective tank areas for more accurate assignment of bumper distances from the backup material. The bumper distances for the major contributing areas of the cabin are relatively constant so that no gains are possible from sectioning. Planetary shielding was, however, estimated in a conservative manner for the cabin and a more detailed analysis should provide some reliability improvement for the cabin. Further improvement would require actual shielding of the tank areas.

The final limitation is the cabin, and if its reliability is to be further increased, the weight penalties will be large because the entire wall and skin thicknesses will have to be increased.

The radiators were not included in this evaluation because their configuration is still too uncertain at this stage. If they are shaded, the vehicle's reliability will improve. Just how much will be difficult to calculate because the meteoroid specification does not handle that type of multi-skin arrangement. If the radiators can be located where they will protect the water tanks, and/or the hatches, considerable reliability gains would be achieved.

3.5.2 Radiation Hazard Evaluation

The major radiation hazard for lunar missions comes from the high-intensity solar flare events that are encountered around solar maximum. The statistical model and spectrum used for AES analyses is the Apollo environmental model documented in LSP 470-1A.

The two potential radiation problems that have to be considered are:

- Biological dose to the crew in excess of the allowable emergency skin dose of 500 rad.
- Degradation in equipment performance because of prolonged exposure to space radiation

In evaluating the statistical probability of a Shelter crewman receiving an excessive biological dose, two approaches were used. In one case, it was assumed that the mission would not be aborted because of the onset of a solar flare event. The "no-abort" probability calculated in this instance represented the likelihood of actually encountering a total integrated solar proton flux, during the manned portion of the Shelter/Taxi mission, that would result in a biological dose greater than 500 rad.

For the second case, it was assumed that the mission would be aborted, if it became apparent that a high-intensity solar event were occurring. Since it would be extremely difficult to predict in advance the precise total integrated flux for an event, it was assumed that the mission would be aborted whenever a total dose in excess of 200 rad were actually accumulated. This yielded a probability of mission success for the "abort" situation. This second case represents a more reasonable operational ground rule. The Shelter configuration was assumed to have a shielding effectiveness equivalent to a 1-lb/sq ft spherical shield. By adding shielding around the cabin, the probability of not exceeding the allowable dose would be increased. The tradeoff data for both the "abort" and the "no-abort" cases is presented in Fig. 3.5-2. It was estimated that about 600 lb of shield weight penalty would be required to make the Shelter equivalent in shielding effectiveness to the CM. At that point, both the "abort" and "no-abort" cases would coincide, since an astronaut would receive essentially the same biological dose whether or not he aborted the mission. This is indicated by the dotted line in Fig. 3.5-2. The equivalent probabilities for the 8.3-day Apollo Design Reference Mission are also shown for comparison purposes.

The degradation in equipment performance from radiation damage is believed to be a potentially serious problem for the proposed Shelter 90-day storage period on the lunar surface. It should be emphasized that this degradation effect is a potential problem only prior to manned Shelter operations. Once the astronaut enters the Shelter, he becomes the most sensitive "component" to radiation damage. There is, of course, a wide variation in the relative susceptibility of components to radiation damage. Low-frequency silicon transistors tend to be among the most radiation sensitive devices.

3.6 FUNCTIONAL FLOW DIAGRAMS

Functional flow diagrams for the Shelter mission are given in Fig. 3.6-1 through 3.6-15. These diagrams define the operations and functions to be mechanized to achieve the mission objectives. They also serve as a ready reference, identifying all the operations and functions. These diagrams considered the operations and functions associated with a success oriented flight mission; future work will consider contingencies.

The functional flow diagrams for the Shelter mission have been structured in four levels. The top level has been structured on an overall program basis and calls out the hardware, facilities, ground support, and manufacturing requirements to fulfill the program activities. The numbering system essentially corresponds to the LEM Design Reference Mission phase numbering system. The Shelter portion of the entire AES Program has been numbered from 4.0 through 18.0 in the top level functional diagram.

The first level diagram describes the Shelter mission phases starting with Earth launch and ending with the completion of Shelter lunar surface operations. These phases are represented in the first level diagram by the operational functions 4.0 through 4.11. It is to be noted that operational functions 4.0 through 4.11 cover the total lunar landing mission. Since the Shelter is active only during operational functions 4.7, 4.9, 4.10, and 4.11, only these functions are expanded into second and third level diagrams.

For each box identified in the first level diagrams, second level diagrams are provided for the necessary operations and functions. For most of the operations and functions listed on the second level diagrams, third level diagrams are provided which generally detail the operations and functions required of the Shelter major subsystems to accomplish the mission objectives. Specific hardware is not called out, but rather vehicle functional requirements such as "Provide Shelter - CSM Telecommunication Functions," "Provide Required Thrust Duration and Levels," etc.

Functions and operations identified on the diagrams at each level are numbered in a manner which preserves the continuity of functions and provides information with respect to function origin throughout the system. Functions which further subdivide these top functions contain the same parent identifier and are coded at the next decimal level for each indenture. For example, the first subdivision function of function 4.0 is 4.1, the second 4.1.1, the third 4.1.1.1, etc. Each diagram contains a reference block. For example, function 4.7 is shown as a reference block in the case where the functions 4.7.1, 4.7.2, and 4.7.n, are used to expand function 4.7. Reference blocks are also used to indicate interfacing functions as appropriate.

Each separate function is presented in a single box enclosed by a solid line. Blocks used for reference to other flows are indicated as dotted boxes labeled "Ref." The level of detail of each function corresponds to the level of functional diagram on which it appears. Lines connecting functions indicate the order in which the functions must be performed. In indicating the flow with vertical and horizontal lines between blocks, all functions so interrelated are performed in either a parallel or series sequence as indicated.

The Functional Diagrams are laid out so that the functions are performed left to right. Primary input lines enter the function block from the left side; the primary output, or "go" line, exits from the right. In some cases of special interest, a "no go" line from the bottom of the box is shown.

A circle is used to depict a logic gate. The logic gate is used to indicate the convergence of parallel or alternate functional paths and is annotated with the terms "AND" or "OR," respectively. The term "AND" is used to indicate that all parallel functions leading into the gate must be accomplished before proceeding into the next function. The term "OR" is used to indicate that any one of several alternate paths may initiate a succeeding function.

Table 3.3-1
SHELTER MISSIONS SUMMARY

Mission No. Item	1	2	3	4	5
Site	Hyginus Crater	Alphonsus	Alphonsus	Alphonsus	Alphonsus
Position (LAT-LONG)	7°45'N/6°18'E	13°13'S/1°20'W	13°13'S/1°20'W	13°13'S/1°20'W	13°13'S/1°20'W
Primary Payload Characteristics	MFS/ 100-ft Drill	LSSM/ 100-ft Drill	2 LSSMs	LSSM/MFS	LSSM/4 ESSs
Shelter Electrical Energy (Less Drill), watt-hr	27	178	338	187	262
Drill Energy, kw-hr	73.5	73.5	--	--	--
Ingress/Egress Cycles	26	28	28	28	28
Repressurizations Required (No Airlock)	44	42	42	42	42
Oxygen Required For Repressurizations (No Airlock), lb	304	290	290	290	290
Oxygen Required For Repressurizations, lb	66	63	63	63	63
PLSS Recharges (Water, O_2 & Batteries)	36	38	38	38	38
PLSS Backpacks Required	5	5	6	6	5
Total Payload/ Exper Weight, lb	2693	2765	3003	3037	2950
Total EVA Time, hr	110	115	115	115	118

Table 3.3-2
EXPERIMENT EQUIPMENT LIST

Mission Equipment (Used on Mission Nos:)	Weight, lb	Volume, cu cm	Dimensions, cm	Power Reqd, watts	Location	Duty Cycle, %
I Topographical Survey Equipment (1, 2, 3, 4, 5)						
Theodolite and Ranging Laser	50	40,050	30 x 13 x 45 30 x 30 x 25	40	LSSM	5
Theodolite and Ranging Laser	50	40,050	30 x 13 x 45 30 x 30 x 25	40	Ascent Stage of Shelter	5
Surveying Markers	20	92,800	12.5 x 10 x 180 30 x 38.5 x 60	-	LSSM	-
Sketchboard and Maps	5	10,125	45 x 45 x 5		LSSM	
Subtotal	125			80		
II Surface Geology Equipment (1, 2, 3, 4, 5)						
1. Geological Survey Equipment		40,000			LSSM	
Sample Containers	10					
Surveying Staff	29	21,000	10 x 15 x 140	25	LSSM	
Spare Battery for Surveying Staff	13					
Hand Tools - rock pick with chip catches, flashlight, hardness indicator, etc.	17					
Subtotal	69			25		
2. Multiband Photography and Radiometry		15,100	78 x 38 x 51		LSSM	5 Stopped 100 during travel
70mm Framing Cameras	22			300		
Radiometer	15.4			20		
Spectroradiometer	22			50		
Interferometer Spectrometer	8.8			10		
TV	11.0			15		
Platform and Mounting for Boresighted Pkg.	6.6					
Subtotal	85.8			395		
3. Erosion Samples	10	13,500	30 x 30 x 15		Stored in D.S. Used in vicinity of Shelter	

Table 3.3-2 (cont.)

Mission Equipment (Used on Mission Nos:)	Weight, lb	Volume, cu cm	Dimensions, cm	Power Reqd, watts	Location	Duty Cycle, %
III Subsurface Geology						
10 foot Drill Assembly and Accessories (2, 3, 4,5)	30			350	Stored in D.S. Used in LSSM	100
100 foot Drill Assembly and Accessories (1,2)	200			3,500	Stored in D.S. Used in Vicinity of Shelter	100
IV LEM/Shelter Laboratory Geology (1, 2, 3, 4,5)						
Hammer, mortar, pestle for powdering rock pieces	1			-		
Glass Microscope slides and cover slips	1					
Set of immersion index liquids, range n=1.45-1.80	3			-		
Petrographic microscope and accessories	10			5		
Optical determinative tables for minerals	2			-	-	
Subtotal	17	9000	30 x 15 x 20	5	Ascent Stage of Shelter	5
V Surface Geophysics						
1. Gravity Survey (1, 2, 3, 4,5) La Coste Romberg Gravimeter (modified)	13	3630	11 x 22 x 15	4	LSSM	3 (Stopped)
2. Magnetic Survey (1, 2, 3, 4,5) Metastable Helium Magnetometer	8.8	3760	15 cm Dia. Sphere & 10 x 10 x 20	5	LSSM	3 (When Stopped)
3. Seismic Refraction and Reflection (2, 3, 4,5)					Used in LSSM stored on Descent Stage	
Basic equipment i.e., geophones, cables, etc.	55.9	302,400	60 x 60 x 84	12		5
Deep refraction instrumentation i.e., explosives etc.	142.1			-		
Shallow refraction instrumentation	15.4			-		
Reflection instrumentation	26.4			-		
Subtotal	239.8			12		

Table 3.3-2 (cont.)

Mission Equipment (Used on Mission Nos:)	Weight, lb	Volume, cu cm	Dimensions, cm	Power Reqd, watts	Location	Duty Cycle, %
4. Telluric Current Measurements (2, 3,5)						
Electrodes (3)				-		
Cable and reel				-		
Electronics (Same as for Seismic)				-		
Subtotal	31	27,235	1 Dia. x 100 30 x 30 x 30	3	Stored in D.S. Used in Vicinity	100
5. In Situ Measurements (1, 2, 3, 4,5)						
Penetrometer	6	7,560	28 x 15 x 18	7	Stored in D.S. Used in LSSM	3
γ-γ logging device from nuclear exp. pkg.	-					
Surface electrical pkg (Resistivity & Detective Const)	3.3	810	5 x Dia. x 25 8 x 8 x 5	28	Stored in D.S. Used in LSSM	
Radiometry pkg.	8.8	-		40		3
Subtotal	18.1			75		
VI Subsurface Geophysics (1, 2, 3, 4,5)						
1. Nuclear Core Hole Logging						
2. Sonic Velocity	10.8	2,754	5 dia x 91 long 10 dia x 6.6 long 18 x 6 x 6.6	3	Stored in Descent Stage Used in vicinity of Shelter and LSSM	5
3. Electrical Induction Logging	5	5,196	2.3 Dia x 20 long 20 x 20 x 12.5	2	Stored in Descent Stage Used in vicinity of Shelter and LSSM	2
VII Geochemistry (1, 2, 3, 4,5)						
1. Nuclear Measurements Gamma Source Pulsed Neutron Source Gamma Ray Detector Neutron Detector Count Rate Meter 128 Channel Analyzer Data Processor Source Detector Shield	34.4	11,670	5 dia x 85 long & 25 x 20 x 20	52	LSSM	3
2. Gas Analysis Quadrupole mass spectrometer	10	9,120	12 x 10 x 76	28	Used in LSSM Stored in Descent Stage used in vicinity of Shelter	3

Table 3.3-2 (cont.)

Mission Equipment (Used on Mission Nos:)	Weight, lb	Volume, cu cm	Dimensions, cm	Power Reqd, watts	Location	Duty Cycle, %
VIII Emplaced Scientific Station ESS (1, 2,5)						
1. Lunar Atmosphere Measurements						
Ionization Gauze	2.2			6		
Mass Spectrometer	10			23		
Lyman - α Spectrometer	6.6			0.5		
Solar Plasma Spectrometer	10			1		
Magnetometer	4.3			4.1		
Ion Traps	4.3			5		
Electric Field Meters	8.8			0.4		
Subtotal	46.2			40		
2. Lunar Tides, Libration, Body Motions and Seismic Activity Measurements						
Tidal Gravimeter	7			5		
Star Tracker	20			16		
Quake Seismometer	10			2		
Subtotal	37			23		
3. Meteoroid Measurements						
Meteoroid Spectrometer	8.8			0.4		
4. Radiation Measurements						
Neutron Detectors	5.5			2		
Charged Particle Spectrometers	3.0			2.5		
Ion Chamber	0.2			0.01		
Gamma Detectors	1.8			0.4		
Subtotal	10.5			4.91		
5. Subsurface Measurements						
Subsurface Probe	42			15		
Total	300	629,139	91.5 dia x 76 51 dia x 63.5	own power source	Stored in D.S Use varies with mission	
IX Astronomical Measurements (2, 3, 4,5) Phase I						
1. X-Ray Astronomy						
X-Ray telescopes	8			2		
XUV telescopes (2)	2			1		
Subtotal	10			3		

Table 3.3-2 (cont.)

	Mission Equipment (Used on Mission Nos:)	Weight, lb	Volume, cu cm	Dimensions, cm	Power Reqd, Watts	Location	Duty Cycle, %
	2. Optical Astronomy						
	6" Schmidt cassegrain Telescope	8					
	Modules - Total	9					
	70MM SLR film back	3					
	PE photometer	.5			2		
	filter corrector sets (3)	3					
	Objective Prism (11°)	2					
	Calibration Source	.5			2		
	Film supply (100 ft.)	1					
	Subtotal	27			4		
	3. Radio Astronomy						
	3 Single beam antennas	5					
	3 receivers	6.6			6		
	Subtotal	11.6			6	Stored in Descent Stage.	
	Total	43.6			13	Used in vicinity of Shelter	20
X	Support Instrumentation (1, 2, 3, 4,5)						
	1. Astronaut Hazards	6.2			1.8		
	Ejecta Detector acoustic type	1.1	16	4 x 4 x 1	.005	Stored in D.S. Used in vicinity of Shelter and LSSM	100
	Tissue equivalent ion chamber	5.1	500	5 x 5 x 20	1.8	Stored in D.S. Used in vicinity of Shelter and LSSM	100
	Gamma Ray Detector (included in Nuclear Pkg.)	-			-		
	2. Environment Exposure Panel	2.2	1,837	35 x 35 x 1.5	1	Stored in D.S. Used in vicinity of Shelter	100
	3. Data Handling and Interface Equipment	55	40,000	-	80	Stored in D.S. and LSSM Used in LSSM and vicinity of Shelter	100 during traverse
XI	3 Satellite ESS (5)						
	1. Passive Seismometer	20					
	2. Magneto-Telluric Particle Field	20					
	3. Heat Flow	5					
	4. Lunar Atmosphere	25					
	5. Power & Telemetry Supports	75					
XII	LSSM (Local Scientific Survey Module)	1000					
XIII	MFS (Manned Flying Station)	1120					

Table 3.3-3
POWER REQUIREMENTS - MISSION 1

Day	Time	Experiment Performed	Hr	Power, watts	Duty Cycle, %	watt-hr	Total watt-hr/day
1		None					
2	0500-0800	Shelter Lab Experiments	2	5	5	0.50	
	2000-2400	Shelter Lab Experiments	4	5	5	1.00	
							2.0
3	0200-0300	Shelter Lab Experiments	1	5	5	0.25	
							0
4	0130-0730	Shelter Lab Experiments	2	5	5	0.50	
	2130-2400	Shelter Lab Experiments	2.5	5	5	0.625	
	2130-2400	Shelter Lab Experiments	1.5	5	5	0.375	2.0
5	0130-0730	Activate & Monitor 100-ft Drill	6	3,500	100	21,000.00	
	0130-0730	Shelter Lab Experiments	4	5	5	1.00	
	0830-0930	Shelter Lab Experiments	1	5	5	0.25	
	2000-2300	Shelter Lab Experiments	3	5	5	0.75	
							21,002.0
6	0130-0730	Shelter Lab Experiments	4	5	5	1.0	
	0130-0730	Radio Astronomy	1	6	20	1.8	
	2000-2300	Radio Astronomy	3	6	20	3.6	
	0130-0730	Monitor Drill	6	3,500	100	21,000.0	
	2000-2300	Shelter Lab Experiments	1	5	5	0.25	
							21,006.0
7	0130-0430	Shelter Lab Experiments	2	5	5	0.50	
	1630-2230	Shelter Lab Experiments	5	5	5	1.25	
	1630-2230	Monitor 100-ft Drill	6	3,500	100	21,000.00	
	0130-0430	Radio Astronomy	3	6	20	3.60	
							21,005.0
8	0730-1330	Shelter Lab Experiments	1	5	5	0.25	
	1400-1700	Complete 100-ft Hole	3	3,500	100	10,500.00	
	0730-1330	Radio Astronomy	3	6	20	3.60	10,503.0
9	2130-2400	Shelter Lab Experiments	1.5	5	5	0.375	
	0130-1730	Shelter Lab Experiments	2	5	5	0.50	
	2130-2400	Shelter Lab Experiments	2.5	5	5	0.625	
							2.0

Table 3.3-3 (cont.)

Day	Time	Experiment Performed	Hr	Power, watts	Duty Cycle,%	watt-hr	Total watt-hr/day
10	0130-0730	Shelter Lab Experiments	3.5	5	5	0.875	
	1330-1630	Shelter Lab Experiments	1.5	5	5	0.375	
	0130-0730	Radio Astronomy	1	6	20	1.8	
	0130-0730	Log 100-ft Hole	5	2	2	0.20	
	1700-1800	Shelter Lab Experiments	1	5	5	0.25	4.0
11	0130-0430	Complete Logging 100-ft Hole	2	5	5	0.50	1.0
12	0500-1100	Shelter Lab Experiments	2	5	5	0.50	1.0
13 & 14		None					0

Table 3.3-4
POWER REQUIREMENTS - MISSION 2

Day	Time	Experiment Performed	Hr	Power, watts	Duty Cycle,%	watt-hr	Total watt-hr/day
1		None					0
2	1130-1430	Position Fix on ESS Site	3	40	5	6	6
3	0130-0730	Shelter Lab Experiments & Fixes	6	45	5	13.5	
	0800-1100	Shelter Lab Experiments	3	5	5	.75	
	0800-1100	Activate & Monitor 100-ft Drill	3	3,500	100	10,500	
							10,514.
4	0800-1100	Monitor 100-ft Drill	3	3,500	100	10,500	
	0130-0730	Shelter Lab Experiments & Fixes	6	45	5	13.5	
	0800-1100	Shelter Lab Exp.	3	5	5	.75	
							10,514.
5	0800-1100	Telluric Current Survey	3	3	100	9	
	0800-1100	X-Ray Astronomy	3	3	20	1.8	
	0800-1100	Monitor 100-ft Drill	3	3,500	100	10,500	
	0130-0730	Shelter Lab Exp. & Fixes	6	45	5	13.5	
	0800-1100	Shelter Lab Exp.	3	5	5	.75	
							10,525.
6	0800-1100	Monitor Drill	3	3,500	100	10,500	
	0130-0730	Lab Exp. & Fixes	6	45	5	13.5	
	0800-1100	Lab Exp.	3	5	5	.75	
							10,514.
7		Same as Day 6					10,514.
8	0800-1100	Optical Astronomy	3	4	20	2.4	
	0800-1100	Monitor Drill	3	3,500	100	10,500	
	0130-0730	Lab Exp. & Fixes	6	45	5	13.5	
	0800-1100	Lab Exp.	3	5	5	.75	
							10,516.
9		Same as Day 6					10,514.
10	0800-1100	Radio Astronomy	3	6	20	3.6	
	0130-0730	Lab Exp. & Fixes	6	45	5	13.5	
	0800-1100	Lab Exp.	3	5	5	.75	17.

Table 3.3-4 (cont.)

Day	Time	Experiment Performed	Hr	Power, watts	Duty Cycle,%	watt-hr	Total watt-hr/day
11	0800-1100	Sonic Velocity Measurements	3	3	5	.45	
	0130-0730	Lab Exp. & Fixes	6	45	5	13.5	
	0800-1100	Lab Exp.	3	5	5	.75	
							14.
12	0800-1100	Log 100-ft Hole (Nuclear & Elec)	3	2	2	.12	
	0800-1100	X-Ray Astronomy	3	3	20	1.8	
	0800-1100	Optical Astronomy	3	4	20	2.4	
	0130-0730	Lab Exp. & Fixes	6	45	5	13.5	
	0800-1100	Lab Exp.	3	5	5	.75	
							18.
13	0800-1100	Optical Astronomy	3	4	20	2.4	
	0800-1100	Radio Astronomy	3	6	20	3.6	
	0800-1100	Complete Logging 100-ft Hole	3	5	5	.75	
	0130-0730	Lab Exp.	3	5	5	.75	
	0800-1100	Lab Exp.	3	5	5	.75	
							8.
14		None					0

Table 3.3-5
POWER REQUIREMENTS - MISSION 3

Day	Time	Experiment Performed	Hr	Power, watts	Duty Cycle,%	watt-hr	Total watt-hr/day
1		None					
2	0500-0800	Monitor Sortie No. 1	3	40	5	6	
	0830-1100	Monitor Unmanned Vehicle	3	40	5	6	
	1130-1430	Monitor	3	40	5	6	18
3	0130-0730	Monitor Sortie No. 2	6	40	5	12	
	0130-0730	Lab Exp.	6	5	5	1.5	
	0800-1100	Monitor	3	40	5	6	
	0800-1100	Lab Exp.	3	5	5	.75	
	1130-1400	Monitor Unmanned Vehicle	2.5	40	5	5	25.
4	0130-0730	Monitor	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Monitor	3	40	5	6	
	0800-1100	Lab	3	5	5	.75	
	0800-1100	Set Up Astronomy Exp.	3	13	20	7.8	
	1130-1400	Monitor	2.5	40	5	5	33.
5	0130-0730	Monitor	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Monitor	3	40	5	6	
	0800-1100	Lab	3	5	5	.75	
	0800-1100	Telluric Current	3	3	100	9	
	1130-1400	Monitor	2.5	40	5	5	34.
6	0130-0730	Monitor Traverse (Sortie)	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Monitor	3	40	5	6	
	0800-1100	Lab	3	5	5	.75	
	0800-1100	X-Ray, Optical	3	3.5	20	2.1	
	1130-1400	Monitor	2.5	40	5	5	27.
7	0130-0730	Monitor Traverse (Sortie)	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Monitor	3	5	5	6	
	0800-1100	Lab	3	5	5	.75	
	0800-1100	Optical Astronomy	3	4	20	2.4	
	1130-1400	Monitor	2.5	40	5	5	27.

Table 3.3-5 (cont.)

Day	Time	Experiment Performed	Hr	Power, watts	Duty Cycle,%	watt-hr	Total watt-hr/day
8		Same as Day 3					
9		Same as Day 3					
10		Same as Day 3					
11	0130-0730	Monitor	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Monitor	3	40	5	6	
	0800-1100	Lab	3	5	5	.75	
	0800-1100	Radio Astronomy	3	6	20	3.6	
	1130-1400	Monitor	2.5	40	5	5	
							28.
12		Same as Day 5					
13		Same as Day 4					
14		None					

Table 3.3-6
POWER REQUIREMENTS - MISSION 4

Day	Time	Experiment Performed	Hr	Power, watts	Duty Cycle,%	watt-hr	Total watt-hr/day
1		None					
2	0600-0800	Shelter Lab Exp.	2	5	5	.5	
	1130-1430	Monitor Sortie (LEEM) No. 1	3	40	5	6	
							7.
3	0130-0730	Monitor Sortie (LSSM)	6	40	5	12	
	0130-0730	Shelter Lab	6	5	5	1.5	
	0800-1100	Shelter Lab	3	5	5	.75	
							14.
4	0130-0730	Monitor Sortie	6	40	5	12	
	0130-0730	Shelter Lab	6	5	5	1.5	
	0800-1100	Shelter Lab	3	5	5	.75	
	0800-1100	Set up Astronomy	3	13	20	7.8	
							22.
5	0130-0730	Monitor	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Lab	3	5	5	.75	
							14.
6	0130-0730	Monitor	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Lab	3	5	5	.75	
	0800-1100	X-Ray & Optical	3	3.5	20	2.1	
							16.
7	0130-0730	Monitor	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Lab	3	5	5	.75	
	0800-1100	Optical Astronomy	3	4	20	2.4	
							17.
8, 9, 10		Same as Day 3					
11	0130-0730	Monitor	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Lab	3	5	5	.75	
	0800-1100	Radio Astronomy	3	6	20	3.6	
							18

Table 3.3-6 (cont.)

Day	Time	Experiment Performed	Hr	Power, watts	Duty Cycle,%	watt-hr	Total watt-hr/day
12		Same as Day 3					
13	0130-0730	Monitor	6	40	5	12	
	0130-0730	Lab	6	5	5	1.5	
	0800-1100	Lab	3	5	5	.75	
	0800-1100	X-Ray, Optical, Radio Astronomy	3	13	20	7.8	
							22.
14		None					

Table 3.3-7
POWER REQUIREMENTS - MISSION 5

Day	Time	Experiment Performed	Hours	Power Watts	Duty Cycle	Watt Hours	Total W-hrs per day
		None					
	0500-0800	Monitor Sortie	3	40	5	6	
	130-1430	Monitor Sortie	3	40	5	6	12
	0130-0730	Shelter Lab Exp	6	5	5	1.5	
	0130-0730	Monitor Sortie	6	40	5	12	
	130-1400	Monitor Sortie	2.5	40	5	5	19
		Same as day 3					19
		Same as day 3					19
	0130-0730	Shelter Lab Exp	6	5	5	1.5	
	0130-0730	Monitor Sortie	6	40	5	12	
	130-1400	Monitor Sortie	2.5	40	5	.5	
	0800-1100	Set up Astronomy Exp	.3	13	20	7.8	
	0800-1100	Telluric current survey	3	3	100	9	35
		Same as 3 except add					
	0800-1100	X-ray astronomy	3	3	20	1.8	
	0800-1100	Optical astronomy	3	4	20	2.4	23
		Same as 3 except add					
	0800-1100	Telluric current survey	3	3	100	9	28
		Same as 3 except add					
	0900-1100	Radio astronomy	3	6	20	3.6	23
10		Same as 3 except add					
	0800-1100	X-ray astronomy	3	3	20	1.8	
	0800-1100	Optical astronomy	3	4	20	2.4	23
11		Same as day 3					
12		Same as day 3 except add					
	0800-1100	Radio astronomy	3	6	20	3.6	23
13		Same as day 3					19
14		None					0
							262

Table 3.3-8
INGRESS/EGRESS PROFILE - MISSION 1

Day	Time	SE	Cmdr
1	0615-0645		I
	0830-0900	I	
2	0100-0130	E	
	0430-0500	I	E
	0800-0830		I
3	0100-0130		E
	0430-0500		I
	1130-1200	E	
	1800-1830	I	
4	0100-0130		E
	0730-0800	E	I
	1100-1130	I	
5	0100-0130	E	
	0730-0800	I	
	1930-2000		E
	2300-2330		I
6	0100-0130		E
	0730-0800		I
	1930-2000	E	
	2300-2330	I	
7	0100-0130		E
	0430-0500		I
	1600-1630	E	
	2230-2300	I	
8	0700-0730		E
	1330-1400	E	I
	1700-1730	I	
9	0100-0130	E	
	0730-0800	I	E
	1100-1130		I
10	0100-0130		E
	0730-0800		I
	1300-1330	E	
	1630-1700	I	
11	0100-0130		E
	0430-0500	E	I
	1100-1130	I	
12	0100-0130		E
	0430-0500	E	I
	1100-1130	I	
13	0100-0130		E
	0430-0500	E	I
	0800-0830	I	
14	1630-1700		E
	1900-1930	E	

Abbreviations:

E: Egress
I: Ingress
SE: Systems Engineer
Cmdr: Commander

Table 3.3-9
INGRESS/EGRESS PROFILE - MISSIONS 2, 3, 4 & 5

Day	Time	SE	Cmdr
1	0213-0343	I	
	0621-0631	I	I
2	0100-0130	E	
	0430-0500	I	E
	0800-0830		I
	1100-1130	E	
	1430-1500	I	
3	0100-0130	E	
	0730-0800	I	E
	1100-1130		I
4 - 12	Same as Day 3		
13	0100-0130	E	
	0430-0500	I	E
	0800-0830		I
14	1700-1730		E
	1930-2000	E	I
	2058-2108		E

Table 3.3-10
TOTAL EVA TIME - MISSION 1

Day	Time	hr	Activity	Total EVA, hr
1	0140-0410	2.5	Surface Inspection	5
	0445-0615	1.5	Walk to Shelter	
	0730-0830	1	Walk to Shelter	
2	0130-0430	3	Unload MFS and Equipment	6
	0500-0800	3	Local Exploration	
3	0130-0430	3	Walk to Rim of Hyginus Crater	9
	1200-1800	6	Establish ESS & Local Exploration	
4	0130-0730	6	Conduct Sortie No. 1	9
	0800-1100	3	Local Exploration	
5	0130-0730	6	Activate 100-ft drill	9
	2000-2300	3	Walk to Hyginus Rille	
6	0130-0730	6	Monitor 100-ft drill	9
	2000-2300	3	Radio Astronomy Exp. on Surface	
7	0130-0430	3	Radio Astronomy Exp. on Surface	9
	1630-2230	6	Monitor 100-ft drill	
8	0730-1330	6	Experiments & Exploration	9
	1400-1700	3	Complete 100-ft hole	
9	0130-0730	6	Conduct Sortie No. 2	9
	0800-1100	3	Local Exploration	
10	0130-0730	6	Exp. & Log 100-ft hole	9
	1330-1630	3	Local Exploration	
11	0130-0430	3	Logging & Local Exploration	9
	0500-1100	6	Local Exploration	
12	0130-0430	3	Walk to LEM with samples &	9
	0500-1100	6	return Local Exploration	
13	0130-0430	3	Local Exploration Walk to	6
	0500-0800	3	LEM with samples & return	
14	1700-1815	1.25	Walk to LEM	110 hr 2.25
	1930-2030	1	Walk to LEM	
			Total	110

Table 3.3-11
TOTAL EVA TIME - MISSIONS 2, 3 & 4

Day	Time	hr	Activity	Total EVA, hr
1	0140-0410 0445-0615 0730-0830	2.5 1.5 1	Taxi Inspection Walk to Shelter Walk to shelter	5
2	0130-0430 0500-0800 1130-1430	3 3 3	Unload LSSM & Equipt. Conduct Sortie No. 1 Conduct Sortie No. 2	9
3	0130-0730 0800-1100	6 3	Conduct Sortie No. 3 Exp. in vicinity of shelter	9
4-12			Same as Day 3	9 (each)
13	0130-0430 0500-0800	3 3	Local Surface Activities Local Surface Activities	6
14	1330-1630 1700-1845 2045-2100	3 1.75 .25	Equipment Stowage Load LSSM & return to Taxi Return to Taxi by LSSM	5
			Total	115 hr.

Table 3.3-12
TOTAL EVA TIME - MISSION 5

Day	Time	hr	Activity	Total EVA, hr
1	0140-0410 0445-0615 0730-0830	2.5 1.5 1	Taxi Inspection Walk to Shelter Walt to Shelter	5
2	0130-0430 0500-0800 1130-1430	3 3 3	Unload LSSM & Equip. Conduct Sortie No. 1 Conduct Sortie No. 2	9
3	0130-0730 0800-1100	6 3	Conduct Sortie No. 3 Exp. in vicinity of shelter	9
4-13			Same as Day 3	9 (each)
14	1330-1630 1700-1845 2045-2100	3 1.75 .25	Equipment Stowage Load LSSM & return to Taxi Return to Taxi by LSSM	5
			Total	118 hr.

Table 3.3-13
SHELTER REFERENCE TIMELINE - MISSION 2

for Mission to Alphonsus Exploration Site with 1 LSSM, 100-ft drill, and ESS

Phase A. Prelaunch to Lunar Touchdown

Time, hr:min	
-10:	Shelter Pre-Launch Check-out
0:00	Shelter Lift-Off
:02	Begin S-II Thrusting
:03	Jettison LES + Interstage
:09	Begin S-IV B Thrusting
:12	Earth Orbit Insertion
3:01	Begin Translunar Injection on Second Orbit
3:06	Begin Initial Coast to Transposition & Docking
3:21	Begin Transposition & Docking
3:48	CSM Docked - Begin Coast thru S-IV-B Jettison
3:51	Jettison S-IV-B Begin Coast to Lunar Orbit Insertion
5:06	First Midcourse Correction
55:30	Second Midcourse Correction
63:15	Third Midcourse Correction
64:15	Begin Lunar Orbit Insertion
64:21	Begin Lunar Orbit Coast
65:47	Transfer to Shelter
65:51	Checkout Shelter
66:24	Begin Second Lunar Orbit
67:49	Astronaut Returns to CSM
68:04	Shelter/CSM Separation on Second Orbit
68:24	Begin Transfer Orbit Insertion
68.25	Begin Coast
68:49	Shelter Begins LOS with Earth
69:23	Begin Powered Descent
69:31	Landing Phase
69:32	Touchdown

Phase B. Lunar Storage*

Day	Time, hr:min	Activity
1	00:00 - 00:15	Post-Landing Verification
	00:15 - 01:00	Post-Landing Shutdown
	12:00 - 12:12	Shelter Status Data Monitoring
2-56	once per day	Warm Up and Stabilization (10 min) Data Transmission (2 min) Turn off all Status Data

* A three-month lunar storage period is presented whereas the actual lunar storage period may be from zero to three months.

Table 3.3-13 (cont.)

Phase B. Lunar Storage* (cont'd)

Day	Time, hr:min	Activity
57		Warm Up (10 min) Data Transmission (20 min)
57-85	once per day	Warm up and Stabilization (10 min) Data transmission (2 min) Turn off all Status Data

* A three-month lunar storage period is presented whereas the actual lunar storage period may be from zero to three months.

Phase C: Taxi Prelaunch to Lunar Touchdown

Day	Activity
85	Activate Shelter (48 hr before Taxi Launch)
90	Taxi Touchdown

Phase D: Lunar Surface Activities

Day 1

Time	Systems Engineer	Commander
0	Taxi Touchdown	Taxi Touchdown
00:00-00:15	Post Landing Checkout	Status Check
00:15-00:35	Eat and Hygiene	Eat and Hygiene
00:35-01:15	Prepare for Shelter Inspection	Assist Systems Engineer
01:15-01:28	Egress Taxi	Monitor Systems Engineer
01:28-01:33	Perform Walk-Around Inspection	Monitor Systems Engineer
01:33-01:53	Erect & Align, S-band Dish Antenna	Checkout of S-band Communications
01:53-02:13	Walk to Shelter	Monitor Systems Engineer
02:13-03:43	Checkout and Inspection, Deploy Airlock - Make go/no go decision	Secure Taxi for Quiescent Storage
03:43-03:56	Monitor Commander	Egress Taxi
03:56-04:16	Monitor Commander	Walk to Shelter
04:16-05:16	Replace PLSS & Recharge	Unload LSSM, Activate and C/O

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 1

Time	Systems Engineer	Commander
05:16-05:31	Monitor Commander	Remove RTG and Place on LSSM
05:31-05:36	Monitor Commander	Drive LSSM to Taxi
05:36-05:56	Monitor Commander	Install RTG unit in Taxi
05:56-06:06	Monitor Commander	Ingress Taxi and Switch Power to RTG. Check
06:06-06:16	Monitor Commander	Engress Taxi
06:16-06:21	Monitor Commander	Drive LSSM to Shelter
06:21-06:31	Monitor Commander	Ingress Shelter
06:31-07:01	Establish Earth Commuication	Recharge PLSS
07:01-07:30	Eat and Hygiene	Eat and Hygiene
07:30-10:00	General Familiarization Position Fix and Internal Checkout	Same, Photograph Surrounding Terrain from Shelter
10:00-12:00	Mission Planning for 2ndDay	Mission Planning for 2nd Day
12:00-13:00	Eat and Hygiene	Eat and Hygiene
13:00-24:00	Rest	Rest

Day 2

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Earth Report and Planning	Visual and Photographic Survey of Near Vicinity
1:00-1:30	Egress	Monitor Systems Eng.
1:30-4:30	Unload Externally Stowed Scientific Equipment from LSSM Specimen collection and in situ measurements	Complete Photographic Survey (1:00) Monitor Systems Eng, and Rest (2:00)
4:30-5:00	Ingress	Egress
5:00-8:00	Monitor Commander Recharge PLSS, Plan ESS Site Emplacement, Eat, Hygiene and Rest	Conduct ISSM Sortie #1 past small impact crater to contact between floor and wall material. Perform the following experiments and measurements 1) Sample collection 2) Continuous magnetic Survey 3) Nuclear experiments Package

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 2 (cont'd)

Time	Systems Engineer	Commander
5:00-8:00 (cont'd)		4) Geological observation of crater and contact area 5) Gravity at approximately 1 KM intervals 6) Typographic surveying
8:00-8:30	Monitor Commander	Ingress
8:30-10:15	Earth Reports and Planning	Recharge PLSS
10:15-11:00	Eat and Hygiene	Eat and Hygiene
11:00-11:30	Egress	Monitor Systems Eng.
11:30-14:30	Conduct LSSM sortie #2 in vicinity of Shelter. Drill 10 ft. hole and erect and emplace ESS	Monitor Systems Eng. Position Fix on ESS
14:30-15:00	Ingress	Monitor Systems Eng.
15:00-15:20	Eat and Hygiene	Eat and Hygiene
15:20-15:40	Recharge PLSS	Rest
15:40-24:00	Rest	Rest

Day 3

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Egress	Monitor Systems Eng.
1:30-7:30	Conduct LSSM Sortie #3 to Rille and chain crater. Perform the following experiments and measurements 1) Geological mapping and sampling 2) Gravity at 1 Km intervals 3) Continuous magnetic survey	Conduct Shelter Laboratory Experiments. Monitor Systems Engineer and Establish Position Fixes and Plot Traverse at 15-minute Intervals for 5 minutes, Eat, Hygiene, and Rest

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 3 (cont'd)

Time	Systems Engineer	Commander
1:30-7:30 (cont'd)	4) Nuclear experiments package 5) Topographical surveying 6) Multiband photography and radiometry.	
7:30-8:00	Ingress	Egress
8:00-11:00	Perform Shelter Laboratory experiments and communications, Recharge PLSS, Eat, Hygiene, and Rest	Set up and activate 100 ft. drill. Layout test samples for erosion studies - polished sheets of granite, basalt, metal, etc.
11:00-11:30	Monitor Commander	Ingress
11:30-14:00	Earth Reports, Shelter Housekeeping and Planning	Recharge PLSS, Eat, Hygiene, Rest and Planning
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Day 4

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Monitor Commander	Egress
1:30-7:30	Conduct Shelter Laboratory Experiments. Monitor Commander and Establish Position Fixes and Plot Traverse at 15-minute Intervals for 5 minutes Eat, Hygiene, and Rest.	Conduct LSSM Sortie #4 to Alphonsus crater wall. Observe features of Alphonsus wall material, crater in wall material, crater floor material and small impact craters. Perform the following experiments and measurements: 1) Geological mapping and sampling 2) Gravity at 1 Km intervals 3) Continuous magnetic survey 4) Nuclear experiments package 5) Topographical surveying 6) Multiband photography and radiometry

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 4 (cont'd)

Time	Systems Engineer	Commander
7:30-8:00	Egress	Ingress
8:00-11:00	Complete ESS activation. Monitor 100 ft. drilling operation	Perform Shelter Laboratory Experiments and Communications, Recharge PLSS, Eat and Hygiene
11:00-11:30	Ingress	Monitor Systems Engineer
11:30-14:00	Eat, Hygiene, Recharge PLSS, Rest and Planning	Earth Reports, Shelter Housekeeping and Planning
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Day 5

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Egress	Monitor Systems Engineer
1:30-7:30	Conduct LSSM Sortie #5 to inner ridge of crater wall. Observe the floor and wall material. Perform the following experiments and measurements. 1) Geological mapping and sampling. 2) Gravity at 1 Km intervals. 3) Continuous magnetic survey. 4) Nuclear experiments package. 5) Topographical surveying. 6) Multiband photography and radiometry. 7) Remote geological mapping of formations and structures in crater wall.	Conduct Shelter Laboratory Experiments. Monitor Systems Engineer and Establish Position Fixes and Plot Traverse at 15-minute intervals for 5 minutes, Eat and Hygiene and Rest
7:30-8:00	Ingress	Egress
8:00-11:00	Perform Shelter Laboratory Experiments and Communications, Eat, Hygiene, Re-PLSS, and Rest	Set up telluric current survey. Perform X-Ray Astronomy Experiments. Monitor 100 ft. Drill.

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 5 (cont'd)

Time	Systems Engineer	Commander
11:00-11:30	Monitor Commander	Ingress
11:30-14:00	Earth Reports, Shelter Housekeeping, and Planning	Eat, Hygiene, Recharge PLSS, Rest and Planning
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Day 6

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Monitor Commander	Egress
1:30-7:30	Conduct Shelter Laboratory Experiments. Monitor commander and Establish Position Fixes and Plot Traverse at 15-Minute Intervals for 5 Minutes, Eat, Hygiene, and Rest.	Conduct LSSM Sortie #6 to Dark halo crater. Observe crater floor material, two maar type craters; small rille; large rille, dark halo material; impact craters and ejecta material. Perform the following experiments and measurements. 1) Geological mapping and sampling 2) Gravity at 1 Km interval 3) Continuous magnetic survey 4) Nuclear experiments 5) Topographical surveying 6) Multiband photography and radiometry 7) Insitu experiments on dark halo material
07:30-08:00	Egress	Ingress
08:00-11:00	Place geophones and cable in proximity of Shelter and detonate explosive at either end. Monitor 100 ft. drill	Perform Shelter laboratory experiments and communications, Eat, Hygiene, Recharge PLSS
11:00-11:30	Ingress	Monitor Systems Engineer
11:30-14:00	Eat, Hygiene, Recharge PLSS and Rest and Planning	Earth Reports, Shelter Housekeeping and Planning

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 6 (cont'd)

Time	Systems Engineer	Commander
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Day 7

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Egress	Monitor Systems Engineer
1:30-7:30	Conduct LSSM Sortie #7 to inner ridge of crater wall. Observe crater floor material; crater wall material, small impact craters and ridge material. Perform the following experiments and measurements: 1) Geological mapping and sampling 2) Gravity at 1 Km intervals 3) Continuous magnetic survey 4) Nuclear experiments 5) Topographical surveying 6) Multiband photography and radiometry	Conduct Shelter Laboratory Experiments. Monitor Systems Engineer and Establish Position Fixes and Plot Traverse at 15-Minute intervals for 5 Minutes, Eat, Hygiene, and Rest.
7:30-8:00	Ingress	Egress
8:00-11:00	Perform Shelter Laboratory Experiments and Communications, Eat, Hygiene, Recharge PLSS, and Rest	Conduct seismic refraction shot at 0.5 Km distance from either end of geophone spread. Activate and Monitor 100 ft. drill.
11:00-11:30	Monitor Commander	Ingress
11:30-14:00	Earth Reports, Shelter Housekeeping and Planning	Eat, Hygiene, Recharge PLSS, Rest and Planning.
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 8

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Monitor Commander	Egress
1:30-7:30	Conduct Shelter Laboratory Experiments. Monitor Commander and Establish Position Fixes and Plot Traverse at 15-Minute Intervals for 5 Minutes, Eat, Hygiene, and Rest	Conduct LSSM Sortie #8 to impact crater in floor. Observe crater floor material, rim and ejecta material of floor and ridge material and small impact craters. Perform the following experiments and measurements: 1) Geological mapping and Sampling 2) Gravity at approximately 1-km intervals. 3) Continuous magnetic survey 4) Nuclear experiments package 5) Topographical surveying 6) Multiband photography and radiometry 7) Insitu on crater rim Material
7:30-8:00	Egress	Ingress
8:00-11:00	Perform optical astronomy experiments. Activate and monitor 100 ft. drill.	Perform Shelter Laboratory Experiments and Communications. Eat, Hygiene, Recharge PLSS.
11:00-11:30	Ingress	Monitor Systems Engineer
11:30-14:00	Eat, Hygiene, Recharge PLSS, Rest, and Planning	Earth Reports, Shelter Housekeeping and Planning
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Day 9

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Egress	Monitor Systems Engineer

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 9 (cont'd)

Time	Systems Engineer	Commander
1:30-7:30	Conduct LSSM Sortie #9 west on seismic line from Shelter. Perform seven seismic shots at 1, 2, 3 4, 5, 6 and 7 Km.	Conduct Shelter Laboratory Experiments. Monitor Systems Engineer and Establish Position Fixes and Plot Traverse at 15-Minute Intervals for 5 Minutes, Eat, Hygiene and Rest
7:30-8:00	Ingress	Egress
8:00-11:00	Perform Shelter Laboratory Experiments and Communications, Eat, Hygiene, Recharge PLSS and Rest	Prepare seismic spread for reflection measurements and conduct experiment, Activate monitor and complete 100 ft. drill hole.
11:00-11:30	Monitor Commander	Ingress
11:30-14:00	Earth Reports, Shelter Housekeeping, and Planning	Eat, Hygiene, Recharge PLSS, Rest and Planning
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Day 10

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Monitor Commander	Egress
1:30-7:30	Conduct Shelter Laboratory Experiments. Monitor Commander and Establish Position Fixes and Plot Traverse at 15-Minute Intervals for 5 Minutes, Eat, Hygiene, and Rest.	Conduct LSSM Sortie #10 east on seismic line from Shelter. Perform six seismic shots at 1, 2, 3, 4, 6, and 8 Km.
7:30-8:00	Egress	Ingress
11:30-14:00	Eat, Hygiene, Recharge PLSS, Rest and Planning	Earth Reports, Shelter Housekeeping, and Planning.
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 11

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Egress	Monitor Systems Engineer
1:30-7:30	Conduct LSSM Sortie #11 to rille and chain crater. Observe rille, fumerole area, maar craters, crater floor materials, impact craters, and ejecta from maar crater. Perform the following experiments and measurements: 1. Geological mapping and sampling 2. Gravity at approximately 1-Km intervals. 3. Continuous magnetic survey. 4. Nuclear experiments package. 5. Topographical surveying. 6. Multiband photography and radiometry. 7. Gas measurements from fumarole.	Conduct Shelter Laboratory Experiments. Monitor Systems Engineer and Establish Position Fixes and Plot Traverse at 15-Minute Intervals for 5 Minutes Eat, Hygiene, and Rest.
7:30-8:00	Ingress	Egress
8:00-11:00	Perform Shelter Laboratory Experiments and communications. Eat, Hygiene, Recharge PLSS, and Rest.	Perform sonic velocity measurements on 100 ft. hole.
11:00-11:30	Monitor Commander	Ingress
11:30-14:00	Earth Reports, Shelter Housekeeping and Planning.	Eat, Hygiene, Recharge PLSS, Rest and Planning.
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 12

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Report and Preparation	Report and Preparation
1:00-1:30	Monitor Commander	Egress
1:30-7:30	Conduct Shelter Laboratory Experiments. Monitor Commander and Establish Position Fixes and Plot Traverse at 15-Minute Intervals for 5 minutes.	Conduct LSSM Sortie #12 to floor/ridge contact. Observe impact crater on contact between ridge and floor material, ridge material, and crater floor material Perform the following experiments and measurements: 1. Geological mapping and sampling 2. Gravity at approximately 1-Km intervals. 3. Continuous magnetic survey. 4. Nuclear experiments package. 5. Topographical surveying. 6. Multiband photography and radiometry. 7. Drill, core and log 10 ft. hole on ridge material.
7:30-8:00	Egress	Ingress
8:00-11:00	Perform nuclear and electrical logging of 100 ft. hole. Perform X-ray astronomy experiments and optical astronomy experiments	Perform Shelter Laboratory Experiments and Communications. Eat, Hygiene, Recharge PLSS and Rest.
11:00-11:30	Ingress	Monitor Systems Engineer
11:30-14:00	Eat, Hygiene, Recharge PLSS, Rest and Planning	Earth Reports, Shelter Housekeeping, and Planning
14:00-15:00	Eat and Hygiene	Eat and Hygiene
15:00-24:00	Rest	Rest

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 13

Time	Systems Engineer	Commander
00:00-00:30	Eat and Hygiene	Eat and Hygiene
00:30-1:00	Reports and Preparation	Report and Preparation
1:00-1:30	Egress	Monitor Systems Engineer
1:30-4:30	Local surface Activities. Check ESS Operation.	Monitor Systems Engineer Shelter-Laboratory Experiments Eat, Hygiene, and Rest.
4:30-5:00	Ingress	Egress
5:00-8:00	Monitor Commander Shelter-Laboratory Experiments. Eat, Hygiene, Recharge PLSS, and Rest.	Local Surface Activities. Check ESS Operation.
8:00-8:30	Monitor Commander	Ingress
8:30-10:15	Reports, Sample Collection, and Data Analysis	Recharge PLSS
10:15-11:00	Eat and Hygiene	Eat and Hygiene
11:00-15:00	Data Analysis	Data Analysis
15:00-15:30	Eat and Hygiene	Eat and Hygiene
15:30-24:00	Rest	Rest

Table 3.3-13 (cont.)

Phase D: Lunar Surface Activities (cont'd)

Day 14

Time	Systems Engineer	Commander
0-0100	Eat and Hygiene	Eat and Hygiene
0100-0200	Report and Preparation	Report and Preparation
0200-0600	Final Reporting and Sample Preparation	Final Reporting and Sample Preparation
0600-0700	Eat and Hygiene	Eat and Hygiene
0700-0900	Sample Preparation	Sample Preparation
0900-1600	Rest	Rest
1600-1700	Eat and Hygiene	Eat and Hygiene
1700-1730	Monitor Commander	Egress
1730-1930	Final Preparation of Shelter Interior	Final Surface Examination and Equipment Storage
1930-2000	Egress	Ingress
2000-2048	Load Return Payload into LSSM	Monitor Systems Engineer
2048-2053	Return to Taxi	Prepare to Depart Shelter
2053-2054	Walk around Taxi for Visual Inspection	
2054-2058	Ingress Taxi and Activate ARS	Monitor Systems Engineer
2058-2108	Monitor Commander	Egress Shelter & Secure
2108-2128	Monitor Commander	Walk to Taxi
2128-2157	Assist Commander	Load Experiment Payload into Taxi and Stow
2157-2200	Monitor Commander	Ingress Taxi
2200-2300	Activate Taxi and Recharge PLSS	Activate Taxi and recharge PLSS
2300-2400	Prelaunch Checkout	Prelaunch Checkout
2400	Ascent Ignition	Ascent Ignition

Table 3.3-14
MISSION PROGRAMMER SWITCHING FUNCTIONS

No.	FUNCTION	
	PROPULSION	
1	Depressurize He Desc Eng (Vent Valve)	P
2	Depressurize Fuel (Vent Valve) Desc Eng*	E
3	Depressurize Oxidizer (Vent Valves) Desc Eng*	E
4	RCS Heater Switches ON/OFF	P
5	RCS Pressurization	P
6	RCS Fuel Vent*	P
7	RCS Oxidizer Vent*	P
	EPS	
8	Connect Load No. 1 ON/OFF	E
9	Connect Load No. 2 ON/OFF	E
10	Connect Load No. 3 ON/OFF	E
11	RTG Power ON/OFF	E
12	Battery Power ON/OFF	E
13	Fuel Cell (FCA) Power ON/OFF	E
14	FCA Reactant Squibs - Fire	P
15	FCA Start-up No. 2	P
16	FCA Start-up No. 3	P
17	FCA Start-up No. 4	P
	ECS	
18	Electronic Coolant Pump (Glycol Loop) Select 1/2/3 AUTO/OFF	PE
19	Suit Fans Power ON/OFF**	P
20	Suit Fans Select 1/2**	P
21	Cabin Fan Power ON/OFF**	P
22	Cabin Fan Select 1/2**	P
23	Oxygen Tank Valve for Cabin Press**	P
	COMMUNICATIONS	
24	VHF ON/OFF	E
25	Search Mode S-band Steerable ON/OFF	P
26	X-band Transponder ON/OFF	E
27	S-band Ranging ON/OFF	E
28	Primary S-band Transceiver ON/OFF	E
29	Primary S-band Power Amplifier ON/OFF	E
	COMMUNICATIONS (Cont.)	
30	Secondary S-band Transceiver ON/OFF	E
31	S-band Antenna Select INF1/INF2/STEERABLE ERECTABLE	PE
32	VHF Antenna Select VHF1/VHF2/EVA	PE
33	R&D TM Transmitters ON/OFF	E
34	TM Calibrate	PE
35	S-band Doppler Tracking	E
	INSTRUMENTATION	
36	Instrumentation mode STATUS/CHECKOUT/OFF	E
37	Instrum. PCM ON/OFF	P
38	Bit-Rate Select 16/51.2	P
39	Signal Cond Assy No. 1 ON/OFF	P
40	Signal Cond Assy No. 2 ON/OFF	P
41	Status Sensor ON/OFF	P
42	Operational Sensors ON/OFF	P
43	Caution & Warning Equipment ON/OFF	P
44	Master Caution & Warning Reset	E
45	Individual Caution & Warning Reset	E
46	Tape Recorder HIGH/LOW/REWIND/PLAYBACK/OFF	P
	GN&C	
47	Landing Radar Turn ON/OFF	P
48	GN&C Shutdown	P
49	GN&C Temperature Controls ON/OFF	P
50	PCA ON/OFF	E
	CONTROL	
51	Separation RCS Impulse	P
52	Control Mode Select	P
53	Descent Engine ARM/OFF	P
54	Engine Start Override	E
55	Separation Explosive Bolts	P
56	Landing Gear Deploy	P
57	Deploy RCS Dust Covers***	P
	TEST	
58	Test Sequence Initiate	E

*Pressure, not entire contents, of tank vented
**For pre-utilization checkout
***May be eliminated at future date

Legend: P = Preprogrammed
E = Earth Command

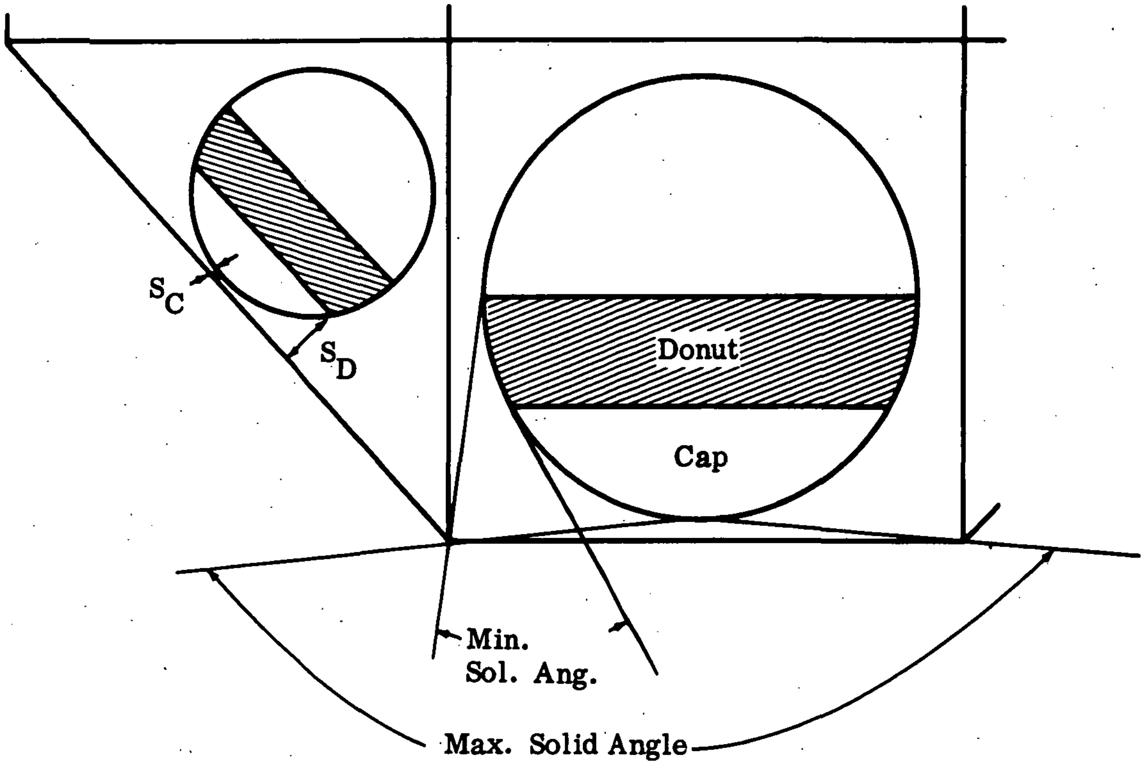


Fig. 3.5-1 Micrometeoroid Hazard - Critical Tank Area

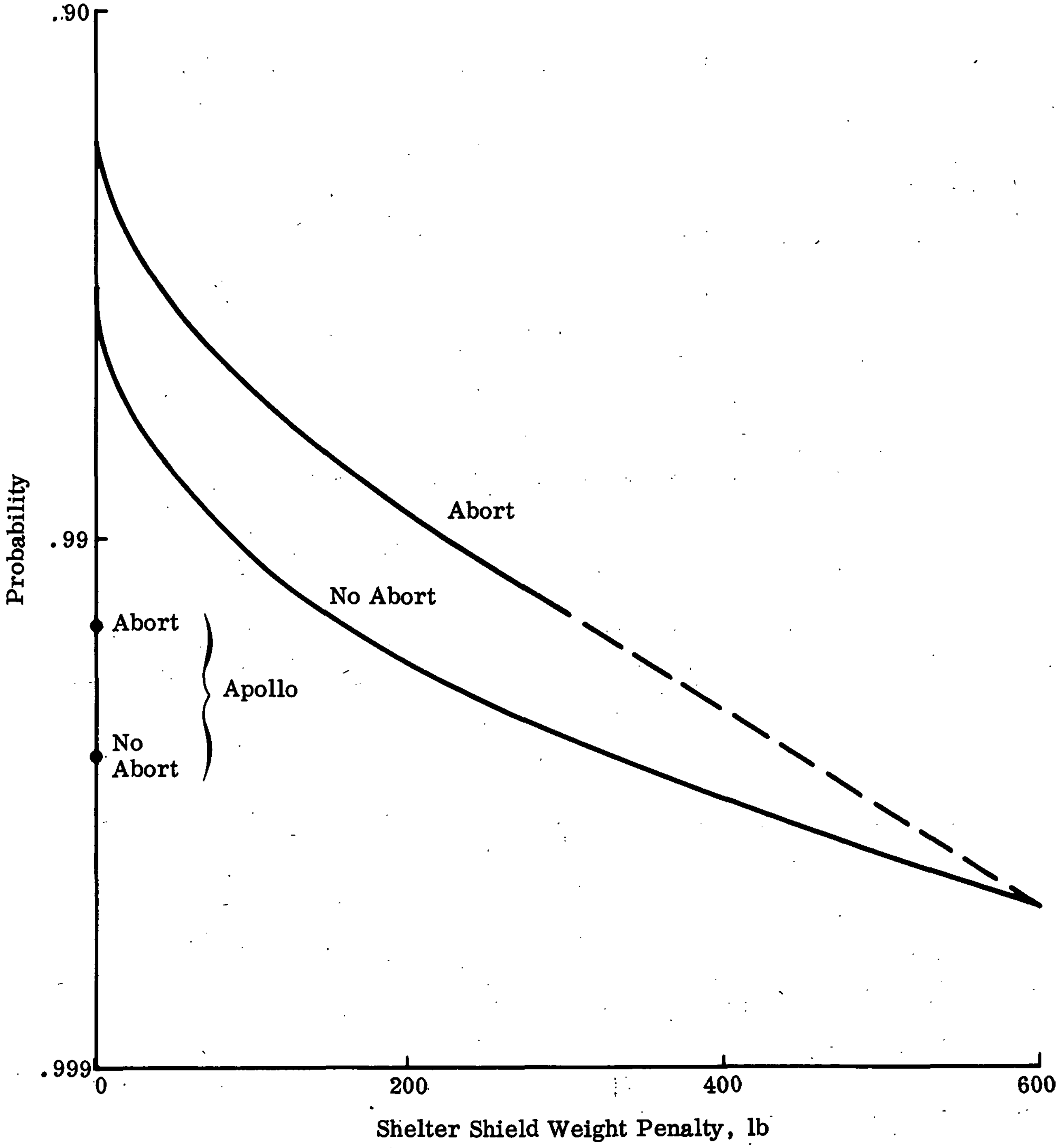


Fig. 3.5-2 Radiation Shielding Weight Penalty

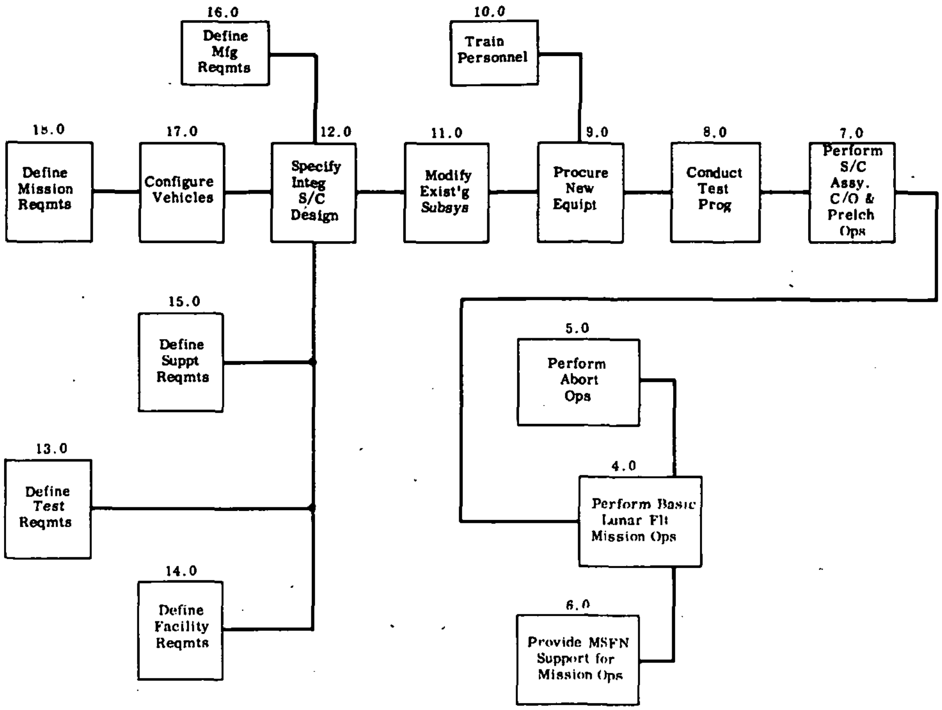


Fig. 3.6-1 Top Level Functional Flow Diagram

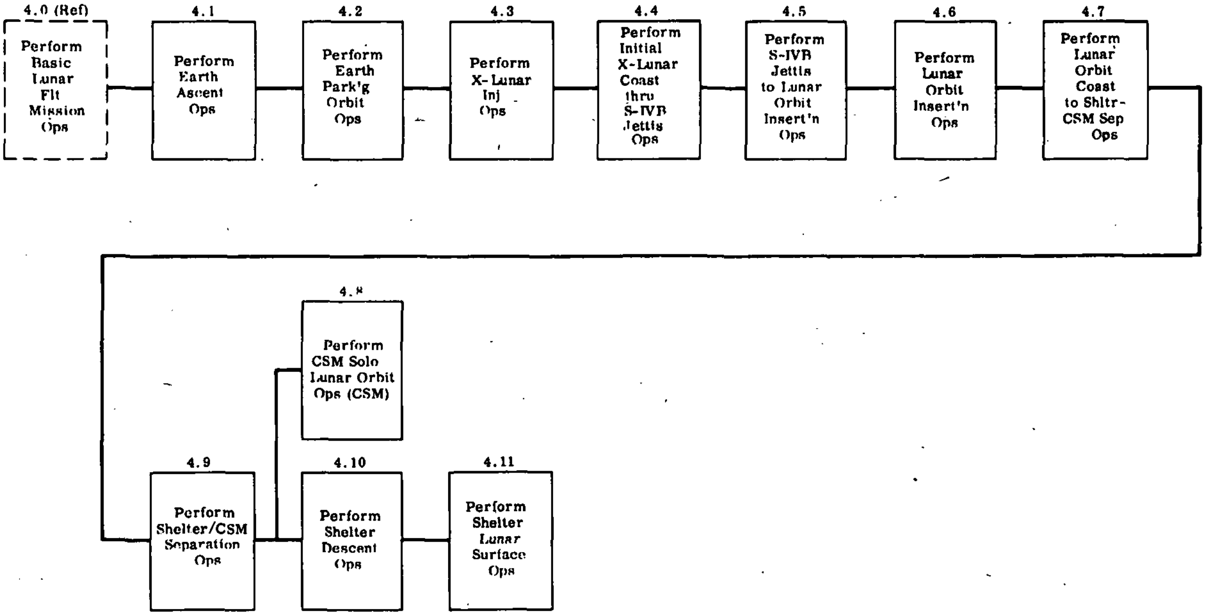


Fig. 3.6-2 First Level Functional Flow Diagram-Perform Basic Lunar Flight Mission Operations

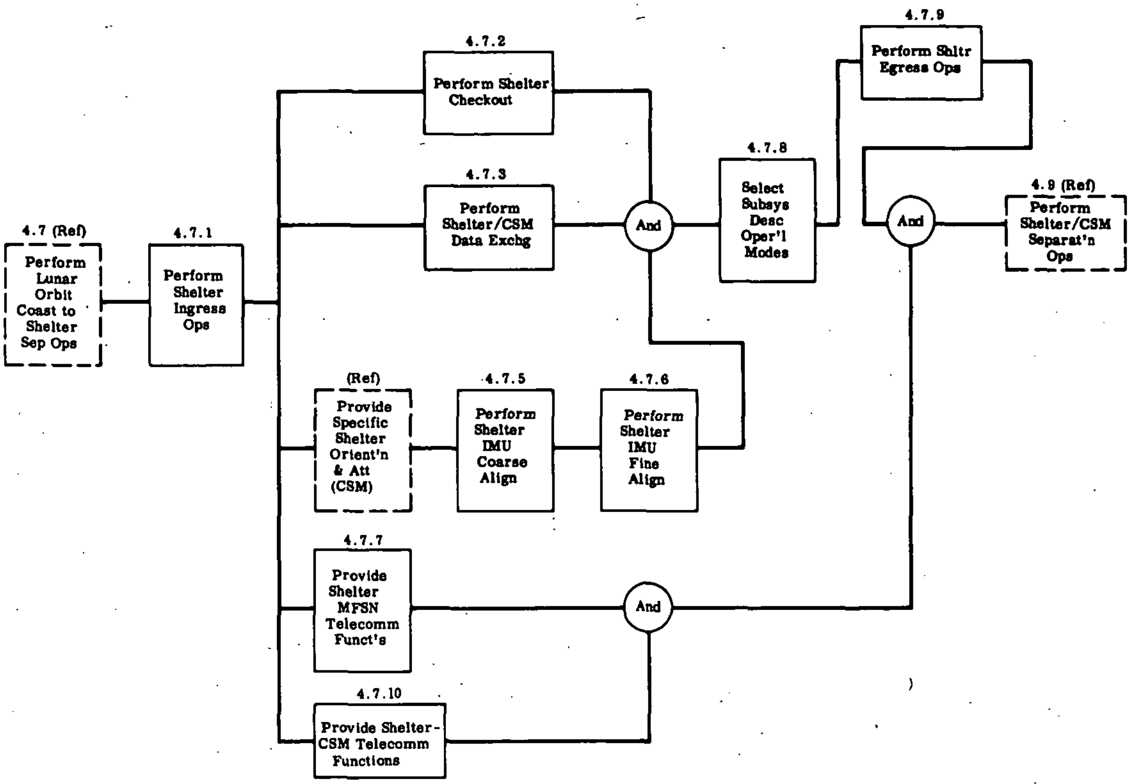


Fig 3.6-3 Second Level Functional Flow Diagram-Perform Lunar Orbit Coast to Shelter Separation Operations

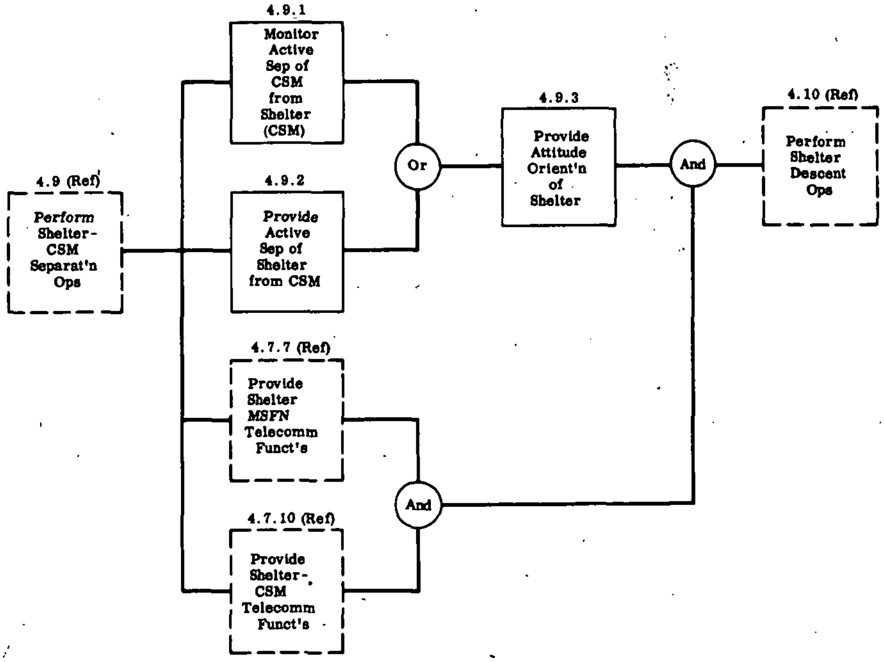


Fig. 3.6-4 Second Level Functional Flow Diagram-Perform Shelter - CSM Separation Operations

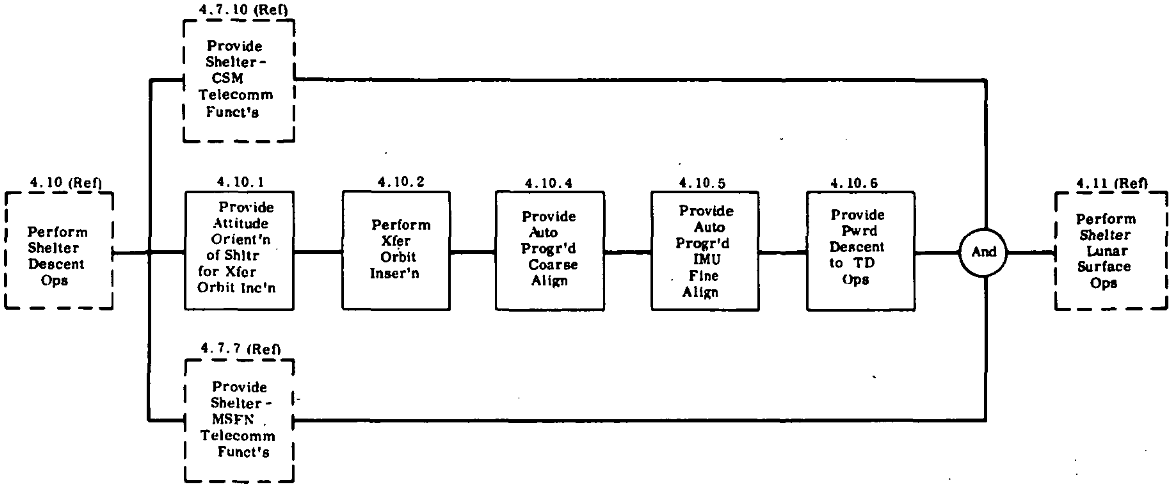


Fig. 3.6-5 Second Level Functional Flow Diagram-Perform Shelter Descent Operations

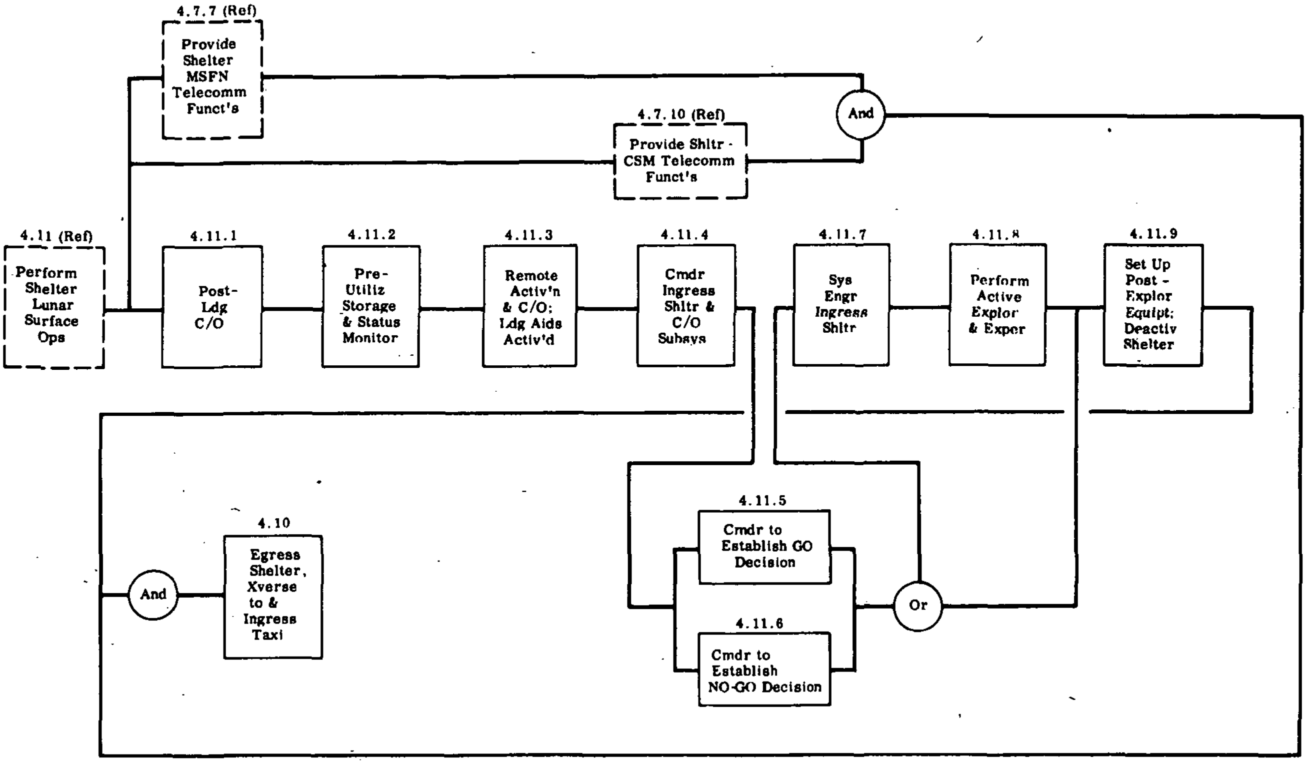


Fig. 3.6-6 Second Level Functional Flow Diagram-Perform Shelter Lunar Surface Operations

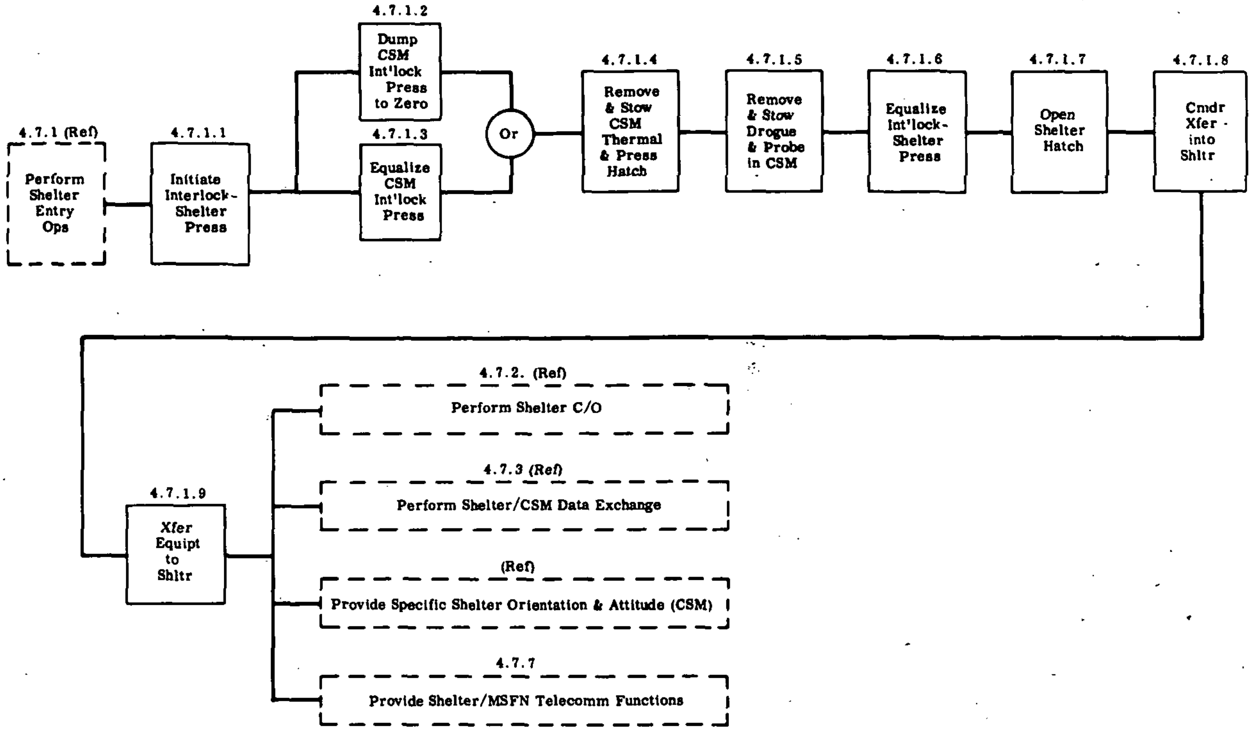


Fig. 3.6-7 Third Level Functional Flow Diagram-Perform Shelter Entry Operations

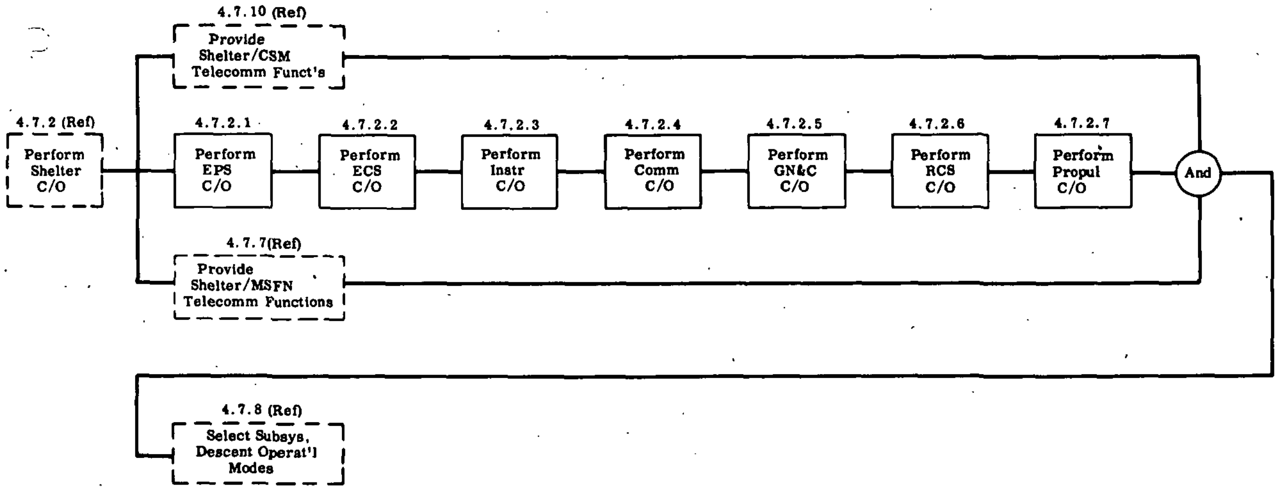


Fig. 3.6-8 Third Level Functional Flow Diagram-Perform Shelter Checkout

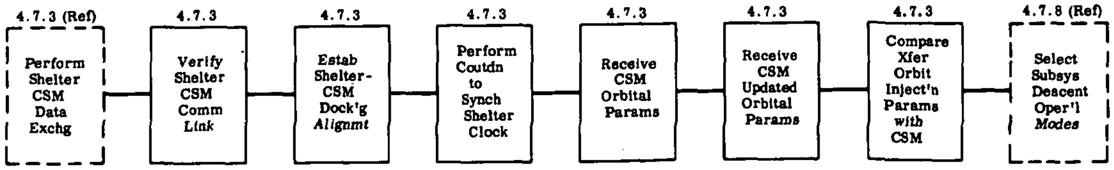


Fig. 3.6-9 Third Level Functional Flow Diagram-Perform Shelter-CSM Data Exchange

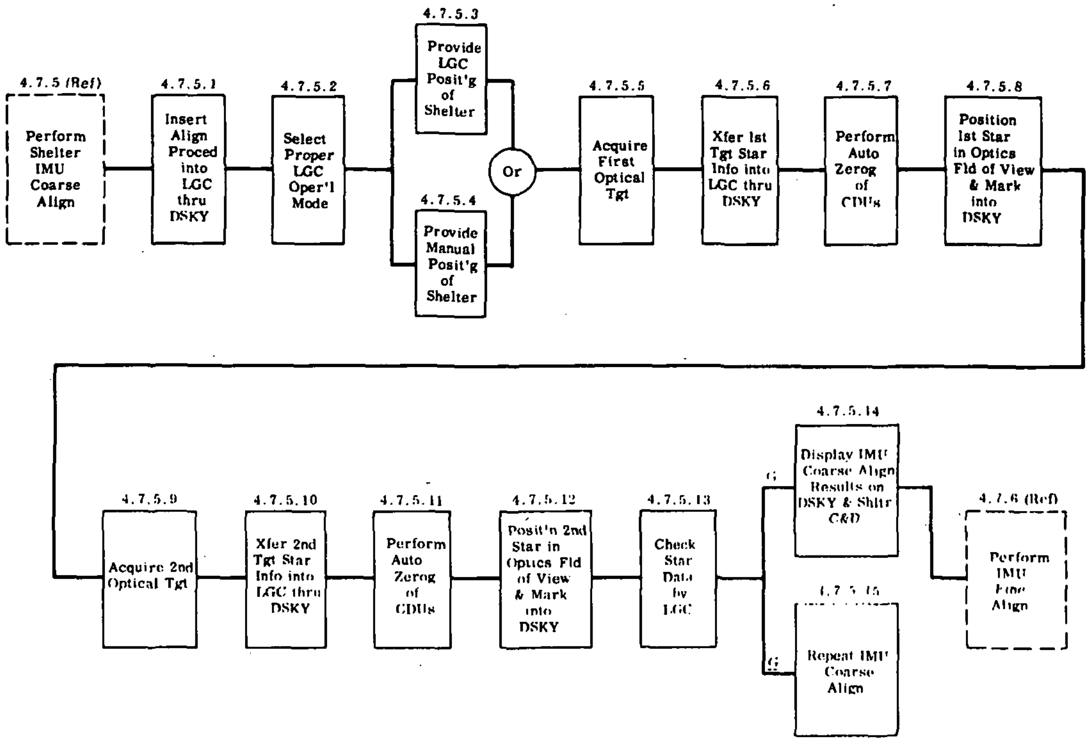


Fig. 3. 6-10 Third Level Functional Flow Diagram–Perform Shelter IMU Coarse Alignment

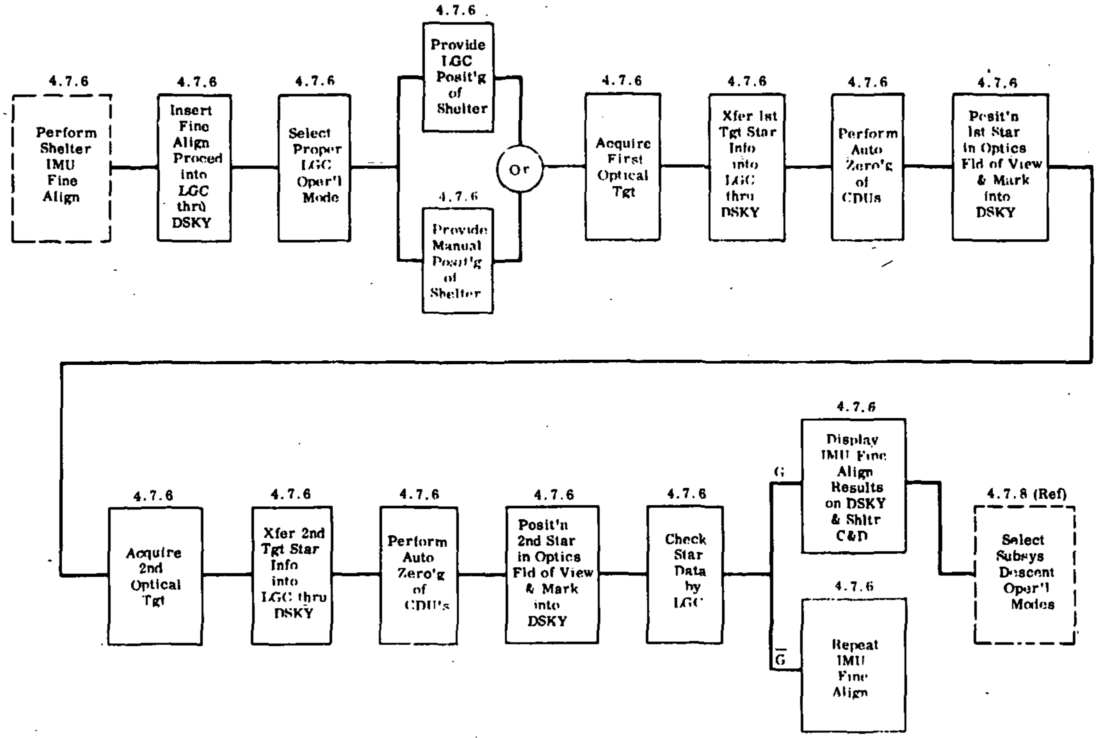


Fig. 3.6-11 Third Level Functional Flow Diagram–Perform Shelter IMU Fine Alignment

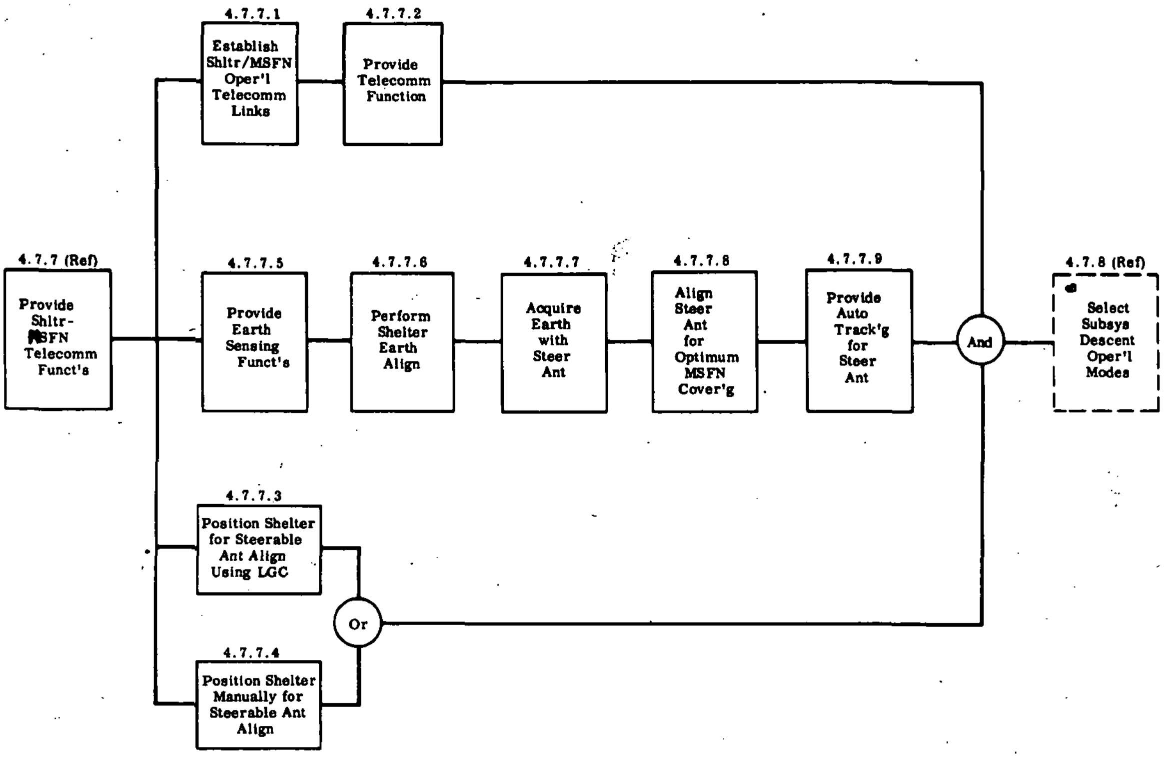


Fig. 3.6-12 Third Level Functional Flow Diagram-Provide Shelter/MSFN Telecommunication Functions

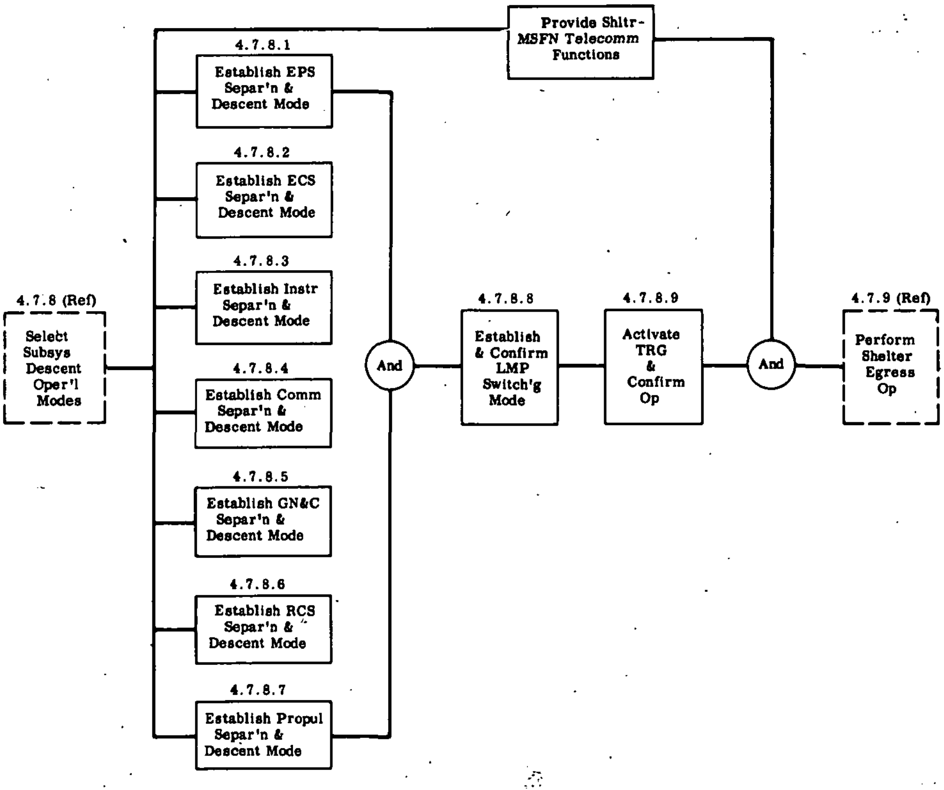


Fig. 3.6-13 Third Level Functional Flow Diagram-Select Subsystem Descent Operational Modes

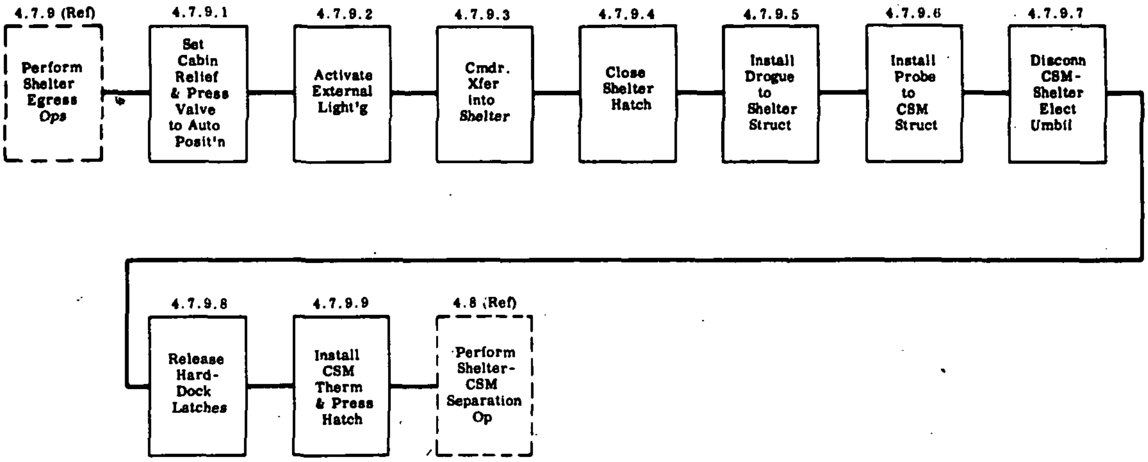


Fig. 3.6-14 Third Level Functional Flow Diagram-Perform Shelter Egress Operations

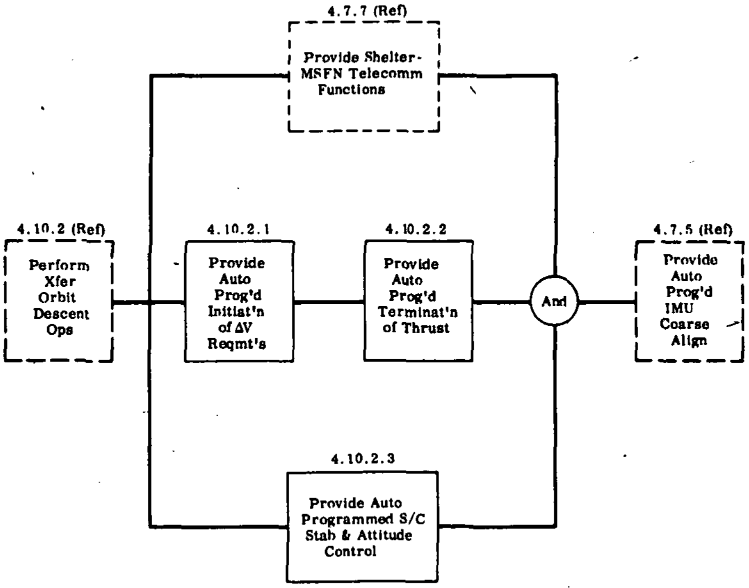


Fig. 3.6-15 Third Level Functional Flow Diagram-Perform Transfer Orbit Descent Operations

4. SYSTEM ENGINEERING

4.1 THERMODYNAMICS

4.1.1 Ground Rules

During the manned mission phase, the cabin atmosphere is to be maintained at 75 ±5°F. This applies directly to environmental control, however, it is considered a thermal control requirement to maintain the pressure vessel and vehicle mid-structure near this temperature range during manned operation.

4.1.2 Assumptions and Background Data

It is assumed that the thermal control requirements of the Shelter for all mission phases prior to lunar surface operations are identical to the requirements of the LEM.

During lunar surface operations, there are thermal control requirements for the quiescent storage phase, the pre-utilization phase, and the manned phase. During quiescent storage, it is the objective of the thermal design to minimize the day-night temperature variation in the Shelter. This is done to as great an extent as is possible through passive means, with utilization of active heating and cooling systems only when necessary to maintain tolerable storage temperatures for specific items. During manned operation, it is necessary to maintain the entire ascent stage at about 75°F, maintain equipment within its operational temperature limits, and reject waste heat to the environment. Active cooling is required during the manned phase.

It is assumed that the experiments will be thermally isolated, and therefore, they are not included in the heat load. Also, the 100-ft surface drill does not dissipate heat to the Shelter.

4.1.2.1 Thermal Loads

While the thermal loads due to the environment are computed as part of the normal thermal analysis, the following assumptions are made concerning internal sources of thermal energy:

- Rate of electrical power heat dissipation within the Shelter is based upon the power generation rates presented in Paragraph 5.1. All electrical power supplied to equipment within the Shelter external insulation blanket produces an equivalent heat load. Major electrical devices, such as the lunar surface drill, are located outside the insulation blanket and do not contribute to the heat load. Distribution losses of 7-1/2% are included; however, the electrical growth allowance is not included in the analysis.
- SNAP 27 Radioisotope Thermo-electric Generator (RTG) is available and the heat dissipation rate is at all times equal to 1400 watts. This heat is not directly applied to the vehicle, since the RTG is in partial thermal isolation. Utilization of this heat load is further discussed in Paragraph 4.1.3.2 where use of the "heat pipe" is explained.
- Throughout the 14 days of the manned phase of lunar surface operations, the crew will dissipate heat at the constant rate of 1000 btu/hr.

4.1.2.2 Environmental Conditions

It is assumed that the Shelter landing site is located on the lunar equator (with the sun passing directly overhead). The lunar surface is assumed to be a flat, black body radiator which is in thermal equilibrium with the sun during the lunar day and is at a temperature of -250°F (210°R) during the lunar night. In effect, this treatment ignores the 7% albedo of the lunar surface, and replaces it with IR radiation. This is an over-estimation of the daytime thermal environment for all Shelter surfaces having $\alpha/\epsilon < 1$.

It is assumed that no preferred vehicle orientation may be specified, and therefore, "worst case" analyses must be performed when orientation has an effect. This is the case when dealing with vertical radiators.

4.1.2.3 Temperature Limitations

The general objective of thermal control is to provide all vehicle components with a suitable thermal environment during all Shelter mission phases. The allowable temperatures for various subsystems components are as follows:

Component	Temperature (°F)	
	Min	Max
Ascent structure	30	130
Water tanks	40	160
Batteries (storage)	-30	40
Batteries (operating)	40	80
Fuel cells (storage)	-30	185
Antennas	-65	160
Cabin pressure vessel (Unmanned)	30	130
Cabin pressure vessel (manned)	60	90
Fuel cell reactant tanks		130
Electronics	-65	130

These allowable temperature limits indicate that special attention must be given to the water tanks and the operating batteries to prevent excessively low temperatures, and to the cabin pressure vessel during manned operation to prevent either extreme.

4.1.3 Recommended Configuration

The primary objective of the Shelter thermal design is to minimize the effect of the lunar day-night cycle on the structural temperatures through the application of insulation and the proper thermal coatings. When this objective is accomplished, the problem of maintaining proper temperatures of the equipment and expendables can be solved by proper thermal coupling or decoupling with the vehicle structure. Under these conditions, completely passive thermal control is achieved. In the Shelter, this objective is achieved with insulation and coatings, and supplemented with the controlled use of waste heat from the RTG.

4.1.3.1 Passive Thermal Control

Passive thermal control of the Shelter is based on insulation techniques utilized on the LEM, with the following modifications:

- Addition of an insulation blanket to cover the top docking tunnel; estimated weight is 10 lb.
- Addition of insulated reflective covers applied to the interior surfaces of the cabin windows; estimated weight is 10 lb.
- Addition of 75 layers (3/4in.) of NRC-2 insulation to all external surfaces of the ascent stage. This is in addition to the 25 layers used on the basic LEM; estimated weight is 87 lb.

The window covers are applied prior to separation. The top docking tunnel insulation is automatically deployed after lunar touchdown. The purpose of these alterations is to minimize the thermal coupling between the ascent stage structure and the lunar environment during both the lunar day and lunar night.

Based on these modifications, the steady-state heat-leak rate into or out of the ascent stage has been calculated. The resulting heat transfer rates (Fig. 4.1-1) are a function of the solar angle and the ascent stage structural temperature. The important heat transfer paths coupling the recommended Shelter configuration with the external environment include the exterior insulated surfaces, the top docking tunnel (with its insulated cover deployed), and the RCS clusters. It should be noted that the recommended Shelter RCS utilized only eight thrusters rather than the 16-thruster configuration of the basic LEM. Additional couplings which are assumed to account for 10% of the heat leak, occur through the descent stage, the forward hatch, and the externally mounted equipment. The external surface thermal coating characteristics are:

- Ascent Stage α/ϵ = 0.20/0.25
- Descent Stage α/ϵ = 0.25/0.25

It may be seen from Fig. 4.1-1 that it is necessary to remove heat from the interior of the cabin at a rate of 500 btu/hr to maintain the cabin at 70°F during lunar high noon. During the lunar night, 360 btu/hr must be added to keep the cabin at 70°F. During the lunar day portion of the quiescent storage, the need for active heat removal is avoided by allowing the ascent stage structure to go above 70°F. A transient analysis, discussed in Paragraph 4.1.8.3, has shown that the transient response of the ascent stage is sufficiently slow that the cabin structure may be designed to never exceed its allowable temperature.

4.1.3.2 Active Thermal Control

4.1.3.2.1 Heating Requirements. Thermal control of the Shelter cabin, during the lunar night portion of the quiescent storage phase, is accomplished by using the thermal energy rejected by the RTG. Heat is transferred from the RTG which is carried in the descent stage of the Shelter, to the ascent stage structure by a "heat pipe" distribution system; the design details are given in Paragraph 5.2-3. In this system, heat is transferred by radiation from the RTG to a heat exchanger containing a volatile liquid. The heat vaporizes the liquid, which rises in a pipe to a condensing section in the ascent stage. The vapor then condenses on the cold surface giving up its latent heat to the ascent stage and returning by gravity to the descent stage boiler. The cold condensing surface could consist of tubes having good thermal contact with the cabin pressure vessel. This system requires the presence of the lunar gravity field to insure proper circulation of the fluid.

Preliminary calculations have been made on the use of water as the fluid in the heat pipe system. Typical operating pressures and temperatures for the system are; 30 psi and 250°F throughout the system when there is a demand for heat from the ascent stage, and 300 psi and 600°F in the boiler and descent stage piping when no heat is required. The maximum operating temperature is determined by the surface temperature of the RTG, and the maximum pressure is a function of the total quantity of water and the volume of the system.

A parametric study has been conducted to determine the suitability of maintaining the temperature of the entire ascent stage pressure vessel by heating a relatively small area of the pressure shell. The ability of this small heated surface to then transfer heat to a larger enclosure depends primarily on the temperature of the enclosure and the area and emittance of the small heated surface. Figure 4.1-2 shows the mean radiant temperature of a surface transferring a net rate of 500, 750 and 1,000 btu/hr to a 40°F enclosure as a function of the radiating surface area. analysis of the ascent stage pressure vessel was performed using a numerical relaxation procedure that accounted for both radiation and two-dimensional conduction effects. The effect of thermal conduction is to increase the effective radiating area, thereby reducing the mean radiant temperature required to transfer a given rate of heat from a fixed area to its enclosing surfaces. The analysis used a conductive coupling based only on the 0.03-in. pressure vessel thickness, and neglected any advantage afforded by the conductive coupling of the structural reinforcing members. The actual conduction tends to lower the required mean radiating temperature. The small radiating surface area of the cabin is assumed to have an emittance of 0.9, and can be assumed to be the area to which the condenser tubes of the heat pipe system are attached.

4.1.3.2.2 Cooling Requirements. The active heat rejection system of the Shelter is is made up of the glycol coolant loop of the environmental control system, a 75-sq-ft horizontal radiator located on the top of the Shelter, and a supplementary water boiler. This active system is required to maintain the proper vehicle thermal balance during the manned operation phase. During the daytime portion of this phase, the entire heat load resulting from the structural heat leak, electrical equipment, and crew metabolism must be rejected by the active system. A nighttime manned mission does not present this difficulty, since the crew load is balanced by a structural heat loss. During unmanned storage, active heat rejective is not required because of the wider range allowed to the vehicle transient temperature.

4.1.3.3 Pre-Utilization Phase Cooling Requirements.

Prior to the start of the 14-day manned phase, critical components of the Shelter will be checked out by remote operation. Systems of primary interest include the

- Communications
- Electrical power supply (fuel cells)
- Environmental control system.

The start-up sequence for the fuel cells and environmental control system is designed to provide adequate heat rejection capability throughout this phase of operations. The sequential order for bringing the system up to operational status is as follows for lunar night-time start-up:

- 1 kw of battery power is used to heat one fuel cell to its operating stack temperature of 200°F (approx. 1 hr).
- Available fuel cell output is used to defrost the fuel cell radiator. This requires approximately 1 kw-hr. During this period, the fuel cell is cooled by the water boiler. Less than 10 lb of boil-off water is required for all fuel cell and ECS boiler requirements.
- Horizontal radiator shade is automatically deployed.
- Second fuel cell is brought on line.
- While both fuel cells reject heat through the fuel cell radiator, the ECS radiator is defrosted with 1 kw-hr of power.
- Fuel cells and ECS are now operational.
- ECS radiator dust cover need not be removed for a night-time start-up, since the heat rejection capability is sufficient to handle the output of the fuel cells.

For a daytime start-up, the defrosting operation is not required. Either the ECS radiator dust cover must be automatically removed, or additional supplementary water will be required.

4.1.3.4 ECS Radiator Selection

The active means of heat rejection for the recommended configuration is a horizontal radiator and a supplementary water boiler. The nominal inlet and outlet temperatures of this radiator are 75°F, and approximately 65°F for the design thermal load. The selection of the horizontal radiator, discussed in Paragraph 4.1.6, was based primarily on system simplicity and the available area. During the noontime portion of the daytime manned mission, the effective sink temperature of the horizontal radiator limits the heat rejection capacity. Instead of designing for this extreme condition, a 14-day sunlight mission was assumed and the optimum combination of radiator area and water boil-off was determined. To determine the quantity of supplementary water required, it is assumed that the heat rejection load consists of a constant electrical and crew metabolic load, and the variable structural heat load. The variable radiator capacity is then integrated over this period to determine the heat rejection capability, the difference representing the portion of the load which must be rejected by the water boiler.

For the selected ECS 75-sq-ft radiator surface, and assuming present LEM coolant flow rates, the water requirement is 110 lb. This result is comparable with the information shown in Fig. 4.1-3 which is based on a constant load of 1 kw, and a radiator weight of 1 lb/ft^2 for an inlet/outlet temperature of 100°F/40°F.

4.1.3.5 Special Thermal Control Systems

Various subsystem components cannot be kept within their desired temperature ranges by passive means or active control of the cabin; therefore, special active thermal control systems are required to take care of these situations. For the Shelter, several heaters are required to prevent low-temperature limitation from being exceeded on the S-band antenna, IMU, water tanks, and descent stage batteries.

4.1.3.5.1 S-band Steerable Antenna The S-band antenna, when not in use, requires heater power to maintain the steering components above the low-temperature survival limits. Components such as, servomotors, electronic equipment, and gimbal mechanisms must be maintained above -65°F. It is estimated that 5-w heater power will be required to accomplish this during the condition of zero external heat flux. When the antenna is in direct sunlight no extra heat is required.

4.1.3.5.2 IMU and Auto Tracker. For the unmanned lunar landing, the Shelter requires the addition of an optical star tracker. This tracker is located outside the vehicle in the present location of the AOT and is attached to the IMU. The present LEM navigation base is retained and the ASA is removed.

At present, the temperature control of the IMU, when not operating, is achieved by utilizing the coolant loop as well as the heaters. This mode of operation uses excessive heater power to over-drive the coolant loop. The Shelter incorporates a by-pass valve in the coolant loop to by-pass the IMU when the units are not operating. When the IMU is operating it must be kept at 135°F, despite conductive losses to the startracker. Figure 4.1-4 shows both the heater power required to maintain the IMU at its proper operating temperature and the tracker temperature as a function of percent time in sunlight.

4.1.3.5.3 Descent Stage Water Tanks. The transient analysis has indicated that the descent stage water tanks will freeze unless adequate protection is provided. Based on the tank support system and the recommended insulation level, it is estimated that 5-w heater power is necessary to insure maintaining the water tank temperature above freezing.

4.1.3.5.4 Descent Stage Batteries. Special thermal control for the descent stage batteries is required to prevent excess degradation while in storage. The internal inefficiency of the battery is assumed adequate to compensate for the heat loss during a night mission; however, it is necessary to supply glycol coolant to the battery during a day storage mission. The estimated boil-off water required during a day storage mission, with the structure at 135°F and the battery at 80°F, is 4 lb.

4.1.3.6 Fuel Cell Assembly

The selection of the Allis-Chalmers (A-C) fuel cell for the recommended configuration is discussed in detail in Paragraph 5.1. Thermal characteristics and the effects on the thermal control system of the three fuel cells considered are discussed in Paragraph 4.1-8.

4.1.3.6.1 Passive Requirements. The A-C fuel cell can be placed in the ascent stage with no requirements for maintaining controlled compartment temperatures. If required, the fuel cells can be partially isolated from the structure.

4.1.3.6.2 Active Requirements. A separate radiator, distinct from the ECS radiator, is provided to reject the waste heat from the fuel cells. In the recommended configuration, the radiator is a vertical panel located on the rear of the aft equipment bay of the ascent stage. The radiator is provided with a deployable horizontal reflector shade as shown in Fig. 4.1-5. This shade eliminates a large portion of the lunar surface radiation to which the radiator would otherwise be exposed, and thus reduces the effective environmental temperature. The radiator sizing is based on the following heat rejection characteristics of the A-C fuel cell:

Maximum heat rejection rate = 1625 btu/hr

Radiator inlet temperature = 185°F

Radiator outlet temperature = 136°F

The radiator surface is assumed to have a solar absorptance, α_S, of 0.18, and an emittance, ϵ, of 0.9. The conditions used for design purposes are the 14-day mission starting at the dawn terminator and ending at the night terminator, with the radiator panel facing either east or west. With this worst case orientation, the radiator receives the maximum amount of solar radiation. Figure 4.1-6 shows the effective environmental temperature throughout the 14-day mission, and Fig. 4.1-7 gives the resulting radiator heat rejection capability for several radiator sizes. That portion of the heat load which is not handled by the radiator must be taken care of by supplementary boil-off water.

An optimization study, based on weight, was performed to determine the appropriate radiator size. The radiator weight was taken as 2.0 lb/ft^2, 1.5 lb of which was the actual radiator, and 0.5 lb of which was the shade. The resulting trade-off is shown in Fig. 4.1-8, and indicates that the radiator size of the optimum weight system lies in the range of 25 to 40 sq ft. The recommended configuration uses 57.5 sq ft to avoid the need for additional boil-off water.

4.1.3.7 Fuel Cell Reactant Storage

Ambient storage for fuel cell reactants has been selected as the recommended configuration. While this system is proposed primarily on the basis of simplicity and system reliability, there are several attractive alternative techniques for reactant storage which offer potential weight and volume savings. These are discussed under alternate configurations in Paragraph 4.1.7.

4.1.4 Baseline Configuration

The Shelter baseline configuration incorporated Pratt and Whitney (P&W) fuel cells. While the general characteristics of the three fuel cells investigated (A-C, P&W, and GE) are fairly similar, one difference in heat rejection characteristics has an appreciable effect on the Shelter thermal design. As a result of its high stack temperature and the cooling requirement of the fuel cell controls, the P&W fuel cells tend to reject heat to their environment at a greater rate than the other designs. The effect of this heat rejection on the thermal control system is discussed in Paragraph 4.1.8.

4.1.5 Alternate Configuration - Direct Radiation of RTG Waste Heat

An alternate active control system under consideration consists of an RTG waste heat system, using direct radiation heat transfer for cabin heating. In this configuration, the RTG is mounted on top of the descent stage in an insulated enclosure which has one side open to space and another side open to an exposed portion of the ascent stage pressure vessel. An insulated hinged panel is placed in the enclosure between the RTG and the pressure vessel, and by varying the position of this panel, the amount of heat transferred to the cabin is controlled.

The analysis on the use of the pressure vessel for transferring heat from the RTG to the ascent stage cabin using the recommended heat pipe system is also valid for the alternate direct-radiation system. In the performance curves presented in Fig. 4.1-2, the cabin surface area can be considered to be the exposed pressure vessel area viewing the RTG.

4.1.6 Alternate Configuration - Radiators

An analysis was performed on four different types of radiator configurations for the 14-day manned phase of the Shelter mission. The following configurations were considered:

- Case a: Vertical radiators with shades (Fig. 4.1-5) placed on the descent stage at each of the four quadrants
- Case b: Geometrically Selective Radiators (GSR) placed on the descent stage at each of the four quadrants
- Case c: One GSR panel placed on the lunar surface with the optimum orientation
- Case d: Horizontal radiator placed on top of the Shelter.

The ground rules for the analysis were to hold the radiator inlet temperature of all configurations at 100°F and the water boiler outlet temperature at 40°F with a heat load of 1 kw. If a radiator outlet temperature was over 100°F, the radiator was bypassed. In Cases a and b, the radiators were connected in parallel. In Case a, normal vectors drawn from the radiator surface outward pointed in the north, south, east, and west directions and each radiator had a specific weight of 1.5 lb/ft^2. In Case b, the radiator planes were parallel to the lunar surface and pointed in the north, south, east, and west directions with a specific radiator weight of 3.0 lb/ft^2. In Case c, the GSR was carried away from the vehicle and placed on the lunar surface such that the plane of the Sun was always parallel to the longitudinal axis of the radiator. (The two-sided radiator faces north-south). Specific weight was 2.0 lb/ft^2. In Case d, the horizontal radiator was assumed inclined 20 deg to the lunar surface and the specific weight of the radiator was 1.0 lb/ft^2. The specific weights are conservative values.

Figure 4.1-9 shows a comparison of the sum of radiator weight and water weight required as a function of radiator area for the four configurations described. The lightest system is a 30-sq-ft GSR with a total weight of 60 lb. The next best configuration is Case b, with the four GSR Panels. The minimum weight is about 150 lb for 50 sq ft of radiator. Case d is also competitive from a weight standpoint; however, it requires an excessive horizontal area.

4.1.6.1 GSR Test Confirmation

A thermal vacuum test of a scaled model of a GSR is presently being conducted under Grumman Advanced Development funding. The purpose of the test is to demonstrate the operational feasibility of a GSR under simulated lunar environmental conditions, and to measure the performance of the model to evaluate the effectiveness of the parabolic specular reflector and the accuracy of the theoretical calculations. The present test is being conducted without solar simulation. Curves a, b, and c of Fig. 4.1-10 show the theoretical effects of the reflector specularity on the GSR radiator performance. These curves were extracted from Ref. 4.1-1. Curve a shows the net heat rejection of the GSR as a function of solar angle for a reflector with a specularity of 100%. Similarly, curves b and c show the heat rejection for 95% and 0% (perfectly diffuse) specularity. These curves are based on an effective radiator temperature of 65°F and an emittance of 0.86. The emittance of the reflector was 0.10. Figure 4.1-10 demonstrates the GSR performance dependence on high reflector specularity.

From the preliminary test results on the model GSR, the net heat rejection was determined and is shown in Fig. 4.1-10 as test points. These data points have not been corrected, and are therefore shown with a conservative tolerance band of ±10%. It should be noted that the emittance of the test radiator was 0.91, and this would tend to lower the test points about 5%. Figure 4.1-11 shows the actual test specimen being inserted in a vacuum chamber.

The design of the parabolic reflector is such that an IR ray emanating from the radiator is reflected into space. This is ray 1 in Fig. 4.1-12. Any incoming rays parallel to the radiator surface will be reflected to the focus of the parabolic reflector by virtue of the reflector geometry. In a realistic condition, the GSR could be aligned so that the lunar IR rays are parallel to or below the radiator surface and would therefore never fall on the radiator surface. These conditions are demonstrated by rays 2 and 3 of Fig. 4.1-12.

Figure 4.1-13 is a photo of the GSR scaled test model and is a visible demonstration of rays 1 and 2 of Fig. 4.1-12. Lunar rays parallel to the radiator surface were simulated by aligning the radiator surface parallel to the sun's visible rays. It can be seen in Fig. 4.1-13 that the sun's rays did not fall on the radiator. A visible demonstration of the manner in which this reflection occurs can be noted in the reflection on the white paper placed on a portion of the radiator. This shows that a ray coming from the radiator is reflected to space.

4.1.7 Alternate Configuration - Cryogenic Reactant Storage

A significant weight saving is afforded the Shelter if cryogenic tankage is used for fuel cell reactant storage. Estimates of tank weights and storage times have been made for the NAA AES tanks with added insulation. Figure 4.1-14 shows the system weight per lb of usable H_2 following 3- and 6-months storage periods, as well as the required insulation thickness. These studies are based on the results of Grumman insulation tests, NAA AES tank specifications, and Beech test data. The wet weights of all systems considered for both storage periods are presented below. The usable reactant weights are 43 lb of H_2 and 545 lb of O_2.

	3 months			6 months		
Configuration	H_2	O_2	ΔW*	H_2	O_2	ΔW*
Ambient tanks	720	1065	-	720	1065	-
AES (no insulation)	432	1040	313	System Inadequate		
AES (insulated)	403	1010	372	460	1100	225
Cryo tanks (new design)	350	760	675	410	800	575

* ΔW = Weight savings with cryogenic storage.

4.1.8 Discussion of Configuration Choices

4.1.8.1 Fuel Cells - Thermal Characteristics

4.1.8.1.1 General. The electrical power for the Shelter will be supplied by fuel cells of either the General Electric, Pratt & Whitney, or Allis-Chalmers design. Each of these systems has been evaluated with respect to heat generation characteristics, environmental temperature requirements, and storage and remote startup requirements. All three fuel cell designs have been found to be thermally compatible with the mission requirements of the Shelter.

4.1.8.1.2 Heat Generation. Hydrogen-oxygen fuel cell efficiency has a theoretical upper limit of 0.83 with the remaining energy of reaction appearing as heat. The practical efficiency of the fuel cell is governed by its polarization characteristics, which are different for each cell design but are sensitive to cell operating temperatures (the high-temperature cells tending to be more efficient). The heat generation characteristics of the A-C, GE, and P&W fuel cells are given in Section 5.1 with the 400°F P&W design being the most efficient, and the 205°F A-C design and the 120°F GE design decreasing in efficiency in that order.

4.1.8.1.3 Environmental Temperature Requirements. When operating in a vacuum, the GE and A-C fuel cells may be placed in thermal environments of -60 to 160°F and -120 to 185°F, respectively, without damage and without depending upon heat exchange with the environment for survival. The P&W fuel cell uses a radiant heat exchange with the environment to cool its control components and must therefore be placed in an environment between 30 to 130°F. The anticipated heat load from the P&W fuel cells to the ECS loop is 300 btu/hr per fuel cell, and results in a weight penalty to the Shelter ECS loop of 81 lb.

4.1.8.1.4 Remote Storage. The estimated environmental temperature requirements for non-operating storage of the GE, A-C and P&W fuel cells are 40 to 120°F, -30 to 185°F, and -20 to 130°F, respectively. The GE fuel cell is limited by water freezing on the lower end of its temperature range and a comparatively low stack temperature on the high end. The A-C fuel cell is assumed to be filled with an inert gas and is therefore capable of going below 32°F since there is no water present. The P&W fuel cell is stated as being capable of storage over 130°F without any specified upper limit, and it appears that levels as high as 200°F should be allowable. The temperature levels specified for all three fuel cells appear compatible with Shelter ascent stage locations. Alternate fuel cell locations in the descent stage will require active thermal control for GE fuel cells, because of their upper temperature limit of only 120°F, and would require heaters to maintain the low-temperature requirement of A-C and P&W fuel cells.

4.1.8.1.5 Remote Start-up. To start any of the three fuel cells on the lunar surface remotely, they must first be brought up to their stack operating temperatures. The energy required to bring the A-C and GE fuel cell systems (2 A-C fuel cells and 4 GE fuel cells) is about 1 kw-hr, if an initial 70°F environment is assumed. The P&W fuel cells would require about 4 kw-hr, if warmed up from the same 70°F environment.

4.1.8.2 Quiescent Storage - Thermal Control Tradeoff

Studies conducted during Phase A established that quiescent storage during lunar night represented the most severe of all the Shelter mission phases. This results because the electrical equipment power dissipated within the cabin during the storage mission is not enough to replace the passive heat loss from the Shelter.

The two approaches to solving the night heating problem of the Shelter during storage are to either add insulation to the structure, thereby reducing the heat leak, or to have larger power supplies to replace the passive heat loss. Therefore, a basic tradeoff exists between the addition of insulation to the Shelter structure and the addition of thermal energy sources for night mission heating.

The following changes to the insulation level of the LEM are considered for the Shelter:

- Change 1: LEM insulation level and an automatically deployed insulation cover over the top tunnel; weight estimate of tunnel cover is 10 lb
- Change 2: Change 1 plus manually deployed insulation covers on the cabin side of the windows; weight estimate for window covers is 10 lb
- Change 3: Change 2 plus the addition of 75 layers of NRC-2 insulation to the existing 25 layers on the ascent stage external skins; weight estimate of 75 layers of insulation is 87 lb
- Change 4: Change 3 plus manually deployed insulation covers for each RCS cluster; weight estimate of RCS covers is 40 lb.

Two sources of thermal energy are considered for heating the Shelter during the night mission. These sources and an estimate of their power/weight ratio are:

- RTG electrical energy, 1.0 w/lb
- RTG thermal energy (waste heat), 5.0 w/lb.

It is recognized that the power output of the thermal energy sources does not increase linearly with weight but rather in stepwise manner; however, for this analysis the linear relation was used.

Figure 4.1-15 shows the weight of added insulation and also the total weight of added insulation and power supply for the two power systems considered, as a function of required heater power. This figure shows that using waste heat from the

RTG for night mission heating results in the lightest total weight of added insulation and power supply. Moreover, for a particular power supply, the optimum weight of added insulation increases as the weight of the power supply increases.

Since the recommended Shelter uses RTG thermal energy for night heating, there is no unique optimum insulation level. This is shown in Fig. 4.1-15 where it can be seen that the total weight of added insulation and power supply is the same for the LEM insulation level as it is for the insulation levels with added docking tunnel cover and with added window covers.

An additional factor, which influences the tradeoff between extra insulation and additional active heat sources, is the reduction in the weight of boil-off water required for cabin cooling during a day mission resulting from the addition of insulation.

Based on an evaluation of these factors influencing the insulation level weight tradeoff, it is recommended that the top tunnel insulation, the window shades, and the ascent stage insulation be used for the recommended Shelter configuration.

4.1.8.3 Transient Analysis of Storage Phase

The estimated heating and cooling loads for the ascent stage given in Paragraph 4.1.3 are based on steady state conditions which are valid if the vehicle has no appreciable heat capacity, and if the entire vehicle structure located within the insulation blanket is at a uniform temperature. No allowance is made for the stabilizing effect of the vehicle mass absorbing or releasing appreciable quantities of heat as the cabin temperature varies within its acceptable limits. The vehicle heat capacity prevents rapid temperature changes of the cabin, and thereby constitutes an element of conservatism in the estimated heating and cooling loads.

The transient response of a simplified model of the ascent and descent stages of the Shelter during the quiescent storage phase has been determined using a digital computer program. The model reduces the descent stage to 22 uniform temperature elements, and the ascent stage to 11 elements. The elements chosen for the computer model are those vehicle components having the most significant influence on the vehicle transient response. Among the vehicle elements included in the simple model are: the exterior surfaces, ascent and descent stage structure, fuel cell reactant tanks, water tanks, and descent propulsion engine. The ascent cabin structure accounts for three of the ascent stage elements. These include the cabin pressure vessel forward of the +Z27 bulkhead, the pressure vessel and structure located between the +Z27 and -Z27 bulkheads, and the structure and equipment located in the aft equipment bay. The thermal model accounts for heat transfer between the ascent and descent stages, and between the Shelter external skins and the lunar environment. The influence of both the RCS clusters and the docking tunnel on the ascent stage balance is also included in the computer program. The range of thermal environments the Shelter can encounter, during a normal 3-month lunar surface storage mission, is sufficient to vary Shelter component temperatures beyond their allowable limits. Therefore, transient analysis of this mission phase has been performed to determine active thermal control requirements. It has been assumed that limiting the allowable range of cabin structural temperature between 40 to 130°F will hold the temperature variations of most of the Shelter subsystems and components within their allowable limits. Separate active temperature control systems will be provided for the components and subsystems which the cabin temperature control system cannot stabilize. These special thermal control systems were discussed in Paragraph 4.1.3.5.

Figure 4.1-16 shows the transient thermal response of the ascent and descent stage structure during the 3-month storage. The structure starts the storage mission at a uniform 70°F temperature, and the external environment corresponds to the start of lunar night. Initially, no heat is supplied to the ascent stage cabin until its temperature drops to the minimum allowable 40°F. At this temperature, sufficient heat is supplied to the cabin to stabilize its temperature for the remainder of the night portion of the cycle. In a similar manner, no active thermal control is provided until the cabin structure falls to 40°F during each successive lunar cycle. The dashed line continuation of the first cycle cooling curve in Fig. 4.1-16 shows the ascent stage temperature history for the remainder of the storage mission, if no heat is supplied to the cabin.

The temperature response of the descent stage structure shown in Fig. 4.1-16 is essentially the same regardless of whether the ascent stage is heated or not. The maximum and minimum temperatures, during the storage mission of the ascent and descent stage structure, for both the heated and unheated cabin are presented below:

	Ascent Structure		Descent Structure
	Cabin Heated	Cabin Unheated	
Max Temp (°F)	86	70	70
Min Temp (°F)	40	-13	-53

The descent stage structural temperature is close to the temperature of the batteries, water tank and GOX tank located in that stage. Since the descent stage low temperature exceeds the allowable low temperature limit of the water and batteries, special active thermal control systems are required for these elements (Paras. 4.1.3.5.3 and 4.1.3.5.4).

Additional investigation was undertaken to determine the active thermal control requirements during the daytime part of the storage mission. The ascent and descent stage temperature histories, during a day-night cycle with a constant 45-w heat dissipation within the cabin, are shown in Fig. 4.1-17 for initial temperatures of both 70 and 90°F. The resulting maximum and minimum structural temperatures for this analysis are:

	Ascent Structure		Descent Structure	
Initial Temp (°F)	70	90	70	90
Max. Temp (°F)	127	136	82	92
Min. Temp (°F)	48	50	-23	-20

Since the vehicle temperatures at the end (night) of the first cycle, which correspond to the vehicle temperatures at the start (day) of the second cycle, are lower than the initial temperatures, subsequent cycles will always be colder than the initial cycle. Therefore, analysis of the day storage mission is confined to the first day-night cycle. Although the maximum ascent stage temperature slightly exceeds the allowable 130°F temperature, for the case when the Shelter lands at 90°F at the dawn terminator, no allowance is made for active cooling of the cabin. It is assumed that either the cabin will be allowed to exceed the 130°F for a brief time during the first cycle, or the initial temperatures at the start of the lunar surface phase will be less than 90°F.

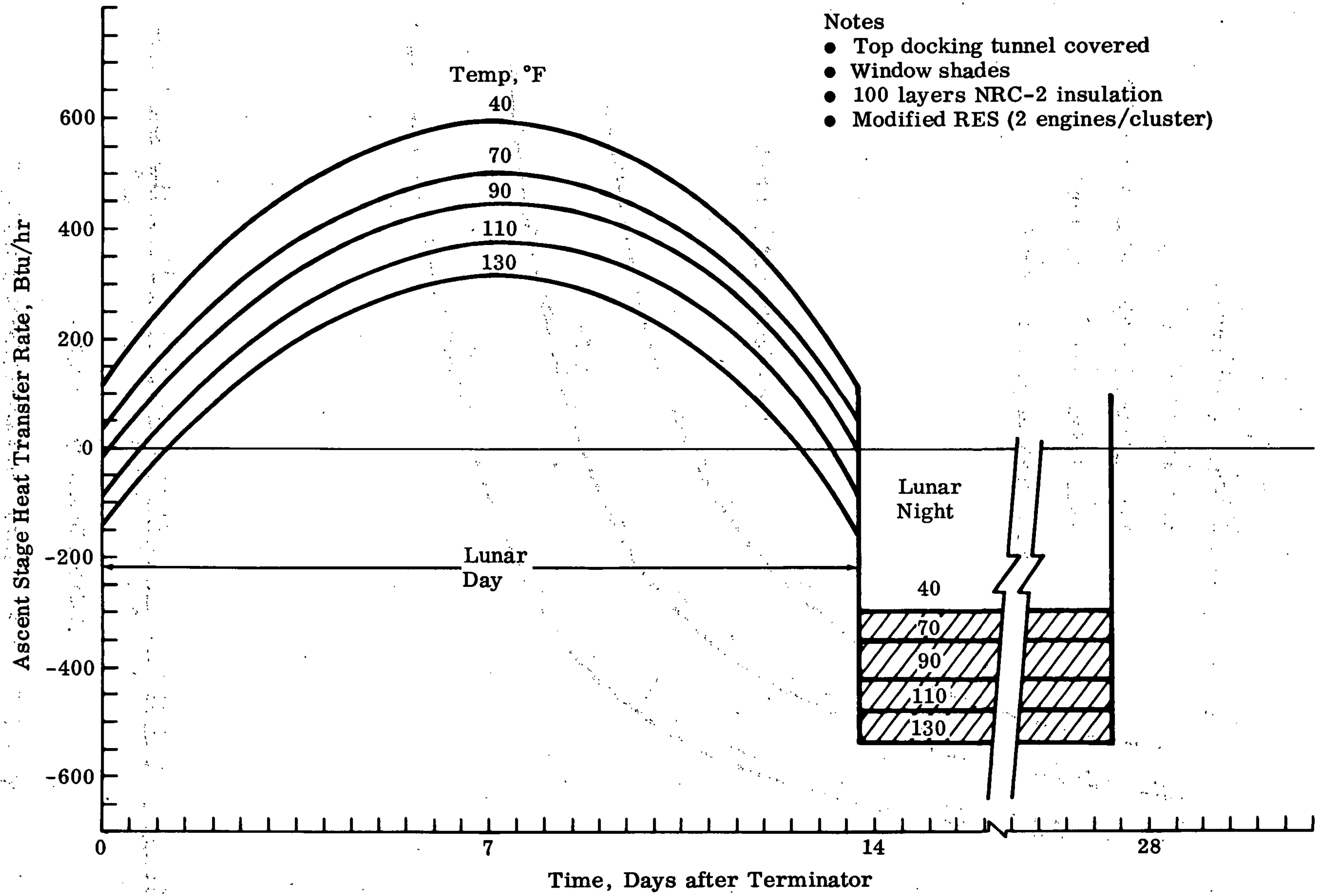


Fig. 4.1-1 Thermal Characteristic of Shelter - Asc. Stage

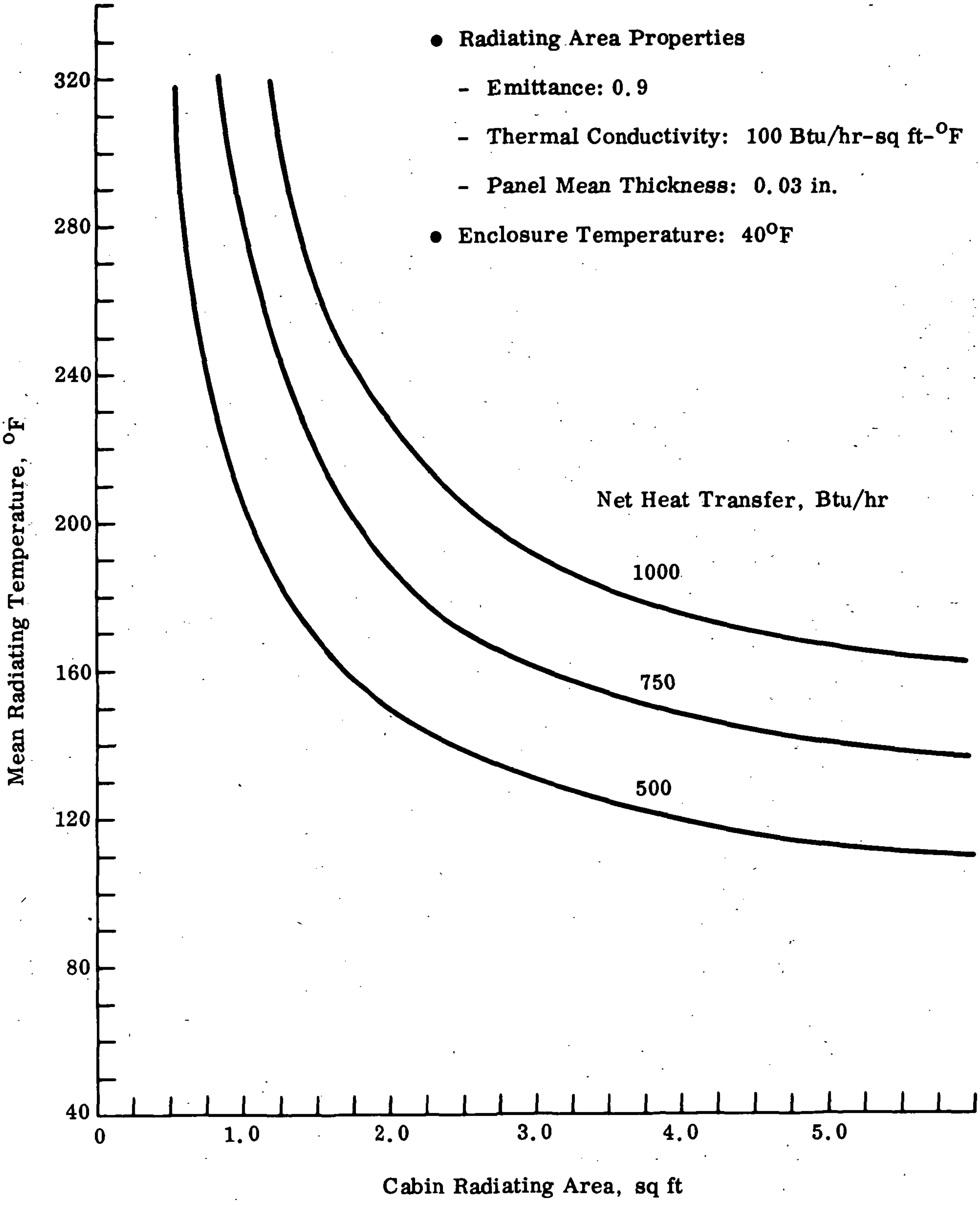


Fig. 4.1-2 Cabin Radiant Heat Transfer Capability

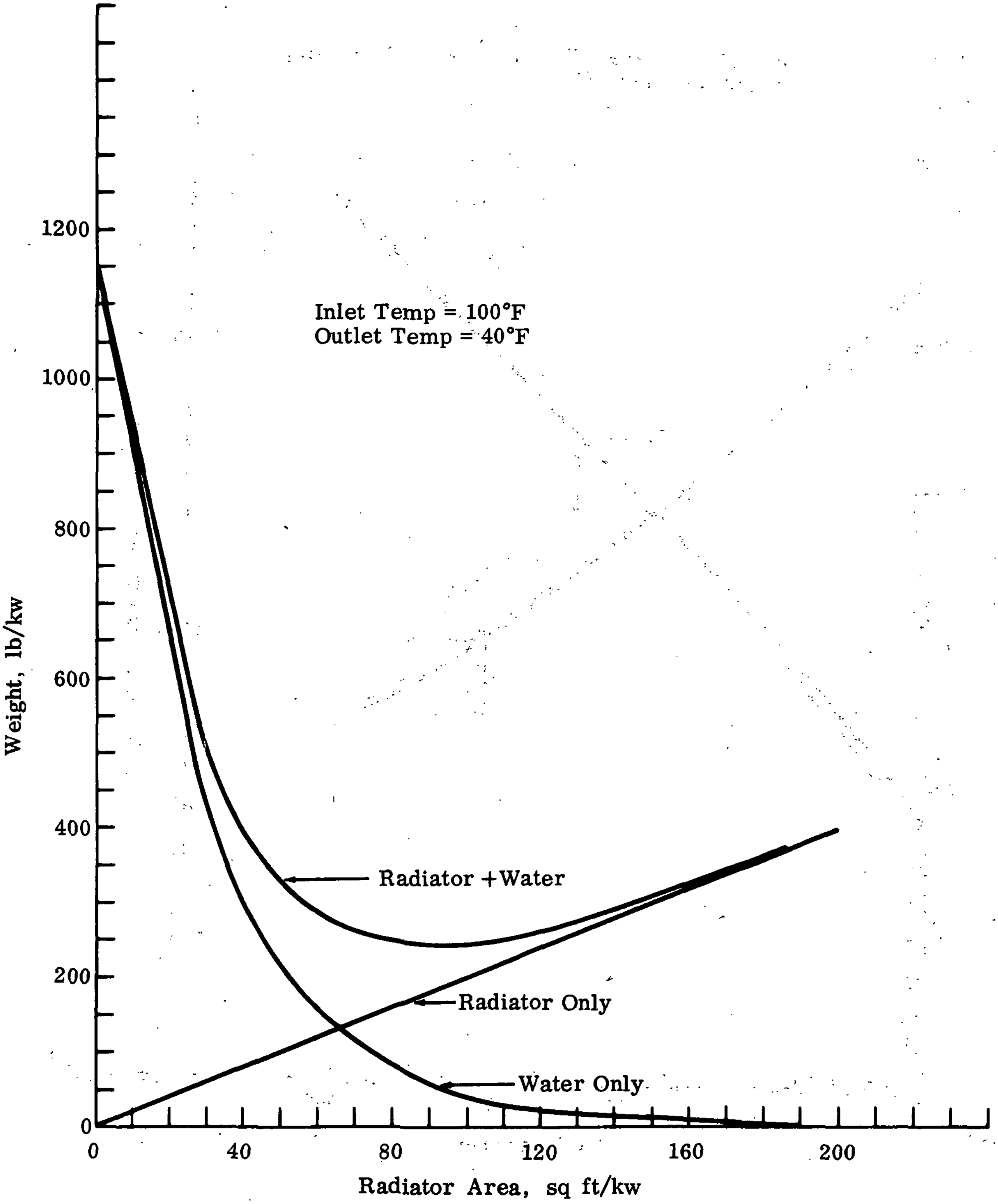


Fig. 4.1-3 Horizontal Radiator Optimization

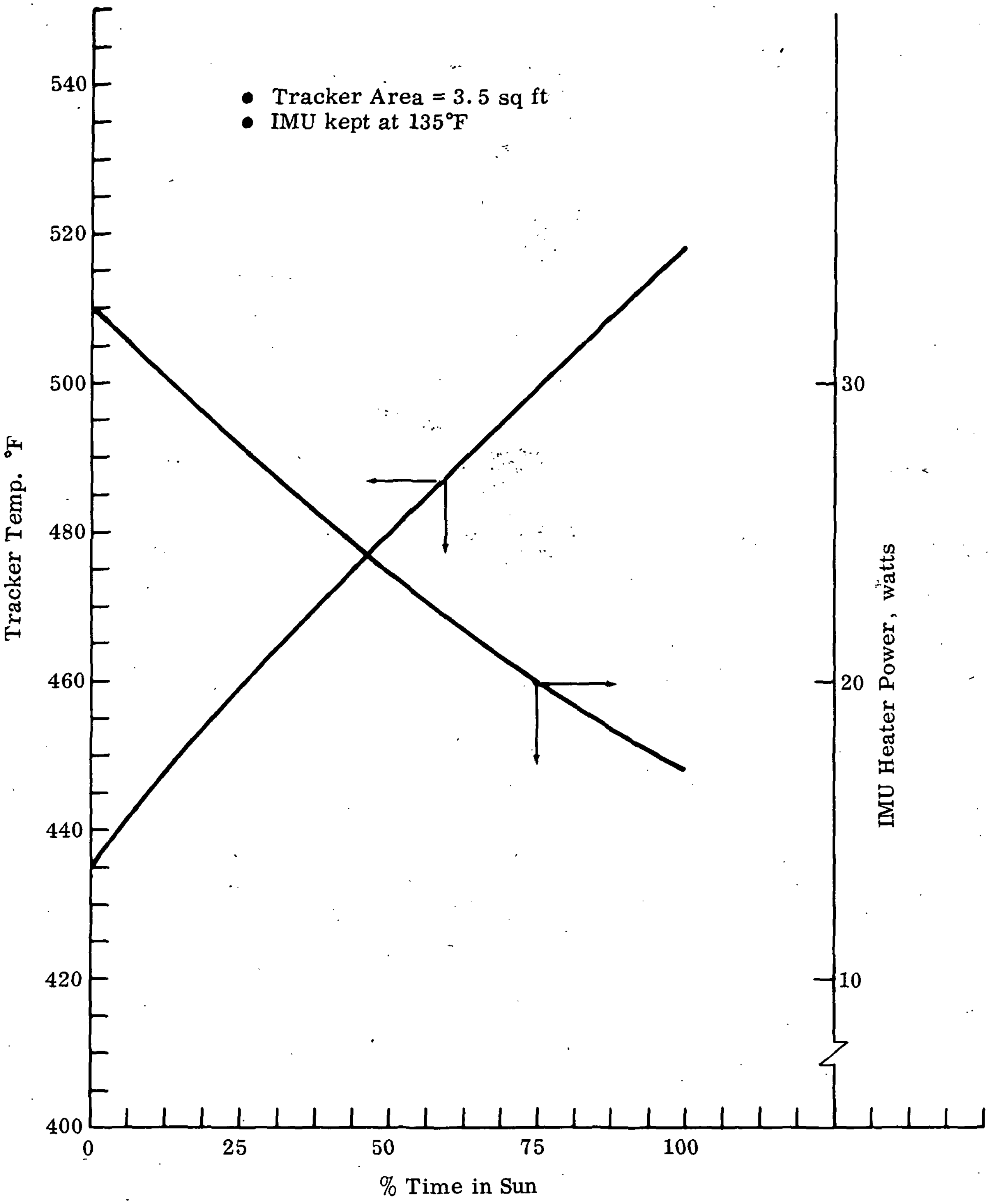
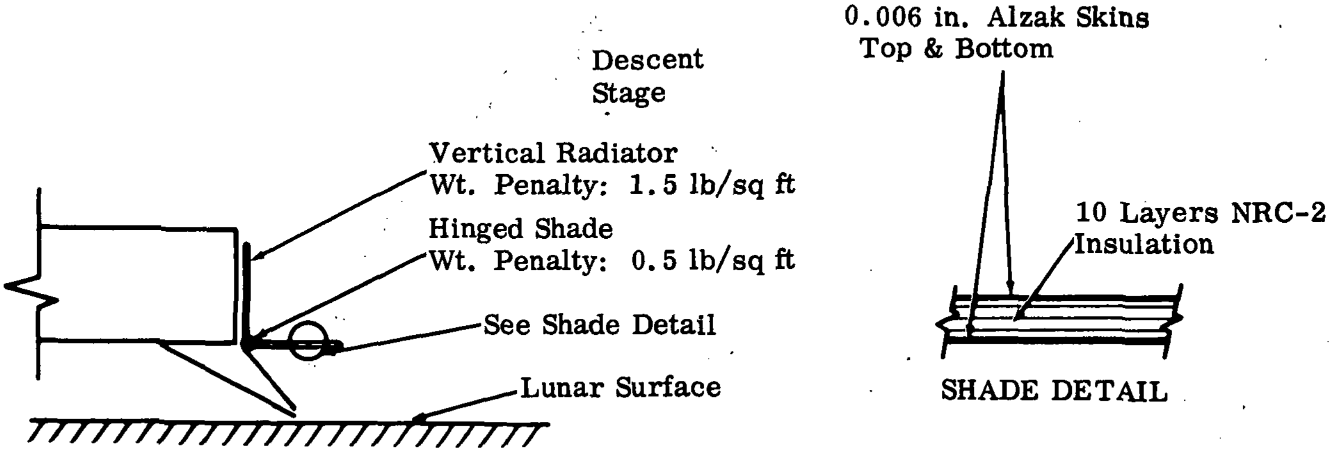


Fig. 4.1-4 Star Tracker Thermal Characteristics



Area of shade = Area of radiator

Alzak Properties
$\alpha = 0.15$
$\epsilon = 0.75$
Specular Reflector in
Visible & Infrared wavelengths

Fig. 4.1-5 Vertical Radiator Shade Configuration

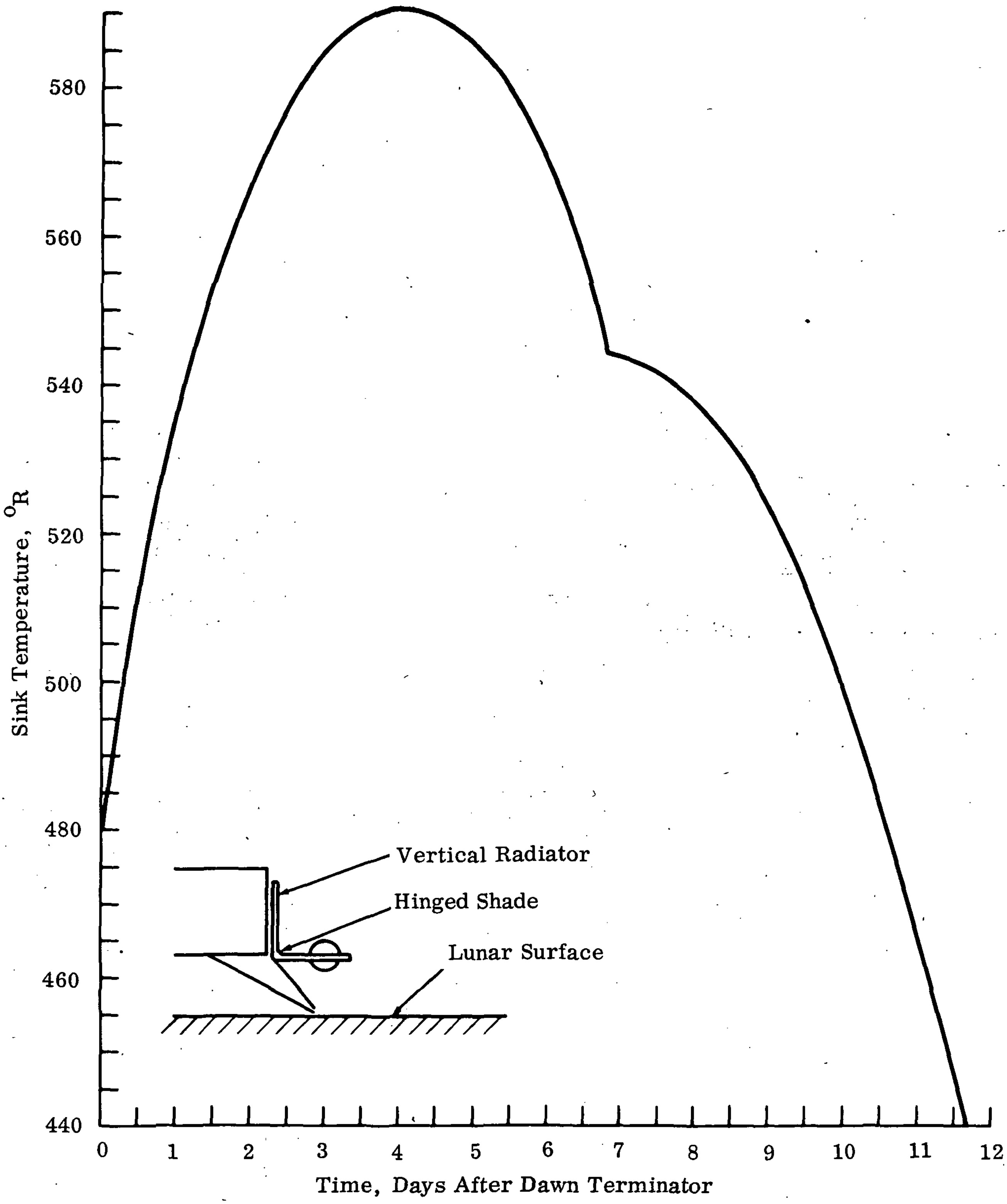


Fig. 4.1-6 EPS Radiator - Sink Temperature

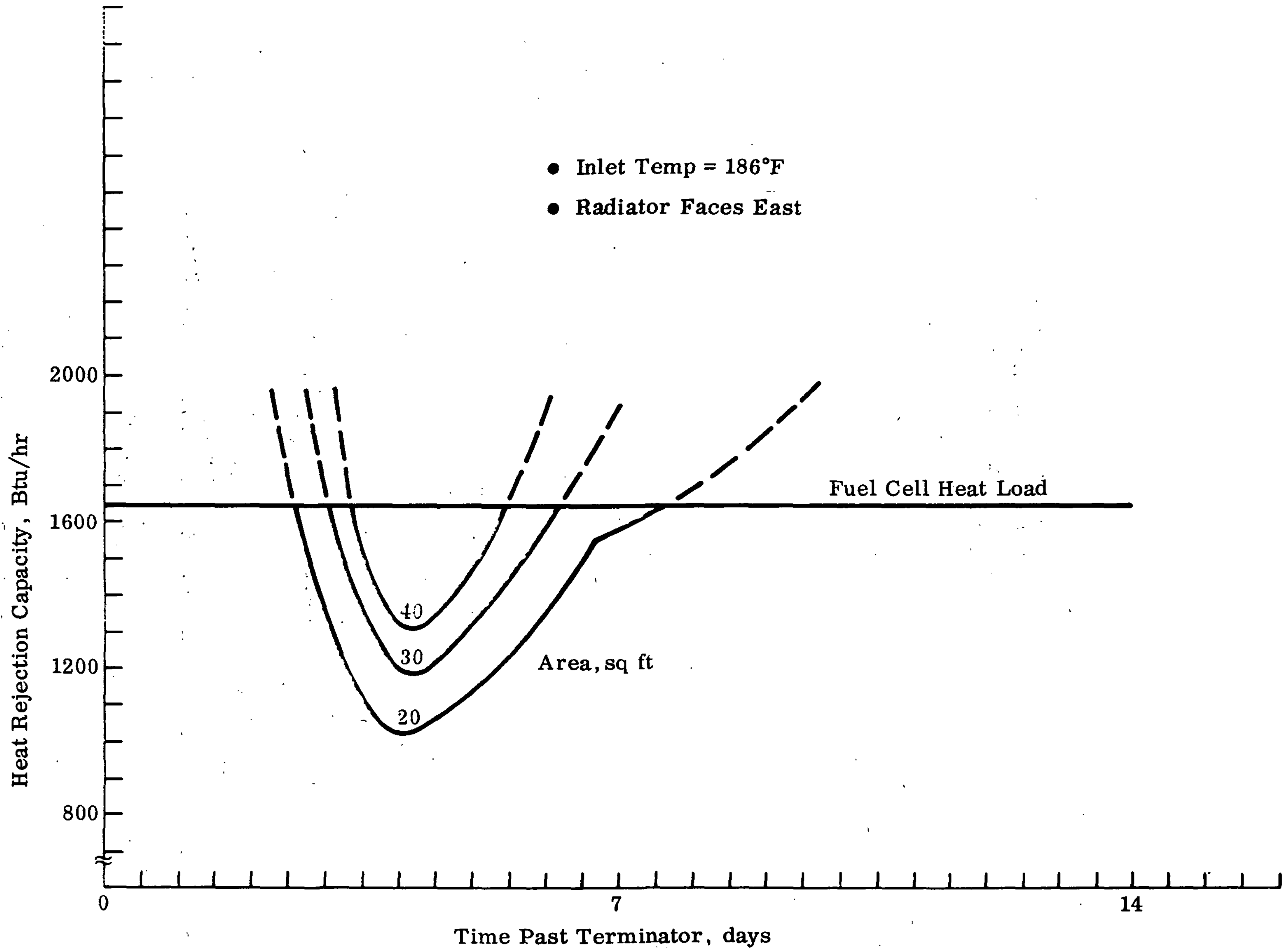


Fig. 4.1-7 EPS Radiator - Heat Rejection Capability

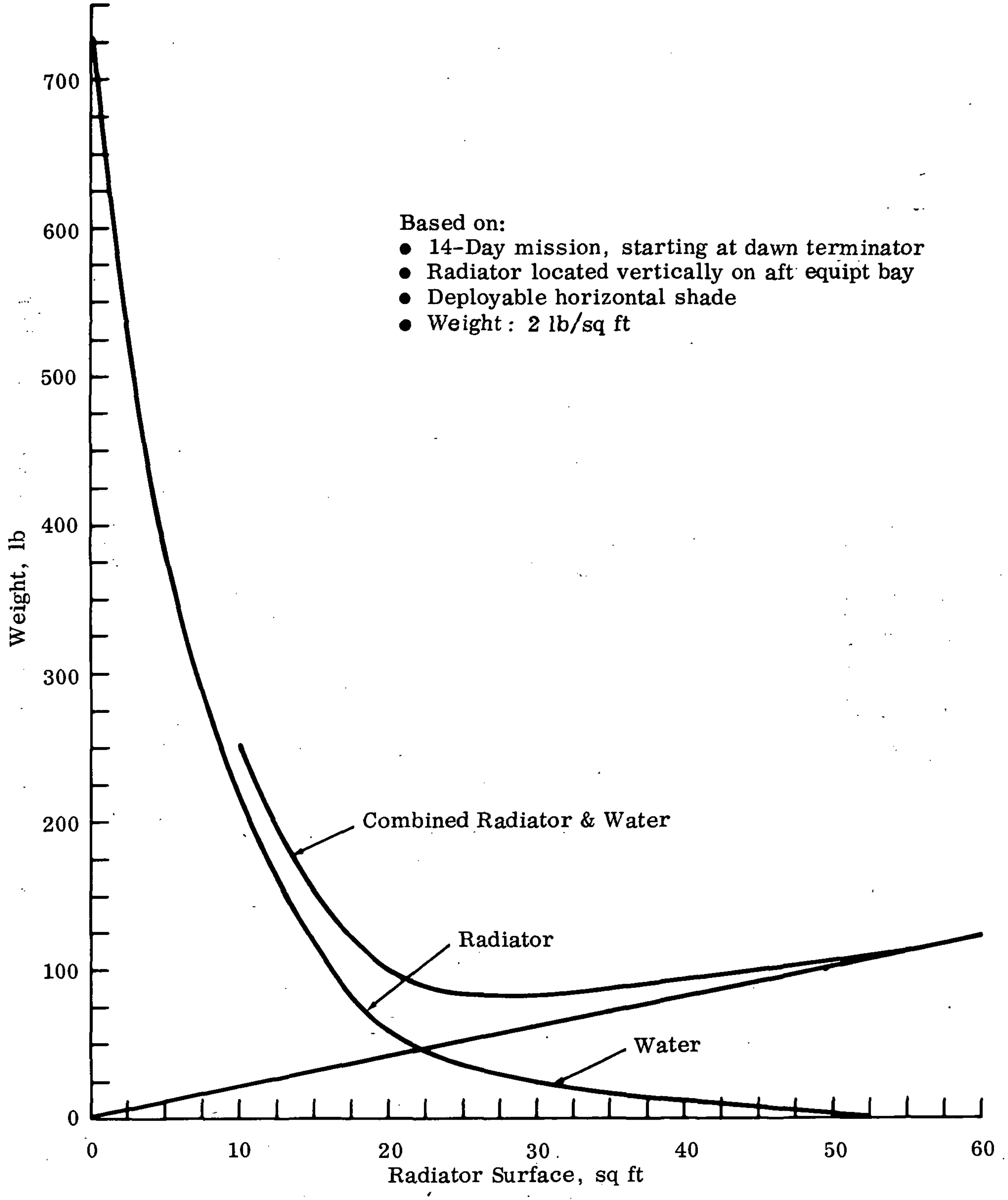


Fig. 4.1-8 Vertical Radiator Optimization

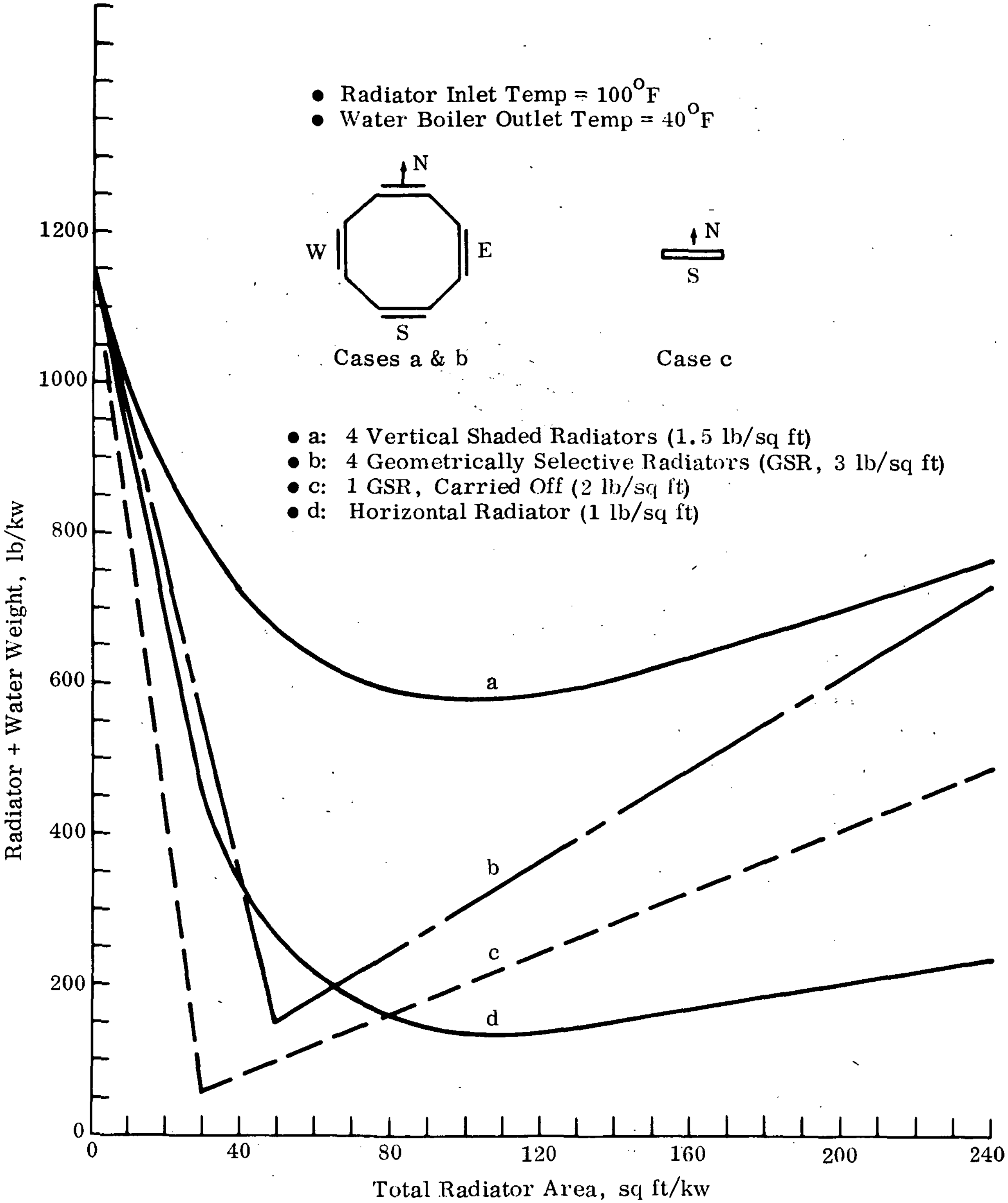


Fig. 4.1-9 Alternate Radiator Configuration - System Wt.

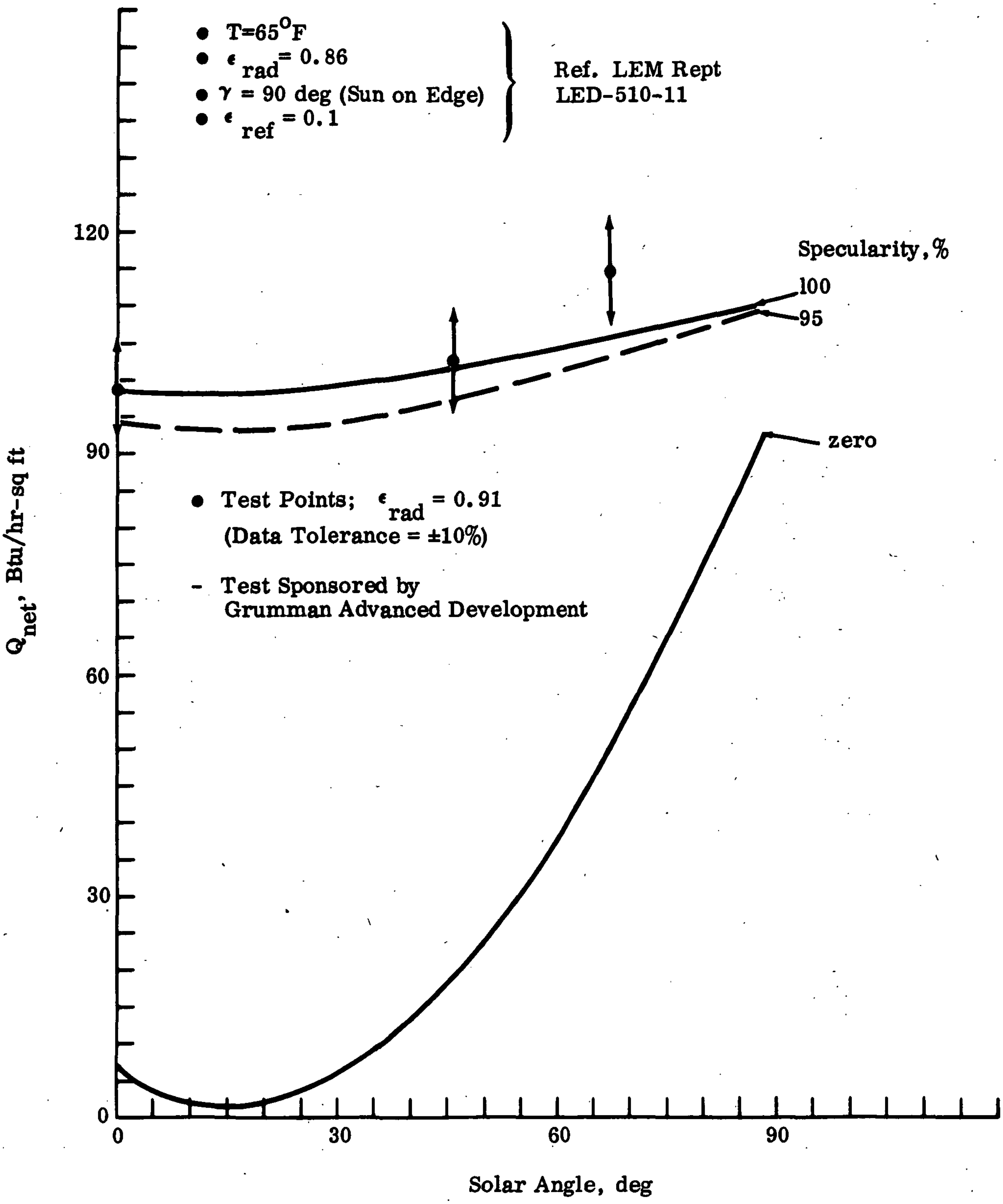


Fig. 4.1-10 GSR Performance Characteristics

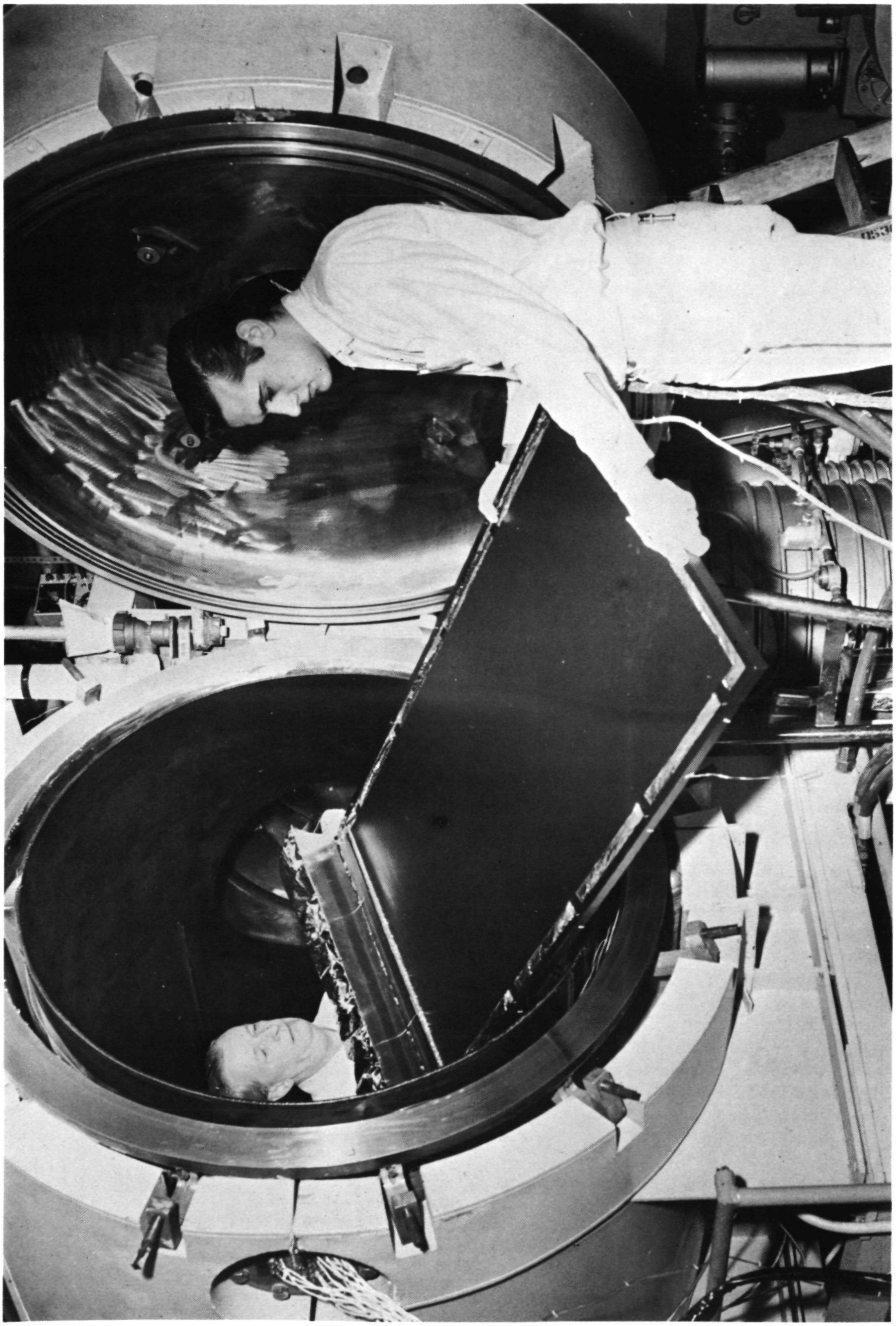
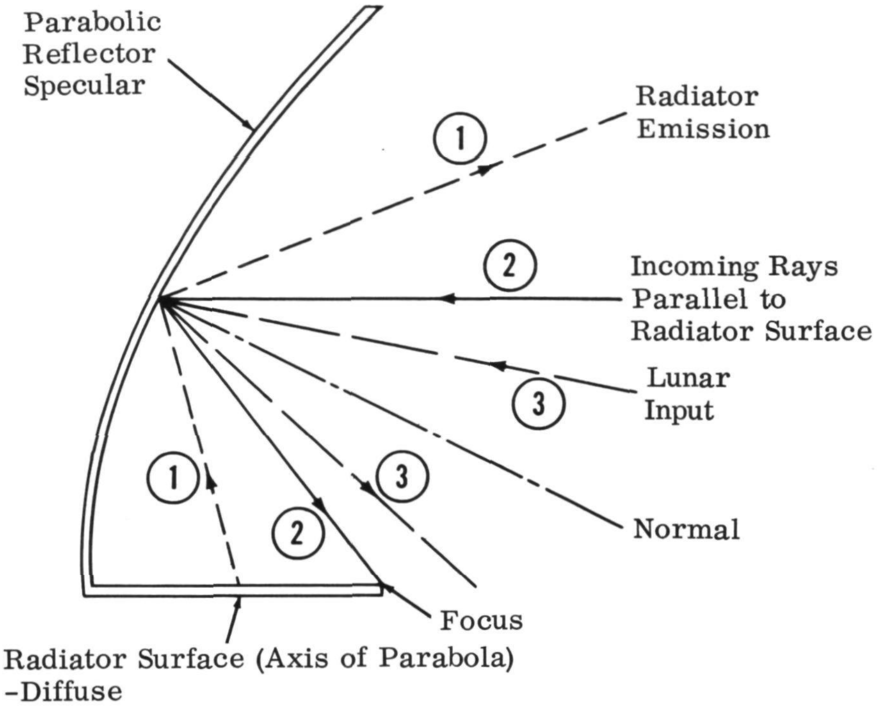


Fig. 4.1-11 GSR Test Assembly



Radiation Emanating from the Focus and Impinging on the Parabola is Reflected Parallel to the Axis.

Fig. 4.1-12 GSR Principle of Operation

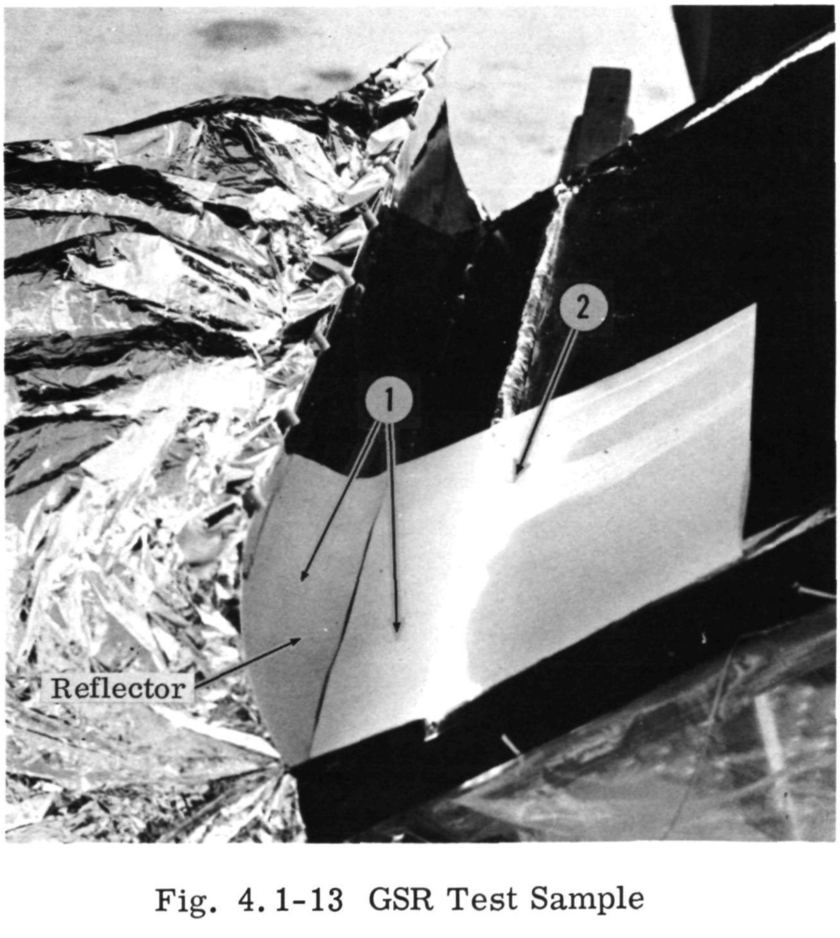


Fig. 4.1-13 GSR Test Sample

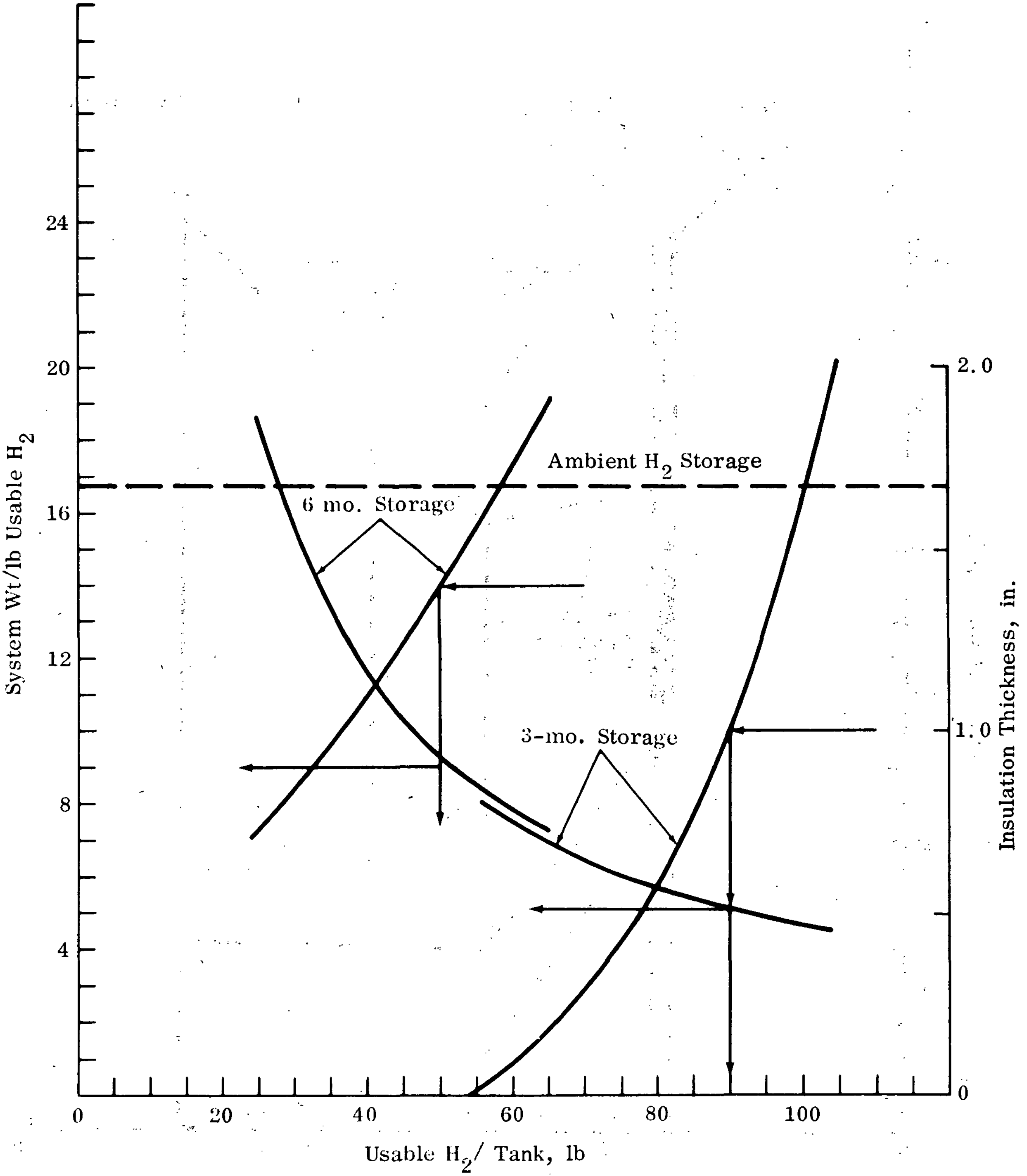


Fig. 4.1-14 Storage Capability - AES H_2 Cryo Tank

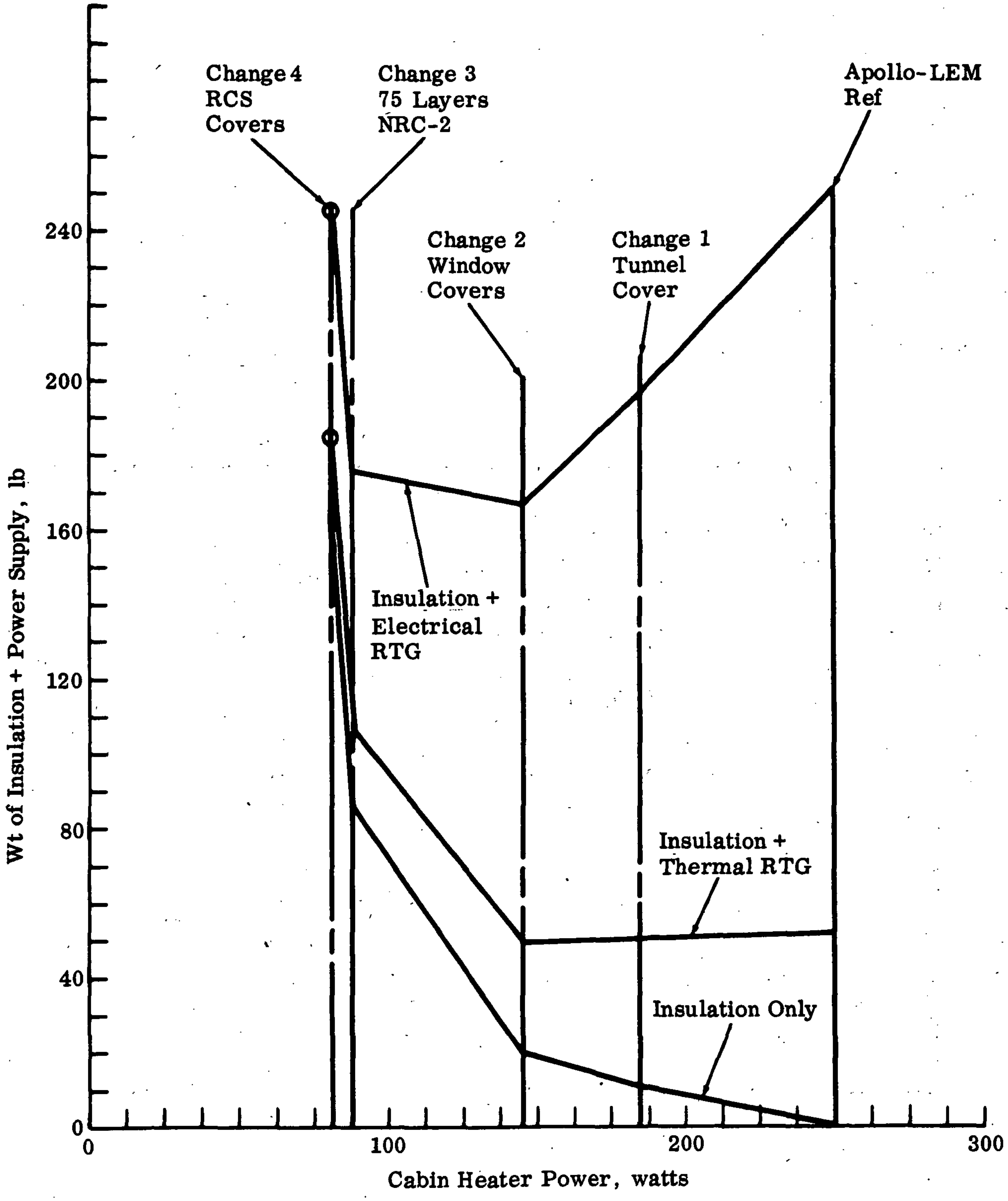


Fig. 4.1-15 Insulation/Heat Source Relationship

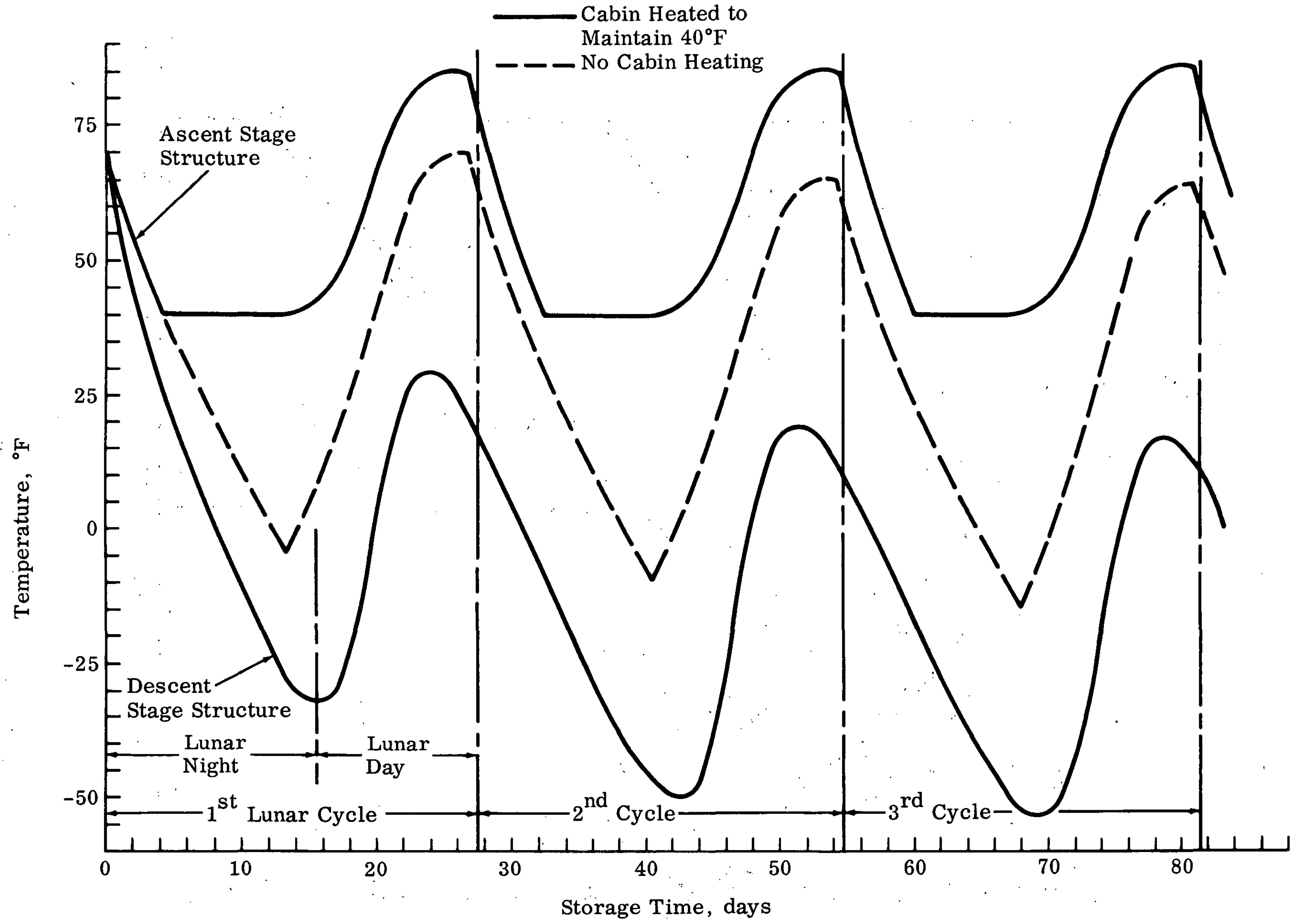


Fig. 4.1-16 Structural Temperature - Quiescent Storage

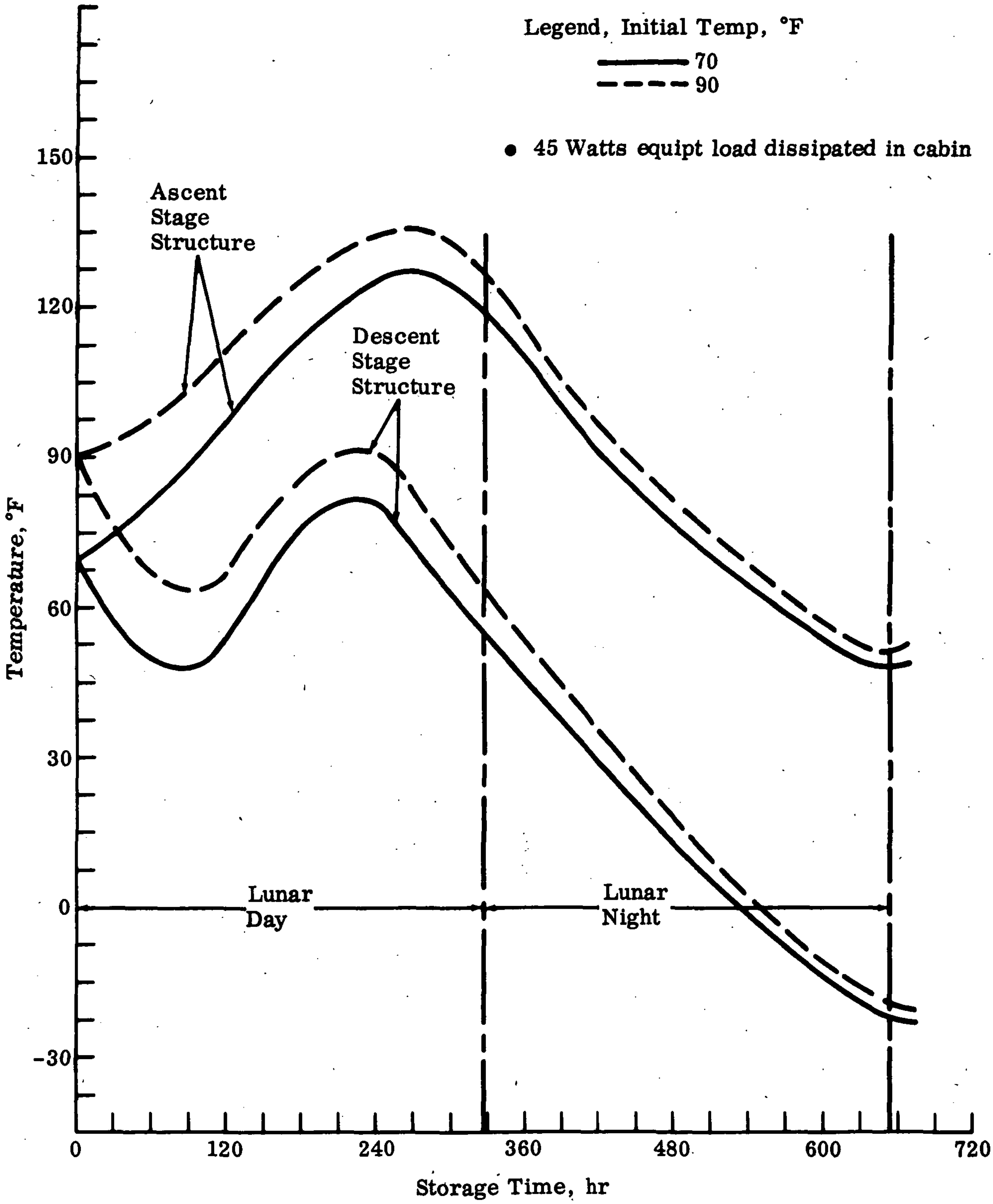


Fig. 4.1-17 Structural Temperature - First Day/Night Cycle

4.2 INTEGRATED GUIDANCE & CONTROL

4.2.1 Ground Rules

The following ground rules were applicable to this area:

- Shelter shall have the capability to make a preprogrammed unmanned automatic landing using the PNGCS
- Design for an 80-n.mi Hohmann trajectory; study effects of direct descent trajectory

4.2.2 Direct Descent vs Hohmann Transfer

Figure 4.2-1 is a comparative time line of the major GN&C events associated with the two descent techniques considered here. The following advantages can be gained from the direct descent:

- Lower CEP at landing (decrease in position uncertainty)
- Higher reliability (decrease in probability of GN&C system failure)
- Fewer major GN&C events (4 as opposed to 7)
- Fewer descent propulsion system (DPS) ignitions (1 as opposed to 2)
- Flexibility to effectively use AOT and MSFN update via voice link prior to separation and descent to the lunar surface.

The advantages of the Hohmann technique as compared to the direct are as follows:

- Minimum change to current LEM GN&C guidance equations (software)
- Maximum effective use of the auto-startracker concept in the Shelter mission
- Shelter will be visible to the CSM at touchdown (of questionable value).

In computing the CEP, the uncertainties resulting from the MIT Model 4 orbit navigation scheme as applied to the nominal LEM Hohmann descent was used for the initial condition uncertainties (position and velocity) of both trajectories. This assumption is conservative in estimating the CEP for the direct descent technique, but is an accurate measure for the Hohmann technique. If sufficient time exists between the time at which the CSM/Shelter establishes LOS with the Earth and initiation of the powered descent, additional landmark sightings or MSFN updating via the voice link could significantly decrease the CEP numbers for the direct descent technique. Thus, additional potential for improving the accuracy of the GN&C Subsystem do not exist for the Hohmann approach without modifying the uplink capabilities of the PNGCS to allow automatic update. It is the access of the crew to the Shelter before powered descent (up to approximately 5 min prior to engine ignition) that provides the desired flexibility in the direct descent approach. Preliminary reliability figures (0.99335 for direct descent, and 0.99159 for Hohmann descents) were computed by using the failure rates of the current LEM GN&C components. The addition of an auto-startracker to the Shelter, for purposes of performing the Hohmann descent, will reduce the reliability and make the percentage decrease in failure between the descent techniques more significant. While numbers are not provided here, the overall reliability of the equipment will improve, since the operating time of all equipments will be reduced for the direct powered descent trajectory.

The errors in velocity to be expected at touchdown and the time at which the DPS will be performing at high-thrust levels will be approximately the same for both techniques.

4.2.2.1 Δ V Requirements

Figure 4.2-2 indicates the minimum ΔV required to perform the Shelter landing using either a direct powered descent or a Hohmann transfer technique, as a function of CSM parking orbit altitude. The ΔV numbers used to generate this figure were taken from Ref. 4.2-1 and 4.2-2 assuming an initial T/W of 0.323. It should be noted that these ΔV numbers represent the minimum fuel expenditure required to perform a braking maneuver between two specified conditions of position and velocity. Additional fuel expenditure will be required over and above that quoted in Fig. 4.2-2 to provide flexibility for guidance and control uncertainties and operational requirements.

Typical ΔV expenditures for Hohmann and direct descents, including allowances for performing a direct descent from 20 n.mi are 5919 and 6017 fps, respectively. (Note that these figures exceed those shown in Fig. 4.2-2 by the amount of allowance made for contingencies - relative values are not affected, nor are the resulting conclusions different).

Compared to the current LEM Hohmann approach (i.e., transfer from 80-n.mi to 50,000-ft pericynthion altitude), a direct descent from 20 n.mi will save approximately 100-fps ΔV in the LEM budget. To achieve a comparable Shelter ΔV savings using the Hohmann technique, the parking orbit altitude must be lowered to 44 n.mi. The SPS ΔV required to lower the CSM parking orbit from 80 to 20 n.mi during insertion from the translunar trajectory, would be approximately 37 fps. The additional SPS propellent requirement is available from the 680-fps ΔV allocated for CSM rescue of LEM (Ref. 4.2-3). In the Shelter mission, no CSM rescue requirements are foreseen, and therefore these additional propellants should be available for modifying the mission to increase Shelter payload.

A direct descent from 20 n.mi would require approximately the same engine duty cycle as that for an 80-n.mi Hohmann descent. A unique advantage of the direct approach is the requirement for only one-engine ignition, as opposed to two required in the Hohmann approach.

4.2.2.2 Guidance

To determine the CEP attained by the 80-n.mi Hohmann descent, using an AST, a statistical error analysis was performed along the Shelter descent trajectory. The statistical analysis included the effects of the 1σ uncertainties of the IMU, the LR, and the 1σ uncertainty involved in the CSM orbit navigation technique. Based on this analysis, it was found that the CEP for the 80-n.mi Hohmann descent was 2704 ft. The CEP was composed of a downrange uncertainty of 3799 ft (1σ) and a and a track 1σ uncertainty of 792 ft (1σ).

In addition to CEP, a determination of the thrust and attitude deviations commanded by the guidance law to correct the trajectory was made. Figure 4.2-3 is a time history of thrust deviations. This figure also shows a time history of pitch and yaw attitude deviations during powered descent. Both curves show that the thrust and attitude deviations are within the capability of the vehicle performance, i.e., a) the maximum 1σ thrust command uncertainty was 134 lb of thrust at a time the throttle was set at 9888 lb (max thrust possible is 10,500 lb); and b) the maximum attitude deviation was 2.8 deg at a rate which is possible to compensate within the vehicle rate limit of 10 deg/sec. Examination of Fig. 4.2-3 and 4.2-4 shows a 10-sec region between the end of Phase 1 radar update and start of Phase 2 radar update. The reason for this gap is that as the velocity-to-be-gained to reach the end conditions goes to zero, the attitude commands become extremely large. Therefore, a constant attitude phase is shown at the end of each phase to avoid erratic attitude commands.

For comparison purposes, an analysis was made of a descent from an 80-n.mi CSM parking orbit which used the AOT for a manual fine alignment of the IMU prior to separation of the LEM from the CSM. It was assumed that the uncertainty in the stable member alignment was 5 arc-min, and that no realignment was performed after separation. All other uncertainties were the same as the AST case above. For this descent, the CEP was 3319 ft.

An error performance analysis was made for the 20-n.mi direct powered descent based on the following assumptions:

- Manual alignment via AOT (coarse and fine) prior to CSM separation per basic LEM requirements spec LPS-470-2A
- Powered descent maneuver and guidance law for powered descent similar to that for powered descent portion of Hohmann transfer trajectory.

The computer value of CEP for the 20-n.mi direct descent was 1982 ft. This represents a considerable improvement over the value computed using the Hohmann transfer prior to powered descent.

4.2.3 Eight vs Sixteen Jets RCS

The 16-jet RCS configuration for the LEM provides optimum performance and reliability for all requirements of the manned mission. The abort consideration calls for torques requiring four-jet control about certain axes in contingency situations, and (manual) handling quality considerations play a major role in establishing the need for and location of the 16 jets. However, for the Shelter, neither abort nor handling qualities considerations are applicable. Two-jet rotational control can adequately meet dynamic control requirements. Translation is required only along the vehicle X-axis for separation and ullage. Thus, the possibility of using a single system with eight RCS jets becomes a feasible configuration, if reliability is not degraded and other mechanization changes necessitated do not outweigh the savings resulting from the RCS simplification.

Table 4.2-1 presents the operational capability of various 8-jet RCS configurations. All possible combinations of the jets lying in the Y-Z plane were considered, assuming removal of the eight System-A jets (Fig. 4.2-4). Note that removal of System B would result in the same control capability because of symmetry.

When one system of eight jets is removed, there are only four jets lying in the Y-Z plane, each of which can have two possible locations. Therefore, there are 16 possible Y-Z RCS jet configurations. Only 15 combinations are given in Table 4.2-1, because rotating all four jets simultaneously to their alternate positions yields the existing System-A RCS configuration.

From Table 4.2-1 it, is apparent that full capability is available for response to pitch (q), roll (r), and X translation commands if System A is removed. It is also apparent that full capability cannot be generated by any possible configuration of the four jets lying in the Y-Z plane. However, response to yaw (p) and Y or Z translation commands can be performed, thus all Shelter functional requirements can be satisfied.

Since a requirement for Y or Z translations does not exist for the descent trajectory, rotation of jet 7 to 8 and jet 3 to 4, or rotation of jet 12 to 11 and 16 to 15 will yield satisfactory performance during descent. However, it should be noted that failure of a single X-aligned jet will preclude completion of the Shelter mission, if any of the eight-jet configurations are used.

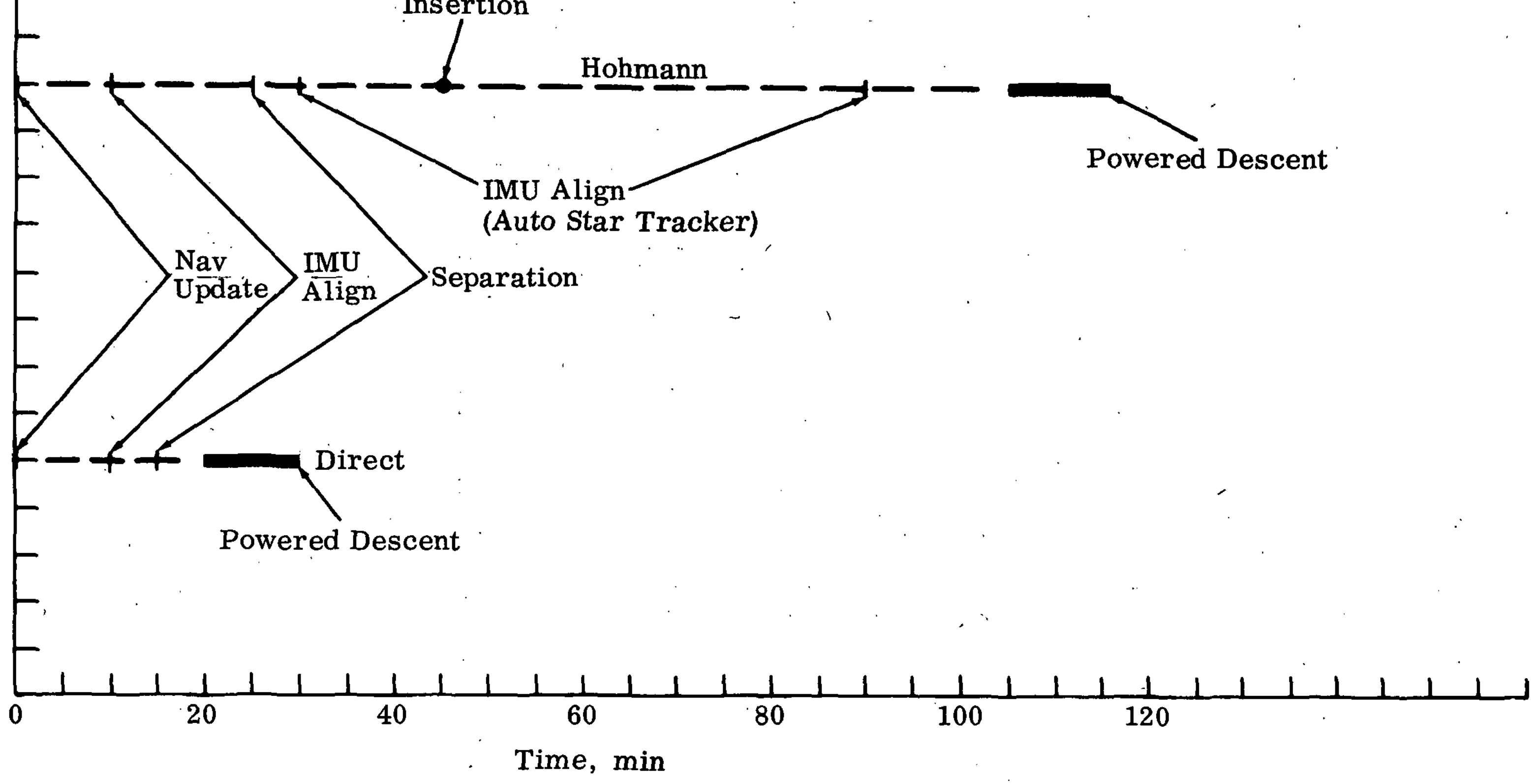
Reliability analyses have indicated very little advantage for the 16-jet configuration over an eight-jet configuration. However, going to eight jets may require modification of jet logic (software). The ability to use alternate jet combinations in the 16-jet configuration requires the ability to detect jet failures and select alternate paths, either manually or automatically. This requires a more thorough failure effect analysis than has been performed to date.

Table 4.2-1
OPERATIONAL CAPABILITY - 8 JET RCS

Rotation or Translation Commanded	Exist'g Posit'n	Rotate Jets from____ to____													
		7 to 8 3 to 4	7 to 8 16 to 15	7 to 8 12 to 11	3 to 4 16 to 15	3 to 4 12 to 11	12 to 11 16 to 15	7 to 8	3 to 4	16 to 15	12 to 11	7 to 8 3 to 4 16 to 15	7 to 8 3 to 4 12 to 11	7 to 8 16 to 15 12 to 11	3 to 4 16 to 15 12 to 11
		Jets Used to Accomplish Rotation or Translation													
Q1	(9,14)														
Q2	(1,6)														
R1	(14,1)														
R2	(9,6)														
X1	(6,14)														
X2	(1,9)														
P1	NPC	(3,12)	NPC	NC	(7,16) or (3,12)	NPC	(7,16)	NPC	(3,12)	(7,16)	NPC	(3,12)	NPC	NPC	(7,16)
P2	NPC	(16,7)	NPC	(3,12) or (7,16)	NC	NPC	(3,12)	(7,16)	NPC	NPC	(3,12)	NPC	(7,16)	(3,12)	NC
Y1	(12,16)	(16,12)	NC	NC	NC	NC	NC	(16,12)	(16,12)	NC	NC	NC	NC	NC	NC
Y2	NC	(7,3)	NC	NC	NC	NC	NC	NC	NC	NC	NC	(3,7)	(3,7)	NC	NC
Z1	NC	NC	NC	NC	NC	(7,12)	(7,12)	NC	NC	NC	(7,12)	NC	NC	NC	(7,12)
Z2	NC	NC	(3,16)	NC	NC	NC	(3,16)	NC	NC	(3,16)	NC	NC	NC	(3,16)	NC

NC: No capability

NPC: No pure couple



	Direct	Hohmann
● CEP, ft	1982	2704
● GN & C Reliability	.993350	.991590
● TD Velocity Errors ● Time at High Thrust Levels	Same	
● No. Desc Propul Ignitions	1	2
● No. GN & C Major Events	4	7
● Nav Update Just Proir to Pwrd Descent Without GN & C Mod ● AOT Align Prior to Pwrd Descent	Possible	Not Possible
● Shelter Visible at TD	No	Yes

Fig. 4.2-1 Holimann/Direct Descent Comparison

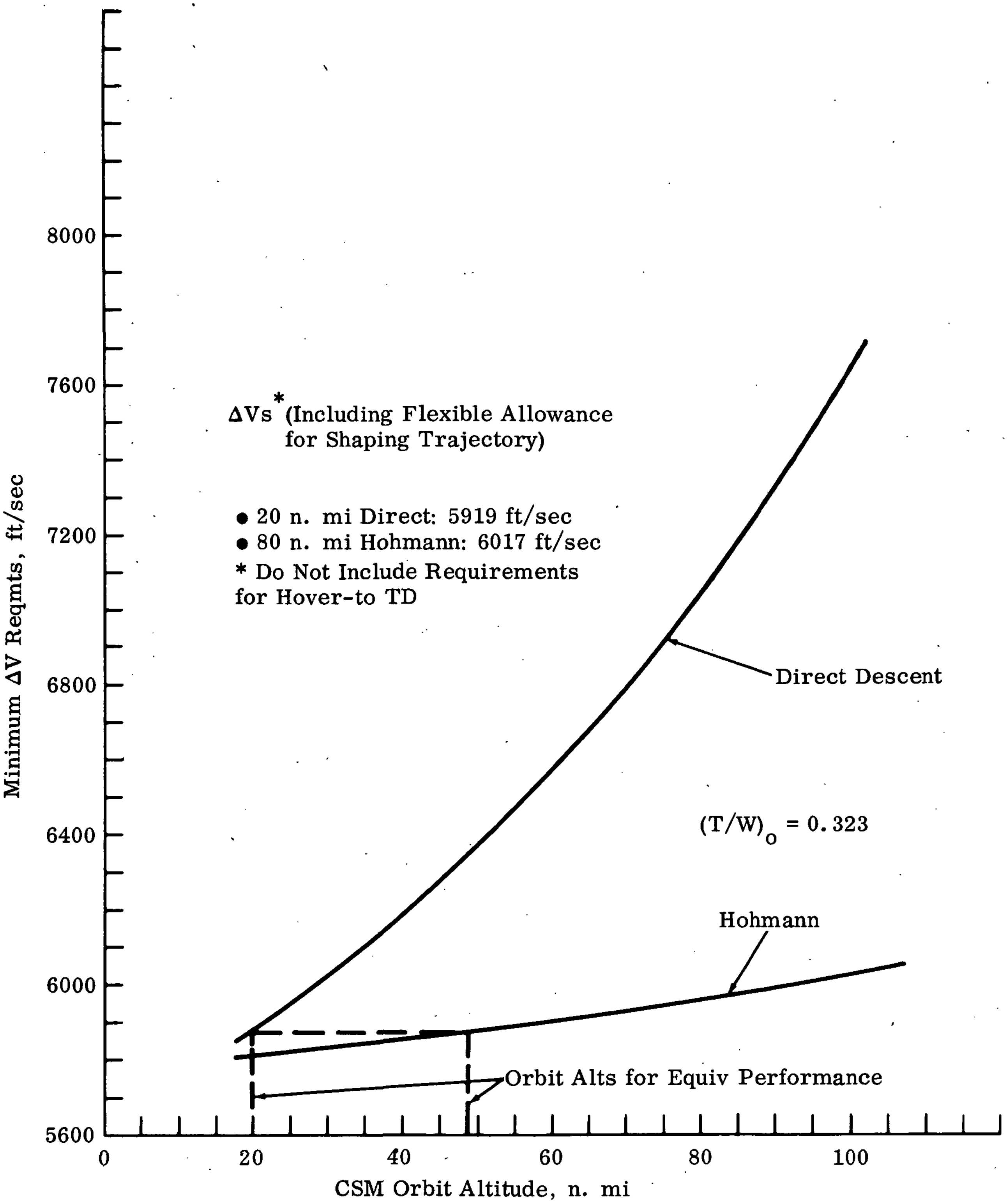


Fig. 4.2-2 Holimann/Direct Descent - Minimum ΔV Requirements

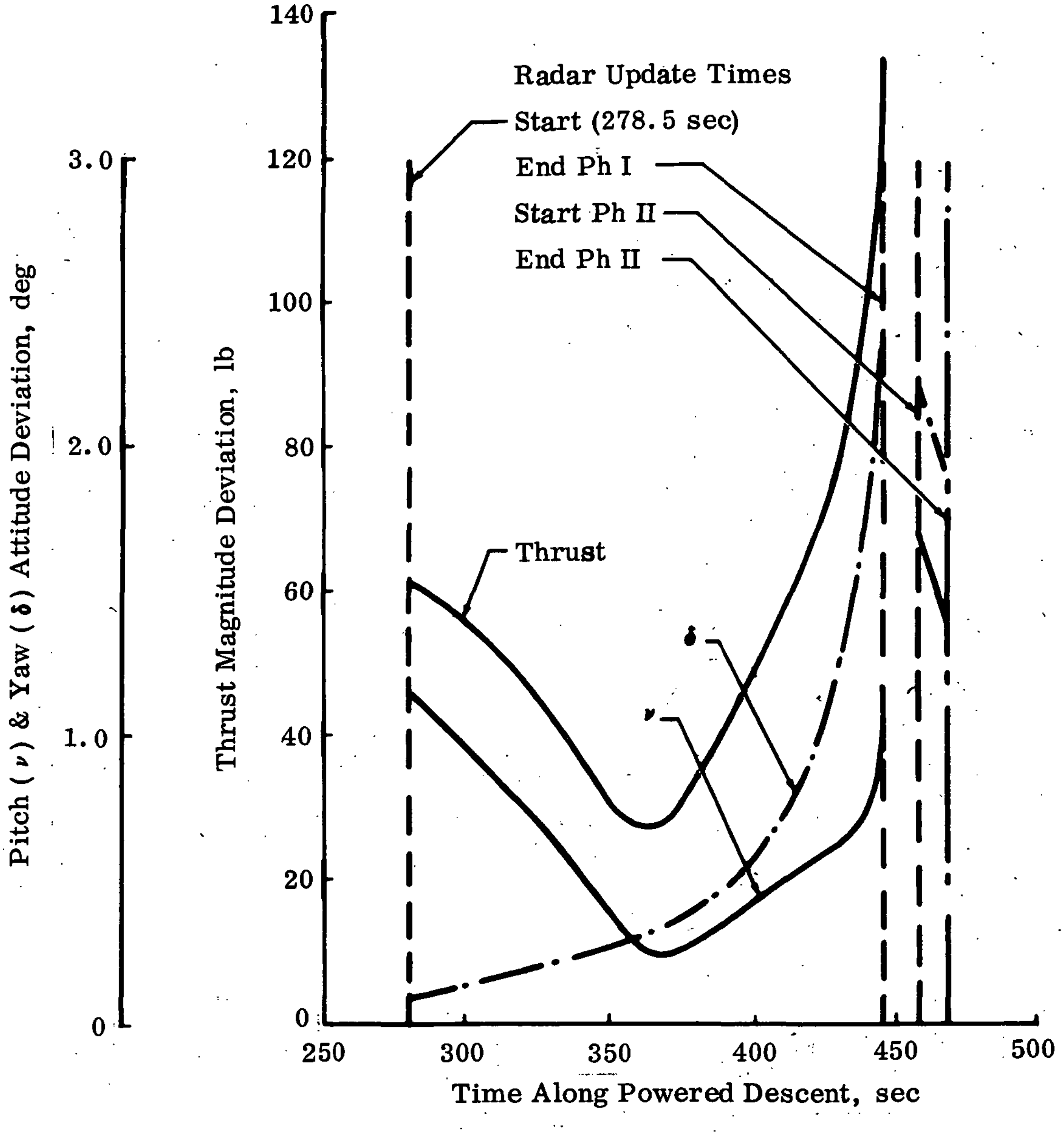


Fig. 4.2-3 Time History of Thrust Deviations and Pitch and Yaw Attitude

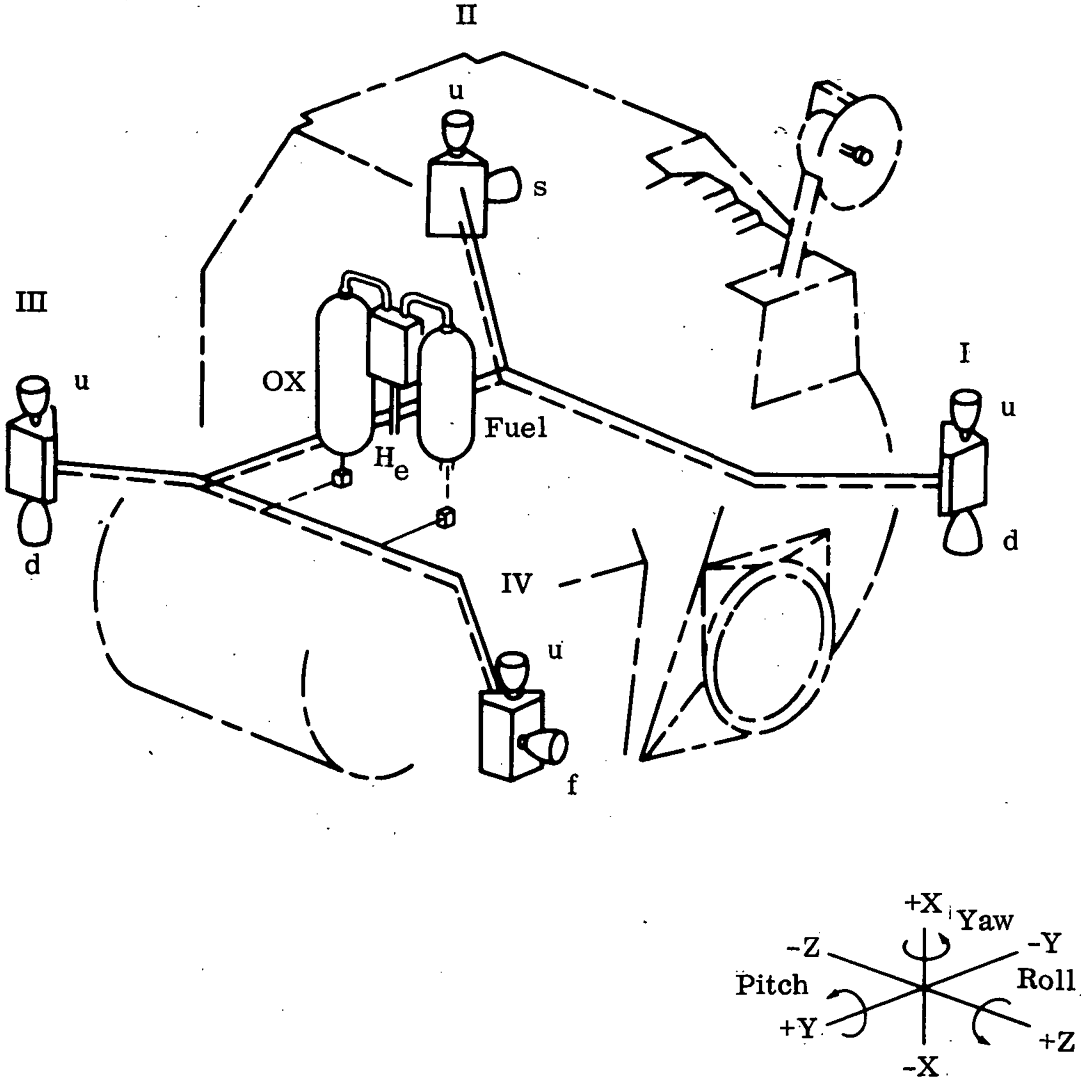


Fig. 4.2-4 RCS Jet Configuration

4.3 REACTION CONTROL AND PROPULSION

4.3.1 Ground Rules

The following ground rules were applicable to this area:

- An 80-n.mi Hohmann descent shall be the primary mode of descent to the lunar surface
- Direct, fully-powered descents will be studied as alternates to the primary mode.

4.3.2 Assumptions and Background Data

The main propulsion syttem in the Shelter is identical to the LEM descent propulsion system with the exception of three additional vent valves provided for the purpose of depressurizing the propulsion system after lunar landing. The following descent engine characteristics were assumed:

- Time averaged, specific for all modes of descent considered in this analysis, is 300 sec
- Maximum descent engine spec operating life at near maximum thrust is 417 sec
- When the descent propulsion system is used for SPS backup the maximum demonstrated operating life is 512 sec.

4.3.3 Recommended Configuration

The selection of an eight-jet RCS for the Shelter was primarily motivated by the desire to eliminate problems associated with RCS jet-plume impingement on externally mounted equipment. The eight-jet design shows no additional thrust loss caused by jet impingement over that produced by the basic LEM RCS. It also allows for radiators to be placed outside of the RCS heat envelope. Preliminary calculations show that a negligible (less than5%) thrust loss will be incurred by placing the radiators as proposed.

4.3.4 Baseline Configuration

The RCS for the recommended and baseline configurations are identical.

The mode of descent for the baseline configuration was a fully-powered 20-n.mi direct descent. Figure 4.3-1 shows that a 153-lb payload advantage can be obtained by using this mode of descent compared to an 80-n.mi Hohmann descent. Figure 4.3-2 shows that a descent engine burn time of 447 sec, at near maximum thrust, is required for a direct descent from 20 n.mi. This long burn time at maximum thrust is the result of reducing the visibility phase from 115 sec for the LEM, to 20 sec for an unmanned automatic descent.

This burn time exceeds the crrent spec limit on the descent engine operating life (417 sec) at maximum thrust. However, when descent propulsion is used for SPS backup, the engine is required to demonstrate a lifetime of approximately 512 sec at near maximum thrust. This is an "over-stress" condition, and corresponds to burning a full load of propellant at near maximum thrust. Therefore, from Fig. 4.3-2, direct descents must be restricted to altitudes below 74 n.mi. Descents from higher CSM altitudes would require re-qualification of the descent engine for greater life at maximum thrust, larger propellant tanks, and more helium for pressurization.

4.3.5 Alternate Configuration

A 16-jet RCS configuration with one set of oxidizer tanks and a single pressurization system was considered as an alternate configuration. This configuration is discussed in Paragraph 5.4.

4.3.6 Potentital Modifications Per Flight

No per flight modifications were considered.

4.3.7 Discussion of Configuration Choices

4.3.7.1 Hohmann Vs Direct Descent Landing Techniques

Figure 4.3-1 shows the change in Shelter payload for direct descents from various CSM parking orbit altitudes as compared with Hohmann descents. The Vs used to generate the curve are given in Paragraph 4.2 (Fig. 4.2-2). Although these Vs neglect flexibility allowances for guidance and control uncertainties and operatioal requirements, they do represent a realistic estimate of the change in ΔV that would be required for descents employing either of the two landing techniques. It is apparent that direct descent from 20 n.mi results in an increase in Shelter payload of approximately 150 lb over that which could be achieved using an 80-n.mi Hohmann descent. For a direct descent from 26 n.mi, the change in payload is zero, while direct descents from higher CSM altitudes result in a net loss in payload over that achievable using an 80-n.mi Hohmann descent.

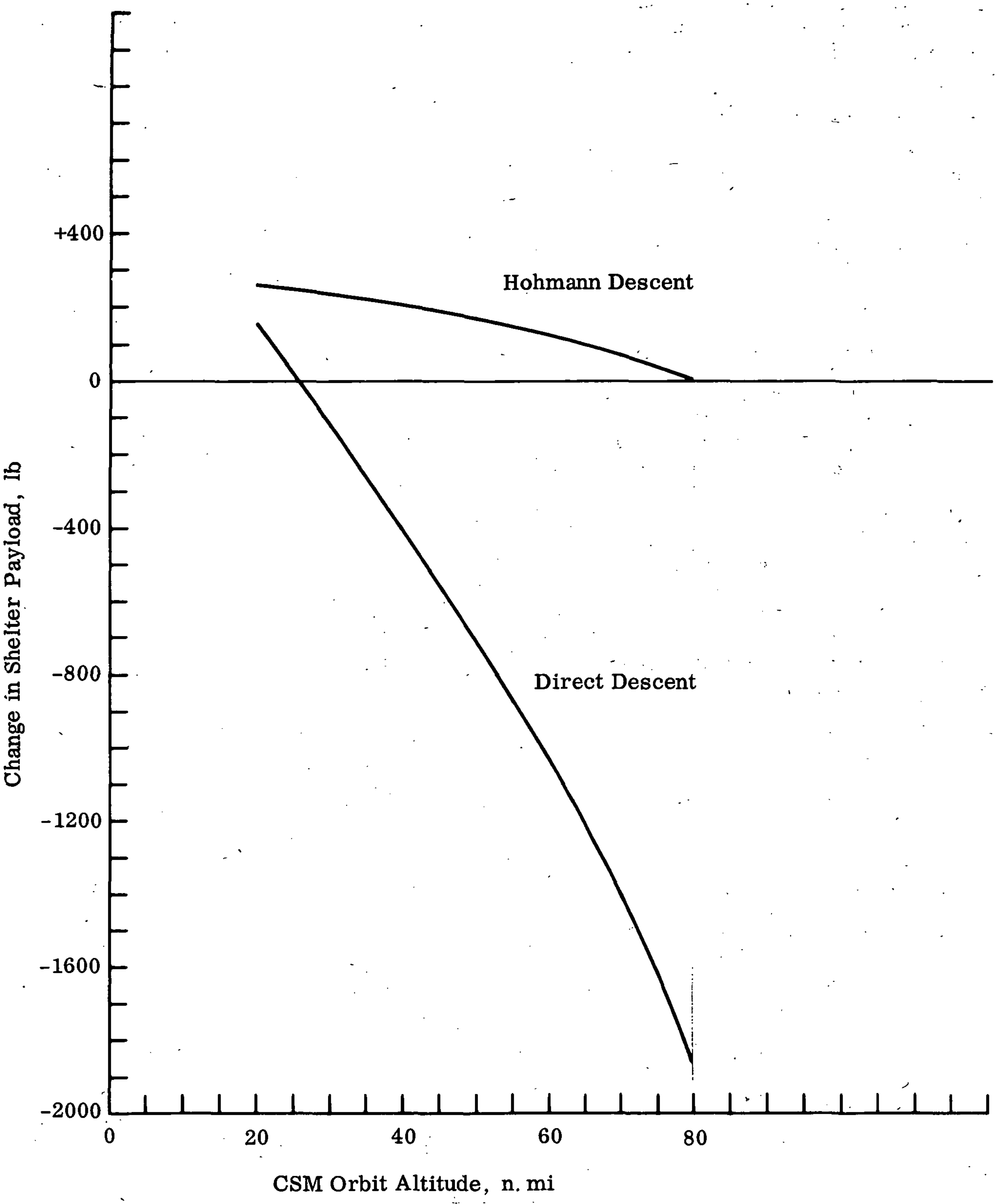
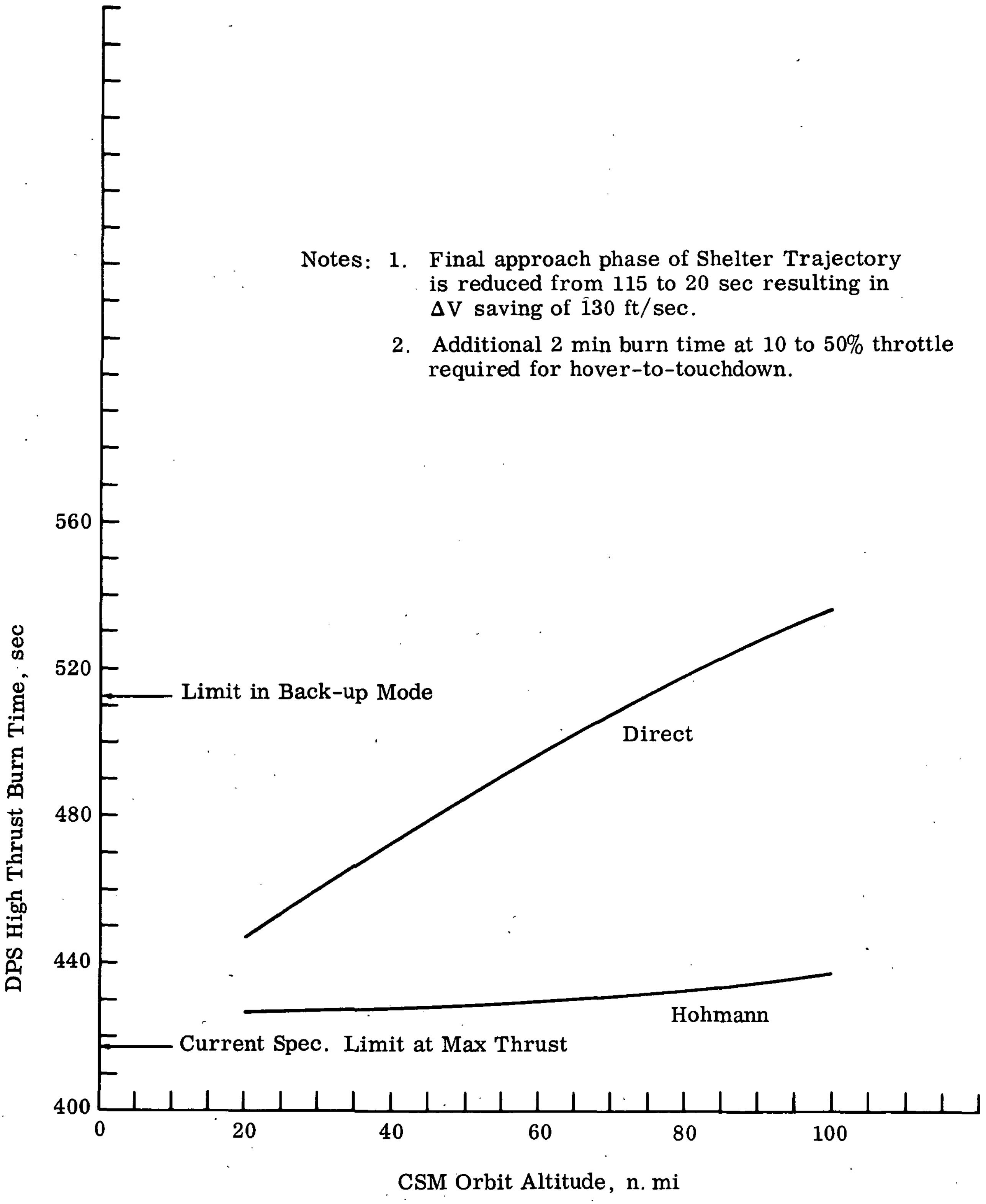


Fig. 4.3-1 Shelter Payload Capability - Holimann/Direct Descent



Notes: 1. Final approach phase of Shelter Trajectory is reduced from 115 to 20 sec resulting in ΔV saving of 130 ft/sec.

2. Additional 2 min burn time at 10 to 50% throttle required for hover-to-touchdown.

Fig. 4.3-2 Descent Engine Burntime - Holimann/Direct Descent

4.4 CREW SYSTEMS

4.4.1 Ground Rules

The NASA ground rules unique to this area of study are:

- Missions as described by NASA/MSFC
- One hard suit shall be carried in the Shelter for EVA.

4.4.2 Assumptions and Background Data

It was assumed that the crew life support and human engineering requirements for the Shelter mission are essentially the same as the LEM.

4.4.3 Recommended Configuration - Crew Functions

The mission profile, or sequence of events, describing the crew functions to be performed during the Shelter missions is presented in Section 3. The unique aspects of the Shelter mission are:

- Transfer of the RTG from the Shelter to the Taxi
- Performance of Extra-Vehicular Activities (EVA) in a hard suit
- 6-hr EVA exploration time
- Airlock considerations.

A detailed discussion of these areas are presented in the succeeding paragraphs.

4.4.3.1 RTG Transfer

After it has been established that the Shelter is in a "go" condition, the RTG is disconnected, removed from the Shelter and loaded onto the LSSM. The LSSM is then driven back to the Taxi where the RTG is unloaded, installed in the Taxi, and checked out. In transferring the RTG from the Shelter to the Taxi, the major human factor items of concern are:

- Thermal radiation (heat emmission)
- Thermal conductivity (contact burns)
- Nuclear radiation (health physics)
- Mechanical assembly, detachment connections, etc.
- Physical transport of the unit from the Shelter to Taxi.

The RTG generates more thermal energy (heat) than can be effectively used. To avoid self-destruction and to provide the required Δt at the thermoelectric N-P junctions, the unit must radiate considerable excess heat to its surroundings. The astronaut's space suit and back pack cooling system has been sized to dissipate metabolic heat plus solar thermal loads. Excess heat loading to the astronaut, by exposure to the RTG thermal radiation, could overload the thermal balance of the suit. Under ordinary circumstances, however, this can be easily avoided by the astronaut moving away from the unit (1 meter) or moving into the heat shadow. The efficiency of proposed thermal radiation garments may also obviate this problem.

Direct contact burns offer the greatest threat to the space suited astronaut. The surface temperature of the RTG exceeds the melting point of the space suit. A direct brief physical contact of the suit against the radiation surface of the RTG, or against a wire type guard, would melt and/or degrade the fabric to the point where its integrity as a pressure vessel could not be maintained. Prevention of direct contact burns is the prime human factors/safety consideration.

The radioactivity of the unit will add to the overall dosage of crew radiation and may require slight upward revision of the NASA allowable Apollo mission dosage. The dosage is not heavy, and, under the most adverse conditions, the astronaut could carry a cold fin assembly unit in his hands for over 30 min before receiving a 1-rad dose. The ground handling of the unit would have to be under strict administrative control. The greatest crew and ground nuclear hazards are not associated with normal operations but with accidents such as a capsule explosion. The SNAP program has proven RTG units to be apparently safe, dependable, and easily handled.

An indirect radiation problem is that of heavy irradiation of the drinking water tank which is located only a few centimeters from the RTG capsule. Minute impurities in the water could become radioactive and cause excessive irradiation of the GI tract, and could enter the metabolic processes (i.e., remain in the body). Preliminary analyses show that the radiation problem is minimal for the assumed mission profile parameters. However, it is recommended that a more thorough study be made especially of stored purity of water/shielding/location/time interface.

Accurate estimation of the problems and techniques of transporting the unit from the Shelter to the Taxi is impeded by the lack of knowledge of the exact nature of the lunar surface. At present, the only mode of transport considered is on the LSSM.

In summary, there are no serious human factor obstacles to transporting the RTG and attaching it to the Taxi. Contact burn, melting, and failure of the space suit is the greatest hazard. The major effort should be devoted to minimizing this hazard. The nuclear radiation doses exceed presently specified limits, but are within a tolerable range.

4.4.3.2 Man in Hard Suit Capabilities

During the course of the study, an evaluation was made of the RX-2A Litton hard suit configuration. A comparative versatility analysis between the Litton hard suit and the International Latex Block II Apollo soft suit was made. The standard format shown below was employed to evaluate the mobility of the anthropomorphic pressure suits:

No.	Component	Plane	Movement	Flexometer	Goniometer
1	Neck	Saggital	Flexion, Extension	X	
2	Neck	Frontal	Lateral Flexion	X	
3	Forearm	Frontal	Super-Pronation	X	
4	Wrist	Frontal	Flexion, Extension	X	
5	Hip	Frontal	Adduction, Abduction	X	
6	Hip	Saggital	Flexion, Extension	X	
7	Shoulder	Saggital	Flexion, Extension		X
8	Shoulder	Frontal	Adduction, Abduction	X	
9	Neck	Transverse	Rotation	X	
10	Shoulder	Saggital	Rotation	X	
11	Elbow	(None Specified)	Flexion, Extension	X	
12	Wrist-Forearm	(None Specified)	Flexion, Extension	X	

No.	Component	Plane	Movement	Flexometer	Goniometer
13	Hip	Transverse	Rotation	X	
14	Ankle	Saggital	Flexion, Extension	X	
15	Trunk	Transverse	Rotation	X	
16	Shoulder	Transverse	No Particular One Specified	X	
17	Knee	Saggital	Flexion, Extension	X	
18	Foot	Saggital	Flexion	X	
19	Trunk-Hip	Saggital	Flexion, Extension	XX	
20	Trunk-Hip	Frontal	Lateral, Flexion	XX	

The results of this comparative evaluation are shown in Table 4.4-1

The Litton RX-2A two-piece hard suit is incompatible with the present Shelter configuration and volumetrics, considering donning/doffing and storage capabilities. The chief deterrent is the need to lay supine to don and doff and back-trunk-leg extremity section of the suit envelope. However, a somewhat modified suit, designated the RX-3, is presently being designed, to be delivered in the latter part of 1966, which should overcome the immediate difficulties. This suit will consist of three major segments with disconnectors at neck line, mid-torso, and mid thighs. Additional disconnects are located at upper arms, at the mid-bicep, and ankles.

With this improved version, the subject would be able to don the suit while in a vertical position. In sequence, he simply steps into the torso segment, attaches extremities and boots. Then sitting, if necessary, dons the upper segment, attaches arm extremities, and finally the helmet. He doffs the suit in reverse order. To facilitate suit storage, the arm extremities are stored in the leg segments. One leg is placed within the torso sections. The latter is attached to the upper section and together with the remaining leg extremity is stowed within the airlock where it is readily accessible by merely opening the Shelter/airlock hatch.

4.4.3.3 EVA Excursions

The missions as described by NASA/MSFC define lunar explorations with EVA periods lasting 6 hr. Two human factor problems to be considered in a continuous, one-man, 6-hr EVA involve the development of methods to enable the astronaut to:

- Remove thermal garment
- Exchange PLSS.

It has been assumed that assistance is required to don and doff the thermal garment over the suit/PLSS configuration. Since the PLSS provides for life support of only 4 hr, a 6-hr excursion would necessitate an exchange of backpacks. To accomplish this, the thermal garment and expended PLSS must be doffed; a charged PLSS and the thermal garment donned in that order. State-of-the-art methods do not permit one man to accomplish these tasks alone.

The specified mission profile requires one crewman to conduct EVA geological investigation for a period of 6-consecutive-hr/day, wearing a pressurized hard suit after which the second crewman prepares to conduct a similar EVA excursion for a 3-hr period the same day. It is felt that missions requiring an excursion for 6-consecutive-hrs by one crewman are incompatible with the life support requirements, such as metabolic energy expenditure rate, water/food intake intervals, and muscle fatigue. Failure to take corrective action or provide a required need in time, whichever the case may be, could result in the following:

- Considerable performance degradation
- Irreversible physiological debilitation
- Possible physical injury.

Other psychological considerations, which impair and actually become detrimental to the prescribed mission, are suit comfort and its subsequent effects on motivation of the exploring subject to adhere to established methods required to conduct a fruitful EVA mission.

Until such time that design configurations are so developed as to enhance the life support capabilities of the hard suit, in addition to the human factors problems (i.e. don/doff the PLSS and thermal garment alone while on the lunar surface), it is suggested that a 3/3-hr exploration period be considered instead of the 6/3-hr survey.

The following is a suggested time/task line analysis with a 3/3-hr exploratory period:

TIME	A	B
00:00-8:00	Sleep (unpressurized soft suit)	Sleep
8:00-8:15	Doff/chkt. suit	Doff/chkt. suit
8:15-9:00	Eat/hygiene	Eat/hygiene
9:00-10:00	Comm. ground stations	Chkt. equipment housekeeping task
10:00-12:00	Geol. assay	Assist A
12:00-12:30	Eat/hygiene, rest	Eat/hygiene, rest
12:30-1:00	Don, chkt. hard suit, PLSS	Don soft suit
1:00-4:00	Egress-commence geologic exploration	Monitor A biomedical responses*, eat/hygiene, prepare for egress, (Chkt. PLSS, etc.)
4:00-4:30	Ingress, doff hard suit	Don, chkt. hard suit/PLSS
4:30-7:30	Eat/hygiene, Monitor B*	Egress-commence geologic exploration
7:30-8:00	Communicates-ground station	Ingress, doff chkt. hard suit
8:00-8:30	Eat/hygiene	Eat/hygiene
8:30-9:00	Log	Log
9:00-9:30	Prepare geologic samples	Assist A
9:30-11:30	Recreation	Recreation
11:30-11:45	Comm. ground station (Planning)	Assist A
11:45-12:00	Don soft suit	Don soft suit

---

*Conduct biomedical/behavioral package and/or safety monitoring.

4.4.3.4. Airlock Considerations

Current Shelter requirements call for an airlock to be an integral part of the system.

The recommended configuration incorporates an 88-cu-ft airlock.

This particular design can serve as a storage facility for the EVA hard suit. However, the suit and PLSS will be donned inside the cabin with provisions for a PLSS recharge station being mounted in the cabin also. The egress procedure is as follows:

- Checkout of spacesuit with ECS in the cabin
- Enter airlock from cabin; airlock pressurized to cabin enviroment
- Attach PLSS at airlock donning station
- Inflate space suit with PLSS
- Checkout of space suit with PLSS in the arirlock
- Close hatch between airlock and cabin
- Decompress airlock
- Open hatch to lunar; egress to surface.

In accordance with current plans, provisions will be made to incorporate a suit-loop umbilical in the airlock.

4.4.4 Baseline Configuration

The baseline configuration is essentially the same as the recommended except that it did not include an airlock.

4.4.5 Alternate Configuration - Crew Functions

Two alternate studies performed during the crew systems analysis concern the effects induced by a tilt in the Shelter, and the requirement for a medical and behavioral experiment package.

4.4.5.1 Psychological Effects Induced by a Shelter Tilt

The psychological effects related to perceptual illusions induced by distortions of the vertical-horizontal dimensions from a tilting of the Shelter were studied. The specifications of the LEM will tolerate a maximum 27 to 30 deg tilt; however, the extent of detriment such a position would impose upon the crew in conducting their duties, general or technical, for the duration of the mission is yet to be determined.

The nature of the vertical-horizontal-distortion is inherently related to two representative characteristics:

- Direction of gravitational force
- Visual enviroment outlining the true vertical-horizontal dimensions.

The intrinsic relationship between these two factors yields a unified impression of the "upright." In addition, the gravitational stimulus and vertical upright coincide in direction so that either determinant is a basis of the preceptive phenomenon.

This perceptual process is of continuous importance to the sensing organism, since it implicates the body structure directly and is constantly employed in the adjustment to objects in the enviroment at any one moment. Thus, since the mechanisms are similar in the attainment of the overall objective, they are especially useful in the study of those factors responsible for the patterns of distortions.

Data from investigations in which these two characteristics were utilized demonstrated that subjects differed markedly in perceptual judgment. The contrast results from the relative emphasis assigned to the visual impressions and to bodily experiences in the ultimate integration of the pertinent variables. In a tilted-room test where the subject was required to position himself in line with the vertical dimensions of the room, most subjects moved in the direction of the tilt indicating that the subjects' responses are not necessarily so much an expression of how they felt body-wise as how they appeared, i.e., in alignment with the surrounding field. On the other hand, other subjects "fell at both ends of the curve," i.e., some relied upon body sensations alone while the others employed visual impressions only to orient themselves. In view of these problems, it must be stressed again that the properties associated with perceptual judgment of the upright, although related, are subjective in varying degrees.

It is rather doubtful that the astronaut population is so exclusive of this phenomenon that differences do not exist among themselves. In short, a norm in this case is measured in terms of the individual rather than the population. Therefore, it would seem that recommendations to evaluate this problem with the crew members who will be given assignments in the lunar surface exploration program is warranted. This would consist of various duty cycles relevant to the worst possible cases where the tilting phenomenon may definitely affect the critical requirements necessary, which otherwise may jeopardize the lives of the crew. Secondly, it might possibly occur that the period of time, required to adapt to an environment 1/6 the gravitational pull of Earth, may also be a function of the physical properties of the lunar body, and its subsequent interactive forces on the organism. Thirdly, the problem of egressing from a tilted Shelter to the level of the lunar surface not only requires transitional reorientation in terms of time and space, but may induce physiological symtoms of vertigo, vestibular unbalance, or muscular incoordination. A similar situation could occur when ingressing from the lunar surface to the Shelter. Therefore, the following recommendations are offered:

- Provide means for uprighting the vehicle
- Perform static simulation studies of worst conditions in a Shelter mock-up
- Perform simulation studies with crew members selected for lunar exploration missions.

4.4.5.2 Medical and Behavioral Package for Shelter

In conjunction with the geological exploration, certain medical and behavioral experiments are recommeded to ascertain and evaluate the effects of 1/6-g upon man. The effects of a zero-g environment will be studied on the Earth orbiting Lab. In addition, an artificial g environment will be induced and studied in the Earth orbiting Lab, simulating environments from 0.2 through 1 g. The data obtained from these studies will provide sufficient information to develop a gravity spectrum of g loads on man. Further, the medical and behavioral tests will provide ground station physical scientists with information relating to the astronaut's physiological and psychological real-time status.

The Shelter mission also offers an opportunity to assure the physical scientists that astronauts exploring the moon, making observations and taking measurements, are physiologically and psychologically sound. Therefore, a thorough preparation and a sound operational philosophy is warranted for the lunar missions of the AES Program. To realistically evalute man's role in lunar exploration, a suggested medical and behavioral package is defined which can be reasonably utilized in a well planned experimental format.

The following assumptions are considered:

- One-sixth-g and a crew of two men
- Crew member capable of participating as subject and/or observer
- Mission duration of 14 days
- A symptotic pre-post flight medical/behavioral evaluation of crew
- Equipment evaluation and calibration tested under simulated lunar conditions.

The package will consist of the following major categories:

- Physiological monitoring
- Medical/behavioral experiments
- Physical conditioning techniques.

Physiological monitoring will provide real-time evaluation of critical body system measures for each crew member. Simultaneous monitoring of critical environmental parameters (e.g. CO_2) will likewise be recorded and scrutinized. It is assumed this real-time information will provide adequate safety indices to enable the presiding medical officer to form a judgment as to go/no-go status and determine the remedial course necessary to correct difficulties encountered. This portion of the package is essential and must therefore be carried in the Shelter.

The medical and behavioral experimental package will serve a two-fold purpose, since it is designed to:

- Determine physiological and psychological reactions to long-term stay duration under near-weightlessness conditions (1/6 g)
- Detect range and degree of change of these reactions.

This portion of the package will be incorporated with the crew support provisions, since the monitoring crew member will be aware of the exploring members's activities via medical monitoring and communication. To optimize data collection/reduction. the monitoring crew member is to serve as both subject and observer in prescribed behavioral experiments where feasible.

The importance of the recommended behavioral package lies in its practical application, since special emphasis will be placed upon psychomotor activity (gross/fine) which is paramount to the main research effort (e.g. geologic core sampling, instrument implantation, and locomotion to and from Shelter). Furthermore, docking/rendezous experiments are incorporated as part of behavioral package to maintain proficiency utilizing the integrated performance test panel.

One of the more critical demands of this mission will be to observe the psychomotor/motor capabilities and mechanical efficiency of the subject. Several methods are available to obtain data and evaluate the results, such as subjective impressions (subject and observer), film study, and TV telemetry. The first method is severely restricted in that it certainly could not provide reliable objective and analytical data. The second method would necessitate the second operator to operate the camera outside the Shelter; this is inconsistant with present mission guidelines which require the Shelter to be manned at all times. In addition, the number of film cartridges required are prohibitive for reasons of weight and storage. Thus, the third alternative, TV telemetry, is the most practical since a TV camera could be mounted both on the Shelter for short EVA (0 to 1,000 ft) and LSSM for extended EVA.

Table 4.4-1

HARD/SOFT SPACESUIT EVALUATION

No.	Int'l Latex	Littion RX-2A	±	COMMENTS
1	-	-	0	None
2	-	-	0	None
3	179	215	+	Better able to place forearm in prone and supine positions.
4	125	114	-	Less able to flex and/or extend wrist in frontal plane.
5	15	48	+	Better able to adduct and abduct hip in frontal plane.
6	65	66	+	Better able to flex and extend hip in saggital plane.
7	168	137	-	Less able to flex and extend shoulder in saggital plane.
8	117	50	-	Less able to adduct and abduct shoulder in frontal plane.
9	-	-	0	None
10	165	210	+	Better able to rotate shoulder in saggital plane.
11	150	150	=	Equal in ability to flex and/or extend elbow.
12	89	-	0	None
13	106	67	-	Less able to rotate hip in transverse plane.
14	56	45	-	Less able to flex and extend ankle in saggital plane.
15	-	-	0	None
16	102	154	+	Better able to move shoulder in all directions in transverse plane.
17	145	120	-	Less able to flex and extend knee in saggital plane.
18	-	-	0	None
19	-	55	0	None
20	-	25	0	None

4.5 RELIABILITY

4.5.1 Assumptions and Background Data

A timeline summary for a design reference LEM Shelter Mission (DRM) is presented in Table 4.5-1. This profile is not intended to represent any particular flight. It has been selected to provide a basis for reliability estimation, configuration analysis, trade-off studies, and mission success predictions. The mission times are divided into boost and non-boost periods. Applicable environmental stress factors (K factors) are shown for each period depending on operation or non-operation of the equipment during boost and non-boost periods. These factors are used to modify equipment inherent failure rates. In accordance with the mission time lines, K factors, subsystem equipment failure rates, math models, and operating usage times shown in this report, the probability of mission success can be calculated on a subsystem basis.

Mission success is defined as the probability of not aborting the DRM because of a failure of the defined configuration. Although failures of the booster, CSM, or experiment packages would cancel the scientific and engineering experiments, they could not be judged failures against the Shelter. A mission shall be aborted if the future occurrence of a single functional failure may endanger the general well-being of any crew member, or if the projected probability of catastrophe would be greater than a maximum acceptable level.

Whenever possible, failure rate data were extracted from LEM Report LED-550-58, "Failure Rates Used for LEM Reliability Estimate". Data used from other sources are specifically denoted.

4.5.2 Recommended Configuration - Reliability Estimates

Subsystem reliability math models, functional block diagrams (Fig. 4.5-1), and equipment utilization times (Table 4.5-2) were developed to determine recommended system reliability estimates.

4.5.2.1 Subsystem Reliability Estimates

4.5.2.1.1 Navigation, Guidance and Control. Components of the guidance and navigation system are operative only in the descent phase. The program coupler assembly, digital command assembly, transponder, and scanner operate for: 12-min. intervals each day for 84 days, 120 min. on the 30th day before Taxi launch, and continuously for 124 hrs. before Taxi touchdown on the lunar surface. Operation of the program coupler assembly beyond that time is not included, as the astronauts are assumed to manually operate the controls. The subsystem reliability estimate is 0.970846.

4.5.2.1.2 Reaction Control Subsystem. Reliability analysis of the RCS involved investigation into the attitude and translation capabilities of the Shelter, including helium, oxidizer, propellant storage, and regulation and thrust capability. The mathematical modeling for the RCS appears below:

$$
\begin{aligned}
R_{RCS} = {} & R_1 \times R_2^4 \times R_3 \times R_4^5 \times R_5(2 - R_5) \times R_6 \times R_7 \times R_8(2 - R_8) \\
& \times R_9^2 \times \left[2 - R_7 \times R_8(2 - R_8) \times R_9^2\right] \times \left[R_{10}^4 + 4R_{10}^3(1 - R_{10}) + 2R_{10}^2(1 - R_{10})^2\right] \\
& \times \left[R_{11}^4 + 4R_{11}^3(1 - R_{11}) + 2R_{11}^2(1 - R_{11})^2\right] \times \left[R_{12}^4 + 4R_{12}^3(1 - R_{12}) + 4R_{12}(1 - R_{12})^2\right] \\
& \times \left[R_{13}^4 + 4R_{13}^3(1 - R_{13}) + 4R_{13}^2(1 - R_{13})^2\right] \times R_{14}^2 \times (R_{15} \times R_{16} + R_{17} - R_{15}R_{16}R_{17})^2 \\
& \times R_{18} \times R_{19} \times R_{20} \times (R_{21} + R_{22} - R_{21}R_{22})^2 \times \left[2 - (R_{21} + R_{22} - R_{21}R_{22})^2\right] \\
& \times (R_{23} + R_{24} - R_{23}R_{24})^{15} \times R_{25}^2 \times R_{26}^2 \times R_{27}^8 \times R_{28}^8 \times R_{29}^{60} \times R_{30}^8 \times R_{31}^8 \\
& \times R_{32}^3 \times R_{33}^2
\end{aligned}
$$

When the combined factors are introduced for each reliability block established above, the product yields a reliability of the RCS equal to 0.966589. The propellant tank bladders are the major contributing factors to the mission unreliability, because of their high failure rate, and because the loss of any one bladder during the post separation period will require CSM rescue. No additional problem areas are pointed out. The reliability of the Taxi RCS is slightly lower than the value available from the LEM mission.

4.5.2.1.3 Descent Propulsion Subsystem. The reliability analysis of the descent propulsion subsystem (DPS) involved investigation into the storage, regulation and thrust capabilities of the main propulsion subsystem. Evaluation of the subsystem was accomplished through the utilization of the existing LEM descent propulsion subsystem reliability analysis with some slight modification (two vent valves and a pressure relief valve added on the Taxi subsystem). The mathematical reliability model for the DPS is:

$$
\begin{aligned}
R_{DPS} = {} & R_1 \times R_2 \times R_3^5 \times R_4^2 \times R_5 \times R_6 \times R_7^3 \times R_8^{60} \times R_9 \times R_{10}(2 - R_{10}) \\
& \times R_{11}\left[2 - R_9 \times R_{10}(2 - R_{10})R_{11}^2\right] \times R_{12} \times \left[R_{13}^4 + 4R_{18}^3(1 - R_{13}) + 2R_{13}^2(1 - R_{13})^2\right] \\
& \times \left[R_{14}^4 + 4R_{14}^3(1 - R_{14}) + 2R_{14}^2(1 - R_{14})^2\right] \times \left[R_{15}^4 + 4R_{15}^3(1 - R_{15}) + 4R_{15}^2(1 - R_{15})^2\right] \\
& \times \left[R_{16}^4 + 4R_{16}^3(1 - R_{16}) + 4R_{16}^4(1 - R_{16})^2\right] \times R_{19}^5 \times \left[R_{17} \times R_{18} + R_{19} - R_{17}R_{18}R_{19}\right] \\
& \times R_{20}^5 \times R_{21}^2 \times R_{22}^2 \times R_{23}^2 \times R_{24}^4 \times R_{25}^2 \times R_{26} \times R_{27} \times R_{28}^4 \\
& \times \left[R_{29} + R_{30} - R_{29}R_{30}\right]^2
\end{aligned}
$$

When the combined reliability degrading factors time (t), mechanical stress factor (K), and failure rate (λ) are introduced into the above mathematical model, according to the exponential relationship $R = \exp(-K\lambda t)$, the product yields a descent propulsion subsystem reliability equal to 0.997986. This value is slightly lower than the LEM DPS reliability estimate which is caused by the subsystem modifications.

4.5.2.1.4 Electrical Power Subsystem. The EPS consists of two Allis-Chalmers fuel cells with associated oxygen/hydrogen ambient tankage supply system, three modified LEM descent batteries and associated ECA, and one RTG utilized during the quiescent storage period to supply the low quiescent power levels. The RTG evaluation was included as part of the Taxi assessment, based on the degradation experienced during the Shelter quiescent storage period, and is therefore excluded from this analysis. For the purpose of the analysis, all batteries are considered operational when they are charged and activated, and the ECA's are considered operational only during battery discharge time.

The fuel cell assemblies were assessed for mission success, based on the experiment portion duty cycle of 7-day continuous operation (both fuel cells required) and for the 14-day housekeeping function (one fuel cell required). The EPS critical design reference mission (with contingencies) was used for the reliability assessment. Based on the above ground rules, the mission success probability is 0.863200.

A separate study was conducted to evaluate the baseline and alternate configurations for the GE and P&W fuel cell assemblies. The configurations were assessed for the housekeeping and experiment portion (drill) combined, and for the housekeeping function exclusive of the drill experiment. The results of this analysis are contained in Paragraph 4.5.3

4.5.2.1.5 Environmental Control Subsystem. The ECS consists of four integrated sections: atmosphere revitalization, heat transport, oxygen supply and pressure control, and water management.

The following ground rules and assumptions were incorporated into the ECS reliability model:

- Water tanks undergo one operating cycle for the extent of the mission
- Heat transport system is considered in an operative state from touchdown through the 14-day manned stay phase
- Oxygen supply system for the atmosphere revitalization section was considered integrated with the EPS fuel cell configuration and is not included in this analysis
- Atmosphere revitalization section is considered pressurized at the start of the 7-day pre-utilization checkout phase
- LED-550-58, dated 18 June 1965, and failure rate data supplied by Hamilton Standard were used as the basis for the reliability assessment.

The mission success probability based on the above assumptions and ground rules is 0.967260.

4.5.2.1.6 Communications Subsystem. The reliability analysis of the Taxi Communications Subsystem consists of an investigation into the S-band transmission and receiving capabilities for communications between the crew and Earth, including status data, and the VHF communications mode in EVA.

Several assumptions have been made to expedite the reliability modeling analysis. The first involves the failure rate apportionment to the signal processor assembly. Since this part of the system has multiple operational modes, sometimes acting independently of one another and at other times operating in a completely dependent arrangement, it was assumed that for the majority of the mission time the entire failure rate of the unit ($\lambda = 64.549 \times 10^{-6}$) shall be applied to the mathematical model during any period of mission time where any one section of the signal processor is used.

Another assumption is the VHF channel B transmitter has the capability to be used as a backup mode for voice communications with the CM (assuming CM capability to receive voice communications on this channel). Consequently, the VHF transmitters A and B are considered as active redundancies in the reliability analysis (as are VHF receivers A and B). Also configured as redundant items in the modeling analysis are the astronaut's headset receiver and microphone assemblies - under the assumption that headset receiver 1 and microphone 1 operate together in series.

The mathematical representation of reliability appears below:

$$
\begin{aligned}
R = {} & \left[1 - (1 - R_1)(1 - R_2)(1 - R_3)^2\right] \times R_4 \times R_5 (2 - R_5) \times R_6 (2 - R_6) \\
& \times \left[1 - (1 - R_7)(1 - R_8)^2\right] \times R_9 \times R_{10} \times R_{18} \times R_{11} \times R_{12} (2 - R_{11} R_{12}) \\
& \times \left[1 - (1 - R_{13})(1 - R_{14})^2\right] \times R_{15} \times (R_{16A} + R_{16B} - R_{16A} R_{16B}) \\
& \times (R_{17A} + R_{17B} - R_{17A} R_{17B})
\end{aligned}
$$

When the combined factors are introduced for each of the reliability blocks established above, the product yields a reliability equal to 0.958426.

4.5.2.1.7 Instrumentation. The instrumentation configuration is divided in two parts: one for the manned phases of the mission, another for the un-manned phase. In the manned phases, the C&WEA, status displays, and voice recorder are required. The PCM is considered in parallel with the C&WEA and displays.

In the unmanned phase, the C&WEA, status displays and voice recorder are not operated. During this phase, a time sequencer is required to turn on the equipment at intervals. The sequencer itself operates on a 5.83% duty cycle; the PCMTEA on a 1.67% duty cycle; the transducers on a 5.83% duty cycle, and the SCEA on a 5.83% duty cycle. Based on these duty cycles, the reliability for Instrumentation is equal to 0.910375.

4.5.2.1.8 Controls and Displays Subsystem. The reliability analysis of the C&D Subsystem consisted of an examination of all of the individual displays and controls required by the other subsystems in the Shelter. The overall C&D Subsystem reliability was obtained from the following mathematical model:

$$
\begin{aligned}
R_{C\&D} = {} & R_1 \times R_2 \times R_3 \times R_4 \times R_5 \times R_6 (2 - R_6) \times R_7 \times R_8 \times R_9 \\
& \times R_{10} \times R_{11} \times R_{12} \times R_{13} + R_{14} - R_{13} R_{14} \times R_{15} \\
& \times R_{16} (2 - R_{16}) \times \left[1 - (1 - R_{17})^2 (1 - R_{18})^2 \right] \times R_{19} (2 - R_{19}) \\
& \times R_{20} (2 - R_{20}) \times R_{21} (2 - R_{21}) \times R_{22} (2 - R_{22}) \times R_{23} (2 - R_{23}) \\
& \times R_{24} \times (R_{25} + R_{26} R_{27} - R_{25} R_{26} R_{27}) \times (R_{28} + R_{29} - R_{28} R_{29}) \times R_{30} \times R_{31}
\end{aligned}
$$

Applying t, K, and λ data to this equation and solving yields a reliability equal to 0.946551.

4.5.2.2 System Reliability Analysis

A summary of subsystem reliability estimates for the Shelter, together with pertinent LEM data are shown in Table 4.5-3. Approximation of structure, explosive, controls and displays, and instrumentation subsystem reliabilities were obtained by utilizing LEM estimates with exponential degradation allowed for the extended duration.

In general,

$$R = e^{-k\lambda t}, \text{ and } Q = 1.0 - R$$

For small values of $k\lambda t$,

$$Q \approx k\lambda t, \text{ and } k\lambda \approx \frac{Q}{t}$$

Then

$$Q_2 \approx \frac{Q_1 \times t_2}{t_1}$$

$$Q_2 \approx \frac{Q_1}{115.567} \times 2575.787 \approx 22.288 Q_1$$

where subscript 1 represents LEM and subscript 2 represents AES

Subsystem	Q_1	Q_2	R_2
Controls & Displays Instrumentation	0.000622	0.013863	0.986137
Structure	0.000022	0.000490	0.999510
Explosives	0.000076	0.001694	0.998306

Figure 4.5-2 represents vehicle reliabilities for various mission durations. The Shelter reliability curve shown is based on an exponential degradation of reliability with mission duration, and therefore represents a close approximation to the actual estimate. Also included in Fig. 4.5-2 are a series of curves representing experiment package reliabilities plotted against a scale which indicates the product of vehicle and experiment package reliabilities.

Although the Shelter reliability curve indicates values above the LEM DRM point estimate, both fall below the LEM specification goal. The Shelter is dependent on LEM subsystems design. Therefore, improvement of the reliability can only be achieved by upgrading the inherent reliability of each component therein.

4.5.3 Reliability Studies

4.5.3.1 EPS Reliability Configuration Analysis

A study was conducted to assess the GE, P&W, and Allis-Chalmers fuel cell assemblies for the Shelter baseline, alternate, and recommended configurations. The following tabulation presents the evaluation with the drill experiment required during 7 days of continuous operation compared to mission success achieved exclusive of the drill experiment.

Shelter Fuel Cell Evaluation

Configuration Requirement	Fuel Cell Type *	Qty. Provided	Qty. Required	Reliability
Mission with Drill Exp.	P&W	2	2 for 7 days 1 for 14 days	0.990695
	GE	4** (12 stacks)	12 stacks for 7 days 6 stacks for 14 days	0.724194
	A-C	2	2 for 7 days 1 for 14 days	0.988830
Mission without Drill	P&W	2	1 for 21 days	0.999808
	GE	4 (12 stacks)	6 stacks for 21 days	0.999991
	A-C	2	1 for 21 days	0.999726

*Cell Failure Rates:
A-C-1f/10^6 hr/cell section
P&W-.86f/10^6 hr/cell
GE 5f/.10^6 hr/cell

**With one additional section added, the reliability will increase to 0.999471

4.5.3.2 RCS - Eight Versus Sixteen Jets

A configuration analysis was made to determine the reliability advantage of using a 16-jet system rather than the recommended eight-jet RCS. The sixteen-jet reliability model consists of a redundant set of thrust chamber assemblies, isolation valves, propellant filters, isolation valves in series, and additional plumbing in series. The calculations assumed a mission failure condition if any one isolation valve fails to open (fails to close) after pre-separation checkout. Computations were made assuming isolation valve failure mode proportions of 50/50, 80/20, and 20/80 fail-open to fail-close.

The results of applying isolation valve failure mode ratios indicated the lack of sensitivity to the subsystem reliability estimates. The 16-jet RCS reliability equals 0.982, and the eight-jet equals 0.976. Since the net effect on the entire Shelter system is insignificant, reliability should not be the determining factor in the selection of one configuration over the other.

A review of the basic elements of both configurations shows a disproportionate value of the propellant tankage failure rate to that of the entire subsystem. This indicates that the greatest reliability gain can be arrived at through improvement in that area, and that utilization of redundancies elsewhere will show only minor gains.

Table 4.5-1
RELIABILITY - DESIGN REFERENCE MISSION

Nom Phase	Description	Boost Time K_O = 10.0 K_{NO} = 0.01	Non-Boost Time K_O = 1.0 K_{NO} = 0.001	Total Time
1	Total Preseparation (Includes 10 hr of Pre-Earth Launch Checkout)	0.39	75.83	76.22
2	AES Checkout to Insertion (Total Checkout, 1.85)		2.18	2.18
3	Insertion and Hohmann Transfer Orbit	0.01	0.968	0.978
4	Powered Descent from Pericynthion to Hover	0.14		0.14
5	Hover to Touchdown and Post-Landing Checkout	0.019	0.25	0.269
6	Lunar Stay		2496.0	2496.0
	TOTAL	0.559	2575.228	2575.787

Table 4.5-2

EQUIPMENT UTILIZATION TIMES

A. Stabilization & Control (R = .970846

Ident No.	Name (& Quantity if More Than One)		Fail Rate f/10^6 hr	Equipment Usage Time, hr			
				Operate		Non-Operate	
				Boost	Non-Boost	Boost	Non-Boost
1	IMU	Inertial Measuring Unit	137	.169	2.338	.39	76.89
2	PSA	Power Servo Ass'y	126	↑	↑	↑	↑
3	PTA	Pulse Torquer Ass'y	62				
4	CDU	Coupling Data Unit	543				
5	LGC	LEM Guidance Computer	353				
6	CES P/S	Control Electronics Pwr Sply	20		↓		↓
7	ATCA	Att. & Trans. Cntrl Ass'y	17.4		2.338		76.89
8	PCA	Program Coupler Ass'y	55.5		143.448		2429.951
9	DCA	Digital Command Ass'y	29.3		143.448		2429.951
10	LORS	Lunar Optical Rendezvous System	292.0		2.338		76.89
11	T	Transponder	61.4		143.448		2093.95
12	Scanner	X-Y S-Band Scanner	6.3		143.448		2093.95
13	DECA	Desc. Engine Cntrl Ass'y	21.0		.100		79.128
14	DELD	Desc. Eng. Latching Device	12.0	↓	.100	↓	79.128
15	GDA	Gimbal Drive Actuator	31.0		.100		79.128
16	LR	Landing Radar	144.5	.169	2.338	.39	76.89
		B. Descent Propulsion (R = .9979863)					
1	He pressure vessel		.04	.559	79.228	0	0
2	Liquid Level Transducer		.05	.559		0	0
3	Temperature Transducer (5)		.05	.559	│	0	0
4	Pressure Transducer (2)		.05	.559		0	0
5	Helium Initiate valve - squib		.06	.559		0	0
6	Heat Exchanger		.60	.559		0	0
7	Filter (3)		.31	.559		0	0
8	Lines, joints, fittings (60)*		.05	.559		0	0
9	Shutoff valve		14.2	.559	↓	0	0
10	Pressure Regulator - fail open		13.67	.559	0	0	0
11	Press Regulator - fail closed		13.67	.559	0	0	0
12	Manifold		.04	.559	79.228	0	0
13	Quad check valve - oxidizer - fail closed		8.7*	.159	0	0	0
14	Quad check valve - fuel - fail closed		8.7*	.159	0	0	0
15	Quad check valve - oxidizer - fail open		8.7*	.40	79.228	0	0

Table 4.5-2 (Cont.)

B. Descent Propulsion (R = .9979863) (Cont.)						
Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10^6 hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
16	Quad check valve - fuel - fail open	8.7*	.40	79.228	0	0
17	Press Rel Valve } 5 Redundancies in Series	5.7	.559	↓	0	0
18	Test Point } 5 Redundancies in Series	12.5	.559	↓	0	0
19	Burst Disc } 5 Redundancies in Series	.11	.559	↓	0	0
20	Burst disc (5)	.11	.559	↓	0	0
21	Oxidixer storage tank (2)	.04	.559	↓	0	0
22	Fuel storage tank (2)	.04	.559	↓	0	0
23	Vent valve (2)	12.5	.459	↓	0	79.228
24	Low Level sensor (4)	.05	.559	79.228	0	0
25	Trim orifice (2)	.5	.559	79.228	0	0
26	Descent Engine Assembly - fire	226.005	.159	0	0	0
27	Descent Engine Assembly - no fire	226.005	0	0	.40	79.228
28	Diffuser (4)	.05	.559	79.228	0	0
29	Fill valve } 12 Redundancies in Series	3.66	.559	79.228	0	0
30	Cap } 12 Redundancies in Series	80.0	.559	79.228	0	0
* Assumed vendor estimate.						
C. Reaction Control Subsystem (R = .966589)						
1	Helium Pressure Vessel	.04	.559	79.228	0	0
2	Pressure Transducer (4)	.05		↓	↓	↓
3	Manifold	.04*		↓	↓	↓
4	Temperature Transducer (5)	.05		↓	↓	↓
5	Helium Initiate squib valve	.06		↓	↓	↓
6	Helium filter	.31		↓	↓	↓
7	Shut-off valve - solenoid	14.2		↓	↓	↓
8	Pressure Regulator - fail open	13.67	.159	0	↓	↓
9	Pressure Regulator - fail closed	13.67	.159	0	↓	↓
10	Quad check valve - oxidizer - fail closed	8.7*	.159	0	↓	↓
11	Quad check valve fuel - fail closed	8.7*	.159	0	↓	↓
12	Quad check valve - oxidizer- fail open	8.7*	.40	79.228	↓	↓
13	Quad check valve - fuel - fail open	8.7*	.40	79.228	↓	↓
14	Burst Disc (2)	.11	.559		↓	↓
15	Pressure relief valve	5.7			↓	↓
16	Test point	12.5	.559	79.228	0	0

Table 4.5-2 (Cont.)

C. Reaction Control Subsystem (R = .966589)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10^6 hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
17	Burst Disc	.11	.559	79.228	0	0
18	Ox Tank (Bladder) } failure rate 10^6 cycles	8400.0	0	1	↓	↓
19	Fuel Tank (Bladder) } failure rate 10^6 cycles				↓	↓
20	Main shutoff valve	3.09	.559	79.228	↓	↓
21	Fill valve	3.66	↓	↓	↓	↓
22	Cap	80	↓	↓	↓	↓
23	Fill Valve } 15 redundancies in series	3.66	↓	↓	↓	↓
24	Cap } 15 redundancies in series	80	↓	↓	↓	↓
25	Thrust Chamber Assembly - fire (2)	1057.9	.159	0	↓	↓
26	Thrust Chamber Assembly - no fire (2)	1057.9	0	0	.40	79.228
27	Isolation Valve (8)	3.09	.559	79.228	0	0
28	Propellant Inlet filter (8)	.31	0	0	.559	79.228
29	Lines, joints, fittings (60)*	.05	.559	79.228	0	0
30	Thrust Chamber Assembly Injector Valve - fire - (8)	34.4	.159	0	0	0
31	Thrust Chamber Assembly Injector Valve - no fire (8)	34.4	0	0	.39	79.228
32	Vent Valve (2)	3.66	.459	1	0	79.228
33	Pressure Transducer (2)	.05	.559	79.228	0	0

* Assumed vendor estimate.

D. Electrical Power Subsystem (R = 0.86320)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10^6 hr	Operate Boost	Operate Non-Boost	Non-Operate Boost	Non-Operate Non-Boost
1	Descent Battery (3)	20*		2114.85		
2	Descent ECA (3)	20		16.9		
3	Fuel Cell Assembly (2)	1.0**		504		
A	AMBIENT STORAGE SYSTEM					
4	H_2 Tank (2)	.10		2575		
5	Fill Valve } 3 in series	.171		2575		
6	Cap } 3 in series	80		2575		
7	GOX Tank	.10		2575		
8	Pressure Transducer (2)	.05		2575		
9	Pressure Relief (4 in series)	3.30		2575		
10	Squib Valve (2)	.06		2575		
11	Pressure Regulator (2)	1.46		504		
12	Shutoff Valve (4)	2.43		504		

* Based on Eagle-Picher estimate.

** Assumed one f/10^6 hr/Section

Table 4.5-2 (Cont.)

E. Environmental Control Subsystem (R = .967258)						
			Equipment Usage Time, hr			
			Operate		Non-Operate	
Ident No.	Name (& Quantity if More Than One)	Fail Rate $f/10^6$ hr	Boost	Non-Boost	Boost	Non-Boost
1	Select valve	.81		504	.559	2071.228
2	Pressure Regulator	1.46		504	.559	2071.228
3	H_2O Tank (2)	296/c	1 cycle ea.			
4	Fill Valve } 2 in series	3.66	.559	2575.228		
5	Cap	80	.559	2575.228		
6	Check Valve 4	.67	.559	2575.228		
7	Pressure Regulator (2 in series)	1.46		504.0	.559	2071.228
8	Squib Valve	.06	.559	2071.228		504.0
9	Shutoff valve 4	2.43		504	.559	2071.228
10	Chiller	.5		118.0	.559	
11	Heater	2.0		118.0	.559	
12	Manual divertor valve (2)	.81		504	.559	2071.228
13	H_2O Separator Select valve	.09		504	.559	2071.228
14	H_2O Separator	1.01		504	↓	2071.228
15	Check Valve	.67		504	↓	↓
16	Suit Circuit regen. heat exchanger	2.0		504	↓	↓
17	Suit circuit assy	2.95		504	↓	↓
18	Suit circuit relief valve	2.54		504	↓	↓
19	Select valve	.09		504	↓	↓
20	LiOh canister	.14		504	↓	↓
21	Suit ckt fan	15.50		504	↓	↓
22	Fan check value	.44		504	↓	↓
23	Pressure control	22.17		504	↓	↓
24	Pressure sensor	2.0		504	↓	↓
25	Water evaporator	2.0		504	↓	↓
26	Suit circuit heat exchanger	2.0		504	↓	↓
27	Primary water boiler	2.0		504	↓	↓
28	Glycol accumulator	1.34		2496	.559	79.228
29	Glycol filter	0.0		2496	.559	79.228
30	Radiator control valve	.81		2496	.559	↓
31	Radiator	.5		2496	.559	↓
32	Cabin Heat Exchanger	2.0		2496	.559	↓
33	Cabin Temp control valve	.39		2496	.559	↓
34	Regen. heat exchanger (2)	2.0		2496	.559	↓
35	Cabin fan (2)	8.58		504	.559	2071.228
36	Glycol pump	16.1		2496	↓	79.228
37	Check valve	.67		2496	↓	79.228
38	Bypass relief valve	1.12		2496	↓	79.228
39	Cabin dump valve	3.01		504	↓	2071.228
40	H_2O hose	.1		504	↓	2071.228

Table 4.5-2 (Cont.)

E. Environmental Control Subsystem (R = .967258) (Cont.)						
Ident No.	Name (& Quantity if More Than One)	Fail Rate $f/10^6$ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
41	H_2O disconnect	1.33		.504	.559	2071.228
42	H_2O hose assy	.05		↓	↓	↓
43	O_2 relief valve	3.37		↓	↓	↓
44	O_2 Manual shutoff valve	2.43		↓	↓	↓
45	O_2 filter	.05		↓	↓	↓
46	O_2 hose	.05		↓	↓	↓
47	O_2 disconnect	.24		↓	↓	↓
48	O_2 hose assy	.05		↓	↓	↓
F. Communications Subsystem (R = .958426)						
1	S-Band erectable antenna	.025	.169	461.961	.39	2113.268
2	S-Band steerable antenna	41.000	.169	461.961	↓	↓
3	S-Band omnidirectional antenna	.025	.169	461.961	↓	↓
4	S-Band diplexer	1.700	.169	461.961	↓	↓
5	S-Band Power supply - power ampl.	36.531	.169	461.961	↓	↓
6	S-Band transmit - receive ERA	52.900	.169	461.961	↓	↓
7	FM modulator	.162*	.169	461.961	↓	↓
8	PM modulator	.757*	.169	461.961	↓	↓
9	Signal processor assembly	64.549	.169	461.961	↓	↓
10	Command decoder	10.000*	.169	461.961	↓	↓
11	Headset audio receiver	.300	.169	461.961	↓	↓
12	Headset microphone	.120	.169	461.961	↓	↓
13	VHF omnidirectional antenna	.025	0	461.961	.559	↓
15	VHF Diplexer	1.700	0		↓	↓
16A	VHF transmitter A	12.067*	0	461.961	↓	↓
16B	VHF transmitter B	12.067*	0	461.961	↓	↓
17A	VHF receiver A	13.252*	0	461.961	↓	↓
17B	VHF receiver B	13.252*	0	461.961	↓	↓
18	Antenna switching matrix	50*	.169	461.961	.39	↓
19	VHF erectable antenna	.025	0	461.961	.559	↓
* Assumed vendor estimate.						
G. Instrumentation Subsystem ($R = R_M + R_u$ = .910375)						
1. Manned Phases (R_M = .938356)						
1	Transducers	49.06		336		
2	Signal conditioning electrncs ass'y	122.69		336		
3	Pulse code modulator	20.00		168		168

Table 4.5-2 (Cont.)

G. Instrumentation Subsystem ($R = R_M + R_u = .910375$) (Cont.)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10^6 hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
	1. Manned Phases ($R_M = .910375$)					
4	Timing electronics ass'y	8.20		168		168
5	Caution & Warning electronics ass'y	59.55		336		
6	Displays	121.00		336		
7	Voice Recorder	12.90		336		
	2. Unmanned Phases ($R_u = .970181$)					
1	Transducers	29.53	.169	143.448	.39	2093.95
2	Signal conditioning electrncs ass'y	61.35	↕	↕	↕	↕
3	Pulse code modulator	20.00	↕	↕	↕	↕
4	Timing electronics ass'y	8.20	.169	143.448	.39	2093.95
5	Caution & Warning Electrncs ass'y	59.55			.559	2237.40
6	Displays	121.00			.559	2237.40
7	Voice Recorder	12.90			.559	2237.40

H. Controls & Displays Subsystem (R =)

Ident No.	Name (& Quantity if More Than One)	Fail Rate f/10^6 hr	Operate Boost	Operate Non-Boost	Non-Operate Boost	Non-Operate Non-Boost
1	Explosive devices	5.7			.390	75.830
2	Electrical power system	61.5		331.294	.559	2264.160
3	Caution & Warning*	66.0		337.850	.559	2264.160
4	Environmental control system	33.8		337.850	.559	2264.160
5	Reaction control system	18.7		1.850	.559	76.160
6	RCS - regulators	0.9		1.850	.559	76.160
7	Flight controls	19.3		218.306	.559	2383.704
8	Main Propulsion	3.9		1.850	.559	76.160
9	MP - Descent regulators	0.9		1.850	.559	76.160
10	Stabilization & Control	5.6		1.850	.559	76.160
11	Navigation & Guidance	44.6		1.850	.559	76.160
12	Communication	19.9		337.850	.559	2264.160
13	Comm - VHF A	1.11		337.850	.559	2264.160
14	Comm - VHF B	1.21		337.850	.559	2264.160
15	Communication Antennas	13.1		337.850	.559	2264.160
16	Audio - S-Band	0.91		337.850	.559	2264.160
17	Audio - VHF A	0.91		337.850	.559	2264.160
18	Audio - VHF B	0.91		337.850	.559	2264.160
19	Audio - VOX	0.91		337.850	.559	2264.160
20	Audio - ICS	0.91		337.850	.559	2264.160

Table 4.5-2 (Cont.)

H. Controls & Displays Subsystem (R =) (Cont.)						
Ident No.	Name (& Quantity if More Than One)	Fail Rate $f/10^6$ hr	Equipment Usage Time, hr			
			Operate		Non-Operate	
			Boost	Non-Boost	Boost	Non-Boost
21	Audio - Audio	0.3		337.850	.559	2264.160
22	Audio - Master	0.51		337.850	.559	2264.160
23	Audio - Relay	0.3		337.850	.559	2264.160
24	Lighting Control	8.8		337.850	.559	2264.160
25	Lighting - Anun/Num control	0.2		337.850	.559	2264.160
26	Lighting - Anun override	0.3		337.850	.559	2264.160
27	Lighting - Num override	0.3		337.850	.559	2264.160
28	Lighting - Integral control	2.2		337.850	.559	2264.160
29	Lighting - Integral override	0.3		337.850	.559	2264.160
30	Radar controls	2.2		337.850	.559	2264.160
31	Heater controls	10.3		337.850	.559	2264.160

* Calculation included with instrumentation

Table 4.5-3

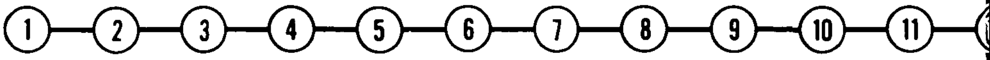
RELIABILITY SUBSYSTEM SUMMARY

	LEM (See Note)			AES		
Subsystem	Crew Safety	Apportion	Estimate	Equiv LEM DRM	300-hr Activate Period	Shelter DRM
Nav/Guidance	.999651	.990700	.988205	.970846	Not Reqd	.970846
Descent Propul.	.999899	.999075	.998764	.997986	Not Reqd	.997986
Ascent Propul.		.999961	.998300	Not Reqd	Not Reqd	Not Reqd
RCS	.997807	.999804	.919600	.966589	Not Reqd	.966589
EPS	.999993	.998600	.963896	.983262	.943949	.863200
ECS	.999994	.999446	.994760	.996032	.987391	.967258
Communications		.999910	.997680	.982586	.959800	.958426
Instrumentation		.999500	.999378*	.999878**	.987752**	.986137**
Controls & Displays						
Structure	.999999	.999950	.999978	.999978**	.999567**	.999510**
Explosives	.999954	.999980	.999924	.999924**	.998504	.998306**
Crew Provisions		.999990	Not Avail	Not Avail	Not Avail	Not Avail
SYSTEM		.987	.866	.901	.882	.737

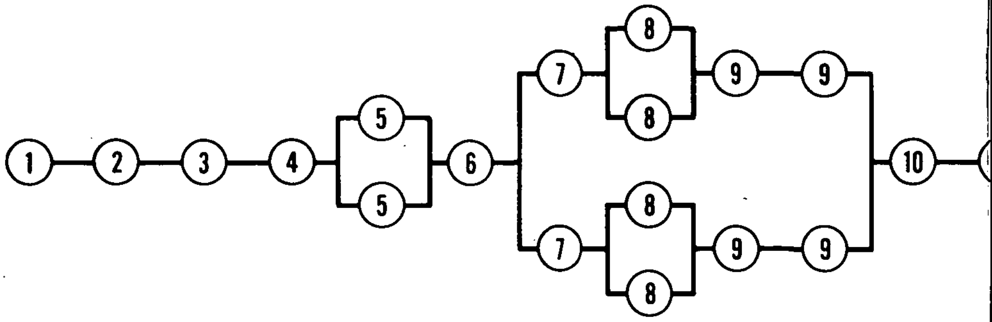
* Does Not Include Sensors

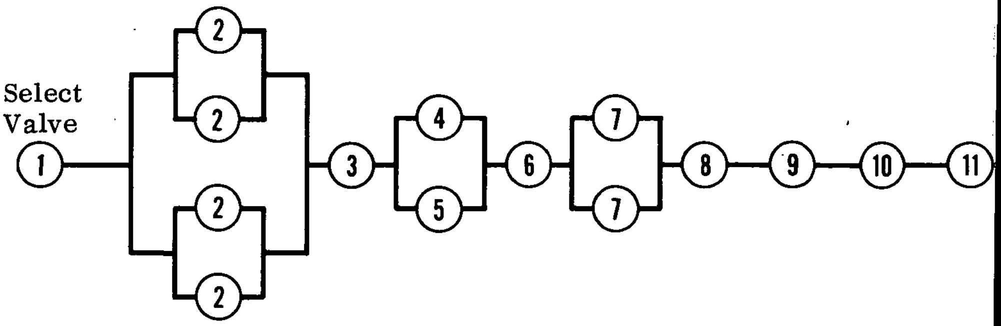
** Utilizes LEM Estimate With Exponential Degradation For Extended Duration

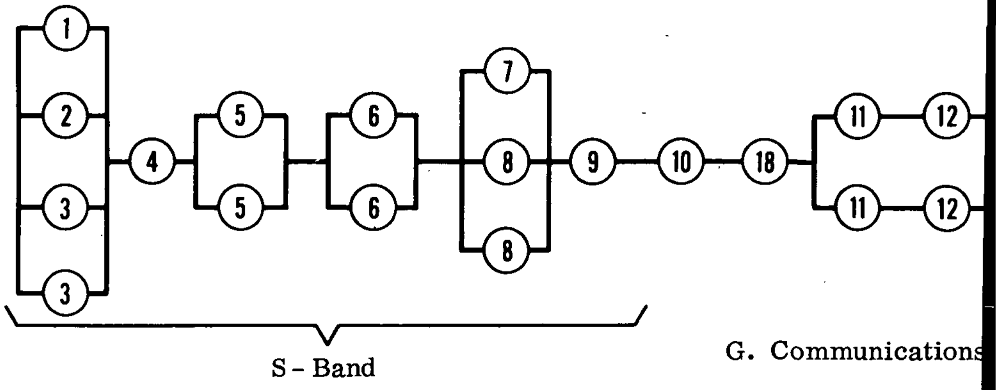
Note: Values Obtained From LPR-550-9 Quarterly Reliability Status Report, 1 Aug. 1965



A. Stability & Control



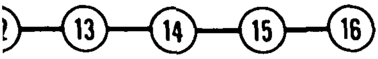


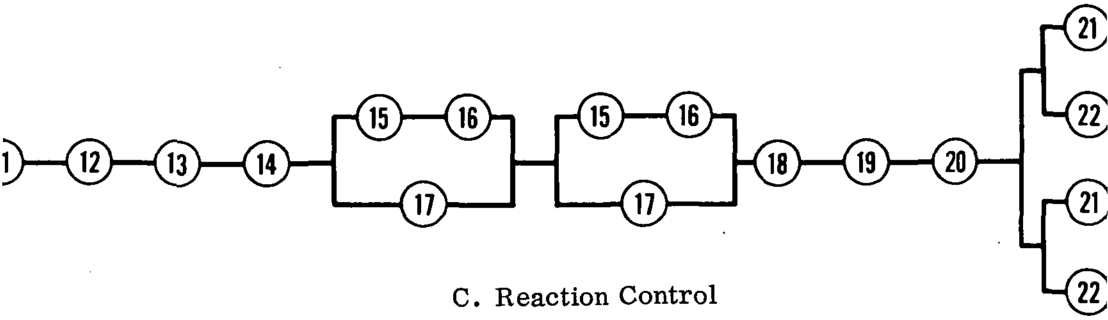


G. Communications

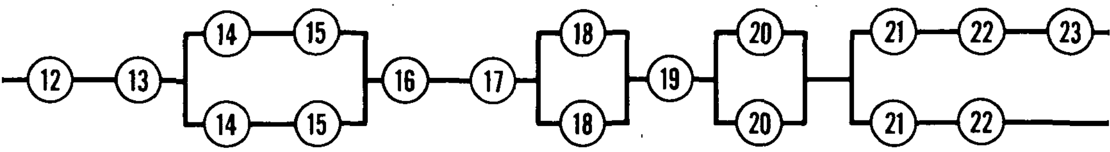
4.5-1

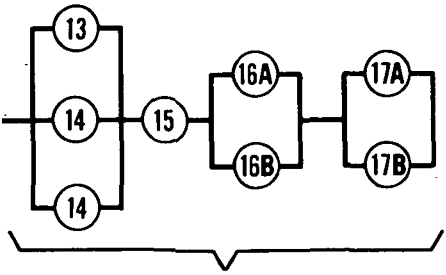
1





C. Reaction Control





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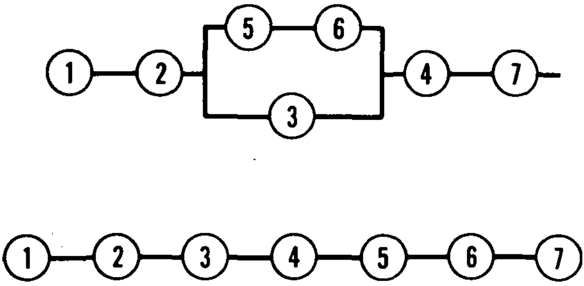
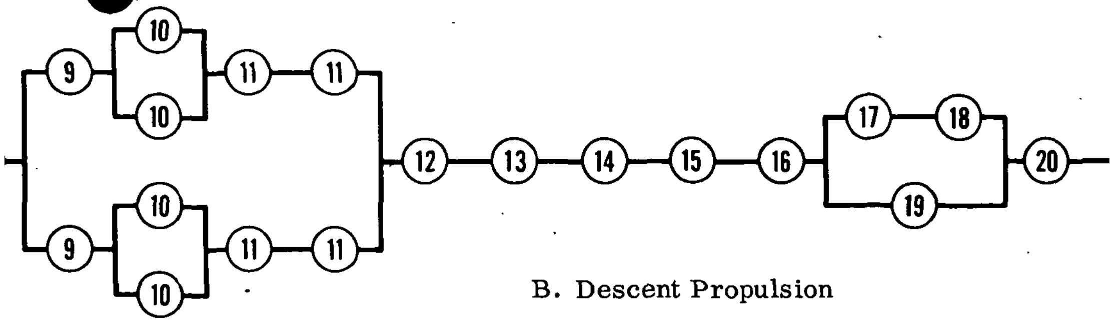


H. Instrumentation

4.5-1

②



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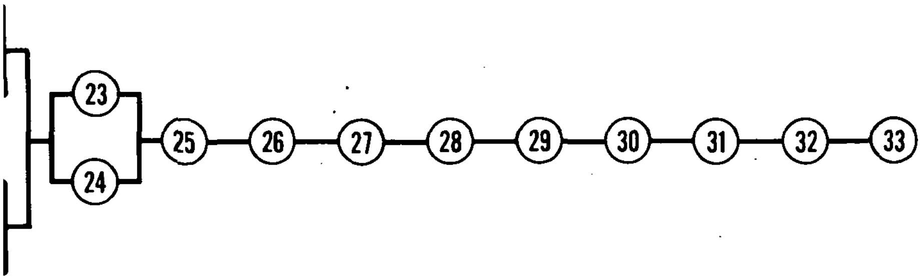

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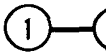
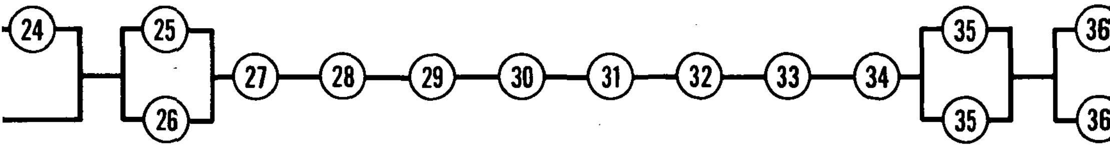
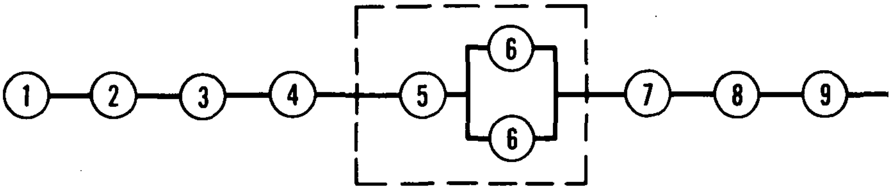




Environmental Control

:anned

Unmanned



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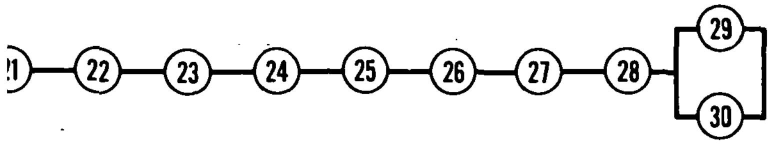
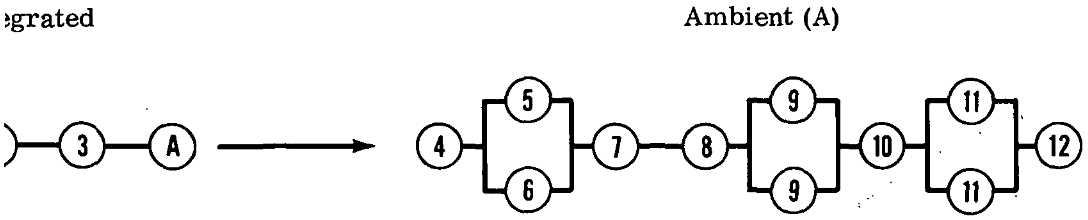
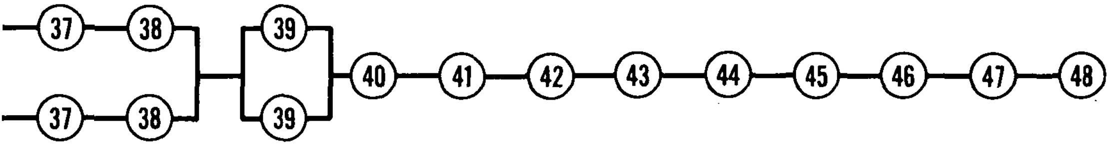
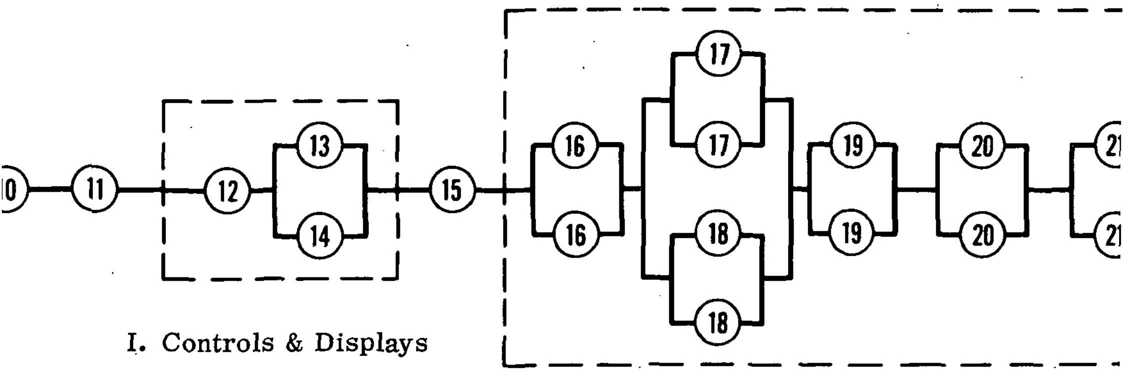




D. Electrical Power





I. Controls & Displays

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④

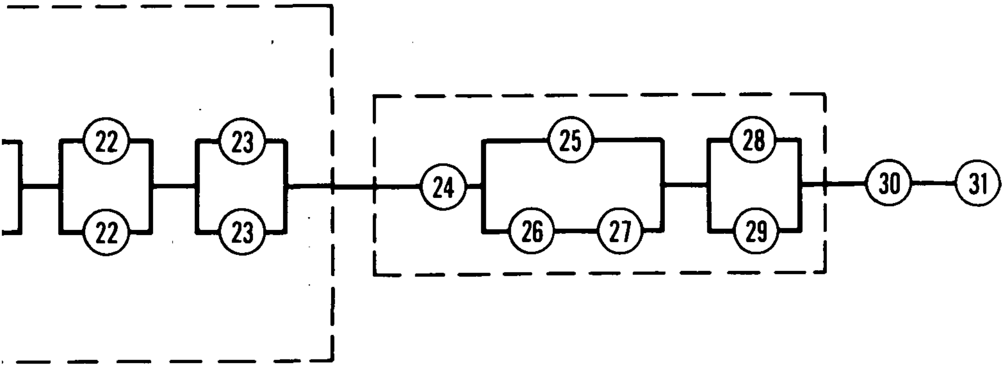

Fig. 4.5-1 Reliability Block Diagram

(5)

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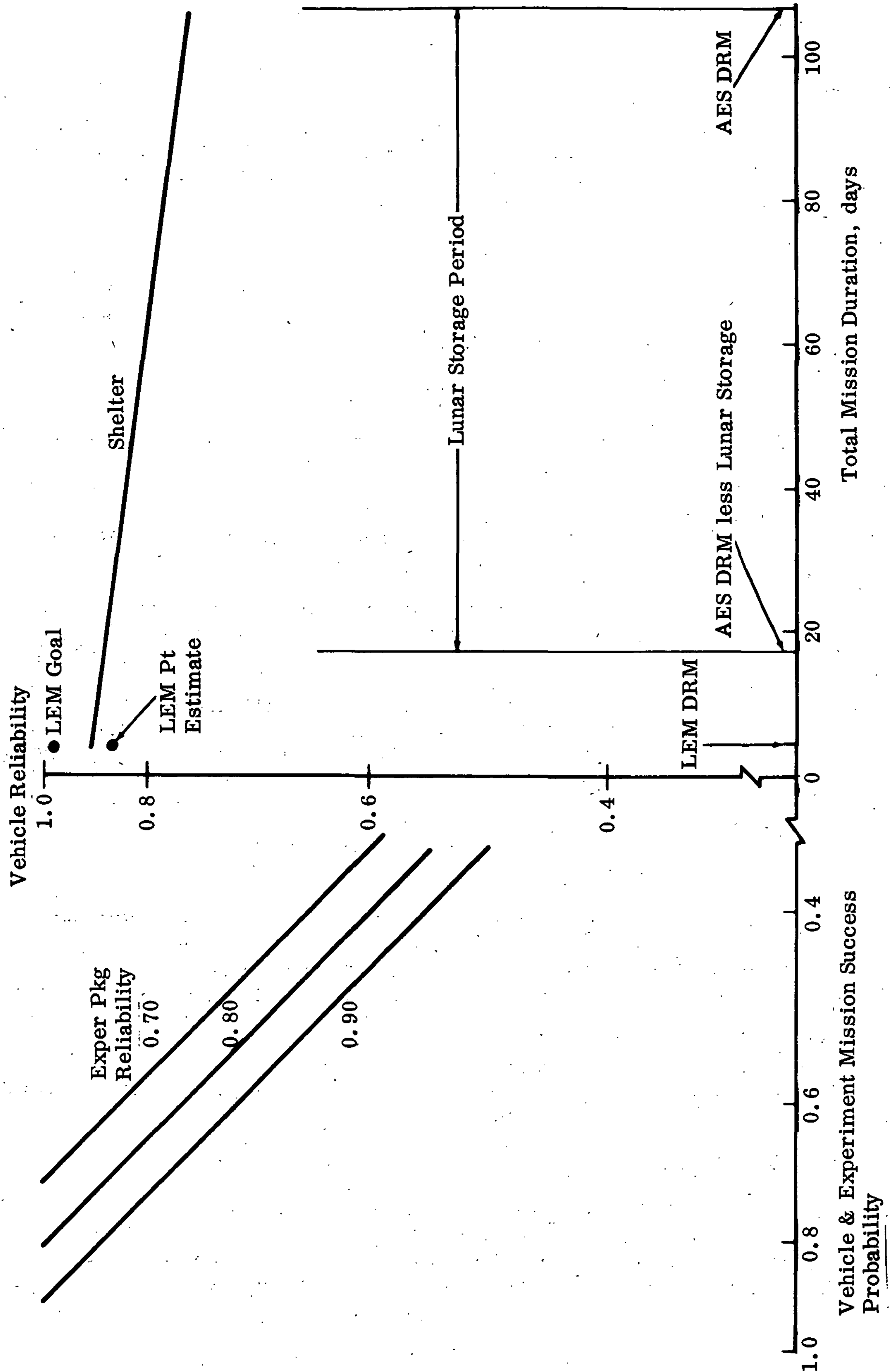

Fig. 4.5-2 Shelter Mission Success Probability

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4.6 MASS PROPERTIES

4.6.1 Ground Rules

The basic ground rule affecting the mass properties analysis of the Shelter is to stay within the propulsion capability of the descent stage. In areas where limits have yet to be defined, as with cg moments of inertia, the configurations presented maintain present LEM values wherever possible.

4.6.2 Assumptions and Background Data

The basis for all reported mass properties is the 1 August 1965 LEM weight statement, modified by the addition of 77 lb of descent propulsion and 18 lb of ascent stage structure to attain the LEM design separation weight.

Specific assumptions affecting the mass properties of the Shelter are:

- Payload and associated weight penalties are not included in the baseline or recommended Shelter
- Water, oxygen, and LiOH for 117 hr of EVA, 44 repressurizations, and 14-day cabin occupancy are provided in the Shelter
- 12 PLSS rechargeable batteries (inclusive of two brought by astronauts from the Taxi) provide 117-hr EVA
- One hard spacesuit is carried in the Shelter
- 539.6 kw-hr of electrical energy are supplied for housekeeping requirements for the recommended configuration. This includes 39 PLSS battery charges
- 110-lb allowance has been included for additional micrometeoroid shielding for the Shelter, exclusive of payload
- RTG unit carried for thermal and electrical energy during storage
- 1000-lb growth contingency is added to the basic Shelter to account for future growth. This value represents approximately 25% of the total weight of new or modified items added to the existing LEM. This contingency is meant to account for weight growth of the recommended Shelter, not the payload. If any of the alternate configurations are selected, growth contingency and the allowable payload weight must be adjusted.
- Payload weight must include:

  - o Supports, mounts, and deployment, including any possible increases in backup structure to accommodate payloads
  - o Micrometeoroid and thermal shielding for payload protection
  - o Electric power, wiring, and controls, including additional penalties for reactants storage (The total weight increase for 79.2 kw-hr of electrical energy for the 100-ft drill is 483 lb)
  - o Controls and displays for payload requirements
  - o Life support expendables, as required, in addition to those provided in the basic Shelter as detailed above.

4.6.3 Recommended Configuration

The recommended configuration mass properties summary by mission phase and by subsystem are presented in Tables 4.6-1 and 4.6-2, respectively. These tables describe the weight, cg, and moments of inertia for each of the mission phases or subsytems listed. Table 4.6-4 presents a mass properties summary of a recommended

Shelter, including a payload consisting of an LSSM, ESS, and 100-ft drill.

A detailed weight statement for the recommended configuration is presented in Table 4.6-5. In most cases, the initial weight in each subsystem is a one line entry taken directly from LEM. The subsequent items indicate additions or deletions from the basic LEM subsystem. Where only one or two items from the LEM are used, a "build-up" technique is used. The allowable payload weight, based on the recommended Shelter configuration, is 2935 lb.

Changes from the baseline configuration to the recommended configuration are detailed in Table 4.6-7.

4.6.4 Baseline Configuration

The mass properties of the baseline configuration are defined in the following tables:

- Mass Properties Summary by Mission Phase, Table 4.6-1
- Mass Properties Summary by Subsystem Table 4.6-3
- Detailed Weight Statement Table 4.6-6
- Changes to the Baseline Configuration Table 4.6-8.

4.6.5 Alternate Configuration

Weight estimates have been made of the various alternates considered. The delta effects of these alternates on the mass properties of the recommended configuration at lunar orbit separation are summarized in Table 4.6-9 and detailed in Table 4.6-10.

Table 4.6-1
MASS PROPERTIES SUMMARY - BASELINE & RECOMMENDED CONFIGURATIONS - BY MISSION PHASE

Mass Property		Dry		Burn-out		Lunar Landing		Separation		Earth Launch	
		Base*	Rec*	Base	Rec	Base	Rec	Base	Rec	Base	Rec
Weight, lb		9,571	10,586	10,438	11,459	11,520	12,318	29,017	29,815	29,028	29,827
cg, in.	x	203	209	201	205	198	202	175	178	175	178
from	y	3	4	3	3	2	4	1	1	1	2
Ref. Datum	z	-3	-3	-3	-3	0	-1	0	-1	0	-1
Moments	I_{x-x}	7,354	9,432	7,690	10,068	8,447	11,027	19,964	22,580	18,706	21,324
of Inertia (cg),	I_{y-y}	11,151	12,641	12,196	13,862	13,335	14,763	23,110	25,178	22,522	24,595
slug-ft^2	I_{z-z}	9,659	10,690	10,635	11,971	11,381	12,785	18,745	20,819	18,190	20,269

*Base: Baseline
Rec : Recommended

Notes:
- cg Given in inches from Ref. Datum.
- x-cg In LEM stations (Ascent/Desent separation plane is LEM Sta. 200.0)
- y & z cg Measured from vertical center line.
- Moments of Inertia in slug-ft^2 about vehicle gg.

Table 4.6-2
MASS PROPERTIES SUMMARY - RECOMMENDED CONFIGURATION - BY SUBSYSTEM

Code	Subsystem	Wt, lb	cg, in. from Ref. Datum			Moments of Inertia, slug-ft^2		
			x	y	z	I_{xx}(roll)	I_{yy}(pitch)	I_{zz}(yaw)
1.0	Structure	3246	209	0	6	2605	3871	3327
2.0	Stab & Cont	43	227	22	-36	19	38	29
3.0	Nav & Guidance	395	256	-11	16	216	346	269
4.0	Crew Provisions	514	236	-4	29	128	121	68
5.0	Environ Control	472	267	4	-9	249	314	263
6.0	Landing Gear	531	121	0	4	2043	1128	1071
7.0	Instrumentation	210	247	-14	-47	40	52	21
8.0	Electric Power	2609	216	18	-23	1610	1782	1280
9.0	Propulsion	1150	153	3	-6	530	356	348
10.0	Reaction Control	152	265	-28	0	127	61	74
11.0	Communications	136	255	25	-11	110	135	89
12.0	Cont & Display	128	264	4	60	17	5	17
14.0	Growth Contingency	1000	210	0	0	894	1187	1014
	TOTAL DRY WEIGHT	10586	209	4	-3	9432	12641	10690
	TRAPPED & RESIDUAL							
4.0	Crew Provisions	199	188	-27	-7	143	201	245
5.0	Environ Control	142	182	-1	0	122	151	184
8.0	Electric Power	6	169	54	54	0	0	0
9.0	Propulsion	505	132	1	-2	300	196	124
10.0	Reaction Control	21	263	45	14	9	1	8
	TOT WT AT BURNOUT	11459	205	3	-3	10068	13862	11971
	EXPENDABLES CONSUMED ON LUNAR SURFACE							
4.0	Crew Provisions	78	210	0	45	4	2	2
5.0	Environ Control	246	145	-46	-47	18	59	62
8.0	Electric Power	535	172	51	47	125	119	70
	TOT WT AT LUNAR LOG	12318	202	4	-1	11027	14763	12785
	CONSUMED ON DESCENT							
9.0	Propulsion	17357	160	0	0	11383	7309	4788
10.0	Reaction Control	140	270	-45	15	67	6	60
	TOT WT AT SEP	29815	178	2	-1	22580	25178	20819

Table 4.6-2 (cont.)

Code	Subsystem	Wt,lb	cg, in. from Ref. Datum			Moments of Inertia, slug-ft^2		
			x	y	z	I_{xx}(roll)	I_{yy}(pitch)	I_{zz}(yaw)
	CONSUMED ON TRANSLUNAR FLIGHT							
5.0	Environ Cont	12	150	-49	-49	2	2	2
	TOT WT AT EARTH LCH	29827	178	2	-1	21324	24595	20269

Table 4.6-3

MASS PROPERTIES SUMMARY - BASELINE CONFIGURATION - BY SUBSYSTEM

Code	Subsystem	Wt, lb	cg, in.*			Moments of Inertia, slug-ft^2		
			x	y	z	I_{xx}(roll)	I_{yy}(pitch)	I_{zz}(yaw)
1.0	Structure	3,183	208	0	4	2,286	3,514	3,270
2.0	Stab & Cont	43	227	22	-36	19	38	29
3.0	Nav & Guid	383	256	- 3	- 1	143	270	231
4.0	Crew Provisions	476	260	0	2	20	35	16
5.0	Environ Cont	455	270	4	- 9	135	313	300
6.0	Landing Gear	531	121	0	4	2,043	1,128	1,071
7.0	Instrumentation	205	246	-14	-47	39	50	19
8.0	Elect Power	2,746	193	7	- 9	1,556	2,147	1,287
9.0	Propulsion	1,150	153	3	- 6	530	356	348
10.0	Reaction Control	152	265	28	0	127	61	74
11.0	Communications	134	257	25	-12	107	133	89
12.0	Cont & Displ	113	264	5	60	17	5	17
	TOTAL DRY WT	9,571	203	3	- 3	7,354	11,151	9,659
	TRAPPED & RESIDUAL							
4.0	Crew Provisions	199	265	0	0	-	-	-
5.0	Environ Control	124	262	3	- 3	5	4	4
8.0	Elect Power	18	162	0	50	-	-	-
9.0	Propulsion	505	132	1	- 2	300	196	124
10.0	Reaction Control	21	263	45	14	9	1	8
	TOT WT AT BURN-OUT	10,438	201	3	- 3	7,690	12,196	10,635
	EXPENDABLES CONSUMED ON LUNAR SURFACE							
4.0	Crew Provisions	78	220	0	0	-	-	-
5.0	Environ Cont	278	144	-47	-47	19	59	62
8.0	Elect Power	726	162	0	50	54	130	130
	TOT WT AT LUNAR LDG	11,520	198	2	0	8,447	13,335	11,381
	CONSUMED ON DESCENT							
9.0	Propulsion	17,357	160	0	0	11,383	7,309	4,788
10.0	Reaction Control	140	270	45	15	67	6	60
	TOT WT AT SEP	29,017	175	1	0	19,964	23,110	18,745
	CONSUMED ON TRANSLUNAR FLIGHT							
5.0	Environ Cont	11	155	-49	-49	2	2	2
	TOT WT AT EARTH LCH	29,028	175	1	0	18,706	22,522	18,190

*From Ref. Datum.

Table 4.6-4
MASS PROPERTIES SUMMARY - RECOMMENDED CONFIGURATION - INCLUDING EXPERIMENTS

Item	Wt, lb	cg, in. from Ref. Datum x	y	z	Moments of Inertia, slug-ft^2 I_{xx}(roll)	I_{yy}(pitch)	I_{zz}(yaw)
Basic Shelter - Touchdown	12318	202	4	-1	11027	14763	12785
Payload	2878	277	-7	6	2745	3634	5580
Shelter - Touchdown	15196	216	2	0	13858	21267	21268
Basic Shelter - Separation	29815	178	2	-1	22580	25178	20819
Payload	2878	277	-7	6	2745	3634	5580
Shelter - Separation	32693	187	1	0	25399	34405	32006

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RECOMMENDED SHELTER DRY WEIGHT

CODE	TITLE	WEIGHT POUNDS	C.G. X	C.G. Y	C.G. Z
1.0	STRUCT ASC	1326	259	- 1	9
1.0	STRUCT DES	1499	156	2	0
1.1317	BLAST DEFL-	6	190	0	0
1.313	ENG COVER -	13	245-	0	2
1.323	PROP TK SH-	11	252	0	0
1.3821	PROP TK SU-	3	228-	45-	27
1.3822	PROP TK SU-	2	239-	59-	27
1.3823	PROP TK SU-	1	238	45-	27
1.3824	PROP TK SU-	2	228	34-	27
1.3825	PROP TK SU-	14	222	50	47
1.323	PROP TK MM-	11	252-	0	0
1.0	MM SHIELD	110	270	0	0
1.0	WINDOW CVR	2	275	0	62
1.0	TUNNEL CVR	13	305	0	0
1.0	CON WT INC	18	259	- 1	9
1.0	INSUL ASC	87	250	0	0
1.15	BATTS INSU	10	184	48	-48
1.1510	RTG INSUL	6	188	-50	-70
1.15	H2O TK INS	5	145	-49	-49
1.1511	RTG SUPTS	7	188	-50	-70
1.0	H2O TK MTG	6	145	-49	-49
1.0	MISC SUPTS	20	265	0	0
1.1111	BAT+ECA SU	- 50	164	57	36
1.1111	BAT+ECA SV	50	184	48	-48
-1.1113	STEPS	-10	230	0	64
1.1113	STEPS MOVE	13	230	0	64
1.1114	PLATFORM	- 10	198	0	91
1.119	LIOH SUPTS	7	136	50	50
1.1511	F/C ECA ST	3	250	0	-50
1.159	LIOH SUPTS	10	140	-68	-42
1.384	RCS TK SUP	-15	275	0	0
1.385	RCS HE SUP	- 4	263	0	0
1.39	PLSS O2 SU	2	304	24	12
1.39	AL BLKHEAD	17	235	0	86
1.39	RING+CLAMP	10	235	0	86
1.39	AIRLOCK	78	235	0	91
1.39	AL BLKHEAD	10	235	0	95
1.39	HATCH	25	235	0	95
1.39	ADAPTER	10	235	0	74
1.39	MISC HDWE	8	235	0	91
1.48	F/C SUPTS	5	254	20	-52
1.48	F/C SUPTS	5	254	-20	-52
1.4831	HE TK SUPT	- 2	245	25	-49
1.4832	HE TK SUPT	- 2	245	-25	-49
1.49	H2 TK SUPT	12	220	-24	-48
1.49	H2 TK SUPT	12	220	24	-48
1.49	O2 TK SUPT	16	169	54	57
1.0	STRUCTURE	3246	209	0	6
2.0	S+C ASC	87	273	16-	31
2.0	S+C DES	15	158	32	12
2.3	RATE GYROS	- 2	302	9	54
2.61	ABORT SENS-	20	307	0	63
2.62	ABORT ELEC-	37	260	25-	63
2.0	STAB+CONTROL	43	227	22	-36

3.11	IMU PL
3.13	LGC CO
3.14	PWR SE
3.16	LGC CA
3.17	NAVIG
3.18	PULSE
3.110	COUPL
3.111	UNDEFI
3.19	SIG CO
3.1	PRGM C
3.1	AUTO T
3.1	TRANSP
3.	SBND S
3.31	LAND R
3.32	LAND R
3.0	NAV+GUID
4.1	HARD S
4.1	CW GAR
4.4	DOME L
4.4	LIGHTI
4.53	MEDIC
4.6	WSTE M
4.71	FLOOD
4.71	FLOOD
4.81	WORK
4.81	WORK T
4.81	WORK T
4.83	CYCLE
4.84	HAND E
4.85	HAND B
4.86	REC EQ
4.87	SEAT
4.87	SEAT
4.88	MISC
4.88	BUNKS
4.88	BUNKS
4.89	RAD MO
4.810	HYGN E
4.111	EMERG
4.12	PLSS
4.12	PLSS B
4.112	PLSS S
4.0	CREW PRO
5.0	ENVIRN
5.0	ENVIRN
5.8	ECS E
5.8	ECS E
5.222	REDUNT
5.31	O2 TK
5.31	ASC GO
5.313	DES GO
5.41	ASC H2
5.4	FC H2O
5.54	FC H2O
5.54	H2O PL
5.7	GLYCOL
5.911	RADIAT
5.912	RADIAT
5.913	RADIAT
5.914	RADIAT

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Table 4.6-5 ②

DETAILED WEIGHT STATEMENT - RECOMMENDED CONFIGURATION

```
FM      42  307    0   50
TR      58  248   0-   24
O       15  239   0-   26
E       10  261   0-   26
SE       6  307    0   55
RQ      12  305    0   30
TA      33  265   0-   24
D       10  258    0    5
 A       6  238   0-   26
PL      78  240  -40   45
CK      50  295    0   59
DR      22  290    0   85
NR      15  295   80    0
AR      24  115-  54-  53
AR      14  161-  72-  33

ICE    395  256  -11   16

IT      85  240  -38    0
NT      12  275   21  -14
GHT      2  263    0   43
        26  257   0-    4
IT       3  240  -40   45
IGE     26  215    0   46
ITE      2  130    0  -80
LTE      2  130    0   80
ITE      2  260    0   45
         8  252   28   40
         8  252  -28   40
GO       5  245  -38    0
OM       1  245  -38    0
IGE      1  245  -38    0
IP      10  240    0   45
         5  235  -16   37
         5  235   16   37
         5  250    0   45
         5  260   25   60
         5  260   25   60
ITO      7  230    3  -45
IIP     15  250    0  -45
         7  238   37   49
       244  230    3   45
ES      20  230    0   45
PT       3  265    0    0

ISN    514  236  - 4   29

SC     347  269   12    0
ES     302  156-  19-  46
ND-     61  293   2-    3
ND-    213  148-  30-  47
OP   -   3  280   25  -29
SS      11  303   25   13
TK-      7  266    0  -53
TK-     46  184   40  -40
TK-     11  302    0    0
K       15  265    0  -55
MB       5  275    0    0
NG   -   7  246   10   22
     -  37  255  10-   10
        22  294  -45   63
        10  294   31   65
        22  309   41    0
        22  309  -41    0
```

```
5.915 RADIATOR        67  294   0  -65
5.916 RAD SYSTEM      27  290   0    0
5.91  HT PIPE AS       3  250   0    0
5.92  HT PIPE DS       4  190 -50  -65

5.0 ENVIRON CONT     472  267   4 -  9

6.0   LANDG GEAR     531  121   0    4

7.11  SIGNAL CON      86  246- 18-  64
7.12  PCMTE           39  249- 18-  64
7.13  VOICE RECD       5  285   0  -35
7.2   C+W EQUIP       25  266- 18-  64
7.4   SENSORS AS      50  245-  6    0
7.4   SENSORS DS       5  153   8-  15

7.0 INSTRUMENTN      210  247 -14  -47

8.0   EPS  ASC       767  255   1-  28
8.0   EPS  DES       656  162  58   33
8.112 BATTRYS DS    -556  159  63   36
8.12  BAT CONTLS    - 38  171  44   36
8.11  ASC BATTRS -   261  253   0-  66
8.121 BAT CON AS-     20  276   0-  66
8.112 BATTERIES      429  184  48  -48
8.112 BATRY CONT      28  184  50  -50
8.112 BATY START      11  250   0  -50
8.1   BATY CHRGE       3  260   0    0
8.1   RTG UNIT        50  188 -50  -70
8.002 RADIATOR        80  250   0  -75
8.006 AC F/C         164  254 -20  -52
8.006 AC F/C         164  254  20  -52
8.1   RTG ECA         10  185 -50  -70
8.008 F/C ECA         28  250   0  -50
8.007 PLUMBING        22  250   0  -65
8.    GLYCOL PMP      10  250   0  -40
8.    MISC            14  190   0  -10
8.1   02 TANK        461  169  54   54
8.1   H2 TANK        293  220  24  -48
8.1   H2 TANK        294  220 -24  -48

8.0 ELECTRIC PWR    2609  216  18  -23

9.22  PROP TANKS     239  154   0    0
9.24  OXID TANKS     269  154   0    0
9.26  PLUMBING        57  126   0-   6
9.32  HE TANKS       100  148  49-  46
9.36  PLUMBING        49  178- 17-  35
9.36  VENT VALVE      15  180- 17-  35
9.42  ENGINE DES     400  154   0    2
9.46  MISC            21  152   0    0

9.0 PROPULSION      1150  153   3-   6

10.21 FUEL TK LH       9  276 -45    0
10.22 OXIDIZ TK       11  272 -45    0
10.23 PLUMBING        36  265 -45    0
10.24 SENSORS         10  279 -45    0
10.31 HE TK   LH      11  263 -45    1
10.33 PLUMBING        18  285 -41    2
10.4  THRUSTERS       57  254   0    0
```

```
10.0 RCS              152   26

11.    COMMUNICTN     100   26
11.    COMM             8   24
11.    COMM             5   28
11.    COMM            15   13
11.    COMM DECOD      15   27
11.3   TV      ASC-     8   24
11.3   TV      DSC-     2   13
11.    CMD RECVR        3   25

11.0 COMMUNICATN      136   25

12.0   CONTS+DSPL     213   26
12.2   S+C         -   73   26
12.7   INSTRUMENT-      9   28
12.9   PROPULSION-     10   27
12.10  RCS         -    8   27
12.    MISC C+DTS      15   26

12.0 CONTS+DISPL      128   26

14.0 GRWTH CONTG     1000   21

REC SHELTER DRY     10586   20

  ******     ******     ******

SHELTER WEIGHT AT BURNOUT

 CODE    TITLE     WEIGHT
                   POUNDS   X

REC SHELTER DRY     10586   20

4.113 PLSS BATTS       28   24
4.54  LIOH      12     54   26
4.54  LIOH      17     76   14
4.54  LIOH       9     41   13

4.0 T+R CRW PROV      199   18

5.7   GLYCOL           37   25
5.72  GLYCOL      -     3   25
5.811 LIOH              8   26
5.81  LIOH             45   14
5.81  LIOH             45   13
5.812 LIOH              7   25
5.82  02 PLSS RS        3   30

5.0 TRP+RESD ECS      142   18

8.1   02 RESIDL         6   16

8.0 TRP+RESD EPS        6   16
```

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```
-28   0

 37- 35
 40  35
 34  29
- 44 44
  0  70
 40  35
- 71 30
 10  70

 25 -11

-  1 58
- 10 51
   1 72
-  4 68
   3 69
   0 58

   4 60

   0  0

   4 - 3

 ******




C.G.
 Y    Z

  4 - 3

  0 -10
-40   0
-68 -42
 50  50

-27 - 7

 10- 10
 10 -10
 19   5
-68 -42
 50  50
 17 -19
 24  12

- 1   0

 54  54

 54  54
```

```
9.12  PROP TRAPD     455  129    0-  1
9.34  HELIUM          50  156    8-  8

9.0   T+R PROP       505  132    1 - 2

10.11 PROP TRAPD      20  263 -45   15
10.32 HELIUM   LH      1  263 -45    1

10.0 T+R RCS          21  263 -45   14

REC SHELTER B/O    11459  205    3 - 3

  ******    ******    ******    ******


SHELTER WEIGHT AT TOUCHDOWN

 CODE    TITLE    WEIGHT       C.G.
                  POUNDS  X     Y    Z

REC SHELTER B/O    11459  205    3 - 3

4.52  FOOD            78  210    0  45

4.0 EXPND PROV        78  210    0  45

5.82  O2 PLSS          9  304   24  12
5.83  H2O            237  139  -49 -49

5.0 EXPEND ECS       246  145  -46 -47

8.1   02             500  169   54  54
8.1   H2              17  220  -24 -48
8.1   H2              18  220   24 -48

8.0 EXPEND EPS       535  172   51  47

REC SHELTER T/D    12318  202    4 - 1

     ******       ******       ******


SHELTER WEIGHT AT SEPARATION

 CODE    TITLE    WEIGHT       C.G.
                  POUNDS  X     Y    Z

REC SHELTER T/D    12318  202    4 - 1

9.112 PROPELLANT    1862  135    0   0
9.112 PROPELLANT      76  150    0   0
9.112 PROPELLANT   15057  162    0   0
9.112 PROPELLANT     362  188    0   0

9.0 EXPEND PROP    17357  160    0   0

10.11 PROP USBLE     140  270  -45  15
```

```
10.0 EXPEND RCS      140  270 -45  15

REC SHELTER SEP    29815  178   2 - 1

      ******       ******      ******



SHELTER WEIGHT AT EARTHLAUNCH

 CODE    TITLE    WEIGHT       C.G.
                  POUNDS  X     Y    Z

REC SHELTER SEP    29815  178   2 - 1

5.83  H2O             12  150 -49 -49

5.0  EXPEND ECS       12  150 -49 -49

REC SHELTER EL     29827  178   2 - 1

*********************************
```

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```
AES SHELTER BASELINE CONFIG

SHELTER DRY WEIGHT

 CODE    TITLE    WEIGHT      C.G.
                  POUNDS  X     Y    Z

1.0    STRUCT ASC  1326  259 - 1    9
1.0    STRUCT DES  1499  156   2    0
1.313  ENG COVER -   13  245-  0    2
1.323  PROP TK SH-   11  252   0    0
1.3821PROP TK SU-     3  228- 45-  27
1.3822PROP TK SU-     2  239- 59-  27
1.3823PROP TK SU-     1  238  45-  27
1.3824PROP TK SU-     2  228  34-  27
1.3825PROP TK SU-    14  222  50   47
1.385  HE TK SUPT-    7  263   0    0
1.1317BLAST DEFL-     6  190   0    0
1.323  PROP TK MM-   11  252   0    0
1.0    MM SHIELD    110  270   0    0
1.0    INSULATION   150  250   0    0
1.0    SUPPORTS     150  200   0    0
1.0    CON WT INC    18  259 - 1    9


1.0 STRUCTURE      3183  208   0    4

2.0    S+C    ASC    87  273  16-  31
2.0    S+C    DES    15  158  32   12
2.3    RATE GYROS -   2  302   9   54
2.61   ABORT SENS-   20  307   0   63
2.62   ABORT ELEC-   37  260  25-  63

2.0 STAB+CONTROL     43  227  22  -36


3.11   IMU PLATFM    42  307   0   50
3.13   LGC COMPTR    58  248   0-  24
3.14   PWR SERVO     15  239   0-  26
3.16   LGC CABLE     10  261   0-  26
3.17   NAVIG BASE     6  307   0   55
3.18   PULSE TORQ    12  305   0   30
3.19   SIG COND A     6  238   0-  26
3.110  COUPL DATA    33  265   0-  24
3.111  UNDEFINED     10  258   0    5
3.31   LAND RADAR    24  115- 54-  53
3.32   LAND RADAR    14  161- 72-  33
3.     MISSN PROG   120  265   0    0
3.     TRANSPONDR    18  290   0   85
3.     SBND SCANR    15  295  80    0

3.0 NAV+GUIDANCE    383  256 - 3 -  1
```

```
4.1    HARD SUIT     85  265   0    0
4.12   PLSS      4  244  265   0    0
4.112  PLSS SP PT     3  265   0    0
4.1    OVERALLS14    12  265   0    0
4.4    LIGHTING      26  257   0-   4
4.4    DOME LIGHT     2  280   0    0
4.53   MEDICAL KI     3  265   0    0
4.6    WSTE MANGE    26  215   0   46
4.1    FURNISHING    75  250   0    0

4.0 CREW PROVISN    476  260   0    2


5.0    ENVIRN ASC   347  269  12    0
5.0    ENVIRN DES   302  156- 19-  46
5.8    ECS  EXPND-   61  293   2-   3
5.8    ECS  EXPND-  213  148- 30-  47
5.222  REDUNTLOOP -   3  280  25  -29
5.31   ASC GOX TK-    7  266   0  -50
5.31   O2 TK PLSS    11  303  25   13
5.313  DES GOX TK-   46  184  40  -40
5.41   ASC H2O TK-   11  302   0    0
5.4    FC H2OTANK     8  303 -25  -12
5.4    H2O TK NAA    10  140- 50-  50
5.54   FC H2OPLMB     5  275   0    0
5.54   H2O PLMBNG -   7  246  10   22
5.     RADIATORS    150  315   0    0
5.7    GLYCOL    -   37  255  10-  10
5.91   HT PIPE AS     3  250   0    0
5.92   HT PIPE DS     4  190 -50  -65

5.0 ENVIRON CONT    455  270   4 -  9


6.0    LANDG GEAR   531  121   0    4

6.0 LANDING GEAR    531  121   0    4


7.11   SIGNAL CON    86  246- 18-  64
7.12   PCMTE         39  249- 18-  64
7.2    C+W EQUIP     25  266- 18-  64
7.4    SENSORS AS    50  245-  6    0
7.4    SENSORS DS     5  153   8-  15

7.0 INSTRUMENTN     205  246- 14-  47


8.0    EPS  ASC     767  255   1-  28
8.0    EPS  DES     656  162  58   33
8.112  BATTRY DES - 278  159  63   36
8.122  BAT CON DS-   19  175  44   36
8.11   ASC BATTRS - 261  253   0-  66
8.121  BAT CON AS-   20  276   0-  66
```

```
8.1    BATY CHR
8.1    P+W FC
8.1    P+W FC
8.     O2 TANK
8.     H2 TANK
8.1    RTG UNIT
8.     RADIATOR
8.     MISC

8.0 ELECTRIC P


9.22   PROP TAN
9.24   OXID TAN
9.26   PLUMBING
9.32   HE TANKS
9.36   PLUMBING
9.36   VENT VAL
9.42   ENGINE D
9.46   MISC

9.0 PROPULSION


10.21  FUEL TK
10.22  OXIDIZ T
10.23  PLUMBING
10.24  SENSORS
10.31  HE TK
10.33  PLUMBING
10.4   THRUSTERS

10.0 RCS


11.    COMMUNIC
11.    COMM
11.    COMM
11.    COMM
11.1   AUTO SWV
11.    COMM DEC
11.3   TV      A
11.3   TV      D

11.0 COMMUNICA


12.0   CONTS+DSP
12.2   S+C
12.7   INSTRUME
12.9   PROPULSI
12.10  RCS

12.0 CONTS+DISP
```

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Table 4.6-6

DETAILED WEIGHT STATEMENT - BASELINE CONFIGURATION

```
   3   260    0    0
 266   225   21  -48
 266   225  -21  -48
 600   162    0-  50
 600   162    0   50
  50   188  -50  -70
  70   220    0-  70
  46   191    0   12

2746   193    7 -  9

 239   154    0    0
 269   154    0    0
  57   126    0-   6
 100   148   49-  46
  49   178-  17-  35
  15   180-  17-  35
 400   154    0    2
  21   152    0    0

1150   153    3-   6

   9   276   45    0
  11   272   45    0
  36   265   45    0
  10   279   45    0
  11   263   45    1
  18   285   41    2
  57   254    0    0

 152   265   28    0

 100   267   37-  35
   8   240   40   35
   5   288   34   29
  15   138-  44   44
   1   270    0   70
  15   270    0   70
   8   240   40   35
   2   138-  71   30

 134   256   25-  12

 213   267-   1   58
  73   267-  10   51
   9   288    1   72
  10   276-   4   68
   8   277    3   69

 113   264    5   60
```

```
TOTAL SHELTR DRY  9571   203    3 - 3

TOTAL SHELTER AT BURN OUT

 CODE    TITLE    WEIGHT        C.G.
                  POUNDS   X     Y     Z

         SHELTR DRY  9571   203    3 - 3

4.113 PLSS BATT5    28   265    0     0
4.54  LIOH    38   171   265    0     0

4.0   T+R CRW PR   199   265    0     0

5.7   GLYCOL        37   255   10-  10
5.72  GLYCOL     -   3   255   10  -10
5.81  LIOH          90   265    0     0

5.0 TRP+RESD ECS   124   262    3 -   3

8.    02 RESID      14   162    0    50
8.    02 RESDPLS     4   162    0    50

8.0   T+R EPS       18   162    0    50

9.12  PROP TRAPD   455   129    0-    1
9.34  HELIUM        50   156    8-    8

9.0   T+R PROP     505   132    1 -   2

10.11 PROP TRAPD    20   263   45    15
10.32 HELIUM  LH     1   263   45     1

10.0  T+R RCS       21   263   45    14

SHELTER BURNOUT  10438   201    3 -  3

SHELTER TOUCHDWN

 CODE    TITLE    WEIGHT        C.G.
                  POUNDS   X     Y     Z

SHELTER BURNOUT  10438   201    3 -  3

4.52  FOOD          78   220    0     0

4.0   EXPND PROV    78   220    0     0
```

```
5.82  02 PLSS             9   303   25   13
5.83  H20                25   141-  49-  49
5.83  H20               244   139  -49  -49

5.0 EXPEND ECS          278   144  -47  -47

8.    H2                 34   162    0   50
8.    02                692   162    0   50

8.0 EXPEND EPS          726   162    0   50

SHELTER TOUCHDWN 11520  198    2    0

SHELTER SEPARATION WEIGHT

 CODE    TITLE    WEIGHT        C.G.
                  POUNDS   X     Y     Z

SHELTER TOUCHDWN 11520  198    2    0

9.112 PROPELLANT    362  188    0    0
9.112 PROPELLANT  15057  162    0    0
9.112 PROPELLANT   1862  135    0    0
9.112 PROPELLANT     76  150    0    0
9.0 EXPEND PROP   17357  160    0    0

10.11 PROP USBLE    140  270   45   15

10.0  EXPND RCS     140  270   45   15

SHELTER SEPARATN 29017  175    1    0

 IELTER EARTHLAUNCH WEIGHT

 CODE    TITLE    WEIGHT        C.G.
                  POUNDS   X     Y     Z

SHELTER SEPARATN 29017  175    1    0

5.83  H20            11  155-  49-  49

5.0 EXPEND ECS       11  155  -49  -49

SHELTER EARTHLNC 29028  175    1    0
```

Table 4.6-7
WEIGHT CHANGES FROM BASELINE TO RECOMMENDED CONFIGURATION

Code	Subsystem	Item	ΔWt	Description of Change
1.0	Structure	Insulation	- 27	More detailed information
		Steps	3	Now movable
		Platform	- 10	Removed due to airlock Instn
		Supports	- 61	More detailed information
		Airlock	158	Added
3.0	Nav + Guid	Auto Tracker	50	Added
		Transponder	4	Installation added
		Mission Programmer	- 42	Replaced by Program Coupler
4.0	Crew Provision	Flood Lights	4	Added requirement
		Emergency O_2	7	
		Radiation Monitoring	7	
		PLSS Insulation Boxes	20	Boxes to shore PLSS units outside
5.0	Environ Cont.	Cooling System	20	More detailed information
		H_2O Tank	- 3	
7.0	Instrumentation	Voice Recorder & Cartridge	5	
8.0	Electric Pwr.	Starter Battery	11	Added
		RTG Control Unit	10	
		Fuel Cells	- 204	AC in lieu of P&W
		Battery Control Unit	9	Additional battery
		Batteries Descent	151	1 additional battery
		Cooling System	10	Bigger radiator
		Reactant Tanks	- 152	AC fuel cell use
		Fuel Cell ECA	28	
11.0	Communication	Command Receiver	3	Added
		Auto S/W VHF	- 1	Not required
12.0	Conts + Display	Misc.	15	Allowance for modifications & additions
14.0	Growth Contingency		1000	
		TOTAL DRY WEIGHT	+1015	
	TRAPPED & RESIDUAL			
5.0	ECS	LiOH	15	Omitted in error
		O_2 PLSS	3	Transferred from EPS
8.0	EPS	O_2	- 12	AC fuel cell use
		TOTAL TRAPPED & RESIDUAL	+ 6	

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Table 4.6-7 (cont.)

Code	Subsystem	Item	ΔWt	Description of Change
	EXPENDABLES			
5.0	ECS	H_2O	-32	Changed requirements
8.0	EPS	O_2	-192	AC fuel cell use
		TOTAL EXPENDABLES	-224	
		TOTAL CHANGES	+797	

Table 4.6-8
WEIGHT CHANGES FROM MID-TERM BASELINE TO PRESENT BASELINE

Code	Subsystem	Item	ΔWt	Reason for Change
1.0	Structure	Control Weight Δ	+18	Omitted by error from Mid-Term Report.
2.0	Stab & Control	Rate Gyros	-2	
3.0	Nav & Guid	S-Band Scanner	+15	
5.0	Environmental Control	Redundant Loop Controls	-3	Omitted by error from Mid-Term Report.
		Fuel Cell Tank	+8	
		H_2O Plumbing	+5	
		PLSS O_2 Tank	+11	Transferred from EPS.
		H_2O Plumbing	-7	Mid-Term Report omission.
		Heat Pipe	-18	Better information.
8.0		Battery charger	-10	Added PLSS charger, removed main chgr.
		PLSS O_2 Tank	-11	Transferred to env cont
		P & W Fuel Cells	+40	Better information.
		Miscellaneous	+11	
		TOTAL DRY WT Δ	+57	
5.0	Environ Control	Redundant Loop Glycol	-3	Mid-Term Report omission
		TRAPPED & RESIDUAL Δ	-3	
5.0	Environ Control	PLSS O_2	+9	Transferred between groups.
8.0	Elect Power	PLSS O_2	-9	
		TOTAL EXPENDABLE WT	-0	
		TOTAL WT CHANGES	+54	

Table 4.6-9
MASS PROPERTIES SUMMARY - SUBSYSTEM ALTERNATES

Alternates	Wt, lb	cg, in. from Ref. Datum			Moments of Inertia, slug-ft^2		
		x	y	z	I_{xx}(roll)	I_{yy}(pitch)	I_{zz}(yaw)
Air Radiator Designs & Locations		No weight estimate has been made.					
Direct RTG Radiation	10	237	-63	-19	0	-4	-1
Pump Down System	-111	155	66	47	17	24	36
Use of GE Fuel Cells	547	157	-32	28	354	345	276
Cyro Storage of Reactants	-172	491	461	-274	10503	6187	11533
16 RCS Thruster Config	67	255	2	0	122	61	61
Add RCS Cluster Covers	80	254	0	0	167	84	84
S-Band Convert to UHF	2	267	31	-63	0	0	0
Couple S-Band Omni-Ant	5	274	0	90	0	0	0
Replace Transponder with Beacon	0	0	0	0	0	0	0
LGC Control S-Band Antenna	0	0	0	0	0	0	0
Add Expandable Pressurized Storage	72	316	0	0	2	1	1
Add Pass Thru Air-lock	8	275	25	65	0	0	0
External PLSS Charge Station	10	140	60	-60	0	0	0
Carry Second Hard-suit	157	275	-21	0	14	50	62
Add Water Tank Heaters	2	143	-49	-49	0	0	0

NOTE: All inertias are about the alternate delta change cg.

DETAILED WEIGHT STAT

ALTERNATES TO RECOMMENDED SHELTER

ALT RADIATOR DESIGNS AND LOCATIONS

NO WEIGHT ESTIMATE HAS BEEN MADE

****** ****** ******

DIRECT RTG RADIATION

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
1.0	INSUL INST	15	215	-53	-43
1.	SUPT BEAM	10	202	-50	-50
1.0	DOOR INST	3	215	-36	-43
1.0	MISC	2	215	-40	-43
1.1510	RTG INSUL	-6	188	-50	-70
1.1511	RTG SUPTS	-7	188	-50	-70
5.0	HEAT PIPE	-4	190	-50	-65
5.0	HEAT PIPE	-3	250	0	0
	DELTA WEIGHT	10	237	-63	-19

****** ****** ******

PUMP DOWN SYSTEM

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
8.1	O2 TANK	-461	169	54	54
8.1	O2	-500	169	54	54
8.1	O2 TANK	396	169	54	54
8.1	O2	435	169	54	54
5.1	PUMP INV V	25	232	0	86
8.1	O2 RESIDL	-6	169	54	54
	DELTA WEIGHT	-111	155	66	47

****** ****** ******

USE GE FUEL CELLS,REMOVE AC F/C

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
1.1511	F/C ECA ST-	3	250	0	-50
1.48	F/C SUPTS -	5	254	20	-52
1.48	F/C SUPTS -	5	254	-20	-52
1.129	H2O TK SPT	9	140	-49	49
1.410	FCA MT STR	16	254	0	-58
1.411	ECA MT STR	7	250	0	-55
8.002	RADIATOR -	80	250	0	-75
5.44	H2O	305	140	-49	49
5.99	H2O TANK	30	140	-49	49
8.006	AC F/C -	164	254	-20	-52
8.006	AC F/C -	164	254	20	-52

8.007 PLUM
8. GLYC
8.008 F/C
8.1 H2 TA
8.1 H2 TA
8.1 O2
8.1 O2 TA
8.1 H2 TA
8.1 H2 TA
8.1 O2 TA
8.1 O2
8.002 RADIA
8.002 RADIA
8.002 RADIA
8.002 RADIA
8.006 FUEL
8.007 PLUMB
8.008 ECA
8.009 VOLT
8.22 H2O
8.22 GLYCO

DELTA W

******

16 RCS THRU

CODE TIT

10.23 ISOLA
10.23 ISOLA
10.23 ISOLA
10.23 ISOLA
10.4 THRUS

DELTA W

******

ADD RCS CLU

CODE TIT

1.0 RCS C
1.0 RCS C
1.0 RCS C
1.0 RCS C

DELTA W

******

S-BAND CONV

CODE TIT

NG -	22	250	0	-65
PMP-	10	250	0	-40
A -	28	250	0	-50
K	-294	220	-24	-48
K	-292	220	24	-48
	-500	169	54	54
K	-461	169	54	54
K	289	220	24	-48
K	290	220	-24	-48
K	456	169	54	54
	496	169	54	54
OR	43	165	0	-83
OR	42	165	0	83
OR	43	165	-83	0
OR	42	165	83	0
ELLS	380	254	0	-53
NG	25	250	0	-65
	56	254	0	-53
EG	24	250	0	-58
ILER	3	255	0	-40
PMP	20	260	0	-40
IGHT	547	157	-32	28

***** ****** ******

TER CONFIG

E	WEIGHT POUNDS	C.G. X	Y	Z
VLV	3	258	65	-65
VLV	3	258	65	65
VLV	2	264	-65	-65
VLV	2	264	-65	65
ERS	57	254	0	0
IGHT	67	255	2	0

***** ****** ******

TER COVERS

E	WEIGHT POUNDS	C.G. X	Y	Z
CVR	20	254	65	65
CVR	20	254	65	-65
CVR	20	254	-65	-65
CVR	20	254	-65	65
IGHT	80	254	0	0

***** ****** ******

TO UHF

E	WEIGHT POUNDS	C.G. X	Y	Z

11.2	CONVERTER	2	267	31	-63
	DELTA WEIGHT	2	267	31	-63

****** ****** ******

COUPLE S-BAND OMNI ANTENNAS

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
11.2	COUPLER	5	274	0	90
	DELTA WEIGHT	5	274	0	90

****** ****** ******

REPLACE TRANSPONDER WITH BEACON

NO WEIGHT CHANGE

****** ****** ******

LGC CONTROL S-BAND ANTENNA

NO WEIGHT CHANGE

****** ****** ******

ADD EXPANDABLE PRESSURIZED STORAGE

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
	EXP STR VL	72	316	0	0
	DELTA WEIGHT	72	316	0	0

****** ****** ******

PASS THRU AIR LOCK

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
1.39	AIRLOCK	8	275	25	65
	DELTA WEIGHT	8	275	25	65

****** ****** ****** ******

EXTERNAL PLSS CHARGE STA

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
4.1	PLSS CHARG	10	140	60	-60
	DELTA WEIGHT	10	140	60	-60

****** ****** ****** ******

CRYO STORAGE OF REACTANTS

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
8.1	SOX TANK	395	148	-49	49
8.1	CRYO HYDRG	142	162	49	49
8.1	H2	-17	220	-24	-48
8.1	H2 TANK	-294	220	-24	-48
8.1	H2 TANK	-292	220	24	-48
8.1	H2	-18	220	24	-48
8.1	O2	-500	169	54	54
8.1	O2 TANK	-461	169	54	54
8.1	CRYO OXYGN	590	148	-49	49
8.1	LH2 TANK	290	162	49	49
8.1	O2 RESIDL	-6	169	54	54
	DELTA WEIGHT	-172	491	461	-274

****** ****** ****** ******

ADD WATER TANK HEATERS

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
8.45	HEATER	1	140	-49	-49
8.45	WIRE+ INST	1	145	-49	-49
	DELTA WEIGHT	2	143	-49	-49

****** ****** ******

CARRY SECOND HARDSUIT

CODE	TITLE	WEIGHT POUNDS	C.G. X	Y	Z
1.3	EXPND PRES STORAGE	72	316	0	0
4.1	HARD SUIT	85	240	-38	0
	DELTA WEIGHT	157	275	-21	0

5. SUBSYSTEM ENGINEERING

5.1 ELECTRICAL POWER

5.1.1 Ground Rules

The following NASA ground rule is applicable to this area:

- Mission requirements as defined by NASA/MSFC

5.1.2 Assumptions and Background Data

5.1.2.1 Housekeeping Design Profile

The EPS housekeeping design profile for the Shelter is shown in Fig. 5.1-1. This profile is composed of all those loads that are not considered as experimental or directly associated with the performance of the experiments. For the purpose of this analysis, the mission was divided into the following phases:

- Earth launch through lunar touchdown
- 83-day quiescent storage
- 7-day pre-utilization
- 1-hr manned checkout
- 14-day manned phase

The first part of the mission, Earth launch through lunar touchdown, follows essentially the same profile as the Taxi, except as slightly lower levels (Taxi mission requires more equipment to support a manned landing). An analysis of each phase is presented in Tables 5.1-1.

The 83-day quiescent storage period was derived from the following assumptions:

- 7-day Taxi timeline from countdown through lunar touchdown (2-day launch countdown plus 5-day translunar).
- Shelter equipment started up and verified operational prior to start of Taxi countdown. Equipment then left on at minimum operational level for the 7-day pre-utilization period.

Thus, for the EPS critical design mission time line, the quiescent storage period ends 7 days before Taxi lunar touchdown. The profile for a typical day during storage is shown in Fig. 5.1-2.

It should be noted that most of the housekeeping loads shown in the analysis data sheets are LEM equipment where current status LEM values have been used. As in LEM, a 7-1/2% factor for distribution losses has been added above the current status numbers. Twenty-percent growth allowance has been added for power and energy to account for contingencies and equipment developments. Table 5.1-2 summarizes the energy requirements for each phase and from each of the power sources.

5.1.2.2 Integrated Design Profile

The EPS integrated design profile for the Shelter is the combination of housekeeping and experimental loads and is shown in Fig. 5.1-3. Experiment power requirements occur only during the 14-day manned phase and consist of a 100-ft drill and the energy to recharge PLSS backpack batteries for the Alphonsus mission. This mission was selected as the reference since it presented the highest power and energy requirements.

Operational requirements of the drill were given as 73.5 kw-hr expended in the third through ninth days (Section 3). Since there were problems in defining the specific operational requirements of this drill, it has been assumed that the recommended EPS configuration will be capable of handling the power requirements if enough energy was available. In developing the profile, the drill was assumed to operate at a 2.5-kw power level and expend 10.5 kw-hr on each of the 7 days it was operated.

A total of 38 PLSS battery recharges with an overall charging efficiency of 66.5% was assumed. With these assumptions, 13.7 kr-hr of energy was required for the mission. An additional 0.118 kw-hr of experiment requirements was also included. Distribution losses (7-1/2%) were added to all the experiment loads. Total experiment requirements are shown in Table 5.1-3, and are equal to 94.0 kw-hr.

The total energy required from each power source is summarized as follows:

Power Source	Housekeeping Energy kw-hr	Experiment Energy kw-hr	Total Energy kw-hr
CSM FCA	9.5	-	9.5
Descent Batteries	28.4	-	28.4
RTG	79.7	-	79.7
Shelter FCA	407.5	94.0	501.5

5.1.2.3 Vehicle Constraints and Other Subsystem Requirements

- Vertical fixed radiators will be used for EPS heat rejection purposes
- Heat dissipation above 1 kw to be taken out by water boiling
- 100-sq-ft maximum vertical area available for EPS Radiator
- Radiator weight penalties assumed to be 2 lb/sq ft
- Radiator sizing for initial system trade-offs based on the following:
    - Sub-solar (442 btu/hr/ft^2
    - Lunar surface temperature 250°F
    - = 0.18/0.9 = 0.2
- Radiator resizing for selected configuration based on the following:
    - Vertical radiator with deployable horizontal shade, (shade area equal to the radiator area)
    - Mission starts at night/day terminator, ends 14 days later at day/night terminator
    - Solar radiation and lunar radiation varies as a function of time
    - = 0.18/0.9 = 0.2
- Voltage at FCA terminals
    - Max voltage: 32.5
    - Min voltage: 28.0

- Environmental temperature
  - o Ambient tanks: -20 to +130°F
  - o Cryo tanks: +130°F max.
  - o Fuel cells: +40 to +130°F
- ECS O_2 Requirements: 229.4 lb.

5.1.2.4 Fuel Cells

In response to a technical information request, vendors have submitted the following documents:

- Pratt & Whitney - Powercel Technical Information PWA-2676 (27 Aug 1965)
- Allis-Chalmers - Response to T.I.R. and Supplement (31 Aug 1965)
- General Electric - Preliminary Technical Information (1 Sept 1965).

The fuel cells and their respective operating characteristics are described in the following paragraphs:

5.1.2.4.1 General Electric. The General Electric fuel cell is a low-temperature (120°F), low-pressure (20 psi) fuel cell that utilizes a solid ion exchange electrolyte and a static water removal system.

The basic cell unit consists of the solid electrolyte, two platinum film electrodes, a dacron water removal wick, and integral cooling tubes between the cells. Thirty-two cell units form a stack and three stacks form a fuel cell section.

A titanium container, whose void is filled with a unicellular foam, houses the three stacks. Accessory equipment, such as purge valves and fluid control components, are mounted on the exterior of the container between the vehicle mounting brackets.

To cool the fuel cell, a glycol water mixture is pumped in two parallel loops that flow in series through the three stacks. The dacron wicks that are adjacent to the coolant tubes, condense and absorb by capillary action the product water that is formed by the hydrogen-oxygen reaction. This product water is then carried to a main separator plate from which the water is removed and sent to storage.

Hydrogen fuel is fed to each stack from a manifold and each stack is capable of independent operation. The container housing the stacks is filled with oxygen and the cells draw on this environment for the oxidant.

A schematic of the fuel cell is shown in Fig. 5.1-4. The characteristics of the fuel cell are shown in Table 5.1-4 and Fig. 5.1-5 through 5.1-7.

5.1.2.4.2 Pratt & Whitney. The Pratt & Whitney fuel cell is a Bacon-type fuel cell that utilizes dual porosity sintered nickel electrodes and high concentration (75 to 85%) KOH electrolyte. Operation of the cell is carried out at 382 to 425°F and 55 psi.

Hydrogen and oxygen are manifolded to each of the 31 cells that make up the fuel cell stack. Excess hydrogen is used to carry product water from the anode, through a glycol-water cooled condenser, to a hydrogen pump separator. The centrifugal action of the pump separates the heavier water particles from the gaseous hydrogen sending the by-product water to storage and recirculating the hydrogen.

The recirculating hydrogen is actually a dual purpose stream. Besides serving as a carrier for the water it also acts as a heat transport medium that allows the cell to be maintained at the desired operating temperature.

Temperature regulation of the P&W cell is necessary because of the dependence of the polarization characteristics on operating temperature. By using a by-pass valve, regenerator, and in-line heater on the hydrogen stream, and a regenerator by-pass valve combination on the glycol-water loop a fairly wide range of operating temperatures may be obtained.

A schematic of the fuel cell is shown in Fig. 5.1-8. The characteristics of the fuel cell are shown in Table 5.1-4 and Fig. 5.1-9 through 5.1-12.

5.1.].4.3 Allis-Chalmers. The Allis-Chalmers fuel cell is a moderate temperature (200°F) and pressure (55 psi) fuel cell that uses 37-to-40% KOH electrolyte imbibed in an asbestos matrix.

A basic cell is composed of two porous electrodes separated by a KOH saturated asbestos matrix, oxygen and hydrogen distribution plates, a water transport matrix (also a KOH saturated asbestos matrix) supported by porous plaques, and a water removal plate. Two such basic cells joined electrically in parallel form a section, and 33 sections make up the fuel cell stack.

Heat is removed from the cells by conduction through the metal electrode support plates to the surface of the stack. The ends of the plates extend beyond the surface of the stack to form cooling fins over which helium is circulated to remove the heat. The helium is then drawn through a heat exchanger, where a glycol water loop removes heat from the helium which is then recirculated by a set of fans back through the stack.

A magnesium canister houses the fuel cell stack, the helium-glycol heat exchanger, and the helium recirculating fans.

Moisture is removed from the stack by creating a pressure differential across the water transport matrix which is located between the hydrogen electrode and the water removal plate. This is accomplished by the use of a temperature, vacuum concentration controller which senses the operating conditions and maintains a proper balance in the system. The moisture is then drawn outside the main fuel cell canister to the water recovery unit. In this unit, the moisture is condensed by a glycol-water loop and water removed through a porous plate and drawn through a deionizer by means of a diaphragm pump. The diaphragm pump is discharged by using 40-psi helium or oxygen gas and the water is sent through a pH sensor to a storage tank.

A schematic of the AC fuel cell is shown in Fig. 5.1-13. The characteristics are shown in Table 5.1-4 and Fig. 5.1-14 through 5.1-16.

5.1.2.5 Cryogenic Tanks

The cryogenic tank characteristics used during the study were supplied by NASA and are shown in Table 5.1-5. In addition, the following characteristics were assumed:

- Maximum pre-launch standby limited to 30 hr
- Vapor-colled shield design

- Minimum flow design based on insulation heat leak
- 12 lb per tank for mounted componenets.

Three manufacturers of cryogenic storage tanks were contacted during Phase B for optimum tank designs applicable to the Shelter missions. The manufacturers contacted and the programs for which they are currently supplying tanks are listed below:

Manufacturer	Program	O_2 Tank Storage Capacity (lb)	H_2 Tank Storage Capacity (lb)
AiRearch	Gemini	104 177	22
Beech	Apollo (Block II)	320	28
Bendix	NAS9-2978		
	Phase A	175	
	Phase B		29

The Bendix Phase A and B tanks for the NAS9-2978 Program were developed in sizes to duplicate current Apollo and Gemini tanks. Since none of the existing tank designs listed above is capable of supplying the required usable reactants for the Shelter mission after the long standby time specified, each manufacturer was asked to submit design data for specified usable quantities. The usable quantities and pertinent design constraints given to the vendors were as follows:

Usable O_2:	545 lb
Usable H_2:	42.5 lb
Min flow rates	
O_2:	0.259 lb/hr
H_2:	0.033 lb/hr
Standby time:	2155 hr
Delivery time:	19 days
Max environmental temp:	130°F

These requirements were established early in the Phase B study and were used as being most representative of the mission profiles then being considered. The information presented by each manufacturer has been normalized to reflect consistent environmental and design safety factors. Table 5.1-6 is a comparison of the pertinent information received for each design. Discussion of the design approaches used by each vendor are presented in the following paragraphs.

5.1.2.5.1 AiResearch. The tanks proposed by AiResearch reflect the design concepts developed for the Gemini cryogenic storage tanks, with one important exception; the use of a vapor cooled shield within the insulation. The inner pressure vessel is supported by local composite support pads, and the vacuum space is filled with aluminized mylar superinsulation and the vapor cooled shield. The tank materials proposed are as follows:

	O_2	H_2
Inner Shell	Inconel 718	Ti 5 Al-2.5-Sn
Outer Shell	Ti 5 Al-2.5 sn	Ti 5 Al-2.5 Sn

Both inner and outer shells are presently planned to be manufactured by the hydroforming process. The heater is a cal-rod element brazed to one or more concentric spherical copper shells which are used to distribute the heat input into the tank so as to minimize temperature stratification in a zero-g environment. The external tank components are mounted on a girth ring which is used to mount the tank in the vehicle as well as transmit induced loads. AiResearch is currently fabricating tanks using a vapor-cooled shield for the BIOS Program for which the development and fabrication is 90% complete.

Past Gemini heat-leak test data has indicated that a high degree of quality control is required in applying the mylar superinsulation for this design to minimize the "artisan" factor during tank manufacture, and thus achieve consistent heat leak values from tank to tank. It is estimated that 50% of the heat leak into the tanks is by conduction through the support pads.

In addition to the conventional rigid vacuum jacket tank designs submitted, AiResearch presented tank weights for the Shelter based on "soft" and "semi-rigid" outer shells and subcritical storage. The soft and semi-rigid outer shell concept effects a substantial weight savings, while entailing numerous development, manufacturing, ground handling, and pre-launch servicing problems. Weight savings can also be realized by the use of subcritical storage for long-standby lunar surface missions; however, high-pressure back pack and accummulator refills are a problem for the oxygen for the oxygen system. Further investigation into these areas for possible weight savings in cryogenic storage systems would be required in the detail design phase.

5.1.2.5.2 Beech. The tanks proposed by Beech reflect the design concepts developed for the CSM H_2 cryogenic storage tanks for the Block II vehicle. This design features a discrete vapor-cooled shield in the evacuated annulus. The inner pressure vessel is supported by a network of beams or straps which distribute the induced loadings evenly throughout the system. Beech has not demonstrated the feasibility of this support system for tanks in the size range being considered for Shelter missions, and it appears to require some development work. The tank materials proposed are as follows:

	O_2	H_2
Inner Shell	Inconel 718	Inconel 718
Outer Shell	Al 6061	Al 6061

The CSM Block II tanks make use of titanium for the hydrogen inner pressure vessels. However, indications of fabrication problems with these tanks have led Beech to propose the materials mentioned above. The tank shells, both inner and outer, can be forged and machined or formed, depending on the size, cost, and schedule effects. Beech makes use of a calrod heater element brazed to a support tube and two fans and motors to distribute the incoming heat evenly throughout the stored fluid. The fluid delivery line, which carries the vapor to cool the shield, is not brazed to the shield in the proposed design. This concept simplifies manufacture of the tank;

however, the effect of the vapor cooling may be lessened if heat transfer from the shield to the fluid is not complete. The discrete shield design presents a great possibility of eliminating the "artisan" factor from cryogenic tank manufacture. Beech has indicated that they are investigating a composite insulation system which utilizes superinsulation and the discrete vapor cooled shield. Preliminary thermodynamic investigation at Grumman has shown that it may be desirable to insert superinsulation between a discrete vapor-cooled shield and the outer shell in some cases.

5.1.2.5.3 Bendix. The tanks proposed by Bendix reflect the design of the Phase B tank for the NAS9-2978 Program. The purpose of that program was to determine the feasibility of the discrete shield/radial bumper design for tanks in the size ranges of the Gemini and CSM tanks. The proposed tanks use discrete shields with vapor cooling, radial bumpers for pressure vessel support, and motor fans with an electrical heater to mix the fluid. The materials proposed by Bendix are as follows:

	O_2	H_2
Inner Shell	Cryo-formed 301SS	Cryo-formed 301SS
Outer Shell	Al 6061	Al 6061

The use of cryo-formed 301 SS for the inner pressure vessels is very attractive from a weight standpoint because of its high strength; however, further investigation into its use for these critical items are required.

The radial bumper support system transmits a very small amount of heat when loaded and negligible amounts of heat when unloaded during zero-g operation. This type of design yields essentially radiative thermal coupling through the insulation space, resulting in a low heat-leak design.

The radial bumper concept requires further analysis and testing to verify the structural integrity of the inner pressure vessel and outer shell. The tank mounting scheme used by Bendix is adaptable for skirt or truss mounting, utilizing flanges which are integral with the tank outer shell. As mentioned in Paragraph 5.1.2.5.2, discrete shield design should yield a more repeatable heat leak from tank to tank, because of the elimination of the "artisan" effect in manufacture. However, quality control on shields and plated surfaces must be very thorough to insure this repeatability.

5.1.2.6 Ambient Storage Tank Data

General data, presented in Fig. 5.1-17 through 5.1-20, have been developed so that ambient storage tank weights could be calculated for: given quantities of H_2 and O_2, tank material, tank diameter, storage pressure, and temperature.

The ratio of tank weight to gas weight is a minimum when the gas is stored at an optimum based on the compressibility factor for that particular gas. In the case of O_2, the optimum storage pressure is approximately 3000 psia, and in the case of the H_2, optimum storage pressure is approximately 1500 psia. Because of volume limitations, it is not possible to store the required quantities of H_2 at or near optimum pressure. All design concept data have been analyzed in relation to spherical tanks which is the most efficient configuration from a weight standpoint.

Materials considered for the fabrication of storage tanks are the following:

- 6 Al-4V titanium (H_2 only)
- 301 stainless steel cryogenically stretched
- 18% nickel maraging steel
- Inconel 718
- D6AC steel
- Composite filament winding (resin coated fiberglass wound over a metal liner.

A summary of material properties and vendor sources contacted is presented in Table 5.1-7. This data, with the exception of the composite wound tanks, is generally accepted as present state-of-the-art by the vendors contacted. However, since substantial weight reduction is afforded by increasing strength-to-weight ratios, vendors were also asked to recommend areas in which they felt further development would be beneficial. A brief summary of their responses follows:

- Airite recommends that 300 series maraging steel presently be considered with a tensile strength of 260 kpsi, and that tensile strengths of 300 kpsi are anticipated by developing spin forgung techniques.
- Aeroject (Downey) recommends use of tanks designed and fabricated by their "5 Sigma" process. The "5 Sigma" process is a method by which the vendor controls the tank material and fabrication process to such a degree that the safety factor used in design of the tank can be reduced, e.g. 1.5 to 1.1.
- Aerojet (Azusa) is currently being funded by NASA to develop and evaluate filament wound tanks up to 40 in. in diameter and storage pressures up to 4000 psia with safety factors of 1.25, 1.5, and 2.
- Arde has preliminary test results that indicate tensile strengths in excess of 300 kpsi can be attained by slightly modifying material composition.

Table 5.1-8 presents a compilation of tanks presently being fabricated for manned space programs, suitable for consideration for ambient storage tanks.

5.1.2.7 Radioisotope Thermoelectric Generator

The SNAP 27 radioisotope thermoelectric generator (RTG) produces 1300 w of thermal energy and 50 w of electrical energy at 14 v DC. The RTG works with a power conditioning package (PCP) that is used to boost and regulate the RTG voltage to 29 v ±1% so that it will be compatible with spacecraft equipment.

The RTG consists of a fuel component (radioisotope heat sourch) and a thermoelectric generator. The fuel used is Pu-238. Initially, enough heat is produced to generate 66 w of electrical energy. At the end of 1 year, the amount of heat produced generates 56 w. The RTG design characteristics are shown in Table 5.1-9.

Full load efficiency of the PCP is 90%. Output from the PCP is 59 w at 29 v ±1% at initial conditions, and 50 w at 29 v ±1% after 1 year. It may be necessary to modify the PCP regulating point from 29 to 32 v, so that the RTG may be paralleled with the Shelter silver-zinc batteries and properly share its load requirements. Performance curves for the RTG are shown in Fig. 5.1-21.

5.1.2.8 Silver-Zinc Batteries

The LEM ascent and descent batteries each have been designed and optimized for their specific missions and profiles. Although both are high merit factor, silver-zinc, primary-type batteries, there are differences in their design. The ascent battery has been designed to be used with a pre-discharge and discharged at high rates of up to 3000 to 4000 w. The descent battery is designed for cell taps and discharge rates approximately 1/3 of the ascent battery.

Along with energy and voltage regulation requirements, stand life for these type of batteries is a primary design consideration. The main failure mode for silver-zinc batteries is separator deterioration, which is primarily governed by temperature and activated-wet stand time. Activated-wet life of a silver-zinc battery is significantly reduced when battery temperatures approach and exceed 100°F. Operating at temperatures below 40°F will minimize degradation and allow operation over extended times.

Although Taxi and Shelter energy requirements differ, the critical design power requirements, descent missions, and quiescent phase power requirements are essentially the same. Since a new battery design was needed for the Shelter, a design that would satisfy both the Shelter and the Taxi requirements was considered. Effectively, it would be designed for the 83-day Shelter time line and the Taxi/Shelter descent mission with the capability of performing a descent with a battery failure. The capacity would be optimized for minimum Taxi weight.

The LEM, Taxi, and Shelter descent battery requirements are summarized below:

Descent Battery Requirements	LEM	Taxi	Shelter
Maximum (kw):	3.9	3.0	3.0
Energy for descent mission (Earth launch through lunar touchdown and c/o), (kw):	10.25	7.53	5.65
Total Energy from descent supply (kw-hr):	46.9	35.6	28.4
Mission time line for descent batteries (plus 30 days storeage activated wet prior to use), (days):	7	14	88

Figure 5.1-22 shows the estimated relationship between activated-wet life, temperature, available capacity, and reliability of the LEM batteries as applied to the Taxi mission. As can be seen from this figure, not only is battery stand life adversely affected by high temperatures, but available capacity and reliability is also lowered. On the basis of this information, it was estimated that the LEM batteries could support the Taxi mission, if their temperature were maintained below 88°F. By extrapolation, it can also be seen that the Shelter 83-day lunar storage requirement is not compatible with the LEM battery design. Consulting with battery vendor, Eagle-Picher, it was decided it was necessary to increase the battery separator thickness and redesign it to meet the Shelter 83-day storage requirements.

Table 5.1-10 shows the estimated characteristics of the resulting 12 kw-hr battery, along with the present LEM ascent and descent batteries. In addition to the advantages cited above for common usage for the Shelter and Taxi descent batteries, the resulting battery would provide for a higher reliability for the Taxi mission than the present LEM batteries.

5.1.3 Recommended Configuration

5.1.3.1 General

The recommended EPS configuration supplies all the power required to perform the Shelter mission with the exception of the translunar phase, during which power is supplied by the CSM. The total energy to be supplied is 619 kw-hr; of which 9.5 kw-hr is supplied by the CSM. See Table 5.1-2 for the energy summary.

The recommended configuration shown in Fig. 5.1-23, consists of the following components:

- Two Allis-Chalmers 2000 w (nominal), 33-section fuel cells
- Two 21.25-lb usable capacity ambient storage hydrogen tanks
- One 560.4-lb usable capacity ambient storage oxygen tank for EPS and ECS
- One 9-lb capacity ambient storage oxygen tank for PLSS recharging
- Three 12-kw-hr primary batteries
- One 50-w radioisotope thermoelectric generator (SNAP 27)
- One LEM water glycol pump circulation assembly
- One 57.5-sq-ft vertical radiator (Refer to Paragraph 4.1 for radiator sizing)
- Four ECAs, two for the fuel cells and two for the batteries (each descent battery ECA can control two batteries)
- Plumbing, feed components, and electrical wiring
- Two LEM single-phase inverters (350-VA, 400-cycle, 115-v)
- One H_2O storage tank.

5.1.3.2 Performance

The Shelter EPS performance capability is as follows:

- Voltage output: 28 to 32.5 v DC
- Fuel cell peak power available (net)
    - At start of mission: 4400 w
    - At end of mission: 3570 w
- Fuel cell energy available (total: 501.5 kw-hr)
    - Housekeeping: 319.9 kw-hr
    - Experiment: 94.0 kw-hr
    - FCA parasitic: 87.6 kw-hr
- Peak fuel cell heat rejection rate: 10,500 btu/Hr at 3570 w
- Total water generated: 382 lb
- RTG peak power available: 50 w
- Energy supplied by RTG: 79.68 kw-hr
- Peak power available from battery: 3.0 kw
- Battery energy available from battery: 36 kw-hr.

The system performance in terms of voltage and specific reactant consumption as a function of net available power for one and two fuel cells on the line is shown in Fig. 5.1-24.

5.1.3.3 Expendables

The expendables required consists of the following:

Fluids	Stored Quantity (lb)	Residuals (lb)	Usable (lb)
Gaseous H_2	43	0.5	42.5
Gaseous O_2 (ECS & EPS)	566	5.6	560.4
Gaseous O_2 (PLSS)	12	3.0	9.0
Water	206.0		206.0

The oxygen is used as follows:

EPS	340 lb
ECS	220.4
ECS/PLSS	9.
Total	569.4 lb

5.1.3.4 Operation

Prior to Earth launch, the system is checked out, the batteries loaded and activated, the ambient tankage pressurized, the RTG loaded and activated, and the fuel cells filled with inert gas and sealed.

The three descent batteries supply power to the Shelter during the countdown, launch, and transposition phases. The CSM supplies power to the Shelter during the translunar phase. The descent batteries then supply power for the pre-separation checkout, descent, and post landing checkout. During the quiescent storage phase the RTG supplies the steady-state power required to maintain the vehicle. The daily-status-report power peaks, above the 50-w RTG capability, are supplied by the descent batteries. For night missions, approximately 74 w of thermal energy is extracted from the RTG by the ECS heat transport equipment.

At the end of the quiescent storage phase, the batteries supply 1 kw-hr of energy to start one of the fuel cells. The start sequence is initiated by remote command from Earth. The squib valves sealing the lines from the reactant tanks are fired and the fuel cells activated by the admission of reactant to the electrodes. DC power is supplied from the batteries to the fuel cell heaters, and the internal fans deliver heat to the cell stack. In 1 hr the fuel cell stack is heated from 40°F (assumed fuel cell compartment temp) to 205°F operating temperature. The fuel cell is then capable of supplying the required 450-w housekeeping power and starting the other fuel cell. Once it has been ascertained that both cells are operating satisfactorily, one of the cells is taken off the line and kept in a self-sustained standby-state. This is necessary for reactant economy at the average housekeeping power. Periodic reporting of EPS performance is performed during this phase. The EPS is maintained in this state until the manned period when experiment plus housekeeping loads, which require power in excess of approximately 2000 w, are utilized. For this condition, the second fuel cell is switched on the line and the two fuel cells share the load equally.

The EPS has an independent heat rejection system that contains a water glycol circulation assembly containing three motor pump units, two of which are redundant and each capable of supplying 200 lb/hr.

The two fuel cells are connected in parallel in the coolant loop, each receiving 110 lb/hr of glycol-water through the fuel cell heat exchanger or its by-pass valve, as required to maintain the fuel cell temperature.

Fuel cell waste heat (up to 1 kw of system output) is rejected from the vehicle through a space radiator. Supplementary cooling for the drilling operations is provided by water boiling.

5.1.3.5 Interface Requirements

The interface between the EPS and the Shelter includes the following:

- Electrical
    - Main feeder lines
    - Instrumentation and displays
- Fluid
    - Oxygen line to ECS
    - Oxygen line to PLSS recharge
    - By-product water line to water storage tank
    - System vent lines
    - Vent and relief valve line
- Structural mounting provisions
- Launch pad interface
    - Instrument lines
    - Control lines
    - O_2 and H_2 fill and vent lines

5.1.3.6 Component Description

5.1.3.6.1 Fuel Cell. The fuel cell unit proposed in the recommended configuration is an Allis-Chalmers, 33-section, hydrogen-oxygen unit having the following nominal characteristics:

- Power output: 2000 w
- Voltage limits: 28 to 32.5 v
- Reactant consumption: 0.774 lb/kw-hr gross
- Thermal efficiency: 65.5% @50% power
- Parasitic power: 115 w (110 w for internal cooling loop, plus 15 w for glycol loop)
- Total weight: 164 lb.

A description of the fuel cell is presented in Paragraph 5.1.2.4.3.

5.1.3.6.2 Coolant Pump Assembly - The coolant circulation assembly is identical to that used in the LEM ECS. It consists of check valves, pressure relief valve, filter and three DC-motor pumps, any two of which are capable of 220 lb/hr at 30 psi. Approximately 30 w of power is required at full load.

5.1.3.6.3 Radiator. The EPS radiator is mounted vertically on the aft equipment bay and is designed to meet the peak power heat rejection requirement of the fuel cells up to 1 kw total. It has a total area of 57.5 sq ft and a heat rejection rate of 130 btu/sq ft at a rated operating inlet temperature of 185°F and outlet temperature of 136°F. Supplementary cooling above 1 kw is done by water boiling. Refer to Paragraph 4.1 for radiator sizing.

5.1.3.6.4 Batteries. The three 12 kw-hr primary batteries used in the Shelter configuration are the same type recommended for the Taxi configuration. They consist of LEM batteries modified for 12 kw-hr and longer activation time. The batteries are described in Paragraph 5.1.2.8.

5.1.3.6.5 RTG. A description of the RTG is presented in Paragraph 5.1.2.7.

5.1.3.6.6 Reactant Tanks. The reactant tanks store the expendables at ambient temperature and feed them to the system through pressure reducing valves. They include the following:

Fluid	Tank	Total Capacity(lb)	Operating Pressure(psi)	Dry Weight(lb)	Loaded Weight(lb)
H_2	(2) 39-in. dia	43 (includes 0.5-lb res.)	4750	712 (total 2 tanks)	755
O_2	(1) 47-in. dia	566 (5.6-lb res.)	3500	515	1081
O_2 (PLSS)	(1) 14.5-in. dia	12 (3.0-lb res.)	2850	12.5	24.5

5.1.4 Baseline Configuration

The baseline configuration differs from the recommended configuration in the following areas:

- Two Pratt & Whitney fuel cells were used in lieu of two Allis-Chalmer fuel cells in the recommended configuration. Relative differences between these units are described in Paragraph 5.1.2.4.
- One 55-in. dia ambient O_2 tank was used compared to one 47-in. ambient tank. The baseline configuration required 771 lb of O_2. This included power for the 100-ft drill, but did not include an airlock. The recommended configuration requires 560.4 lb, because of the addition of an airlock.
- One 42-in. dia by 60-in. long ambient H_2 tank was used on the baseline configuration compared to two-39-in. dia spherical ambient tanks on the recommended configuration. The baseline configuration required 43 lb of H_2 and the recommended configuration requires 42.5 lb of H_2; both including drill power.
- Two modified batteries used in the baseline configuration; three modified batteries were required on the recommended because of increased energy requirements.
- Baseline configuration contained a battery charger and storage battery, since RTG capability was assumed available to recharge the storage battery. The recommended configuration does not have this excess power available, and therefore does not utilize a rechargeable battery. Peaking is obtained by utilizing the descent battery.

5.1.5 Alternate Configuration - Cryogenic Storage and Supply

5.1.5.1 System Description

An alternate Shelter configuration was studied which used cryogenic storage and supply (CSS) for fuel cell reactants and ECS oxygen in lieu of high-pressure ambient tanks. The fuel cells, RTG batteries and other components of the EPS are unchanged for this alternate. The EPS power generating section is shown in Fig. 5.1-25. The components which make up the alternate configuration are as follows:

- One AES cryogenic H_2 tank*
- One AES cryogenic O_2 tank*
- Two cryogenic reactant pre-heaters (heat exchangers)
- Two tandem pressure relief valves
- Associated lines, plumbing, and electrical wiring
- Gaseous oxygen accumulator including pressure transducer, and fill connection.

5.1.5.2 Output Performance

The performance for this configuration is as follows:

- Total standby: 2145 hr (launch pad: 30 hr, translunar: 123 hr, lunar surface: 1992 hr)
- Usable capacity after standby: 42.5 lb H_2 and 560.4 lb O_2
- Vented fluid: 92.0 lb H_2 and 0 lb O_2
- Unusable residual: 7.0 lb H_2 and 28.0 lb O_2
- Minimum flow rates: 0.047 lb/hr H_2 @ 130°F ambient environment
  0.470 lb/hr O_2 @ 130°F ambient environment
- Maximum operating pressure: 300 psi H_2 and 1000 psi O_2

5.1.5.3 Operational Sequence During Mission

The tanks are filled to final capacity on the launch pad and sealed no sooner than 30 hr prior to launch. The H_2 tank is filled to its maximum capacity, and the O_2 tank to approximately 43% of its capacity. Heat leak into the tanks (during launch, translunar, and lunar storage) increases the H_2 pressure to 300 psia, approximately 300 hr after cap-off, and then causes venting loss of stored fluid until use is initiated. The O_2 pressure rises more slowly and reaches 1000 psia at the time use is initiated, with no venting loss. The motor fans are turned on at frequent intervals for short periods of time during the standby period, to keep an even temperature distribution in the stored fluid. Once use is initiated, the tanks supply O_2 to the fuel cells and ECS, and H_2 to the fuel cells on demand, with the pressure switches and motor fan heater combination maintaining the proper tank pressures. Toward the end of the mission, when the H_2 tank reaches a maximum temperature of -260°F and the O_2 tank reaches a maximum of 70°F, the pressure is allowed to decay at essentially constant temperature until each tank reaches 100 psia. If accumulator or PLSS recharges are required at the very end of the mission, then the O_2 tank must be maintained above 875 psia. An alternative would be to supply a small gaseous tank between the CSS and the Shelter.

5.1.5.4 Interfaces

Interfaces between the CSS and the Shelter required for this alternate configuration are as follows:

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* Including associated fill and vent connections, instrumentation heaters, motor-fans, and controls. Tank characteristics are presented in Paragraph 5.1.2.5.

- Electrical
  - AC power for motor fans
  - DC power for heaters and actuation of solenoid valves
  - Displays and controls
- Structural mounting provisions
- ECS
  - Oxygen supply to ECS module from cryogenic O_2 tank and GOX accumulator
  - Coolant supply to reactant preheaters (heat exchangers).

The interfaces required between the CSS and the launch pad are as follows:

- Cryogenic H_2 and O_2 servicing fill and vent disconnects
- Gaseous O_2 fill disconnect for accumulator
- Fluid and electrical test points.

5.1.6 Alternate Configuration - General Electric Fuel Cells

An alternate configuration for the power generation section is the use of four GE fuel cells in place of the two AC fuel cells. This configuration differs from the recommended configuration as follows:

	Alternate	Recommended
• Fuel Cells:	(4) GE	(2) A-C
• Total net peak power (w):	3940	3770
• Reactant required (lb)		
o O_2 :	556.4*	560.4*
o H_2 :	42.0	42.5
• Total system weight (lb)		
o with vertical radiator:	3152	2589
o with horizontal radiator:	2759	2549
• Radiator area required (sq ft)**		
o Vertical:	100	40
o Horizontal:	52.5	20
• Cooling water required (lb) with vertical radiator		
o nominal operation:	261	0
o drill operation:	250	206

The proposed fuel cells for this alternate configuration would consist of the 92-lb, 3-stack Gemini fuel cell configuration modified to the S-membrane configuration and qualified to a 1200-hr life. The performance of this fuel cell would be boosted from 560 w to 1 Kw at 28-v minimum by utilizing a voltage regulator to boost performance. Since the average Shelter power is 800 w, the voltage regulator would only be utilized when high powers are required, such as drilling or other high-power experiments.

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* Includes 220.4 lb for ECS

** Radiator and water requirements based on single-point sub-solar design condition. Recommended A-C radiator requires 57.5 sq. ft.

Normal operation of this system would require two fuel cells to supply the average power requirement with the other two fuel cells in the standby mode. When peak power, in excess of the capability of two fuel cells is required, the additional two fuel cells would be switched on the line.

The performance of this fuel cell configuration is presented in Paragraph 5.1.7.4, and for the individual GE fuel cell in Paragraph 5.1.2.4.1.

5.1.7 Discussion of Configuration Choices

The recommended EPS configuration evolved from evaluations of the following:

- H_2 and O_2 ambient storage tank system and weights
- H_2 and O_2 cryogenic storage tank systems, weights, and vendor evaluation
- Cryogenic versus ambient H_2 and O_2 storage systems
- A-C, P&W, and GE fuel cell configurations
- Power supplies for descent and quiescent storage phases.

5.1.7.1 Ambient Tankage Evaluation

Ambient tankage requirements are 569.4 lb of O_2, and 42.5 lb of H_2. Tankage weights generated for the various materials discussed in Paragraph 5.1.2.6 are presented in Table 5-1-11. The configurations considered during the study were: System A, made up of existing tanks; System B, consisting of four similar 39-in. dia tanks; and System C, consisting of two 39-in. dia H_2 tanks and one 47-in. dia O_2 tank.

- System A (Existing Tanks): To meet Shelter requirements with the existing tanks described in Paragraph 5.1.2.6, it is necessary to utilize 13 LEM descent stage type GOX tanks for O_2 storage and two CSM helium tanks for H_2 storage. Dry tankage weights for this system total 1513 lb.
- System B: This system consists of four (2-H_2, 2-O_2) 39-in. dia tanks, made from cryo-stretched 301 stainless steel. The use of four similar tanks was considered desirable since development and fabrication costs are minimized. Dry tankage weights for this system total 1294.5 lb.
- System C: This system is similar in design to System B, but has only one O_2 tank (47-in. dia). Dry tankage weights for this system total 1239.5 lb

As noted, Systems B and C are similar in design and weight. However, System C was selected because of volume limitations and potential RCS plume impingement problems.

5.1.7.2 Cryogenic Tankage Evaluation

A technical evaluation was made of the cryogenic tank designs submitted by AiResearch, Beech, and Bendix, considering the following major categories with the weight factors shown:

● Design and Performance	(46%)
● Weight	(27%)
● Reliability	(27%)

The scores achieved by each tank design are as follows:

	AiResearch	Beech	Bendix
Design and Performance	29.23	28.24	32.02
Weight	14.75	18.00	21.75
Reliability	17.75	15.00	14.25
Totals	61.73	61.24	68.02

Table 5.1-12 is a detailed breakdown of the items considered in each major category, the relative weight of each item, and the ratings of each individual design. The result of this technical evaluation indicates a technical advantage in using the Bendix tanks, if cryogenic tanks other than the AES tanks were to be utilized. A further evaluation of vendor capability, cost, and schedule effect is required to make a final selection.

5.1.7.3 Cryogenic vs Ambient Storage of H_2 and O_2

A trade-off study was performed to determine the recommended system for the Shelter reactant storage and supply for H_2 and O_2 for use by the fuel cells and the ECS. The total weights and predicted reliabilities, as well as the operational and performance characteristics of each configuration were compared.

The assumptions used in this study were as follows:

- Total usable reactants required (based on two A-C fuel cells)
  - EPS O_2: 340 lb
  - ECS O_2: 229.4 lb
  - EPS H_2: 42.5 lb.
- Cryogenic tank configuration makes use of a 900-psia gaseous oxygen (GOX) accumulator for PLSS and cabin repressurizations
- Ambient tank configuration makes use of a 2850-psia PLSS oxygen tank for PLSS recharges
- The GOX accumulator for the cryogenic configuration has the following characteristics
  - 19.6-in. OD
  - 7.5-lb usable O_2
  - 1.8-lb residual O_2
  - 18.8-lb dry weight
  - 900-psia operating pressure
- PLSS recharge tank for ambient configuration has the following characteristics:
  - 14.5-in. OD
  - 9.0-lb usable O_2
  - 3.0-lb residual O_2
  - 12.5-lb dry weight
  - 2850-psia operating pressure
- Weights are based on reactant storage and supply (RSS) only
- Reliability based on RSS only; tanks are non-redundant, i.e. all tanks are required for mission success.

The results of a weights analysis are shown in Table 5.1-13. The total ambient storage system weighs 1882 lb, whereas the cryogenic storage weighs 1484 lb. However, an analysis of the reliability for mission success resulted in the following:

- Cryogenic storage: 0.96617
- Ambient storage: 0.994165.

An investigation into increasing the mission success reliability of the cryogenic storage system, by using completely redundant tanks and feed system, resulted in the following:

- Mission success reliability: 0.97519
- Total weight of system: 2900 lb

In addition to the above analysis, the following hybrid configurations were investigated:

- Cryogenic oxygen - ambient hydrogen
  - Cryogenic O_2 assembly: 1005 lb
  - Ambient H_2 assembly: 755
  - GOX accumulator: 29
  - Plumbing and feed components: 15
  - 1804 lb
- Ambient oxygen - cryogenic hydrogen
  - Ambient O_2 assembly: 1081 lb
  - Cryogenic H_2 assembly: 440
  - PLSS tank: 25
  - Plumbing and feed components: 15
  - 1561 lb

The reliability of the ambient-cryogenic hybrid sections will be higher than the all cryogenic, but less than the all ambient. The weight advantage of ambient oxygen and cryogenic hydrogen merits further study.

The cryogenic storage system for the Shelter presents many operational problems which are not thoroughly considered when evaluating the relative reliabilities. The cheif problem arises from the long standby period (up to 90 days) on the lunar surface. Off-design heat leak, or unexpected thermal environments, can cause boil-off loss of usable fluid during quiescent storage. Continuous venting imposes increased duty cycles on pressure relief valves at cryogenic temperature. In addition, since the tanks are just capable of meeting the 90-day storage period and still supplying the usable reactant quantities, there is no room for growth with respect to longer quiescent storage periods without vehicle and tank modification. Unlike the cryogenic tanks, ambient tankage is insensitive to standby time. Because of these reasons, as well as the relatively poor reliability of the cryogenic system as compared to the ambient system, the ambient system was selected with a weight penalty of 400 lb.

5.1.7.4 Fuel Cell Configuration Evaluation

The three fuel cell configurations considered in the evaluation were as follows:

- Two Allis-Chalmers 2-kw (nominal) fuel-cells, as described in Paragraph 5.1.2.2.1.3
- Four General Electric 1-kw fuel cells with voltage regulators as described in Paragraph 5.1.2.2.1.1
- Two Pratt & Whitney 2-kw (nominal) fuel cells as described in Paragraph 5.1.2.2.1.2

The guide lines used in this evaluation were:

- Consideration was given but not limited to utilization of existing Gemini, Apollo, and proposed AES hardware.
- Fuel cell power was considered redundant for simultaneous housekeeping and EVA power, but not redundant for simultaneous housekeeping and drill power.
- FCA considered are used for Phase II Lab and Shelter
- 1200-hr life (based on Phase II Lab)
- FCA must be capable of remote command start
- FCA can exist under hot-standby condition, i.e. hot but not generating
- FCA must be capable of 3-months dead storage prior to use on the lunar surface
- Paralleling capability: 100%
- Fuel cell must be capable of being checked-out prior to Earth launch
- LEM glycol pump package to be used in cooling loop
- Glycol-water mixture (62.5/37.5%) to be used as coolant.

The technical evaluation consisted of the following categories with the weight factors shown:

- Design and Performance (46%)
- Weight (27%)
- Reliability (27%)

The specific criteria evaluated under the above categories and the rating given each criteria are presented in Table 5.1-14.

The specific reactant comsumption (SRC) trade-off is summarized in Fig. 5.1-26, which presents the power plant net SRC as a function of the net power available at the bus connection, i.e. after the parasitic powers of the fuel cells on and off the line have been deducted from the gross power generated. The SRC includes the purge rates, as well as the flow required to keep fuel cells in a self-sustained hot standby condition. The net SRC is obtained by dividing the total reactant flow of the system by the net power delivered.

Figure 5.1-26 shows the SRC for different modes of operation. It is apparent that the large parasitic power of the Allis-Chalmers and Pratt & Whitney fuel cells, and also the necessity of using a voltage clipper at low power, penalize these fuel cells in the low-power range. It is therefore necessary to use only one fuel cell at the Shelter average powers; utilizing the other fuel cell for high-power requirements. This is done to optimize the reactant quantity, which is proportional to the specific reactant consumption at the average power of the mission.

Because of its low parasitic power and voltage converter, the General Electric configuration requires the least reactants at the average power of the Shelter mission; Allis-Chalmers is second, and Pratt & Whitney is third.

The effect of degradation on the total EPS fuel cell output for the three fuel cells, based on 504 hr of operation, is shown in Fig. 5.1-27. This is based on test data performed on experimental units. All fuel cell manufacturers indicate that the production units will have reduced degradation. The GE unit is less sensitive to degradation when a voltage regulator with sufficient capacity is used.

The step load capabilities of the three systems are compared in Fig. 5.1-28. Both the A-C and GE systems are capable of delivering peak power immediately, because both systems perform at constant temperature throughout the polarization curve. The P&W fuel cell performance occurs at constant temperature, although the steady-state polarization curve is at variable temperature. The steep constant temperature polarization curve severely limits step load performance.

The results of the design and performance evaluation are as follows:

Max Possible Rating	A-C	GE	P&W
46	29.80	28.98	22.75

The itemized weights for each complete EPS system including radiator and all expendables are given in Table 5.1-15. The weight evaluation results are as follows:

Max Possible Rating	A-C	GE	P&W
27	17.25	11.25	13.50

The GE configuration with the vertical radiator is penalized by the necessity for water (in addition to by-product water) to supplement the radiator.

The reliability evaluation was performed in accordance with the following assumptions:

- Reliability predictions were estimated using the following individual cell failure rates:

Vendor	Failure Rate Per Individual Cell/10^6 hr	Source
A-C	1.0	GAEC assumed no data supplied by vendor
GE	5.0*	GE
P&W	0.86	P&W

GE had estimated a rate of $1/10^6$ hr for their S-membrane unit. Since there was no substantiating data or any long history of test runs with the S-membrane, the $5/10^6$-hr failure rate was used for all GE reliability estimates.

- Fuel cell reliability model used for all configurations consisted of the series connection of only the individual cells; no other peripheral components or equipment in the fuel cell package were considered.

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*The failure rate of $5/10^6$ hours is based on Gemini D-membrane units.

- Individual stacks of the GE fuel cell section could be isolated from the section in the event of a failure, and stacks of other sections could be individually put on the lines as a replacement.

For reliability purposes, the following specific Shelter missions were chosen as the basis for calculation:

- Mission A: A 21-day mission consisting of a 7-day pre-utilization period and a 14-day manned phase. The total capacity is required for 30 hr (drill operation) distributed over a 7-day period. For the remaining 14 days, only one-half of the capacity is required for housekeeping.
- Mission B: A 21-day mission where the peak power is within the capability of half the fuel cells, the remaining units being redundant over the 21-day operational period.

The computed reliability of the three candidate fuel cell configurations for the two missions are as follows:

	Mission A (with drill)	Mission B (without drill)
A-C	0.98883	0.999726
GE	0.7215 (4 fuel cells) 0.999471 (5 fuel cells)	0.999991 (4 fuel cells)
P&W	0.990695	0.999808

Because of the low reliability value with the four GE fuel cells, consideration was given to adding an additional fuel cell in the system. This brought the system to an acceptable level as shown in the above tabulation. Further investigation into failure rates for these operating conditions are required to ascertain the number of fuel cells needed.

The results of the reliability evaluation are as follows:

Max Possible Rating	A-C	GE	P&W
27	11.25	12.50	16.2

The summary results of the fuel cell technical evaluation are as follows:

	A-C	GE	P&W
Design and Performance	29.80	28.98	22.75
Weight	17.25	11.25	13.50
Reliability	11.25	12.50	16.2
Total	58.30	52.73	52.45

After qualitative analysis of endurance test data, which effects confidence in the fuel cell being able to meet the endurance requirements with acceptable degradation, the A-C fuel cell was recommended as the one showing the best prospect of insuring mission success. Test units have accumulated 4078 hr during which 2000 kw-hr were generated with electrodes and electrolyte identical in materials and size to those included in the fuel cell under development for NASA. The operating temperature

(205°F) is sufficiently high to provide adequate heat removal potential, while not posing any particular vehicle integration problem, even during pre-launch checkout. It is recognized that the mechanical design needs further refinements; these can be worked out in time to satisfy the AES schedule.

The GE fuel cell is a well integrated, flight-tested unit with innovations, such as the solid electrolyte Ion Exchange Membrance and the water removal wicks. The very nature of the Ion Exchange Membrane causes a loss of thermal efficiency (high resistance) and requires a low operating temperature. General Electric has met this requirement with a very efficient liquid cooling loop requiring very little parasitic power. This results in good net fuel cell performance, particularly at low power. The low-cooling-loop temperature on the other hand introduces a high radiator and water boiler penalty, but this would not make the GE fuel cell unapplicable. The major unknown at this time is the lack of test data on the S-membrane which is to replace the D-membrane of the Gemini fuel cells. The D-membrane was found to degrade considerably after initial activations even during storage.

The P&W fuel cell, from an electrochemical viewpoint, is fundamentally sound and obtains excellent cell efficiency. However, the high operating temperature (400°F) required by the high KOH concentration, leads to a heavy and complex mechanical design which, except for smaller radiator requirements, does not lend to easy integration in the vehicle. In addition, the amount of heat radiated to the Shelter is large and requires cooling on the launch pad; the heating period during start-up is long and high in energy; the parasitic power inherent to the H_2 coolant loop and water separator is high, and the step load capability is limited by the thermal time constant. Furthermore, the electrolyte, which freezes at 280°F, requires a high-heat input during hot stand-by. The overall result shows that the P&W fuel cell has a narrower operational range than the A-C and GE fuel cells. This is a definite short coming for the Shelter mission where the average housekeeping power is very low compared to the peak demand.

5.1.7.5 Descent and Quiescent Phase Power Supply Evaluation

In evaluating the different EPS configurations to support the descent and quiescent mission phases, the following guidelines were used:

- EPS descent power supply to supplement RTG thermal energy for cabin heating requirements for the night mission
- Common usage of Shelter and Taxi power components.

Table 5.1-16 is an energy weight trade-off summary of the candidate configurations evaluated.

5.1.7.5.1 RTG. The use of a RTG power source offers significant weight savings over the best silver-zinc batteries when energy requirements within the RTG power range start to exceed 5 kw-hr. For the Shelter 1992-hr quiescent phase, the RTG supplies approximately 80 kw-hr of electrical energy at 63 lb (50 plus 13 lb for installation). To supply the same energy by batteries, the silver-zinc batteries alone would weigh close to 800 lb. An equally important advantage of the RTG installation is a "heat pipe" boiler concept which transports a portion of RTG excess heat to help sustain the cabin within temperature limits; 88 w of thermal energy is required to balance the cabin thermal leakage rates during the night mission. Equipment dissipating to the cabin thermal loop provides 14 w of the required energy. To complete the cabin requirement, 74 w of thermal energy would then be supplied by the

RTG. Without this source of thermal energy, the descent power supply would have to provide the thermal energy through the use of electrical heaters at a cost of another 74 kw-hr of energy. Without the RTG for a source of thermal and electrical energy, the descent power supply weight would become prohibitive; approximately 1500 lb. Thus, all configurations for the Shelter include the RTG as a power source for the quiescent phase.

5.1.7.5.2 Silver-Zinc Batteries. The recommended battery configuration for the Shelter descent power supply was selected as a common usage item to meet both the Shelter and Taxi requirements.

Both vehicles effectively have the same configuration; three 12-kw-hr descent batteries and a RTG plus battery peaking for the quiescent phase. The battery has been sized for the Taxi mission requirements (35.6 kw-hr). The Shelter requires 28.4 kw-hr, and thus has 7 kw-hr of excess energy. Therefore, the loss of one battery at the beginning of the mission would decrease the quiescent storage capability by approximately 17.5 days.

In addition, three 33-1/3% and four 25% battery configurations were considered for the Shelter mission only. The four battery configuration would weigh more than the three battery configuration, but would be capable of supporting 56 days of the quiescent storage with a battery failure at the beginning of the mission while the three battery configuration could supply 47 days of quiescent storage with the same type of failure.

5.1.7.5.3 Zinc-Oxygen Batteries. Based on the Shelter requirements, a zinc-oxygen system would not offer a significant enough weight advantage to justify their selection. However, candidates have been included, since these batteries might be used on the Taxi.

Table 5.1-1
SHELTER MISSION ELECTRICAL POWER SUMMARY

	Subsystem	83-DAY QUIESCENT STORAGE **** Power, Watts	Duty Cycle, %	Avg Pwr, watts	7 DAY PRE-UTILIZATION Power, watts	Duty Cycle, %	Avg Pwr, watts	1-HR MANNED CHECKOUT Power, watts	Duty Cycle, %	Avg Pwr, watts	14-DAY MANNED PHASE (330 HR) Power, watts	Duty Cycle, %	Avg Pwr, watts
ECS	Glycol Pump	28.0	25***	7.0	28.0	Cont	28.0	40.0	Cont	40.0	40.0	Cont	40.0
	Cabin Fan	--	--	--	--	--	--	39.0	Cont	39.0	39.0	Cont	39.0
	Suit Fan	--	--	--	--	--	--	152.2	Cont	152.2	152.2	Cont	152.2
	CO_2 Sensor	1.0	.84*	.01	1.0	Cont	1.0	1.0	Cont	1.0	1.0	Cont	1.0
	Radiator Cont.	--	--	--	--	--	--	3.0	Cont	3.0	3.0	Cont	3.0
	ECS Relay Box	--	--	--	--	--	--	7.0	50	3.5	7.0	50	3.5
	Misc. Valves	--	--	--	--	--	--	22.0	50	11.0	22.0	50	11.0
	Cabin Fan	--	--	--	--	--	--	--	--	--	39.0	62.5	24.4
	RTG Heat Pipe Sensor	1.0	Cont	1.0	1.0	Cont	1.0	--	--	--	--	--	--
	H_2O Gauging	2.0	.84*	.01	--	--	--	--	--	--	--	--	--
COMM	S-Band Heater (Steer Ant)	6.0	Cont	6.0	6.0	Cont	6.0	6.0	Cont	6.0	6.0	Cont	6.0
	S-Band Transceiver	36.0	.84*	.3	36.0	Cont	36.0	36.0	Cont	36.0	36.0	50	18.0
	S-Band Power Amp	62.0	.84*	.52	62.0	Cont	62.0	62.0	Cont	62.0	62.0	25	15.5
	Sig. Proc. Assy	5.0	.84*	.04	15.5	Cont	15.5	15.5	Cont	15.5	15.5	50	7.8
	Digital Command Assy	15.0	.84*	.12	15.0	Cont	15.0	15.0	Cont	15.0	15.0	50	7.5
	VHF	--	--	--	31.0	Cont	31.0	31.0	Cont	31.0	31.0	50	15.5
	Comm Command Assy	4.0	Cont	4.0	--	--	--	--	--	--	4.0	50	2.0
	X-Y Scanner	7.5	**	Neg	7.5	**	Neg	--	--	--	--	--	--
	S-Band Elect	15.0	.84*	.12	--	--	--	--	--	--	--	--	--
INST	Transducers	1.1	.84*	.01	9.4	Cont	9.4	9.4	Cont	9.4	9.4	Cont	9.4
	Sig Cond Elect Assy	17.8	.84*	.15	35.9	Cont	35.9	35.9	Cont	35.9	35.9	Cont	35.9
	Caut & Warn	--	--	--	22.0	Cont	22.0	22.0	Cont	22.0	22.0	Cont	22.0
	Timing Equipt	5.5	.14*	Neg	5.5	Cont	5.5	5.5	Cont	5.5	5.5	Cont	5.5
	Pulse Code Mod	7.4	.14*	Neg	7.4	Cont	7.4	7.4	Cont	7.4	7.4	50	3.7
	Voice Storage Recorder		--	--	--	--	--	--	--	--	2.3(AC)	6	0.1
CREW PROV	Exterior Light (2)	--	--	--	--	--	--	75.0	Cont	150.0	75.0	1.5	2.3
	Flood Light	--	--	--	--	--	--	75.0	Cont	75.0	75.0	60	45.0
	Dome Light	--	--	--	--	--	--	37.5	Cont	37.5	37.5	40	15.0
	EL lighting	--	--	--	--	--	--	6.2AC	Cont	6.2	6.2AC	66.7	4.2
	Worktop Light	--	--	--	--	--	--	10.0	Cont	10.0	10.0	10	1.0
DISP	Meters & Indicators	--	--	--	--	--	--	25.6	Cont	25.6	25.6	Cont	25.6
	Indicators	--	--	--	--	--	--	3.7AC	Cont	3.7	3.7AC	Cont	3.7
EPS	FCA Controls (2)	--	--	--	7.5	Cont	15.0	7.5	Cont	15.0	7.5	Cont	15.0
	Inv Losses (65% Eff)	--	--	--	--	--	--	10.2	Cont	10.2	11.5	Cont	11.5
	Lighting Cont Assy	--	--	--	--	--	--	5.0	Cont	5.0	5.0	Cont	5.0
	Lighting Cont Assy	--	--	--	--	--	--	9.0AC	Cont	9.0	9.0AC	Cont	9.0
	RTG Controls	5.0	Cont	5.0	--	--	--	--	--	--	--	--	--
	ECAs Desc Batt	15.0	Cont	15.0	--	--	--	--	--	--	--	--	--
GN&C	Beacon	--	--	--	65.0	Cont	65.0	--	--	--	--	--	--
	Prog Coupler Assy	15.0	.84*	.12	15.0	Cont	15.0	--	--	--	--	--	--
	Subtotal			39.4			370.7			842.6			560.3
	Distrib Losses (7.5%)			3.0			27.8			63.2			42.0
	Current Status Avg Pwr			42.4			398.5			905.8			602.3
	Growth Allowance (20%)			8.5			79.7			181.2			120.5
	Design Avg Pwr without FCA Parasitics			59.9			478.2			1087.0			722.8
DES, ENER W/O FCA Parasitics (hr x des avg pwr),kw-hr				101.39			80.3			1.087			238.5

*One cycle for 82 days. Four weeks prior to TAXI launch, the transmitting period of 2 min (.14% duty cycle) is increased to 20 min for one day only.

**Initiates radar sweep for Earth acquisitions when S-Band antenna loses lock-on mode.

***Thermo requires 25% duty cycle

****Last hour of Quiescent Storage includes the first fuel cell startup. (See energy summary table for details.)

Table 5.1-2
SHELTER MISSION ELECTRICAL POWER SUMMARY

Mission Phase	Phase Time, hr	Energy kw-hr	Power Source
Countdown, launch & transposition	6.8	0.68	Descent Battery
Translunar	111.6	9.5	CSM (FCAs)
Preseparation checkout	1.5	2.1	Descent Battery
Descent	1.7	2.3	Descent Battery
Post-landing checkout	1.0	0.57	Descent Battery
Quiescent storage	1992.0	79.68	RTG
Quiescent storage	1992.0	21.71	Descent Battery
Fuel cell start-up*	1.0	1.0**	Descent Battery
Seven-day pre-utilization	168.0	109.2	FCAs
One-hr checkout	1.0	1.32	FCAs
Fourteen-day manned phase (with exper)	330.0	391.0	FCAs
	Summary	9.5	CSM FCAs
		28.36	Descent Batteries
		79.68	RTG
		501.5	Shelter FCAs

* Fuel cell start-up during last hr of Quiescent Storage.

** One kw-hr reqd for Allis Chalmer's fuel cell (shown).
Four kw-hr reqd for P & W fuel cell.
None for GE fuel cell.

Table 5.1-3
SHELTER MISSION ELECTRICAL POWER SUMMARY

Phase of Mission	7-Day	1-hr Checkout	14-Day Manned Phase
Housekeeping, watts			
•Design Avg Pwr (less FCA Parasitics)	478.2	1087.0	722.8
•FCA Parasitics*			
-Avg Pwr (operate)	115.0	230.0	177.4
-Avg Power (Standby)	57.0		
-Tot Design Avg Pwr (Incl FCA Parasitics)	650.2	1317.0	900.2
Total Housekeeping Design Energy (Incl Parasitics), kw-hr	109.2	1.316	297.0
Experiments, Kw			
•Other supporting Functions			0.2
•Drill			73.5
•PLSS Battery Recharging			13.7
Distrib Losses (7 1/2%)			87.4 6.6
Total Experiment Energy Reqmts			94.0

*Based on use of 2 Allis-Chalmers fuel cells; assumed fuel cells supply their electrical parasitics. (Zero distrib loss).

Table 5.1-4

FCA Performance Characteristics

	Allis-Chalmers	GE	P & W
Power Capability at 28V, watts			
o Initial	2350	500**	2000
o Degraded	1750	1000**	1800
Operating Temperature, °F	200	120	382 to 427
Operating Pressure, psia	40	20	55
Weight, lb	164	95***	265.4
Volume, cu ft	6.5	5.59	9.3
Product Water			
o Outlet Temperature, °F	150	100	155-170
o Outlet Pressure, psia	40	20	63
Purge Rate, %			
o H_2	0.2	3.0	0.5
o O_2	0.2	3.0	0.5
Environment	He	O_2 (Unicellular)	N_2
Start-up Energy Reqd, kw-hr	1.0	Zero (40° F +)	4.0
Start-up Time, hr	1.0	Zero (Instant)	1.0
Parasitic Power, watts			
o Full power	115*	15	127
o Hot standby/open circuit	57	Zero	113
Storage Environment Limits			
o Temperature, °F	-50 to +185	+40 to +120	-20 to +130
o Pressure		Space Vacuum	

*100 per Internal Cooling Loop + 15 for Glycol Pump.
**With-Voltage Regulator
***Plus 6 for Voltage Regulator.

Table 5.1-5

AES CRYOGENIC TANK CHARACTERISTICS

	Vessel Lox	Sizes LH_2
Outer		
Diameter, in,	41.5	41.5
Overall Length, in.	39.74	59.44
Elliptical Contour	1.43 to 1	1.43 to 1
Cylindrical Length, In.	10.1	29.8
Temperature, of	170	170
Outer Area, sq ft	27	52
Inner		
Volume, cu ft	20.25	34.2
Fluid Weight (usable),lb	1375	144.2
Total		
Weight (Al outer, 718 inner),lb	395	290
Pressure, psia	1000	300
Residual, %	5	5
Min. Flow at 130°F, lb/hr	0.47	0.047

Table 5.1-6
VENDOR CRYO TANK CHARACTERISTICS

		AES		AiResearch		Beech		Bendix	
		H_2	O_2	H_2	O_2	H_2	O_2	H_2	O_2
Max Operating Pressure, Psia				300	1000	100	875	660	1000
Standby Time, hr				2155	2155	2155	2155	2155	2155
Usable Fluid, lb		42.5	561.9	42.5	545.0	42.5	545.0	42.5	545.0
Inner Pressure Vessel	Material			Ti-5Al-2.5Sn	Inconel - 718			Cryo-formed	301SS
	Wt, lb			42.3	101.9	33.6	100.7	89.7	64.0
Outer Shell	Material			Ti-5Al-2.5Sn		Al 6061			
	Wt, lb			80.0	34.0	53.8	25.8	53.8	25.8
Insulation Wt, lb				33.0	11.7	22.4	25.6	35.5	14.4
Press Vessel Suppt Wt, lb				19.1	46.3	(Incl)	(Incl)	3.3	2.5
Mount Wt, lb				20.8	24.1	15.1	17.0	10.6	8.2
Components Wt, lb				19.2	14.0	16.0	16.0	8.5	7.9
Residual Fluid, lb				4.7	35.0	4.0	26.2	2.5	40.5
Vented Fluid, lb				30.0	zero	54.2	83.0	39.0	35.0
Tank OD, in.				51.4	40.5	47.3	37.0	44.2	34.2
Total Dry Wt, lb		290.0	395.0	214.4	232.0	140.9	185.1	201.4	122.8
Total Fluid Wt, lb				77.2	580.0	100.7	654.2	84.0	620.5
TOTAL LOADED WT, lb		431.9	984.9	291.6	812.0	241.6	839.3	285.4	743.3

Table 5.1-7
SUMMARY - AMBIENT TANK MATERIAL PROPERTIES

Material	Min. Ult. Stress, kpsi	Min. Yield Stress kpsi	Safety Factor		Density lb/cu in.	Strength* To Weight Ratio x 16^6	Vendor Contacted
			Ult.	Proof			
6AL-4V Ti	160	155	1.5	1.33	0.160	0.667	Airite
301 Stainless Cryo Stretched	260		1.5	1.33	0.286	0.605	Arde
18%Ni Maraging Steel	240	215	1.5	1.33	0.290	0.553	Airite Aerojet Downey
Inconel 718	170	140**	1.5	1.33**	0.296	0.356	Airite
D6AC Steel	220	190**	1.5	1.33**	0.283	0.504	Airite (LEM)
Composite Filament-Wound	180	-	2	1.33	0.086***	1.05	Aerojet, Azusa

Notes: Table based on oblate spheroid.

* Derived by dividing critical stress by safety factor & density.
** These materials are yield-critical.
***Include 20% penalty for metal liner.

Table 5.1-8
EXISTING HIGH PRESSURE STORAGE TANK CHARACTERISTICS

Vol, cu-ft	O.D., in.	Wt, lb	Min Wall t, in	Mat'l	Pressure, psia Burst	Proof	Oper	Oper Temp, °F	Customer
6	28	162	0.357	6-4 Ti	8000	5000	3250	+250	NAA S&ID
11.35	34.1	228	0.376	6-4 Ti	7000	4650	3500	+ 70	Grumman
19.35	40.9	392	0.450	6-4 Ti	6600	5867	4200	+300	NAA S&ID
3.0	21.8	59	0.123	D6AC	4500	3990	3000	+160	Grumman

Table 5.1-9
RTG DESIGN CHARACTERISTICS

	G.E.
Fuel	Pu 238
Mission Life	3 months
Reliability	0.98813
Net Power Output	50 watts @ 29 vDC ± 1%
RTG Output	56 watts minimum @ 14V
Thermal Power Input, watts	1400
Overall Efficiency %	3.6
Thermoelectric Efficiency, %	5.5
Converter/Regulator Efficiency, %	90
Radiator Efficiency, %	-
RTG Configuration	Finned cylinder
Overall Weight, lb	50 (nominal)
Converter/Regulator Weight, lb	4
RTG Weight, lb	30.4
RTG Dimensions, in.	18.1 long x 16.5 dia.
Thermoelectric Materials	Pb Te (N) Pb Sn Te (p)
No. of Couples	392
Hot Junction Temp. °F	1100
Cold Junction Temp, °F	525
Radiator	Beryllium Fins

Table 5.1-10
BATTERY CHARACTERISTICS

Characteristics	Ascent (LEM/Taxi)	Descent (LEM)	Mod Descent (Shelter/ Taxi Recomd Confg)
Designation	Asc-1C	Desc II-B	Desc. (Mod)
No. Cells	20	20	20
Weight, lb	130.5	139	147
Volume, cu in.	1545	1500	1630
Dimensions in. (h x w x l)	8.0 x 5.125 x 37.0	10.0 x 8.813 x 17.5	10.0 x 8.813 x 19.0
Capacity amp-hr	340/300*	400	400
Energy, kw-hr	10.2/9.0*	12	12.0
watt-hr/lb	78/69*	87	82
watt-hr/cu in.	66/15.8*	8.0	7.35
Mission watt-hr/lb	62(LEM) 60(Taxi)	82	65
watt-hr/cu in.	5.2(LEM) 5.0(Taxi)	7.5	5.9
Wt of Terminals & Other Hdwe, lb	Zero	0.4	0.4
Canister Weight, lb	10.5	10.0	10.2
Canister Material	Mg	Mg	Mg
Reliability Estimate	0.995 (LEM Mission)	0.995 (LEM Mission)	0.995 (Shelter Mission)
Cycling Capability	3	3 (Test only)	3 (Test only)
Cell Weight, lb	6.0	6.28	6.63
Silver Weight/Cell, gm	952	956	975
Zinc Weight/cell, gm	746	850	865
Cell Dimensions, in. (w x th x h)			
with Terminal	4.9 x 1.82 x 7.5	4.3 x 1.68 x 9.25	4.3 x 1.76 x 9.25
without Terminal	4.9 x 1.82 x 7.0	4.3 x 1.68 x 8.75	4.3 x 1.76 x 8.75
No. Cells, Positive/Negative	12/13	9/10	11/12
Total Effective Cell Area, sq in.	620	494	604
Separator System	Polyamide, Cellulose, Rayon	Polyamide, Cellulose, Rayon	Polyamide, Cellulose, Rayon
Electrolyte Qty, cc;wt, gm;Conc, %	320/432/35	300/420/40	330/460/40
Voltage at 10 amp, Initial/Plateau/Final	31.4/30.9/29.5	36.9/30.5/29.2	36.9/30.5/29.2
Voltage at 40 amp, Initial/Plateau/Final	30.2/30.1/27.4	36.3/29.4/27.1	36.3/29.4/27.1
Min. Voltage (40 amp) at 30°/80°/160°F	-	26.2/27.0/29.2	26.2/27.0/29.2
Max. Voltage (40 amp) at 30°/80°/160°F	-	32.2/33.5/35.8	32.2/33.5/35.8
Capacity after 30 days charged			
Stand at 32°/80°/100°F	1.1C/1.1C/1.025C	1.0C/1.0C/0.9C	1.0C 1.0C 0.9C
Heat Generated Btu	7,200/3,800**	16,600/9,800**	
Specific Heat	0.19	0.19	0.19
Short Circuit Current into 0.01Ω Load, amp	750	600	
Mounting Structure Weight, lb	5	5	5
ECA Weight, lb	10	14	10

* After Predischarge

** Normal LEM Mission/Abort (1 Battery)

*** 4 Battery/3 Battery LEM Mission

Table 5.1-11
AMBIENT TANK WEIGHTS FOR DIFFERENT MATERIALS

	Total Amt, lb	Usable Amt, lb	Tank Material	Dry Tank Wt, lb*	Ratio, Tank Wt to Usable O_2	Wet Tank Wt, lb
O_2 (1)	566	560.4	301SS Cryo Stretch	515	.9175	1081***
	566	560.4	Maraging Steel	573	1.02	1139
	566	560.4	D AC	624	1.11	1180
	566	560.4	Inconel	831	1.48	1397
	566	560.4	Filament Wound**	303	.54	869
H_2 (2)	43	425	6-4 Titamium	712	16.75	755***
	43	425	301 SS Cryo Stretch	780	18.35	823
	43	425	Maraging Steel	848	20	891
	43	425	D AC	924	21.7	967
	43	425	Inconel	1232	29	1275
	43**	425	Filament Wound**	465	10.9	507
PLSS O_2(1)	12	9	301 SS Cryo Stretch	12.5		24.5

NOTES:
* Includes 10% allowance for bosses, mounts and tolerances.
** Not state-of-the-art.
*** Recommended configuration.

5.1-12

0

	Wt	Max Possible	AiResearch	Beech	Bendix
I. Design & Performance 46%					
A. Overall Design concept 15%					
1) Size and shape	1		G-3	G-3	F-2
2) Simplicity or complexity	2		G-6	F-4	F-4
3) Pressure vessel & outer shell design	2		F-4	F-4	F-4
4) Pressure vessel support	2		G-6	F-4	G-6
5) Tank mounting scheme	1		G-3	G-3	G-3
6) Component mounting scheme	1		G-3	G-3	G-3
7) Interface requirements	1		G-3	F-2	F-2
	10	40			
I.A Total out of 40 max			28	23	24
Weighted rating based on 15°			10.50	8.62	9.00
B. Thermal Design & Performance 20%					
1) Insulation technique	2		F-3	(G-)-5	(E-)-7
2) Thermal effectiveness	2		F-4	G-6	(E-)-7
3) Growth potential - lowering heat leak w/o redesign	1		P-1	G-3	E-4
4) Thermal optimization with respect to AES mission	1		F-2	F-2	F-2
5) Solution to stratification	1		G-3	E-4	E-4
6) Analytical methods	2		E-8	P-2	F-4
	9	36			
I.B Total out of 36 maximum			21	22	28
Weighted rating based on 20			11.66	12.21	15.56
C. Mechanical Design - 5					
1) Materials selection	2		G-6	G-6	F-4
2) Materials compatibility	1		F-2	G-3	G-3
3) Design approach & analysis of:					
(a) o Pressure vessel	1		P-1	F-2	F-2
(b) o Outer Shell	1		F-2	G-3	F-2
(c) o Insulation	1		G-3	F-2	G-3
(d) Pressure vessel support	1		G-3	F-2	F-2
(e) Outer shell support	1		G-3	G-3	G-3
(f) Components & supports	1		G-3	G-3	G-3
4) Confidence in stress properties	1		F-2	G-3	F-2
5) Manufacturing methods	1		F-2	G-3	F-2
	11	44			
I.C Total out of 44 maximum			27	30	26
Weighted rating based on 5			3.07	3.41	2.96
D. Instrumentation - 2	1		G-3	G-3	G-3
I.D Total out of 4 maximum	1	4	3	3	3
Weighted rating based on 2			1.50	1.50	1.50

②

Table 5.1-12
CRYOGENIC TANK EVALUATION

	Wt	Max Possible	AiResearch	Beech	Bendix	
:. Power - 2						
1) Heater power	1		G-3	F-2	F-2	
2) Heater energy	1		G-3	G-3	F-2	I
	2	8				
E Total out of 8 maximum			6	5	4	
Weighted rating based on 2			1.50	1.25	1.00	
'. GSE Requirements - 2						
1) Handling requirements	1		G-3	G-3	G-3	
2) Filling	1		F-2	F-2	G-3	
	2	8				
F Total out of 8 maximum			5	5	6	I
Weighted rating based on 2			1.25	1.25	1.50	I
:. Weights 27						
ı. Comparative total weights						C
1) Shelter	9		F-18	G-27	E-36	
2) Lab	6		F-12	G-18	E-24	
ı. Weight data validation	5		G-15	F-10	F-10	
:. Weight control (methods procedures, organization)	4		F-8	F-8	F-8	
). Possible wt. savings during development	3		F-6	G-9	G-9	
	27	108				
:. Total out of 108 maximum			59	72	87	
Weighted rating based on 27			14.75	18.00	21.75	
:I. Reliability 27						
ı. Comparative overall reliability						
1) Reliability on basis of overall system	10	40	G-30	F-20	F-20	
2) Failure Rates	3	12	G-9	F-6	G-9	
3) Failure modes & effects analysis	2	8	F-4	G-6	F-4	
ı. Reliability Methods procedures & organization	4	16	F-8	G-12	G-12	
:. Data in support of Reliability analysis						
1) Stress to failure tests	2	8	F-4	G-6	P-2	
2) Actual flight data	2	8	E-8	P-2	P-2	
). Possible future reliability improvement	2	8	F-4	F-4	F-4	
:. Maintainability	2	8	F-4	F-4	F-4	
	27	108				
:I. Total out of 108 maximum			71	60	57	
Weighted rating based on 27			17.75	15.00	14.25	

5.1-12 ③

	Wt	Max Possible	AiResearch	Beech	Bendix
Summary & Totals					
Design & Performance					
Overall design concept	15		10.50	8.62	9.00
Thermal Design & Performance	20		11.66	12.21	15.56
Mechanical Design	5		3.07	3.41	2.96
Instrumentation	2		1.50	1.50	1.50
Power	2		1.25	1.25	1.50
GSE Requirement	2		1.25	1.25	1.50
	46		29.23	28.24	32.02
Weights	27		14.75	18.00	21.75
I. Reliability	27		17.75	15.00	14.25
AND TOTAL	100		61.73	61.24	68.02

Table 5.1-13
CRYOGENIC/AMBIENT WEIGHT ANALYSIS

	Ambient	Cryo
Usable H_2	42.5	42.5
Residual H_2	0.5	6.7
Vented H_2	---	92.7
H_2 Tank	712 (2 tanks)	290.0
H_2 Tank Mount Structure*	Included	8.0
Usable O_2	560.4	561.9
Residual O_2	5.6	28.0
O_2 Tank	515	395.0
O_2 Tank Mount Structure	Included	19.7
Plumbing & Feed Section**	21.1	104
PLSS O_2 Usable	9.0	7.5
Residual	3.0	1.8
Tank	12.5	18.8
Mounting	Included	.6
	1881.6 lb	1484.2 lb

* Structural mount penalty of 2% for cryogenic tanks and GOX accumulator

** Plumbing and Feed Sections

Ambient

3 Pressure transducers at	0.5	= 1.5
4 Fill Connections at	0.45	= 1.8
3 Squib valves at	0.6	= 1.8
6 Pressure relief valves at	0.6	= 3.6
3 Burst diaphragms at	0.8	= 2.4
3 Pressure regulators at	1.0	= 3.0
Lines & fittings		= 7.0
		21.1 lb

Cryo

2 Heat exchangers at	0.64=1.28
2 Pressure relief valves at	0.60=1.20
1 Press transducer (GOX Tank) at	0.5 =0.50
1 Fill valve (GOX Tank) at	0.4 =0.4
Lines & fittings	7.0
	10.38

5.1-14
(1)

	Wt	Max Possible	A.C.	G.E.	P & W
I. Design and Performance (46%)					
A. Design concept of cell (8%)					
1) Originality	1		F-2	G-3	P-1
2) Adaptability to space					
(a) gravitational effects	1		G-3	E-4	F-2
(b) operational temp. as affects ability to reject heat	2		G-6	P-2	E-8
3) Growth potential	1		G-3	F-2	G-3
4) Complexity					
(a) fuel-cell itself	1		F-1	G-3	P-1
(b) water removal concept	1		F-2	G-3	F-2
(c) cooling concept	1		F-2	G-3	F-2
5) Size (amperes per square ft capability)	1		F-2	P-1	G-3
6) Weight (effect of cell conceptual design on power plant weight)	1		F-2	G-3	P-1
7) Development of cell concept	1		F-2	P-1	P-1
I.A Total out of 44 mass	11	44	26	25	24
Weighted rating based on 8			4.72	4.55	4.32
B. Mechanical realization (8)					
1) Electrodes	1		G-3	G-3	F-2
2) Electrolyte	1		G-3	F-2	P-1
3) Reactant passages incell	1		F-2	F-2	F-2
4) Cell stacking method	1		F-2	G-3	F-2
5) Cell wiring	1		G-3	G-3	F-2
6) Operating temperatures (mechanical effects)	1		F-2	G-3	P-1
7) Operating pressure			G-3	G-3	G-3
8) Cooling loop mechanical design	1		F-2	G-3	F-2
9) Reactant feed to stack	1		F-2	F-2	F-2
10) Housing design	1		F-2	F-2	F-2
11) Water removal	1		P-1	E-4	F-2
12) Package in controls and accessories	1		P-1	G-3	G-3
13) Fuel cell mounting	1		F-2	G-3	P-1
14) FCA specific volume, watts/ft^3 in/ft	1		F-2	G-3	P-1
15) FCA Specific Weight in watt per lb	1		E-4	G-3	P-1
I.B Total out of 56 max possible	14	56	34	42	27
Weighted rating (8)			4.86	6.0	3.85

C. Per
1)
2)
3)
4)
5)
6)
7)
8)
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D. Veh
1)
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4)
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II. Weig
A. Miss
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C. Weig
cedu
D. Pote
deve

Table 5.1-14 ②

FCA Evaluation Critieria

	Wt	Max Possible	A.C.	G.E.	P & W
ormance (15)					
oltage range	1		F-2	P-1	F-2
erformance degradations end of LAB II missions 1080 hours)	1		G-3	P-1	F-2
ross thermal efficiency	2		G-6	P-2	G-6
arasitic power	2		P-2	G-6	P-2
pen circuit and/or stand- capability	2		G-6	G-6	P-2
old start (from 40°F)	1		G-3	E-4	P-1
topping procedure:					
emporary	1		G-3	E-4	F-2
ermanent	2		F-2	F-2	F-2
torage capability (at 40°F)	1		G-3	F-2	G-3
tep load	1		E-4	E-4	P-1
	13	52	34	32	23
eighted rating (15)			9.82	9.23	6.64
cle Integration (15)					
hermal interface	2		G-6	E-8	P-2
oolant loop and radiation enalty	2		E-8	P-2	E-8
lectrical interface,	1		F-2	F-2	F-2
re-launch checkout	1		F-2	G-3	P-1
echanical interface	1		F-2	G-3	P-1
product water (effect vehicle integration)	1		F-2	P-1	G-3
otal volume	1		G-3	G-3	F-2
	9	36	25	22	19
eighted rating (15)			10.4	9.2	7.90
ts (27)					
on Weight					
elter	9		G-27	P-9	F-18
b II	6		G-18	P-6	P-16
t Dated Validation	5		F-10	G-15	G-15
t Control (method, pro- e organization)	4		F-8	G-12	G-12
tial weight saving during opment	3		F-6	P-3	P-3
	27	108	64	45	54
ighted rating			17.25	11.25	13.5

III.
A. F
1)
2)
3)
4)
B. F
a
C. E
D. F
E. M
p
III.

Su

I. De
A. D
B. M
C. P
D. V

II. W
III.

GRAND

5.1-14 ③

	Wt	Max Possible	A.C.	G.E.	P & W
eliability					
el cell reliability					
Shelter with peak (DRILL)	6	24	P-6	M-0	F-12
Shelter WITHOUT PEAK	3	12	G-9	E-12	G-9
LAB II with peak (RADAR)	2	8	P-2	M-0	P-2
LAB II WITHOUT PEAK	4	16	F-8	G-12	G-12
liability method procedure d organization	4	16	P-4	G-12	G-12
ck-up Data	4	16	F-8	P-4	G-12
ssible Improvement	2	8	F-4	F-4	F-4
intainability (pre-launch riod)	2	8	F-4	G-6	P-2
otals	27	108	45	50	65
eighted rating			11.25	12.5	16.20
mary & Totals					
ign and Performance:					
sign Concept	8		4.72	4.55	4.36
chanical Realization	8		4.86	6.00	3.85
rformance	15		9.82	9.23	6.64
hicle Integration	15		10.40	9.2	7.90
	46		29.80	28.98	22.75
ights	27		17.25	11.25	13.5
eliability	27		11.25	12.50	16.20
OTALS	100		58.30	52.73	52.45

Table 5.1-15

WEIGHT SUMMARY - FCA CONFIGURATIONS

	2 A-C	4 G E	2 P&WA
Fuel Cells	328.0	404.0	532.0
FC mount structure	10.0	16.0	15.0
ECA's	28.0	56.0	28.0
ECA'2 mount structure	3.3	6.6	3.3
ECA cooling Δ(radiation)	--	1.0	--
FC start-up battery	11.1	--	44.5
Vertical radiator	80.0	200.0	92.2
Cooling water - housekeeping	--	261.0	--
Cooling water - drill	206.0	250.0	170.0
FC cooling (water boiler)	3.0	3.0	3.0
H_2O Tank	20.6	51.1	17.0
H_2O Tank mount structure	6.2	15.5	5.1
ECS Hardware to cool FC & Q mod	--	--	81.0
for FC AC power	--	--	32.0
H_2 Reactants	42.5	42.5	44.0
O_2 Reactants + ECS	560.4	556.4	573.4
Ambient tanks for H_2	712.0	704.0	737.0
Ambient tanks for O_2	515.0	510.0	525.0
Residual H_2	0.5	0.5	0.5
Residual O_2	5.6	5.6	5.6
PLSS O_2 tank	12.5	12.5	12.5
PLSS O_2	9.0	9.0	9.0
Residual O_2 in PLSS tank	3.0	3.0	3.0
Plumbing and Feed Section	22.4	25.2	22.4
Glycol Pump Assy	10.0	20.0	--
Total (vertical radiator)	2589.1	3152.4	2955.3
(Horizontal radiator)	(40)	(105)	(46)
(Cooling water: housekeeping)	--	--	--
(Cooling water: drill)	(206)	(250)	(170)
(H_2O tank)	(20.6)	(25.0)	(17.0)
(H_2O tank mount structure)	(6.2)	(7.6)	(5.1)
Total (Horizontal rad)	(2549.1)	(2759.4)	(2909.3)

DESCENT & QUIESCE

Power Source	Config No.	Desc Batt Energy, kw-hr Req	Desc Batt Energy, kw-hr Avail	Main Batteries No.	Main Batteries Type	Main Batteries Rat'g, kw-hr	Main Batteries Wt, lb/batt	Acc Wt, lb Note 1	Tota Batt w lb
One RTG & AgZn Batts	A-1	28.4	36.0	3	AgZn	12.0	147		441
	A-2	28.4	37.6	4		9.4	121		484
One RTG & ZnO_2 Batts	B-1	28.4	38.1	3	ZnO_2	12.7	87	9	261 (No
	B-2	38.4	40.6	4		10.2	71	10.5	284 (No
One RTG & AgZn Batts	C-1	28.4	28.4	3	Mod Desc AgZn	9.5	125		375
	C-2	28.4	28.4	4		7.1	100		400
One RTG & ZnO_2 Batts	D-1	28.4	28.4	3	ZnO_2	9.5	68	9	204 (No
	D-2	38.4	38.4	4		9.6	69	10.5	276 (No
No RTG, ZnO_2	E-1	202.0	202.0	4	ZnO_2	50.5	310	90 Note 4	1240

ECA TYPE	Assumed Reqmts lb	watts
AgZn Battery		
ZnO_2 Battery	10	7.5
RTG	10	5.0
	4	5.0

Notes:
1. Acc. Wt. - O_2 reactant fluid sy
2. Light weight
3. ZnO_2 battery and O_2 reactant we
4. Includes 80 lbs of O_2 reactant
5. RTG supplies all loads up to it
6. Same batteries as used on taxi
7. Added 10 kw-hr for ZnO_2 ECA to
8. Complete 66 days of quiescent
9. Complete 82 days of quiescent
10. No RTG or problem of moving it
11. Complete 72 days of quiescent
12. Complete 63 days of quiescent
13. Complete 47 days of quiescent
14. Complete 56 days of quiescent
15. Complete 47 days of quiescent
16. Complete 58 days of quiescent

Table 5.1-16

NT PHASE POWER SUPPLY EVALUATION

t,	RTG No.	RTG Wt, lb	RTG Load'g, watts Note 5	RTG Energy, kw-hr	ECA No.	ECA Wt, lb	Total Wt, lb	Major Advantage	Disadv	Remarks No. of Batt & Cap
	1	63	40.0	80.0	4	34	538	Note 8	Weight	3-43% Recomm'd (Note 6)
			45.0	90.0	5	44	591	Note 9		4-33% (Note 6)
te 3)	1	63	47.5	95.0	4	34	367	Notes 2 & 11	Sched Cost to Devel & Reliabil of ZnO_2 Batts	3-41% Alternate
te 3)			50.0	100.0	5	44	402	Note 12		4-26% (Notes 6 & 7)
	1	63	40.0	80.0	4	34	472	Note 13		3-33%
			45.0	90.0	5	44	507	Note 14		4-25%
te 3)	1	63	47.5	95.0	4	34	310	Notes 2 & 15	RTG Cost & Sched Cost to Devel & Reliabil of ZnO_2 Batts	3-33%
te 3)			50.0	100.0	5	44	394	Note 16		4-25% Note 7
	-	-	-	-	4	40	1370	Note 10	Weight	4-25%

stem hardware weights required for ZnO_2 batteries

ights without fluid system weights

tank wt (21 lb of O_2 reactant) not charged with tank wt-come from ECS)

s full load rating, while the batteries take all loads above RTG rating

configurations.

battery reqmts; added 5 kw-hr for ZnO_2 ECA to RTG reqmts.

ith one battery failure at beginning of mission

ith one battery failure at beginning of mission

to Taxi

ith one battery failure at beginning of mission

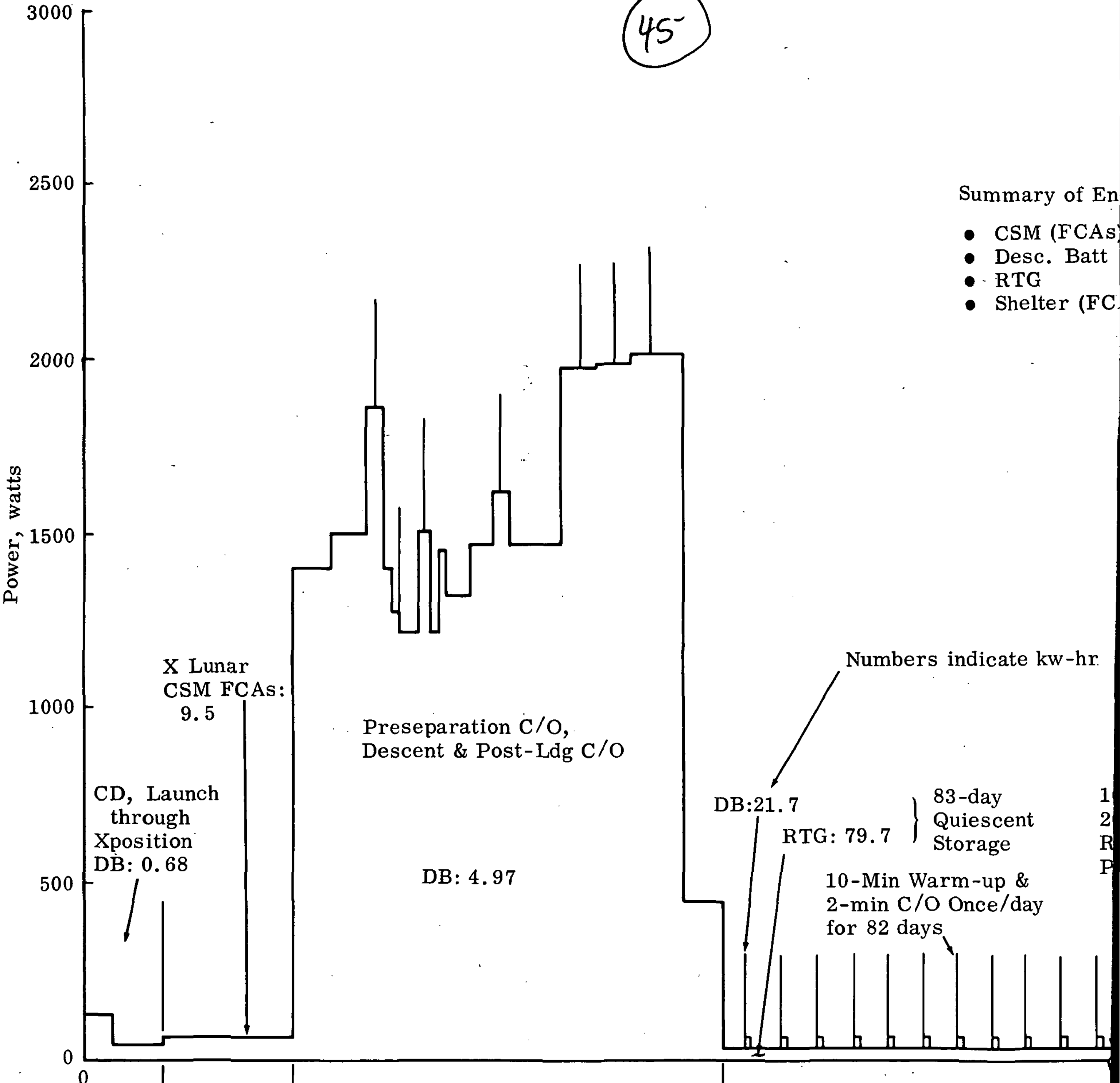
ith one battery failure at beginning of mission

ith one battery failure at beginning of mission

ith one battery failure at beginning of mission

ith one battery failure at beginning of mission

ith one battery failure at beginning of mission


3000
2500
2000
1500
1000
500
0
Power, watts
Summary of En
● CSM (FCAs
● Desc. Batt
● RTG
● Shelter (FC
X Lunar
CSM FCAs:
9.5
Preseparation C/O,
Descent & Post-Ldg C/O
Numbers indicate kw-hr
CD, Launch
through
Xposition
DB: 0.68
DB: 4.97
DB:21.7
RTG: 79.7
83-day
Quiescent
Storage
10-Min Warm-up &
2-min C/O Once/day
for 82 days
1
2
R
P
0
6.8
111.6
4.45
1

	ergy Reqmts, kw-hr
)	9.5
	28.4
	79.7
As)	407.5

*Includes Fuel Cell Parasitics
DB: Descent Batteries
CD: Count-down
RTG: Radioisotope Thermoelectric Generator
C/O: Checkout
FCA: Fuel Cell Assy

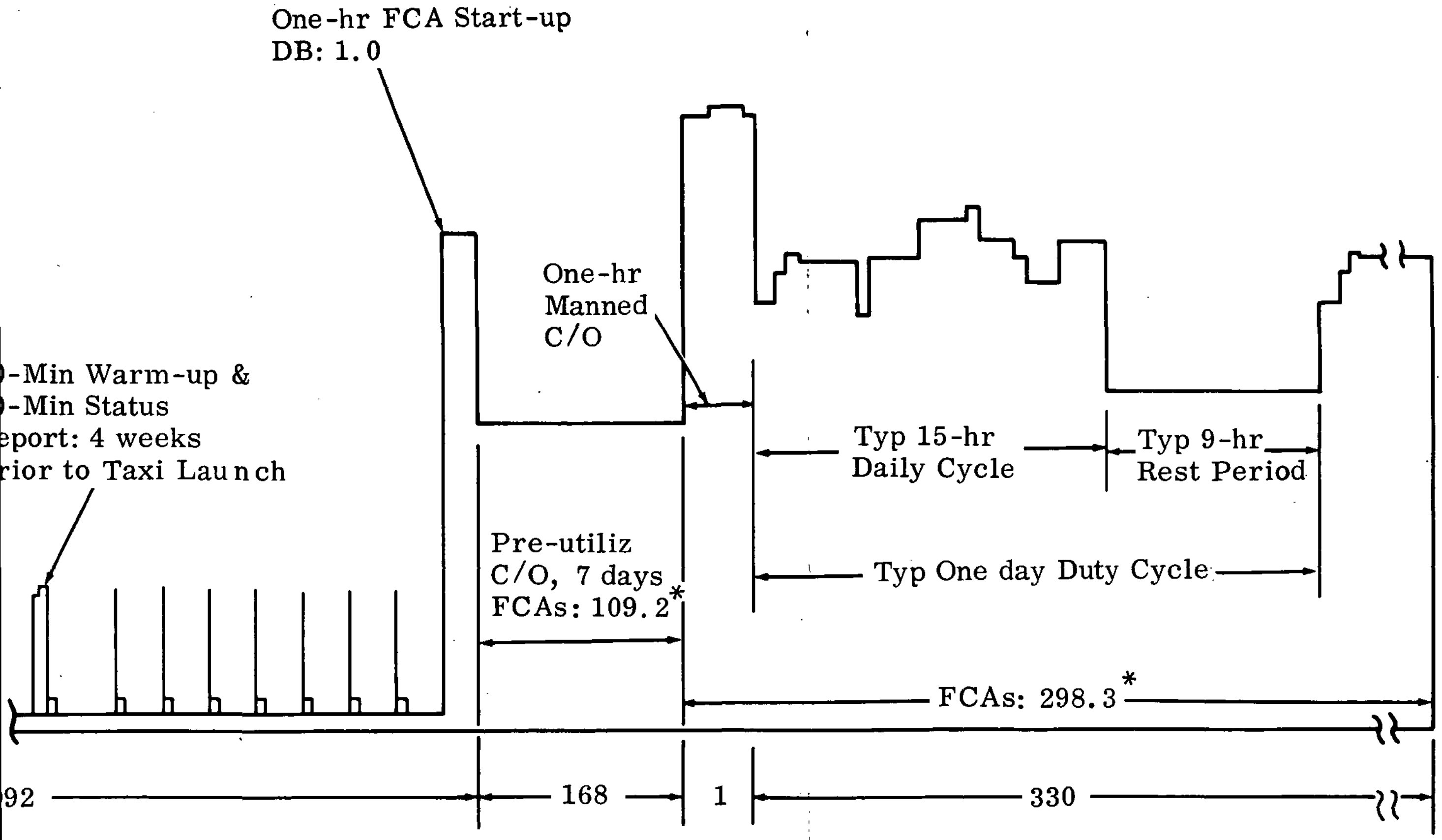
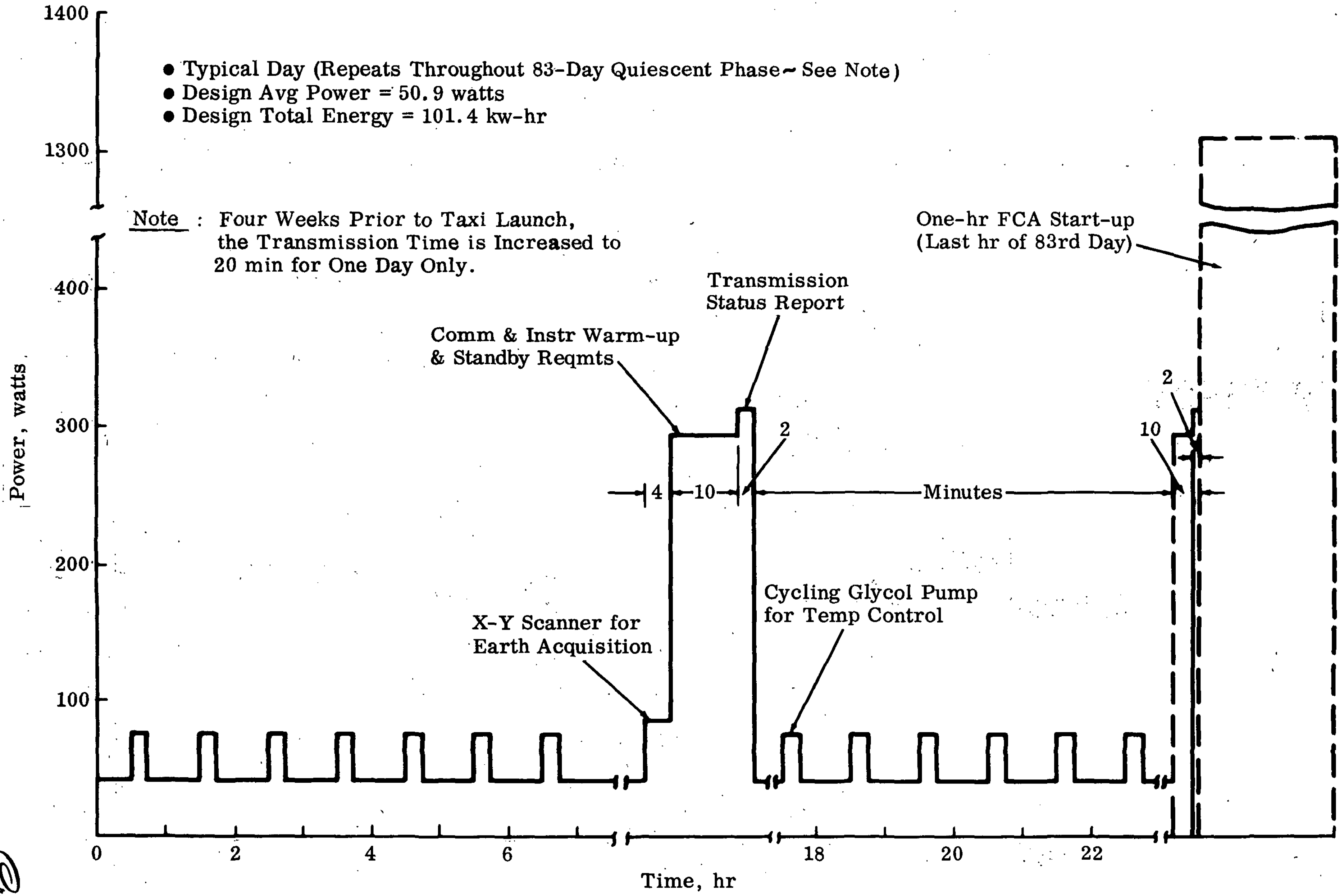


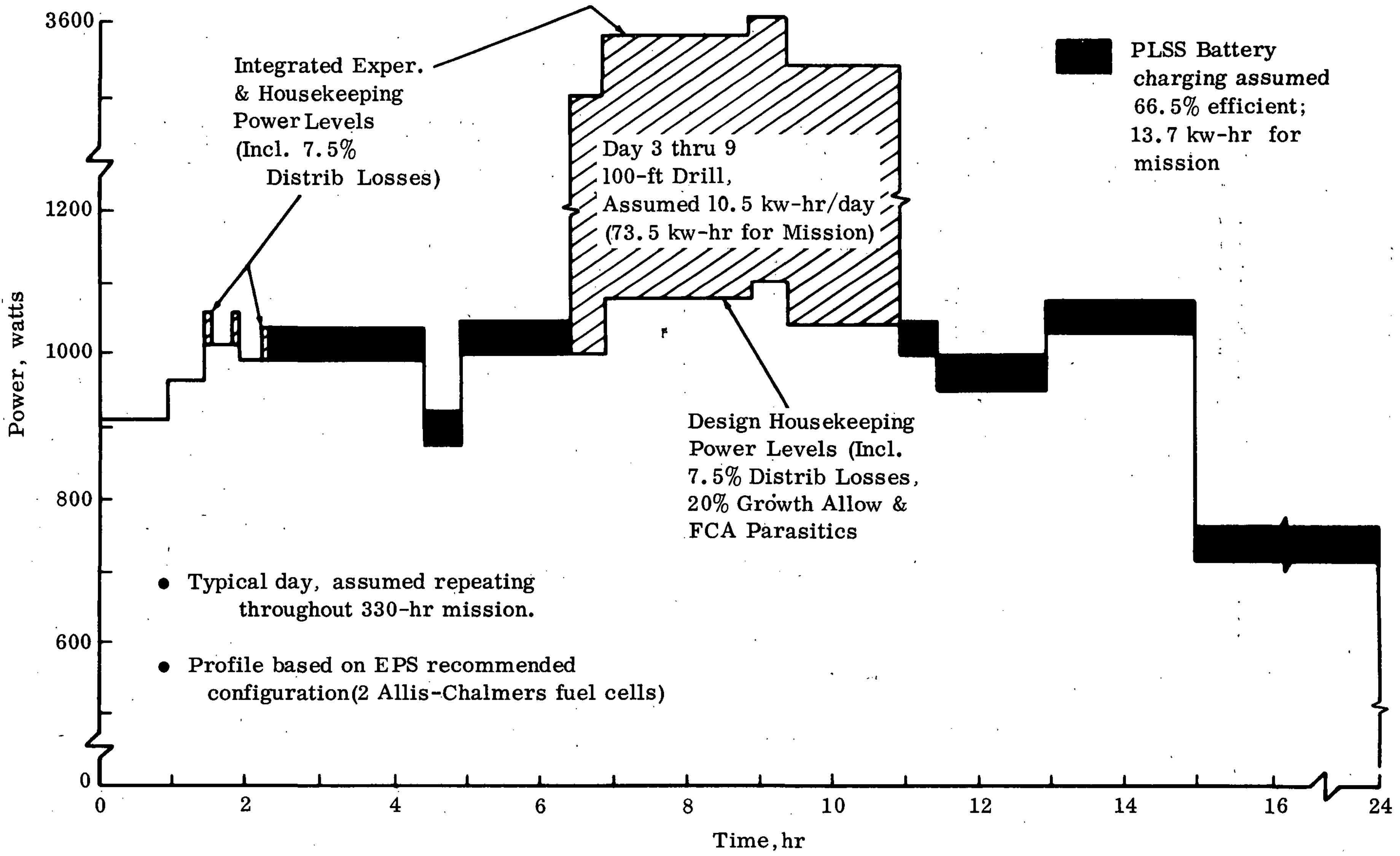
Fig. 5.1-1 Electric Power Profile - Housekeeping



- Typical Day (Repeats Throughout 83-Day Quiescent Phase ~ See Note)
- Design Avg Power = 50.9 watts
- Design Total Energy = 101.4 kw-hr

Note : Four Weeks Prior to Taxi Launch, the Transmission Time is Increased to 20 min for One Day Only.

Fig. 5.1-2 Electric Power Profile - Quiescent Storage (Typical Day)



▇ PLSS Battery charging assumed 66.5% efficient; 13.7 kw-hr for mission

Integrated Exper. & Housekeeping Power Levels (Incl. 7.5% Distrib Losses)

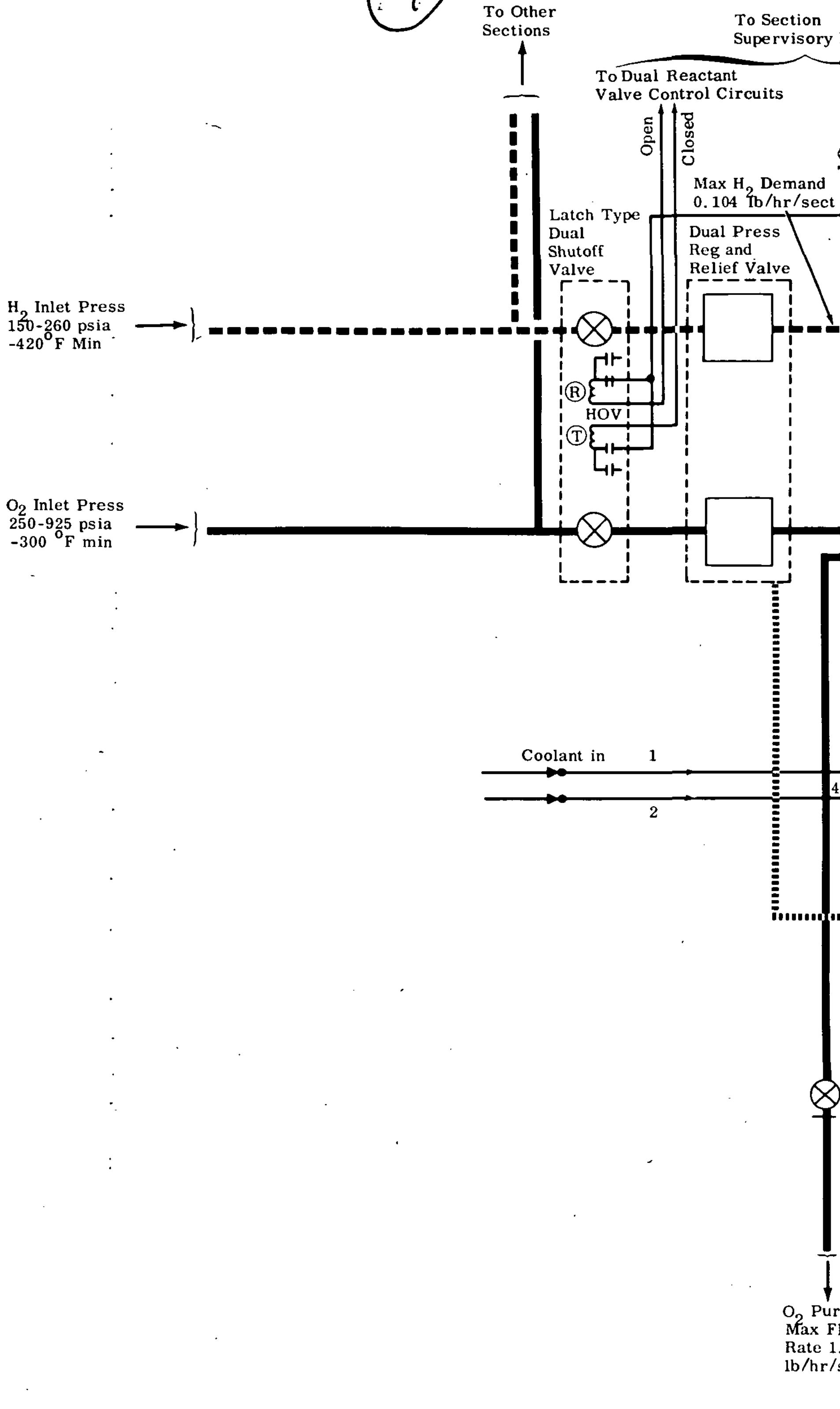
Day 3 thru 9 100-ft Drill, Assumed 10.5 kw-hr/day (73.5 kw-hr for Mission)

Design Housekeeping Power Levels (Incl. 7.5% Distrib Losses, 20% Growth Allow & FCA Parasitics

- Typical day, assumed repeating throughout 330-hr mission.
- Profile based on EPS recommended configuration(2 Allis-Chalmers fuel cells)

Fig. 5.1-3 Electric Power Profile - Manned Phase (Typical Day)

49


To Other Sections
To Section Supervisory
To Dual Reactant Valve Control Circuits
Open
Closed
Max H_2 Demand 0.104 lb/hr/sect
Latch Type Dual Shutoff Valve
Dual Press Reg and Relief Valve
H_2 Inlet Press 150-260 psia -420°F Min
R
HOV
T
O_2 Inlet Press 250-925 psia -300 °F min
Coolant in
1
2
4
O_2 Pur
Max Fl
Rate 1.
lb/hr/s

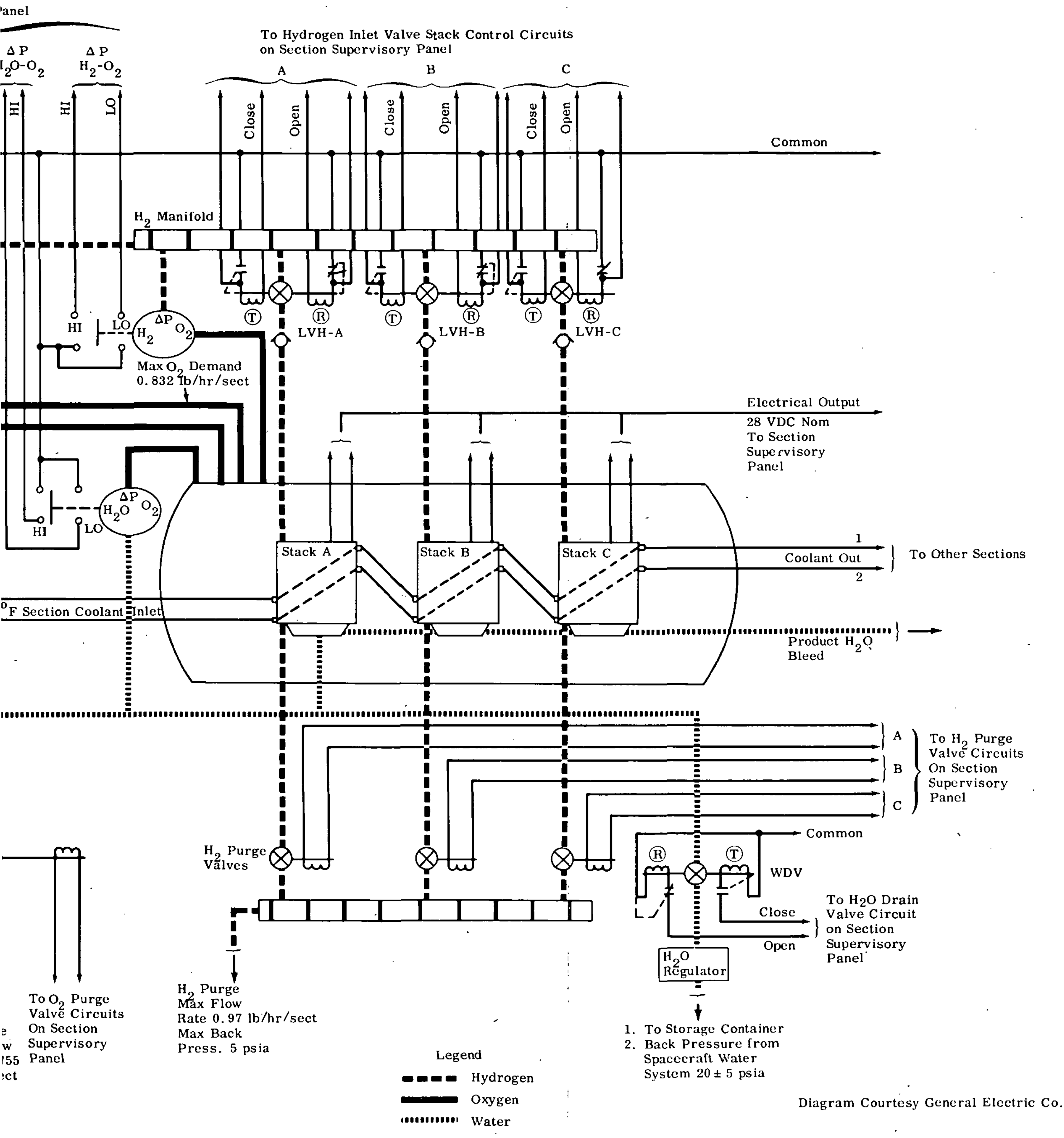


Diagram Courtesy General Electric Co.

Fig. 5.1-4 GE Fuel Cell Assembly

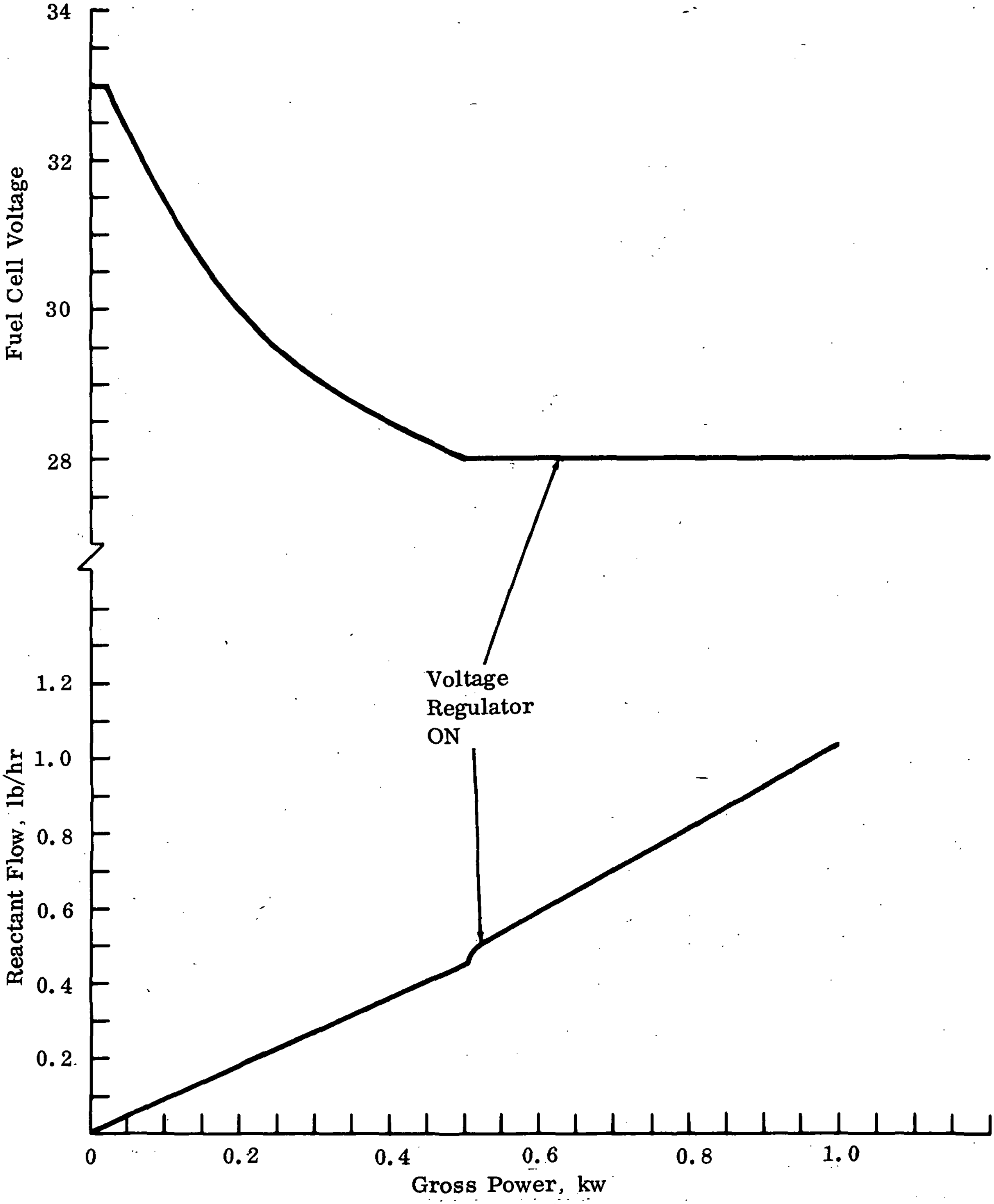


Fig. 5.1-5 Polarization & Reactant Flow - GE FCA

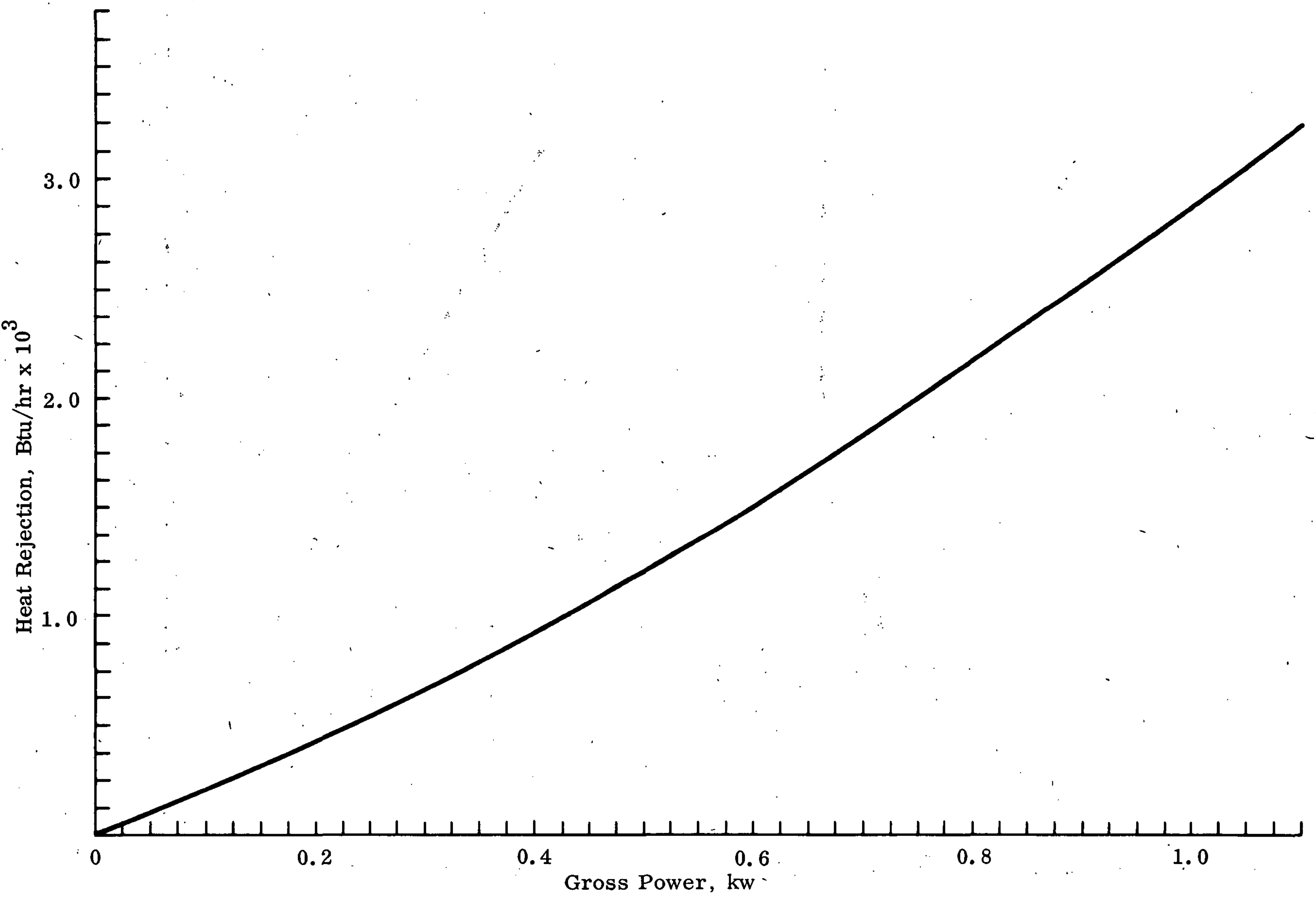


Fig. 5.1-6 Heat Rejection - GE FCA

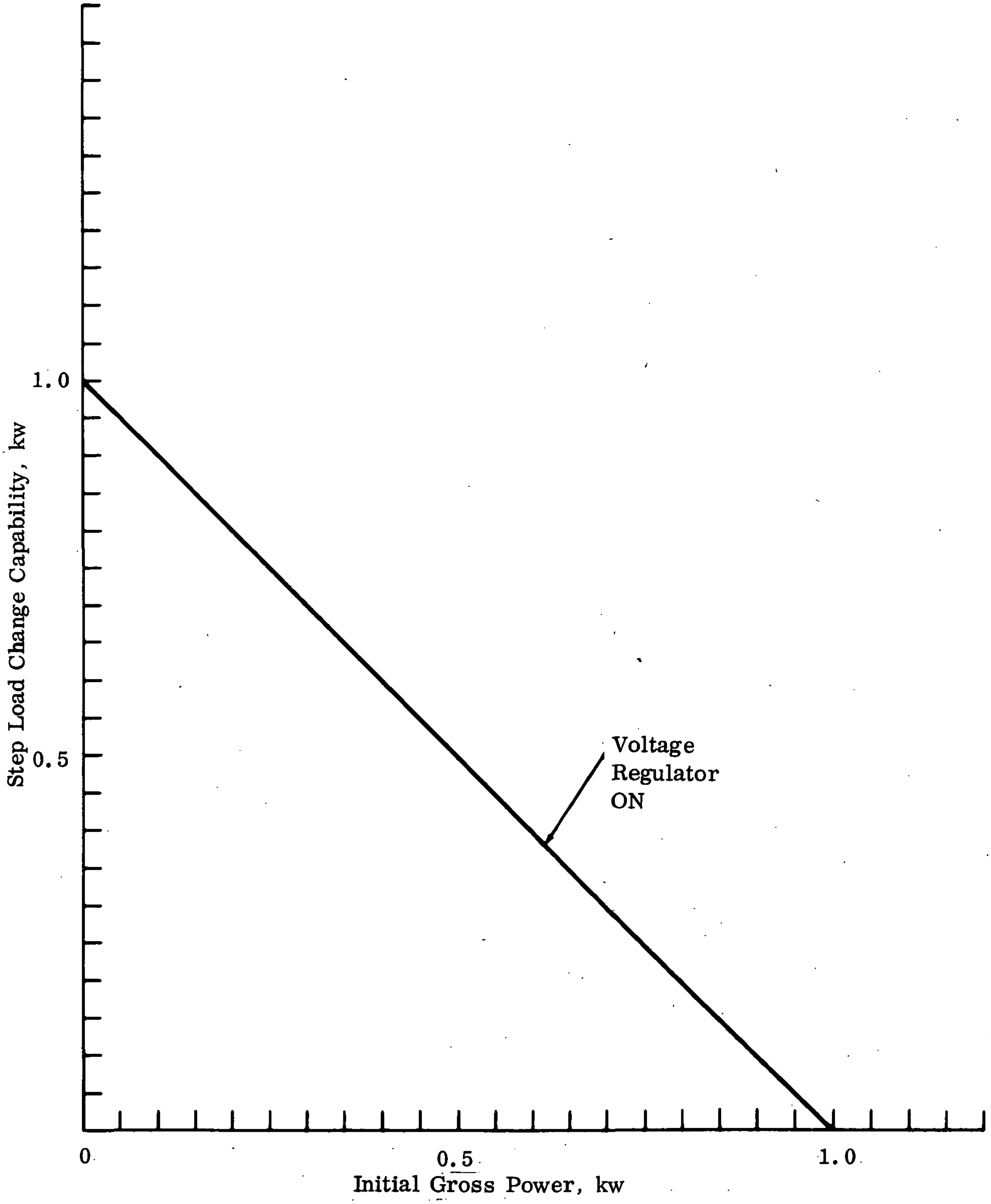
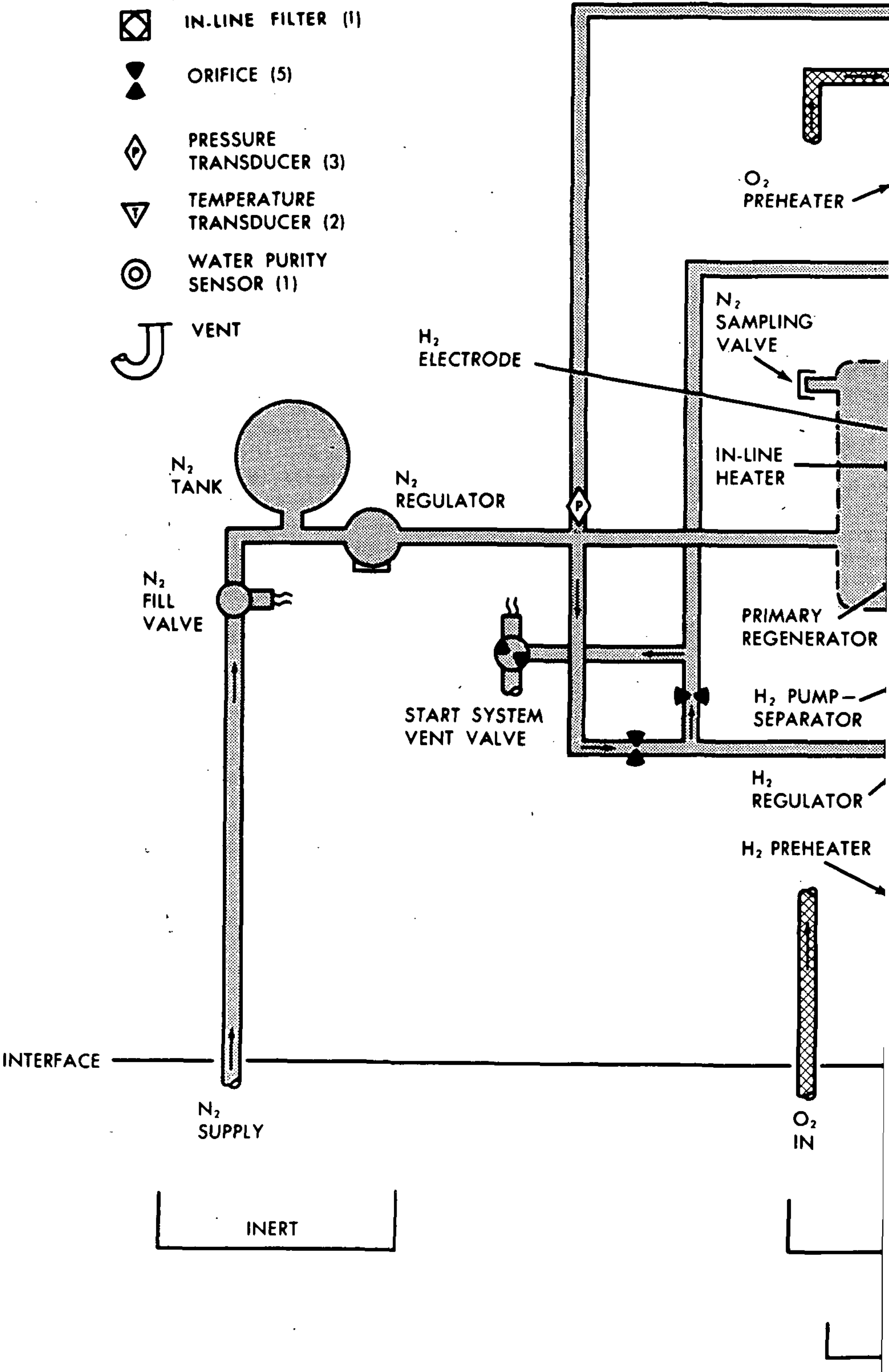


Fig. 5.1-7 Step Load Capability - GE FCA


IN-LINE FILTER (1)
ORIFICE (5)
PRESSURE TRANSDUCER (3)
TEMPERATURE TRANSDUCER (2)
WATER PURITY SENSOR (1)
VENT
O_2 PREHEATER
N_2 SAMPLING VALVE
H_2 ELECTRODE
IN-LINE HEATER
N_2 TANK
N_2 REGULATOR
P
N_2 FILL VALVE
PRIMARY REGENERATOR
START SYSTEM VENT VALVE
H_2 PUMP-SEPARATOR
H_2 REGULATOR
H_2 PREHEATER
INTERFACE
N_2 SUPPLY
O_2 IN
INERT

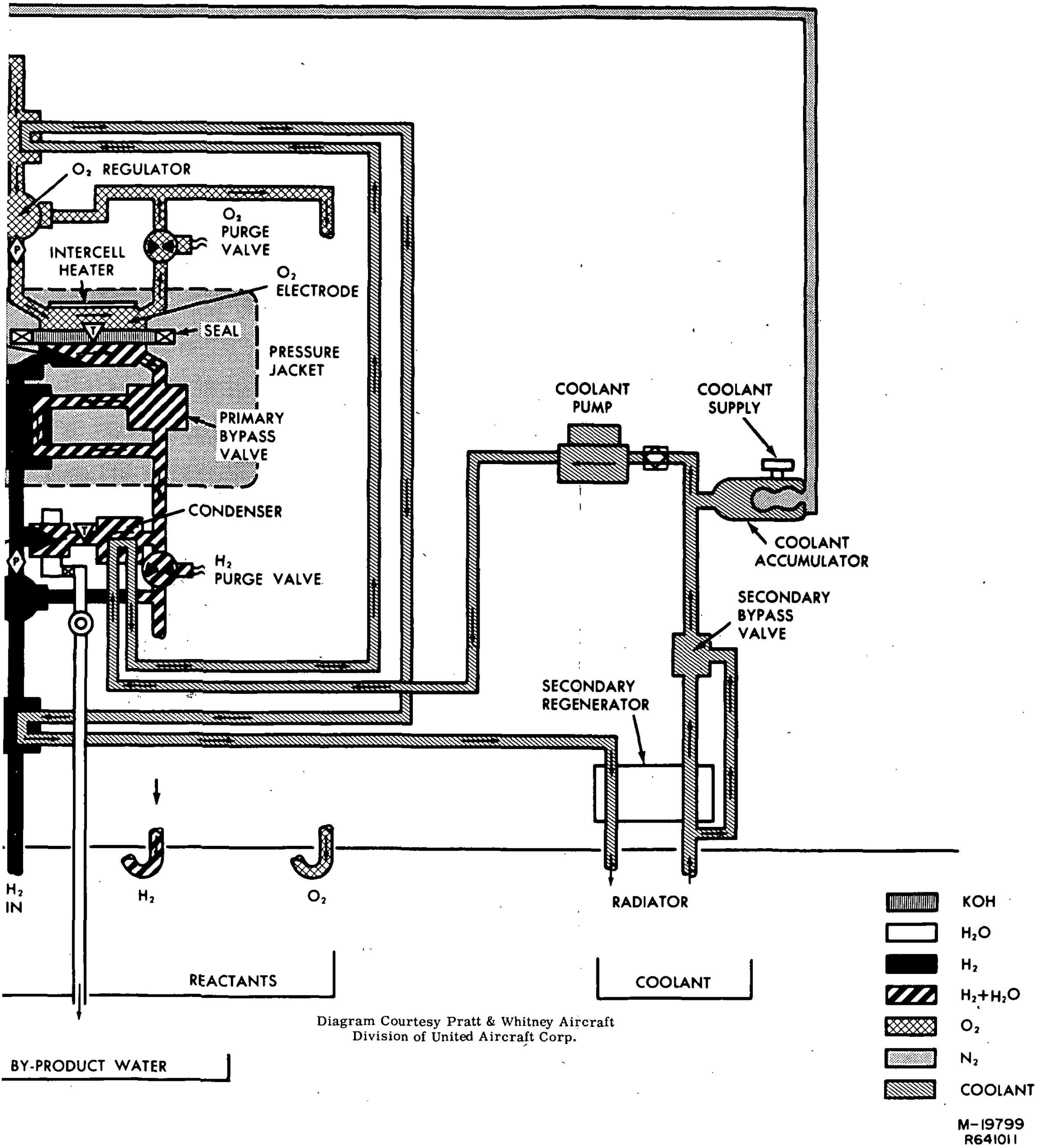


Diagram Courtesy Pratt & Whitney Aircraft
Division of United Aircraft Corp.

Fig. 5.1-8 P&W Fuel Cell Assembly

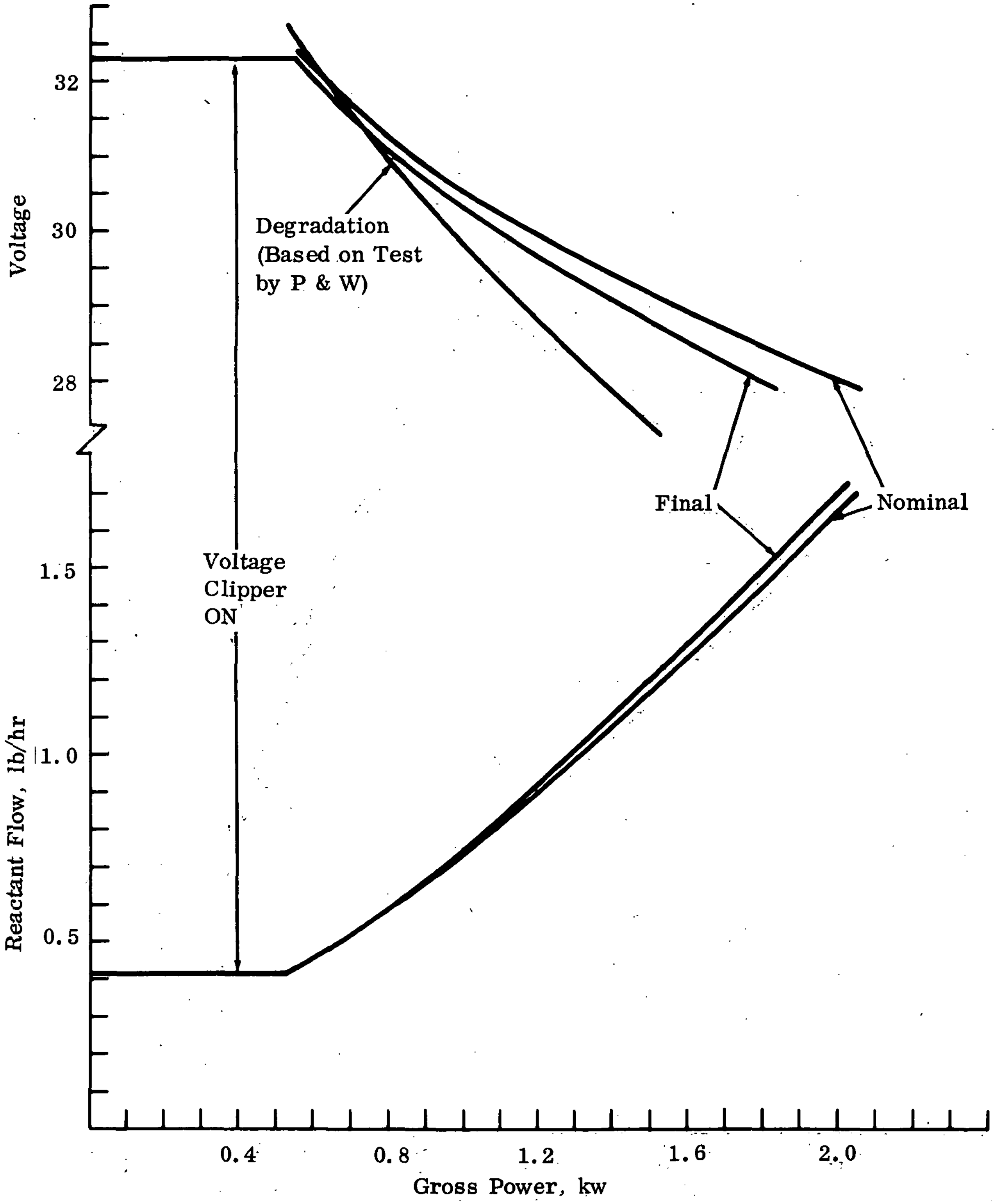


Fig. 5.1-9 Polarization & Reactant Flow - P&W FCA

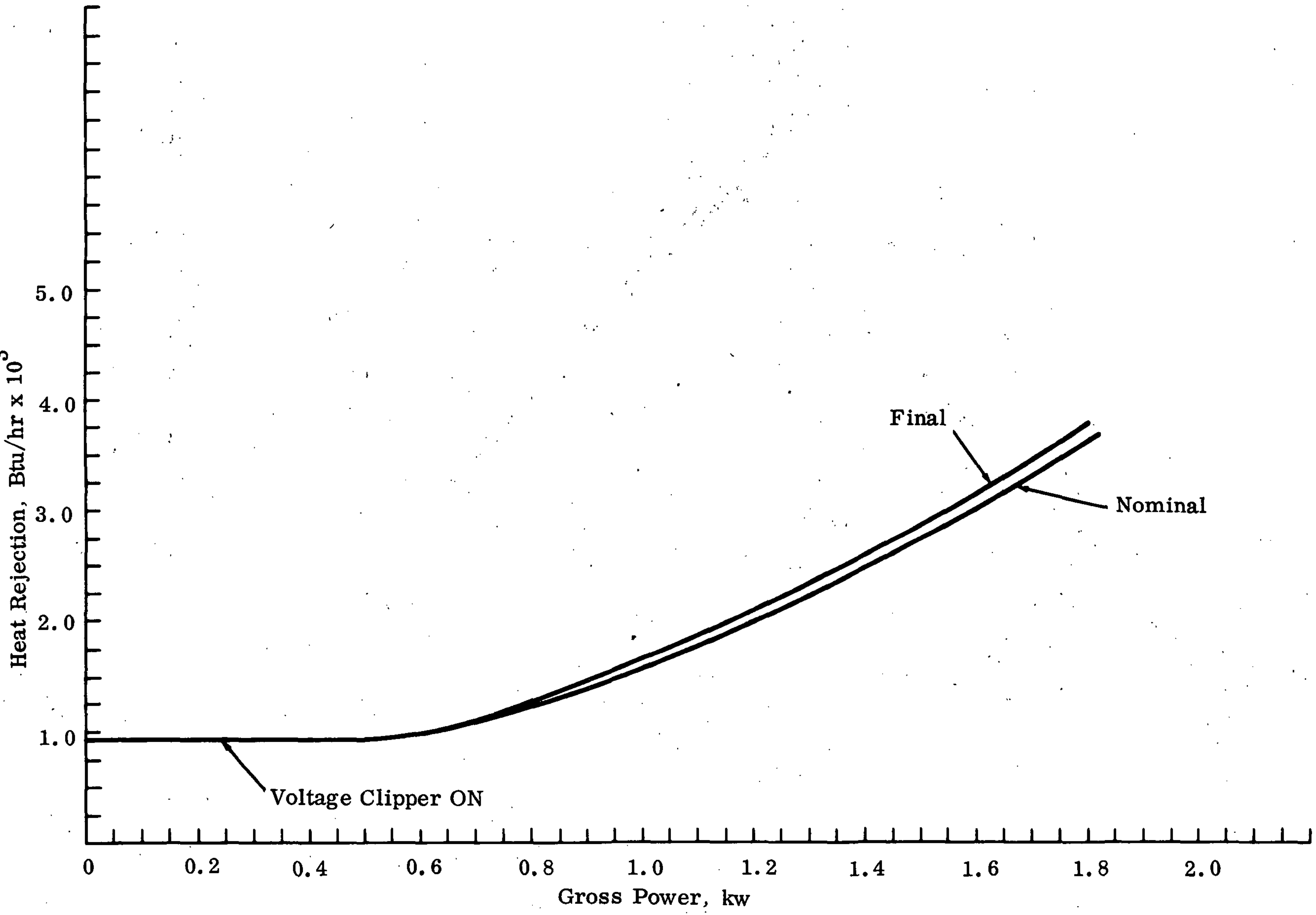


Fig. 5.1-10 Heat Rejection - P&W FCA

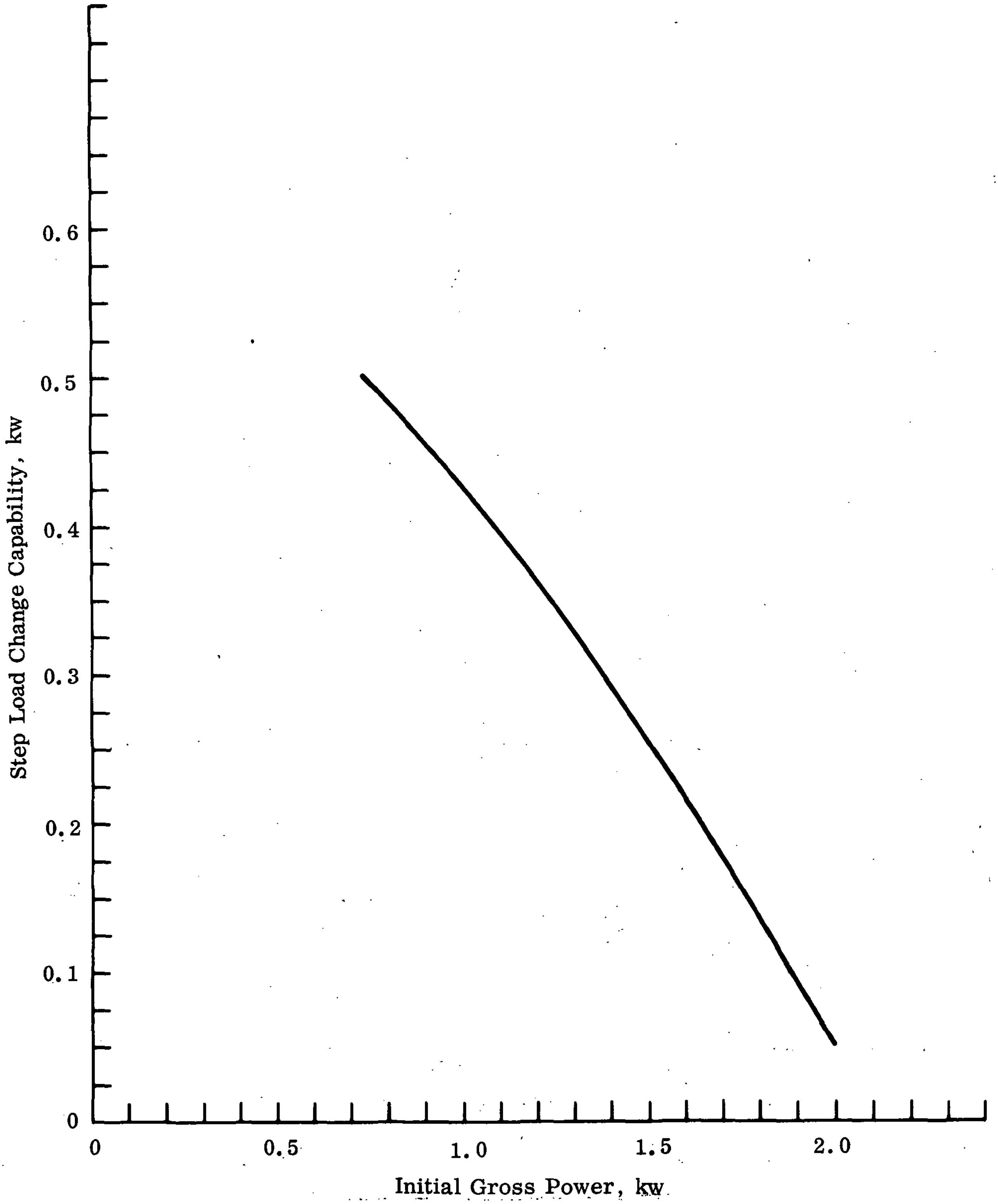


Fig. 5.1-11 Step Load Capability - P&W FCA

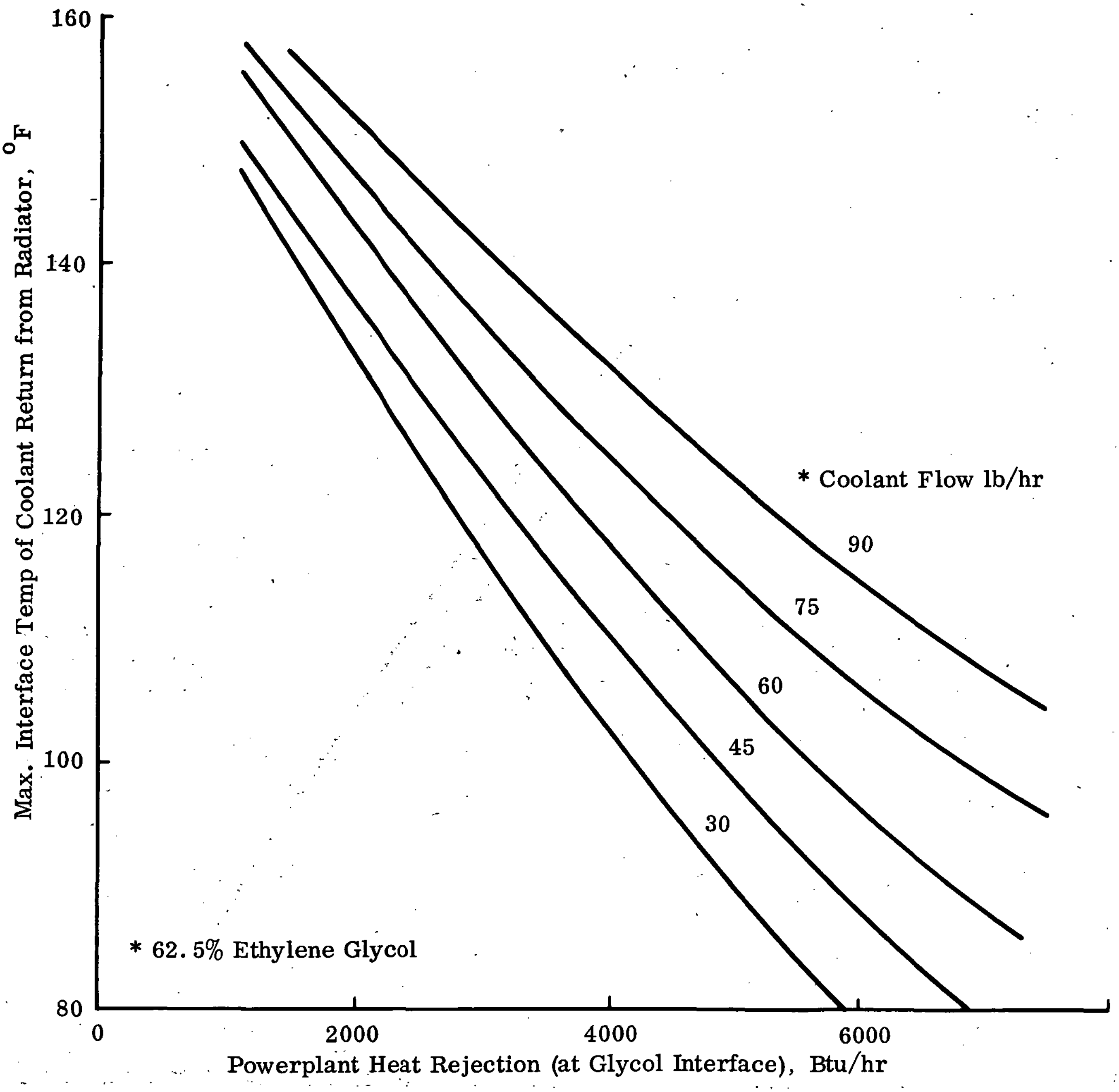
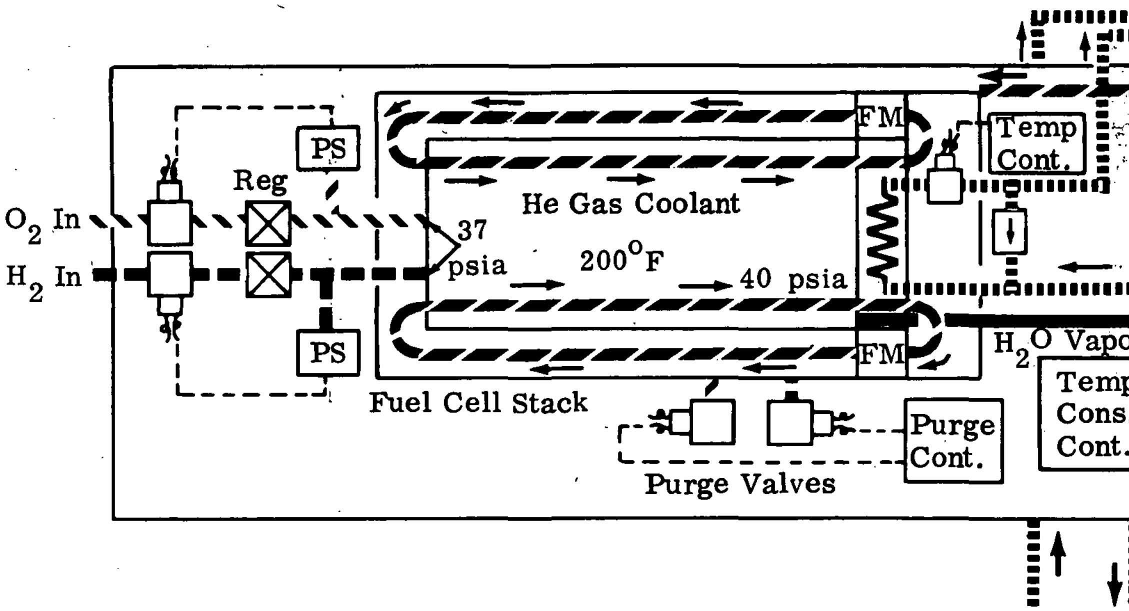


Fig. 5.1-12 Estimated Secondary Cooling Loop Characteristics - P&W FCA

⑥


O$_2$ In
H$_2$ In
PS
Reg
PS
37 psia
He Gas Coolant
200°F
40 psia
FM
FM
Temp Cont.
H$_2$O Vapo
Temp
Cons
Cont.
Fuel Cell Stack
Purge Valves
Purge Cont.

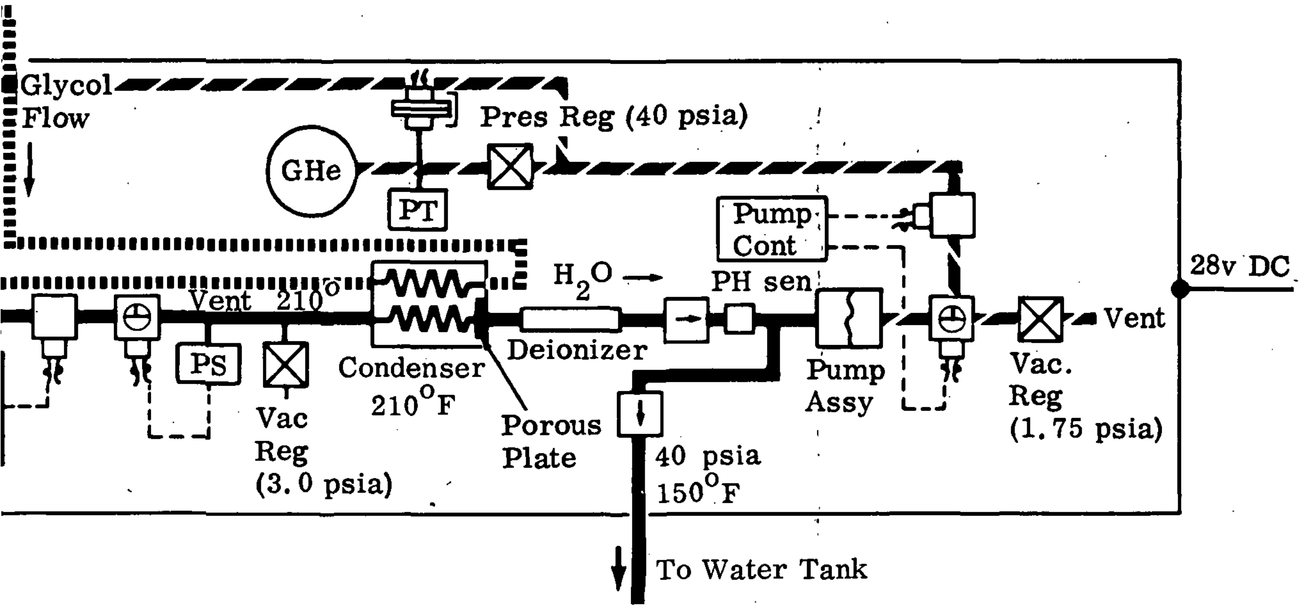


Fig. 5.1-13 A-C Fuel Cell Assembly

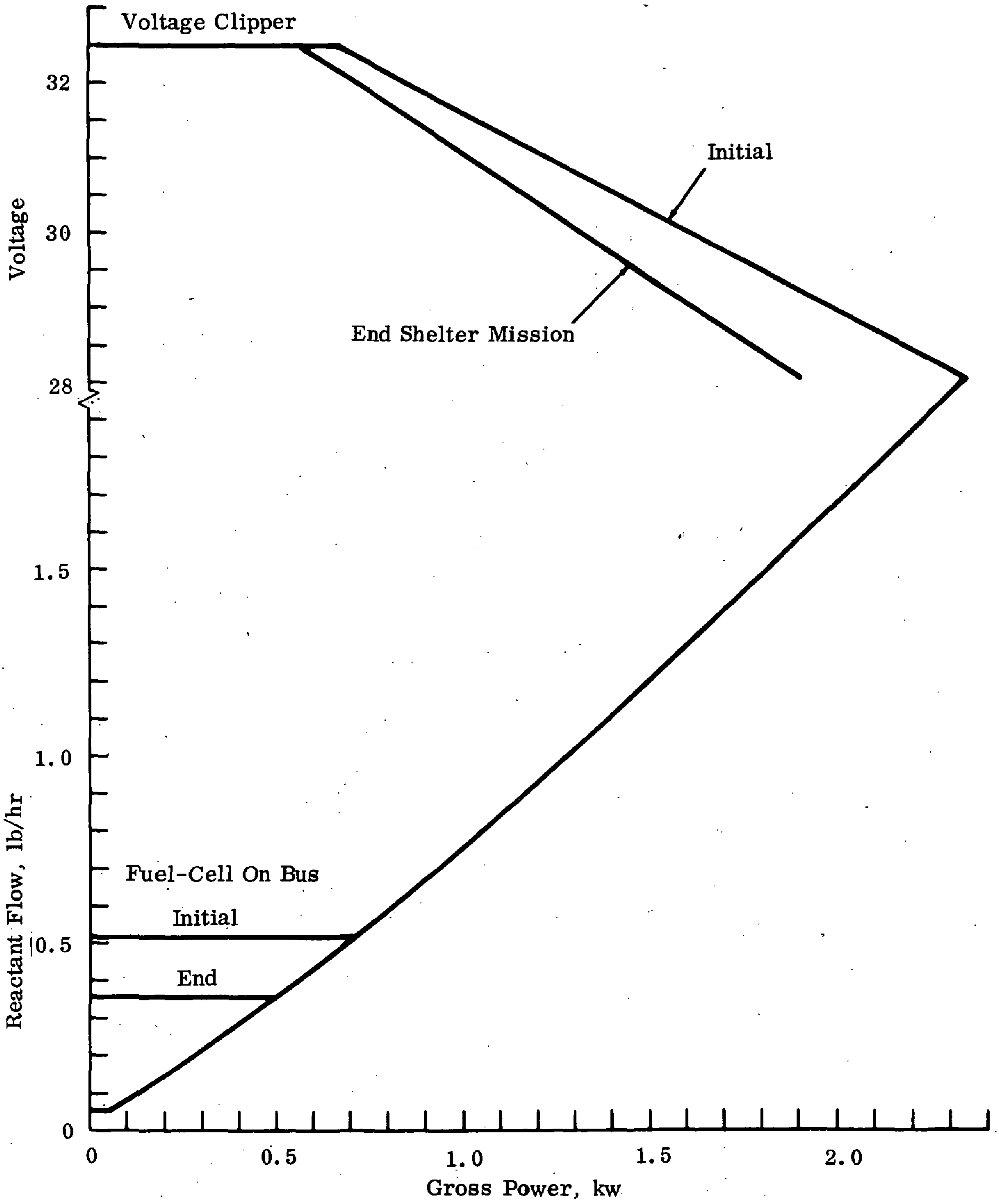


Fig. 5.1-14 Polarization & Reactant Flow - A-C FCA

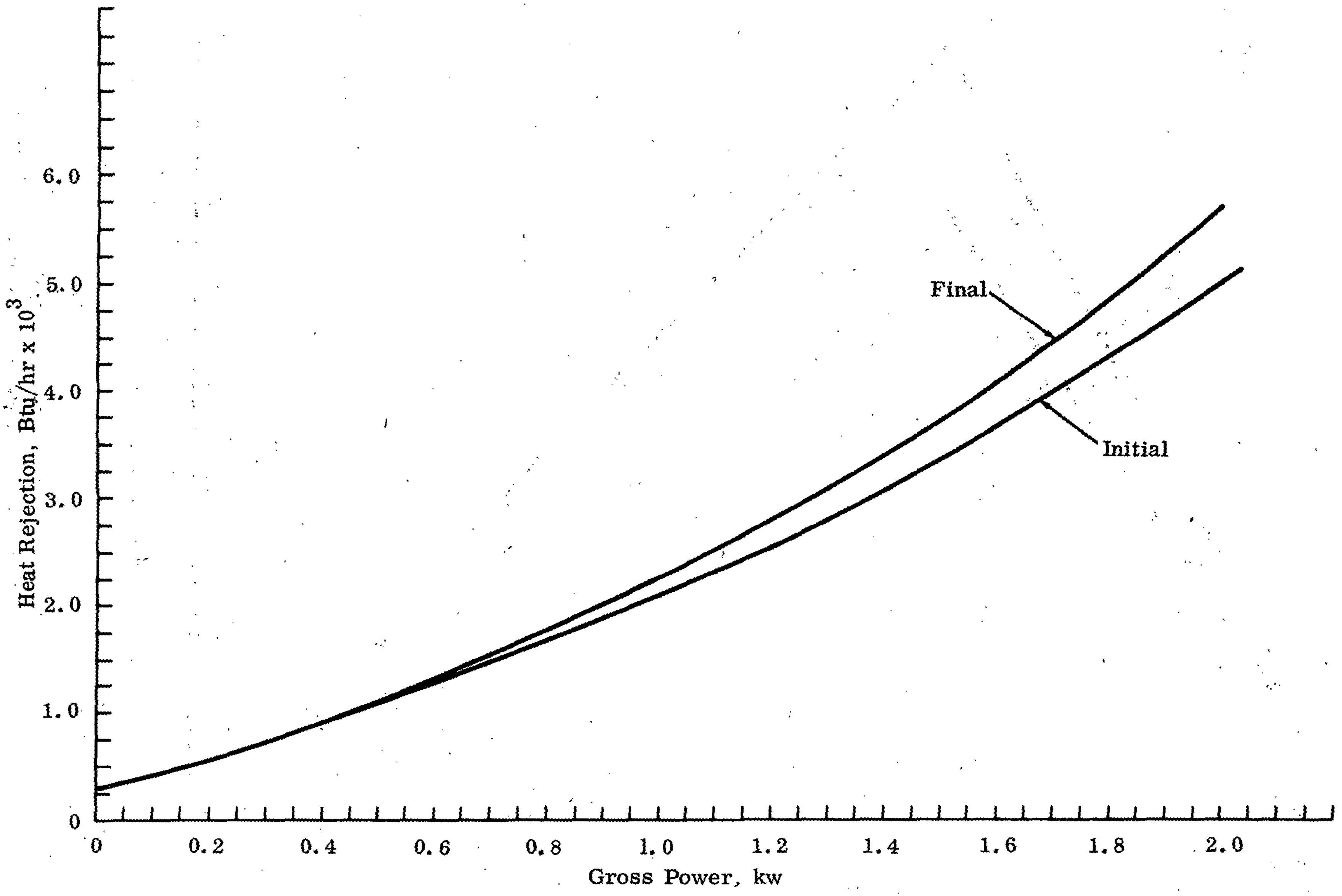


Fig. 5.1-15 Heat Rejection - AC FCA

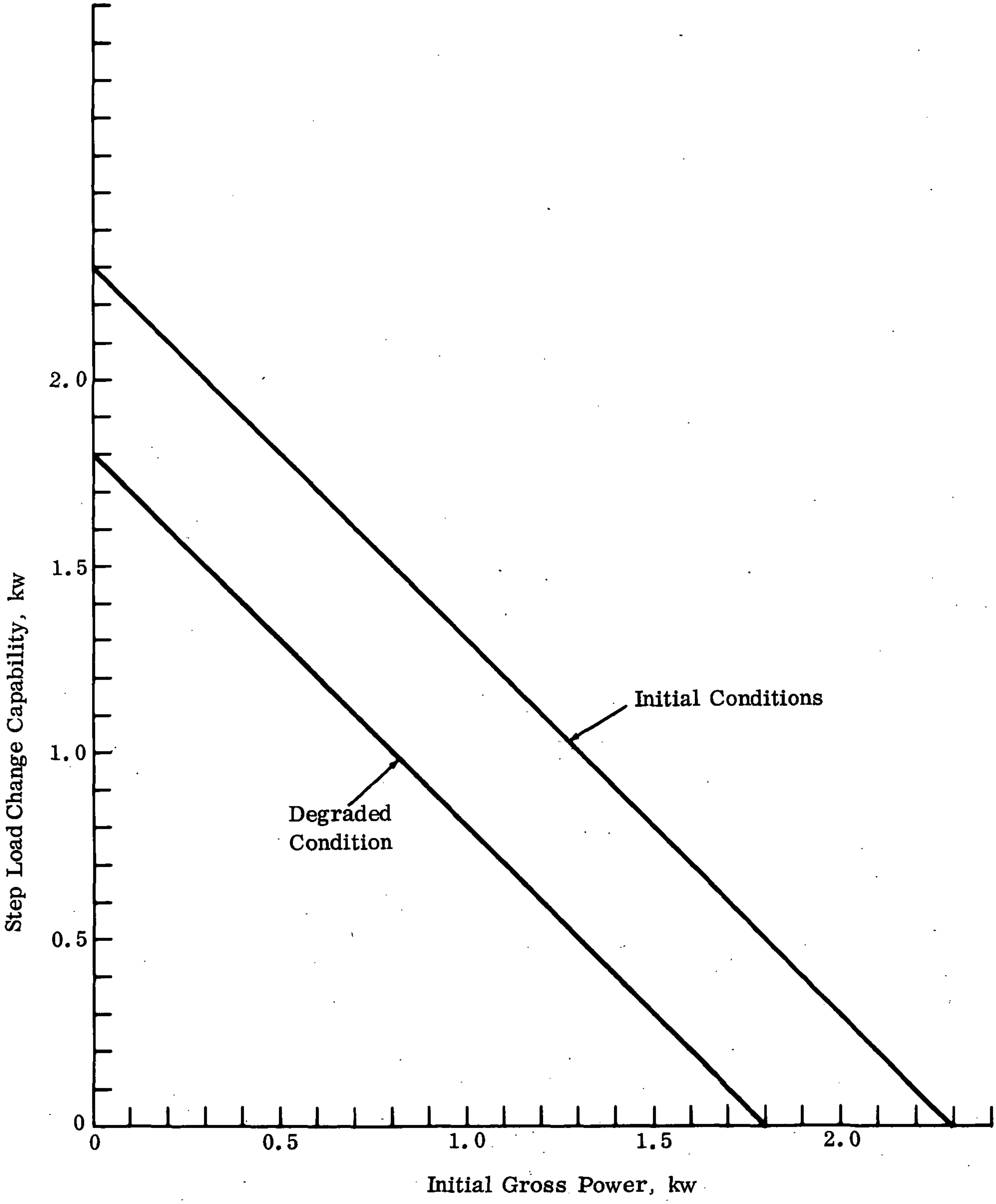


Fig. 5.1-16 Step Load Capability - AC FCA

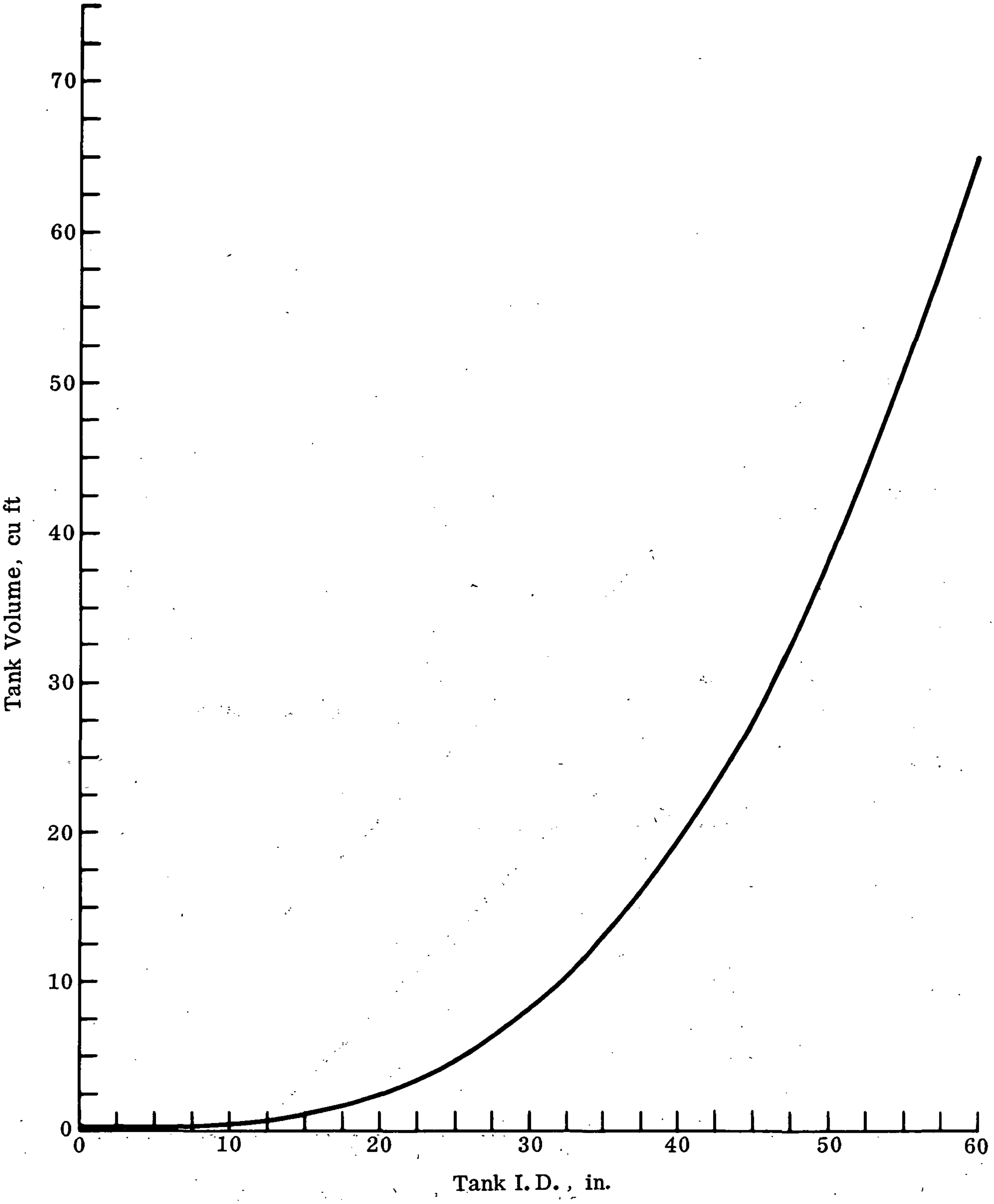


Fig. 5.1-17 Spherical Volume/Diameter Relationship

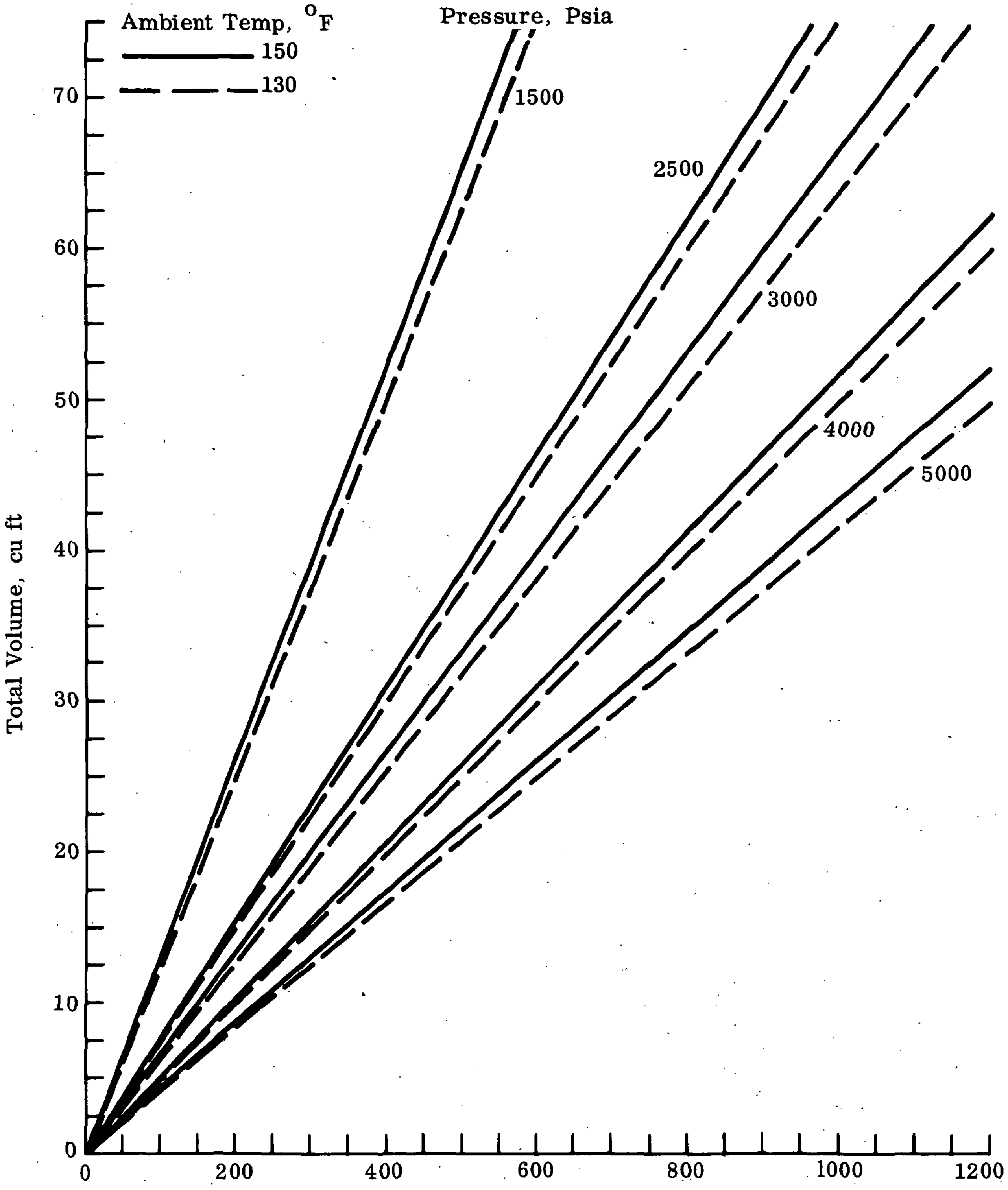


Fig. 5.1-18 Oxygen Ambient Storage Tank Capacity

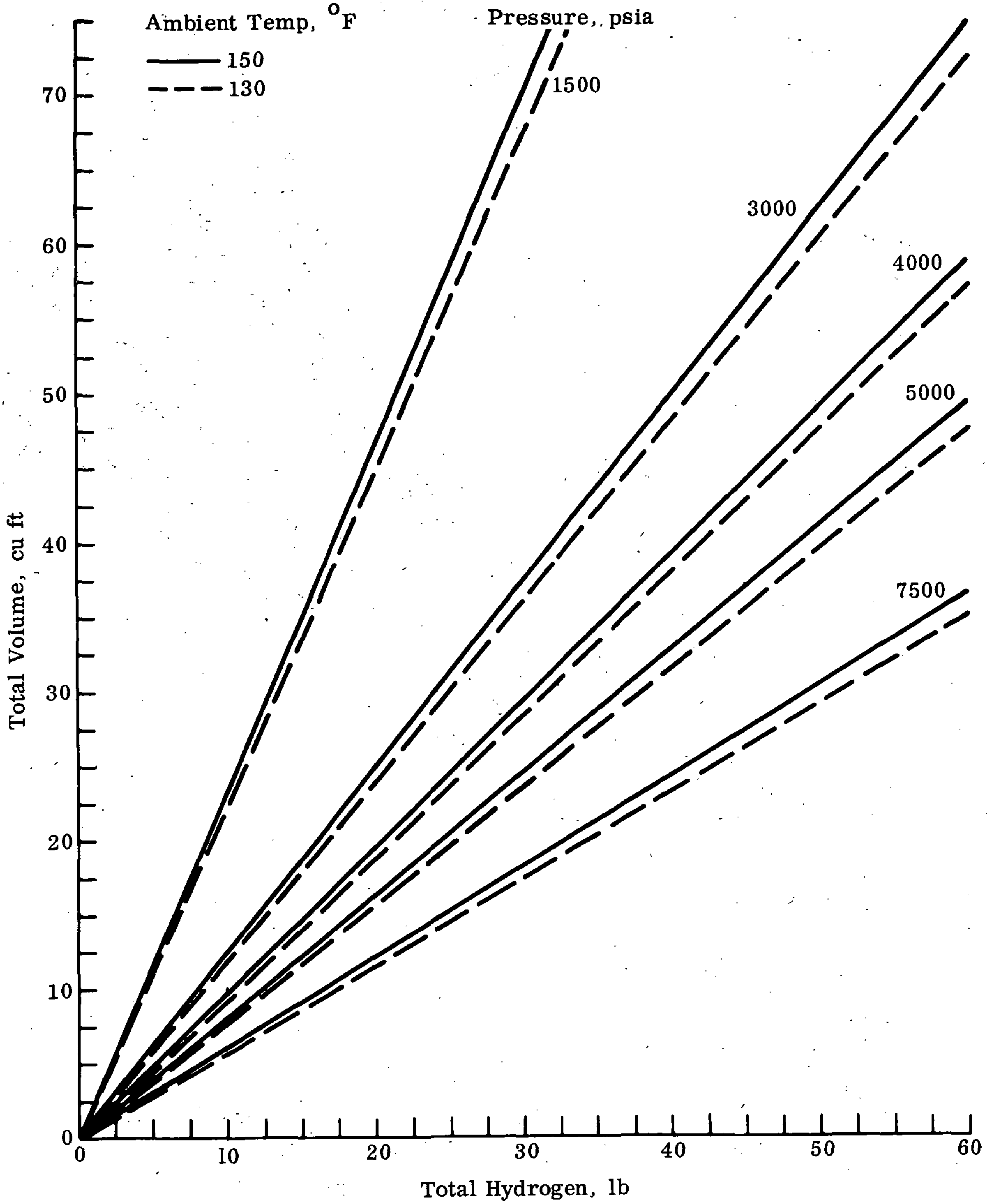
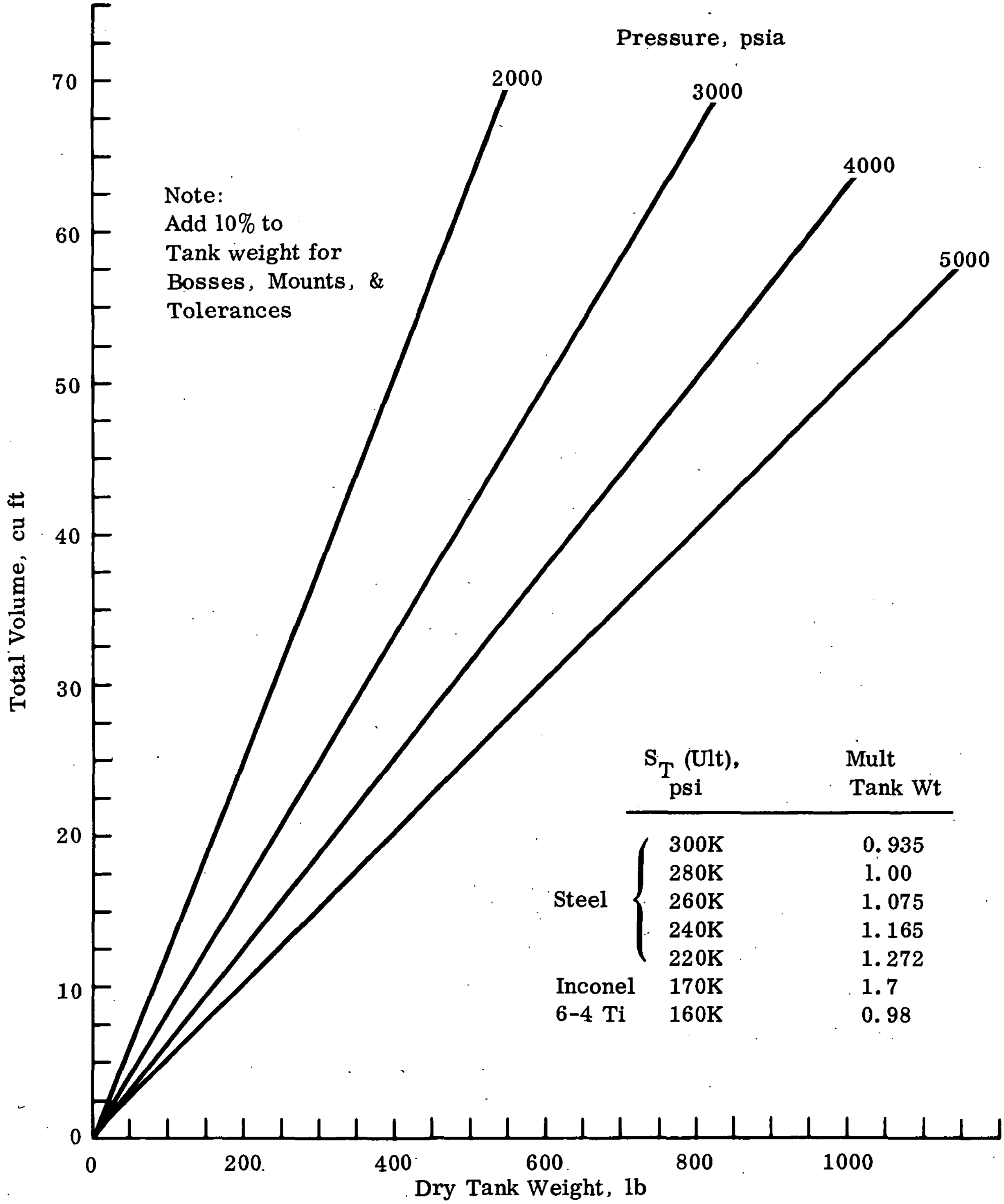


Fig. 5.1-19 Hydrogen Ambient Storage Tank Capacity



Note:
Add 10% to
Tank weight for
Bosses, Mounts, &
Tolerances

	S_T (Ult), psi	Mult Tank Wt
Steel	300K	0.935
	280K	1.00
	260K	1.075
	240K	1.165
	220K	1.272
Inconel	170K	1.7
6-4 Ti	160K	0.98

Fig. 5.1-20 Dry Tank Weight/Volume/Pressure Relationship

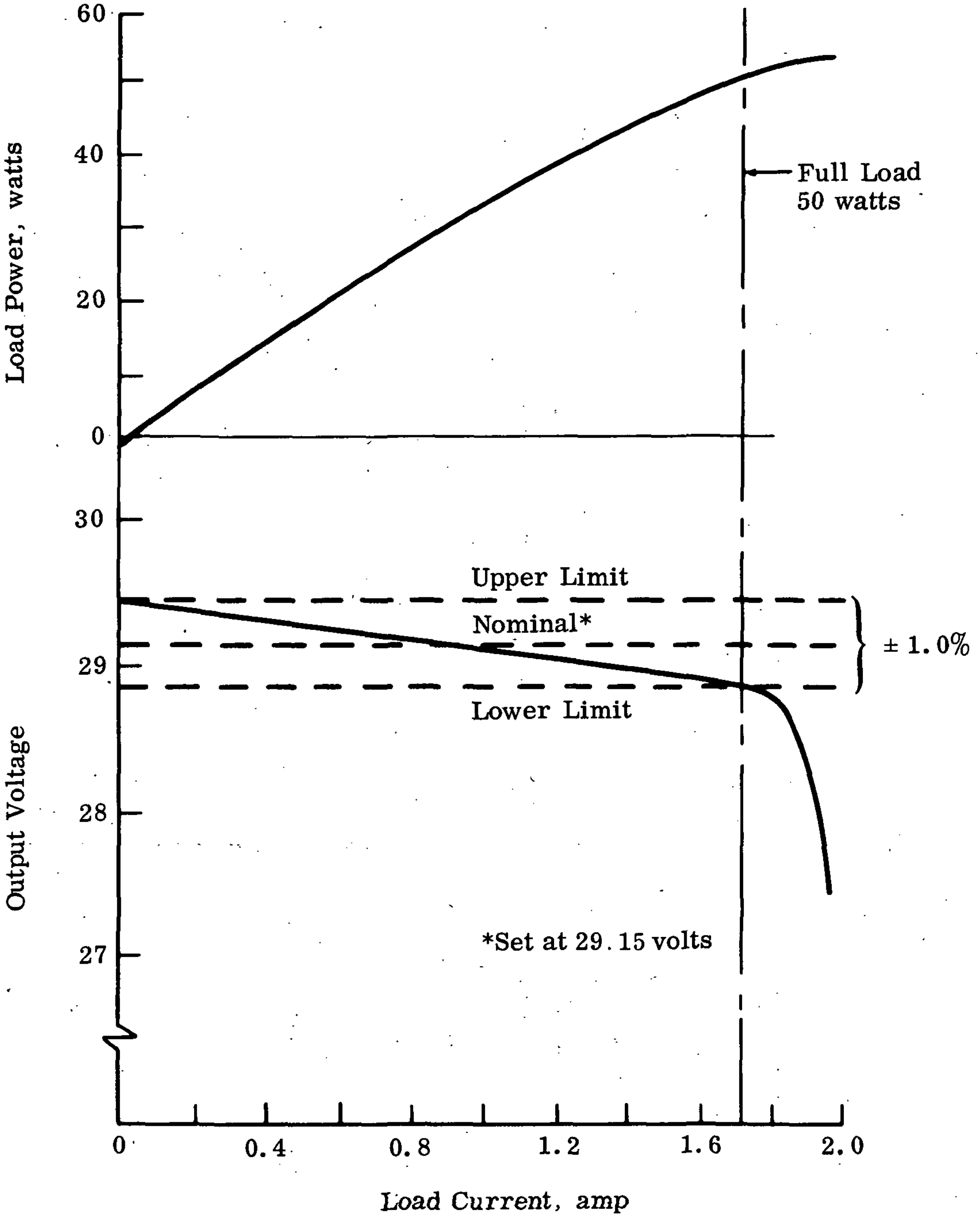


Fig. 5.1-21 RTG Performance

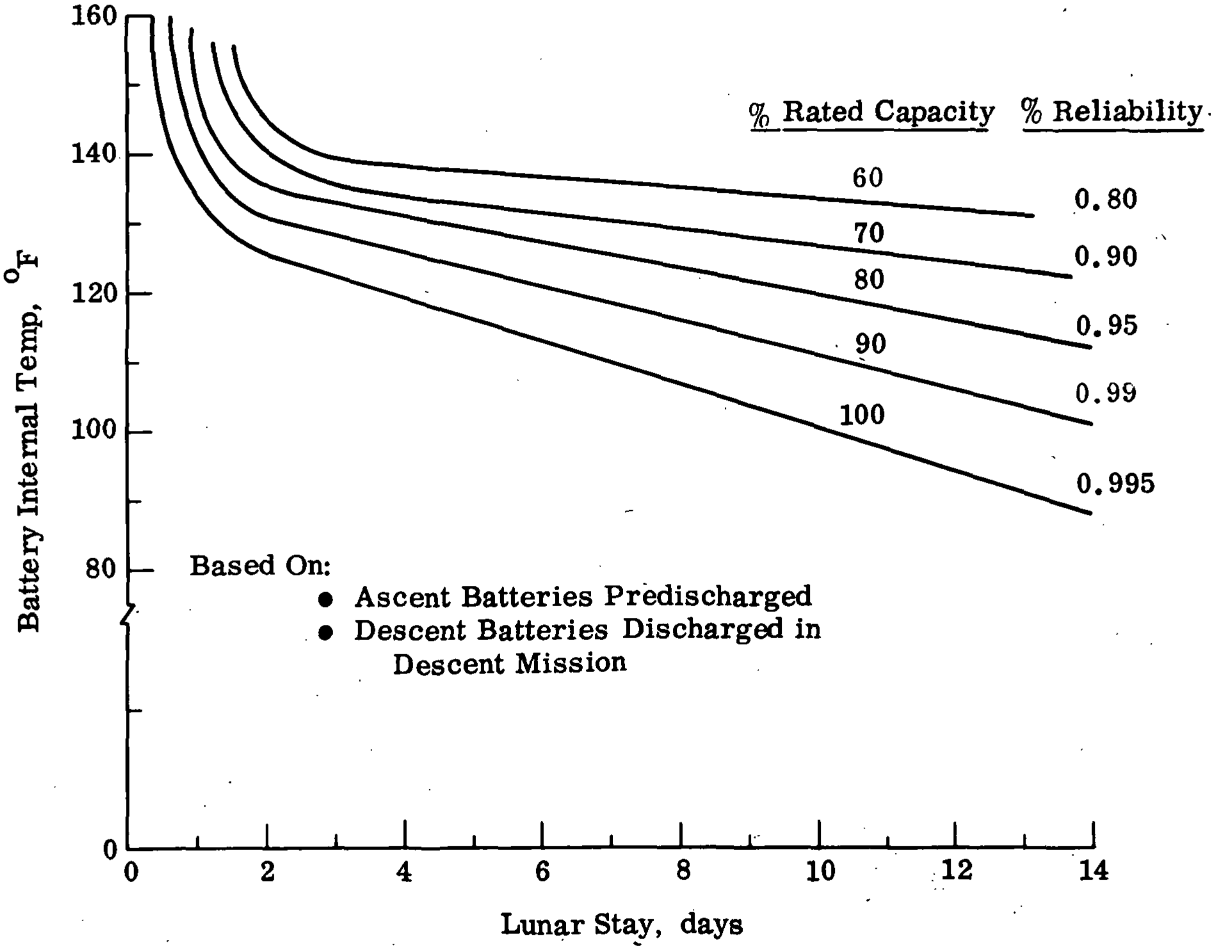
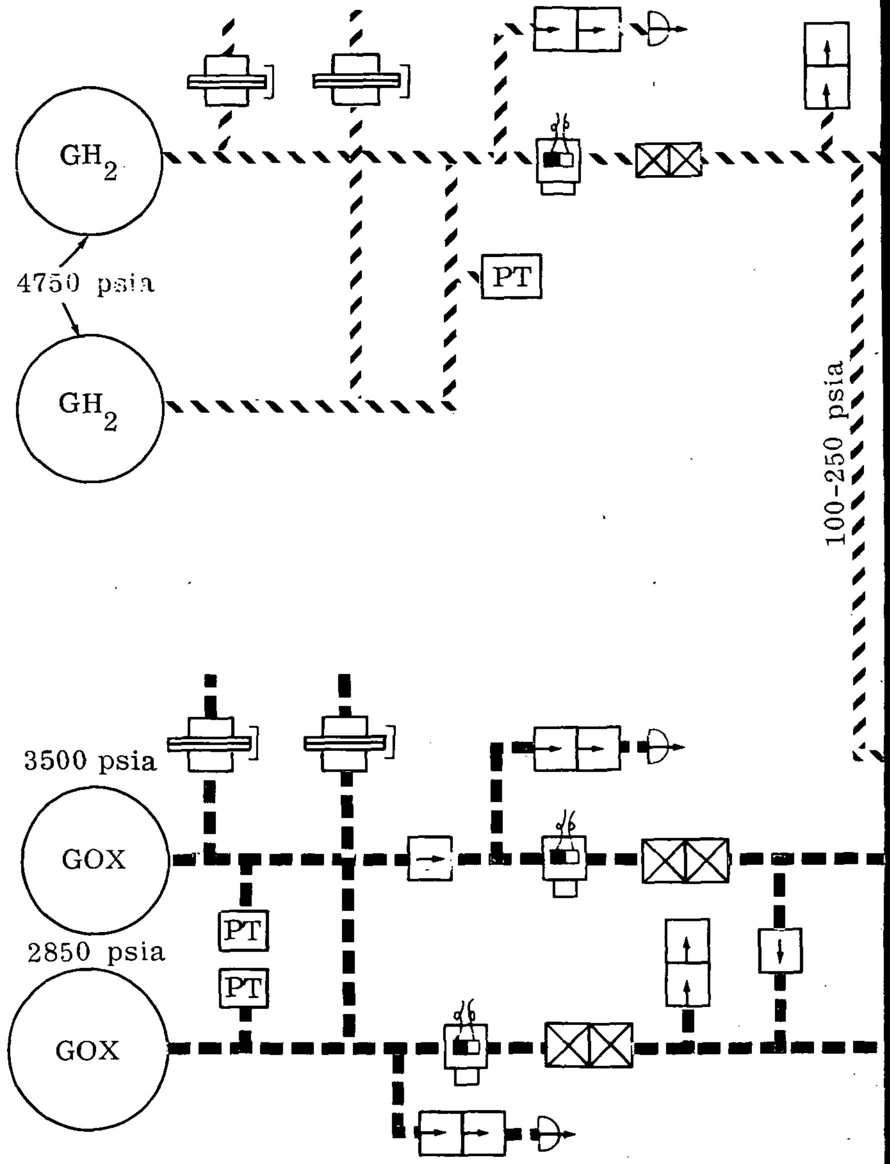
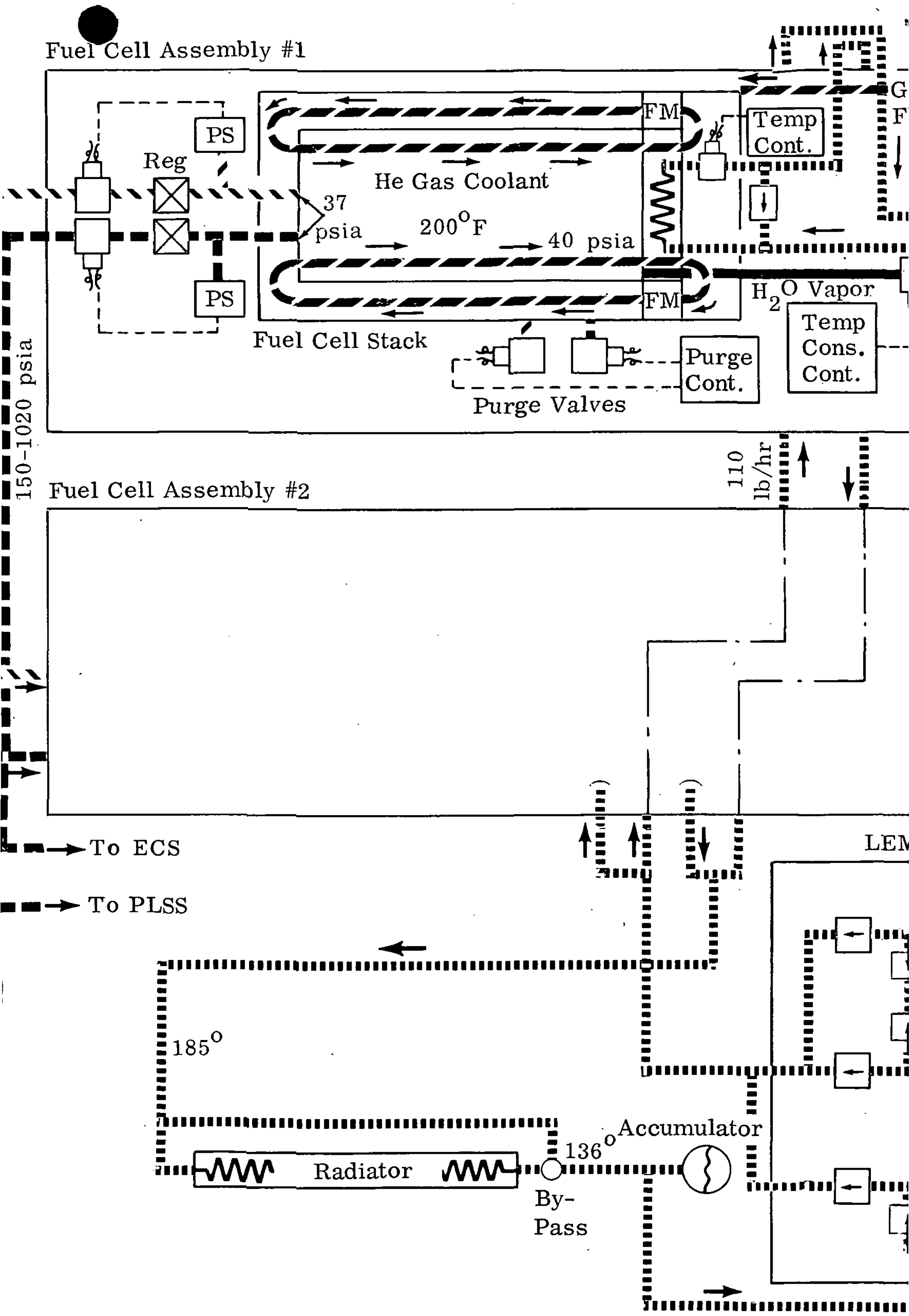


Fig. 5.1-22 Silver Zinc Battery Life

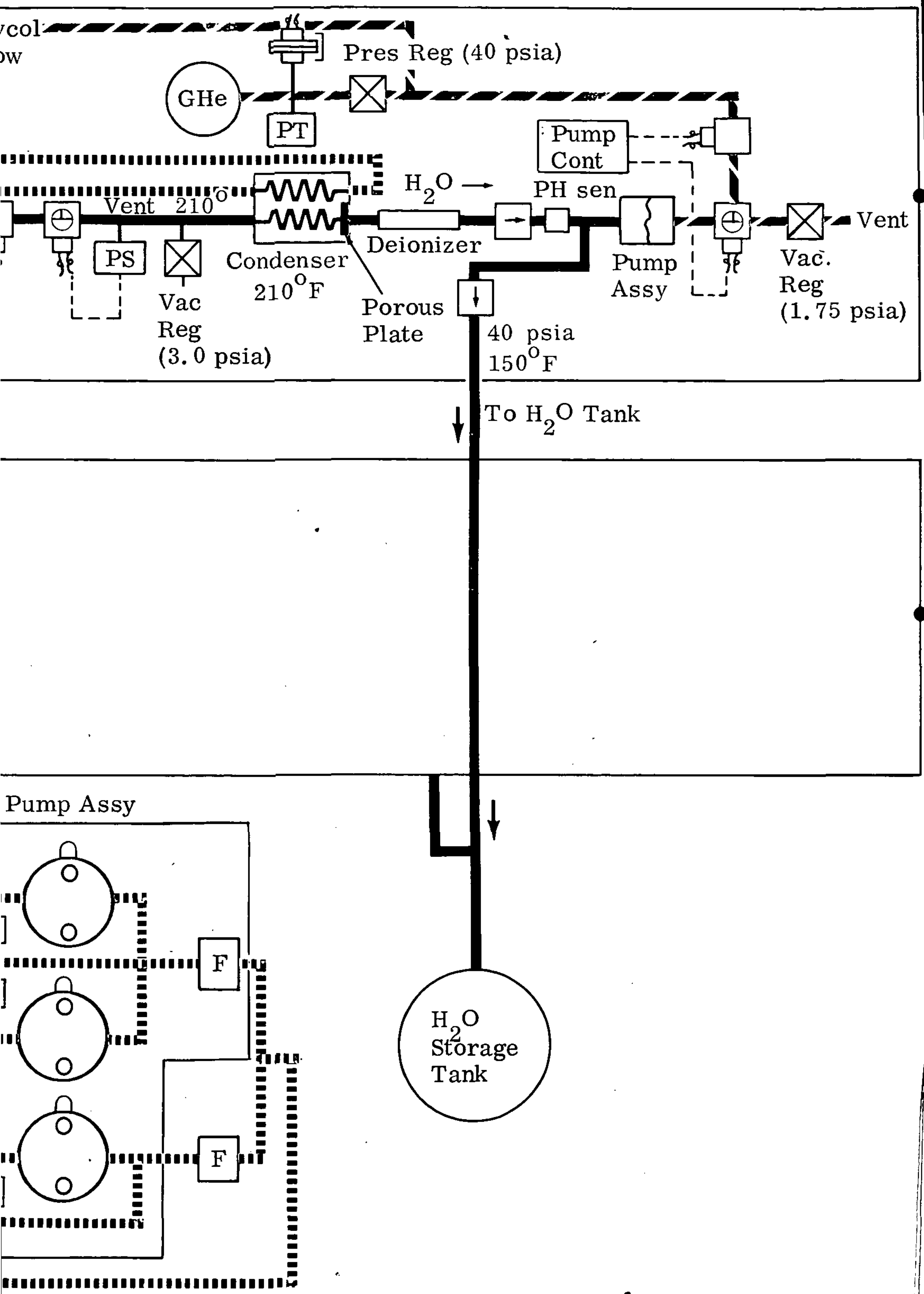

GH$_2$
4750 psia
GH$_2$
PT
100-250 psia
3500 psia
GOX
2850 psia
PT
PT
GOX

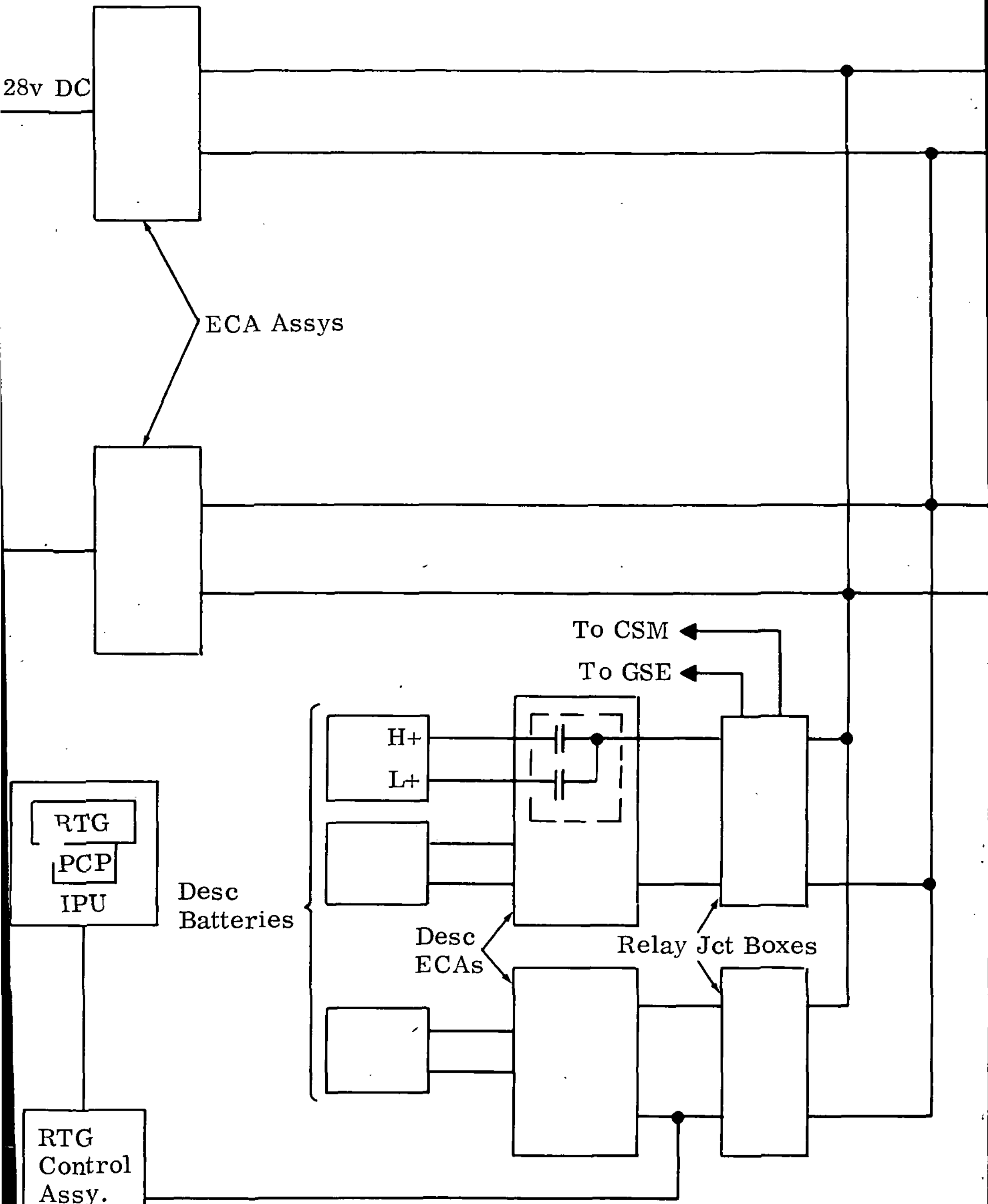
5,1-23 ①


Fuel Cell Assembly #1
PS
Reg
PS
FM
He Gas Coolant
37 psia
$200^{o}F$
40 psia
FM
Temp Cont.
H_2O Vapor
Temp Cons. Cont.
Fuel Cell Stack
Purge Valves
Purge Cont.
150-1020 psia
110 lb/hr
Fuel Cell Assembly #2
To ECS
To PLSS
185^{o}
136^{o}
Accumulator
Radiator
By-Pass

51-23

②


ycol
ow
Pres Reg (40 psia)
GHe
PT
Pump Cont
H_2O →
PH sen
Vent 210°
Condenser 210°F
Deionizer
Porous Plate
Vac Reg (3.0 psia)
PS
Pump Assy
Vac. Reg (1.75 psia)
Vent
40 psia 150°F
To H_2O Tank
Pump Assy
F
F
H_2O Storage Tank


28v DC
ECA Assys
To CSM
To GSE
H+
L+
RTG
PCP
IPU
Desc
Batteries
Desc
ECAs
Relay Jct Boxes
RTG
Control
Assy.

5.1-23

④

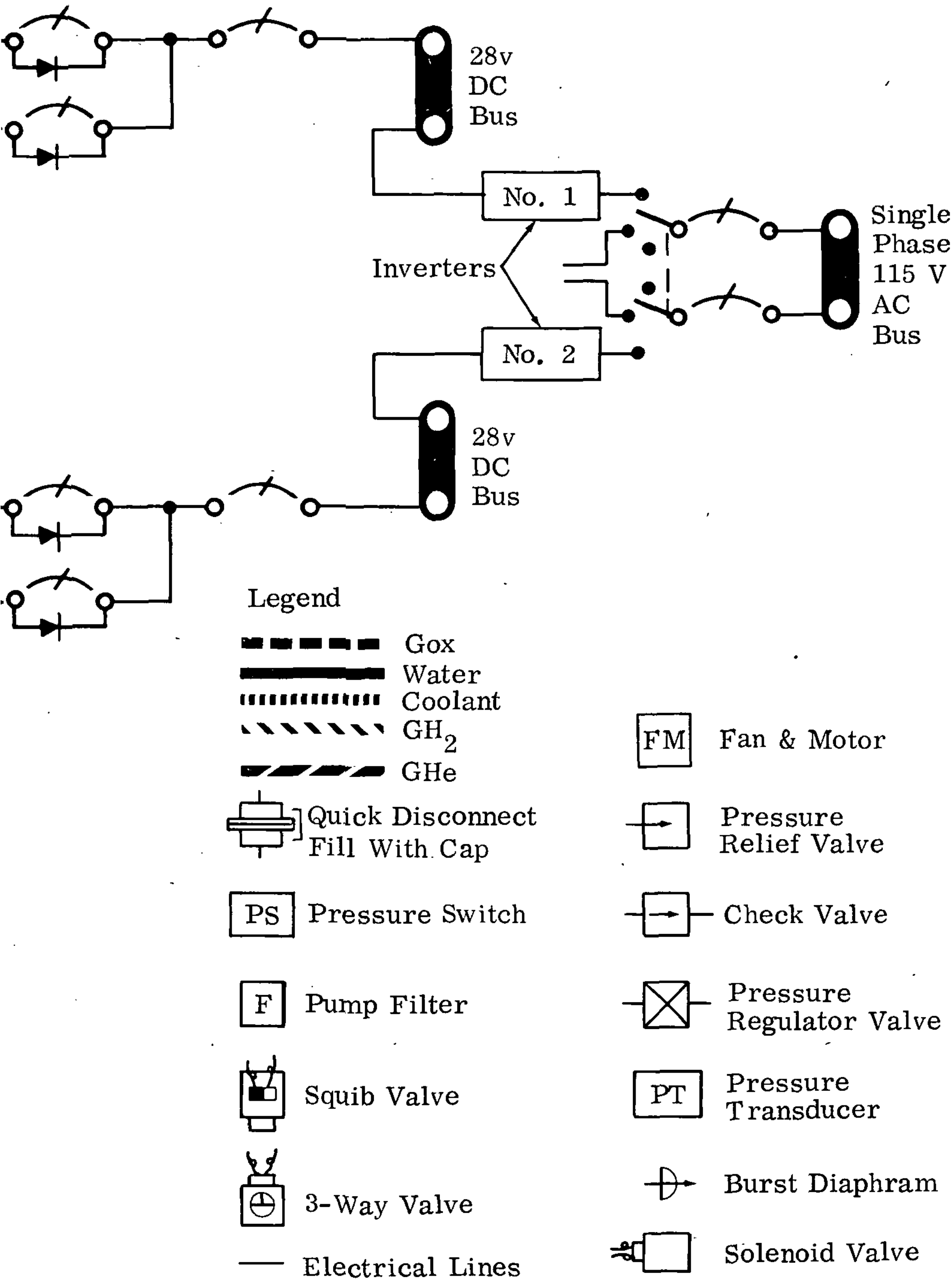


Fig. 5.1-23 Shelter Electrical Power Subsystem

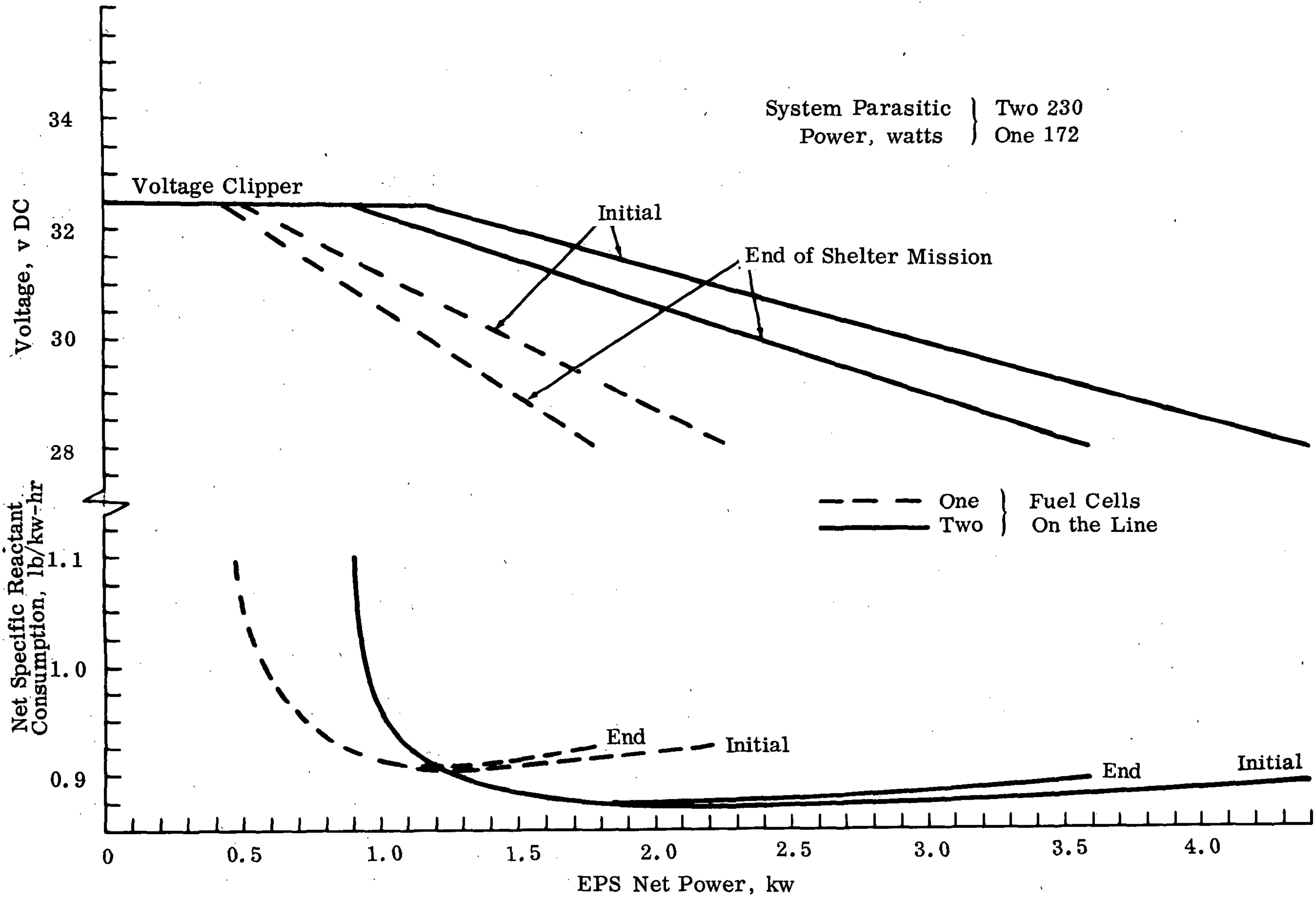


Fig. 5.1-24 AC FCA System Performance

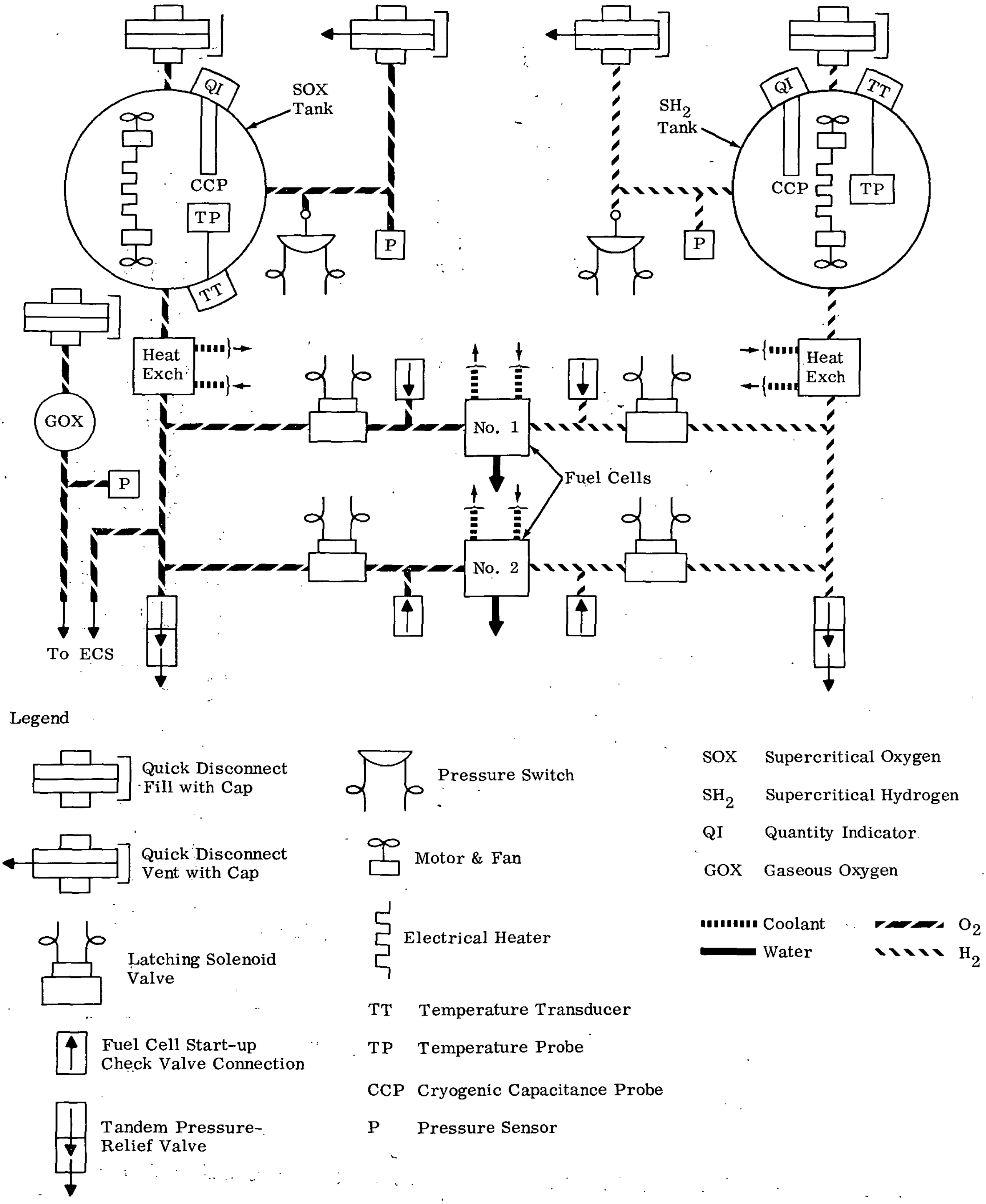
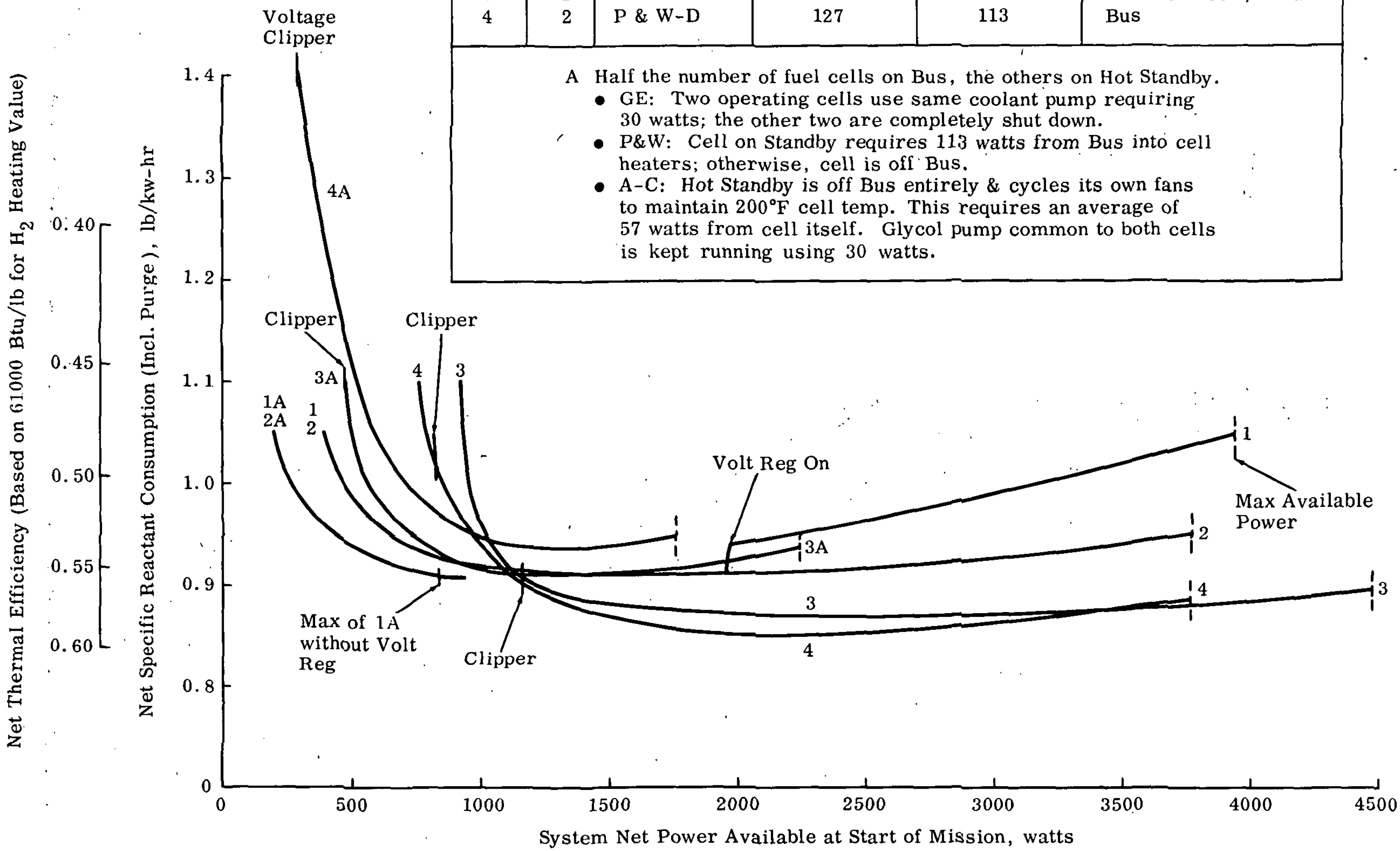


Fig. 5.1-25 Shelter Cryogenic Storage EPS Configuration

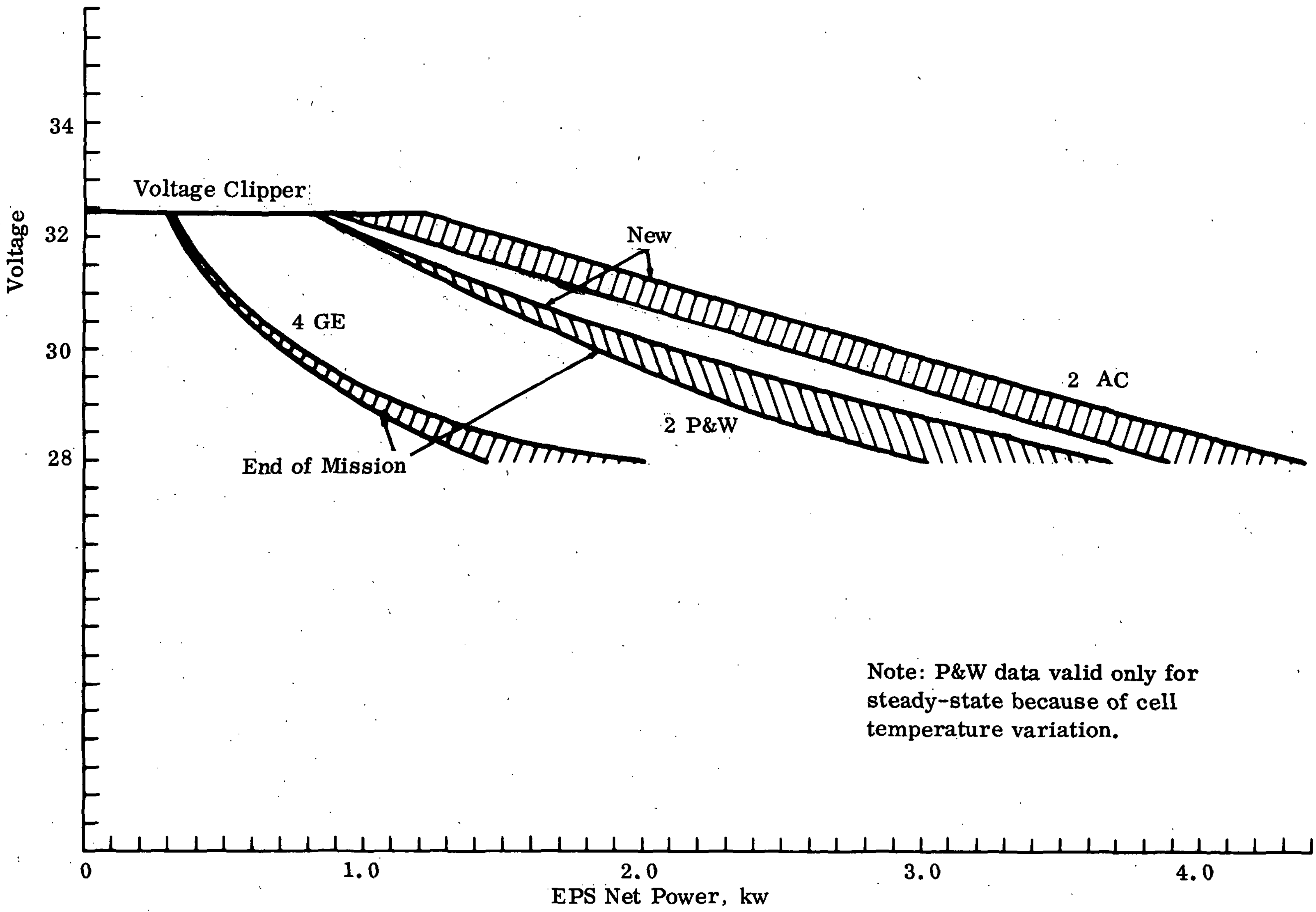


Curve No.	No. Cells	Cell Type	Parasitic Pwr/Cell, watts		
			Operation	Hot Standby	Source
1	4	GE, 32VR	15	0	Bus
2	4	GE 34 Cells	15	0	Bus
3	2	A-C 33	115	57	100 from cell, 15 Bus
4	2	P & W-D	127	113	Bus

A Half the number of fuel cells on Bus, the others on Hot Standby.

- GE: Two operating cells use same coolant pump requiring 30 watts; the other two are completely shut down.
- P&W: Cell on Standby requires 113 watts from Bus into cell heaters; otherwise, cell is off Bus.
- A-C: Hot Standby is off Bus entirely & cycles its own fans to maintain 200°F cell temp. This requires an average of 57 watts from cell itself. Glycol pump common to both cells is kept running using 30 watts.

Fig. 5.1-26 FCA Specific Reactant Consumption



Note: P&W data valid only for steady-state because of cell temperature variation.

Fig. 5.1-27 Degradation Effects on FCA Output

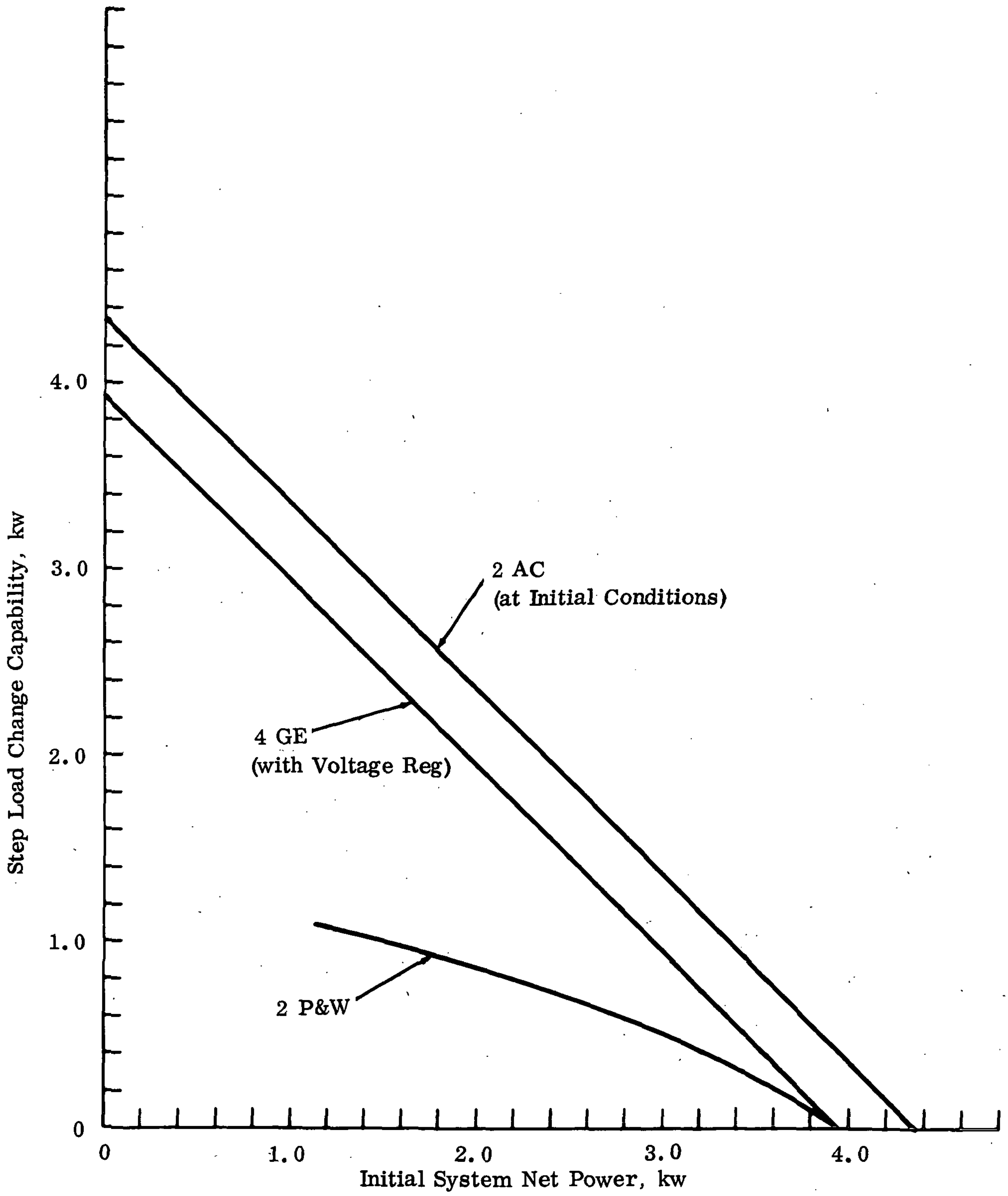


Fig. 5.1-28 FCA Step Load Capabilities

5.2 ENVIRONMENTAL CONTROL

5.2.1 Ground Rules

The following NASA ground rule is unique to the Environmental Control Subsystem (ECS):

- For normal operation, the Shelter internal atmosphere shall be maintained at 75° ± 5° F and 40 to 70% relative humidity during the manned mission.

5.2.2 Assumptions and Background Data

In establishing the functional requirements of Shelter ECS configurations, the following major assumptions have been made:

- All EVA life support is provided by Apollo PLSS which is recharged by the Shelter ECS 39 times during the manned mission phase
- Hard space suit assembly is compatible with the Apollo PLSS and the Shelter suit circuit assembly
- Cabin atmosphere losses from structural leakage and airlock operation are sufficient to preclude the necessity of integrating additional contaminant control equipment
- Electronic heat loads are those associated with the power profiles defined in Paragraph 5.1
- Heat loads imposed on the Shelter ECS by the external thermal environment are as defined in Paragraph 4.1
- No environmental control is provided for the experiment payload
- Airlock and associated support equipment will be integrated into the Shelter.

5.2.3 Recommended Configuration

An ECS capable of supporting all NASA/MSFC lunar surface missions has been developed for the recommended Shelter configuration. Differences from its LEM counterpart are characterized by the: utilization of radiator assemblies for heat rejection during manned mission phases, provisions for managing water produced by fuel cells, a capability of providing life support for extended cabin occupancy and surface exploration, and a capability for cabin and equipment thermal control during a pre-utilization standby period of up to 90 days. The Shelter ECS is synthesized almost in total from hardware developed for the LEM Program. In those instances where this has proved either impractical or unfeasible, the CSM and Gemini subsystems have been scrutinized for appropriate components. Only when these sources have been exhausted have new components been recommended.

The following paragraphs describe the recommended ECS configuration with emphasis on the manner in which it differs from its LEM counterpart. A portion of the component and subsystem performance data presented has been provided by the Hamilton Standard Division of the United Aircraft Corporation as part of a funded Phase B Study subcontract.

5.2.3.1 Atmosphere Revitalization Section

The Atmosphere Revitalization Section (ARS) recommended for the Shelter consists of a slightly modified LEM suit circuit assembly and the LEM atmosphere recirculation assembly, and performs the following functions:

- Ventilates the space suit assemblies during suited operations
- Controls the carbon dioxide level in the atmosphere
- Removes excess water vapor, odor, and particulate matter from the Shelter atmosphere
- Provides temperature control of the gas delivered to the space suit and of the Shelter atmosphere
- Provides control of the gas flow through the space suits and circulation of the Shelter atmosphere

The functional and operational requirements of the suit circuit assembly are identical to those of the current LEM, except for the addition of a third suit connector station located in the airlock. This station is plumbed in parallel with the two cabin stations and consists of an additional suit umbilical hose assembly and suit supply crossover valve.

The atmosphere recirculation assembly provides for ventilation and temperature control in the Shelter cabin. It consists of two cabin fans and a coolant-to-oxygen heat exchanger equipped with wicking material for the collection and re-evaporation of condensate. This assembly is retained intact and will remove a portion of the heat loads introduced into the cabin atmosphere by Shelter structure, equipment and occupants.

The Shelter ARS is shown schematically in Fig. 5.2-1. Thirty-nine PLSS LiOH canisters and 14 suit circuit LiOH canisters are required for the EVA and cabin support capability of the recommended Shelter configuration. The characteristics of regenerable carbon dioxide removal equipment utilizing solid adsorbents were defined and compared to the retention of LEM LiOH canisters during the Phase A Study effort. Since a significant portion of the Shelter mission is devoted to EVA, regenerable adsorbents do not provide the weight advantages that might be expected for a 14-day mission (approximate maximum of 15 lb.). As a result, LiOH is recommended for the Shelter missions considered to date.

5.2.3.2 Heat Transport Section

The Heat Transport Section (HTS) recommended for the Shelter has the following functional capabilities:

- Active thermal control of the Shelter electronic equipment during mission phases as follows:
    - o Continuous operation from pre-separation checkout through postlanding checkout to cool N&G equipment, landing radar electronics, etc
    - o Periodic operation during standby storage to minimize vehicle thermal gradients
    - o Continuous operation during the 7-day pre-utilization period to cool electronic equipment associated with the various subsystems being checked out
    - o Continuous operation during the manned phase to cool all electronics associated with the Shelter housekeeping functions.

- Cooling or heating as required to maintain cabin temperature within predetermined limits during the manned phase
- Sensible and latent cooling or heating as required of ARS oxygen during suited operation
- Heating the Shelter during night standby storage by the controlled distribution of Radioisotope Thermoelectric Generator (RTG) waste heat
- Waste heat rejection during the pre-separation through post-landing checkout phases and the pre-utilization phase, exclusively by water evaporation
- Waste heat rejection during the manned phase by space radiators supplemented by water evaporation.

The recommended Shelter HTS configuration, shown schematically in Fig. 5.2-2 differs from the LEM HTS in the following areas:

- Coolant pump has been modified to provide for higher performance during manned phases
- Radiators and associated control hardware have been added to reject most of the Shelter waste heat during the manned phase
- RTG heat utilization equipment has been added to provide heating during night quiescent storage
- Secondary heat transport loop has been deleted, since it services only that equipment which is critical in a LEM mission abort mode
- Battery water evaporator has been deleted because of the incorporation of radiators and fuel cells
- Low-temperature cold plate network has been rearranged to allow for the deletion and addition of equipment
- Incorporation of radiators required the coolant mixture to be changed to 62.5% glycol and 37.5% water
- Descent battery cold plates have been replumbed such that they are now located upstream of the high-temperature cold plates since the battery water evaporator has been deleted.

5.2.3.2.1 Radiator Integration. It is recommended that radiators be used as the primary means of rejecting heat during the manned phases of the Shelter mission. As described in Paragraph 6.1, the recommended configuration consists of four panels located on top of the ascent stage having a total surface area of approximately 75 sq ft. The panels will be plumbed in a series-parallel arrangement as shown in Fig. 5.2-2. Each panel will be designed to provide a capability to reduce its heat rejection ability by means of selective tube stagnation; i.e., as the thermal load is reduced, successive flow paths in the radiator stagnate. The thermodynamics of this and other control techniques are described in Paragraph 4.1. To insure that the coolant entering the low-temperature cold plate network is above minimum allowable temperatures during low load conditions, a regenerative heat exchanger (identical to LEM) has been added upstream of the radiator. The fluid from the HTS first enters the regenerative heat exchanger and then flows to the radiator panels. Part of the flow leaving the radiators is diverted back to the regenerative heat exchanger by a modulating valve. This component is identical to the LEM cabin temperature control valve except that the sensor has a lower temperature setting. The valve senses and controls the mixed temperature of regenerated and bypassed fluids. During maximum load conditions, the modulating valve will bypass full flow around the regenerator, and the water evaporator will provide cooling to handle peak loads. During the manned phase, the water evaporator will remain inoperative for all but peak load conditions.

Prior to the manned phase, the radiator panels are in an inoperative state and are covered by a protective shield to insure that they will survive the lunar surface environment. During night standby storage, the coolant in the radiators will be allowed to freeze. Heaters have been added to thaw the panels at the initiation of Shelter activation. Approximately 100 w will be provided to these strip heaters on the maximum flow tube of each radiator panel. Once this flow passage has been thawed, the electrical heaters will be de-energized and the recirculating coolant will supply the heat required to thaw the remaining radiator passages. Since the radiator will operate at reduced performance during this period, the water evaporator will provide supplementary heat rejection.

The coolant loop must be capable of being periodically operated during standby storage to minimize thermal gradients within the Shelter. To provide this capability, a manual bypass valve has been added to the loop to bypass the radiators which may be frozen. This valve will remain in the bypass position until the Shelter is activated.

5.2.3.2.2 Equipment Cooling. The deletion of various electronic assemblies from the basic LEM configuration makes approximately 95 linear in. of aft bay coldrails available for thermal control of experiment payload; this constitutes a cooling capacity of 425-w. During the flight phases of the Shelter mission, the coolant low-temperature requirement is dictated by the Navigation and Guidance electronics; and during the manned phase it is dictated by suit circuit and cabin heat exchanger needs. It is therefore recommended that experiment thermal loads, except those requiring low-temperature (40 to 60°F) cooling, be integrated into the coolant loop downstream of the cabin heat exchanger, such that the coolant low-temperature requirement may be maintained at its highest allowable level. This will maximize the heat rejection capability of the radiators.

Table 5.2-1 lists the maximum and minimum heat loads of housekeeping equipment and cabin structure. As shown in Fig. 5.2-3, at the minimum load condition, the coolant temperature control valve bypasses full flow through the regenerative heat exchanger to boost the temperature of the coolant at the radiator outlet from -31 to 42°F. Regeneration is also required downstream of the low-temperature electronics to provide coolant to the cabin heat exchanger at a high enough temperature to maintain the cabin above 70°F. Since heat rejection is handled by the radiators for all but the peak load condition, the supply valve to the water evaporator is shut off, and the water evaporator heat rejection is then zero.

The maximum load condition is shown on Fig. 5.2-4. This condition assumes maximum housekeeping and radiator performance associated with a sub-solar external environment (sun directly overhead of the Shelter). At this condition, the heat rejection of the radiator is 1150 btu/hr; therefore, 4050 btu/hr of the total load must be rejected by water evaporation. The total water requirements for ECS thermal cooling for the Shelter are summarized in Paragraph 5.2.3.3.

The loads used in the performance analysis of Fig. 5.2-3 and 5.2-4 reflect maximum and minimum instantaneous values, respectively, while the Shelter water requirements were determined using the average load analysis discussed in Paragraph 4.1.

5.2.3.2.3 RTG Heat Utilization. Since heat must be provided to maintain the Shelter within acceptable temperature limits during night time quiescence, Radioisotope Thermoelectric Generator (RTG) waste heat utilization equipment has been added (Fig. 5.2-5). This system is capable of transporting 500 btu/hr of RTG waste heat to the ascent stage structure, and is designed such that the Shelter will reach and maintain thermal equilibrium (at approximately 60°F) with the external environment. Distilled water is used as the heat transport fluid and operates at a temperature and pressure of 250°F and 30 psi, respectively.

The RTG heat utilization equipment operates as follows. Prior to system activation, water is stored on the condenser side of the control valve. The control valve electrically opens when sensors mounted on the ascent stage signal that structural temperatures have reached a predetermined lower limit. Water is gravity fed to the boiler, where it evaporates and rises to condensers which provide a thermal path into the ascent stage pressure shell. The steam condenses and returns to the boiler by gravity feed beginning another cycle until the Shelter temperature rises and eventually reaches equilibrium.

If the external environment changes and the maximum temperature limit of the ascent stage structure is exceeded, the valve closes. When this occurs, condensate collects above the control valve, and the temperature and pressure of steam remaining in the boiler rises. The control valve, having relief capability, eventually cracks and equalizes overall system pressure and then closes again. The system remains in a non-operating state with residue steam at 400°F on the boiler side of the control valve and the remaining fluid in condensate form on the condenser side of the valve. In the non-operating mode, the heat leak across the control valve is 7.5 btu/hr which has a negligible effect on ascent stage temperature.

The weight summary for the RTG heat utilization equipment is as follows:

Condenser	1.30
Boiler	1.12
Control valve	1.25
GSE connection	0.15
Interstage fitting	0.30
Tubing	1.13
Sensors	0.50
Controller	1.50
Insulation	1.30
Water	0.15
Total	8.70 lb

5.2.3.2.4 Recirculation Assembly. An investigation was made to determine methods of increasing the capacity of the LEM Coolant Recirculation Assembly to meet the following new requirements imposed by the recommended Shelter configuration:

- Integration of the radiator network has imposed the following additional pressure drop:

o	Radiators	1.00
o	Regenerative heat exchanger	
	Hot side	0.70
	Cold side	0.80
	Coolant temperature control valve	0.80
	Total	3.30 psi

- Pressure drop has increased 2.5/1 on a per item basis because of changing the coolant from the LEM fluid (65% water/35% glycol) to RS 89A ($37\frac{1}{2}$% water to $62\frac{1}{2}$% glycol).
- Flow requirement must increase to maintain the LEM heat transport capability (c_p) at the same level in view of a 15% reduction in c_p caused by changing the fluid to RS 89A.

The present LEM coolant pump operates at a nominal design point of 220 lb/hr with a 30-psi pressure rise. Modifications can be made to the existing pump package to allow operation at different weight flows and pressure demands. Figure 5.2-6 defines the penalties associated with operating the pump at various conditions. As noted on the figure, fixed weight includes the entire pump package, including three pumps and motors, three relief valves, three check valves, a filter, and a pressure sensor. It is recommended that the recirculation assembly for the Shelter provide dual performance characteristics because of limited electrical power availability during flight phases and the standby storage phase of the mission. It is thereby recommended that the existing LEM design point be used during these phases, since the coolant loop requirements are minimized; that is the radiators are being bypassed and the electronics are at a low-load condition. During the manned phase, 40 w have been allocated to run the glycol pump, indicating the maximum growth point selected in Fig. 5.2-6.

5.2.3.3 Water Management Section

The functional capabilities of the LEM Water Management Section (WMS) must be expanded to meet the additional requirements of the Shelter. These are primarily a result of closed-cycle fuel cell integration and the integration of provisions for conditioning crew water. Specifically, the Shelter WMS will perform the following functions:

- Provide for storage of water requirements in excess of that produced by fuel cells and recovered from suit circuit water separators
- Deliver and regulate water for PLSS recharge in support of EVA
- Collect and distribute metabolic condensate
- Condition the water required by the crew for drinking, food preparation, and personal hygiene
- Regulate and deliver water required for the supplementary rejection of waste heat.

The current LEM descent stage water tank (322-lb capacity) is retained in the recommended Shelter configuration to store a net water requirement of 244 lb. The Shelter water balance is summarized below:

● Drinking, food preparation, and personal hygiene	252 lb
● Thermal control	
- Translunar flight	
- Checkout-to-touchdown	27
- Standby	
- Pre-utilization checkout (supplement)	40
- Manned phases (supplement)	110
● PLSS recharge	265
Total Requirement	694 lb
Fuel cell production and metabolic condensate recovery	-450
Net Storage requirement	244 lb

A functional schematic of the Shelter WMS is shown in Fig. 5.2-7. A normally closed squib valve will isolate the descent stage water tank from the remainder of the system during the standby storage phase. The LEM Water Control Module is retained, but is modified to meet additional functional requirements. This module regulates water pressure from the fuel cells, while additional regulators have been added to regulate water pressure from the storage tank. The additional set of regulators are necessitated by the difference in pressures between the fuel cell supplied water (40 psia) and the LEM storage tank (variable: 43 to 10 psia). A water conditioning assembly has been added to provide temperature control of crew drinking, food preparation, and personal hygiene water. This assembly is identical to that used in the CSM and consists of an electrically heated water reservoir, a cold water chiller, and a manually operated diverter valve.

5.2.3.4 Oxygen Supply and Pressurization Control Section

The recommended Shelter Oxygen Supply and Pressurization Control Section (OSPCS) has been developed by modifying the current LEM OSPCS to provide a capability to perform the following functions:

- Store and deliver PLSS oxygen after EPS oxygen tank pressure falls below minimum PLSS recharge pressure
- First-stage regulation of FCA oxygen
- Regulate and deliver oxygen as required to maintain cabin pressure because of leakage
- Regulate oxygen for ARS delivery to replenish metabolic consumption
- Store and deliver oxygen in support of airlock operations.

The recommended configuration is shown schematically in Fig. 5.2-8. The bulk of the required ECS oxygen is stored at ambient temperature with EPS reactants (Paragraph 5.1). Storage of supplementary oxygen for PLSS recharge late in the mission is provided by the ECS.

LEM high-pressure oxygen regulators and LEM pressure relief valves are retained and perform the same function as in the current LEM. The regulator maintains an outlet pressure of 1000 psia maximum, until source pressure falls below this level, at which time the regulator functions only as a flow limiter. In the Shelter OSPCS, the PLSS oxygen supply is not needed until the EPS oxygen supply pressure has fallen below 875 psia and the regulator is performing only as a flow limiter. At this time, the oxygen supply is rerouted by a selector valve to bypass the regulator through a flow limiter, and the PLSS oxygen supply is opened to the regulator. The LEM relief valve is located in a line common to the two sets of equipment and services both.

The LEM Oxygen Control Module is modified for the Shelter configuration by simply plugging one line. Its functions are the same as in the LEM; filtering incoming oxygen and making it available for cabin pressurization, PLSS recharge, and regulation of ARS supply.

The airlock is pressurized from the cabin atmosphere through a valve connecting the airlock with the cabin. Two pressure profiles for a typical Shelter day are shown in Fig. 5.2-9 and 5.2-10. In Fig. 5.2-9, the airlock is assumed empty at the start of each day. When the airlock valve is opened and no additional oxygen is supplied to the cabin, the airlock-cabin volume will reach an equilibrium pressure of 3.7 psia, the low-pressure setting on the suit-circuit assembly. The airlock volume is dumped during egress of the first crewman, and the cabin is repressurized to 5 psia requiring 1.8 lb of oxygen. This procedure is repeated for the simultaneous ingress/egress of both crewmen and repeated once again for ingress of the second crewman. The airlock is allowed to leak down during the 14 hr between surface exploration activity.

An alternate procedure (Fig. 5.2-10) allows the airlock to be used as a ready storage volume, accessible during shirt-sleeve operation, because the pressure is maintained from the cabin at 5 psia. Considering airlock leakage, the two procedures require approximately the same quantity of oxygen per day. A dump and relief valve is added to the airlock for depressurization.

The total ECS oxygen requirements for the Shelter are summarized below:

Leakage	0.2 lb/hr x 330 hr	66.0 lb
Metabolic consumption	2.0 lb/man-day x 660 man-hrs less EVA time	45.5
Initial pressurization	250 cu ft @ 5 psia	6.9
Airlock repressurization	as shown in Fig. 5.2-9 and 5.2-10	75.5
PLSS recharge	0.91 lb/recharge x 39 recharges	35.5
	Total ECS Oxygen Requirement	229.4 lb

5.2.3.5 Shelter Egress Procedures

The airlock is located forward of the Shelter front hatch and does not provide sufficient volume for donning space suits. The airlock will be provided with a suit circuit station and is pressurized from the cabin through a manual valve. The recommended major egress procedures outlined below were developed using current LEM procedures as a guideline:

- Perform communications, telemetry and warning equipment checkout, and calibrate environmental and biomedical sensors prior to entering the airlock
- Perform suit gas-leakage check in the Shelter cabin (suit pressurized to 3.7 psi above cabin pressure)
- Pressurize airlock with cabin repressurization valve closed (cabin/airlock equilibrium pressure: 3.7 psia)
- Select low-pressure setting on suit circuit (3.7 psia)
- Enter airlock and transfer suit circuit connector to airlock station
- Verify suit cooling flow
- Close airlock hatch, decompress airlock, and transfer to PLSS
- Complete egress.

It is assumed that the External Thermal Garment parka can be donned prior to entering the airlock.

If the airlock is to be maintained at cabin pressure to provide storage volume during the 14 hr between EVAs, the first egress of each Shelter day will be made with both the cabin and airlock at 5 psia. The egress procedure is the same as above, except that the suit circuit remains at 5 psia. It is assumed that no difficulty will be encountered in transferring from the suit circuit at 5-psia pressure to the PLSS prior to depressurizing the airlock. If difficulty is encountered, the suit circuit operating pressure will be reduced and the crewman remaining in the cabin will be without suit ventilation for a brief period.

5.2.3.6 Implications of ECS Pre-utilization Checkout

ECS functional and redundant operating mode selection on the basic LEM is accomplished manually by the crew. However, since the Shelter pre-utilization checkout will be performed by remote control, certain modifications will be required in the ECS.

In general, a complete check of all ECS operating modes and redundancies would require prohibitive increases in weight and complexity, and is not recommended. Very moderate modifications and weight increases will, however, allow remote determination of the Shelter pre-utilization status to a high degree of confidence for the basic modes of ECS operation. In addition, redundancies of a critical nature can be checked out with reasonable weight addition.

A description of the modifications required for the various ECS sections follows. These modifications have not been incorporated into the schematics described in the previous paragraphs, and are pending final definition of checkout philosophy.

5.2.3.6.1 Oxygen Supply and Pressurization Control. To check out the Shelter cabin pressure vessel integrity and the status of the oxygen supply and pressurization equipment, the following modifications are required:

- Remote control relay must be added in the power supply line for the cabin repressurization emergency oxygen valve
- Remote control relay must be added in the cabin fan power supply lines

Activation of the control relay will supply power to the cabin repressurization emergency oxygen valve initiating oxygen flow to the cabin. The cabin pressure switch will maintain cabin pressure from 4.3 to 5.0 psia. Existing instrumentation will monitor pressure decay, thereby establishing structural leakage. Cabin fan operation will be controlled by a separate relay and monitored by the RPM sensors.

5.2.3.6.2 Atmosphere Revitalization Section. The Atmosphere Revitalization Section performs the following functions:

- Maintain and regulate pressure in the suit loop (5 or 3.7 psia)
- Provide oxygen circulation
- Provide for automatic separation of the suit loop from the cabin in case of cabin pressure failure
- Provides suit loop oxygen cooling

- Removes metabolic carbon dioxide
- Condenses and removes metabolic water

It is recommended that a remote checkout capability be provided for the first four of the above functions. The following modifications are required on the basic LEM to incorporate this checkout capability:

- Remote control solenoid valve must be added upstream of the oxygen pressure regulators
- Remote control relay must be provided in the suit fan power supply lines
- Remote controlled servo drive for opening the suit circuit diverter valve must be added

Prior to separation from the CSM, the O_2 pressure regulators are turned to the "Normal" position, and the oxygen supply to the pressure regulators is shut off by the remotely controlled upstream solenoid valve. During the remote checkout, the upstream solenoid valve is opened, allowing suit loop pressure to build up to 5 psia. Both suit fans are alternately energized. Existing LEM instrumentation is sufficient to confirm the suit circuit integrity and confirm its operation. The suit fan will supply sufficient heat in the suit loop to check the suit circuit heat exchanger operation.

Additional study is required to evaluate the marginal gains vs additional weight that can be achieved by providing the remote opening capability for the suit diverter valve. Existing LEM instrumentation is sufficient to confirm the integrity of the water separator and the carbon dioxide removal system. Lack of water and carbon dioxide in the cabin atmosphere prevents a functional check for these equipments. If means are provided for injecting water and carbon dioxide in the cabin environment, there is sufficient basic LEM instrumentation aboard the Shelter to confirm the functional capabilities of one water separator and one LiOH cartridge. However, the marginal gains do not justify the recommendation of a checkout capability for the latter two functions.

5.2.3.6.3 Heat Transport Section. No additional instrumentation or remote controls are required to check out the operation of one coolant pump. However, to increase the Shelter mission success, it is recommended that two remote control relays be added in the coolant pump power supply lines for checking out the redundant coolant pumps. The coolant pump selector switch will be turned to the "Automatic" position prior to separation from the CSM. During remote checkout, removal of power from the operating pump and the maintenance of power to the automatic pump control will simulate operating coolant pump failure and induce automatic switching of the coolant pumps. Basic LEM instrumentation is sufficient to confirm pump switch over and operation of the selected pump. Since radiators are not required to operate until the pre-utilization checkout phase, they are bypassed and allowed to freeze and thaw during standby. The following remotely controllable equipment are thereby required to establish radiator operation:

- Remote control relay for energizing and de-energizing strip heaters on the maximum flow passage of each radiator panel
- Remote control solenoid valve to direct coolant flow to the radiators.

5.2.3.6.4 Water Management Section. The functional integrity of the Water Management Section will be monitored while the section is supporting the operation of the Heat Transport Section. LEM instrumentation is adequate to monitor water tank status and equipment operation. However, the following additions are required to activate the water management section prior to start of checkout:

- Remote control solenoid feature on the valve that is added to control water flow from the water evaporators
- Remote control solenoid valve to initiate water flow from the fuel cell water accumulators to the water evaporator.

5.2.4 Baseline Configuration

The baseline Shelter ECS configuration differs from the recommended configuration in the following areas:

- Baseline configuration did not incorporate provisions for supporting airlock operations
- Electrical heaters, integrated into the descent stage water tank to prevent freezing during standby storage, have been deleted in favor of the utilization of RTG waste heat
- Radiator panels and controls have been refined as a result of design and analysis efforts subsequent to baseline configuration definition.

An airlock, originally rejected in the interest of minimizing changes to the basic LEM, has been incorporated in the recommended configuration. ECS oxygen requirements have been adjusted to reflect the decrease afforded by airlock integration (Paragraph 5.2.3.4). In addition, a suit circuit connector station has been added in the airlock.

Approximately 5 w was allocated to a descent stage water tank heater in the baseline configuration. Since the RTG and portions of associated waste heat utilization equipment (Paragraph 5.2.3.2) are located in close proximity to the descent stage water tank, provisions will be made to insure sufficient RTG heat transfer to prevent freezing during night storage.

Changes to the Shelter radiator and radiator control configuration have been dictated by the results of additional performance analysis and should not be classified as a configuration change.

5.2.5 Alternate Configuration - Low-Capacity Suit Circuit Compressor for Shirtsleeve Operation

Maintenance of the comfort levels for suited astronauts imposes severe requirements on the LEM suit circuit compressor. Power and thermal control water savings may be realized by utilizing a low-capacity compressor during shirtsleeve operation and retaining the LEM compressor only for suited operations. The governing factors determining suit compressor design are:

- Flow requirement for adequate suit cooling
- Dynamic pressure rise for adequate suit flow.

For unsuited operation both of the above requirements are relaxed significantly and a new compressor could be redesigned as follows:

- Fan flow rate from 12 to 6 cfm
- Fan dynamic pressure rise from 14 to 3.5 in. of water.

If shirtsleeve operation constitutes a large portion of the total Shelter operating time, a significant decrease (approximately 14 kw-hr based on current 10-hr/day projections) in energy would be possible. Since heat rejection will be accomplished primarily by radiator assemblies, decreases in thermal control water requirements would be negligible.

Although not recommended at the present time, this alternate should be re-evaluated subsequent to final definition of crew activities in the Shelter cabin.

A shirtsleeve compressor would be functionally integrated into the existing suit circuit and operate in conjunction with the existing water separators and LiOH cartridges.

5.2.6 Alternate Configuration - Airlock Pumpdown

The Shelter airlock may be operated closed cycle by employing a pump to evacuate the airlock and return the gas to the cabin. If this approach were taken, egress oxygen requirements would be reduced to those associated with replenishing losses associated with airlock oxygen residuum. The airlock would be pressurized from the cabin atmosphere resulting in a cabin/airlock equilibrium pressure of approximately 3.7 psia. The egress procedure would be identical to that discussed in Paragraph 5.2.3.5.

The airlock dump cycle would be replaced by pumping the contained atmosphere back into the Shelter cabin. The crewman in the cabin selects the 5.0-psia setting on the suit circuit during airlock pumpdown. The crewman in the airlock receives oxygen from his PLSS, but will be without suit cooling during the depressurization period. When egress is complete, the cabin pressure is slightly lower than 5 psia because of the small residuum lost in the airlock. The cabin pressure will automatically be returned to 5.0 psia by the OSPCS.

Operation of this airlock will require 1.44 lb of oxygen (including ambient tankage penalty) and a 0.39-lb power weight penalty each day for a total daily penalty of 1.83 lb. A total of 10.8 lb are required daily if the airlock is dumped. Total system weights are compared in Fig. 5.2-11. System weight includes the weight of airlock, gas, pump, inverter, and tankage, as well as pump power weight penalty. Estimated pump and inverter characteristics are shown on Fig. 5.2-12.

5.2.7 Alternate Configuration - Passive Utilization of RTG Waste Heat

The RTG waste heat utilization equipment described in Paragraph 5.2.3.2 may be eliminated by mounting the RTG on top of the descent stage and incorporating provisions for controlling the thermal coupling between the RTG heat source and the ascent stage pressure vessel. The thermodynamics of this alternate configuration are discussed in Paragraph 4.1. Summarizing, the RTG is installed in an insulated enclosure which exposes the generator to both space and a selected portion of the ascent stage structure. Radiation to the ascent stage is controlled by a hinged panel which is actuated in response to ascent stage temperature sensors.

Since this alternate configuration involves additional handling of the RTG and the incorporation of new installation provisions, it has been rejected in favor of the equipment recommended and described in Paragraph 5.2.3.2.

Table 5.2-1

SHELTER ECS THERMAL LOADS, Btu/hr (MANNED PHASE)

				No. Men in Cabin	
				1	2
Housekeeping	Cabin Heat Exchgr	Electrical	max	860	1085
			min	300	422
		Windows & Structure	max	1360	1360
			min	-510	-510
	Cold Plates	Low-Temp Electronics	max	52	52
			min	52	52
		Batteries & Adjacent Electronics	max	180	180
			min	180	180
		High-Temp Electronics	max	590	590
			min	131	131
	Suit Circuit	Metabolic	max	525	1050
			min	392	784
		Chemical	max	126	252
			min	97	194
		Electrical	max	500	500
			min	500	500
	Coolant Pump		max	136	136
			min	136	136

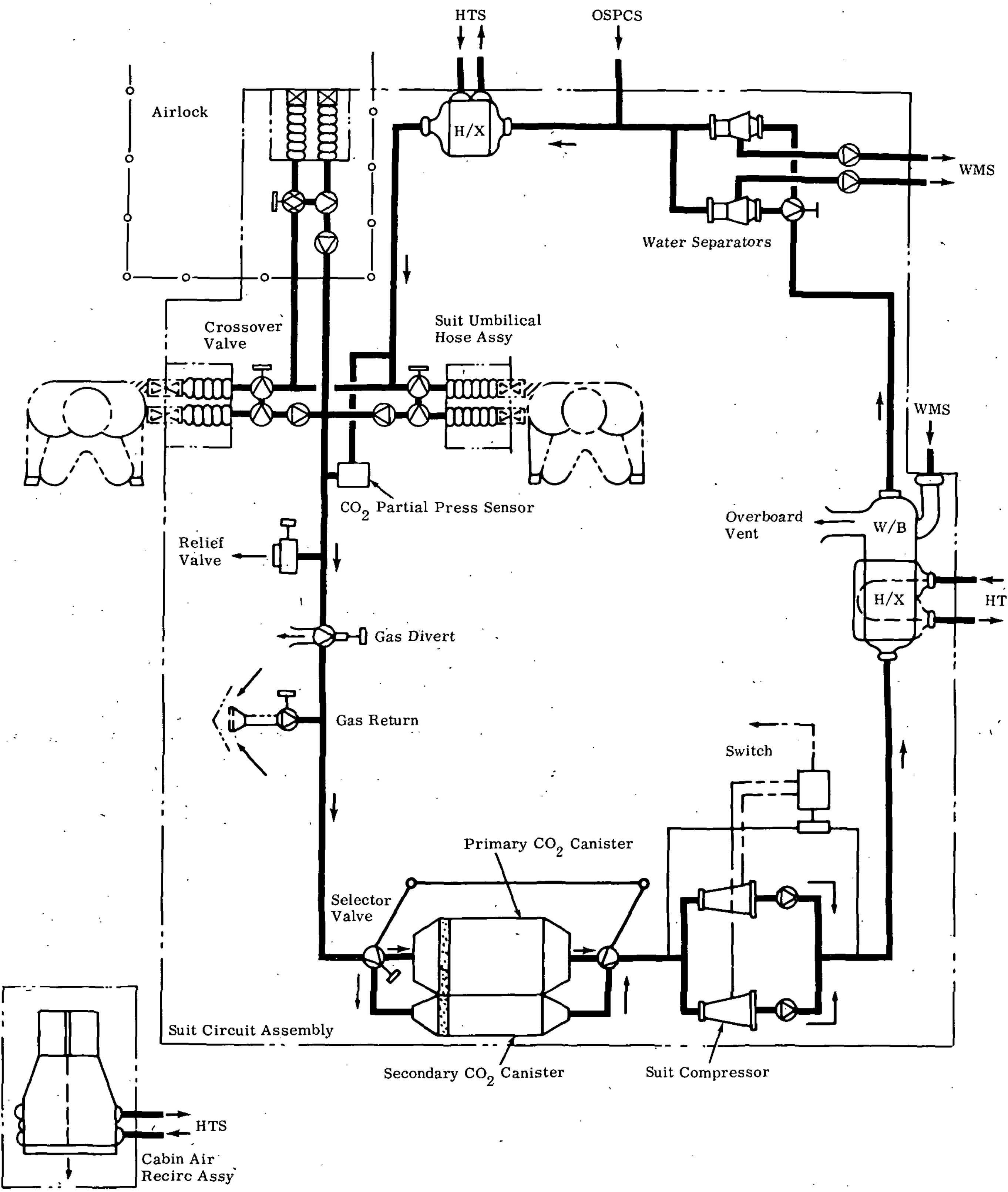
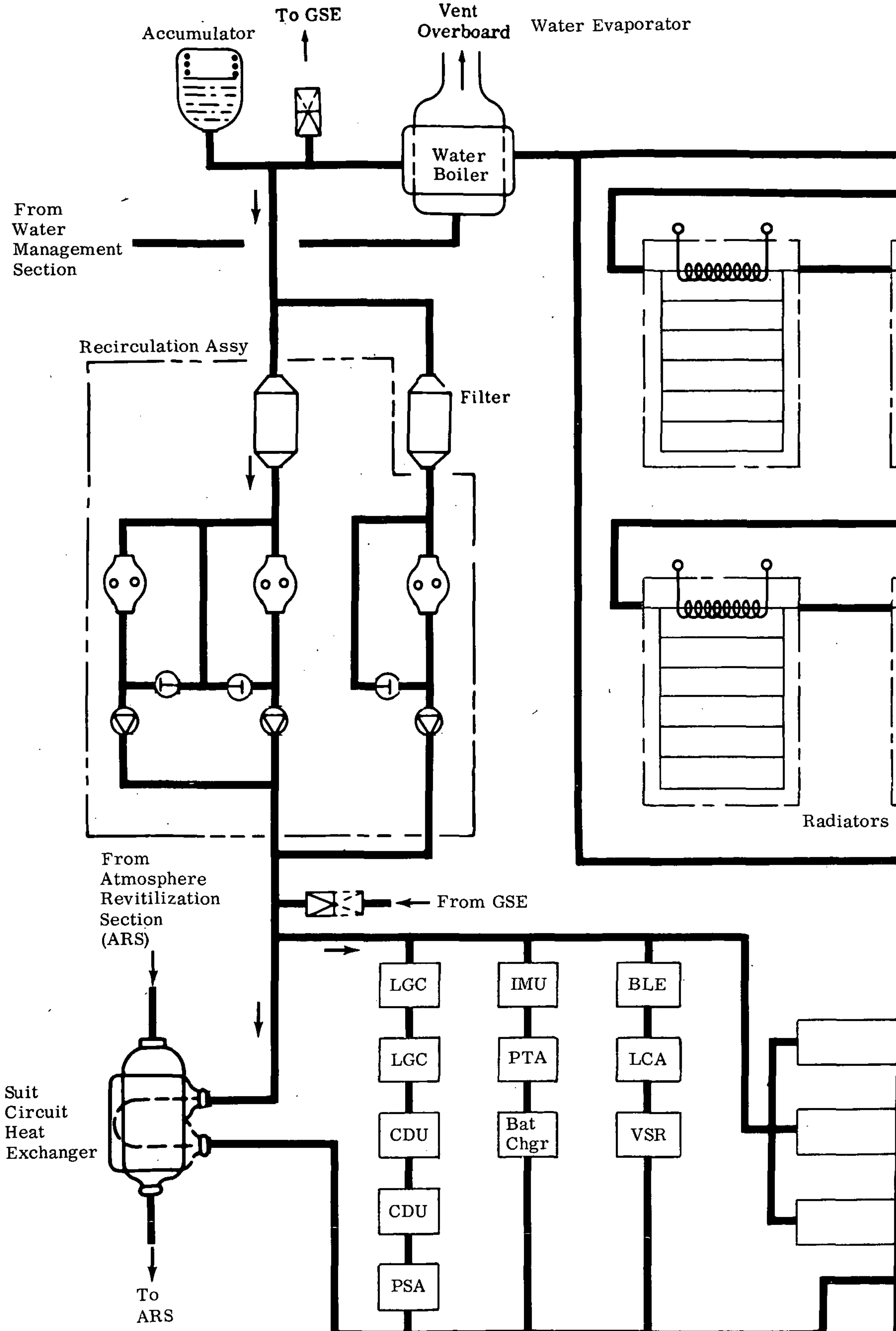
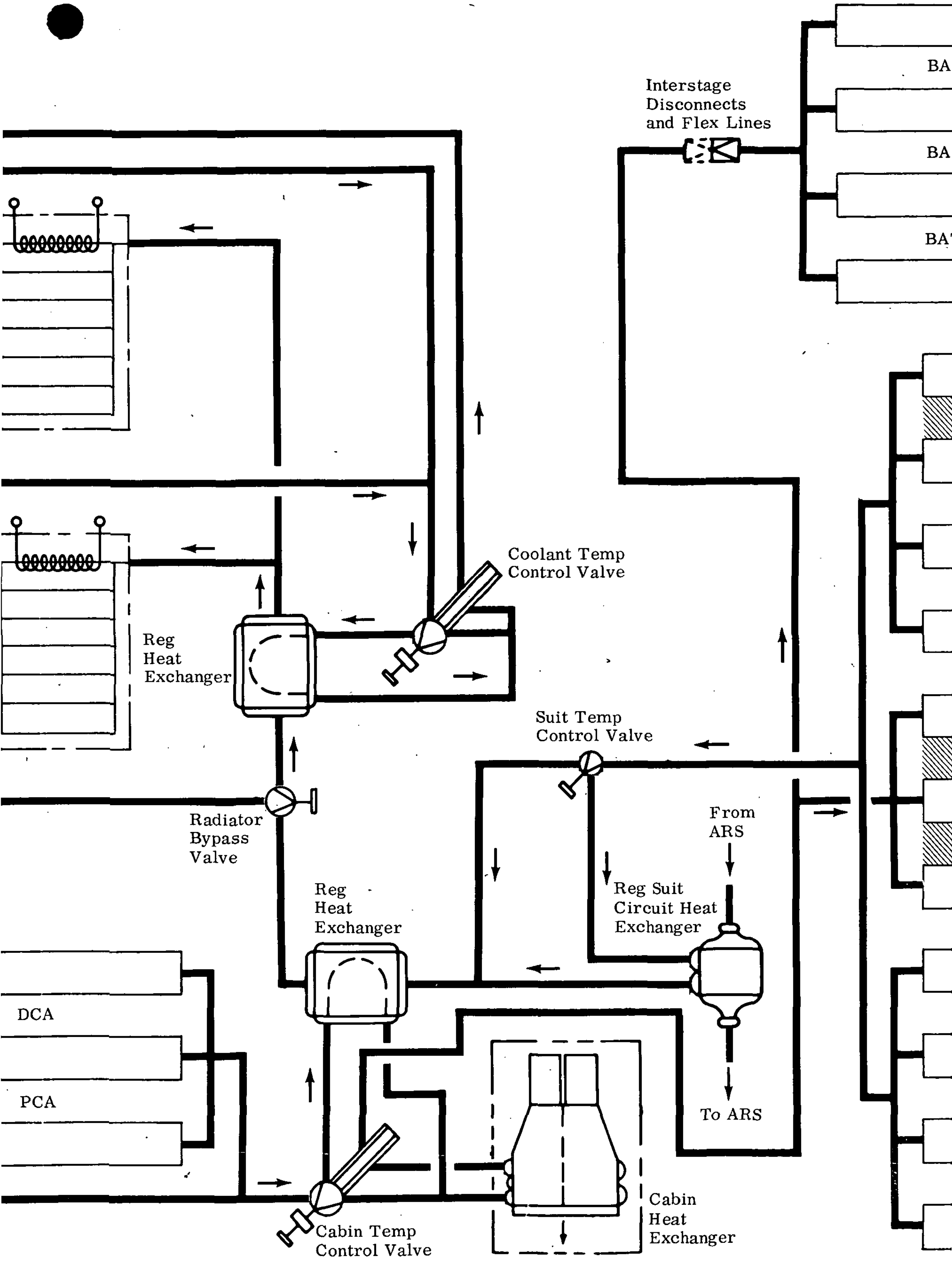


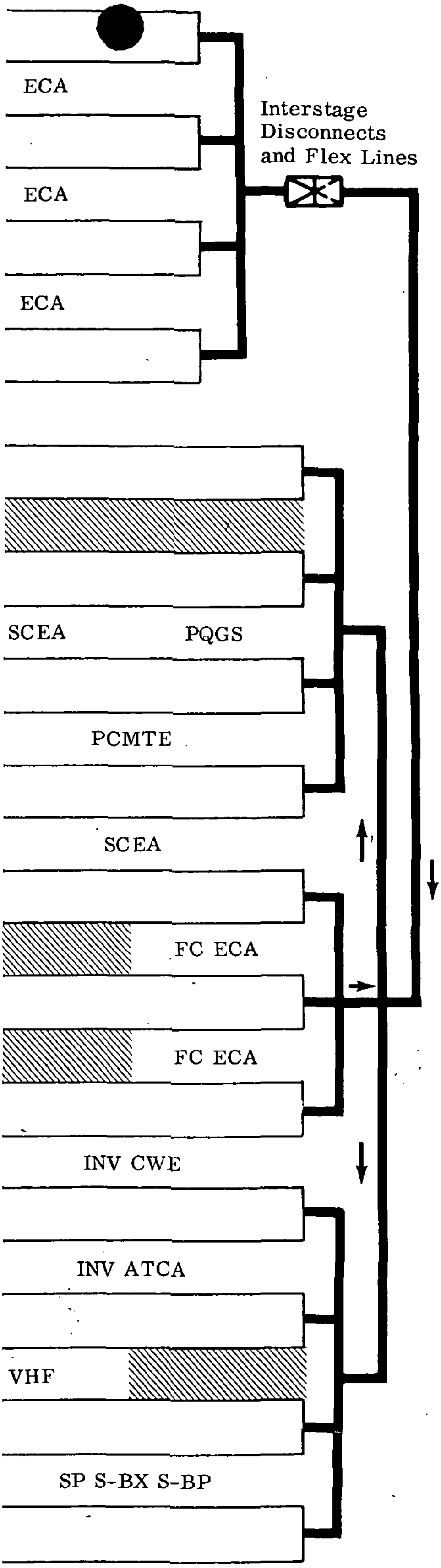
Fig. 5.2-1 Atmosphere Revitalization Section


Accumulator
To GSE
Vent
Overboard
Water Evaporator
Water
Boiler
From
Water
Management
Section
Recirculation Assy
Filter
Radiators
From
Atmosphere
Revitilization
Section
(ARS)
From GSE
LGC
IMU
BLE
LGC
PTA
LCA
CDU
Bat
Chgr
VSR
CDU
PSA
Suit
Circuit
Heat
Exchanger
To
ARS

5.2-2

①


BA
BA
BA
Interstage Disconnects and Flex Lines
Coolant Temp Control Valve
Reg Heat Exchanger
Suit Temp Control Valve
Radiator Bypass Valve
From ARS
Reg Heat Exchanger
Reg Suit Circuit Heat Exchanger
DCA
PCA
To ARS
Cabin Heat Exchanger
Cabin Temp Control Valve



Abbreviations Used on Heat Transport Diagram

LGC	LEM Guidance Computer
CDU	Coupling & Display Unit
PSA	Power Servo Assy
LCA	Lighting Control Assy
VSR	Voice Storage Recorder
BLE	Beacon Light Electronics
IMU	Inertial Measuring Unit
Bat Chgr	Battery Charger
PTA	Pulse Talk Assy
ECA	Electronic Control Assy
SP	Signal Processor
S-BX	S-Band Transponder
S-BP	S-Band Power Amplifier
VHF	Very High Frequency Communications
INV	Inverter
ATCA	Attitude & Translation Control Assy
CWE	Caution & Warning Assy
SCEA	Signal Conditioning Electronic Assy
PCMTE	Pulse Code Modulation & Timing Equipt
FCECA	Fuel Cell Electronics Control Assy
Bat	Battery
DCA	Digital Command Assy
PCA	Program Coupler Assy
PQGS	Propellant Quantity Gaging System
▨	Available for Experiments

Fig. 5.2-2 Heat Transport Section

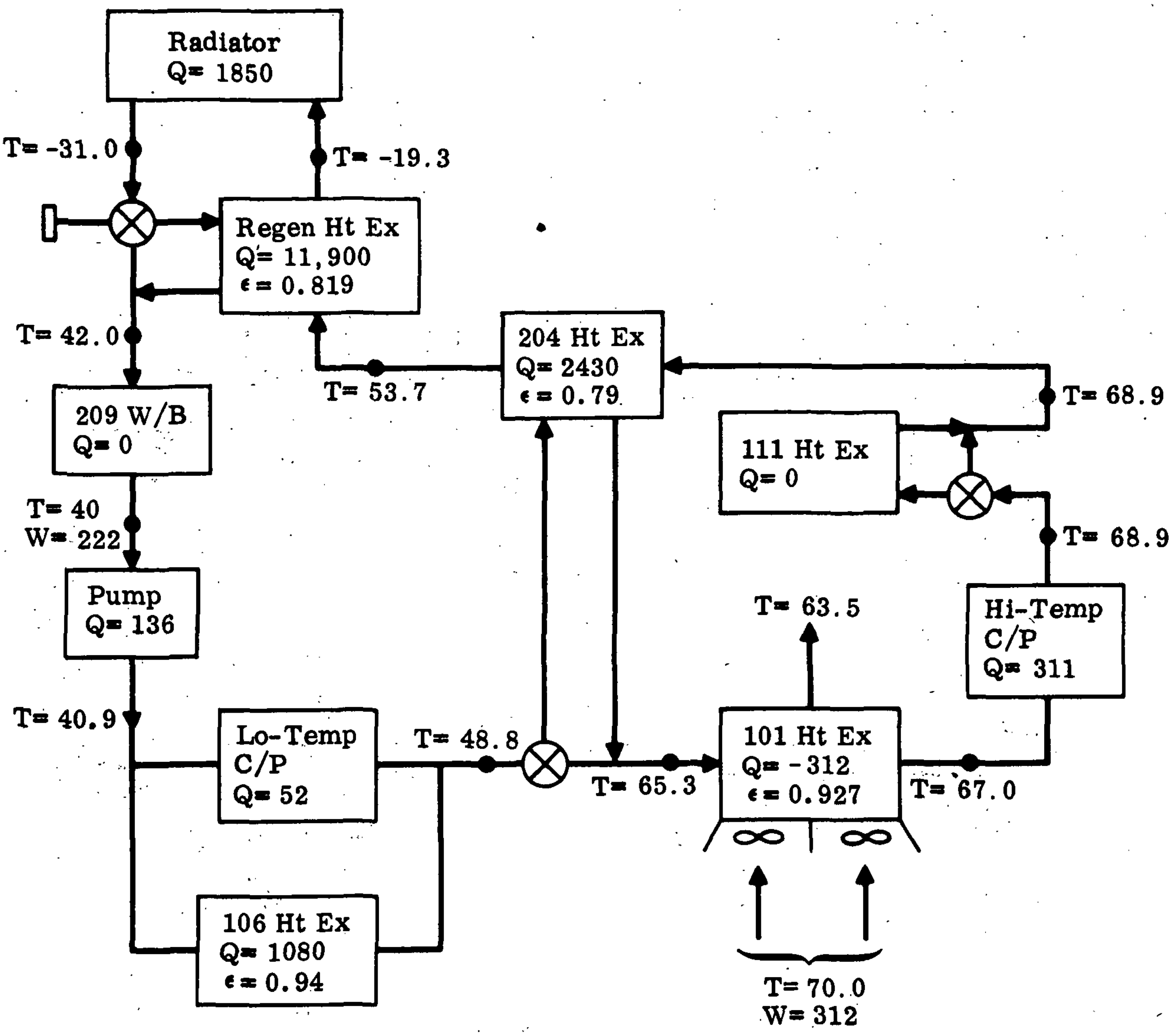


Fig. 5.2-3 Coolant Circuit Performance-Minimum Load

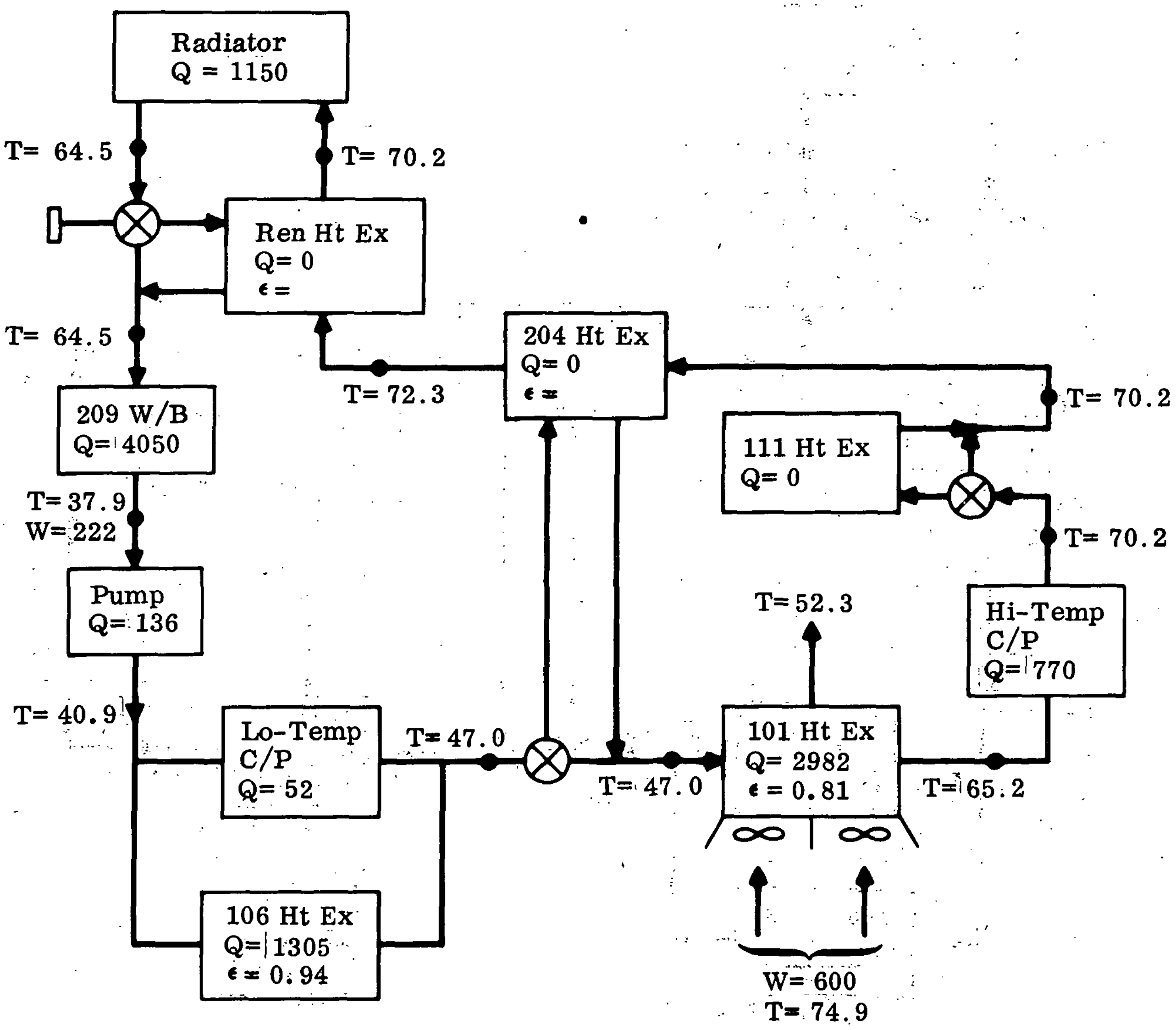
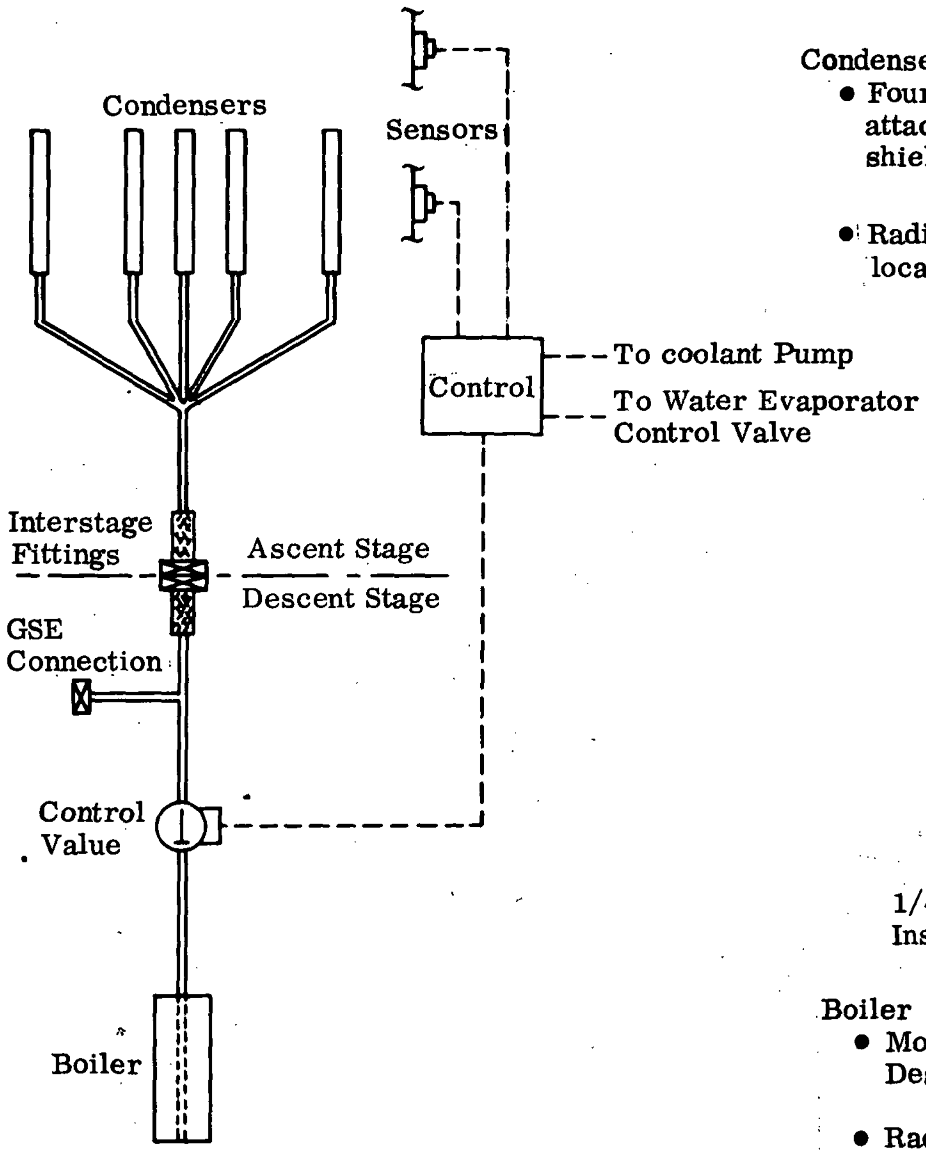


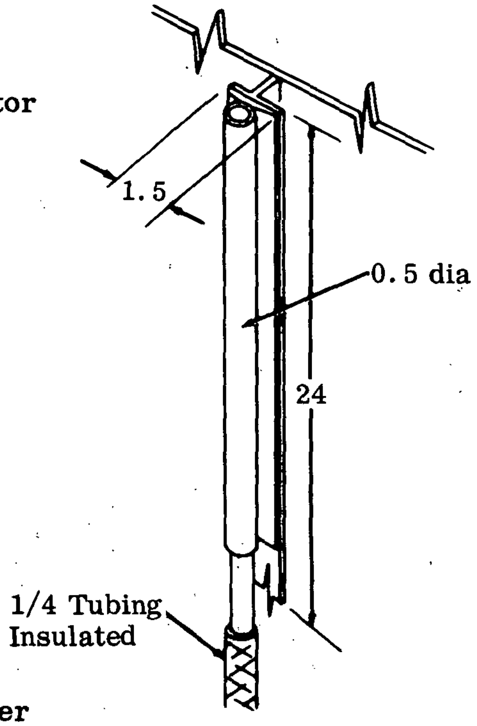
Fig. 5.2-4 Coolant Circuit Performance-Maximum Load



Component Design

Condensers

- Four condensers mechanically attached inboard of thermal shield to pressure shell webs.
- Radiation heat transfer from localized area to remaining cabin.



Boiler

- Mounted inboard of RTG in Descent stage
- Radiation heat transfer between RTG & Boiler

All dimensions in inches.

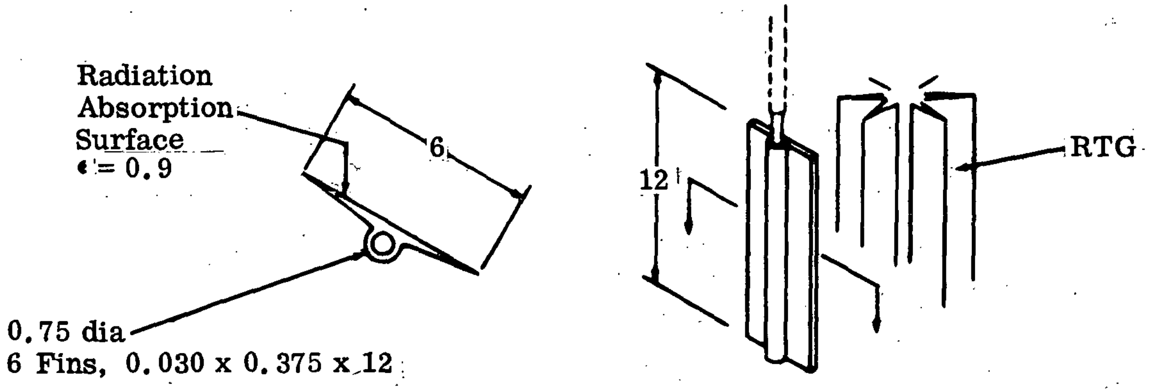


Fig. 5.2-5 RTG Heat Pipe

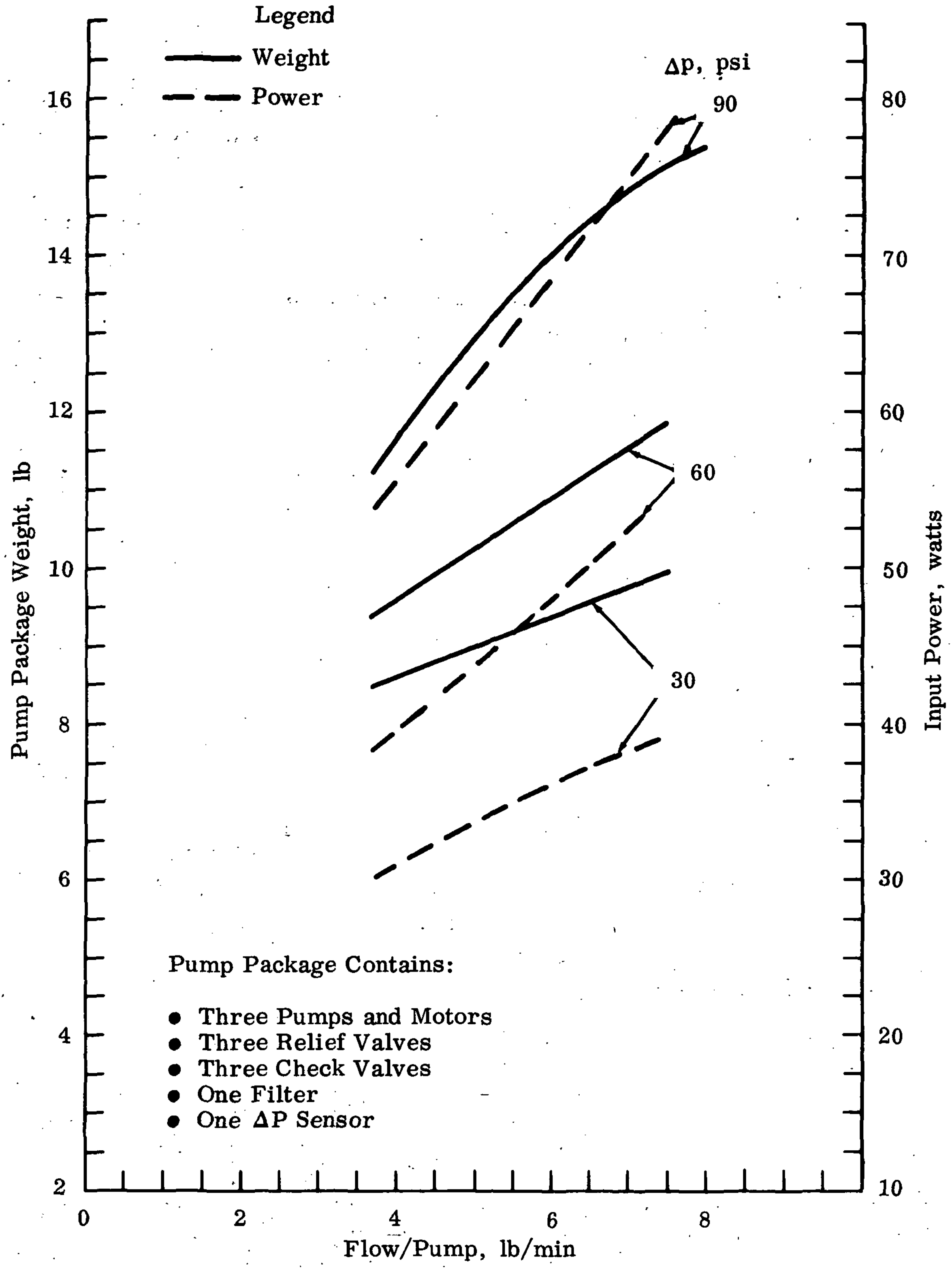


Fig. 5.2-6 Pump Package Growth

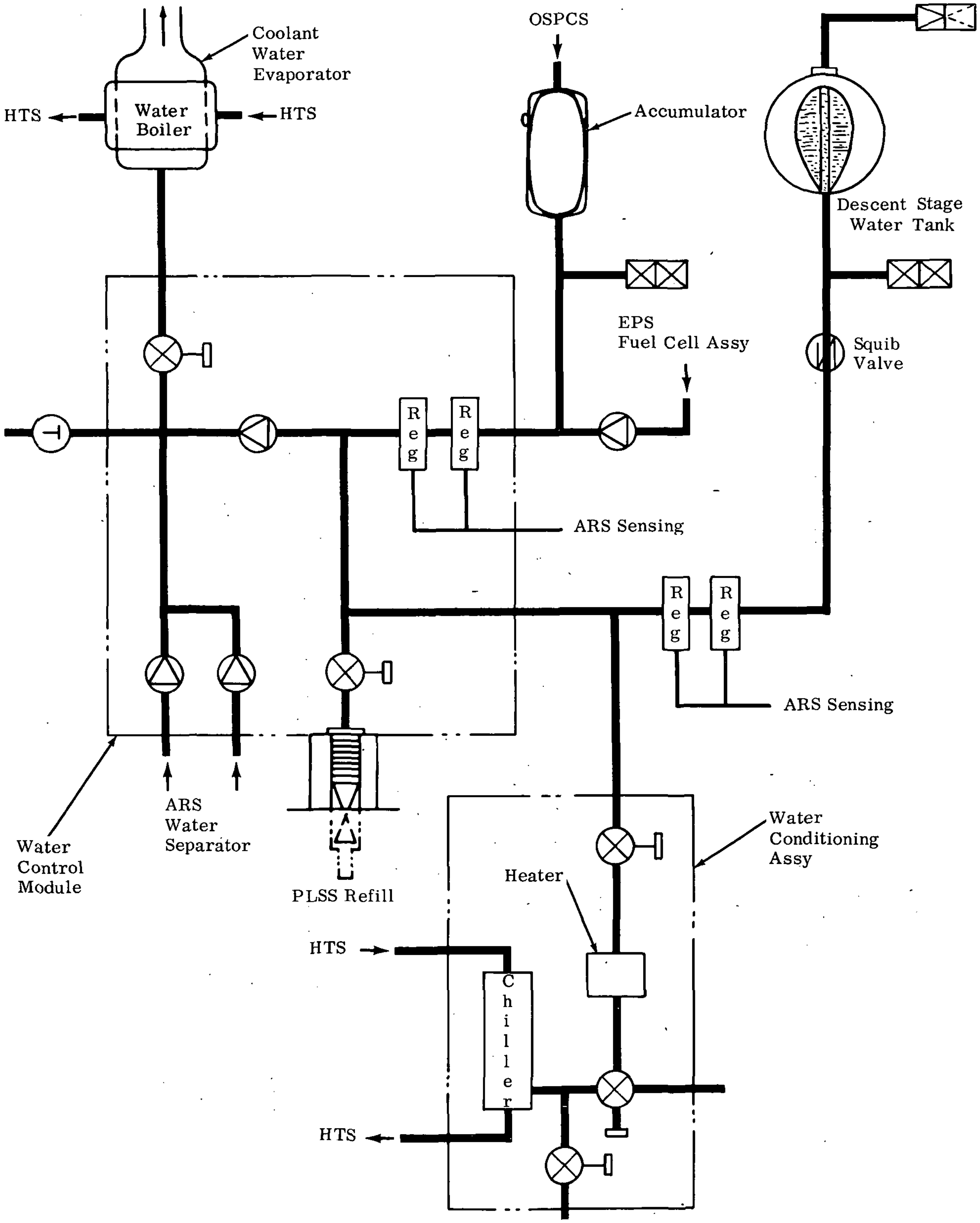


Fig. 5.2-7 Water Management Section

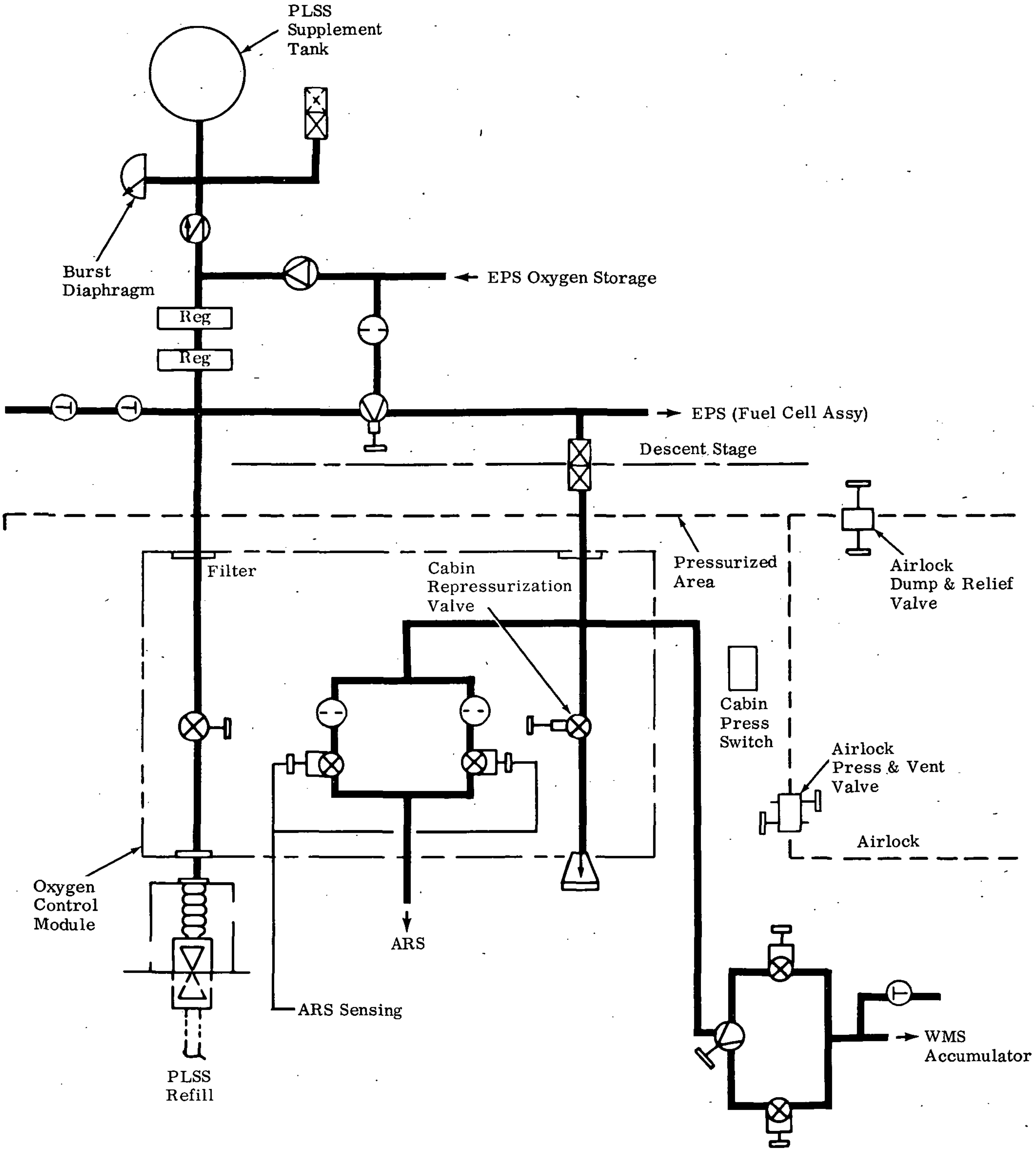


Fig. 5.2-8 Oxygen Supply & Pressurization Control Section

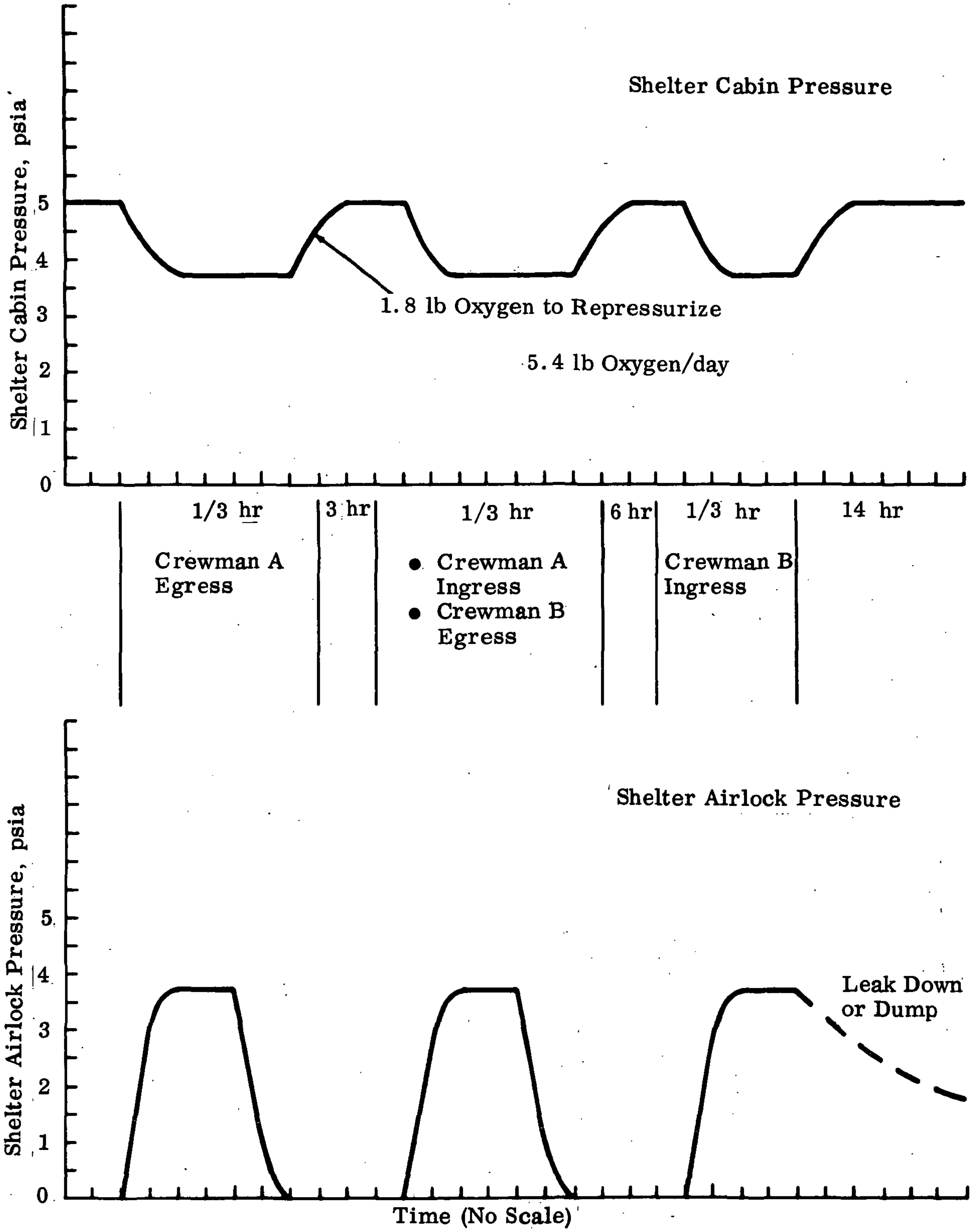


Fig. 5.2-9 Airlock Operation - Mode 1

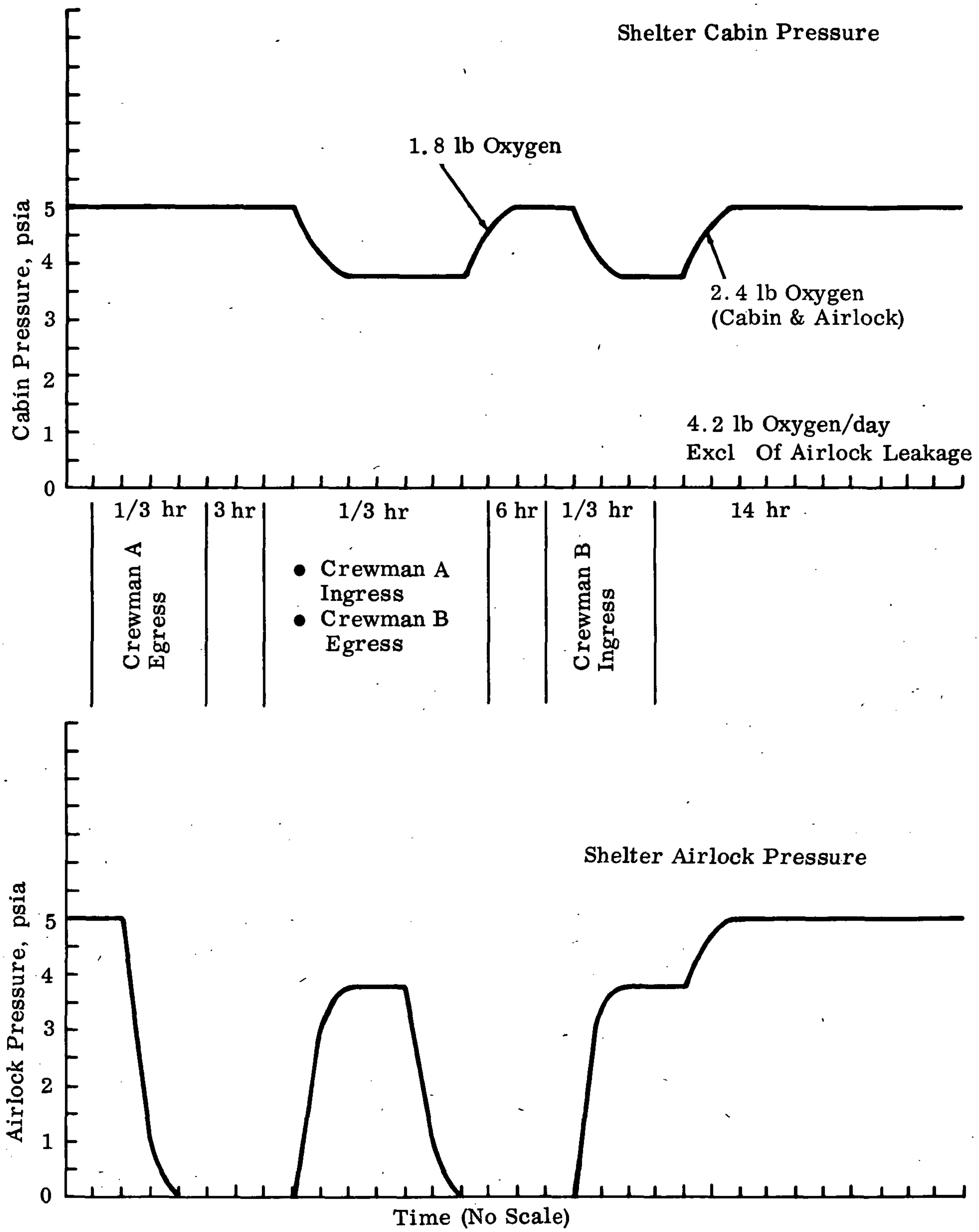


Fig. 5.2-10 Airlock Operation-Mode 2

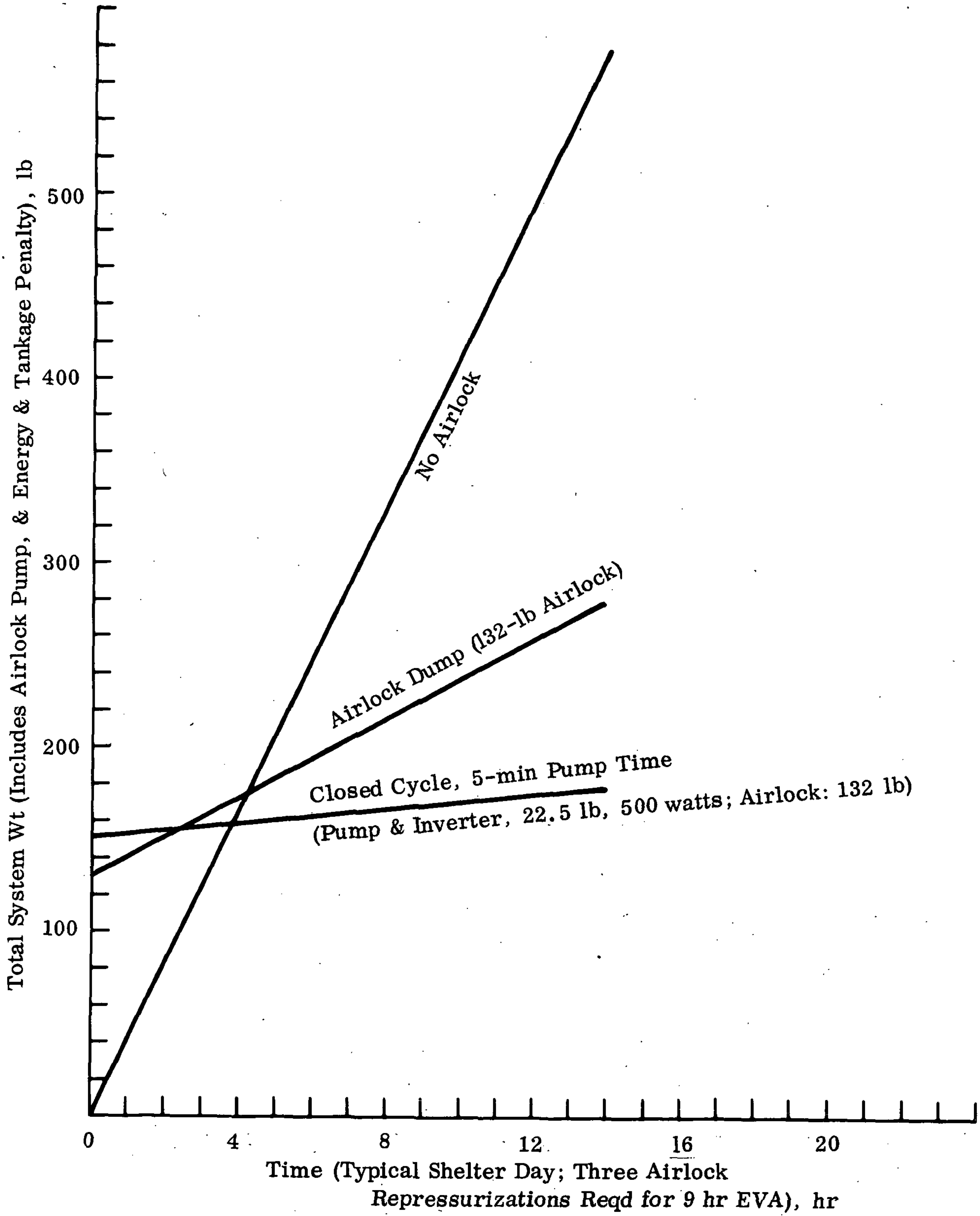
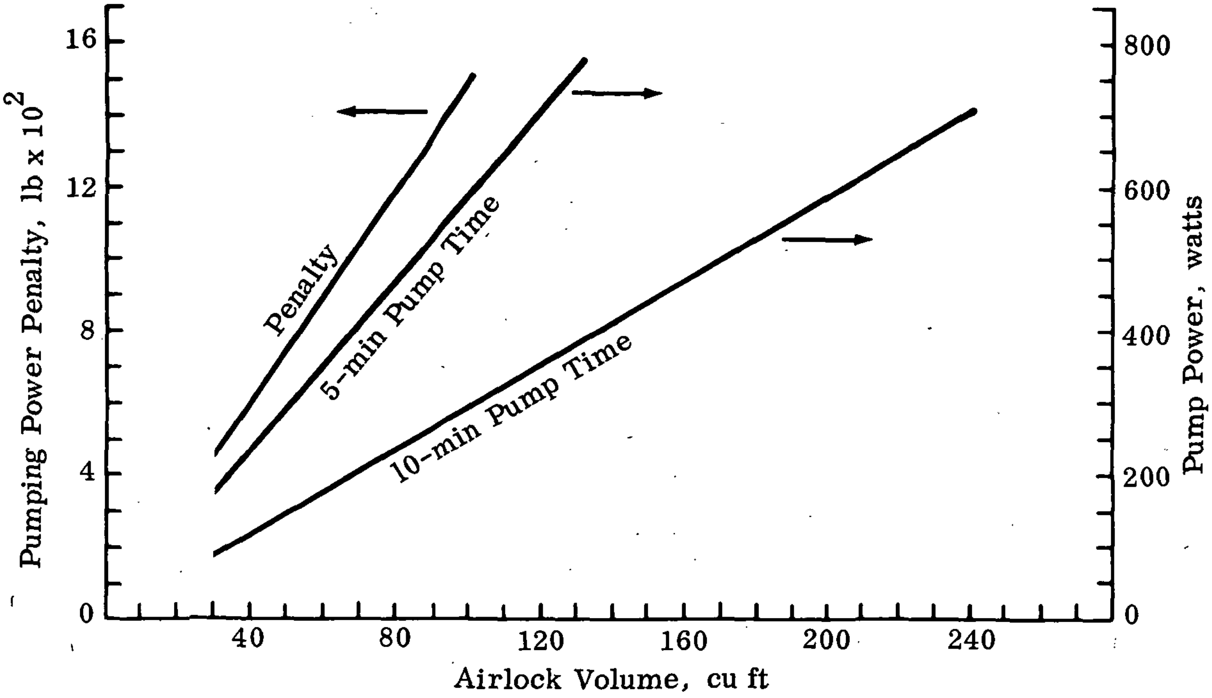


Fig. 5.2-11 Egress/Ingress Analysis



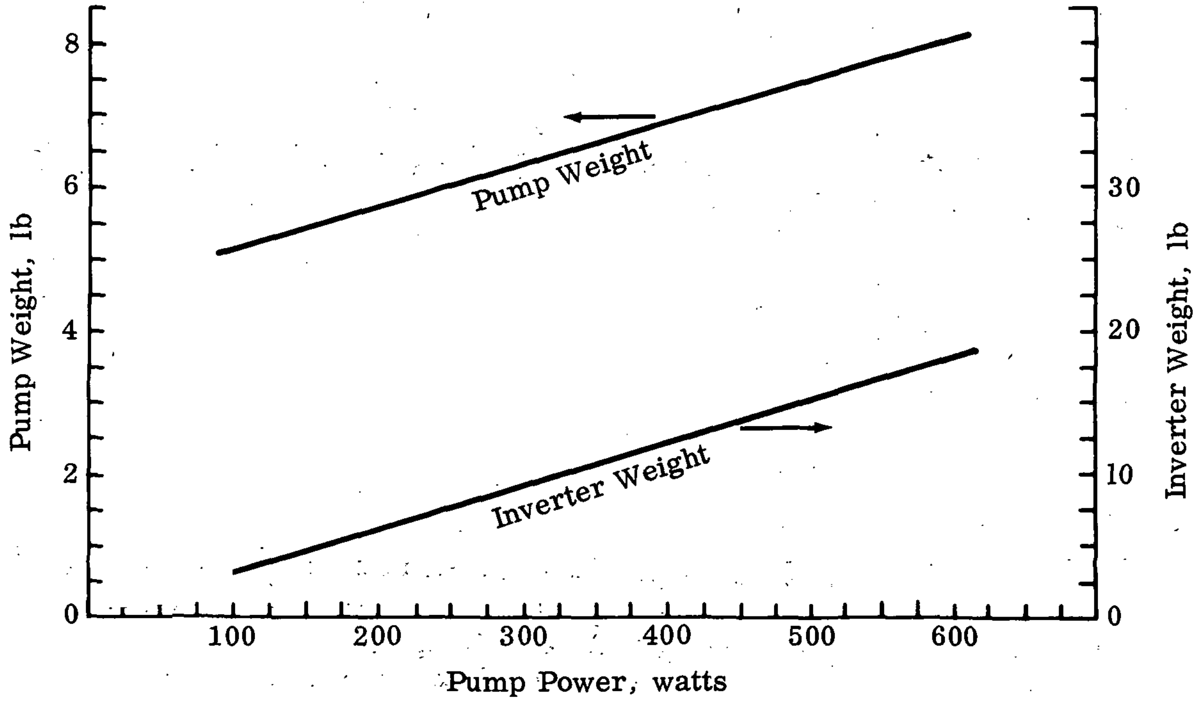


Fig. 5.2-12 Airlock Pump & Inverter Characteristics

5.3 GUIDANCE, NAVIGATION AND CONTROL

5.3.1 Ground Rules

The following NASA ground rules are unique to this area of the study:

- Design for an 80-n.mi Hohmann transfer trajectory; study effects of direct descent trajectory
- Lunar surface missions as defined by NASA/MSFC
- Primary Navigation Guidance and Control Section (GFE) will be capable of performing the functions required for the Shelter
- Shelter shall provide for a landing aid to the taxi.

5.3.2 Assumptions and Background Data

The function of the Shelter Guidance Navigation and Control Subsystem (GNCS) is to make an automatic unmanned landing on the lunar surface. The following assumptions and background data were used during the analysis:

- Shelter is launched and landed prior to Taxi Earth launch
- Unmanned landing is accomplished by a preprogrammed descent trajectory to a preselected landing site
- Orbit initalization and IMU alignment is accomplished prior to separation by the astronaut.
- IMU update in lunar orbit, prior to pericynthion, is accomplished using LEM Optical Rendezvous System (LORS) in conjunction with the LGC
- Post-landing checkout, shutdown, and pre-Taxi launch activation will be controlled by Earth via uplink.
- S-band steerable antenna must be locked on to the Earth transmission during the descent coast phase and on the lunar surface
- LORS as developed and integrated into the LEM vehicle will be provided for the Shelter as GFE.

5.3.3 Recommended Configuration

The recommended Shelter GNCS configuration is shown in Fig. 5.3-1. This consists of a modified LEM Primary Guidance Navigation and Control System (PGNCS), selected portions of the LEM Control Electronics Section, addition of the LEM I Program Coupler Assembly, CSM radar transponder, and a X-Y scanner for the S-band steerable antenna. The Abort Guidance Section has been deleted because the landing is unmanned and therefore no abort requirement is needed.

The LEM Alignment Optical Telescope (AOT) has been removed and is replaced by the LEM Optical Rendezvous System (LORS) which is used to update the IMU during the descent. Since the Shelter does not make a return ascent and rendezvous with the CSM, the rendezvous radar has been removed. A functional description of the Shelter GNCS changes from the present LEM are as follows.

5.3.3.1 X-Y Scanner

The primary steerable antenna operation assumes that prior to Shelter separation the antenna is set to lock on Earth when line of sight (LOS) is achieved (predetermined antenna position). At LOS, and after phase loop lock-on, automatic tracking is initiated. Assuming Shelter maneuvers during descent do not exceed the angular tracking capabilities of the steerable antenna in velocity and acceleration (20deg/sec amd 60deg/sec^2), the antenna will be locked on to Earth at touchdown. During the lunar storage phase, the orientation of the Shelter S-band antenna will rotate ±6deg about the lunar latitude and ± 7deg about the lunar longitude axes as the Moon orbits about the Earth. This rotation will offset the antenna beam by 7deg under worst conditions, causing the Earth to fall on the edge of the 3-db beam width. The loss appears acceptable at present.

To insure the communication link during the unmanned portion of descent and lunar stay, an X-Y scanner provides a search mode for the S-band antenna. The scanner drives the S-band steerable antenna whenever Earth acquisition is interrupted. When acquisition is lost, an error threshold signal energizes a relay in the X-Y search pattern generator, initiating a search pattern to control the X- and Y-axes antenna servo drive. The type of search scan and scan rate is a function of the vehicle dynamics, probability of detection, and ease of implementation. An analysis and study will be conducted during Phase C covering these aspects.

To provide for minimum Earth reacquisition time, a fast acting power integrator (in relation to the phase loop-on interval) should be used during the angle search period. This will separate the search sequence into two phases: power detection (allowing fast search rate), and frequency lock up (initiated when sufficient power is detected). When the track signal is reacquired, the signals fed to a comparator logic circuitry will fall below the threshold level, thereby permitting the automatic Earth tracking mode to be reinitiated. During lunar stay an uplink command via Program Coupler Assembly is required to initiate the X-Y scan mode.

5.3.3.2 Transponder

The incorporation of the CSM transponder electronics and antenna assemblies into the Shelter and the LEM rendezvous radar into the Taxi provides a beacon aided landing capability to the mission. Further discussion on this antenna system is in Paragraph 5.5.

5.3.3.3 Program Coupler

The Program Coupler Assembly (PCA), used on the unmanned LEM I vehicle, is used to perform the switching functions normally performed by the astronaut. The PCA accepts commands from either the LGC or the uplink. However, to conserve power, the LGC will not be used for the periodic checkouts during lunar storage.

The PCA contains two relay matrices: a 16 x 16 matix, containing 127 relays driven from the LGC through relay drivers; and a 16 x 6 matrix, containing 48 relays driven by relay drivers contained in the command decoder. All these relays are latching relays with independent set and reset coils. The preprogrammed LGC performs a post-landing shut-down sequence through the 16 x 16 relay matrix in the PCA. The PCA is then used for periodic monitoring of Shelter systems during lunar storage. The checkout sequence is initiated by ground commands using the 16 x 6 matrix. The uplink differs from the LEM in that S-band is used instead of UHF/VHF. Complete checkout, prior to the Taxi-Earth launch, is performed by uplink through the PCA.

5.3.3.4 LGC Software and Hardware Changes

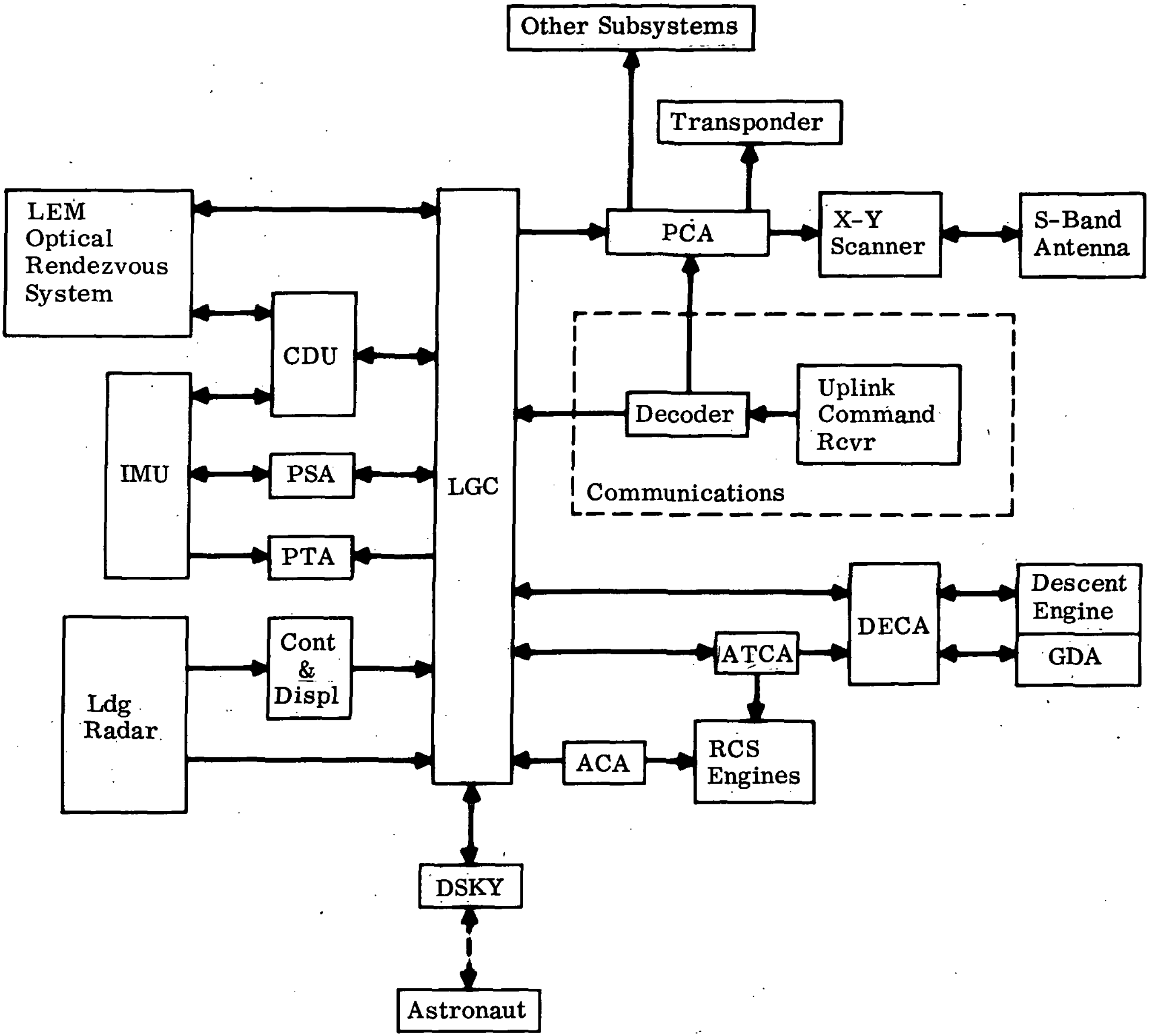
The LGC will require a preprogrammed discrete interface for initiating IMU fine alignment prior to Hohmann transfer at pericynthion. This function is inserted manually by the astronaut in the present LEM. Two methods of generating this discrete are via uplink or preprogrammed LGC command. No software changes should be required to operate with the recommanded eight jet RCS. Since a complete "B" system is used and the present LEM LGC has the capability of operating with this system. It should be clearly noted that in nearly all cases when LGC Shelter software changes differ from LEM it results in a hardware change. This is because of the very high percentage of fixed rope memory in the LGC which results in low flexibility (36,864 fixed vs 2048 variable).

5.3.4 Baseline Configuration

The baseline configuration differs from the recommended configuration in that the Alignment Optical Telescope (AOT) was used in place of the LEM Optical Rendezvous System (LORS). The AOT was used on the baseline configuration because a 20-n.mi direct-descent trajectory was initially chosen for the Shelter mission. With direct descent, the IMU does not require re-alignment after separation from the CSM.

5.3.5 Alternate Configuration - 16 Jet RCS

A 16-jet RCS configuration was considered as an alternate (see Paragraph 5.4). If this system were selected then no changes to the LGC jet logic would be required. However, it may be desirable to have jet-failure descretes sent to the LGC for the unmanned Shelter mission. The need and extent of change in the LGC software and interfacing would depend on the MIT LEM logic when it is defined.



Abbreviations

RCS:	Reaction Control Subsystem	GDA:	Gimbal Drive Actuator
IMU:	Intertial Measuring Unit	DECA:	Descent Engine Control Assy
CDU:	Coupling Data Unit	ACA:	Attitude Control Assy
PSA:	Power Servo Assy	DSKY:	Display & Keyboard
PTA:	Pulse Torque Assy	PCA:	Program Coupler Assy
LGC:	LEM Guidance Computer	ATCA:	Attitude Translation Control Assy

Fig. 5.3-1 Guidance Navigation & Control Subsystem

5.4 RCS AND PROPULSION

5.4.1 Ground Rules

The following ground rules were applicable to this area:

- An 80-n.mi Hohmann descent shall be the primary mode of descent to the lunar surface
- Direct, fully-powered descents will be studied as alternates to the primary mode.

5.4.2 Assumptions and Background Data

The RCS and propulsion subsystems were developed based on the following assumptions:

- Ascent propulsion system has been deleted
- RCS propellant requirements for the Shelter descent are roughly the same as the present LEM, and may be somewhat less if the direct descent trajectory without hover phase is selected
- Maximum RCS propellant requirements are estimated to be 140 lb usable. New trajectory data are not expected to result in significant changes in propellant loading
- LEM descent propulsion system is capable of performing the descent phase of the Shelter mission
- Descent helium pressurant will warm up to the level of the relief valve pressure setting within 24 hr after landing. (Concern over the resultant uncontrolled venting has led to study of alternate methods of venting.)
- Vent valves are also recommended for the RCS to guard against overpressurization resulting from regulator leakage during the long lunar stay.

5.4.3 Recommended Configuration

5.4.3.1 RCS

Since crew safety is not a consideration during descent, only one of the two separate and independent RCS systems, System B, is retained on the Shelter. This consists of one set of helium and propellant tanks and eight thrusters (Fig. 5.4-1 and 5.4-2). In addition, one set of propellant manifolds, ascent system interconnect valves and filters, as well as crossfeed valves have been eliminated, thus, resulting in system simplification.

The deletion of eight thrusters, in addition to minimizing jet impingement problems and Shelter heat losses, make possible an increase in external payload volume. The thruster isolation valves have also been eliminated. These are normally used to prevent loss of propellant when a malfunction occurs in a thruster or thruster control valve. Since malfunction detection and isolation valve control requires action by the astronaut, their presence on the vehicle serves no useful purpose. Mission success reliability of the RCS has been evaluated considering the complete eight-jet subsystem, and compared with the descent phase of the LEM. For this comparison, a single failure results in a mission failure in either case, and the crew safety abort provisions of the LEM were not considered. The resultant reliability is 0.9757 for the Shelter and approximately 0.96 for the LEM descent phase.

This small difference is not considered significant except to indicate the approximate equality of the LEM and Shelter systems.

Squib-actuated vent valves will be added, one in parallel with each pressure relief valve, to depressurize the helium and propellant tanks after landing. This addition will prevent possible catastrophic failure of the tanks because of micrometeoroid penetration or overpressurization from a simultaneous malfunction of a regulator and a relief valve. Recent information generated under a NASA sponsored research program (Ref. 5.4-1) indicates that no hard blockage problems will occur in a vent line discharging propellant vapors and/or propellants into a vacuum. Thus the vent line should operate even if tank bladders leak, and the addition of vent line heaters to prevent freezing and blockage need not be considered.

Actuation of the vent valve will release helium to the lunar vacuum. When the system has drained down to the vapor pressure of the propellant, boiling will take place inside the bladder, releasing vapor and recycling the bladder outward until it reaches the tank wall where, being physically restrained, the boiling will stop. Permeation of propellant through the bladder is expected to release only an unnoticeable quantity of vapors into the lunar atmosphere. A tank pressure of 25 psia, corresponding to a propellant temperature of 90°F, is the maximum anticipated. If a problem in recycling the bladder is found, it will be a simple modification to incorporate a pressure regulating valve in the helium dump line set for a maximum of 40 psia. The propellant will consequently never boil and the bladder will not be recycled.

Other arrangements were studied in Phase A which involved dumping the remaining propellant as well as the helium onto the surface of the Moon. However, the problems associated with the frozen propellant snow (assuming an astronaut might approach the Shelter through a field of frozen oxidizer or fuel) and keeping lines from freezing while dumping propellants into a vacuum led to a reevaluation of the procedure. The proposed solution is simpler and cheaper (two squib valves vs four) and requires no electrical power for heaters or concern about proper sequencing of events.

Cluster covers will not be required to prevent heat loss from the Shelter, since heat energy made available from the RTG power supply will adequately compensate for heat losses during the quiescent storage period.

5.4.3.2 Descent Propulsion

The Shelter descent propulsion will be the same as in the LEM except for the added vent valves which will be used to depressurize the helium and propellant tanks following lunar landing (Fig. 5.4-3). As shown, two low-pressure relief valves are used in series with the propellant tank vent valves to limit the quantity of propellant vapors which are vented to the lunar atmosphere.

The use of vent valves to depressurize the descent helium and propellant tanks is dictated by safety considerations. The use of three vent valves is necessitated by the low temperature of the supercritical helium. Venting the supercritical helium through the propellant tank vent valves would freeze the propellant vapors and might eventually clog the vent line. The sequence of operations is venting of the supercritical helium tanks, followed by venting one set of propellant tanks and then the other. Since the Shelter is unmanned, the venting must be accomplished automatically or by command link.

The primary safety concern is a catastrophic failure of the helium or propellant tanks. Tanks may fail in at least two ways. One is an increase in tank pressure combined with a failed-closed relief valve. It is estimated that the tank pressure will increase to the level of the relief valve pressure setting within 24 hr, as a result of the rise in temperature of the cold pressurizing helium gas. The second means of catastrophic failure is micrometeoroid penetration of a tank with an internal pressure greater than 40 psi. (Based on the tank geometries and material, 40 psi was established as a conservative estimate of the pressure level at which no crack propagation will occur if the tank is punctured.)

A secondary safety factor is the possible contamination of the astronaut's garments with propellants as a result of uncontrolled (random) venting, when the astronaut is on the lunar surface and in close proximity to the vehicle. During the lunar day, the oxidizer vapors could react with the garment material, possibly causing injury. Fuel vapors, clinging to the material, may subsequently contaminate the breathing oxygen when the astronaut re-enters the vehicle. The conditions associated with the lunar night are discussed below.

These considerations require a low-pressure relief valve in series with each of the propellant tank valves. As originally conceived, the tank pressure was to be reduced to lunar atmospheric (vacuum). The reduction in pressure causes propellant boiling and a corresponding reduction in temperature, eventually freezing the propellant bulk. Heat flow from the vehicle structure will then slowly vaporize the frozen propellant, with the vapors flowing overboard through the vent valves, thus presenting the same contamination problem discussed above. As a result, a low-pressure relief valve has been added to limit the quantity of propellant vapors which are vented to the atmosphere. The relief valves are set at 40 psia (maximum), the estimated "safe" pressure level for the tanks. The nominal relief valve reseat pressure is 30 psia.

The phenomenon of liquid/vapor forming "snow" when vented into a vacuum (Ref. 5.4-1) has led to the final design consideration for the vent system. This phenomenon also presents a contamination problem similar to that discussed above. The lunar-night low temperature prevents the "snow" from vaporizing and dispersing. Thus, the lunar surface can be covered with a layer of propellant "snow" which can be tracked into the vehicle on the astronaut's shoes. Therefore, it is desirable to confine the vented propellant into an area which the astronaut will not traverse, such as the area directly below the descent stage. Further studies are required to be certain that the vented propellants will not disperse beyond the perimeter of the descent stage. The possibility of venting the propellants into their respective tank bays is also being explored. The available volume in the bays is sufficient to hold the vented propellant. Problems of sealing adjacent oxidizer and fuel tank bays and compatibility of materials within the bays have not yet been explored. Investigations into these problem areas will be conducted during Phase C.

5.4.4 Baseline Configuration

The baseline configuration assumed a single descent-engine firing from low-altitude orbit. The recommended configuration assumes a descent similar to the LEM. Preliminary studies have indicated the RCS and descent engine subsystems as recommended above would be adequate for either trajectory.

5.4.5 Alternate Configuration - 16-Jet RCS

A 16-jet RCS was considered (Fig 5.4-4) utilizing single pressurization and propellant feed sections with ascent interconnect valves removed. The mission success reliability of this configuration is 0.9817. Retention of all 16 jets results in minimum hardware and software changes from the LEM. However, the plume of System A jets will impinge on such items as tanks and radiators. It is not known whether this impingement could be tolerated, or whether these components would have to be relocated.

5.4.6 Alternate Configuration - Methods of Venting Descent Propellant Tanks

Alternate methods of preventing the contamination problems discussed above were investigated.

- The possibility of decomposing the propellant into non-toxic, low freezing-point gases was explored. Other than burning with a fuel, no means of decomposing the oxidizer was found. The use of Shell Catalyst No. 405 to decompose the fuel was investigated. The manufacturer provided the information that the 50-50 fuel combination has been satisfactorily decomposed using the catalyst. However, no attempt to analyze the decomposition products has been made. Investigation into this possibility will be continued in Phase C.
- A brief investigation into the possible use of a fused quartz helium diffusion cell to separate the helium and propellant vapors was made. The fused quartz, being permeable to helium, will allow it to vent overboard while retaining the propellant vapors. These brief investigations indicate possible problems in regard to the size and weight of the diffusion cells. Further investigations into the size, weight, flow capacity, and material compatibility of the diffusion cell are required.

5.4.7 Potential Modifications per Flight

No per-flight modifications were considered for the Shelter.

5.4.8 Discussion of Configuration Choices

The eight-jet RCS was selected for the recommended Shelter configuration for the following reasons:

- Capable of providing required control functions
- Simplified configuration (67-lb weight reduction)
- Reduced potential plume impingement problems.

A reliability analysis made of both the eight and 16 jet configurations resulted in mission success reliabilities of 0.9757 and 0.9817, respectively. Both of these configurations have higher reliabilities than the LEM, because of lack of crew safety requirements and elimination of one set of tanks. The increased mission success reliability for the 16-jet configuration results from the ability to compensate for certain jet failures. However, it was not obvious that the increased reliability offset the potential plume impingement problem.

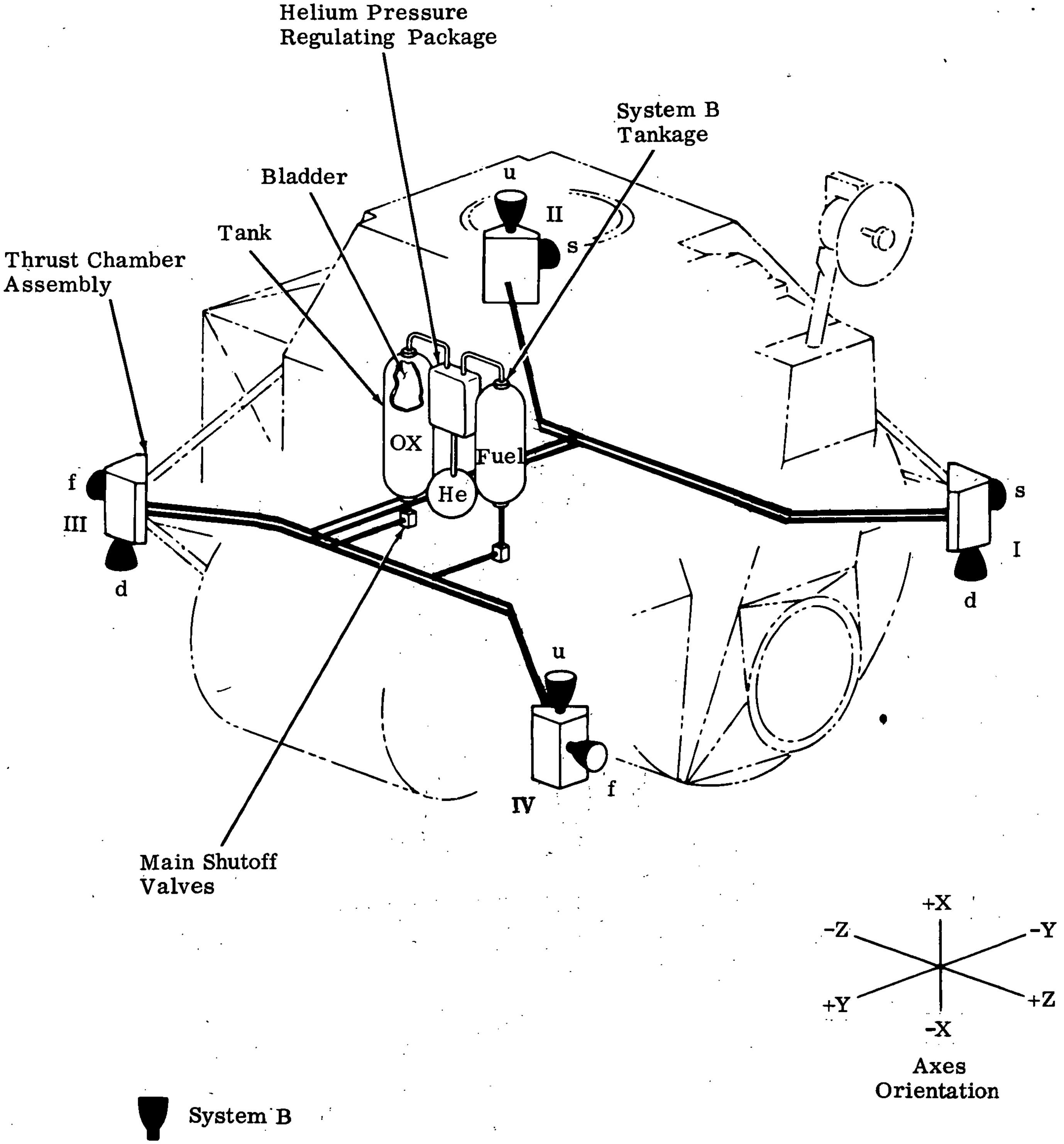
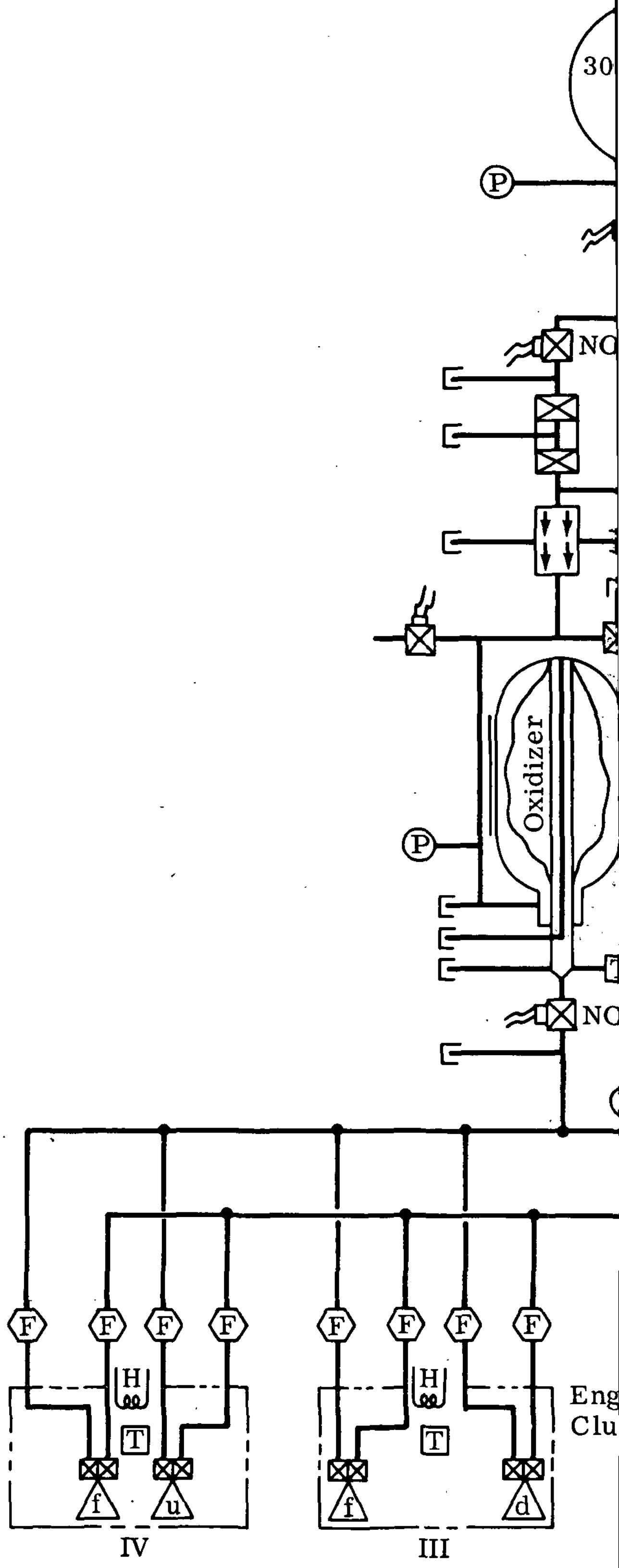


Fig. 5.4-1 8 Thruster RCS General Arrangement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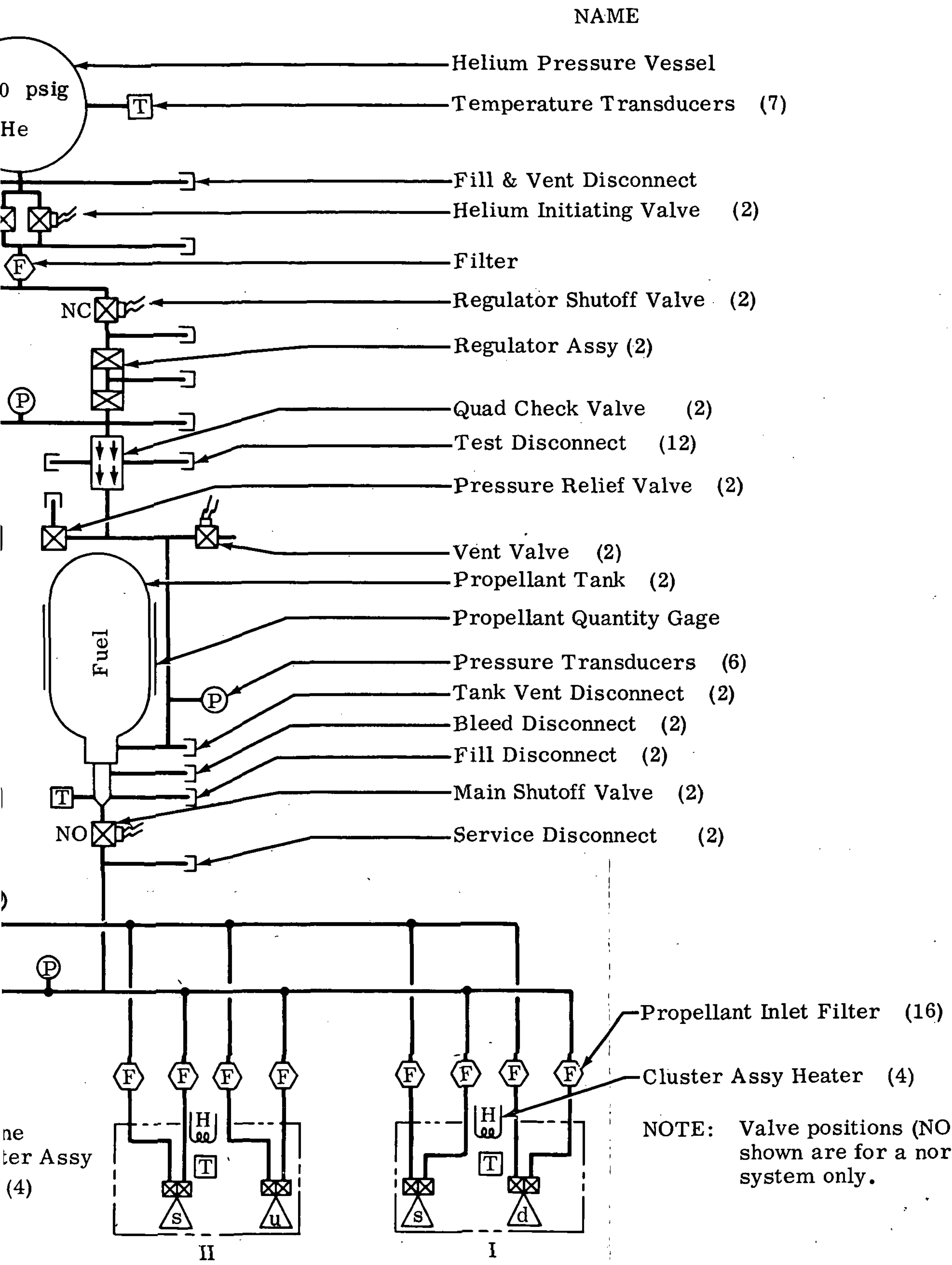


NOTE: Valve positions (NO-open, NC-closed) shown are for a normally operating system only.

Fig. 5.4-2 8 Thruster Reaction Control System

Legend

1 Pressure Relief Valve (3)
2 Fill Disconnect (3)
3 Pressure Transducer (2)
4 He Initiating Valve
5 Liquid Level Transducer
6 Vent Disconnect (3)
7 He Pressure Vessel
8 Heat Exchanger
9 Filter
10 Regulator Shutoff Valve (2)
11 Regulator Assy (2)
12 Test Disconnect (9)
13 Quad Check Valve (2)
14 Vent Valve (3)
15 Diffuser (4)
16 Propellant Tank (4)
17 Temp Transducer (5)
18 Low Level Sensor (4)
19 Trim Orifice (2)
20 Propellant Inlet Filter (2)
21 Descent Engine Assy
22 Low Pressure Relief Valve (2)
23 Isolation Valve (4)

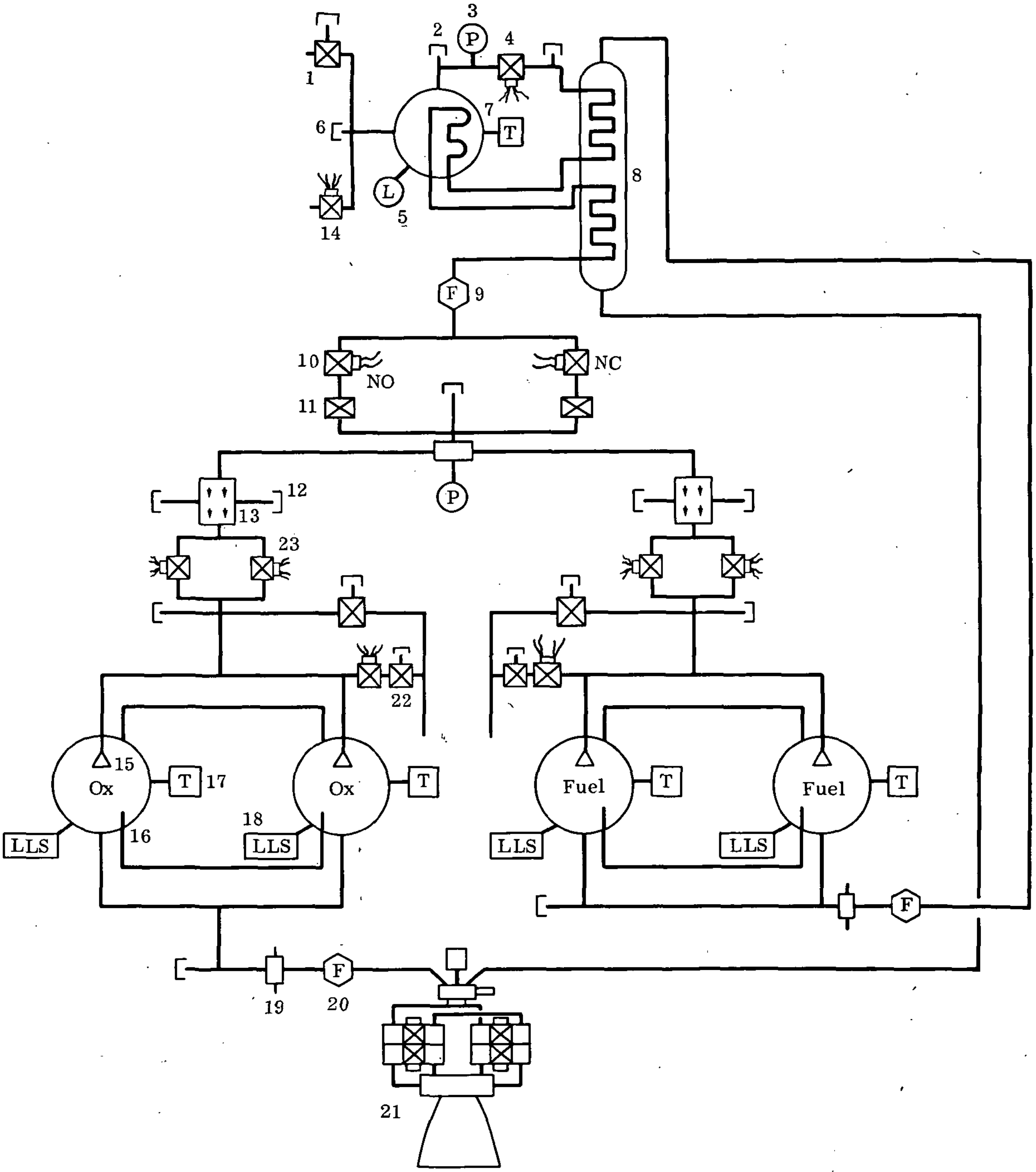
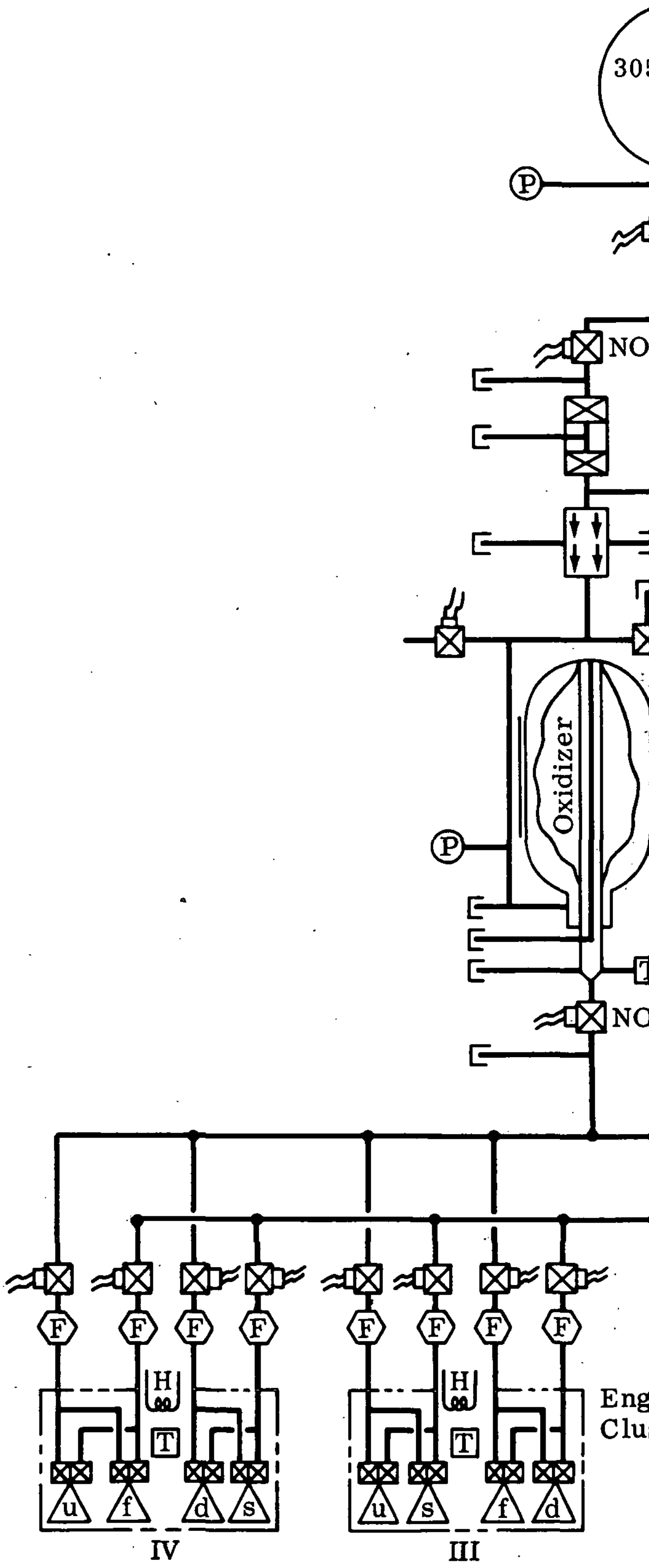


Fig. 5.4-3 Descent Propulsion System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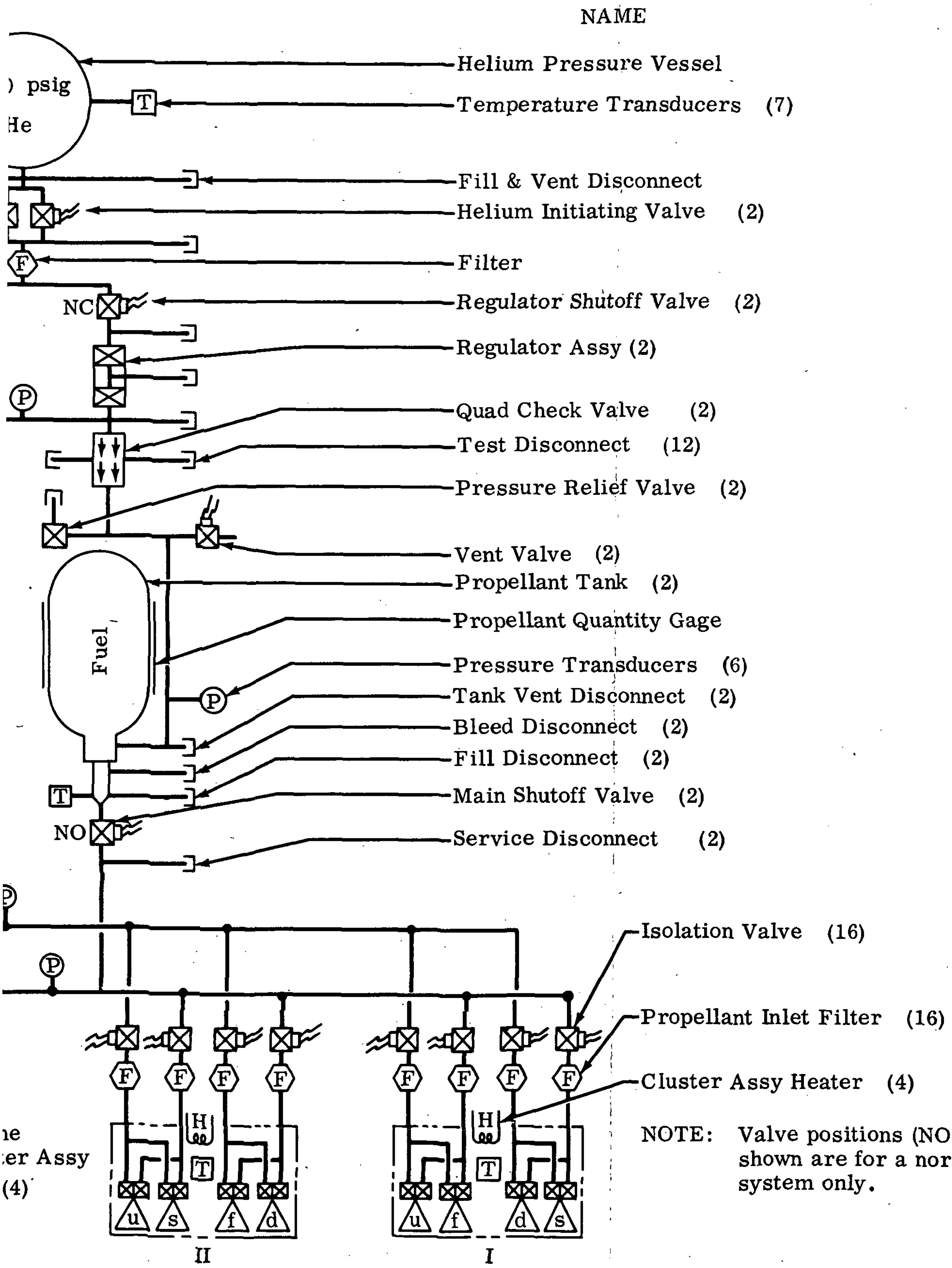


NOTE: Valve positions (NO-open, NC-closed) shown are for a normally operating system only.

Fig. 5.4-4 Reaction Control System - 16 Thrusters

5.5 COMMUNICATIONS

5.5.1 Ground Rules

There are no NASA ground rules unique to Shelter communication subsystem.

5.5.2 Assumptions and Background Data

The Shelter communications function is to provide:

- Communication links to Earth, CSM, and the astronaut on the lunar surface
- Processing and transmission of housekeeping and bio-medical data to Earth
- Aid in tracking and ranging during the lunar landing phase
- Command and data uplink during the unmanned mission phases.

The assumptions used during the study are as follows:

- No communications is required during launch, translunar flight, and lunar orbit insertion
- After separation in lunar orbit from the CSM and prior to Earth acquisition on S-band, status data will be transmitted to the CSM via VHF for storage and transmission to Earth during the CSM-Earth LOS
- S-band antenna is to have automatic acquisition of Earth station
- Continuous status data transmitted during descent and post-landing checkout
- Shelter status monitoring during unmanned mission phases is controlled by Earth command
- Status data, during storage, will be monitored once per day
- TV, if required, is a part of the scientific payload
- No communications interface with scientific experiment payloads
- EVA/Shelter VHF communication via PLSS is limited to the LOS capability of the existing LEM equipment.

In addition, it is assumed that the Earth station can provide adequate communications with all the major components of the Shelter/Taxi mission, and the circuit performance margins of the LEM Communications Subsystem satisfies the missions requirements.

5.5.3 Recommended Configuration

The Shelter communications requirements for S-band, VHF, and transponder activity are shown in Table 5.5-1 for the various mission phases extending from launch to rendezvous at completion of the mission. The communication interface between the various elements of the mission are shown in Table 5.5-2 and figure 5.5-1. The present LEM Communications Subsystem will, in general, satisfy these activities with minor modifications and the addition of some new equipment. A block diagram of the recommended configuration is shown in Fig. 5.5-2. The modifications and new equipment requirements are summarized in the following paragraphs.

5.5.3.1 Command Receiver

To receive commands during the storage period, the S-band receiver must be in an active mode. A recent change on the LEM S-band transceiver removed the receive-only capability, and rather than maintain the complete S-band transceiver in an active mode for the entire storage period, a command receiver is added to the existing LEM Communication Subsystem. This receiver receives on S-band continually during the unmanned portion of the Shelter mission and accommodates the following commands:

- Turn on transceiver - select primary transceiver
- Turn on transceiver - select secondary transceiver
- Turn off transceiver.

Other commands are handled via the transceiver and the decoder. The ability to select the primary or secondary transceiver was included to avoid modification of the transceiver to implement an on-board failure detection and correction device.

5.5.3.2 Command Decoder

A command decoder is added to receive the up-date link 70-kc subcarrier from the S-band transceiver. Demodulation, validation, decoding, and routing of the received commands takes place within this assembly. Outputs to the LGC and PCA, in addition to discrete signals, are provided.

The up-link command will have the same message format for the Shelter as for the Apollo CSM. The vehicle address bits and up-link carrier frequency will differ for the two vehicles, but the command capability of the ground stations will otherwise be compatible with the Shelter up-data link.

5.5.3.3 S-band Transceiver

The S-band transceiver is modified to provide an output line for the up-data link subcarrier on 70 kc. Interfaces are provided to allow the command receiver to switch the transceiver on and off, and to provide selection of the primary or back-up S-band transceiver.

5.5.3.4 RF Antenna Switch

Antenna selection on the recommended Shelter configuration is made through the Earth command up-link.

5.5.3.5 S-band Steerable Antenna

Shelter status data transmission is required from separation to lunar touchdown. These data are transmitted to the CSM via VHF at 1600 bps until Earth/Shelter S-band system lock-on is obtained. The S-band antenna assembly does not have automatic search capability; however, it does have an automatic track mode.

The recommended configuration utilizes an X-Y scanner to automatically initiate S-band antenna Earth acquisition and to re-acquire the Earth in the event the S-band link is interrupted during either the descent or storage phase. A discussion of the X-Y scanner is included in Paragraph 5.3.

5.5.3.6 Transponder Antenna

The optimum transponder system should consist of a point source with hemispherical radiation used in conjunction with a highly directional radar antenna. The most feasible system for the Taxi/Shelter mission is the rendezvous-radar/transponder system presently intended for the Apollo missions. This approach requires the incorporation of the CSM transponder electronics and antenna assemblies into the Shelter and the retention of the rendezvous radar on the Taxi.

The angular coverage provided by the CSM transponder antenna is shown in Fig. 5.5-3. At angles close to the horizon, the radiation level varies between -1 and -15 db. Therefore, for mission trajectories within these angles, the rendezvous-radar/transponder performance will be degraded from 400 to 70 n.mi maximum range.

5.5.4 Baseline Configuration

The baseline configuration differs from the recommended in that no provisions were made for the automatic X-Y scan of the S-band steerable antenna, nor were provisions made for a 70-kc output from the S-band transceiver to the command decoder. In addition, it was assumed that the S-band transceiver could be operated in a receive-only mode; therefore the command receiver was not included.

5.5.5 Alternate Configuration - Modify S-band Transceiver for Receive-Only Mode

As an alternate to including a separate command receiver to turn on the S-band transceiver, the existing transceiver could be modified to provide a receive-only mode of operation with failure detection and correction. The disadvantage of this alternate is that extensive modification is required to the existing LEM equipment. It also requires the receiver to operate for approximately 104 days. The command decoder section is the same as in the recommended configuration and is shown in Fig. 5.5-2.

5.5.6 Alternate Configuration - S-band to UHF Converter

A second alternate to the command receiver approach is to use the LEM-1 Digital Command Assembly (DCA), which operates on UHF, together with a S-band to UHF converter (Fig. 5.5-4). This alternate was not selected because it requires more power during the storage period than the recommended system and does not represent a weight saving.

5.5.7 Alternate Configuration - Coupled S-band Omni-Antenna System and Switching Matrix

The recommended configuration employs an up-data command link which is required to be operational from separation until completion of the mission. The command link acts as a backup for on-board programming from separation until the start of the storage period, and is the prime sequencer during the storage period. The up-link command system is used to modify the mode of the receiving chain, which includes selection of S-band antenna (i.e. Omni 1, Omni 2, or steerable). If an inactive antenna is selected, the up-link would be disabled and all command control lost.

As an alternate approach, an independent automatic antenna switching matrix could be provided. The command receiver is normally connected to the omni-antenna system which is also used for transmission in a contingency role. If the omni system is required for such a contingency, a command via the PCA will connect the S-band transceiver to the omni system, and, after a predetermined time interval, switch the antenna back to the command receiver to re-establish the up-link.

The omni-antenna system consists of two independent log conical spirals mounted on the LEM ascent stage, one forward along the +Z axis, and one aft along the -Z axis. Each antenna theoretically provides hemispherical radiation on each side of the vehicle. Consequently, the composite coverage is spherical in nature. At present, however, these antennas are not coupled, and selection of one for operation is made by the astronaut. Coupling these S-band omni antennas will allow reception of Earth commands and transmission of status data independent of vehicle attitude.

A system of coupling the two antennas can be developed. Systems of two, three, and four in-flight antennas were studied analytically to determine their radiation characteristics. For each system the antennas were distributed symmetrically about the Shelter. A typical log conical spiral antenna pattern was used as the common radiation characteristics of each antenna. Utilizing ray theory and vector summation, distribution patterns were derived. The nonuniform boundary conditions caused by the vehicle were not included in the analysis.

Figure 5.5-5 illustrates the ideal situation wherein the transition from the use of one antenna to two results in a 3-db loss in gain because of the power division. A computer program is available and being used to determine the pattern envelope in more detail and accuracy over the regions 260 deg $< \phi <$ 280 deg, and 80 deg $< \phi <$ 100 deg. Some pattern scalloping should be realized in these regions. Determining the nature and extent of the scalloping requires the vector summation to be taken over finer intervals of 1 deg, whereas 5 deg intervals were chosen for the initial analysis.

5.5.8 Potential Modification Per Flight

The location of antennas on the recommended configuration were assumed to be the same as the LEM. However, the integration of payloads and radiators can cause interferences to these antennas. Particularly with the S-band steerable antenna located on the ascent stage along the +Y axis.

On one of the five missions described by NASA/MSFC, two LSSM's are to be integrated with the Shelter. These vehicles would be carried attached to each side of the ascent stage. This would require relocating the S-band steerable antenna on this mission.

Table 5.5-1

SHELTER COMMUNICATIONS REQUIREMENTS

Mission Phase	S-Band				VHF		
	Telemetry HI	Telemetry LO	Ranging	Voice/Bio	Voice/Bio	Data	Transponder
1. Shelter Launch-Translunar flight and lunar orbit insertion							
2. Lunar Orbit-Shelter separation and descent to Moon	X		X			X	
3. Lunar Touchdown and Post landing verification	X						
4. Shelter Lunar Storage	X*	X*					
5. Taxi Mission Commitment Taxi Launch - Translunar Flight	X						X
6. Lunar Orbit - Taxi separation and Descent to the Moon	X						X
7. Lunar Touchdown and Post landing checkout, securing of Taxi	X			X	X		X
8. Astronauts operate from Shelter, Taxi on Standby	X			X	X		
9. Completion of Shelter operation, transfer to Taxi, Prelunar lift off checkout, Lunar lift off & docking with CSM							

* Selection of high or low bit rate by Earth command.

Table 5.5-2
SHELTER COMMUNICATIONS INTERFACES

RECEIVE

TRANSMIT	CSM	Shelter	Taxi	LSSM	2nd LSSM or MFS	EVA (Note 1)	Earth
CSM		• V:f_7, f_8 A4-A1 • VVER:f_1, f_3 A6-0-A2, A3	• V:f_7,f_8 A4-A1 • VVER:f_1, f_4 A6-0-A_2, A3	• VVER:f_1,f_5 A6-0-A10	• VVER:f_1,f_6 A6-A0-A9	• VR-S/T:f_7,f_8 A4-A1-A8 A4-A7-A8	• V&D:f_1 A6-0 • TV:f_2 A6-0
Shelter	• D:1.6kb/sec V:f_7, f_8 A7, A1-A4 (Note 5) • VVER:f_3, Shelter, f_4 Taxi, f_1 A2, A3-0-A_6		• V:f_7,f_8 A1-A1 • X-Bd Xpndr	• LOS V:f_7,f_8 A1, A7-A8 • VVER: f_3,f_5 A2, A3-0-A10	• LOS V:f_7,f_8 A1-A7-A8 • VVER:f_3,f_6 A2, A3-0-A9	• V:f_7, f_8 A1, A7-A8	• V&D:f_3,A2 A3-0
Taxi		• V:f_7,f_8 A1-A1 • RR		Same as Shelter except VVER f_4, f_5	Same as MFS except VVER f_4, f_6		• V&D:f_3,A_2 A2, A3-0
LSSM	• VVER:f_5, f_1 A10-0-A6	• LOSV: f_7,f_8 A8-A1, A7 • VVER:f_5, f_3 A10-0-A2, A3	• LOSV;f_7,f_8 A8-A1, A7		• LOSV:f_7, f_8 A8-A8 (Rescue)	• LOSV f_7,f_8 A8-A8	• TV, D&V:f_5 A10-0
2nd LSSM or MFS	• VVER:f_6, f_1 A9-0-A6	Same as LSSM except VVER:f_6,f_3 A9-0-A2, A3		• LOSV:f_7,f_8 A8-A8 (Rescue)			• TV, D&V:f_6 A9-0
EVA (Note 1)	• VR-S/T: f_7,f_8 A8-A1, A7-A4	• V:f_7, f_8 A8-A1, A7		• LOSV:f_7, f_8 A8-A8			• VR-S/T:f_7, f_8, f_3, f_4 A8-A1, A7-A2, A3-0 f_7, f_8, f_3, f_4
Earth	• V:f_1 0-A6	• V:f_3 0-A2, A3	• V:f_4 0-A2, A3	• V:f_5 0-A10	• V:f_6 0-A9	Same As EVA to Earth	

NOTES

1. EVA Astronaut Not Aboard LSSM or MFS
2. S-Band Frequencies Are:

CSM	Shelter	Taxi
f_1 - Voice Data	f_3	f_4
f_2 - TV, Data		

o LSSM -f_5, MFS-f_6 (If S-Band is Used)

3. VHF Frequencies f_7, f_8 are common to CSM, Taxi, Shelter, and EVA Astronaut (Backpack).
4. LOS: Line of Sight
5. Shelter & Taxi Data Xmit. At 1.6 KBPS is Used Only On Initial Descent Phase During Earth Communications Blackout.
6. VVER: Voice Via Earth Relay
7. VR-S/T: Voice Relay thru Shelter/Taxi
8. RR: Rendezvous Radar
9. V: Voice, D: Data, TV: Television

ANTENNAS

CSM

A4 VHF Scimitar
A5 S-Band "Notch"
A6 S-Band High Gain

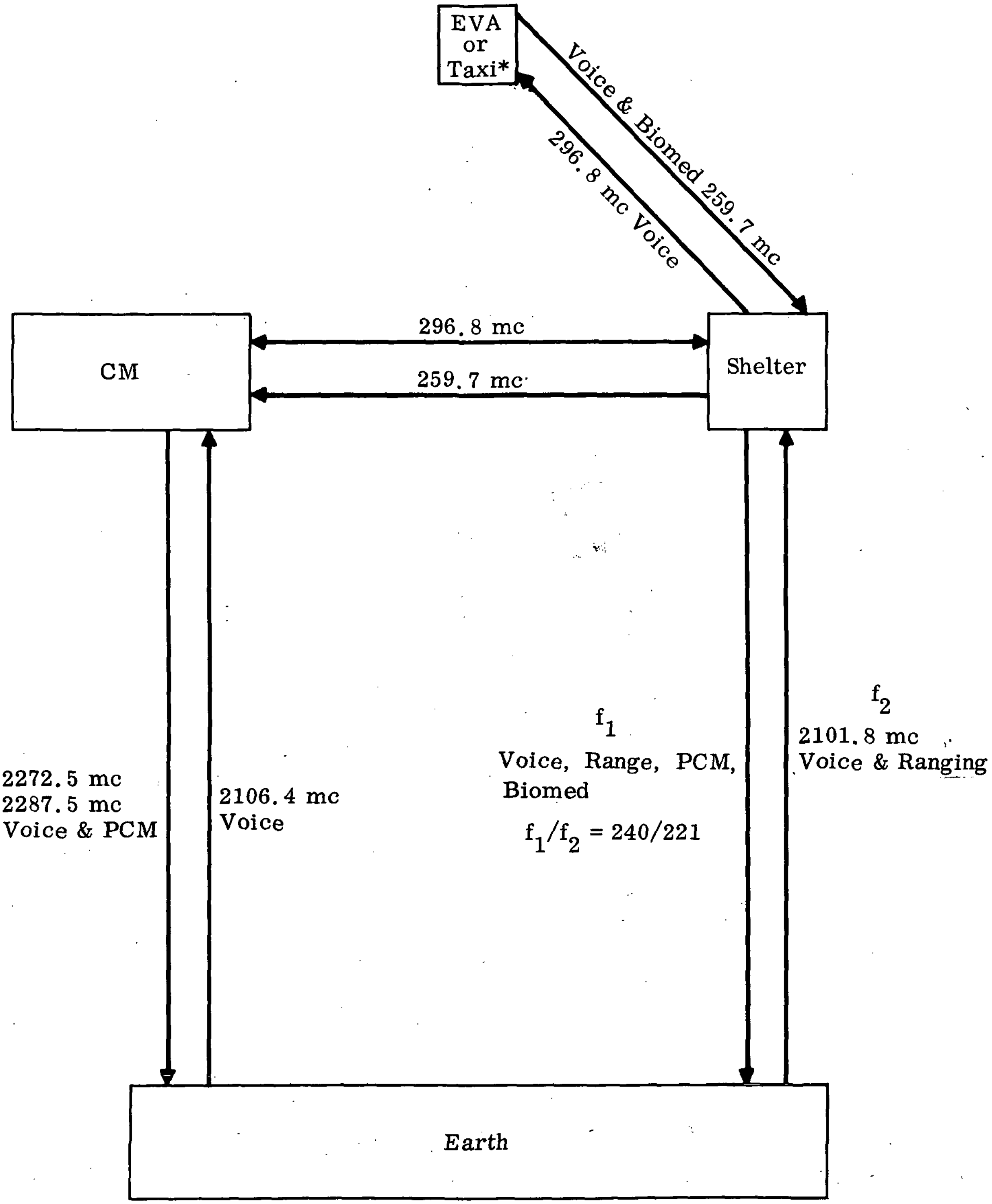
Earth: 0

LEM

A1 - VHF Helix
A2 - S-Band Steerable
A3 - S-Band Erectable
A7 - VHF EVA (Long Dipole)
A8 - VHF EVA Astronaut Back Pact Monopole

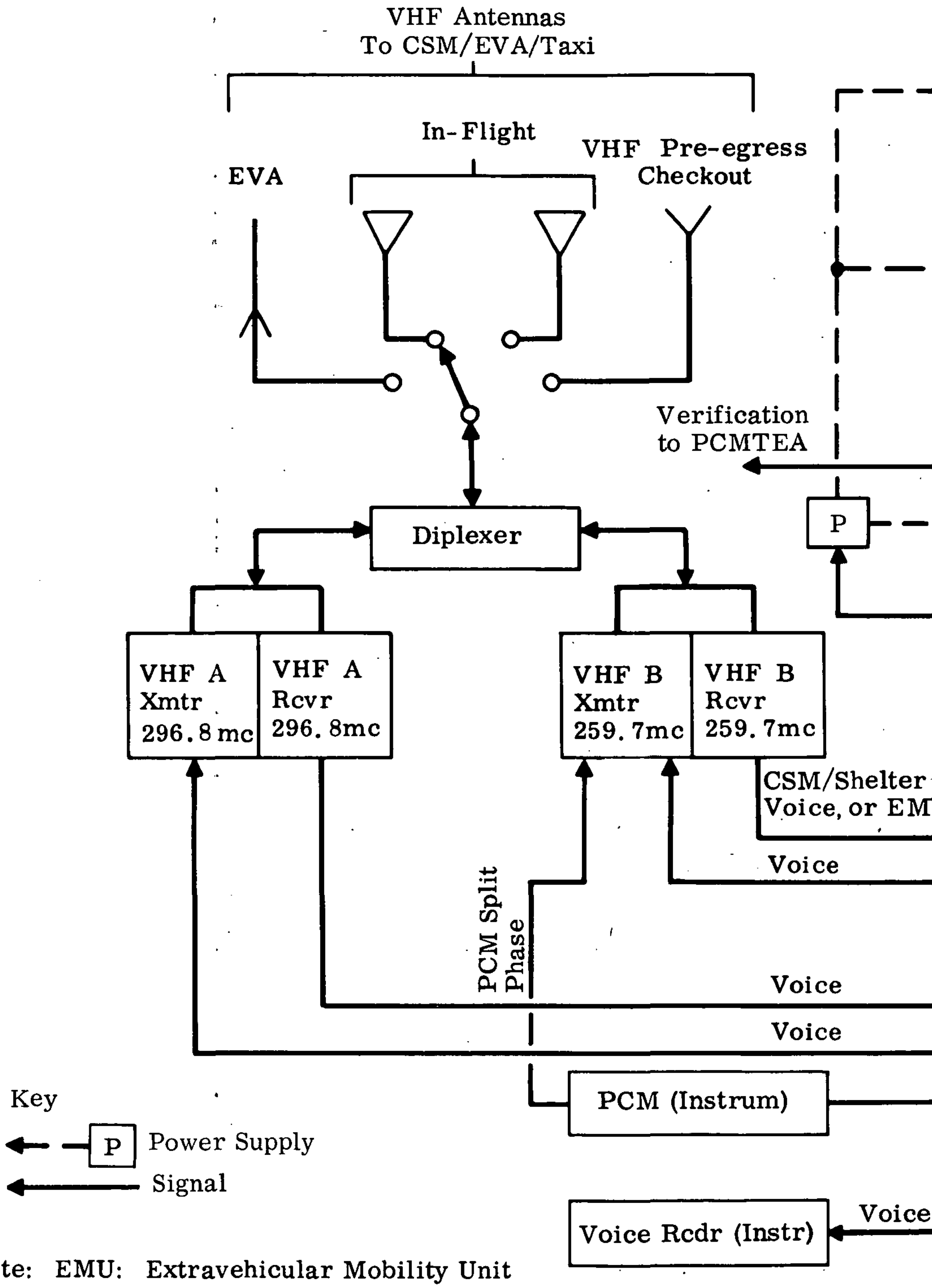
MFS/LSSM

A9 S-Band
A10 S-Band



* Only when Taxi is manned.

Fig. 5.5-1 Shelter Communications Links



Note: EMU: Extravehicular Mobility Unit
- transmits voice & data

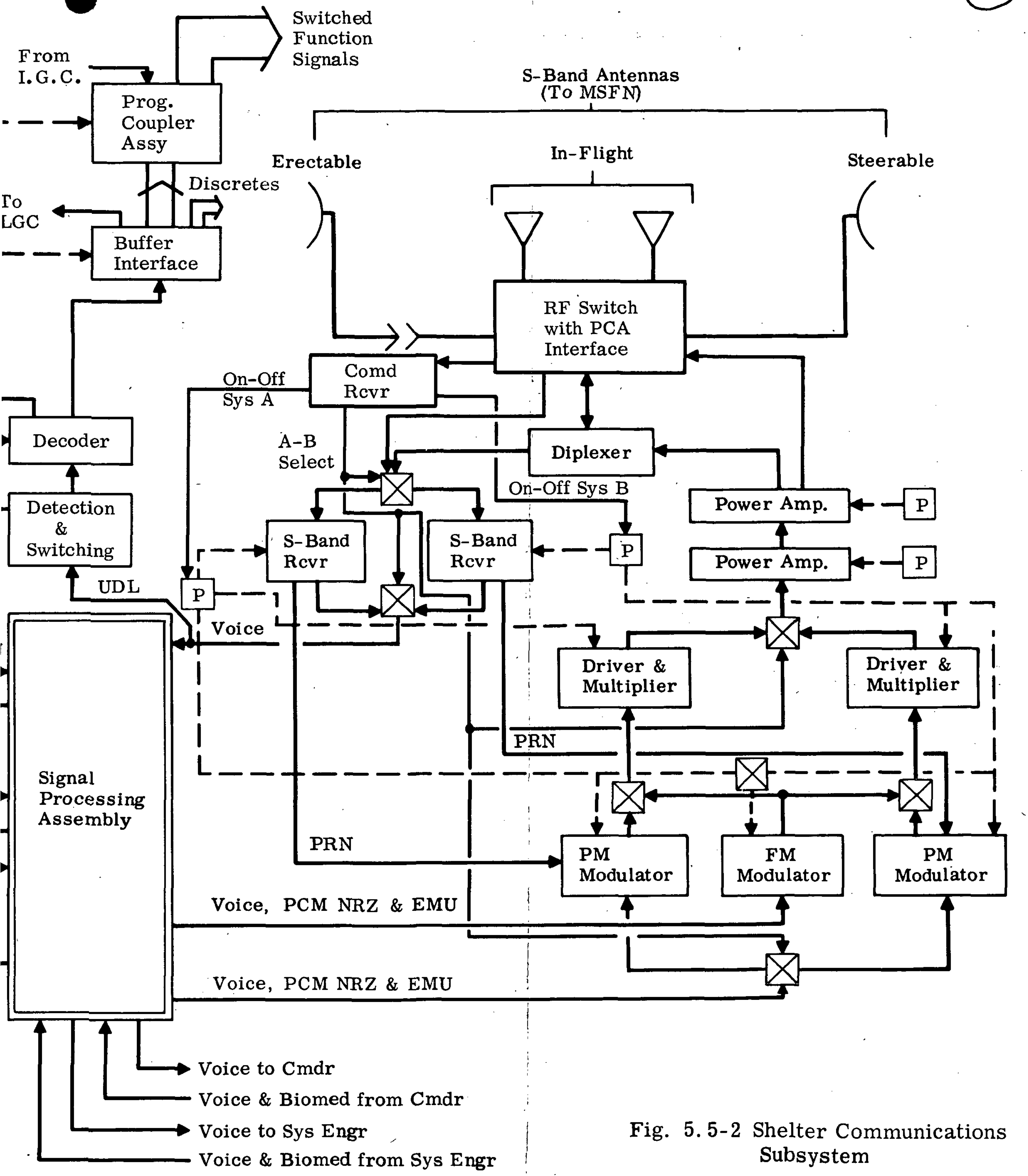
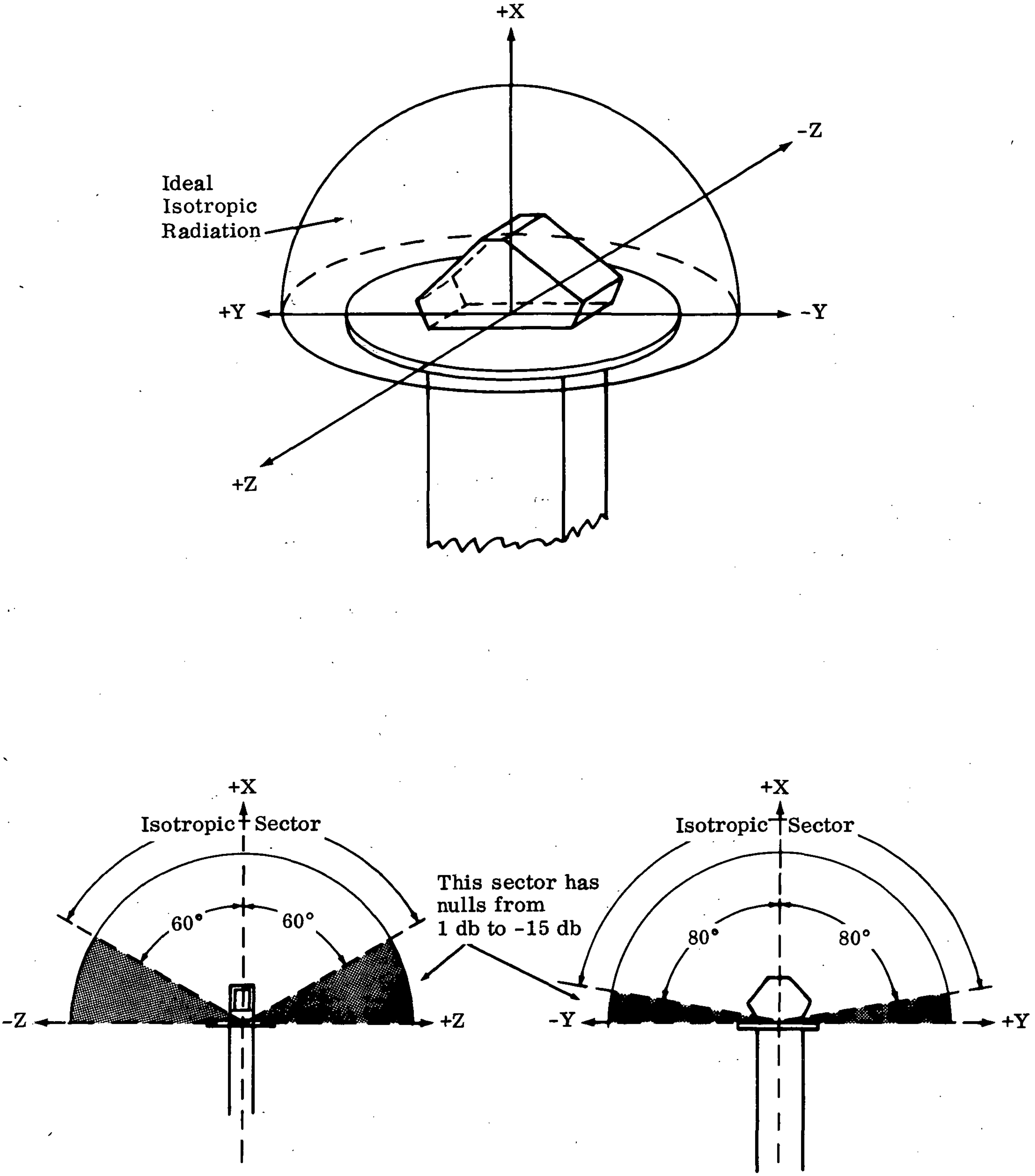


Fig. 5.5-2 Shelter Communications Subsystem



E-Plane Distribution

H-Plane Distribution

Fig. 5.5-3 Transponder Power Level Distribution

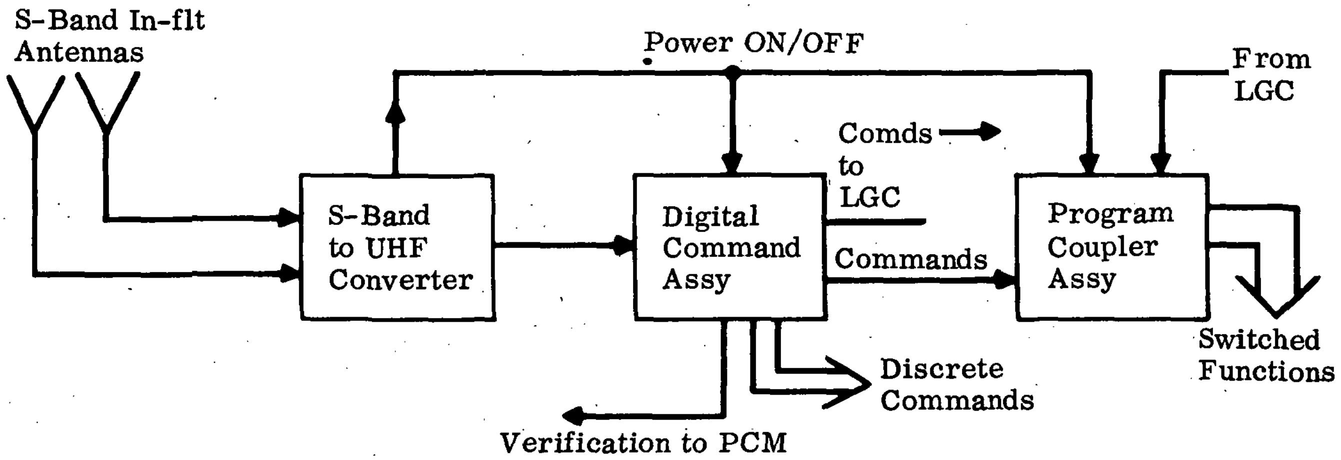
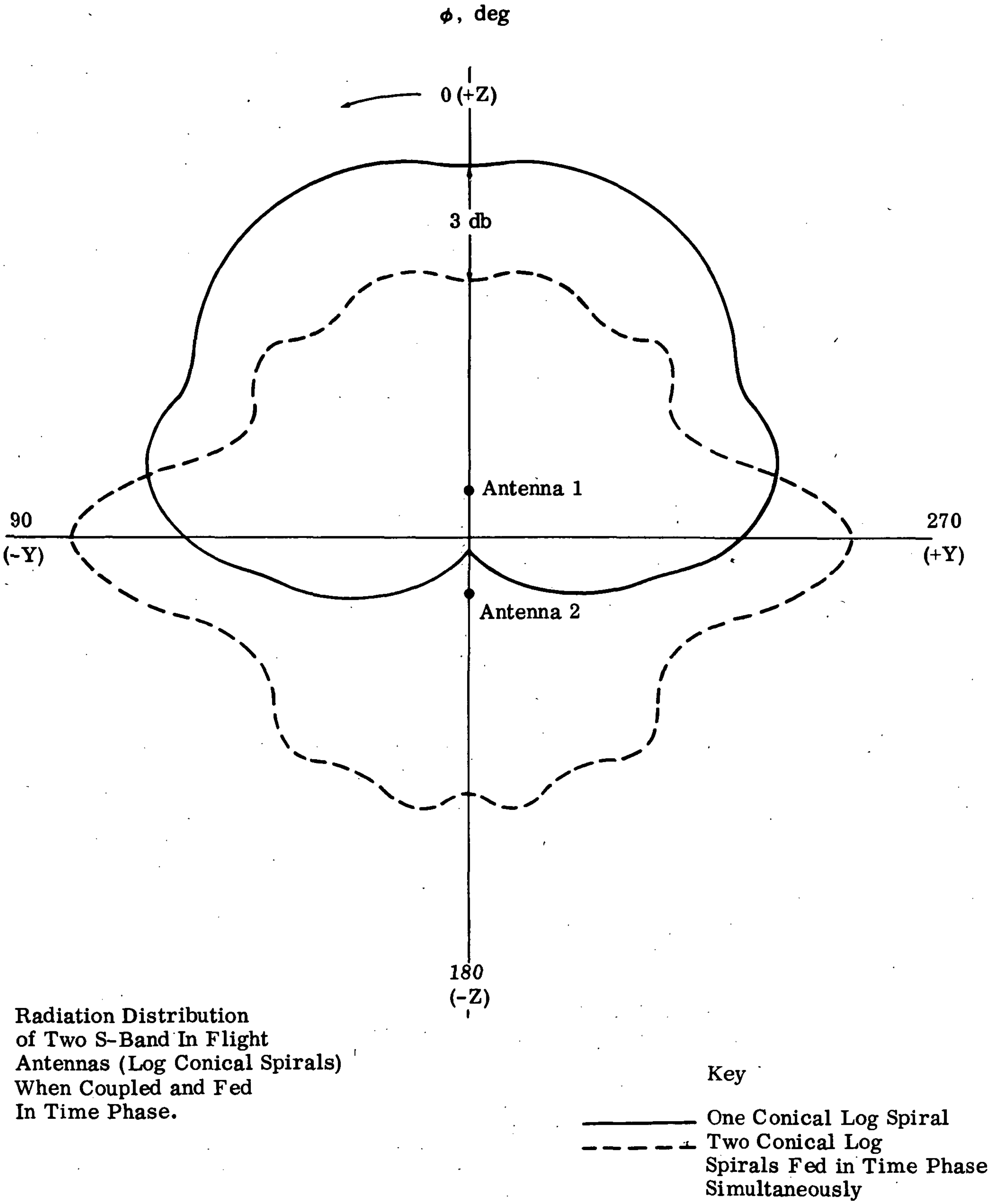


Fig. 5.5-4 Digital Command Assembly - Alternate Configuration



Radiation Distribution
of Two S-Band In Flight
Antennas (Log Conical Spirals)
When Coupled and Fed
In Time Phase.

Fig. 5.5-5 Coupled Omni-Antenna Radiation Pattern

5.6 INSTRUMENTATION

5.6.1 Ground Rules

There were no NASA ground rules unique to the Shelter Instrumentation Subsystem.

5.6.2 Assumptions and Background Data

The primary function of the operational instrumentation section is to acquire and present spacecraft housekeeping data to the astronauts and ground monitoring personnel. In reviewing the measurement requirements of the Shelter, it was concluded that the existing LEM would continue to fulfill this task. However, the excess capacity available for experiment support is limited. This is consistent with the missions as defined by NASA, since the primary experiment data handling is included in the payload description. The following assumptions were used in standardizing an approach for the operational acquisition section of the Shelter:

- Shelter will continue to utilize the existing LEM PCM for operational data
- Shelter will adapt the existing LEM measurements for operational data and any additions resulting from changes in configuration
- Any changes in the operational measurements will not exceed the present LEM measurements for the lunar landing mission
- Maximum utilization of the crew for redudancy monitoring and failure mode corrections/operations will be used
- Safety data will also be carried as vehicle operational data.

5.6.3 Recommended Configuration

5.6.3.1 Spacecraft Operational Section

The recommended operational instrumentation section for the Shelter (Fig. 5.6-1) consists mainly of existing LEM assemblies or components. The existing LEM assemblies have certain built-in flexibility which allows for some minor configuration changes. This flexibility lies primarily with the modular concept of the Signal Conditioning Electronics Assemblies and the input channel interchangeability to the Pulse Code Modulation and the Caution and Warning Electronics Assembly. The measurement list (Table 5.6-6) prepared for the Shelter was reviewed and analyzed to assure that the changed support requirements would still be adequately covered using the existing LEM system. A power and weight summary of the recommended configuration appears in Table 5.6-1.

5.6.3.1.1 Transducers. The transducers convert the physical and electrical phenomena of interest into a usable form for presentation to the astronauts or ground station personnel. These measurements from the various subsystems provide the majority of the input sources to the operational acquisition system. If new spacecraft subsystem measurement requirements demand additional transducers, consideration will be given first to proven units. To date, it is felt that the transducers available from the Apollo Program are capable of making the new measurements identified for the Shelter. These are associated with such items as the RTG heat pipe, the Earth command system used during the quiescent storage, and the fuel cell assemblies. A summary of the parameters to be measured on the Shelter appears in Table 5.6-2. Allocated transducer weight and power consumption is listed on the measurements list (Table 5.6-6).

5.6.3.1.2 Signal Conditioning Equipment. The Signal Conditioning Electronics Assembly (SCEA), as presently designed for LEM, is a unit which conditions the signals from transducers and numerous signal monitoring points throughout the spacecraft and properly routes them to the Pulse Code Modulation and Timing Electronics Assembly (PCMTEA), Caution and Warning Electronics System (C&WEA) or on-board displays. The SCEAs fulfill the following basic functions:

- Acts as a junction and routing assembly for all analog measurements and signals being monitored
- Mechanically supports the signal conditioning subassemblies which condition the measurement input signals.

The SCEA consists of two separate chassis assemblies. Each assembly can accommodate up to 24 separate subassemblies. The measurements list (Table 5.6-6) reflects deletion of some existing LEM measurements and the addition of new measurements required for the Shelter. A review of this listing indicates that the changing measurement requirements can still be accommodated within the existing SCEA using adaption techniques presently employed by LEM. Based on the measurements summarized in Table 5.6-3, it is anticipated that there will be no modification to the assembly as now used by LEM. However, the units will require rewiring of the input-output routings and a new configuration of subassemblies to place the quiescent storage status measurements on the same SCEA.

5.6.3.1.3 Caution and Warning Equipment. This assembly advises the astronauts of the spacecraft subsystem status by continually monitoring critical parameters. During the mission, the C&WEA performs two basic functions:

- Caution function to advise the astronaut of a malfunction which requires his action to correct
- Warning function to advise the astronaut of crew safety items requiring immediate action.

The C&WEA accepts inputs from the SCEA or pre-conditioned signal sources from the subsystems. These inputs are compared to preset reference signals within the C&WEA to detect out-of-tolerance conditions. When an out-of-tolerance condition exists, an appropriate indication is initiated. The C&WEA, as now used for the lunar landing LEM, operates on discrete voltage changes or switch closures. The analog input channels have preset limits. This unit will continue to support the Shelter requirements in its present configuration.

5.6.3.1.4 Pulse Code Modulation and Timing Equipment. The data acquisition capability of the PCMTEA includes the multiplexing, encoding, and timing of high-level analog, parallel digital, and serial digital data. The number of channels, sampling rates, and word lengths for each of the three data forms are presented in Table 5.6-4. The unit operates at a normal data rate of 51,200 bps, and a reduced data rate, commanded remotely, of 1,600 bps. The PCMTEA will operate as it does in the LEM, including accepting a time reference from the LEM Guidance Computer and providing various timing signals to interfacing subsystems. The NRZ(C) data output is routed to the Communications Subsystem for real-time transmission.

5.6.3.1.5 Voice Storage Recorder. This magnetic tape recorder, originally referred to as the Data Storage Electronics Assembly, provides a time correlated voice recording of comments and conversation between the astronauts during EVA. This assembly employs automatic sequential record head switching with four tracks to provide up to a total of 10 hr of recording time. The compact recorder is generally used with voice actuation circuits to run only for a required recording time. The recorder is used to:

- Support egress from CM to Shelter
- Support EVA
- Record comments of vehicle status when not in contact with Earth
- Record proprietary information.

5.6.3.1.6 Status Bus. During the quiescent storage period of the Shelter, limited data will be transmitted to monitor critical spacecraft data and to advise ground personnel of the active readiness of the vehicle. The status system uses reduced power and gathers only chosen information as indicated on the measurements lists (Table 5.6-6). The limited portion of the operational system which will be activated is as follows:

- Transducers associated with the status monitoring requirements will receive their power through a separate feed
- Only one SCEA will receive power for status monitoring
- PCMTEA will be used during the transmission periods only.

A configuration of the status bus power distribution is shown in Fig. 5.6-2 and an electrical power usage summary is shown in Table 5.6-1. It should be noted that the C&WEA, the voice storage recorder, and approximately half the transducers and signal conditioners are off during the storage period.

5.6.3.1.7 Uplink Command System. During the unmanned portion of the Shelter mission the electrical power to the Instrumentation Subsystem will be controlled by the communication uplink. The subsystem will be manually activated by the astronaut during the pre-separation checkout period. At the completion of the checkout period the voice recorder will be deactivated. The uplink command system will shut down the entire Instrumentation Subsystem after post-flight checkout, and will continue to control the status bus described above during quiescent storage. The items commanded by uplink are described in Fig. 5.6-3 and the reduced power system (status) is described in Fig. 5.6-1. When the astronaut enters the Shelter, he will manually activate the unpowered portion of the subsystem which includes the C&WEA and the voice storage recorder.

5.6.3.1.8 Operational Measurements. The measurement requirements for the Shelter are shown in Table 5.6-6. A summary of these measurements is found in Table 5.6-2, which reflects the various types of instrumentation required and the quantities requested for each of the Shelter subsystems. These measurements support the spacecraft performance and management plus provide sufficient information to:

- Enable normal spacecraft operations to be performed
- Provide the capability for decision making by the astronauts
- Monitor crew safety functions
- Provide status of expendable items
- Provide status of operational events.

An Apollo Biomedical System supports EVA by monitoring such items as electro-cardiograms and impedance pneumograms (respiration) with associated power converters, vest, harness, and electrodes. This information is transmitted via the VHF link to the CM or Shelter for re-transmission to Earth. During the on-board stay, however, only the electro-cardiogram is monitored for transmission to Earth (hard-wired).

5.6.3.2 Experiment Support Section

The unused portion of the operational PCMTEA will be available for support of Shelter experiment information. The number of channels, sampling rates, and word lengths available for the experiments are presented in Table 5.6-5. It should be noted that this excess capacity is subject to modification based on changes in the Shelter requirements.

5.6.4 Baseline Configuration

The baseline configuration used for the Shelter is the same as the recommended configuration.

5.6.5 Alternate Configuration

There were no alternate configurations studied because of the ability of the existing LEM system to satisfactorily perform all the described tasks.

5.6.6 Potential Modifications Per Flight

No per flight modifications were considered for the operational instrumentation. However, the excess capacity available for experiment support could be used as needed on a per flight basis, providing the experiment instrumentation is compatible with the PCMTEA input format.

Table 5.6-1
INSTRUMENTATION WEIGHT & POWER SUMMARY

Section	Trans-ducers	SCEA		C & WEA	PCMTEA		VSR	Total
		ERA I	ERA II		PCM	TEA		
Manned Operat'l Power, Watts	9.4	18.1	17.8	22.0	7.4	5.5	2.3	82.5
Unmanned Operat'l Power, Watts	9.4	18.1	17.8	22.0	7.4	5.5	N/A	80.2
Status Storage Power, Watts	1.1	N/A	17.8	N/A	7.4	5.5	N/A	31.8
Weight, lb	19.9	36.1	34.1	25.0	37.0		5.0 (2)	157.1

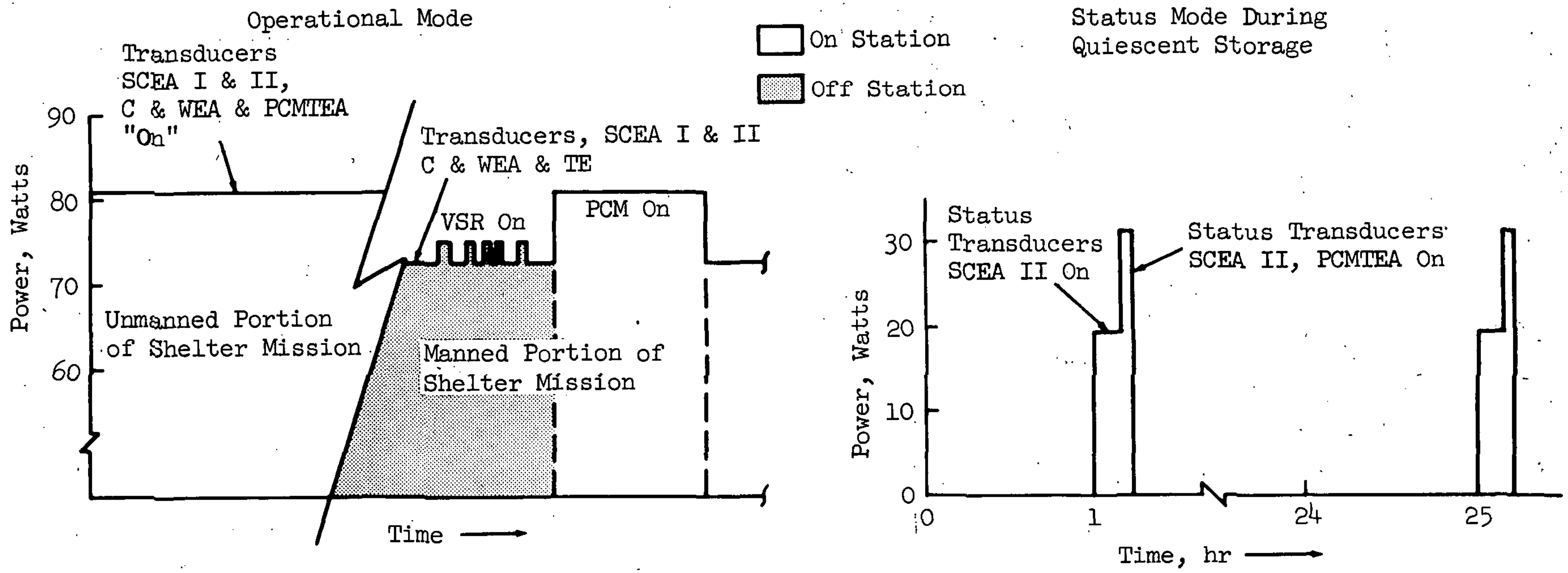


Table 5.6-2
OPERATIONAL MEASUREMENTS SUMMARY

Parameter / Subsystem	Acceleration	Phase	Current	Vibration	Power	Frequency	Force	Position	Biomedical	Radiation	Velocity	Mass	Res./Cont.	Pressure	Quantity	Rate	Strain	Temperature	Combination	Voltage	Time	Descrete	Acoustic	Ph-Acidity	Undefined	Stimuli	Total S/S Measurements	Measurements Useage		
																												TM Total	C&W and DISP	Prelaunch C/O
Structures																		3	1			8					12	4	1	1
Thermodynamics																														
Electrical Power			6			1								10	1	4		15		19		14		2			72	70	63	16
Environ Control														13	3	2		10	2	16		28					74	43	30	57
Nav & Guid		1	2					1			3							5		65		15					92	41	16	76
Radars					4	4		1			3									26		7			11		56	3	9	39
S & C - CES																				58		18			4		80	46	25	73
S & C - AGS																														
Instrumentation						2													8	5	2	40			8		65	14	48	19
Propulsion - Ascent																														
Propulsion - Descent								2						8				5	4			15					34	20	14	22
Reaction Control														16	4			7	6	8		15					56	24	34	32
Communications		1	2		4			2	2											9		3			11		34	5	4	24
Pyrotechnics																														
Totals		2	10		8	7		6	2		6			47	8	6		45	21	206	2	163		2	34		575	270	244	359

Notes: 1. SNAP-27 RTG used for this sizing
2. Two P & W fuel cells were used for this sizing.

Table 5.6-3
SCEA SUMMARY

	502-2	502-3	503-2	503-3	504-1	504-2	504-3	504-4	504-5	505-1	506-2	507-1	509-1	Total
Total Measurement Circuits	18	2	8	1	14	19	22	28	28	1	35	8	2	185
Circuits/ Subassy	4	4	3	3	4	10	12	12	12	3	4	4	4	N/A
Quantity of Sub-assys Reqd	5	1	3	1	4	2	2	3	3	1	11	2	1	37
No. Spare Circuits	2	2	1	2	3	1	2	8	8	2	1	-	2	34
ERA No. 1 Flight Operational Meas. Only	4	-	3	-	3	2	-	-	-	-	3	2	1	18
ERA No. 2 Flight Operational & Quiescent Storage Status Meas.	1	1	-	1	1	-	2	3	3	1	6	-	-	19

Table 5.6-4
PCMTEA INPUT DATA CAPABILITY

Data Format: 51,200 bits/sec Output Rate

Data Form	No. Channels	samples/sec	bits/word	words/sec
Analog - High Level	5	200	8	1000
	17	100	8	1700
	6	50	8	300
	35	10	8	350
	137	1	8	137
Digital - Parallel	1	200	16	400
	3	100	8	300
	4	50	8	200
	1	10	8	10
	37	1	8	37
Digital - Serial	1	50	40	250
	1	50	24	150
Total	248			4834
Partial Format: 1,600 bits/sec Output Rate				
Anaolg - High Level	59	1	8	59
Digital Parallel	15	1	8	15

Note: The low bit rate format of the LEM PCMTEA is presently undergoing design changes. The input capability presented here is incomplete and will be expanded when the design is finalized.

* Normalized to 8 bit words.

Table 5.6-5
EXCESS INSTR. CAPABILITY FOR EXPERIMENTS

Data Format: 51,200 bits/sec Output Rate

Data Form	No. Channels	samples/sec	bits/word	words*/sec
Analog - High Level	5	200	8	1000
	14	100	8	1400
	3	50	8	150
	9	10	8	90
	9	1	8	9
Digital Parallel	3	100	8	300
	4	50	8	200
	1	10	8	10
	23	1	8	23
Digital Serial	1	50	24	150
	72			3332

*Normalized to 8 bit Word.

Table 5.6-6
SHELTER INSTRUMENTATION MEASUREMENTS LIST

```
X X X X X X X X X X X

X       LEM-AES       X

X      BASELINE       X

X       SHELTER       X

X PHASE B     FORM A  X

X X X X X X X X X X X
```

Table 5.6-6 (cont)

```
          CONTRACT NUMBER NAS9-4983                                                                        PAGE NUMBER   2
          BASELINE SHELTER                                                                                 NOVEMBER 8,1965
                                                                                                      C T                       C
                                              INTEREST       FREQ A S S S B G O M MH C F A X   XDCR   FREQ A OSY         REFERENCES H
   ID            MEASUREMENT                   RANGES          OR  C C / I I R P C S/ / / / X  RANGES   OR  C NIP XDCR XDCR     OR     N
  CODE         NAME AND LOCATION         LOW NORM HIGH UNIT  RATE C R S G T D S C SL W L D X LOW HIGH RATE C DGE -PWR  WT.     NOTES   G

 EL0021-B

 E-MODULE CODE
          A-ADAPTER         H-LEM SHELTER        P-LUNAR ORBIT LAB.
          B-BOOSTER         J-STIMULI            S-SERVICE EQUIPMENT
          C-COMMAND MODULE  L-LAUNCH ESCAPE SYS.T-LEM TAXI
          E-EARTH ORBIT LAB M-LEM TRUCK          Y-GROUND TEST ARTICLE
          G-LEM             N-GSE EQUIPMENT

  L-FUNCTIONAL SUBSYSTEM CODE
          A-STRUCTURES      I-STAB/CONTROL-AGS   R-REACTION CONTROL
          B-THERMODYNAMICS  L-INSTRUMENTATION    T-COMMUNICATIONS
          C-ELECTRICAL POWER M-MECHANICAL DESIGN Y-PYROTECHNICS
          F-ENVIRON CONTROL N-RADARS             X-EXPERIMENTS
          G-NAV.AND GUIDANCE P-PROPULSION A/S
          H-STAB/CONTROL-CES Q-PROPULSION D/S

   0021-IDENTIFICATION NUMBER (BY SUBSYSTEM)

         B-MEASUREMENT CLASSIFICATION CODE
          A-ACCELERATION    J-BIOMEDICAL         S-STRAIN
          B-PHASE           K-RADIATION          T-TEMPERATURE
          C-CURRENT         L-VELOCITY           U-COMBINATION MEAS.
          D-VIBRATION       M-MASS               V-VOLTAGE
```

Table 5.6-6 (cont)

```
         CONTRACT NUMBER NAS9-4983                                                                         PAGE NUMBER   37
         BASELINE SHELTER                                                                                  NOVEMBER 8,1965
                                                                                          C T                                 C
                                         INTEREST      FREQ A S S S B G U M MH C F A X    XDCR    FREQ A OSY             REFERENCES  H
  ID            MEASUREMENT               RANGES        OR  C C / I I R P C S/ / / / X   RANGES    OR  C NIP XDCR XDCR      OR       N
 CODE        NAME AND LOCATION     LOW NORM HIGH UNIT  RATE C R S G T D S C SL W L D X LOW HIGH RATE C DGE -PWR  WT.      NOTES      G

         E-POWER          N-RESIST/CONTINUITY W-TIME

         F-FREQUENCY      P-PRESSURE          X-DISCRETE EVENT

         G-FORCE/MECH.IMPED. Q-QUANTITY       Y-ACOUSTICAL

         H-POSITION       R-RATE              Z-PH-ACIDITY


      MEASUREMENT

   NAME AND LOCATION

         DESCRIBES THE MEASUREMENT TO BE OBTAINED AND ITS LOCATION,STATED

           BRIEFLY.


       INTEREST

        RANGES

   LOW NORM HIGH UNIT

         MINIMUM,NORMAL AND MAXIMUM MEASURAND RANGE EXPECTED AND ITS

           ASSOCIATED UNITS.


   FREQ

    OR

   RATE

         REALISTIC RECOVERABLE RESPONSE RATE REQUIRED (IN CPS)


   ACC

         REALISTIC RECOVERABLE END-TO-END SYSTEM ACCURACY IN PERCENT FULL

           SCALE.
```

Table 5.6-6 (cont)

```
       CONTRACT NUMBER NAS9-4983                                                                 PAGE NUMBER   4
       BASELINE SHELTER                                                                          NOVEMBER 8,1965
                                                                                        C T                          C
                                   INTEREST       FREQ A S S S B G O M MH C F A X  XDCR    FREQ A OSY           REFERENCES  H
  ID        MEASUREMENT             RANGES         OR  C C / I I R P C S/ / / / X  RANGES   OR  C NIP XDCR XDCR      OR     N
 CODE     NAME AND LOCATION    LOW NORM HIGH UNIT RATE C R S G T D S C SL W L D X LOW HIGH RATE C DGE -PWR  WT.     NOTES    G

 SCR
       TRANSDUCER PROCUREMENT SOURCE CODE.
            S-SUBCONTRACTOR
            I-INSTRUMENTATION
            G-GROUND SUPPORT EQUIPMENT
            N-NASA(GFE)GOVERNMENT FURNISHED EQUIPMENT.


 S/S
       NUMBER OF SAMPLES PER SECOND.


 SIG
       FORM AND LEVEL OF SIGNAL TO THE PCM EQUIPMENT.
            L-LOW LEVEL ANALOG (0-40MV)   P-PARALLEL DIGITAL (0 OR 5V)
            H-HIGH LEVEL ANALOG (0-5V)    E-DISCRETE EVENT (0 OR 5V)
            S-SERIAL DIGITAL (0 OR 5V)


 BIT
       NUMBER OF BITS PER SAMPLE.


 GRD
       INDICATES THOSE MEASUREMENTS REQUIRED FOR FACTORY TEST OR CHECKOUT.
          A-FACTORY C/O,NON-ACE MONITERED.
          B-FACTORY C/O,ACE MONITERED.
```

Table 5.6-6 (cont)

```
          CONTRACT NUMBER NAS9-4983                                                                    PAGE NUMBER   5
          BASELINE SHELTER                                                                             NOVEMBER 8,1965
                                                                                            C T                          C
                                           INTEREST      FREQ A S S S B G O M MH C F A X   XDCR   FREQ A OSY            REFERENCES  H
   ID            MEASUREMENT                RANGES        OR  C C / I I R P C S/ / / / X  RANGES   OR  C NIP XDCR XDCR      OR      N
  CODE        NAME AND LOCATION     LOW NORM HIGH UNIT RATE C R S G T D S C SL W L D X LOW HIGH RATE C DGE -PWR  WT.      NOTES     G

 OPS

          INDICATES THOSE MEASUREMENTS REQUIRED FOR PRELAUNCH CHECKOUT

            1-PRELAUNCH C/O,NON-ACE MONITERED.

            2-PRELAUNCH C/O,ACE MONITERED.


 MCC

          INDICATES THAT THE TELEMETERED MEASUREMENT IS REQUIRED BY THE

            MANNED SPACE FLIGHT NETWORK FOR REAL TIME DISPLAY(R).


 MSS

          INDICATES THOSE MEASUREMENTS REQUIRED DURING STORAGE PERIOD.(S)


 H/L

          ASSIGNMENT OF MEASUREMENT

            H-HIGH BIT RATE (51.2K BITS/SEC) TELEMETERED SIGNAL.

            L-LOW BIT RATE (1.6K BITS/SEC) TELEMETERED SIGNAL.

            X-INDICATES ON-BOARD RECORDING.

            *-NOT TELEMETERED DIRECTLY.USED TO FORMULATE THE MEASUREMENT

               LISTED IN THE ADJACENT NOTES COLUMN.


 C/W

          INDICATES AN INPUT TO A CAUTION(C)OR WARNING(W)LAMP.
```

Table 5.6-6 (cont)

```
          CONTRACT NUMBER NAS9-4983                                                                    PAGE NUMBER   6
          BASELINE SHELTER                                                                             NOVEMBER 8,1965
                                                                                          C T                                   C
                                         INTEREST       FREQ A S S S B G O M MH C F A X    XDCR   FREQ A OSY              REFERENCES   H
   ID          MEASUREMENT                RANGES         OR  C C / I I R P C S/ / / / X  RANGES    OR  C NIP XDCR XDCR        OR       N
  CODE      NAME AND LOCATION      LOW NORM HIGH UNIT RATE C R S G T D S C SL W L D X LOW HIGH RATE C DGE -PWR  WT.        NOTES      G

  F/L

          INDICATES AN ADVISORY FLAG(F)OR LIGHT(L).


  A/D

          INDICATES AN INPUT TO AN ANALOG(A)OR DIGITAL(D)DISPLAY.


  XXX

          TIME SHARED SWITCHING CODE 1-9


   XDCR
  RANGES
  LOW HIGH
          SELECTED OR ALLOCATED TRANSDUCER RANGE.


  FREQ
   OR
  RATE
          ALLOCATED EQUIPMENT RESPONSE CAPABILITY.


  ACC
          END-TO-END SYSTEM ACCURACY EXPRESSED IN PERCENT FULL SCALE OF
            ALLOCATED RANGE.
```

Table 5.6-6 (cont)

```
           CONTRACT NUMBER NAS9-4983                                                                          PAGE NUMBER   7
           BASELINE SHELTER                                                                                   NOVEMBER 8,1965
                                                                                                         C T                              C
                                                   INTEREST      FREQ A S S S B G D M MH C F A X   XDCR    FREQ A OSY              REFERENCES H
     ID              MEASUREMENT                    RANGES        OR  C C / I I R P C S/ / / / X  RANGES    OR  C NIP XDCR XDCR       OR      N
    CODE          NAME AND LOCATION         LOW NORM HIGH UNIT RATE C R S G T D S C SL W L D X LOW HIGH RATE C DGE -PWR  WT.        NOTES    G

  C T

  OSY

  NIP

  DGE

           SIGNAL CONDITIONING TYPE OF UNITS REQUIRED.

             1-1 REFERS TO SIGNAL CONDITIONER LSP-360-501-1

             1-2 REFERS TO SIGNAL CONDITIONER LSP-360-501-2

  XDCR

  -PWR

           POWER REQUIREMENT FOR TRANSDUCER (IN WATTS)

  XDCR

   WT.

           WEIGHT OF TRANSDUCER ONLY.

              -WEIGHT IN POUNDS(UNMARKED)

             Z-WEIGHT IN OUNCES


  REFERENCES

      OR

     NOTES

           AVAILABLE SPACE FOR REFERENCES OR NOTES.


  CHNG

           REFLECTS LATEST MODIFICATION CODE.
```

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983
BASELINE SHELTER

PAGE NUMBER 8
NOVEMBER 8,1965

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	FREQ OR RATE	STRUCTURES A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HA0041-X	LAND GEAR -Y,LS DEPLOY LK	CONTACT CLOSURE				SS		I							*					CC		SS		-	--	--	HA5000	
HA0042-X	LAND GEAR -Y,RS DEPLOY LK	CONTACT CLOSURE				SS		I							*					CC		SS		-	--	--	HA5000	
HA0043-X	LAND GEAR -Z,LS DEPLOY LK	CONTACT CLOSURE				SS		I							*					CC		SS		-	--	--	HA5000	
HA0044-X	LAND GEAR -Z,RS DEPLOY LK	CONTACT CLOSURE				SS		I							*					CC		SS		-	--	--	HA5000	
HA0045-X	LAND GEAR +Z,LS DEPLOY LK	CONTACT CLOSURE				SS		I							*					CC		SS		-	--	--	HA5000	
HA0046-X	LAND GEAR +Z,RS DEPLOY LK	CONTACT CLOSURE				SS		I							*					CC		SS		-	--	--	HA5000	
HA0047-X	LAND GEAR +Y,LS DEPLOY LK	CONTACT CLOSURE				SS		I							*					CC		SS		-	--	--	HA5000	
HA0048-X	LAND GEAR +Y,RS DEPLOY LK	CONTACT CLOSURE				SS		I							*					CC		SS		-	--	--	HA5000	
HA0064-T	TEMP 1,+Z LEG PRI STRUT	32		500	DEGF	SS	1	I	1	H	8				H					0	500	SS		6-2	0	.13		
HA2001-T	TEMP 1,HEAT SHIELD D/S	0		2000	DEGF	SS	1	I	1	H	8				H					0	2500	SS		9-1	0	.18		
HA2002-T	TEMP 2,HEAT SHIELD D/S	0		2000	DEGF	SS	1	I	1	H	8				H					0	2500	SS		9-1	0	.18		
HA5000-U	LAND LEGS DEPLOYED	CONTACT CLOSURE				SS		I	1	H	1	B	2		H		F			CC		SS		4-4	0	1.00		

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983
BASELINE SHELTER

PAGE NUMBER 9
NOVEMBER 8,1965

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	INTEREST RANGES NORM	INTEREST RANGES HIGH	UNIT	ELECTRICAL POWER FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	XDCR RANGES HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HC0071-V	VOLTAGE,INVERTER BUS	105	115	125	VRMS	SS	5	S	1	H	8	B	2	R	SL	C		A		0	130	SS		3-3	--	--	HL4046	
HC0155-F	FREQ,INVERTER BUS	390	400	410	CPS	SS	.5	S	1	H	8	B	2	R	SL	C				380	420	SS		5-1	--	--	HL4046	
HC0201-V	VOLTAGE,BATTERY NO.1	20	28	40	VDC	SS	5	S	1	H	8	B	2		SL			A		0	40	SS		2-2	--	--		
HC0202-V	VOLTAGE,BATTERY NO.2	20	28	40	VDC	SS	5	S	1	H	8	B	2		SL			A		0	40	SS		2-2	--	--		
HC0301-V	VOLT COMMANDER'S BUS	20		40	VDC	SS	4	S	1	H	8	B	2	R	L			A		0	40	SS		2-3	--	--		
HC0301-V	VOLT COMMANDER'S BUS	26.5			VDC	SS										C						SS		-	--	--	HL4047	
HC0302-V	VOLT SYSTEM ENGR'S BUS	20		40	VDC	SS	4	S	1	H	8	B	2	R	L			A		0	40	SS		2-3	--	--		
HC0302-V	VOLT SYSTEM ENGR'S BUS	26.5			VDC	SS										C						SS		-	--	--	HL4047	
HC1201-C	CURRENT,BATTERY NO.1	0		60	AMPS	SS	5	S	1	H	8	B	2		SL			A				SS		-	--	--		
HC1202-C	CURRENT,BATTERY NO.2	0		60	AMPS	SS	5	S	1	H	8	B	2		SL			A				SS		-	--	--		
HC3501-T	TEMPERATURE,BATTERY NO.1	0		200	DEGF	SS	5	S	1	H	8	B	2		SL			A		20	200	SS		6-2	0	0		
HC3502-T	TEMPERATURE,BATTERY NO.2	0		200	DEGF	SS	5	S	1	H	8	B	2		SL			A		20	200	SS		6-2	0	0		
HC4361-X	HIGH VOLT TAP BATT.NO1	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H		F			CC		SS		4-4	0	0		
HC4362-X	LOW VOLT TAP BATT NO1	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H		F			CC		SS		4-4	0	0		
HC4363-X	HIGH VOLT TAP BATT NO2	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H		F			CC		SS		4-4	0	0		
HC4364-X	LOW VOLT TAP BATT NO2	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H		F			CC		SS		4-4	0	0		
HC6311-X	REVERSE/OVER CUR BAT 1	CONTACT CLOSURE						S	1	E	1	B	2	R	H	C				CC		SS		4-3	0	0	HL4047	
HC6312-X	REVERSE/OVER CUR BAT 2	CONTACT CLOSURE						S	1	E	1	B	2	R	H	C				CC		SS		4-3	0	0	HL4047	
HC8001-V	VOLT,FCA NO1,NEUTRAL				VRMS	SS		S	1	H	8			R	H			A				SS		3-1	0	0		
HC8002-V	VOLT,FCA NO1,PHASE A				VRMS	SS		S	1	H	8				H			A				SS		3-1	0	0		
HC8003-V	VOLT,FCA NO1,PHASE B				VRMS	SS		S	1	H	8				H			A				SS		3-1	0	0		
HC8004-V	VOLT,FCA NO1,PHASE C				VRMS	SS		S	1	H	8				H			A				SS		3-1	0	0		
HC8005-V	VOLT,FCA NO2,NEUTRAL				VRMS	SS		S	1	H	8			R	H			A				SS		3-1	0	0		
HC8006-V	VOLT,FCA NO2,PHASE A				VRMS	SS		S	1	H	8				H			A				SS		3-1	0	0		
HC8007-V	VOLT,FCA NO2,PHASE B				VRMS	SS		S	1	H	8				H			A				SS		3-1	0	0		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	ELECTRICAL POWER FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T DSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HC8008-V	VOLT,FCA NO2,PHASE C				VRMS	SS		S	1	H	8				H			A				SS		3-1	0	0		
HC8009-X	FCA NO1 H2 CLOSED					SS			1	E	1				H		L					SS		4-4	0	0		
HC8010-X	FCA NO1 O2 CLOSED					SS			1	E	1				H		L					SS		4-4	0	0		
HC8011-X	FCA NO2 H2 CLOSED					SS			1	E	1				H		L					SS		4-4	0	0		
HC8012-X	FCA NO2 O2 CLOSED					SS			1	E	1				H		L					SS		4-4	0	0		
HC8013-X	FCA NO1 O2 PURGE CLOSED					SS			1	E	1			R	H		L					SS		4-4	0	0		
HC8014-X	FCA NO1 H2 PURGE CLOSED					SS			1	E	1			R	H		L					SS		4-4	0	0		
HC8015-X	FCA NO2 O2 PURGE CLOSED					SS			1	E	1			R	H		L					SS		4-4	0	0		
HC8016-X	FCA NO2 H2 PURGE CLOSED					SS			1	E	1			R	H		L					SS		4-4	0	0		
HC8017-R	RATE,H2 FLOW,FCA NO1	.018		.223	PPH	SS			1	H	8			R	H							SS		-				
HC8018-R	RATE,H2 FLOW,FCA NO2	.018		.223	PPH	SS			1	H	8			R	H							SS		-				
HC8019-R	RATE,O2 FLOW,FCA NO1	.0		1.27	PPH	SS			1	H	8			R	H							SS		-				
HC8020-R	RATE O2 FLOW,FCA NO2	.0		1.27	PPH	SS			1	H	8			R	H							SS		-				
HC8021-T	TEMP,FCA1 CONDENSER EXIT					SS			1	H	8				H			A				SS		6-2				
HC8022-T	TEMP,FCA2 CONDENSER EXIT					SS			1	H	8				H			A				SS		6-2				
HC8023-T	TEMP,FCA NO1 SKIN	300	500	550	DEGF	SS			1	H	8				H			A				SS		6-2				
HC8024-T	TEMP,FCA NO2 SKIN	300	500	550	DEGF	SS			1	H	8				H			A				SS		6-2				
HC8025-Z	WATER FACTOR PH,FCA 1					SS			1	H	8				H			A				SS		-				
HC8026-P	PRESS,H2 REGULATOR OUT 1		60		PSIA	SS			1	H	8			R	H			A				SS		-				
HC8027-P	PRESS,H2 REGULATOR OUT 2		60		PSIA	SS			1	H	8			R	H			A				SS		-				
HC8028-P	PRESS,O2 REGULATOR OUT 1		60		PSIA	SS			1	H	8			R	H			A				SS		-				
HC8029-P	PRESS,O2 REGULATOR OUT 2		60		PSIA	SS			1	H	8			R	H			A				SS		-				
HC8030-P	PRESS,N2 REGULATOR OUT 1		52		PSIA	SS			1	H	8			R	H			A				SS		-				
HC8031-P	PRESS,N2 REGULATOR OUT 2		52		PSIA	SS			1	H	8			R	H			A				SS		-				
HC8032-Z	WATER FACTOR PH,FCA 2					SS			1	H	8				H			A				SS		-				

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	INTEREST RANGES NORM	INTEREST RANGES HIGH	UNIT	ELECTRICAL POWER FREQ OR RATE	ACC	SCR	S/S	SIG	BIT	GRD	OPS	MCC	MH S/SL	C/W	F/L	A/D	X/X	XDCR RANGES LOW	XDCR RANGES HIGH	FREQ OR RATE	ACC	CT OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	CHNG
HC8033-P	PRESS,H2 TANK NO1					SS			1	H	8			R	SL			A						-				
HC8034-P	PRESS,O2 TANK NO1					SS			1	H	8			R	SL			A						-				
HC8035-T	TEMP,FCA1 RADIATOR OUTLET					SS			1	H	8			R	H			A				SS		6-2				
HC8036-T	TEMP,FCA1 RADIATOR OUTLET					SS			1	H	8			R	H			A				SS		6-2				
HC8037-V	VOLT,FCA NO1 OUTPUT	0	28	50	VDC	SS			1	H	8			R	H			A		0	50	SS		2-2				
HC8038-V	VOLT,FCA NO2 OUTPUT	0	28	50	VDC	SS			1	H	8			R	H			A		0	50	SS		2-2				
HC8039-C	CURR,FCA NO1 OUTPUT	0		100	AMPS	SS			1	H	8			R	H			A		0	100	SS		-				
HC8040-C	CURR,FCA NO2 OUTPUT	0		100	AMPS	SS			1	H	8			R	H			A		0	100	SS		-				
HC8041-T	TEMP H2 TANK NO 1					SS			1	H	8			R	SL			A						6-2				
HC8042-T	TEMP H2 TANK NO 2					SS			1	H	8			R	SL			A						6-2				
HC8043-P	PRESS H2 TANK NO 2					SS			1	H	8			R	SL			A						-				
HC8044-P	PRESS O2 TANK NO 2					SS			1	H	8			R	SL			A						-				
HC8045-T	TEMP O2 TANK NO 1					SS			1	H	8			R	SL			A						6-2				
HC8046-T	TEMP O2 TANK NO 2					SS			1	H	8			R	SL			A						6-2				
HC8047-Q	QUANT WATER TANK NO 1	0		100	PCT	SS			1	H	8				H			A		0	99	SS		-				
HC8048-T	TEMP O2 HX OUTLET					SS			1	H	8			R	H			A				SS		6-2				
HC8049-T	TEMP H2 HX OUTLET					SS			1	H	8			R	H			A				SS		6-2				
HC8060-V	VOLT,PEAKING BATTERY NO 1	0	28	32	VDC	SS			1	H	8			R	H			A		0	32	SS		2-2				
HC8061-C	CURR,PEAKING BATTERY NO 1				AMPS	SS			1	H	8			R	H			A				SS		-				
HC8070-T	TEMP,RTG	500	525	600	DEGF	SS		S	1	H	8	B	2	R	SL					20	600	SS		6-2	0	0		
HC8071-V	VOLTAGE,RTG	26	29	32	VDC	SS		S	1	H	8	B	2	R	SL					0	40	SS		2-2	0	0		
HC8072-C	CURR,RTG	0	2	3	AMPS	SS		S	1	H	8	B	2	R	SL					0	3	SS		-	--	--		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	ENVIRONMENTAL CONTROL FREQ OR RATE	ACC	SCR	S/S	SIG	BIT	GRD	OPS	MCC	MH S/SL	C/W	F/L	A/D	X/X	XDCR RANGES LOW	HIGH	FREQ OR RATE	ACC	C T USY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	CHNG
HF1081-X	PRIME SUIT COMP. SELECT	CONTACT CLOSURE				SS		S	1	E	1	B	2		H					CC		SS		4-5	0	0		
HF1082-X	SPARE SUIT COMP. SELECT	CONTACT CLOSURE				SS		S	1	E	1	B	2		H					CC		SS		4-5	0	0		
HF1083-X	PRIME SUIT COMPRESS.FAIL	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H	C				CC		SS		4-3	0	0		
HF1084-X	SPARE SUIT COMPRESS.FAIL	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H					CC		SS		4-3	--	--		
HF1087-X	SELECT SUIT COMPRESS FAIL	CONTACT CLOSURE				SS											L			CC		SS		4-4	0	0		
HF1111-R	RATE,H2O SEPERATOR NO 1	600		3500	RPM	SS		S								C	L			500	3600	SS		-	.25	.23	HF9999	
HF1112-R	RATE,H2O SEPERATOR NO 2	600		3500	RPM	SS		S								C	L			500	3600	SS		-	.25	.23	HF9999	
HF1201-X	SUIT INLET VPI NO1 CLOSE	CONTACT CLOSURE				SS		S	1	E	1	B	2		H					CC		SS		4-5	0	.13		
HF1202-X	SUIT INLET VPI NO2 CLOSE	CONTACT CLOSURE				SS		S	1	E	1	B	2		H					CC		SS		4-5	0	.13		
HF1211-X	SUIT PRESS.RLF VPI CLOSE	CONTACT CLOSURE				SS		S	1	E	1	B	2		H					CC		SS		4-5	0	.13		
HF1212-X	SUIT PRESS.RLF VPI OPEN	CONTACT CLOSURE				SS		S	1	E	1	B	2		H					CC		SS		4-5	0	.13		
HF1221-X	SUIT DIVERTER VPI CLOSED	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H					CC		SS		4-5	0	.13		
HF1231-X	CABIN GAS RETURN VPI CLD	CONTACT CLOSURE				SS		S	1	E	1	B	2		SL					CC		SS		4-5	0	.13		
HF1232-X	CABIN GAS RETURN VPI OPEN	CONTACT CLOSURE				SS		S	1	E	1	B	2		H					CC		SS		4-5	0	.13		
HF1241-X	CO2 CARTRIDGE IN SEC POS	CONTACT CLOSURE				SS		S	1	E	1	B	2		H					CC		SS		4-5	0	.13		
HF1242-X	CO2 CARTRIDGE IN SEC POS	CONTACT CLOSURE				SS											L			CC		SS		4-4	0	.13	HF9993	
HF1251-X	H2O SEPARATOR NO2 SELECT	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	L					CC		SS		4-5	0	0		
HF1281-T	TEMP,SUIT INLET	30	60	100	DEGF	SS		S	1	H	8	B	2	R	L			A		30	110	SS		6-2	0	.12		
HF1291-T	TEMP,SUIT NO.1 OUTLET	30	80	100	DEGF	SS		S	1	H	8	B	2		H					30	110	SS		6-2	0	.12		
HF1292-T	TEMP,SUIT NO.2 OUTLET	30	80	100	DEGF	SS	5	S	1	H	8	B	2		H					30	110	SS		6-2	0	.12		
HF1301-P	PRESS,SUIT OUTLET	0	5	10	PSIA	SS	5	S	1	H	8	B	2	R	L					0	10	SS		4-1	.28	.31		
HF1301-P	PRESS,SUIT OUTLET	3.2			PSIA	SS										W				3.2		SS		-	--	--		
HF1301-P	PRESS,SUIT OUTLET	0		10	PSIA													A		0	10	SS		4-1	--	--		
HF1521-P	PRESS,CO2 PARTIAL	0	2	30	MMHG	SS	5	S	1	H	8	B	2	R	L	C	L			0	30	SS		4-1	1.00	2.70	HF9993	
HF1522-P	PRESS,CO2 PARTIAL	0		30	MMHG	SS												A		0	30	SS		4-1	1.00	2.70		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	ENVIRONMENTAL CONTROL FREQ OR RATE	A CC	S CR	S / S	S IG	B IT	G RD	O PS	M CC	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	CT OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	CHNG
HF1651-T	TEMP,CABIN	50	80	110	DEGF	SS	5	I	1	H	8	B	2	R	SL			A		30	110	SS		6-2	0	.12		
HF2021-P	DEL P,PRIM COOLANT PUMP	0	45	50	PSID	SS	5	S	1	H	8	B	2	R	L					0	50	SS		-	.28	.31		
HF2041-X	COOLANT ACC.FLUID LO LVL	CONTACT	CLOSURE			SS		S	1	E	1	B	2	R	SL	C				CC		SS		4-3	0	0		
HF2071-X	COOLANT PUMP NO.1 SELECT	CONTACT	CLOSURE			SS		S	1	E	1	B	2		L					CC		SS		4-5	0	0		
HF2072-X	COOLANT PUMP NO.2 SELECT	CONTACT	CLOSURE			SS		S	1	E	1	B	2		L					CC		SS		4-5	0	0		
HF2581-T	TEMP,MAIN W/B COOL.OUT	30	40	160	DEGF	SS		I								C		A		0	160	SS		-	0	.12	HF9998	
HF2741-P	PRESS,PRIM PUMP DISCHRG	0	50	60	PSIA			I										A		0	60	SS		-	.28	.28	HF9997	
HF2931-X	COOLANT PUMP NO.1 FAIL	CONTACT	CLOSURE			SS		S	1	E	1	B	2	R	SL	C				CC		SS		4-3	0	0		
HF2932-X	COOLANT PUMP NO.2 FAIL	CONTACT	CLOSURE			SS		S	1	E	1	B	2	R	SL	C				CC		SS		4-3	0	0		
HF2933-X	COOLANT PUMP NO1 FAIL	CONTACT	CLOSURE			SS		S									L			CC		SS		4-4	0	0		
HF2934-X	COOLANT PUMP NO2 FAIL	CONTACT	CLOSURE			SS		S									L			CC		SS		4-4	0	0		
HF3071-X	OX.REG VLV 306A CLOSED	CONTACT	CLOSURE			SS		S	1	E	1	B	2		H					CC		SS		4-5	0	.13		
HF3072-X	OX.REG VLV 306A OPEN	CONTACT	CLOSURE			SS		S	1	E	1	B	2		SL					CC		SS		4-5	0	.13		
HF3073-X	OX.REG VLV 306B CLOSED	CONTACT	CLOSURE			SS		S	1	E	1	B	2		H					CC		SS		4-5	0	.13		
HF3074-X	OX.REG VLV 306B OPEN	CONTACT	CLOSURE			SS		S	1	E	1	B	2		SL					CC		SS		4-5	0	.13		
HF3081-X	EMERGENCY O2 VPI OPEN	CONTACT	CLOSURE			SS		S	1	E	1	B	2	R	H	W				CC		SS		4-3	0	.13		
HF3571-P	PRESS,CABIN	0	5	10	PSIA	SS	5	I	1	H	8	B	2	P	H					0	10	SS		-	.28	.28		
HF3571-P	PRESS CABIN	0		10	PSIA	SS												A		0	6	SS		-	--	--		
HF3572-X	EMER.O2 VLV ELECT OPEN	CONTACT	CLOSURE			SS		S	1	E	1	B	2	R	L	W				CC		SS		4-3	0	.13		
HF3581-P	PRESS PLSS SUPPLEMT TANK	0		100	PSIA	SS												A		0	100	SS		-	--	--		
HF3591-P	PRESS,SAFETY VLV 1 SERVO	0		25	PSIA	SS	5	I	1	H	8	B	2		H					0	25	SS		-	.28	.28		
HF3592-P	PRESS,SAFETY VLV 2 SERVO	0		25	PSIA	SS	5	I	1	H	8	B	2		H					0	25	SS		-	.28	.28		
HF4101-P	DEL P MAIN H2O SEP/ARS	0	1	2	PSIA	SS		I	1	H	8	B	2		H					0	2	SS		-	.28	.31		
HF4511-T	TEMP,MAIN W/B IN WATER	30	70	160	DEGF	SS	5	I	1	H	8				SL					0	160	SS		6-2	0	.16		
HF4541-T	TEMP,SUIT W/B IN WATER	30	70	160	DEGF	SS	5	I	1	H	8				H					0	160	SS		6-2	0	.16		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	INTEREST RANGES NORM	INTEREST RANGES HIGH	UNIT	ENVIRONMENTAL CONTROL FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	XDCR RANGES HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HF4580-Q	QUANTITY,FCA WATER TANK	0		100	PCT	SS	4	I	1	H	8	B	2	R	L			A		0	100	SS		4-1	.50	.75		
HF4581-Q	QUANTITY,DESC.TANK WATER	0		100	PCT	SS	4	I	1	H	8	B	2	R	L			A		0	100	SS		4-1	.50	.75		
HF4581-Q	QUANTITY,DESC TANK WATER	10			PCT	SS										C				10		SS		-	--	--		
HF8019-V	VOLT COOL PUMP SW DK9PO A	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8020-V	VOLT COOL PU SW DK 10PO A	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HE8024-V	VOLT PUMP DP SW DK 1 LO	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8025-V	VOLT PUMP DP SW DK 2 HI	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8026-V	VOLT PUMP DP SW DK 2 LO	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8027-V	VOLT PUMP DP SW DK 3 HI	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8028-V	VOLT PUMP DP SW DK 3,LO	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8507-V	VOLT SUIT DIVERT VLV POS	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8509-V	VOLT 02 REG ULV A/B TEST	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8521-V	VOLT CABIN FAN NO1	0		15	VDC	SS						B	2							0	15	SS		-	--	--		
HF8522-V	VOLT CABIN FAN NO1	0		15	VDC	SS						B	2							0	15	SS		-	--	--		
HF8523-V	VOLT CABIN FAN NO2	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8524-V	VOLT CABIN FAN NO2	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8525-V	VOLT H2O SOLENOID VALVE	0		28	VDC	SS						B	2							0	28	SS		-	--	--		
HF8535-V	VOLT SUIT FAN NO2	0		15	VDC	SS						B	2							0	15	SS		-	--	--		
HF8536-V	VOLT SUIT FAN NO2	0		15	VDC	SS						B	2							0	15	SS		-	--	--		
HF8601-T	TEMP HEAT PIPE CONDENSER	30		160	DEGF	SS		I	1	H	8	B	2	R	H			A		0	160	SS		6-2	0	.31		
HF8602-T	TEMP HEAT PIPE EVAPORATER	30		160	DEGF	SS		I	1	H	8	B	2	R	H			A		0	160	SS		6-2	0	.31		
HF8603-T	TEMP RADIATOR OUT GLYCOL	30	40	160	DEGF	SS		I	1	H	8	B	2	R	H			A		0	160	SS		6-2	0	.31		
HF9993-U	LIOH SEL/HI CO2 7DS6 ADV	CONTACT CLOSURE				SS											L			CC		SS		4-4	0	0		
HF9999-U	RATE,SELECT H2O SEPARATOR	600		3500	RPM	SS			1	H	8		2	R	L	C	L			500	3600	SS		4-1	--	--		

Table 5.6-6 (cont)

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BASELINE SHELTER

PAGE NUMBER 15
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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	NAVIGATION AND GUIDANCE FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HG0001-X	COMPUTER DIGITAL DATA							N	50S		40B		2	R	SH									-	--	--		
HG0117-H	POS,ALTITUDE (LGC)				FT	SS												D				SS		-	--	--		
HG0118-L	VEL,ALTITUDE RATE (LGC)				F/S	SS												D				SS		-	--	--		
HG0119-L	VEL,FORWARD (LGC)				F/S	SS												A				SS		-	--	--		
HG0120-L	VEL,LATERAL (LGC)				F/S	SS												A				SS		-	--	--		
HG1000-V	VOLT 120 VDC PULSE TOR.REF	0		120	VDC	SS		N	1	H	8	B	2		H					0	120	SS		-	--	--		
HG1020-V	VOLT LGC +14 VDC SUP LEV				VDC	SS			1	H	8	B	2		SL							SS		-	--	--		
HG1021-V	VOLT LGC +14VDC SUP NOISE				VRMS	SS			1		8	B	2									SS		-	--	--		
HG1022-X	LGC +14VDC SUP NOISE PEAK				GLT	10			10		1	B	2									10		-	--	--		
HG1030-V	VOLT LGC +4VDC SUP LEVEL				VDC	SS			1	H	8	B	2		SL							SS		-	--	--		
HG1031-V	VOLT LGC +4VDC SUP NOISE				VRMS	SS			1		8	B	2									SS		-	--	--		
HG1032-X	LGC +4VDC SUP NOISE PEAK				GLT	10			10		1	B	2									10		-	--	--		
HG1040-V	VOLT CDU +4VDC SUP LEVEL				VDC	SS			1	H	8	B	2		SL							SS		-	--	--		
HG1041-V	VOLT CDU +4VDC SUP NOISE				VRMS	SS			1		8	B	2									SS		-	--	--		
HG1042-X	CDU +4VDC SUP NOISE PEAK				GLT	10			10		1	B	2									10		-	--	--		
HG1050-V	VOLT SCA +20VDC SUPPLY				VDC	SS			1	H	8	B	2		SL							SS		-	--	--		
HG1100-V	VOLT -27.5 VDC SUPPLY	0		-30	VDC	SS			1	H	8	B	2		SL					0	30	SS		-	--	--		
HG1110-V	VOLT,2.5 VDC TM BIAS PCM				VDC	SS	2	N	1	H	8	B	2		SL							SS		-	--	--		
HG1201-V	VOLT IMU 28V 800CPS 1P-OD	0		40	VRMS	SS		N	1	H	8	B	2		H					0	40	SS		-	--	--		
HG1202-V	VOLT IMU 28V 800CPS 5P90D	0		40	VRMS	SS			1		8	B	2							0	40	SS		-	--	--		
HG1203-V	VOLT IMU 28V 800CPS 5P-OD	0		40	VRMS	SS			1		8	B	2							0	40	SS		-	--	--		
HG1306-B	PHASE 3.2KC 1-P/LGC SYNC					SS			1		8	B	2									SS		-	--	--		
HG1307-V	VOLT 3.2KC BUTTERFLY REF				VRMS	SS		N	1	H	8	B	2		H							SS		-	--	--		
HG1307-V	VOLT 3.2KC BUTTERFLY REF				VRMS	4KC						A	1									4KC		-	--	--		
HG1341-V	VOLT SELECT PIPA SCOP SIG	0		7	VRMS	4KC	10					A	I							0	7	4KC		-	--	--		

Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983
BASELINE SHELTER

PAGE NUMBER 16
NOVEMBER 8,1965

NAVIGATION AND GUIDANCE

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HG1342-V	VOLT SELECT HIGH RATE SIG	0		5	VDC	80C			400		8	B	2									80C		-	--	--		
HG1500-V	VOLT IMU OPER +28VDC LEV				VDC	SS			1	H	8	B	2		SL							SS		-	--	--		
HG1501-V	VOLT IMU OPER 28VDC NOISE				VRMS	SS			1		8	B	2									SS		-	--	--		
HG1502-X	IMU OPER 28VDC NOISE PEAK				GLT	10			10		1	B	2									10		-	--	--		
HG1510-V	VOLT IMU STBY 28VDC LEVEL				VDC	SS			1		8	B	2									SS		-	--	--		
HG1511-V	VOLT IMU STBY 28VDC NOISE				VRMS	SS			1		8	B	2									SS		-	--	--		
HG1512-X	IMU STBY 28VDC NOISE				GLT	10			10		1	B	2									10		-	--	--		
HG1513-X	IMU STANDBY/OFF					SS		N	1	E	1			R	H							SS		-	--	--		
HG1520-V	VOLT LGC OPER 28VDC LEVEL				VDC	SS			1	H	8	B	2		SL							SS		-	--	--		
HG1521-V	VOLT LGC OPER 28VDC NOISE				VRMS	SS			1	H	8	B	2		SL							SS		-	--	--		
HG1522-X	LGC OPER 28VDC NOISE PEAK				GLT	10			10		1	B	2									10		-	--	--		
HG1523-X	LGC OPERATE					SS		N	1	E	1				H							SS		-	--	--		
HG2000-V	VOLT X PIPA MODE CHECK	0		7	VRMS	4KC	10					A	1							0	7	4KC		-	--	--		
HG2001-V	VOLT X PIPA SG OPUT INPH	0		7	VRMS	10C		N	50	H	8	B	2		H					0	7	10		-	--	--		
HG2002-V	VOLT X PIPA SG OPUT QUAD				VRMS	SS		N	1	H	8	B	2		H							SS		-	--	--		
HG2003-V	VOLT X PIPA +28VDC PVR				VDC	SS		N	1	H	8	B	2		SL							SS		-	--	--		
HG2020-V	VOLT Y PIPA MODE CHECK	0		7	VRMS	4KC	10					A	1							0	7	4KC		-	--	--		
HG2021-V	VOLT Y PIPA SG OPUT INPH	0		7	VRMS	10C		N	50	H	8	B	2		H					0	7	10		-	--	--		
HG2022-V	VOLT Y PIPA SG OPUT QUAD				VRMS	SS		N	1	H	8	B	2		H							SS		-	--	--		
HG2023-V	VOLT Y PIPA +28VDC PVA				VDC	SS		N	1	H	8	B	2		SL							SS		-	--	--		
HG2040-V	VOLT Z PIPA MODE CHECK	0		7	VRMS	4KC	10					A	1							0	7	4KC		-	--	--		
HG2041-V	VOLT Z PIPA SG OPUT INPH	0		7	VRMS	10C		N	50	H	8	B	2		H					0	7	10		-	--	--		
HG2042-V	VOLT Z PIPA SG OPUT QUAD				VRMS	SS		N	1	H	8	B	2		H							SS		-	--	--		
HG2043-V	VOLT Z PIPA +28VDC PVR				VDC	SS		N	1	H	8	B	2		SL							SS		-	--	--		
HG2107-V	VOLT IGA SERVO ERROR INPH	0		20	VRMS	20C	5	N	100	H	8		2							0	20	20C		-	--	--		

Table 5.6-6 (cont)

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BASELINE SHELTER

PAGE NUMBER 17
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		INTEREST				NAVIGATION AND GUIDANCE																						
ID CODE	MEASUREMENT NAME AND LOCATION	RANGES LOW	NORM	HIGH	UNIT	FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HG2108-V	VOLT IG SERVO ERROR TOTAL	0		20	VRMS	2C	5		10		8	B	2							0	20	2C		-	--	--		
HG2112-V	VOLT,IG 1X RES OUT,SIN	0		28	VRMS	2C		N	10	H	8	B	2	R	H					0	28	2C		-	--	--		
HG2113-V	VOLT,IG 1X RES OUT,COS	0		28	VRMS	2C		N	10	H	8	B	2	R	H					0	28	2C		-	--	--		
HG2122-V	VOLT,IG 1X RES OUT,SIN	0		28	VRMS													A		0	28			-	--	--		
HG2123-V	VOLT,IG 1X RES OUT,COS	0		28	VRMS													A		0	28			-	--	--		
HG2137-V	VOLT MG SERVO ERROR INPH	0		20	VRMS	20C	5	N	100	H	8				H					0	20	20C		-	--	--		
HG2138-V	VOLT MG SERVO ERROR TOTAL	0		20	VRMS	2C			10		8	B	2							0	20	2C		-	--	--		
HG2140-C	CURR MG TORQUE MOTOR INPUT				AMP	SS	10		1		8	B	2									SS		-	--	--		
HG2142-V	VOLT,MG 1X RES OUT,SIN	0		28	VRMS	2C		N	10	H	8	B	2	R	H					0	28	2C		-	--	--		
HG2143-V	VOLT,MG 1X RES OUT,COS	0		28	VRMS	2C		N	10	H	8	B	2	R	H					0	28	2C		-	--	--		
HG2152-V	VOLT,MG 1X RES OUT,SIN	0		28	VRMS													A		0	28			-	--	--		
HG2153-V	VOLT,MG 1X RES OUT,COS	0		28	VRMS													A		0	28			-	--	--		
HG2167-V	VOLT OG SERVO ERROR INPH	0		20	VRMS	20C	5	N	100	H	8	B	2		H					0	20	20C		-	--	--		
HG2168-V	VOLT OG SERVO ERROR TOTAL	0		20	VRMS	2C			10		8	B	2							0	20	2C		-	--	--		
HG2170-C	CURR OG TOR MOTOR INPUT				AMP	SS	10		1		8	B	2									SS		-	--	--		
HG2172-V	VOLT,OG 1X RES OUT,SIN	0		28	VRMS	2C		N	10	H	8	B	2	R	H					0	28	2C		-	--	--		
HG2173-V	VOLT,OG 1X RES OUT,COS	0		28	VRMS	2C		N	10	H	8	B	2	R	H					0	28	2C		-	--	--		
HG2182-V	VOLT,OG 1X RES OUT,SIN	0		28	VRMS													A		0	28			-	--	--		
HG2183-V	VOLT,OG 1X RES OUT,COS	0		28	VRMS													A		0	28			-	--	--		
HG2205-V	VOLT IG CDU FINE ERROR				VRMS	SS			1		8	B	2									SS		-	--	--		
HG2207-V	VOLT IG CDU COARSE ERROR				VRMS	SS			1		8		2									SS		-	--	--		
HG2214-V	VOLT PITCH CDU DAC OUT				VRMS	2C		N	10	H	8	B	2		H							2C		-	--	--		
HG2217-V	VOLT,PITCH ATT ERROR-PGNS	0		10	VRMS													A		0	10			-	--	--		
HG2235-V	VOLT,MG CDU FINE ERROR				VRMS	SS			1		8	B	2									SS		-	--	--		
HG2237-V	VOLT,MG CDU COARSE ERROR				VRMS	SS			1		8	B	2									SS		-	--	--		

Table 5.6-6 (cont)

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BASELINE SHELTER

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NOVEMBER 8,1965

NAVIGATION AND GUIDANCE

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X / X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HG2244-V	VOLT,ROLL CDU DAC OUT				VRMS	2C		N	10H		8	B	2		H							2C		-	--	--		
HG2247-V	VOLT,ROLL ATT ERROR-PGNS	0		10	VRMS													A		0	10			-	--	--		
HG2265-V	VOLT,OG CDU FINE ERROR				VRMS	SS			1		8	B	2									SS		-	--	--		
HG2267-V	VOLT,OG CDU COARSE ERROR				VRMS	SS			1		8	B	2									SS		-	--	--		
HG2274-V	VOLT,YAW CDU DAC OUT				VRMS	2C		N	10H		8	B	2		H							2C		-	--	--		
HG2277-V	VOLT,YAW ATT ERROR-PGNS	0		10	VRMS													A		0	10			-	--	--		
HG2300-T	TEMP,PIPA	0		140	DEGF	SS	2	N	1	H	8	B	2		L					0	140	SS		-	--	--		
HG2301-T	TEMP,IRIG				DEGF	SS			1		8	B	2									SS		-	--	--		
HG2302-X	IMU HEATER ON					SS			1		1	B	2									SS		-	--	--		
HG2303-X	IMU BLOWER ON					SS			1		1	B	2									SS		-	--	--		
HG4300-T	TEMP,LGC				DEGF	SS		N	1		8	B	2									SS		-	--	--		
HG6020-T	TEMP,PIPA CAL MOD				DEGF	SS			1		8	B	2									SS		-	--	--		
HG6022-T	TEMP,PSA				DEGF	SS			1		8	B	2									SS		-	--	--		
HG9000-X	IMU CAGE	CONTACT CLOSURE				SS			1	E	1	B	2		H					CC		SS		4-5	0	0		
HG9001-X	LGC (WARNING)	CONTACT CLOSURE				SS			1	E	1	B	2		L	W				CC		SS		4-3	0	0		
HG9002-X	INRTL REF (WARNING)	CONTACT CLOSURE				SS			1	E	1	B	2		L	W				CC		SS		4-3	0	0		
HG9003-X	PGNS (CAUTION)	CONTACT CLOSURE				SS			1	E	1	B	2		L	C				CC		SS		4-3	0	0		

Table 5.6-6 (cont)

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BASELINE SHELTER

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	STABILITY AND CONTROL-CES FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X / X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HH1211-V	VOLT AUTO TH INCR 3,2KPPS	0		2-5	VDC	SS						B	2							0	5	SS		-	--	--		
HH1212-V	VOLT AUTO TH DECR 3,2KPPS	0		2-5	VDC	SS						B	2							0	5	SS		-	--	--		
HH1214-X	AUTO ENG ON COMMAND	0	OR	15	VDC	SS			1	E	1	B	2		L					0	OR15	SS		4-2	0	0		
HH1217-X	AUTO ENG OFF COMMAND	0	OR	15	VDC	SS			1	E	1	B	2		L					0	OR15	SS		4-2	0	0		
HH1229-X	DESC ENG ARM CMD (PNL)					SS			1	E	1	B	2		H							SS		4-2	0	0		
HH1230-X	ASC.ENG ARM (FROM PNL)					SS			1	E	1	B	2		H							SS		2-2	0	0		
HH1240-V	VOLT,'X' TRANS.CMD	-10	OR	+10	VDC	2C			10	H	8	B	2	R	H					-10	+10	2C		2-2	0	0		
HH1241-V	VOLT,'Y' TRANS.CMD	-10	OR	+10	VDC	2C			10	H	8	B	2	R	H					-10	+10	2C		2-2	0	0		
HH1242-V	VOLT,'Z' TRANS.CMD	-10	OR	+10	VDC	2C			10	H	8	B	2	R	H					-10	+10	2C		2-2	0	0		
HH1247-V	VOLT,PULSE YAW CMD	-13	+.5	+13	VDC	2C	2		10	H	8	B	2		H					-13	+13	2C		2-2	0	0		
HH1248-V	VOLT,PULSE PITCH CMD	-13	+.5	+13	VDC	2C	2		10	H	8	B	2		H					-13	+13	2C		2-2	0	0		
HH1249-V	VOLT,PULSE ROLL CMD	-13	+.5	+13	VDC	2C	2		10	H	8	B	2		H					-13	+13	2C		2-2	0	0		
HH1260-X	A.E. ON/OFF TO PROP	0		28	VDC	SS			1	E	1	B	2	R	H					0	28	SS		-	--	--		
HH1301-X	DESC ENG -ON/OFF- TO PROP	0		28	VDC	SS			1	E	1	B	2	R	SL					0	28	SS		-	--	--		
HH1313-V	VOLT,PITCH GDA POS (.4KC)	-15	+.05	+15	VRMS	1C	2			H	8	B	2	R	H					-15	+15	1C		7-1	0	0		
HH1314-V	VOLT,ROLL GDA POS (.4KC)	-15	+.05	+15	VRMS	1C	2			H	8	B	2	R	H					-15	+15	1C		7-1	0	0		
HH1318-	PITCH GDA EXTEND FROM LGC	TBA										B	2											-	--	--		
HH1319-	PITCH GDA RETRAC FROM LGC	TBA										B	2											-	--	--		
HH1320-X	PITCH GDA EXT/RET(.4KC)	0	OR	90	DEG	SS						B	2									SS		-	--	--		
HH1323-X	PITCH TRIM FAIL	TBA				SS			1	E	1	B	2	R	L	C						SS		4-3	0	0		
HH1330-X	ROLL TRIM FAIL	TBA				SS			1	E	1	B	2	R	L	C						SS		4-3	0	0		
HH1331-V	VOLT,AUTO THRUST CMD	0	.015	12	VDC	1C	2		10	H	8	B	2	R	H					0	15	1C		2-2	0	0		
HH1332-V	VOLT,AUTO/MAN THRUST	0		5	VDC	SS												A		0	5	SS		-	--	--		
HH1343-	ROLL GDA EXTEND FROM LGC	TBA										B	2											-	--	--		
HH1344-	ROLL GDA RETRACT FROM LGC	TBA										B	2											-	--	--		

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BASELINE SHELTER

PAGE NUMBER 20
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		INTEREST RANGES				STABILITY AND CONTROL-CES																					
ID CODE	MEASUREMENT NAME AND LOCATION	LOW	NORM	HIGH	UNIT	FREQ OR RATE	ACC	SCR	S/S	SIG	BIT	GRD	OPS	MCC	MH S/ SL	C/W	F/L	A/D	X/X	XDCR RANGES LOW HIGH	FREQ OR RATE	ACC	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	CHNG
HH1345-X	ROLL GDA EXT/RET (.4KC)	0	OR	90	DEG	SS						B	2								SS		-	--	--		
HH1348-X	DESC ENG ARM (DECA OUT)	0	OR	28	VDC	SS							2							0 / 28	SS		-	--	--		
HH1406-V	VOLT +15V DC SUPPLY			+15	VDC											W							2-2	0	0		
HH1407-V	VOLT -15V DC SUPPLY	-15			VDC											W							2-2	0	0		
HH1408-V	VOLT +4V DC SUPPLY			+4	VDC											W							4-1	0	0		
HH1418-V	VOLT,JET 1 DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1419-V	VOLT,JET 2 DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1420-V	VOLT,JET 3 DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1421-V	VOLT,JET 4 DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1422-V	VOLT,JET 5 DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1423-V	VOLT,JET 6 DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1424-V	VOLT,JET 7 DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1425-V	VOLT,JET 8 DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1426-V	VOLT,JET 9 DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1427-V	VOLT,JET 10DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1428-V	VOLT,JET 11DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1429-V	VOLT,JET 12DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1430-V	VOLT,JET 13DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1431-V	VOLT,JET 14DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1432-V	VOLT,JET 15DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1433-V	VOLT,JET 16DRIVER OUT,28V	6PPS	MAX,	10-400	MS					200E	1	B	2	R	H	W				0 / 28			4-2	0	0		
HH1434-V	VOLT LGC JET CMD NO 1	TBA										B	2										-	--	--		
HH1435-V	VOLT LGC JET CMD NO 2	TBA										B	2										-	--	--		
HH1436-V	VOLT LGC JET CMD NO 3	TBA										B	2										-	--	--		
HH1437-V	VOLT LGC JET CMD NO 4	TBA										B	2										-	--	--		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	STABILITY AND CONTROL-CES FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	CT OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	CHNG
HH1438-V	VOLT LGC JET CMD NO 5	TBA										B	2											-	--	--		
HH1439-V	VOLT LGC JET CMD NO 6	TBA										B	2											-	--	--		
HH1440-V	VOLT LGC JET CMD NO 7	TBA										B	2											-	--	--		
HH1441-V	VOLT LGC JET CMD NO 8	TBA										B	2											-	--	--		
HH1442-V	VOLT LGC JET CMD NO 9	TBA										B	2											-	--	--		
HH1443-V	VOLT LGC JET CMD NO 10	TBA										B	2											-	--	--		
HH1444-V	VOLT LGC JET CMD NO 11	TBA										B	2											-	--	--		
HH1445-V	VOLT LGC JET CMD NO 12	TBA										B	2											-	--	--		
HH1446-V	VOLT LGC JET CMD NO 13	TBA										B	2											-	--	--		
HH1447-V	VOLT LGC JET CMD NO 14	TBA										B	2											-	--	--		
HH1448-V	VOLT LGC JET CMD NO 15	TBA										B	2											-	--	--		
HH1449-V	VOLT LGC JET CMD NO 16	TBA										B	2											-	--	--		
HH1450-V	VOLT PITCH TRIM ERROR	-14		+14	VDC							B	2							-14	+14			-	--	--		
HH1452-V	VOLT ROLL TRIM ERROR	-14		+14	VDC							B	2							-14	+14			-	--	--		
HH1455-V	VOLT,YAW ATT ERROR (.8KC)	TBA				2C			10H		8	B	2	R	H							2C		7-1	0	0		
HH1456-V	VOLT,PITCH ATT ERROR(.8KC)	TBA				2C			10H		8	B	2	R	H							2C		7-1	0	0		
HH1457-V	VOLT,ROLL ATT ERROR(.8KC)	TBA				2C			10H		8	B	2	R	H							2C		7-1	0	0		
HH1461-V	VOLT,YAW RG SIG (.8KC)	-3.5		+3.5	VRMS	2C	2		10H		8	B	2	R	L					-3.5	+3.5	2C		7-1	0	0		
HH1462-V	VOLT,PITCH RG SIG (.8KC)	-3.5		+3.5	VRMS	2C			10H		8	B	2	R	L					-3.5	+3.5	2C		7-1	0	0		
HH1463-V	VOLT,ROLL RG SIG (.8KC)	-3.5		+3.5	VRMS	2C	2		10H		8	B	2	R	L					-3.5	+3.5	2C		7-1	0	0		
HH1492-V	VOLT -4VDC SUPPLY	-4			VDC	SS										W						SS		4-1	0	0		
HH1493-V	VOLT +6VDC SUPPLY			+6	VDC	SS										W						SS		2-2	0	0		
HH1494-V	VOLT -6VDC SUPPLY	-6			VDC	SS										W						SS		2-2	0	0		
HH1603-X	DEADBAND SELECT	TBA				SS			1	E	1	B	2	R	H							SS		4-5	0	0		
HH1608-X	SCS MODE SELECT (AUTO)	TBA				SS			1	E	1	B	2	R	H							SS		4-5	0	0		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	STABILITY AND CONTROL-CES FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HH1609-X	SCS MODE SELECT(ATT HOLD)	TBA				SS			1	E	1	B	2	R	H							SS		4-5	0	0		
HH1615-X	ROLL ATT CONT SEL(PULSED)	TBA				SS			1	E	1	B	2	R	H							SS		4-5	0	0		
HH1616-X	PITCH ATT CONT SEL(PULSED)	TBA				SS			1	E	1	B	2	R	H							SS		4-5	0	0		
HH1617-X	YAW ATT CONT SEL(PULSED)	TBA				SS			1	E	1	B	2	R	H							SS		4-5	0	0		
HH1896-X	UNBALANCED COUPLES	TBA				SS			1	E	1	B	2		H							SS		4-5	0	0		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	INSTRUMENTATION FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	CT OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HL0300	FRAME SYNCH + ID								1	P	32	B	2	R	SL									-	--	--		
HL0300-	FRAME SYNCH + ID								50	P	32	B	2	R	H									-	--	--		
HL0302	FORMAT ID								1	P	8	B	2	R	SL									-	--	--		
HL0401	CALIB 85 PCT HL	4.24	4.25	4.26	VDC	SS			1	H	8	B	2	R	SL					0	5	SS		-	--	--		
HL0401-	CALIB 85 PCT HL	4.24	4.25	4.26	VDC	SS			10	H	8	B	2	R	H					0	5	SS		-	--	--		
HL0402	CALIB 15 PCT HL	.741	.75	.759	VDC	SS			1	H	8	B	2	R	SL					0	1	SS		-	--	--		
HL0402-	CALIB 15 PCT HL	.741	.75	.759	VDC	SS			10	H	8	B	2	R	H					0	1	SS		-	--	--		
HL0411	OUTPUT REG ALL ZERO CK								1	P	8	B	2		SL									-	--	--		
HL0501-W	TIME,GREEMWICH MEAN		TIME						10	P	32	B	2	R	H									-	--	--		
HL0501-W	TIME,GREEMWICH MEAN		TIME						1	P	32	B	2	R	SL									-	--	--		
HL0801-V	VOLT PCMTE 1024KC TIM SIG					SS						B	2											-	--	--		
HL4021-X	(6DS1) TBA	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4022-X	(6DS2) ASCENT LOW PRESS	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4023-X	6DS3 PRES HE REG OUT MFLD	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4024-X	6DS4 LOW DESC PROP QUANT	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4025-X	6DS5 TBA	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4026-X	CES AC PWR SUPP FAIL(6DS6)	CONTACT CLOSURE				SS			1	E	1	B	2		H		L			CC		SS		4-4	0	0		
HL4027-X	CES DC PWR SUPP FAIL(6DS7)	CONTACT CLOSURE				SS			1	E	1	B	2		H		L			CC		SS		4-4	0	0		
HL4029-X	6DS9 N+G LGC WARNING	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4030-X	6DS10 N+G INTERNAL REF	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4031-X	6DS11 RCS TCA JET FAIL	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4032-X	6DS12 PR RCS HE REG A OUT	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4033-X	6DS13 PR RCS HE REG B OUT	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4034-X	6DS14 TBA	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HL4035-X	6DS15 TBA	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		

Table 5.6-6 (cont)

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW NORM	HIGH	UNIT	INSTRUMENTATION FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	D P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C O N D	S I G	T Y P E	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HL4036-X	6DS16 CABIN WARNING	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4037-X	6DS17 SUIT/FAN WARNING	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4038-X	6DS18 RNDZ RADAR DATA NG	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4039-X	6DS19 LDG RADAR	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4040-X	6DS20 TBA	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4041-X	6DS21 ASC HI P OUT MFLD C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4042-X	6DS22 ASC LOW PROP QUAN C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4043-X	6DS23 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4044-X	6DS24 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4045-X	6DS25 PGNS CAUTION C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4046-X	6DS26 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4047-X	6DS27 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4048-X	6DS28 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4049-X	6DS29 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4050-X	6DS30 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4051-X	6DS31 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4052-X	6DS32 RCS CAUTION C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4053-X	6DS33 HEATER CAUTION	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4054-X	6DS34 TBA C	CONTACT	CLOSURE		SS			1	E	1	B	2		L		L			CC		SS			-		--	--		
HL4055-X	6DS35 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4056-X	6DS36 ECS CAUTION C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4057-X	6DS37 ECS O2 ACCUM PRES C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4058-X	6DS38 GLYCOL CAUTION C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4059-X	6DS39 DES-ASC H2O QUAN C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		
HL4060-X	6DS40 TBA C	CONTACT	CLOSURE		SS											L			CC		SS			-		--	--		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	INSTRUMENTATION FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HL4069-X	C+WE MASTER ALARM ID					SS			1	E	1	B	2		L		L					SS		-	--	--		
HL4111-V	VOLT C+WE WRN IN REF V 1	-4.995	-5	-5.005	V	SS						B	2							0	-5	SS		-	--	--		
HL4112-V	VOLT C+WE WRN IN REF V 2	-4.995	-5	-5.005	V	SS						B	2							0	-5	SS		-	--	--		
HL4113-V	VOLT C+WE WRN IN REF V 3	-4.995	-5	-5.005	V	SS						B	2							0	-5	SS		-	--	--		
HL4114-V	VOLT C+WE CAUT IN REF V	-4.995	-5	-5.005	V	SS						B	2							0	-5	SS		-	--	--		
HL4201-F	FREQ DSEA MONI HD OUTPUT	.3		3K	CPS	3KC						A	1									3KC		-	--	--		
HL4202-F	FREQ DSEA BIAS OSC OUTPUT	36		36K	CPS	TBA						A	1											-	--	--		
HL9501-U	TCA FAILURE PR 4A					SS											F					SS		-	--	--		
HL9502-U	TCA FAILURE PR 4B					SS											F					SS		-	--	--		
HL9503-U	TCA FAILURE PP 3A					SS											F					SS		-	--	--		
HL9504-U	TCA FAILURE PR 3B					SS											F					SS		-	--	--		
HL9505-U	TCA FAILURE PR 2A					SS											F					SS		-	--	--		
HL9506-U	TCA FAILURE PR 2B					SS											F					SS		-	--	--		
HL9507-U	TCA FAILURE PR 1A					SS											F					SS		-	--	--		
HL9508-U	TCA FAILURE PR 1B					SS											F					SS		-	--	--		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	INTEREST RANGES NORM	INTEREST RANGES HIGH	UNIT	FREQ OR RATE	RADARS A C C	RADARS S C R	RADARS S / S	RADARS S I G	RADARS B I T	RADARS G R D	RADARS O P S	RADARS M C C	RADARS MH S/ SL	RADARS C / W	RADARS F / L	RADARS A / D	RADARS X X X	XDCR RANGES LOW	XDCR RANGES HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HN7521-X	LR RANGE DATA NO GOOD	CONTACT CLOSURE				SS			1	E	1	B	2		H	W				CC		SS		4-3	0	0		
HN7523-L	VEL LR V'XA VEL(ALT RATE)	TBA			FT/S													D						-	--	--		
HN7524-L	VEL LR V'YA VEL	TBA			FT/S													A						-	--	--		
HN7525-L	VEL LR V'ZA VEL	TBA			FT/S													A						-	--	--		
HN7527-H	POS LR RANGE DATA (DISP)				FEET													D						-	--	--		
HN7529-V	VOLT LR RANGE GATE STROBE	4	7	10	VDC	3.2K						A	1							0	10			-	--	--		
HN7530-V	VOLT LR VXA GATE STROBE	4	7	10	VDC	3.2K						A	1							0	10			-	--	--		
HN7531-V	VOLT LR VYA GATE STROBE	4	7	10	VDC	3.2K						A	1							0	10			-	--	--		
HN7532-V	VOLT LR VZA GATE STROBE	4	7	10	VDC	3.2K						A	1											-	--	--		
HN7533-V	VOLT LR LGC ANT POS CMD	TBA										A	1											-	--	--		
HN7534-V	VOLT LR RESET STROBE	4	7	10	VDC	3.2K						A	1							0	10			-	--	--		
HN7535-V	VOLT LR COUNT READOUT CMD	4	7	10	VDC	3.2K						A	1							0	10			-	--	--		
HN7536-V	VOLT LR COUNTER OUTPUT 0	4	7	10	VDC	3.2K						A	1							0	10			-	--	--		
HN7537-V	VOLT LR COUNTER OUTPUT 1	4	7	10	VDC	3.2K						A	1							0	10			-	--	--		
HN7540-X	VOLT LR LOW SCALE FACTOR	17	TBA	39	VDC	SS						B	2							0	40	SS		-	--	--		
HN7545-E	PWR LR VEL XMTR RF PWROUT				MW													A						-	--	--		
HN7546-E	PWR LR ALT XMTR RF PWROUT				MW													A						-	--	--		
HN7557-X	LR VEL.DATA NO GOOD	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H	W				CC		SS		4-3	--	--		
HN7562-X	LR HEATER CAUTION	CONTACT CLOSURE				SS		S	1	E	1	B	2		H	C				CC		SS		4-3	--	--		
HN7567-V	VOLT LR GAIN STATE D1	-1		+6	VDC	SS						B	2							-1	+6	SS		-	--	--		
HN7568-V	VOLT LR GAIN STATE D2	-1		+6	VDC	SS						B	2							-1	+6	SS		-	--	--		
HN7569-V	VOLT LR GAIN STATE D3	-1		+6	VDC	SS						B	2							-1	+6	SS		-	--	--		
HN7570-V	VOLT LR GAIN STATE D4	-1		+6	VDC	SS						B	2							-1	+6	SS		-	--	--		
HN7571-V	VOLT LR -25 VDC	-27	-25	0	VDC	SS						B	2							-28	0	SS		-	--	--		
HN7572-V	VOLT LR +25 VDC	0	25	27	VDC	SS						B	2							0	28	SS		-	--	--		

Table 5.6-6 (cont)

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	INTEREST RANGES NORM	INTEREST RANGES HIGH	UNIT	FREQ OR RATE	RADARS A C C	RADARS S C R	RADARS S / S	RADARS S I G	RADARS B I T	RADARS G R D	RADARS O P S	RADARS M C C	RADARS MH S/ SL	RADARS C / W	RADARS F / L	RADARS A / D	RADARS X X X	XDCR RANGES LOW	XDCR RANGES HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HN7573-V	VOLT LR +25 VDC (SSC)	0	25	27	VDC	SS						B	2							0	28	SS		-	--	--		
HN7574-V	VOLT LR +4 VDC	0	4	6	VDC	SS						B	2							0	10	SS		-	--	--		
HN7575-V	VOLT LR -2 VDC	-4	-2	0	VDC	SS						B	2							-5	0	SS		-	--	--		
HN7576-X	LR ANTENNA POSIT 1 IND	TBA			VDC	SS						B	2									SS		-	--	--		
HN7577-X	LR ANTENNA POSIT 2 IND	TBA			VDC	SS						B	2									SS		-	--	--		
HN7582-E	PWR LR VEL XMTR RF PWROUT				MW							B	2											-	--	--		
HN7583-E	PWR LR ALT XMTR RF PWROUT				MW							B	2											-	--	--		
HN7584-X	LR MODE CONTROL	TBA										B	2											-	--	--		
HN7585-F	FREQ LR SELF TEST	TBA										B	2											-	--	--		
HN7586-F	FREQ LR RA TRAN BLANK SIG	TBA										B	2											-	--	--		
HN7589-V	VOLT D1 AT ANGLE 0 DEG	TBA										B	2											-	--	--		
HN7590-V	VOLT D2 AT ANGLE 0 DEG	TBA										B	2											-	--	--		
HN7591-V	VOLT D3 AT ANGLE 0 DEG	TBA										B	2											-	--	--		
HN7592-V	VOLT FR AT ANGLE 0 DEG	TBA										B	2											-	--	--		
HN7593-V	VOLT D1 AT ANGLE 90 DEG	TBA										B	2											-	--	--		
HN7594-V	VOLT D2 AT ANGLE 90 DEG	TBA										B	2											-	--	--		
HN7595-V	VOLT D3 AT ANGLE 90 DEG	TBA										B	2											-	--	--		
HN7596-V	VOLT FR AT ANGLE 90 DEG	TBA										B	2											-	--	--		
HN7597-F	FREQ LR ALT TRAN TES CPLR	TBA										A	1											-	--	--		
HN7598-F	FREQ LR VEL TRAN TES CPLR	TBA										A	1											-	--	--		
JN9001	GYRO TEST INPUT SIG																							-	--	--		
JN9002	RCVR(SHAFT ERROR)INPT SIG																							-	--	--		
JN9003	RCVR(SUM)INPUT SIG																							-	--	--		
JN9004	RCVR(TRUN ERROR)INPUT SIG																							-	--	--		
JN9005	SHAFT CHANNEL INPUT SIG																							-	--	--		

Table 5.6-6 (cont)

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	INTEREST RANGES NORM	INTEREST RANGES HIGH	UNIT	FREQ OR RATE	RADARS A C C	RADARS S C R	RADARS S / S	RADARS S I G	RADARS B I T	RADARS G R D	RADARS O P S	RADARS M C C	RADARS MH S/ SL	RADARS C / W	RADARS F / L	RADARS A / O	RADARS X X X	XDCR RANGES LOW	XDCR RANGES HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
JN9006	SUM CHANNEL INPUT SIG																							-	--	--		
JN9007	TRUNNION CHANNEL INPT SIG																							-	--	--		
JN9008	VELOCITY RCVR NO1 INPUT																							-	--	--		
JN9009	VELOCITY RCVR NO2 INPUT																							-	--	--		
JN9010	VELOCITY RCVR NO3 INPUT																							-	--	--		
JN9011	ALTIMETER RCVR INPUT																							-	--	--		

Table 5.6-6 (cont)

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PROPULSION-DESCENT

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	D P S	M C C	MH S/ SL	C / W	F / L	A / D	X / X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	CT OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	CHNG
HQ3001-P	PRESS,HE SUPPLY TANK	190		1398	PSIA	SS		I	1	H	8	B	2	R	L			D		0	4000	SS		-	.28	.25		
HQ3018-P	PRESS,HE REG OUT MANIFOLD	210	235	270	PSIA	SS		I	1	H	8	B	2	F	H	W				0	300	SS		4-1	.28	.25		
HQ3018-P	PRESS HE REG OUT MANIFOLD	210	235	270	PSIA	100C						A	1							0	300	100C		-	.28	.25		
HQ3201-T	TEMP,HE SUPPLY TANK	-445		-335	DEGF	SS		I	1	H	8	B	2	R	SL					-450	-300	SS		-	.25	.25		
HQ3309-X	LHE PRI SOL VLV CLOSED	CONTACT	CLOSURE			SS		S	1	E	1	B	2	R	H		F			CC		SS		4-4	0	Z.05		
HQ3310-X	HE SEC SOL VLV CLOSED	CONTACT	CLOSURE			SS		S	1	E	1	B	2	R	H		F			CC		SS		4-4	0	Z.05		
HQ3718-T	TEMP,FUEL TANK 1,BULK	40	70	100	DEGF	SS		I	1	H	8	B	2	R	SL			A		40	100	SS		6-2	0	.16		
HQ3719-T	TEMP,FUEL TANK 2,BULK	40	70	100	DEGF	SS		I	1	H	8	B	2	R	SL			A		40	100	SS		6-2	0	.16		
HQ3909-X	FUEL TANK 1 LQD LEVEL LOW	CONTACT	CLOSURE			SS		I	1	E	1	B	2	R	H	W				CC		SS		4-3	*	*	SS WT./PWR.	
HQ3910-X	FUEL TANK 2 LQD LEVEL LOW	CONTACT	CLOSURE			SS		I	1	E	1	B	2	R	H	W				CC		SS		4-3	*	*	SS WT./PWR.	
HQ4218-T	TEMP,OX TANK 1,OX BULK	40	70	100	DEGF	SS		I	1	H	8	B	2	R	SL			A		40	100	SS		6-2	0	.16		
HQ4219-T	TEMP,OX TANK 2,OX BULK	40	70	100	DEGF	SS		I	1	H	8	B	2	R	SL			A		40	100	SS		6-2	0	.16		
HQ4409-X	OX TANK 1,LQD LEVEL LOW	CONTACT	CLOSURE			SS		S	1	E	1	B	2	R	H	W				CC		SS		4-3	*	*	SS WT./PWR.	
HQ4410-X	OX TANK 2,LQD LEVEL LOW	CONTACT	CLOSURE			SS		S	1	E	1	B	2	R	H	W				CC		SS		4-3	*	*	SS WT./PWR.	
HQ6001-P	PRESS FUEL CONTROL VLV IN	50	210	270	PSIA	SS		I	1	H	8	B	2	R	L			A		0	300	SS		-	--	--		
HQ6001-P	PRESS,FUEL CONTROL VLV IN	50	210	270	PSIA	150C		I				A	1							0	300	150C		-	.28	.25		
HQ6002-P	PRESS,OX CONTROL VLV IN	50	210	270	PSIA	SS		I	1	H	8	B	2	R	L					0	300	SS		-	.28	.25		
HQ6301-H	POS MIXTURE RATIO ACTUAT	-15		+15	DEG	SS		S												-15	+15	SS		-	--	--		
HQ6306-X	SHUTOFF VLV A NOT OPEN	CONTACT	CLOSURE			SS		S							*					CC		SS		-	0	Z.05	HQ7498	
HQ6307-X	SHUTOFF VLV A NOT CLOSED	CONTACT	CLOSURE			SS		S							*					CC		SS		-	0	Z.05	HQ7498	
HQ6308-X	SHUTOFF VLV B NOT OPEN	CONTACT	CLOSURE			SS		S							*					CC		SS		-	0	Z.05	HQ7498	
HQ6309-X	SHUTOFF VLV B NOT CLOSED	CONTACT	CLOSURE			SS		S							*					CC		SS		-	0	Z.05	HQ7498	
HQ6314-X	SHUTOFF VLV C NOT OPEN	CONTACT	CLOSURE			SS		S							*					CC		SS		-	0	Z.05	HQ7499	
HQ6315-X	SHUTOFF VLV C NOT CLOSED	CONTACT	CLOSURE			SS		S							*					CC		SS		-	0	Z.05	HQ7499	
HQ6316-X	SHUTOFF VLV D NOT OPEN	CONTACT	CLOSURE			SS		S							*					CC		SS		-	0	Z.05	HQ7499	

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	PROPULSION-DESCENT FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HQ6317-X	SHUTOFF VLV D NOT CLOSED	CONTACT CLOSURE				SS		S							*					CC		SS		-	0	Z.05	HQ7499	
HQ6510-P	PRESS, THRUST CHAMBER	11	110	121	PSIA	SS		S	1	H	8			R	L					0	100	SS		-	--	--		
HQ6510-P	PRESS THRUST CHAMBER	0		100	PCT	SS												A		0	200	SS		-	.28	.25		
HQ6806-H	POS, VARIABLE INJ. ACTUATOR	10		100	PCT	SS		S	1	H	8	B	2	R	H					0	100	SS		-	--	--		
HQ7498-U	SHUTOFF VLVS A/B MID POS.	CONTACT CLOSURE				SS			1	E	1	B	2	R	SL					CC		SS		4-5	--	--		
HQ7498-U	SHUTOFF VLVS A/B MID POS.	CONTACT CLOSURE				1MS						A	1							CC		--		-	--	--		
HQ7499-U	SHUTOFF VLVS C/D MID POS.	CONTACT CLOSURE				SS			1	E	1	B	2	R	L					CC		SS		4-5	--	--		
HQ7499-U	SHUTOFF VLVS C/D MID POS.	CONTACT CLOSURE				1MS						A	1							CC		--		-	--	--		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	REACTION CONTROL FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X / X	XDCR RANGES LOW	HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HR1102-P	PRESSURE,HELIUM TANK B	3000	3050	3250	PSIA	SS	3	I	1	H	8	B	2	R	SL					0	3500	SS		4-1	.28	.25		
HR1102-P	PRESS HELIUM TANK B	0		1000	PSIA	SS										C		A		0	1000	SS		-	--	--		
HR1122-T	TEMP,HELIUM TANK B	40	70	100	DEGF	SS	3	I	1	H	8	B	2	R	SL			A		20	120	SS		6-2	0	.16		
HR1202-P	PRESS,HE REGULATOR B OUT	171	191	250	PSIA	SS	3	I	1	H	8	B	2	R	L					0	350	SS		4-1	.28	.25		
HR1202-P	PRESS HE REG B OUTPUT	0		175		SS										W				0	175	SS		-	--	--		
HR1463-X	HE SHUTOFF VLV B-1 CLOSE	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H		F			CC		SS		4-4	0	Z.05		
HR1464-X	HE SHUTOFF B-2 NOT CLOSED	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	SL		F			CC		SS		4-4	0	Z.05		
HR2102-P	PRESSURE,FUEL TANK B	171	191	250	PSIA	SS		I	1	H	8	B	2	R	SL			A		0	350	SS		-	.28	.25		
HR2122-T	TEMPERATURE,FUEL TANK B	40	70	100	DEGF	SS		I	1	H	8	B	2	R	SL			A		20	120	SS		6-2	0	.16		
HR2142-Q	QUANTITY,FUEL TANK B	0		99	PCT	SS		S	1	P	8	B	2	R	L					0	99	SS		-	--	--		
HR2144-Q	QUANTITY,FUEL TANK B	0		99	PCT	SS												D		0	99	SS		-	--	--		
HR2202-P	PRESS,B FUEL MANIFOLD	171	191	250	PSIA	SS	3	I	1	H	8	B	2	R	H			A		0	350	SS		4-1	.28	.25		
HR2462-X	FUEL MAIN FEED S/O B CL	CONTACT CLOSURE				SS		S							*		F			CC		SS		-	0	Z.05	HR9610	
HR3102-P	PRESSURE,OXIDIZER TANK B	171	191	250	PSIA	SS	3	I	1	H	8	B	2	R	SL			A		0	350	SS		-	.28	.25		
HR3122-T	TEMP,OXIDIZER TANK B	40	70	100	DEGF	SS	3	I	1	H	8	B	2	R	SL			A		20	120	SS		6-2	0	.16		
HR3142-Q	QUANTITY,OXID.TANK B	0		99	PCT	SS	3	S	1	P	8	B	2	R	L					0	99	SS		-	--	--		
HR3144-Q	QUANTITY OXIDIZER TANK B	0		99	PCT	SS	3											D		0	99	SS		-	--	--		
HR3202-P	PRESSURE,OXID.MNFLD B	171	191	250	PSIA	SS	3	I	1	H	8	B	2	R	H			A		0	350	SS		-	.28	.25		
HR3462-X	OXID MAIN FEED S/O B CLSD	CONTACT CLOSURE				SS		S							*		F			CC		SS		-	0	Z.05	HR9610	
HR4262-X	TCA ISOL FUEL VLV 1B CLSD	CONTACT CLOSURE				SS		S							*		F			CC		SS		-	0	Z.05	HR9662	
HR4264-X	TCA ISOL FUEL VLV 2B CLSD	CONTACT CLOSURE				SS		S							*		F			CC		SS		-	0	Z.05	HR9664	
HR4266-X	TCA ISOL FUEL VLV 3B CLSD	CONTACT CLOSURE				SS		S							*		F			CC		SS		-	0	Z.05	HR9666	
HR4268-X	TCA ISOL FUEL VLV 4B CLSD	CONTACT CLOSUER				SS		S							*		F			CC		SS		-	0	Z.05	HR9668	
HR4270-X	TCA ISOL OXID VLV 1B CLSD	CONTACT CLOSURE				SS		S							*		F			CC		SS		-	0	Z.05	HR9662	
HR4272-X	TCA ISOL OXID VLV 2B CLSD	CONTACT CLOSURE				SS		S							*		F			CC		SS		-	0	Z.05	HR9664	

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	INTEREST RANGES NORM	INTEREST RANGES HIGH	UNIT	REACTION CONTROL FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	D P S	M C C	MH S/ SL	C / W	F / L	A / D	X / X	XDCR RANGES LOW	XDCR RANGES HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HR4274-X	TCA ISOL OXID VLV 3B CLSD	CONTACT CLOSURE				SS		S							*		F			CC		SS		-	0	Z.05	HR9666	
HR4276-X	TCA ISOL OXID VLV 4B CLSD	CONTACT CLOSURE				SS		S							*		F			CC		SS		-	0	Z.05	HR9668	
HR5002-X	O/F RATIO B OUT,TOLER	CONTACT CLOSURE				SS		S	1	E	1	B	2	R	H	C				CC		SS		4-3	0	Z.05		
HR5012-P	PRESS TCA FUEL INLT PR 1B	171	191	250	PSIA	SS	3	S									F			0	175	SS		-	--	--		
HR5014-P	PRESS TCA FUEL INLT PR 2B	171	191	250	PSIA	SS	3	S									F			0	175	SS		-	--	--		
HR5016-P	PRESS TCA FUEL INLT PR 3B	171	191	250	PSIA	SS	3	S									F			0	175	SS		-	--	--		
HR5018-P	PRESS TCA FUEL INLT PR 4B	171	191	250	PSIA	SS	3	S									F			0	175	SS		-	--	--		
HR5020-P	PRESS TCA OXID INLT PR 1B	171	191	250	PSIA	SS	3	S									F			0	175	SS		-	--	--		
HR5022-P	PRESS TCA OXID INLT PR 2B	171	191	250	PSIA	SS	3	S									F			0	175	SS		-	--	--		
HR5024-P	PRESS TCA OXID INLT PR 3B	171	191	250	PSIA	SS	3	S									F			0	175	SS		-	--	--		
HR5026-P	PRESS TCA OXID INLT PR 4B	171	191	250	PSIA	SS	3	S									F			0	175	SS		-	--	--		
HR6001-T	TEMP,QUAD CLUSTER NO.1	0		200	DEGF	SS	3	I	1	H	8	B	2	R	H					0	200	SS		6-2	0	.08		
HR6002-T	TEMP,QUAD CLUSTER NO.2	0		200	DEGF	SS	3	I	1	H	8	B	2	R	H					0	200	SS		6-2	0	.08		
HR6003-T	TEMP,QUAD CLUSTER NO.3	0		200	DEGF	SS	3	I	1	H	8	B	2	R	H					0	200	SS		6-2	0	.08		
HR6004-T	TEMP,QUAD CLUSTER NO.4	0		200	DEGF	SS	3	I	1	H	8	B	2	R	H					0	200	SS		6-2	0	.08		
HR7121-V	VOLT SEC FUEL + OX INJT 1	0	28	32	VDC							B	2							0	35			-	--	--		
HR7123-V	VOLT SEC FUEL + OX INJT 3	0	28	32	VDC							B	2							0	35			-	--	--		
HR7126-V	VOLT SEC FUEL + OX INJT 6	0	28	32	VDC							B	2							0	35			-	--	--		
HR7127-V	VOLT SEC FUEL + OX INJT 7	0	28	32	VDC							B	2							0	35			-	--	--		
HR7129-V	VOLT SEC FUEL + OX INJT 9	0	28	32	VDC							B	2							0	35			-	--	--		
HR7132-V	VOLT SEC FUEL + OX INJT12	0	28	32	VDC							B	2							0	35			-	--	--		
HR7134-V	VOLT SEC FUEL + OX INJT14	0	28	32	VDC							B	2							0	35			-	--	--		
HR7136-V	VOLT SEC FUEL + OX INJT16	0	28	32	VDC							B	2							0	35							
HR9610-U	MAIN PROP.VALVE B CLOSED	CONTACT CLOSURE				SS			1	E	1	B	2	R	H					CC		SS		4-4	--	--		
HR9662-U	TCA ISOL VLVS 1B CLOSED	CONTACT CLOSURE				SS			1	E	1	B	2	R	H					CC		SS		4-4	--	--		

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REACTION CONTROL

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW NORM HIGH UNIT	FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HR9664-U	TCA ISOL VLVS 2B CLOSED	CONTACT CLOSURE	SS			1	E	1	B	2	R	H					CC	SS		4-4	--	--		
HR9666-U	TCA ISOL VLVS 3B CLOSED	CONTACT CLOSURE	SS			1	E	1	B	2	R	H					CC	SS		4-4	--	--		
HR9668-U	TCA ISOL VLVS 4B CLOSED	CONTACT CLOSURE	SS			1	E	1	B	2	R	H					CC	SS		4-4	--	--		

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ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	NORM	HIGH	UNIT	FREQ OR RATE	COMMUNICATIONS ACC	SCR	S/S	SIG	BIT	GRD	OPS	MCC	MH S/ SL	C/W	F/L	A/D	XXX	XDCR RANGES LOW	HIGH	FREQ OR RATE	ACC	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	CHNG
HT0105	PCM NRZ DATA INPUT		TBA									A	1											-	--	--		
HT0106	TE 512KC SYNC IN		TBA									A	1											-	--	--		
HT0107	PCM SPLIT PHASE IN		TBA									A	1											-	--	--		
HT0108	512KC SUBCARRIER REF IN		TBA									A	1											-	--	--		
HT0145-V	VOLT,SPS AVC RCVD VHF B	0		5	VDC	SS						B	2							0	5	SS		-	--	--		
HT0161-V	VOLT,PMP EMG VOICE LINE		TBA									A	1											-	--	--		
HT0163	VHF RCVD VOICE IN A		TBA									A	1											-	--	--		
HT0164	VHF RCVD VOICE IN B		TBA									A	1											-	--	--		
HT0201-E	POWER,SBAND PA RF PWR OUT	0	18	25	WATTS	SS		S	1	H	8	B	2	R	SL							SS		-	--	--		
HT0202-E	PWR,SBAND PA RF REFLECTED	0	.3	.5	WATTS	SS		S	1	H	8	B	2		H							SS		-	--	--		
HT0206-X	PA RECYCLING SIG NO 1											B	2											-	--	--		
HT0207-X	PA RECYCLING SIG NO 2											B	2											-	--	--		
HT0224-C	CURR, SBAND PWR AMP AN 1	20	25	30	MA	SS						B	2							0	30	SS		-	--	--		
HT0225-C	CURR, SBAND PWR AMP AN 2	20	25	30	MA	SS						B	2							0	30	SS		-	--	--		
HT0226-E	PWR VHF XMTR A+B RF OUT		TBA									B	2											-	--	--		
HT0451-H	POS GIMBAL PICOFF OPUT Y	-60		+240	DEG													A						-	--	--		
HT0452-H	POS GIMBAL PICOFF OPUT X	-75		+75	DEG													A						-	--	--		
HT0453-X	SBAND STEER ANT NO TRACK	CONTACT CLOSURE				SS											L			CC		SS		-	--	--		
HT0504-V	VOLT,SBAND RCVR AGC	0		4.2	VDC													A		0	5			-	--	--		
HT0511	SBAND XPNDR FM INPUT		TBA									A	1											-	--	--		
HT0513	SBAND XPNDR PM INPUT		TBA									A	1											-	--	--		
HT0555	S BD RCVR SBCAR WVFORM OT		TBA									A	1											-	--	--		
HT0604-V	VOLT,VHF RCVR A AGC	0		4.2	VDC	SS						B	2							0	5	SS		-	--	--		
HT0605-V	VOLT,VHF RCVR B AGC	0		4.2	VDC	SS						B	2							0	5	SS		-	--	--		
HT0660-V	VOLT,ST ANT SERV ERR INP		TBA									A	1															

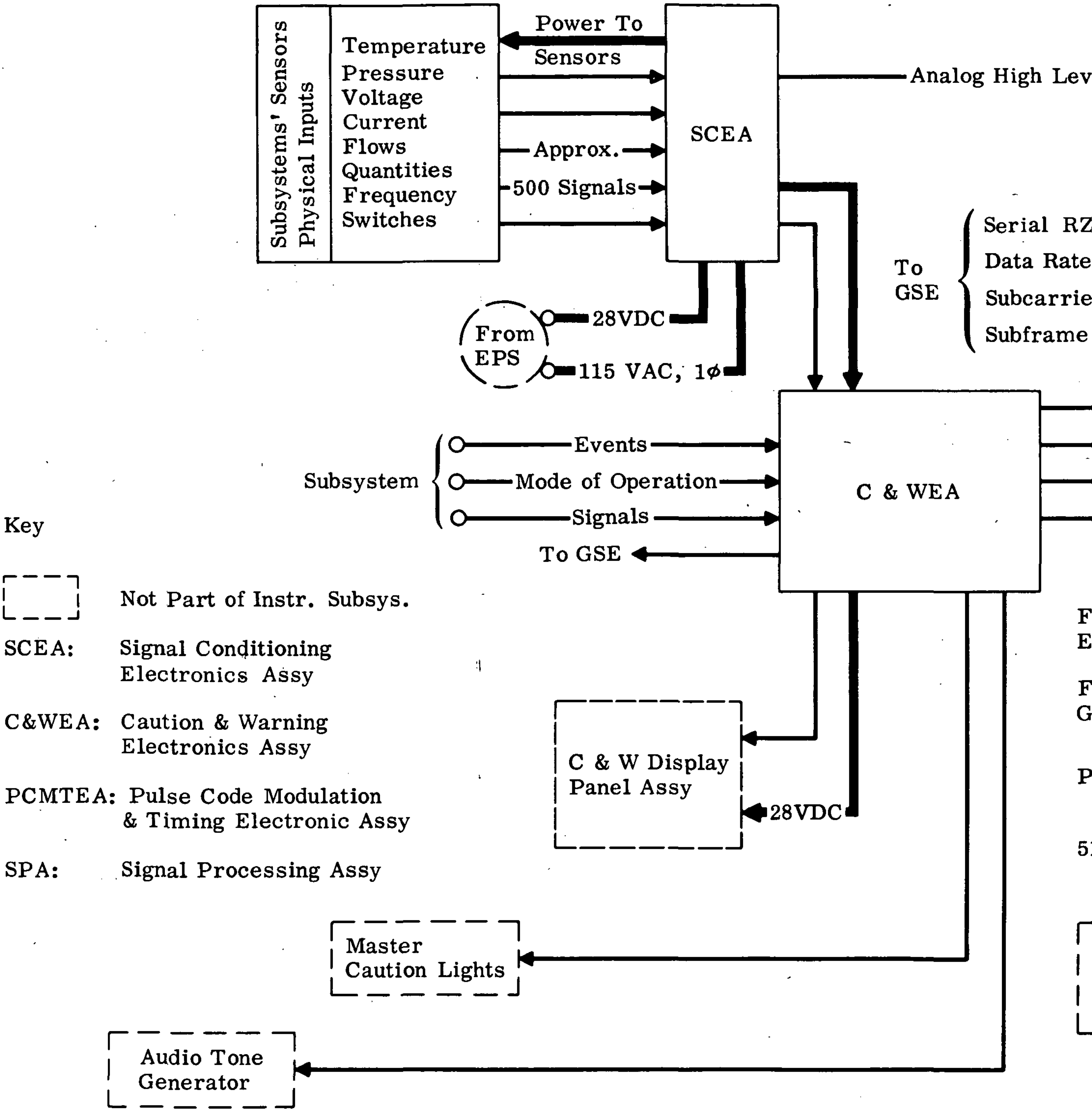
Table 5.6-6 (cont)

CONTRACT NUMBER NAS9-4983
BASELINE SHELTER

PAGE NUMBER 35
NOVEMBER 8,1965

ID CODE	MEASUREMENT NAME AND LOCATION	INTEREST RANGES LOW	INTEREST RANGES NORM	INTEREST RANGES HIGH	UNIT	COMMUNICATIONS FREQ OR RATE	A C C	S C R	S / S	S I G	B I T	G R D	O P S	M C C	MH S/ SL	C / W	F / L	A / D	X X X	XDCR RANGES LOW	XDCR RANGES HIGH	FREQ OR RATE	A C C	C T OSY NIP DGE	XDCR -PWR	XDCR WT.	REFERENCES OR NOTES	C H N G
HT0992-B	PHASE,ST PH ER,SLCTD S/B	-15	0	+15	DEG	2C		S	10	H	8	B	2	R	L							2C		-	--	--		
HT0993-E	PWR,SLCTD SBAND XMTR RF	.5	.75	1	WATT	SS		S	1	H	8	B	2	R	SL							SS		-	--	--		
HT0994-V	VOLT,SLCTD SBAND RCVR AGC	0		4.2	VDC	2C		S	10	H	8	B	2	R	SL					0	5	2C		-	--	--		
HT8001	VHF XMTR A CW CONTROL																							-	--	--		
HT8002	VHF XMTR B CW CONTROL																							-	--	--		
HT8003-V	VOLT,PRIM PWR SUPP CONTR																							-	--	--		
HT8005-V	VOLT,SEC PWR SUPP CONTR																							-	--	--		
HF8701-T	TEMP COOLANT RAD INLET	30	70	160	DEGF	SS						B	2					A				SS						
HT8801-P	PRESS,AIRLOCK	0	5	10	PSIA	SS												A				SS						
HT9991-J	7 SPACE SUIT/PLSS MPX OUT																							-	--	--	SBAND	
HT9999-J	ELECTROCARDIOGRAM NO.1/2																							-	--	--	SBAND	

Grumman


Subsystems' Sensors
Physical Inputs
Temperature
Pressure
Voltage
Current
Flows
Quantities
Frequency
Switches
Power To
Sensors
Approx.
500 Signals
SCEA
Analog High Lev
To
GSE
Serial RZ
Data Rate
Subcarrie
Subframe
From
EPS
28VDC
115 VAC, 1ϕ
Subsystem
Events
Mode of Operation
Signals
To GSE
C & WEA
F
E
F
G
P
5
C & W Display
Panel Assy
28VDC
Master
Caution Lights
Audio Tone
Generator
Key
Not Part of Instr. Subsys.
SCEA: Signal Conditioning Electronics Assy
C&WEA: Caution & Warning Electronics Assy
PCMTEA: Pulse Code Modulation & Timing Electronic Assy
SPA: Signal Processing Assy

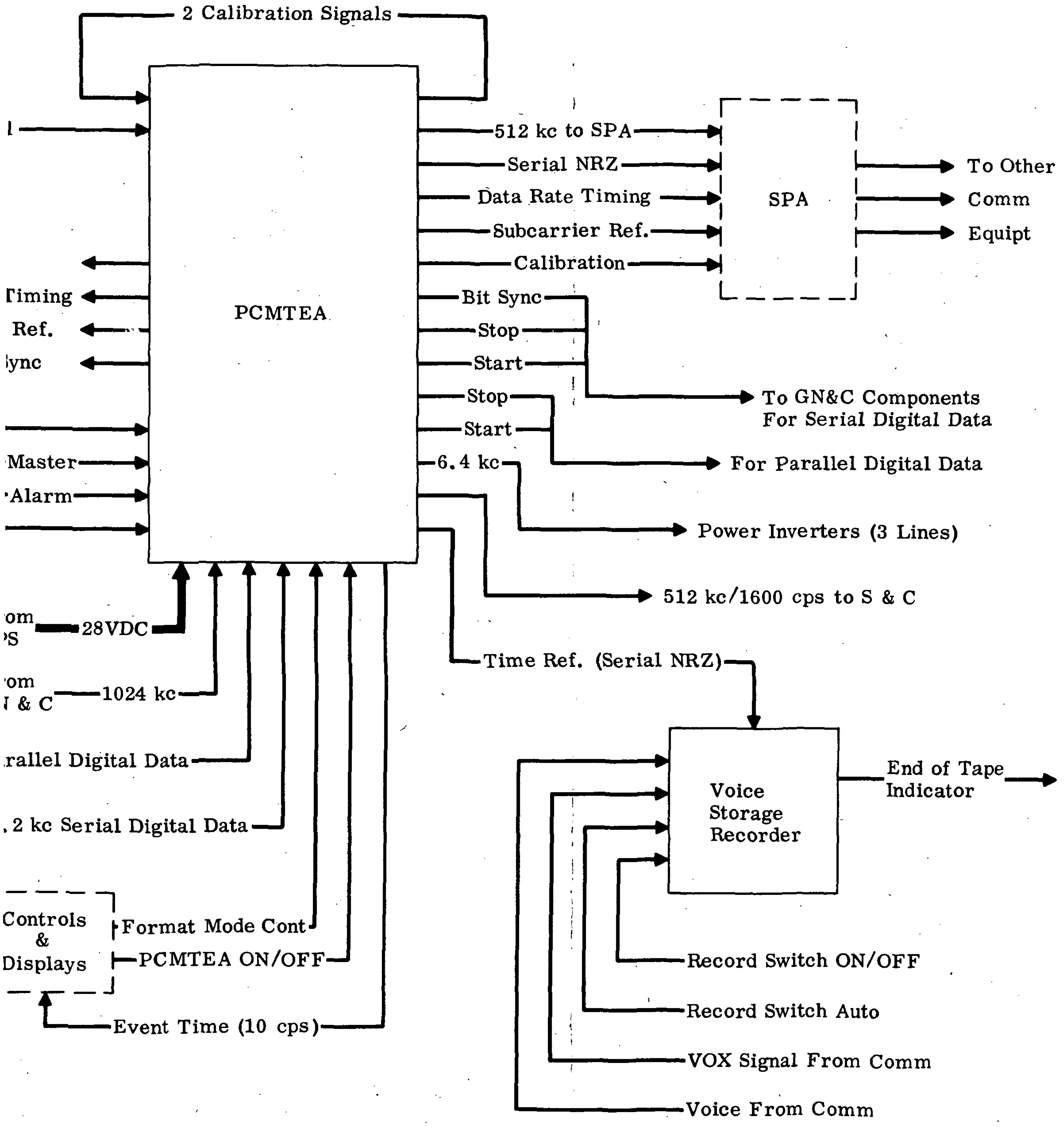


Fig. 5.6-1 Instrumentation Subsystem

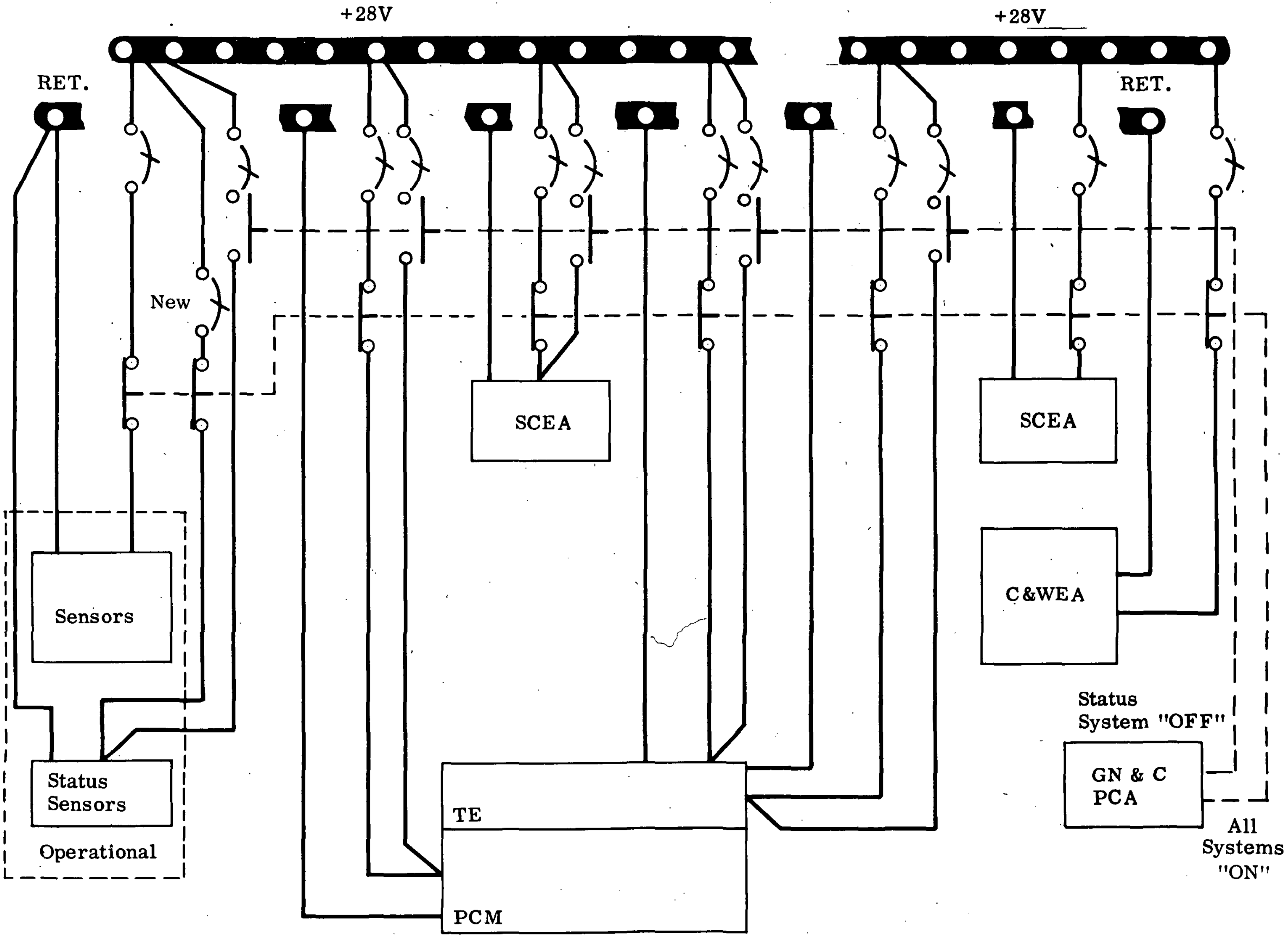
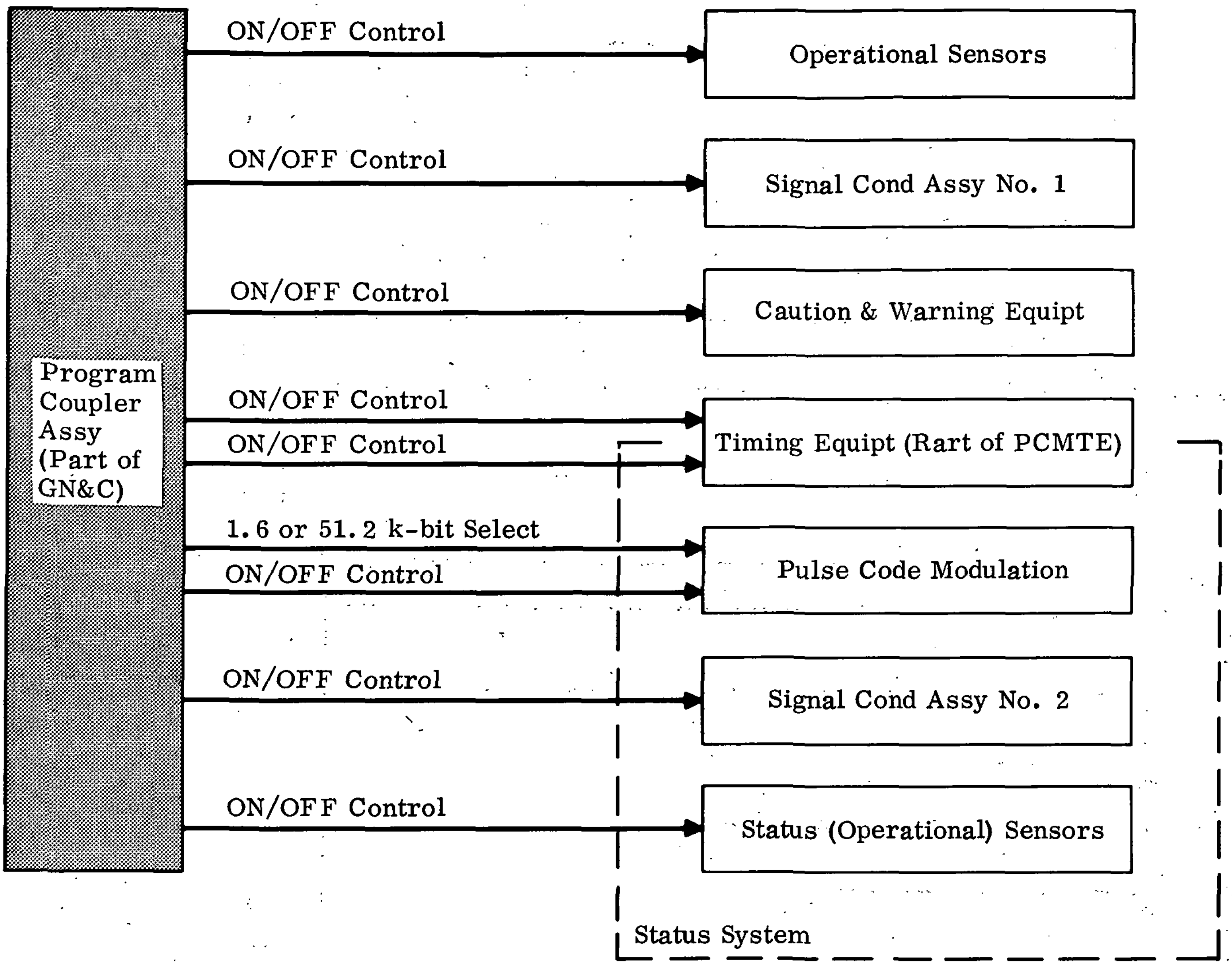


Fig. 5.6-2 Status Bus Power Distribution



During initial checkout (dark side of Moon) with PCA preset to closed (ON) positions & 1.6 k-bit rate selected, manual circuit breakers will activate system via astronaut during prerelease checkout. The remainder of stay period ON/OFF functions (unmanned) will be Earth-commanded via communications to PCA relays.

Fig. 5.6-3 Status Data Ground Command Control

5.7 CONTROLS AND DISPLAYS

5.7.1 Ground Rules

There are no unique ground rules applicable to the Controls and Displays Subsystem.

5.7.2 Assumptions and Background Date

It was assumed that the pre-separation checkout of the Shelter would be performed by an astronaut in the Shelter. It was also assumed that displays not needed for the Shelter mission could be removed to provide panel space for surface mission functions.

5.7.3 Recommended Configuration

Individual control and display panels are shown in Fig. 5.7-1 through 5.7-8. The total integrated Shelter Controls and Displays are discussed in paragraph 6.2. In general, displays that were redundant and which did not affect crew safety, the mission, or vehicle control were deleted. The area made available from modified or deleted equipment (approximately 901 sq in.) may be allocated for experiments.

5.7.3.1 Pre-Separation Checkout

Table 5.7-1 lists the subsystem displays necessary for the following pre-separation checkout functions:

- During the pre-separation checkout, the astronaut will arm the explosive devices and deploy the landing gear (Fig. 5.7-1, Panel 11).
- Since 8 of the 16 jets are removed from the Reaction Control Subsystem (RCS), it is only necessary to provide displays for RCS, System B (Fig. 5.7-2). Before the RCS can be activated, the astronaut must be sure the jets and the lines leading to them are unfrozen. Therefore, he must manually adjust the RCS heater temperature controls (Fig. 5.7-3) and monitor the temperature until proper operating conditions are reached. The astronaut will checkout the RCS by actuating the pressurization switch on the explosive-device panel. This switch activates squib valves which permits helium to flow from the RCS helium tanks to pressurize the RCS. The pressure of the system is now checked on the RCS pressure monitor gauge. If the helium pressure remains low, or if it is zero, the astronaut can close that regulator and open a second. The main shutoff valve switch simultaneously activates a pair of latch-type, solenoid-operated fuel and oxidizer shutoff valves which control the flow of propellant downstream of the propellant tanks. These valves are opened after checkout. The final check of the RCS is the test firing of each jet by the use of the hand controller.
- Main propulsion system (Fig. 5.7-2) is pressurized by actuating the descent pressure explosive device (Fig. 5.7-1). It is necessary that the astronaut can check the fuel and oxidizer tanks to determine if the system is pressurized properly. If there is a malfunction, he can close either descent helium regulator 1 or 2.
- Landing radar is tested and put in the automatic landing mode. Its operating temperature is monitored and adjusted on the heater control panel, and then left in the automatic mode (Fig. 5.7-3).
- Navigation, Guidance, and Control System is initialized using the LORS to align the IMU, and the DSKY to insert orbital information into the LGC (Fig. 5.7-4).

5.7.3.2 Surface Mission

Surface mission controls and displays are listed in Table 5.7-2. The most significant modifications to the controls and displays are a result of the changes to the Electrical Power System (EPS) which now consists of fuel cells and batteries.

The existing LEM EPS panel (Fig. 5.7-1) was unable to provide enough area for the Shelter EPS requirements; therefore, the area left vacant by the Systems Engineer's FDAI was used (Fig. 5.7-2). The monitoring displays for the fuel cells and batteries are as follows: fuel cell tank pressure indicator, O_2 and H_2 tank pressure indicator, fuel cell temperature indicator, regulation-out pressure-warning lights for O_2 and H_2, H_2 and O_2 flow meters, DC volt and amp monitor, AC volt and amp monitor, pH warning light for fuel cell purge, AC bus, and inverters 1 and 2. The fuel cell controls allow the fuel cells to be put in one of the following modes: normal, off, and standby. The standby position allows the fuel cells to remain on, but disconnects them from the bus. The normal position connects the fuel cells on the bus. Each fuel cell is controlled separately and has a status flag to indicate when it is on the bus.

The batteries are controlled in the same manner as the fuel cells, by separate swithes and status flags. The only difference is that the batteries can be put in either high or low power phases.

Other modifications made to the LEM configuration are described below for the Commander and Systems Engineer positions.

- Commander
  - Panel 4 (Fig. 5.7-5) consists of circuit breaker panels which have been modified for the addition or deletion of portions of the following subsystems: primary guidance and navigation, electrical power, stabilization and control, internal lighting, environmental control, reaction control, and communications.
  - Audio panel has been relocated from Panel 6 to Panel 3 (Fig. 5.7-3). This leaves Panel 6 completely empty for experiment integration.
  - Explosive devices have been slightly modified to reflect the changes in the on-board systems.
  - Clock and event timer (Fig. 5.7-6) have been moved to the top of Panel 1 to provide more area for experiment integration.
  - Commander's master alarm switch has been removed, because all of the subsystem displays are on the Systems Engineer's side.
- Systems Engineer
  - Warning indicators have been modified to reflect on-board changes, and have been relocated on Panel 2 (Fig. 5.7-2) since they are only used in preseparation checkout or on the lunar surface. Because of the unmanned landing, the caution and warning displays have been reduced to one 20-light bank.
  - Environmental Control Panel (Fig. 5.7-2) has been slightly modified to reflect changes in O_2 and H_2O tankage. Two ascent H_2O tanks have been deleted and one CSM water management tank added. Both O_2 tanks are deleted from Environmental Control Subsystem; therefore, the GOX displays are deleted.

5.7.4 Baseline Configuration

The controls and displays for the baseline configuration are the same as for the recommended configuration.

5.7.5 Alternate Configuration - 16 Jet RCS

If the RCS were configured with 16 jets, the controls and displays associated with the System A thrusters would be retained.

5.7.6 Potential Modifications Per Flight

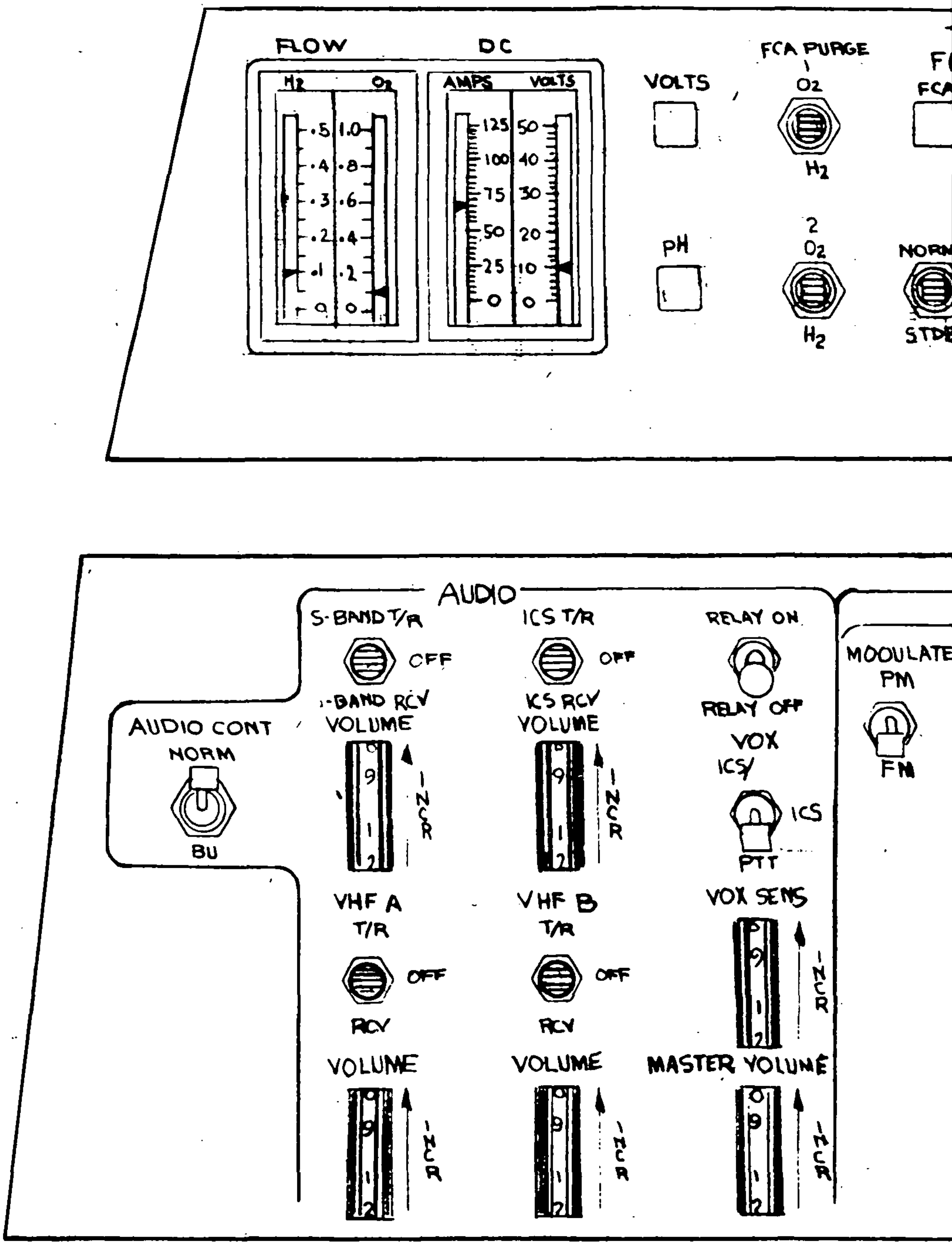
No per flight modifications were considered for the Shelter housekeeping functions. However, the controls and displays associated with the experiment payload may be considered a per flight modification item.

Table 5.7-1
CONTROLS & DISPLAYS - PRE-SEPARATION

Subsystem	Displays
Reaction Control	System B
Explosive Devices	RCS Descent Pressure Landing gear deployment
Heater Controls	RCS Quad Heaters Landing Radar Heater
Main Propulsion	Fuel & Oxidizer Pressure Gauge Descent He Regulators
Navigation, Guidance & Control	Attitude Controller Roll, Pitch, Yaw Attitude Control Mode Control Landing Radar DSKY
Caution & Warning	Caution and Warning Lights Modified to Above Changes
Communications	Same as LEM

Table 5.7-2
CONTROLS & DISPLAYS - SURFACE MISSION

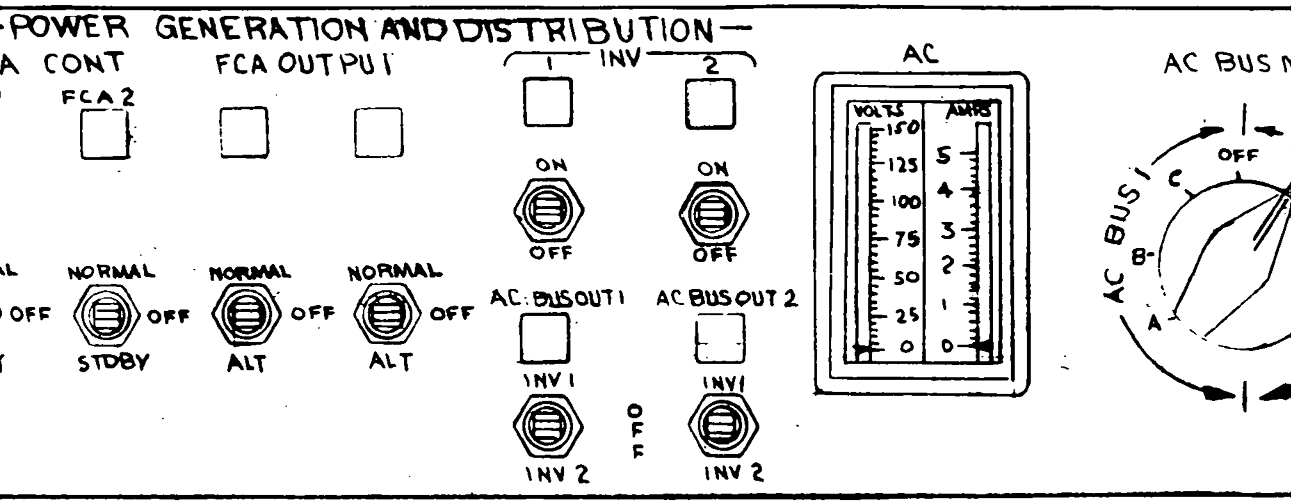
Subsystem	Displays
Environmental Control	Same as LEM
Lighting	
Event Timer	
Communications	
Heater Controls	Fuel Cell Heaters Window Heaters
Electrical Power Supply	2 Fuel Cells 2 Descent Batteries RTG Peaking Battery
Caution and Warning	Modify to Above Changes

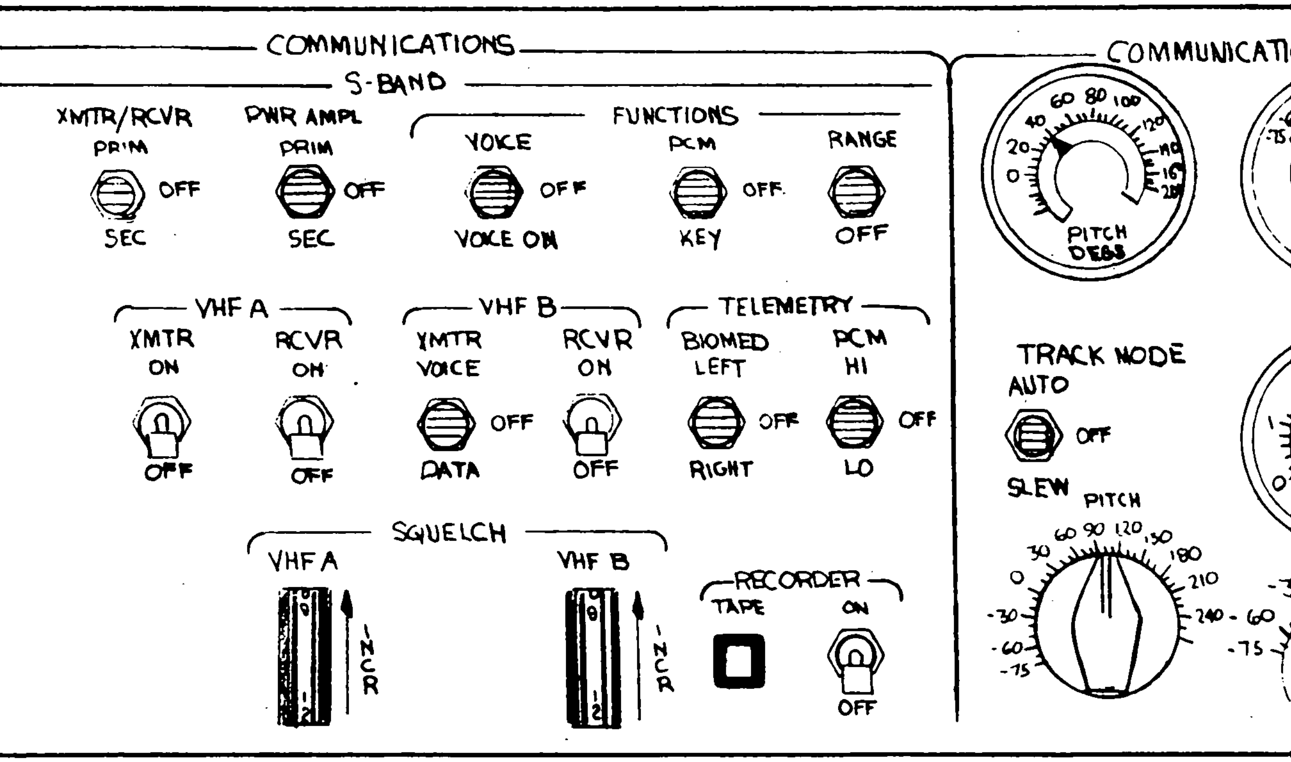

FLOW
DC
H2
O2
AMPS
VOLTS
VOLTS
FCA PURGE
1
O2
H2
pH
2
O2
H2
AUDIO
S-BAND T/R
OFF
S-BAND RCV
VOLUME
ICS T/R
OFF
ICS RCV
VOLUME
RELAY ON
RELAY OFF
VOX
ICS/
ICS
PTT
AUDIO CONT
NORM
BU
INCR
VHF A
T/R
OFF
RCV
VHF B
T/R
OFF
RCV
VOX SENS
VOLUME
VOLUME
MASTER VOLUME
MODULATE
PM
FM

XI

5.7-1

①


POWER GENERATION AND DISTRIBUTION
A CONT
FCA 2
FCA OUTPUT
1 INV 2
ON
OFF
AC
VOLTS
AMPS
150
125
100
75
50
25
0
5
4
3
2
1
0
AC BUS
OFF
AC BUS 1
C
B
A
NORMAL
OFF
STDBY
NORMAL
OFF
ALT
NORMAL
OFF
ALT
AC BUS OUT 1
AC BUS OUT 2
INV 1
INV 2
OFF
INV 1
INV 2


COMMUNICATIONS
S-BAND
XMTR/RCVR
PRIM
OFF
SEC
PWR AMPL
PRIM
OFF
SEC
FUNCTIONS
VOICE
OFF
VOICE ON
PCM
OFF
KEY
RANGE
OFF
VHF A
XMTR
ON
OFF
RCVR
ON
OFF
VHF B
XMTR
VOICE
OFF
DATA
RCVR
ON
OFF
TELEMETRY
BIOMED
LEFT
OFF
RIGHT
PCM
HI
OFF
LO
SQUELCH
VHF A
VHF B
INCR
RECORDER
TAPE
ON
OFF
COMMUNICATI
0
20
40
60
80
100
120
140
160
200
PITCH
DEGS
TRACK MODE
AUTO
OFF
SLEW
PITCH
-75
-60
-30
0
30
60
90
120
150
180
210
240

5,7-1

②

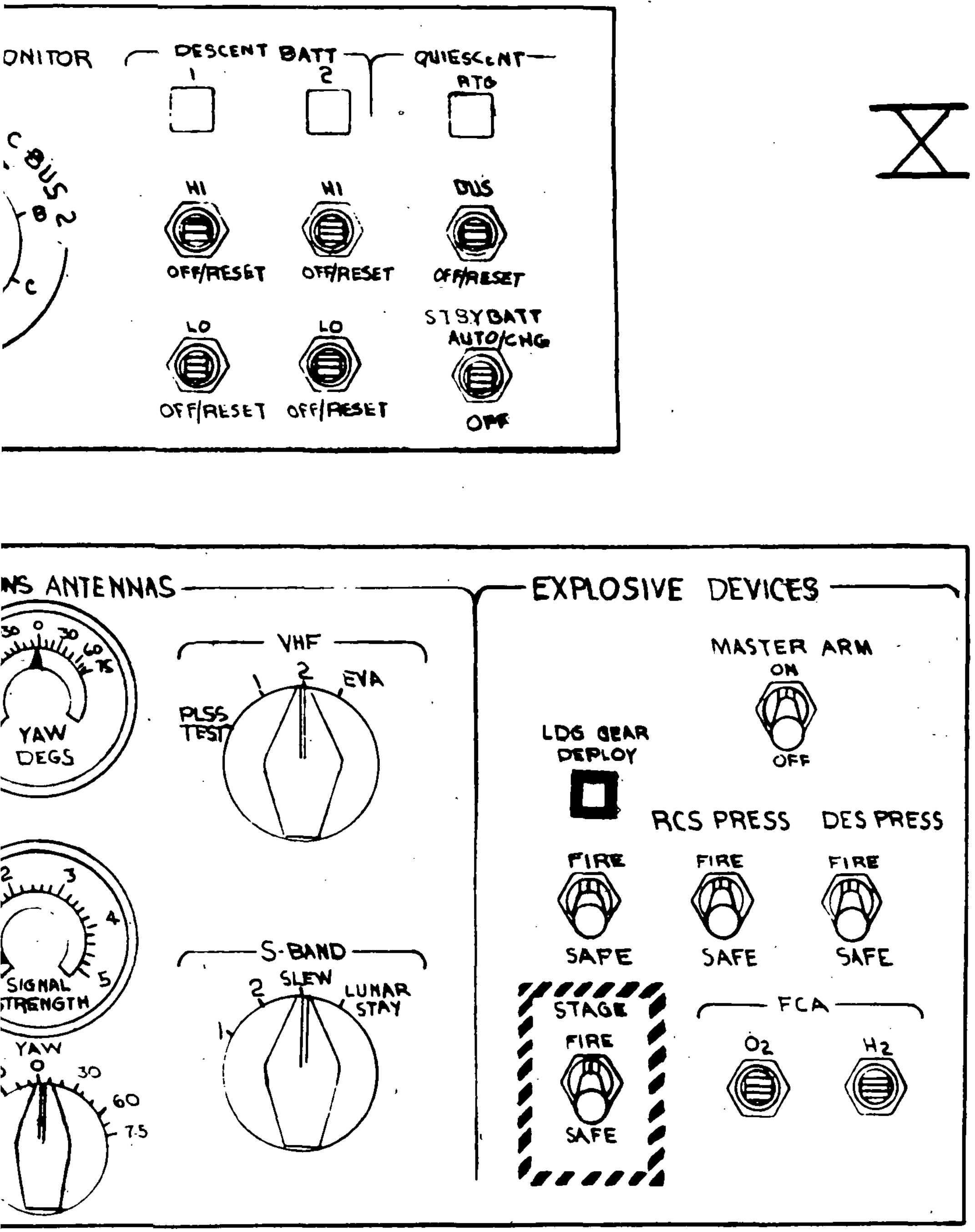


Fig. 5.7-1 Controls & Displays -
Panel X & XI

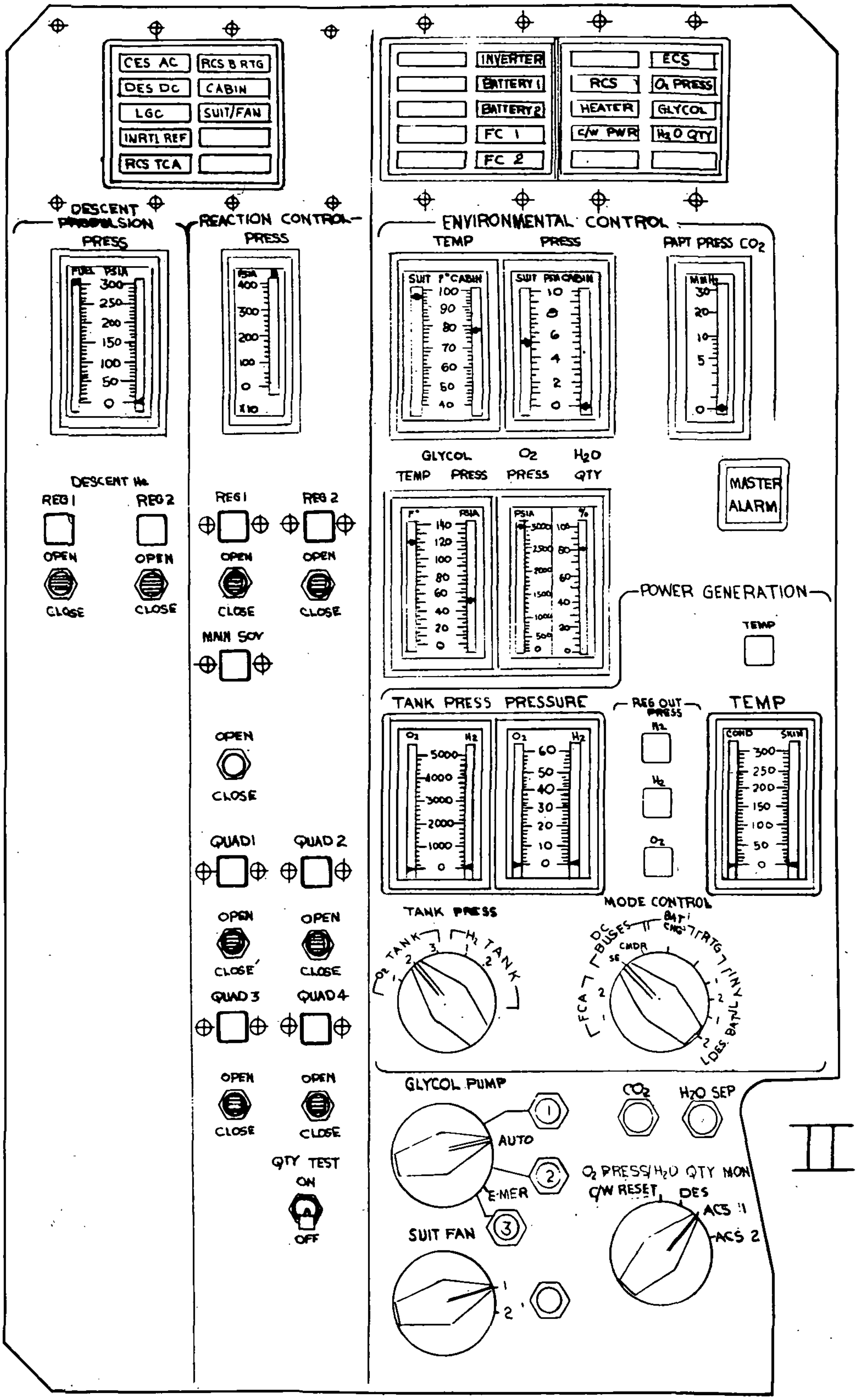
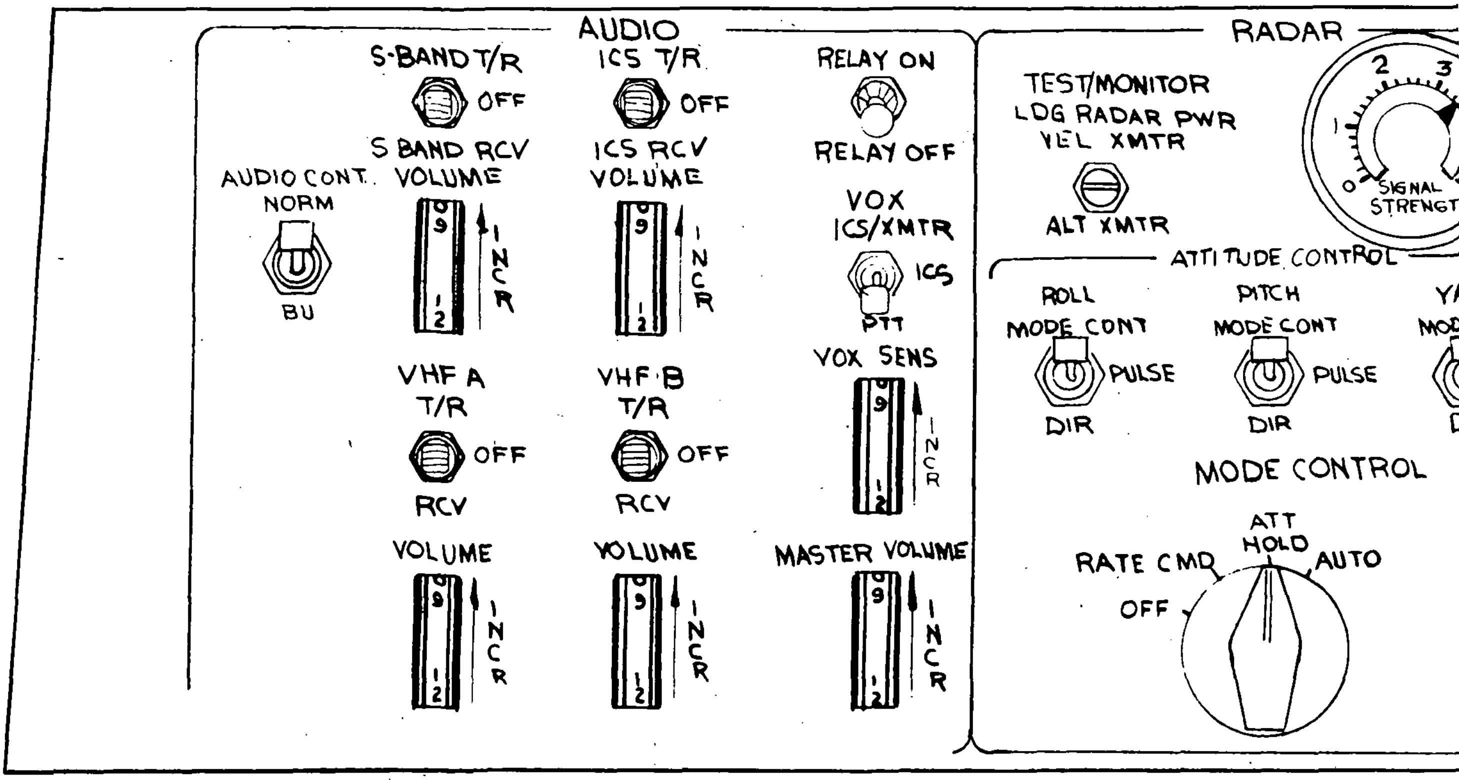


Fig. 5.7-2 Controls & Displays - Panel II


AUDIO
S-BAND T/R
OFF
ICS T/R
OFF
RELAY ON
RELAY OFF
S BAND RCV VOLUME
ICS RCV VOLUME
AUDIO CONT.
NORM
BU
INCR
VOX
ICS/XMTR
ICS
PTT
VOX SENS
VHF A T/R
OFF
RCV
VHF B T/R
OFF
RCV
VOLUME
VOLUME
MASTER VOLUME
9
12
RADAR
TEST/MONITOR
LDG RADAR PWR
VEL XMTR
ALT XMTR
0
1
2
3
SIGNAL STRENGT
ATTITUDE CONTROL
ROLL
MODE CONT
PULSE
DIR
PITCH
MODE CONT
PULSE
DIR
MODE CONTROL
ATT HOLD
RATE CMD
AUTO
OFF

III

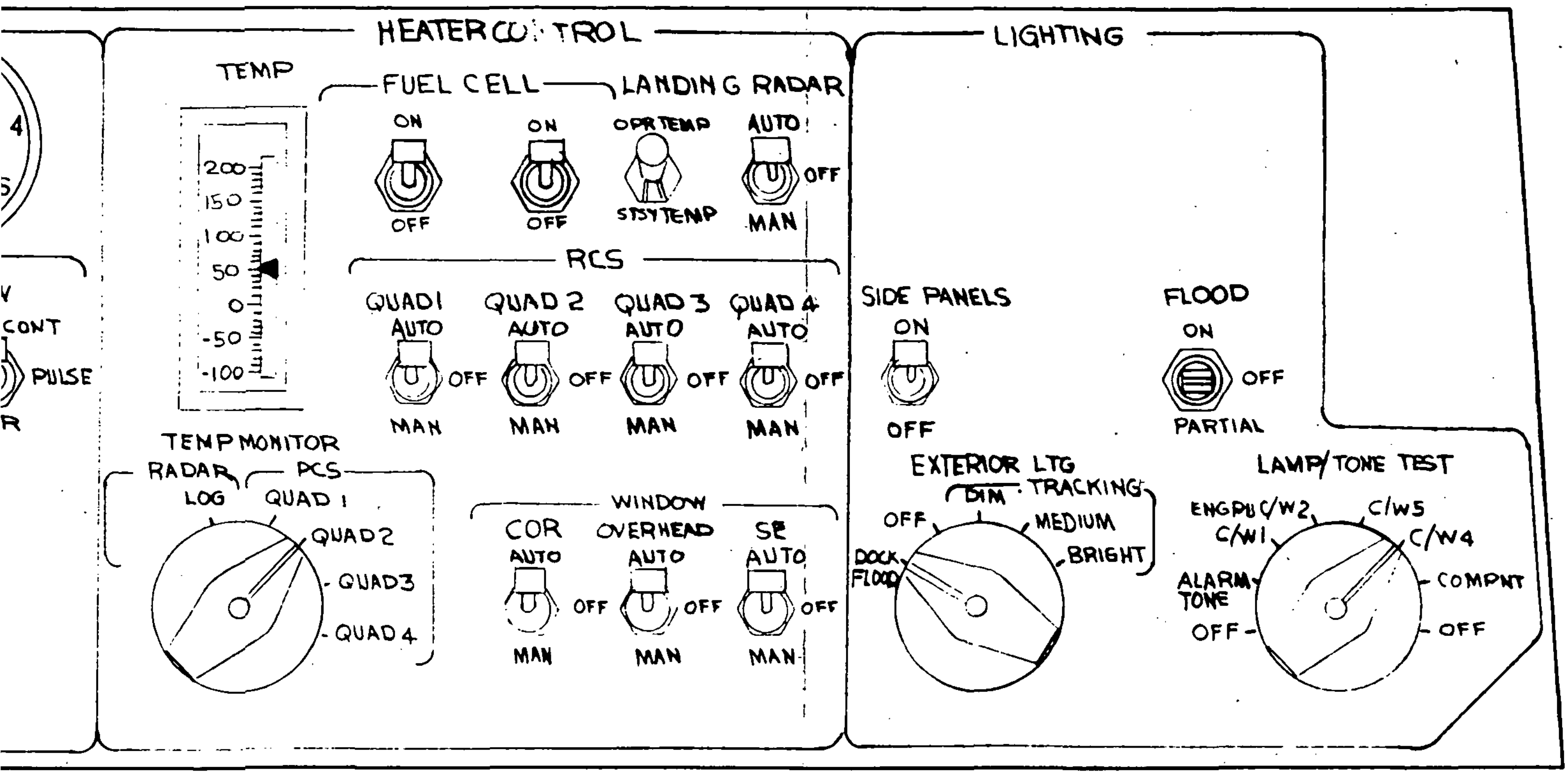


Fig. 5.7-3 Controls & Displays - Panel III

VIII

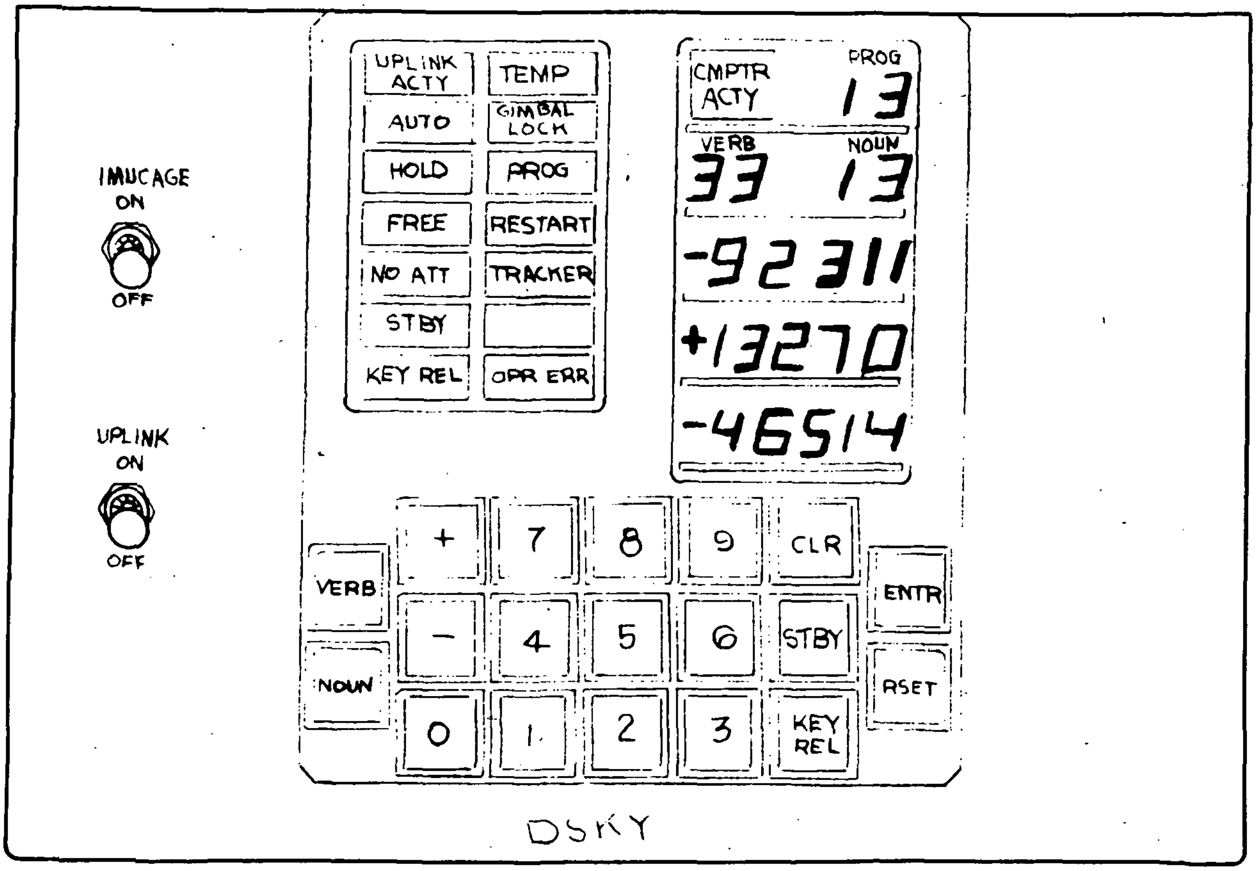
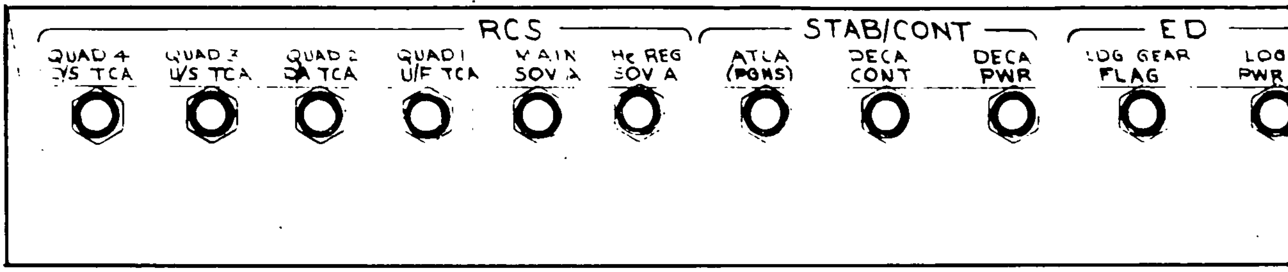
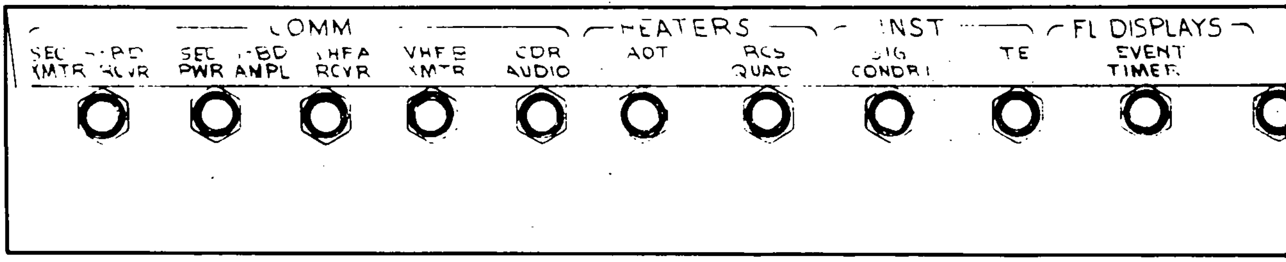
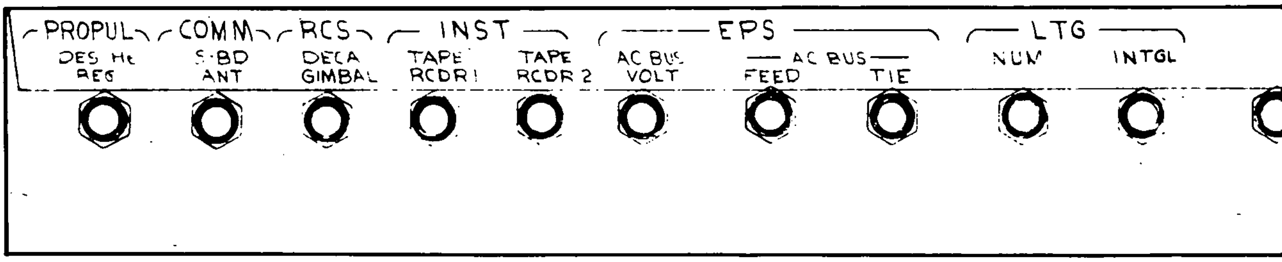
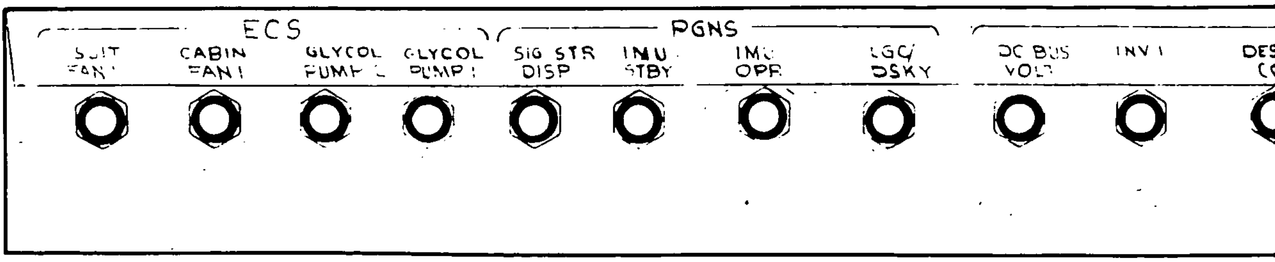


Fig. 5.7-4 Controls & Displays - Panel VIII


RCS
QUAD 4 D/S TCA
QUAD 3 U/S TCA
QUAD 2 D/A TCA
QUAD 1 U/F TCA
MAIN SOV A
He REG SOV A
STAB/CONT
ATCA (PGNS)
DECA CONT
DECA PWR
ED
LDG GEAR FLAG
LOG PWR


COMM
SEC S-BD XMTR RCVR
SEC S-BD PWR AMPL
VHF A RCVR
VHF B XMTR
CDR AUDIO
HEATERS
AOT
RCS QUAD
INST
SIG CONDR 1
TE
FL DISPLAYS
EVENT TIMER


PROPUL
DES He REG
COMM
S-BD ANT
RCS
DECA GIMBAL
INST
TAPE RCDR 1
TAPE RCDR 2
EPS
AC BUS VOLT
AC BUS
FEED
TIE
LTG
NUM
INTGL


ECS
SUIT FAN 1
CABIN FAN 1
GLYCOL PUMP 2
GLYCOL PUMP 1
PGNS
SIG STR DISP
IMU STBY
IMU OPR
LGC/DSKY
DC BUS VOLT
INV 1
DES

IV

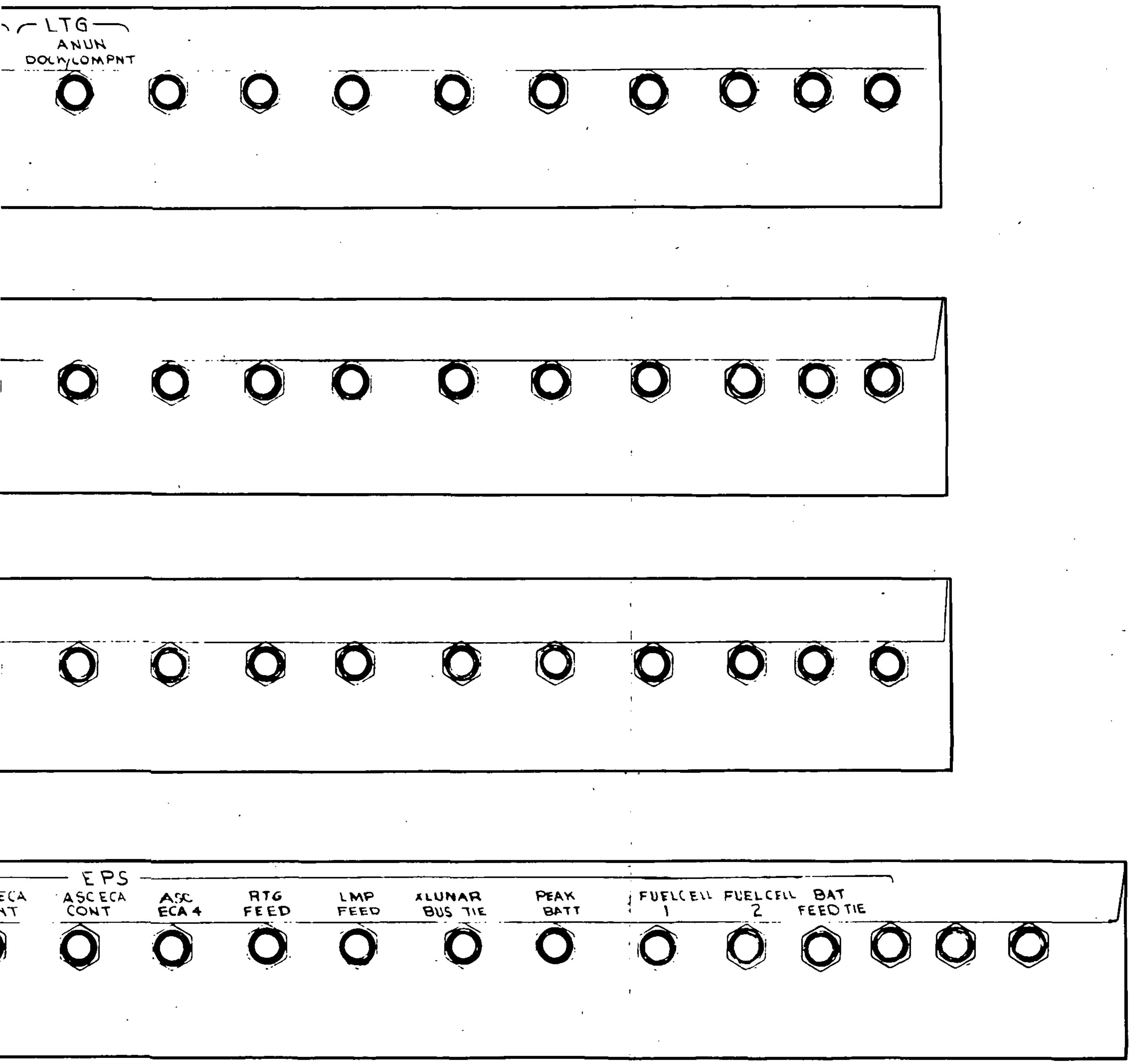


Fig. 5.7-5 Controls & Displays - Panel IV

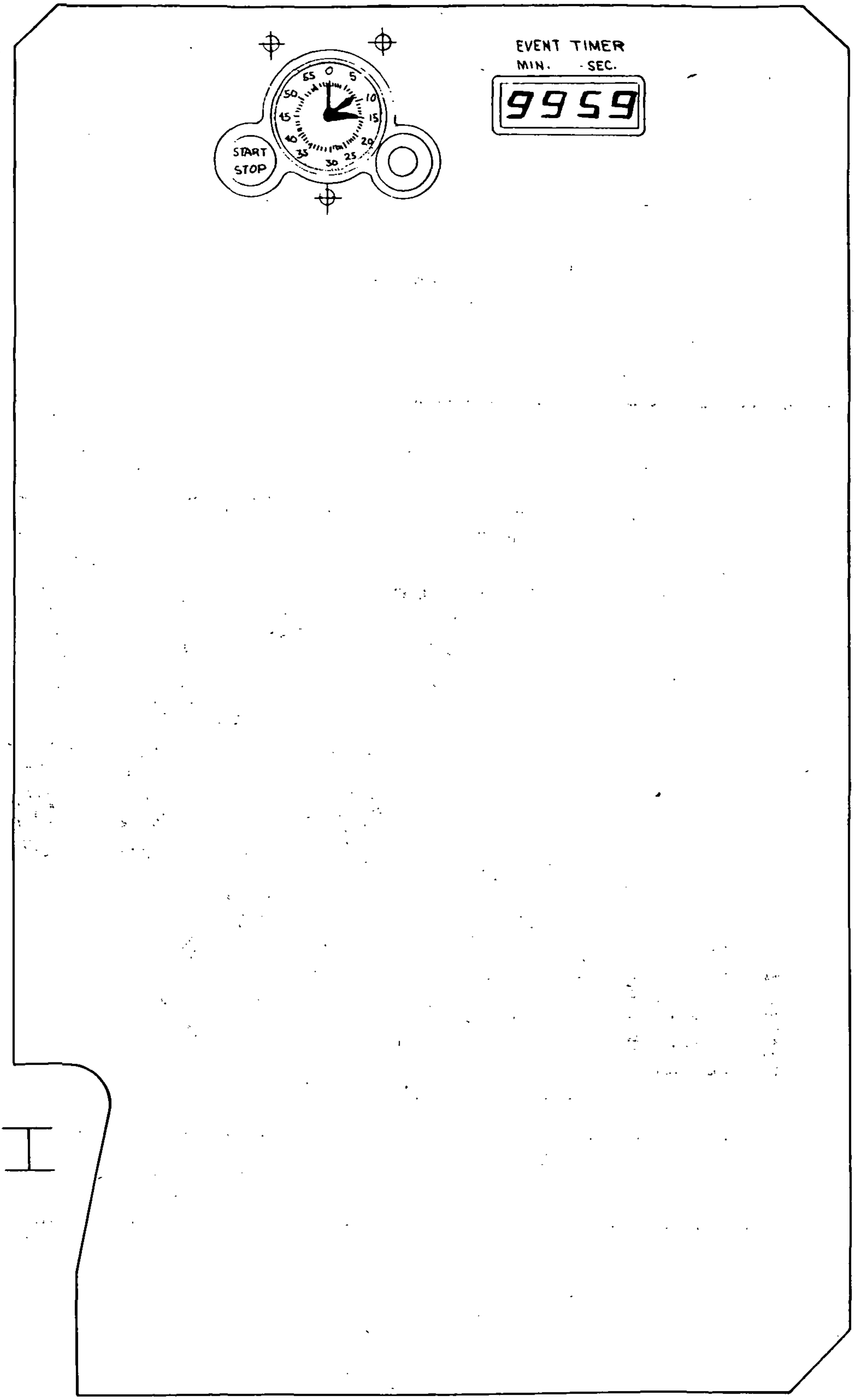


Fig. 5.7-6 Controls & Displays - Panel I

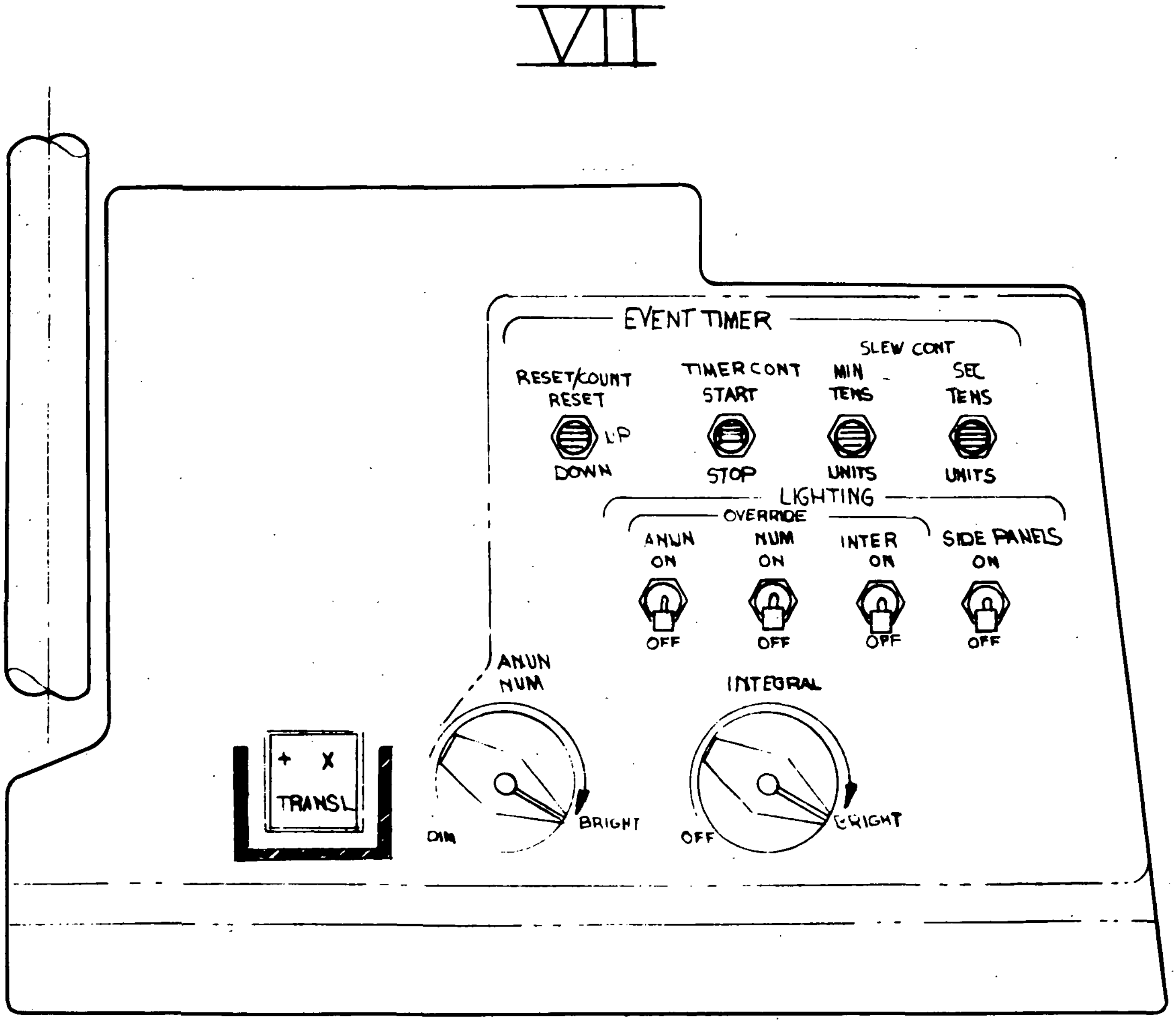
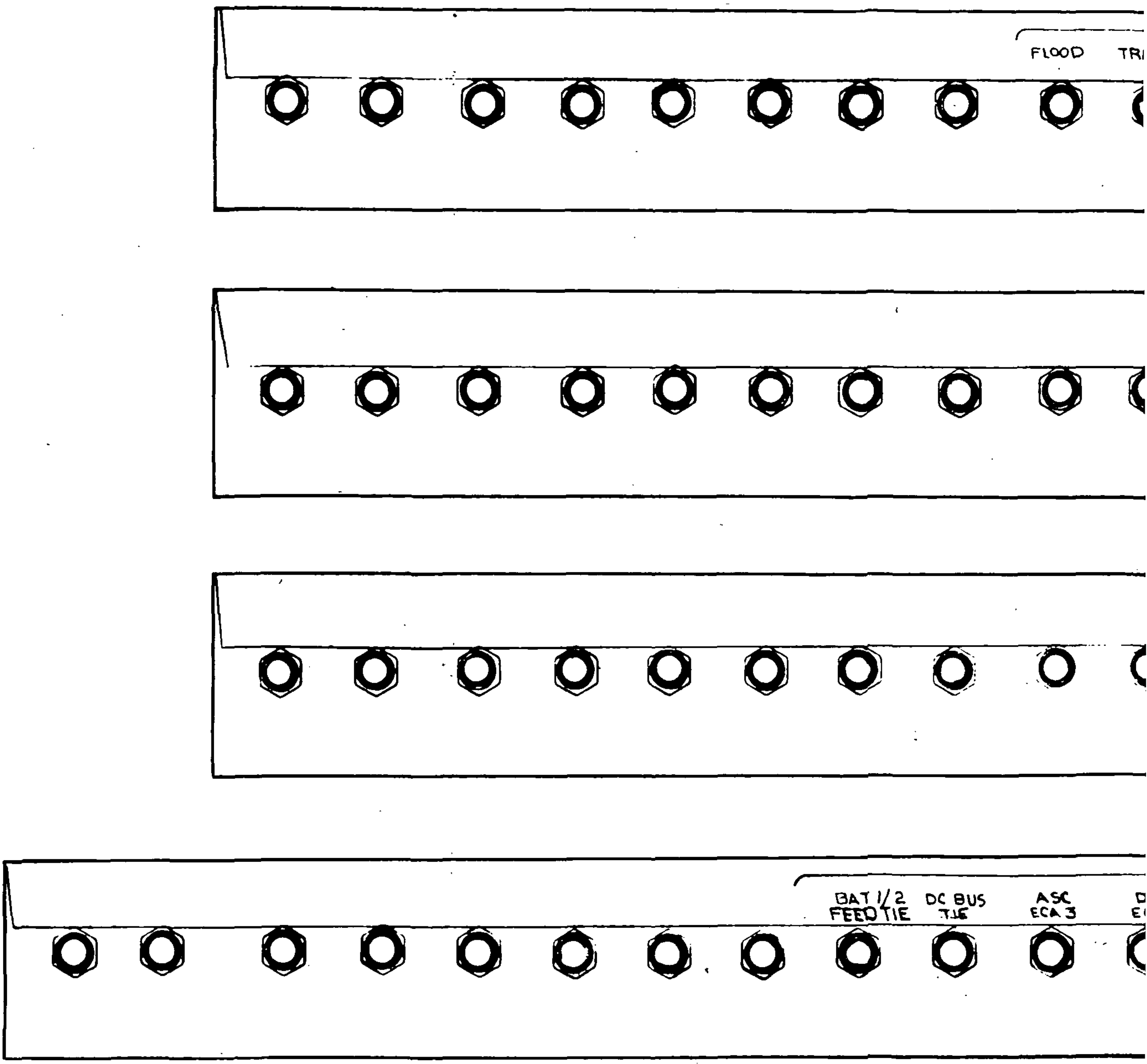


Fig. 5.7-7 Controls & Displays - Panel VII

201



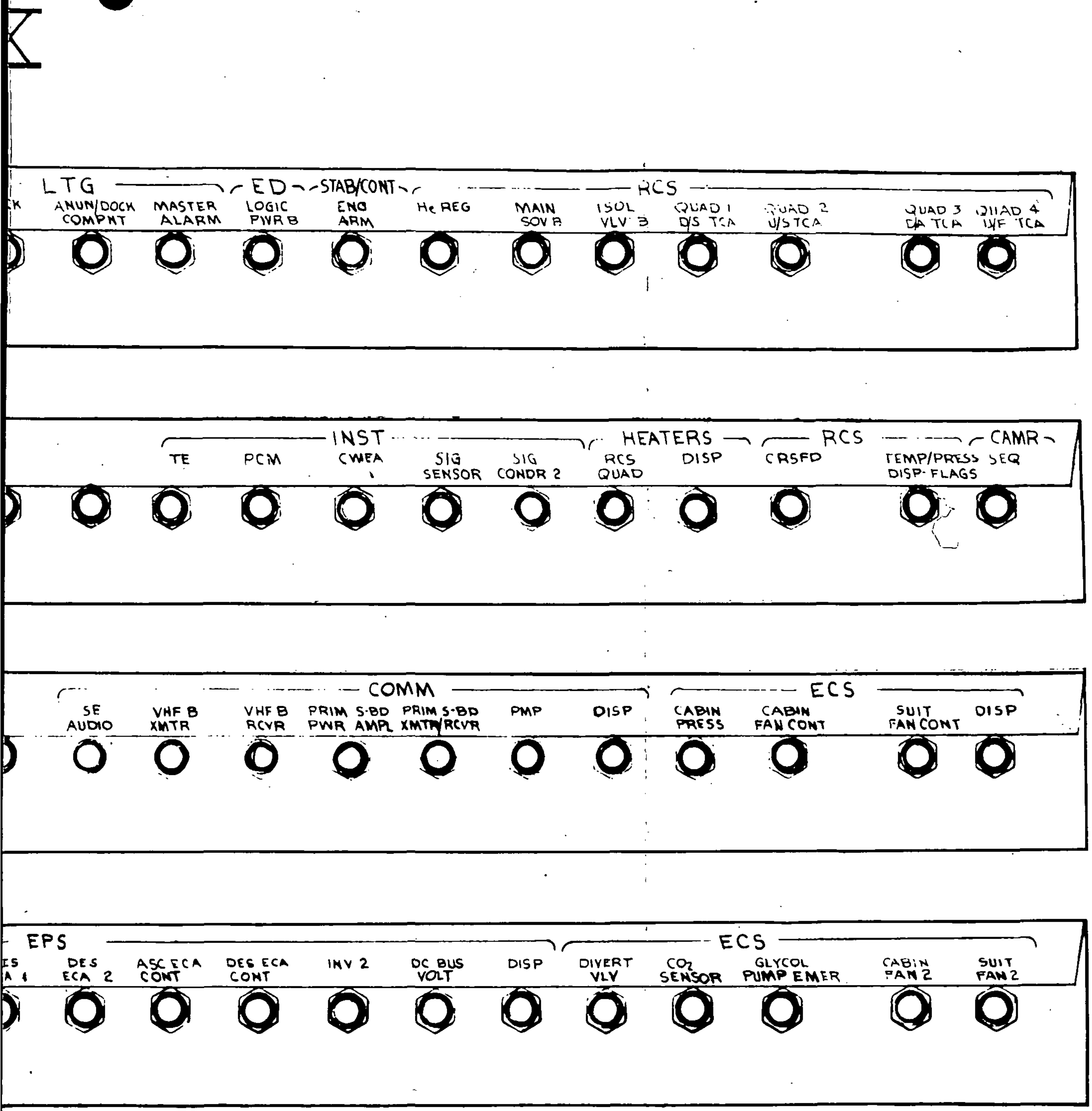


Fig. 5.7-8 Controls & Displays - Panel IX

6. VEHICLE DESIGN AND INTEGRATION

6.1 SPACECRAFT DESIGN

6.1.1 Ground Rules

There were no NASA ground rules unique to this portion of the study.

6.1.2 Assumptions and Background Data

The philosophy guiding the development of the vehicle design is to keep the present LEM intact to the maximum extent possible, satisfying increased subsystem requirements by additions, rather than by modifications. Whereever possible, the these additions have been designed as packages that could be incorporated into the vehicle in minimum time.

The following guidelines have been used during the Phase B study:

- No holes in the pressure shell
- No modification to ascent and descent primary structure
- Retention of existing piping and wiring
- Maintain commonality of subsystems between all AES vehicles
- No change to the Spacecraft LEM Adapter (SLA)
- Location of subsystem additions to retain many of the GSE servicing requirements in the SLA
- Where possible, subsystems are to be located in the descent stage to reduce the complexity that modifications to the ascent stage would require
- Experiments will be mounted to the vehicle at existing hardpoints.

Figures 6.1-1 through 6.1-6 are LEM drawings and are provided for comparison with the AES vehicles. For details not shown on the AES configuration drawings, these figures clearly define the structure.

To achieve mission objectives with maximum utilization of existing hardware, the basic subsystem components of the LEM were used wherever possible. This resulted in a "Stripped LEM" as shown in Fig. 6.1-7. This drawing shows the present LEM components which are directly applicable to the Shelter in their original locations. In addition, packaging constraints within the SLA as pertains to the penetration envelope are also shown.

The following assumptions were used in developing the Shelter configurations:

- Both sides of the Shelter within the 7-in. penetration envelope are allocated for experiment payloads
- Relocation of work platforms within the SLA for on-pad accessibility is permissible provided the ground rule covering structural changes to the SLA is not violated
- LEM constraints in reference to on-pad maneuverability shall apply to the Shelter unless otherwise noted

- First lunar Local Scientific Survey Module (LSSM) is mounted on the left-hand side (-Y) of the Shelter; if two LSSM are required, the S-band antenna would be relocated for that particular flight
- Certain crew provision items stowed inside the cabin during launch may be mounted externally after the astronauts arrive on the lunar surface
- Existing diagonal tension members in the descent stage are to be left intact
- Experiment payload will be capable of surviving the lunar environment independent of the Shelter
- Minimum of 2 days cabin LiOH is stored inside the Shelter
- Minimum of 6 back-pack LiOH cartridges are stored inside the Shelter
- Maximum post landing attitudes to date are as follows: geometric: 30 deg, and dynamic: 15 deg.

6.1.3 Recommended Configuration

Review of the lunar surface mission data provided by MSFC indicates that the payloads are to be relatively independent of the Shelter. That is, the LSSM, flying vehicle (MFS), and emplaced package require no Shelter support other than delivery. After landing, the number of egress/ingress cycles and back-pack recharges are nearly the same for the five missions provided. Therefore, it appears possible to define a single recommended Shelter that will meet all the mission requirements.

6.1.3.1 O_2/H_2 Tankage

The EPS tankage, a three tank ambient system, is shown in the recommended configuration, Fig. 6.1-8. It consists of two 39-in. spherical gaseous hydrogen tanks and a 47-in. spherical gaseous oxygen tank. The ambient system, in addition to providing the 3 month storage capability required for the Shelter, results in a less complex tank design and structural support system relative to a cryogenic system. The tankage presents no impingement to the RCS.

The two hydrogen tanks are located on top of the descent stage, aft of the -Z27 bulkhead and beneath the Electronic Replaceable Assembly (ERA) rack. This location is available without requiring any LEM subsystem relocation. The proximity of the tanks relative to the fuel cells and radiator is another desirable feature. The primary structure of the descent stage, with the addition of local fittings, is ideal for the structural hard points required for the tank supports, resulting in a minimum of structural changes. The hydrogen tanks are located so they present minimum interference with on-pad accessibility.

The oxygen tank is located in the descent stage, quadrant IV. This necessitates relocating the modified descent batteries and pyro relays to quadrant III.

The hydrogen tanks are supported at two lugs which are in a horizontal plane, 180 deg apart. A truss system of tubular members support the tanks from hard points on the primary structure of the descent stage. Two trusses, one forward and one aft, support both tanks for vertical and side loads through interconnecting members. An additional strut, out of plane, is used at each tank to support loads in the ±Z direction. Rotational loads on the tanks are reacted by keying of the lugs. Figure 6.1-9 shows a structural arrangement for these tanks.

The oxygen tank is also supported at two lugs in the X plane by a truss structure. Two "V" trusses in the vertical plane are used to support any vertical loads. These members are connected through attachment fittings to the horizontal deck and vertical beam. An additional member, from each tank lug to the vertical descent beams, is used to support any loads in the X plane which cannot be supported by the vertical trusses. Rotational loads, as on the hydrogen tanks, are reacted by keying the tank lugs. A structural arrangement for this tank is shown in Fig. 6.1-10.

6.1.3.2 Aft Equipment Bay Structure

The aft equipment bay structure is made up of the ERA rack and its truss structure which supports the rack from the -Z27 bulkhead. The rack requires minor modifications to mount the fuel cell assemblies and associated water storage tank. Local stiffening at these support points is required.

The upper truss support of the rack remains unchanged. However, the lower truss is revised to make room for the EPS hydrogen tank installation. To make room for the EPS hydrogen tank installation, the outer two members of the lower truss are removed and an additional diagonal member added between the lower outside corner of the rack and the existing hardpoint on the -Z27 bulkhead, which also supports the existing upper diagonal member. Figure 6.1-9 shows the revised structure.

6.1.3.4 Fuel Cells

To meet the power requirements of the Shelter mission, two Allis-Chalmers fuel cell assemblies (FCA) are installed in the Shelter (Fig. 6.1-11). They are located between the -Z27 bulkhead and the aft equipment rack. The two fuel cells are mounted in the vertical position directly on the equipment rack structure. This location is identical to the Phase II Lab location. Replacement of a fuel cell in an on-the-pad condition can be accomplished through a removable section of the horizontal radiator. The FCA water management tank is located and supported on the forward face of the ERA rack between the tow fuel cell assemblies. This location is also common with the Phase II Lab. The proximity between the tank and the FCA make it a desirable location.

6.1.3.5 Supplementary PLSS O_2 Tank

The supplementary PLSS O_2 tank is located on the upper shelf in the forward right-hand corner, in place of the LEM water tank which has been removed. The diameter of the tank is the same; therefore, by using a similar truss support, the existing hard points are utilized. The tank location is shown in Fig. 6.1-8.

6.1.3.6 Automatic Startracker

The Alignment Optical Telescope (AOT) has been removed and replaced with an automatic startracker, thereby eliminating the necessity for a hole through the pressure skin. The auto tracker assembly is designed to be an exact replacement for the AOT, requiring no change in the mounting bases.

For the installation currently being considered for the LEM, the Abort Sensor Assembly (ASA) is mounted to the aft face of the auto tracker assembly. There is no requirement for the ASA on the Shelter; however, to eliminate redesign of the navigational bases, the ASA will be simulated through the use of ballast, or if possible, another piece of equipment. This will be the only difference between the LEM and Shelter installations.

6.1.3.7 Battery

The recommended battery configuration consists of the following items located in quadrant II of the descent stage:

- Modified LEM descent batteries (3)
- Electrical control assemblies (ECA) (2)
- Pyro batteries (2)
- Pyro relays (2).

The design configuration shows the descent batteries and the ECA supported by a rack structure isolating the batteries as much as possible through the use of a truss as shown in Fig. 6.1-12. The support is designed to allow the batteries to attach to the rack supporting member which in turn is suspended through a truss structure from the descent stage. The space around the batteries is insulated. The supports consist of hat-section aluminum alloy members attached to vertical webs. The structural sizes are based on the structural criteria for the critical design conditions. It appears possible to use or rework some of the existing LEM battery structure for application to the Shelter. Alternate battery installations are shown in Fig. 6.1-13.

6.1.3.8 Radioisotope Thermoelectric Generator

A Radioisotope Thermoelectric Generator (RTG) is included as the primary power source during the 3-month storage period. The waste heat generated is utilized to minimize power requirements associated with heating the Shelter structure and equipment during the storage period.

Removal of the RTG from the Shelter and installation on the Taxi occurs after the latter has landed and the Shelter has been activated. Location and mounting provisions (Fig. 6.1-14) are common to both vehicles. The RTG is mounted to a shelf which is inserted into truss supported rails in quadrant II of the descent stage. Five sides of the RTG are insulated with approximately 1 in. of insulation. The remaining side is open to allow the RTG to radiate into space.

6.1.3.9 Heat Pipe

The waste heat generated by the RTG is utilized by incorporation of a controllable "heat pipe". This assembly consists of a boiler, integrated with the RTG assembly, and five condensers. As shown in Fig. 6.1-15, a single line connects the boiler, located behind the RTG, to a network of distribution lines in the ascent stage. Return of the condensed fluid is accomplished by the lunar gravity field. The thermostatically controlled steam heating loop is the same on the Shelter and the Taxi. A boiler located behind the RTG sends steam through an umbilical in the descent stage, an interstage disconnect fitting (achieves commonality with the Taxi) an onto the ascent stage. The five condensers are located on the aft face of the -Z27 bulkhead, both sides of the cabin at Z0, and on both sides of the aft face of the Z27 bulkhead. As shown in Fig. 6.1-15, there are no structural modifications to the ascent stage other than the addition of bracketry.

6.1.3.10 Thermal Covers

A thermal insulating cover is added to the ascent stage (Fig. 6.1-16) to cover the docking tunnel during the storage period and when the upper hatch is not being used during the 14-day mission. The cover is hinged to the top of the -Z27 bulkhead and held open during launch and translunar flight. After landing, redundant pyrotechnic devices sever the latch allowing torsion springs to rotate the cover into position over the docking tunnel. The cover contains a latch so that it may be retracted by the astronaut and manually latched open when required. Reclosing is accomplished by releasing the manual latch, allowing the torsion springs to operate.

In addition to the above mentioned cover, removable thermal window covers common to both the Shelter and Taxi are installed on the two forward windows. This is accomplished with three simple clip devices as shown in Fig. 6.1-17.

6.1.3.11 Radiators

Approximately 75 sq ft of flat horizontal radiators (Fig. 6.1-18) are provided for cabin thermal control. A truss system attached to local hard points is recommended for structural support to give the radiator system rigidity against launch vibration and landing loads. The horizontal radiator system does not interfere with the ground support platforms inside the SLA, but further investigation is required to determine if they interfere with the internal supports of these platforms. Removable panels are needed in the aft horizontal radiators above the aft equipment bay for accessibility to the fuel cells.

A 55-sq-ft flat vertical radiator, as shown in Fig. 6.1-18, is provided for thermal control of the FCA. A vertical radiator was chosen because of the lack of space on top of the ascent stage for additional horizontal radiators. A deployable shade is also required to shield the radiator from lunar surface radiation. Channels add rigidity to the system and in turn are attached to the aft equipment ERA rack. Removable panels are needed to have on-pad accessibility to the aft equipment ERA rack.

6.1.3.12 Airlock

An 88-cu-ft, one man airlock is incorporated in front of the forward hatch (Fig. 6.1-19) to reduce the oxygen losses associated with egress and ingress operations. The expandable airlock is mounted to the ingress/egress hatch in the stowed configuration. On the lunar surface, the airlock is manually deployed by the astronauts. This is initiated by means of a release mechanism. The stored or potential "spring" energy of the compressed airlock then deploys it to its operational size. Once deployed, there is sufficient turn-around room for a kneeling astronaut to actuate both hatches. Appropriate hand grips will be located internally for astronaut mobility. The basic arilock assembly consists of the following components:

- Shelter airlock adapter
- Inboard bulkhead
- Airlock wall
- Ingress/egress bulkhead.

The adapter is a sheet metal structure with an opening conforming to the LEM hatch on one side and a round "Marman Clamp" shape on the other end. It is appropriately stiffened and permanently attached to the front face of the Shelter. This adapter would be identical to the one used on Phase II Lab flights. The inboard bulkhead consists of an aluminum ring with a machined "Marman Clamp" flange.

The airlock pressure wall is a "soft" compound structure, providing thermal control and micrometeoroid protection. In addition, thin rings would be installed on the periphery at appropriate intervals. An example of the type of compound that might be used has already been developed by Goodyear for NASA-Langley Research Center. Further development is required to explore the broad spectrum of materials and methods of construction to finalize an airlock design.

Constraints added to the Shelter prior to launch as a result of this airlock are:

- SLA/Shelter front hatch tunnel must be withdrawn before installation of the airlock
- Installation must be achieved on the pad; this is a two-man job with the men leaving the SLA by way of the aft access hatch
- Stowed assembly is too large to pass through the SLA openings; hence, temporary stowage within the SLA until installation is a necessity.

6.1.3.13 Inverted Canister

A canister is installed in the space vacated by the LEM ascent engine to provide an additional pressurized volume of over 7 cu ft (Fig. 6.1-20). This canister is sealed to the ascent engine cover through the means of a clamp and requires no structural modification other than removing the engine support lugs from the existing structure. Auxiliary support members for lateral restraint are attached to the top of the descent stage. With the exception of minor differences, this installation is identical to the Lab.

6.1.3.14 LiOH and PLSS Storage

Because of the limited space in the pressurized cabin, 26 of the LiOH canisters used for the PLSS units, and 12 of the LiOH canisters used for ECS are stored in quadrants II and IV of the descent stage, as shown in Fig. 6.1-21. This location results in greater accessibility from the ground. It was decided to store a combination of both types of LiOH canisters in each quadrant in anticipation of an extreme post-landing attitude, where one side of the Shelter might be inaccessible. This provides the astronaut with accessibility to both types of LiOH canisters. In quadrant II, an existing LEM structural container is employed. The structural supports are identical with those used on the LEM. A rack, using the same principal for storage of LiOH canisters for the LEM, is built into the structural container making it a complete unit. In quadrant IV, a similar adaptation of the rack is employed.

Undesirable congestion within the Shelter also necessitates the storage of four PLSS units externally after the astronauts arrive. Two units are shown mounted to the descent stage with the remaining two PLSS units assumed to be in the LSSM. It is recommended that sets of bracketry be provided as shown in Fig. 6.1-21 on the lower portion of quadrants I, III, and IV, of the descent stage. Redundancy is recommended to allow accessibility in case of an extreme post-landing attitude. The back packs are stowed in a container to protect them from extreme temperatures. This box and the PLSS units are stowed internally during the launch and post-landing storage periods.

6.1.3.15 Experimental Payload Envelope

The recommended experiment payload envelope for the -Y side of the Shelter (Fig. 6.1-22) was developed based on the following constraints:

- RCS heat envelope per NASA DWG SK-10-9008
- 7.000-in. penetration envelope as per Interface Control Document MH01-05066-124
- Ascent and descent stage shielding
- Docking requirement envelope.

This envelope satisfies the volume requirements of the proposed LSSM configuration presented in the First Interim Reports submitted September 1965 by the Bendix Corporation and the Boeing Company.

The recommended experiment payload envelope for the +Y side of the Shelter is shown in Fig. 6.1-23. Identical constraints are applicable to this side with additional limitations imposed by the S-band steerable antenna. This envelope does not satisfy the present configuration for the LSSM envelope requirements. If two LSSM are required on the same mission, the S-band steerable antenna would have to be relocated.

The prime purpose of these payload envelopes are to provide a guide to be used in determining volume constraints. The ground support platforms inside the SLA, located on the sides of the LEM are not reflected in the experiment payload envelopes.

6.1.4 Baseline Configuration

The baseline configuration is shown in Fig. 6.1-24. The major differences between the baseline and the recommended configurations are:

- EPS tankage - one cylindrical H_2 tank in descent stage quadrant I; one spherical oxygen tank in quadrant IV
- Fuel Cells - Pratt & Whitney fuel cells mounted on top of the descent stage
- No airlock was included
- S-band antenna was relocated
- EPS radiator sized for P&W fuel cells.

6.1.5 Alternate Configuration - EPS Tankage and Fuel Cells

Various configurations of EPS tankage and fuel cell combinations were investigated in arriving at the recommended configuration. Both ambient tanks, cryogenic tanks, and combinations of both were studied from the viewpoint of least complexity, minimum revision to the LEM, and overall compatiblity. In addition, Allis-Chalmer, General Electric, and Pratt & Whitney fuel cells were considered in conjunction with the different tank configurations. Some of the more feasible configurations are shown in Fig. 6.1-25 and 6.1-26.

6.1.5.1 Alternate Tank Configurations

6.1.5.1.1 Ambient. An alternate ambient configuration consists of four 39-in. spherical tanks (two hydrogen tanks and two oxygen tanks). The two hydrogen tanks are located in the same position as on the recommended configuration. Similar structure would be used to support these tanks and the same reasoning previously stated makes their location favorable.

The oxygen tanks are located in quadrants I and IV of the descent stage. The batteries and pyrotechnic relays were relocated from quadrant IV to quadrant III to make room for the tank. The supporting structure for the tanks consists of two horizontal trusses and diagonal members to carry vertical loads from the two mounting lugs on the tanks.

The tank in quadrant I results in RCS impingement. On the recommended configuration, by increasing the size of the quadrant IV tank, the quadrant I tank was eliminated; thereby eliminating the problem and creating more available volume for future requirements.

6.1.5.1.2 Cryogenic. The cryogenic configuration contains two cylindrical tanks: one H_2 tank 41.5-in. dia x 59.44-in long; and one O_2 tank 41.5-in. dia. x 39.74-in. long. The H_2 tank is located in quadrant IV and the O_2 tank in quadrant I. Batteries and pyro relays have been relocated in quadrant III. Truss supports, similar to those used for the previous tanks are used. Methods for reducing thermal conductivity would have to be evaluated to meet the storage requirements.

6.1.5.1.3 Hybrid. A hybrid system was also studied. It replaces the O_2 cyro tank in quadrant I of the cryogenic system with two ambient O_2 tanks located aft of -Z27 bulkhead, similar to the H_2 tanks in the recommended configuration. The H_2 cryo tank in quadrant IV is retained. This allocates quadrant I for scientific payload or storage of fuel cell assemblies.

6.1.5.2 Alternate FCA Locations

The following sets of fuel cell assemblies were used in determining the recommended location:

- Allis-Chalmer (2 req'd)
- General Electric (4 req'd)
- Pratt & Whitney (2 req'd).

In general, the volume between the ERA rack and the -Z27 bulkhead seems desirable, independent of the fuel cell choice. It is within the ascent shroud, thereby eliminating the need for independent thermal control. The rear of the shroud incorporates the FCA radiator which is then in the proximity of the fuel cells. The P&W fuel cells are the largest and are mounted at the base. This requires a horizontal shelf between the ERA rack and the -Z27 bulkhead when mounted above the EPS tanks (Fig. 6.1-27). The absence of tanks in this area would allow them to be mounted to the descent structure (Fig. 6.1-28). The GE and A-C fuel cells can be mounted directly to the ERA rack.

Two locations were considered as alternates in the descent stage; quadrant I and the outrigger bulkheads. In quadrant I, the GE and A-C fuel cells (Fig. 6.1-28) can be mounted on the vertical beams. The P&W fuel cells would have to be shelf mounted on a structure between the beams. All fuel cells, however, fit within a quadrant. The A-C fuel cell assemblies are shown mounted to the outrigger bulkhead (-Z81) of the descent stage (Fig. 6.1-30). They are removable through the side of the outrigger struts. The GE fuel cells can be mounted in a similar manner, but the size of the P&W fuel cells would present a problem.

The chart shown in Fig. 6.1-31 summarizes the alternate tank configuration considered.

6.1.6 Alternate Configuration - Airlocks

Figure 6.1-32 shows alternate airlock configurations for Shelter applications. Two types of construction were considered: rigid and retractable.

The rigid airlock located in its operating location presents the most reliable system. However, because of space limitations within the SLA, this type of airlock must be stowed on the side of the Shelter. This in turn consumes part of the volume presently allocated for experiment payloads, and requires being rotated and fastened in operational position after the crew arrives. Should payload requirements necessitate use of the volume consumed by the airlock, storage of the payload equipment within the airlock offers another possibility. Because of the lack of storage volume and the uncertainty pertaining to the difficulty of erection on the lunar surface, rigid airlocks were considered only as alternates.

Alternate soft or retractable airlocks are shown in Fig. 6.1-32 c and d. These configurations permit stowage in their operational location. The configuration shown in Fig. 6.1-32 e is also capable of being stowed within the SLA. However this configuration while giving maximum astronaut mobility, involves major structural redesign of the forward face beams.

A small pass-through airlock can be used to transfer small hand tools and lunar samples in and out of the cabin area, thus reducing the number of cabin depressurizations. A pass-through airlock in the window area consists of a 10-in. cylinder, 10-in. long, as shown in Fig. 6.1-33 a. This location requires the least amount of structural change to the vehicle. The window is removed and replaced with a stiffened metal cover welded to a cylindrical pass-through airlock. The sealing principles are the same as those currently being considered for the LEM. Accessibility is attained from the ramp which makes this configuration incompatible with any main cabin airlock.

A second alternate is a 6.8-in. cylinder, 10-in. long, inserted into the forward hatch shown in Fig. 6.1-33 b. This location is compatible with a main cabin airlock, however, structural modifications would have to be made to the front hatch.

The detail of the pass-through airlock is shown in Fig. 6.1-33 a. It consists of a cylinder with a circular sealed cover at each end. A center boss on each cover is connected to the cylinder rim by means of a hinge. An external handle on each cover first operates an internal bleed valve, and then, following pressure equalization, rotates the cover lugs out of their receptacles. If the pressure is not equalized, the high loading on the cover caused by seal friction will not allow rotation of the lugs out of their receptacles, eliminating the possibility of inadvertently dumping the cabin atmosphere.

6.1.7 Alternate Configuration - Top Hatch Thermal Cover/Expandable Storage Volume

The alternate Shelter top hatch cover (Fig. 6.1-34) has been designed to the following guidelines:

- Automatic remote deployment as a thermal shield to reduce Shelter heat loss
- Provide storage volume for one hard suit
- Storage volume must retain pressure, but primary seal is Shelter top hatch seal.

Upon completion of the Shelter unmanned landing, the top hatch thermal cover is released from its stored area by firing either or both of the redundant explosive nuts on the central retaining bolt. The torsion springs now rotate the cover storage volume into position above the docking tunnel. The hinge pins are then withdrawn by a pyrotechnic pin-puller and the spring loaded retaining clamp released by the firing of its explosive bolts. When the Shelter is occupied, the astronauts open the top hatch, energize the cover seal and lock, and then pressurize the Shelter.

The Shelter pressurization causes the expansion of the storage volume so that the hard suit may be stored. The top hatch is then locked, with the hatch seal serving to retain cabin pressurization.

6.1.8 Alternate Configuration - RTG Location

An alternate RTG location (Fig. 6.1-35) mounts the unit on a sheet metal structure spanning the descent stage main beams over quadrant IV. This location, while common to the Taxi, imposes additional restriction on the right-hand side (+Y) experiment payload envelope.

The RTG is shrouded within an insulated box with a hinged door facing the ascent stage cabin structure. The ascent stage thermal shield is removed in this area. The door is thermostatically controlled by means of a silicone-fluid filled sensor and actuator system. The sensor allows the door to open when the ascent stage temperature drops below 40° F. Opening of the door permits RTG heat to radiate to the ascent stage skin. The sensor is mounted to the ascent stage structure, remote from the radiant heat field of the RTG. Ascent stage temperature causes either expansion or contraction of the fluid, which in turn, operates the actuator and door.

6.1.9 Alternate Configuration - RCS Thruster Covers

Two basic approaches to the problem of insulating the RCS clusters have been investigated. The first approach is to cover each individual thruster, and the second appraoch is to cover each cluster with a clam-shell type device.

The individual thruster cover concept is shown in Fig. 6.1-36. The cover is mounted to the base of the thruster. Upon landing, the explosive bolts are fired, releasing the retaining clamp. The compression spring is released and strokes to extend the

NRC-2 insulation around the thruster. At the end of the stroke, the wires rotate the petal-type end closures into position, completing the deployment.

A four-thruster clam-shell-type RCS cover is shown in Fig. 6.1-37. It consists of a fixed baseplate mounted on the cluster support truss and two rotatable frames which deploy NRC-2 superinsulation about the cluster. The cover is actuated by the firing of the explosive retaining units. The torsion springs are then able to rotate the frames and deploy the insulation.

A two-thruster clam-shell-type RCS cover is shown in Fig. 6.1-38. Construction and operation are similar to the four-thruster clam-shell type shown in Fig. 6.1-37, except for the smaller size necessary to insulate only two thrusters.

6.1.10 Alternate Configuration - Shelter Leveling System

This system would be used to correct the post-landing slope of a Shelter whenever such slope exceeded 10 deg (true). This requirement stems from physiological and psychological parameters which affect the efficiency and well being of the crew. The guidelines for Shelter leveling were:

- Worst landed attitude of the Shelter is 30 deg to the lunar horizon (determined by the maximum stroking geometry of the landing gear)
- Leveling to be accomplished by one man
- Time allowed for leveling approximately 30 min
- Leveling to 10 deg of the horizon is satisfactory
- System must adapt to any type of terrian within the Apollo lunar surface model
- System must be capable of unpressurized storage on the Moon for the Shelter unmanned phase
- System must have mechanical "fail-safe" locks.

The leveling system shown in Fig. 6.1-39, consists of a pair of telescoping pneumatic jacks with extensions and a 3000-psi helium bottle with necessary flexlines and controls. Each jack has two spring-loaded pawl locks that are self-locking in 1/2-in. increments. Cross-beams to transfer jack load to the descent stage/SLA truss, and suitable base plates for transferring the jack load to the lunar surface are also provided. The length of each jack is 62 in. stored, and 145 in. extended.

After determining the proper jacking point for either one or two jacks, the astronaut clips the cross-beams to the appropriate descent stage truss(es) and sets up the required jacks. The flex lines between the jacks and bottle are then connected and a small volume of helium fed to the jack(s) to bring them into contact with their respective cross-beams. This is accomplished by means of needle valves located at the jacks. After contact is achieved, the astronaut moves to the remote control module and pressurizes each jack to achieve leveling. A visual check of the locking pawls completes the operation. The complete system weighs approximately 100 lb and requires a stored volume of 12 cu ft; the largest component will weigh approximately 7 lb on the lunar surface.

Other leveling concepts investigated during the Phase B study were:

- Pneumatic bags with adjustable blocking struts
- A-frames and derrick type rigs
- Partial landing gear disassembly and rerigging
- Jacking provisions built into the descent stage.

In general, these systems were either excessively heavy, required larger storage volumes, or violated one or more of the assumed guidelines.

6.1.11 Alternate Configuration - Radiator Location

Potential vertical and horizontal radiator locations for the Shelter are shown in Fig. 6.1-40. The recommended radiators were selected from these available areas.

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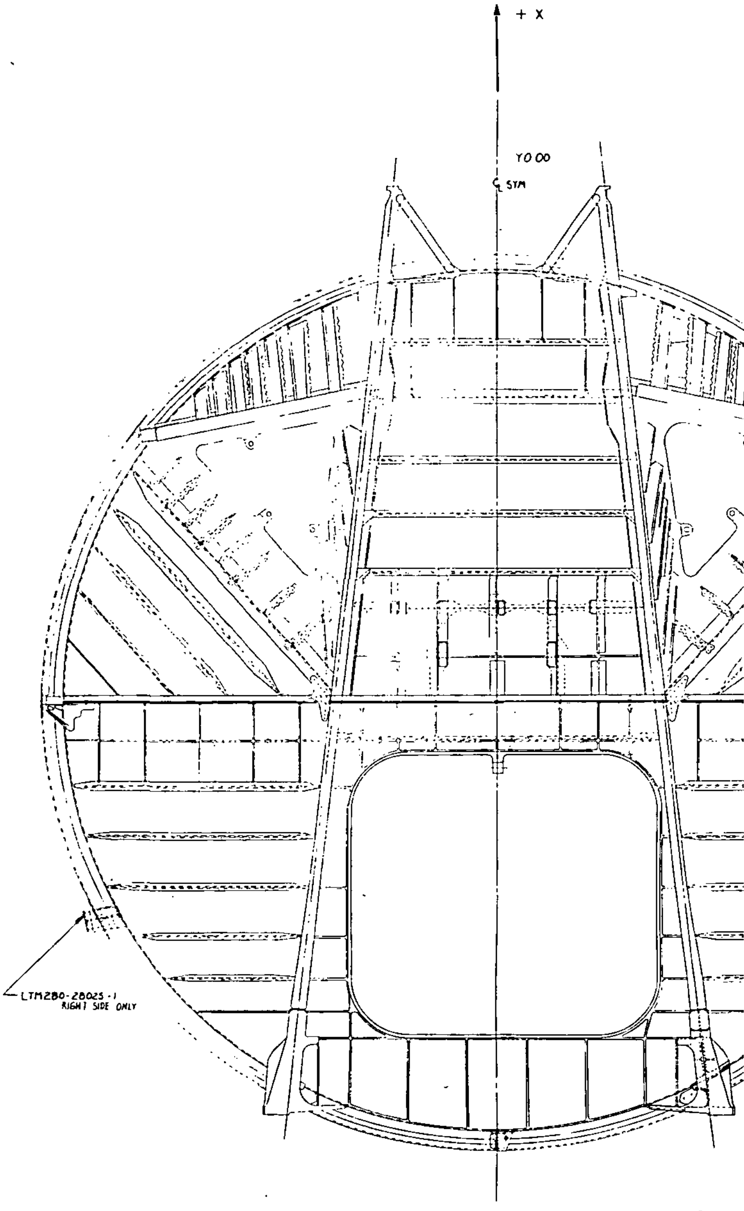

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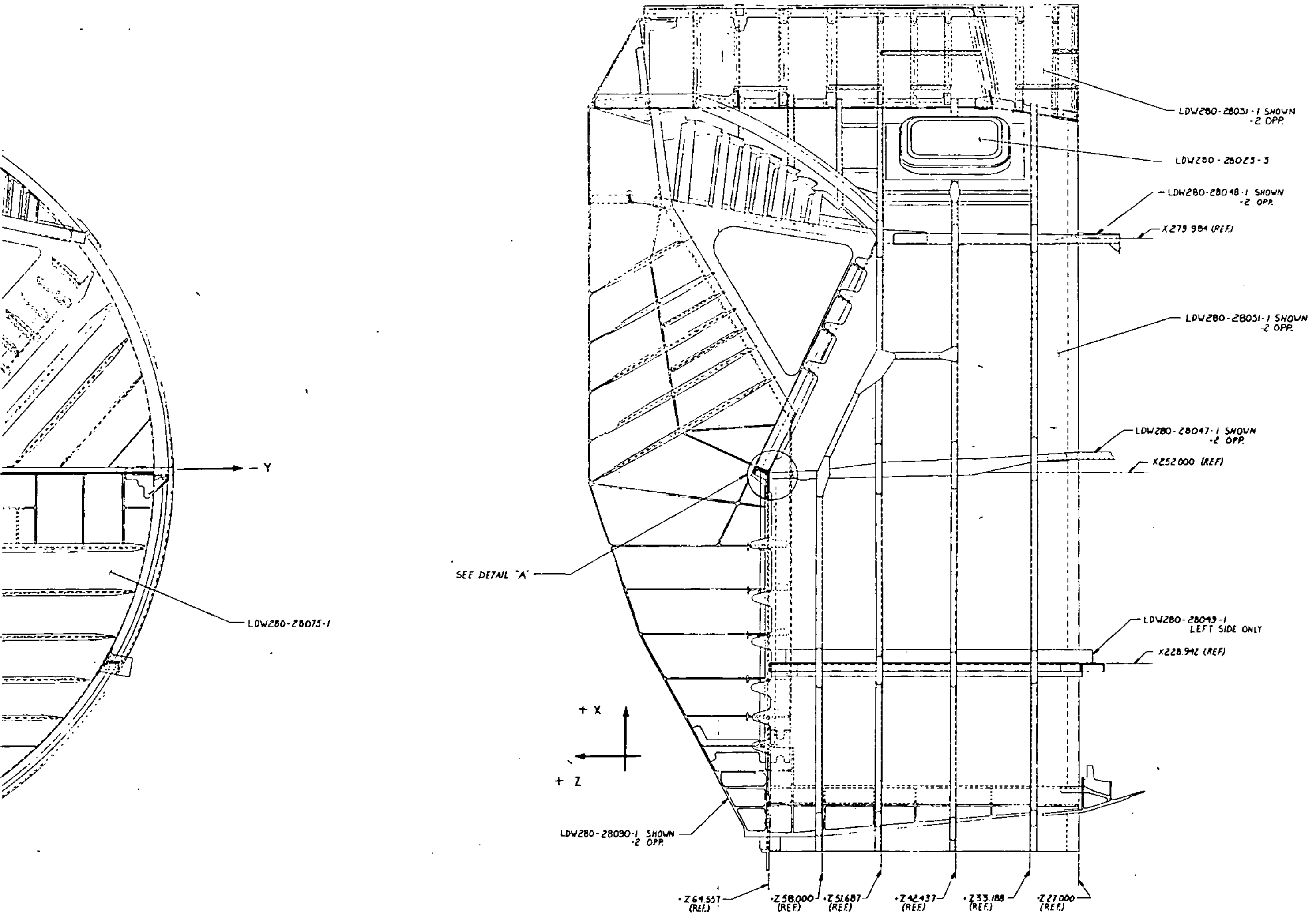
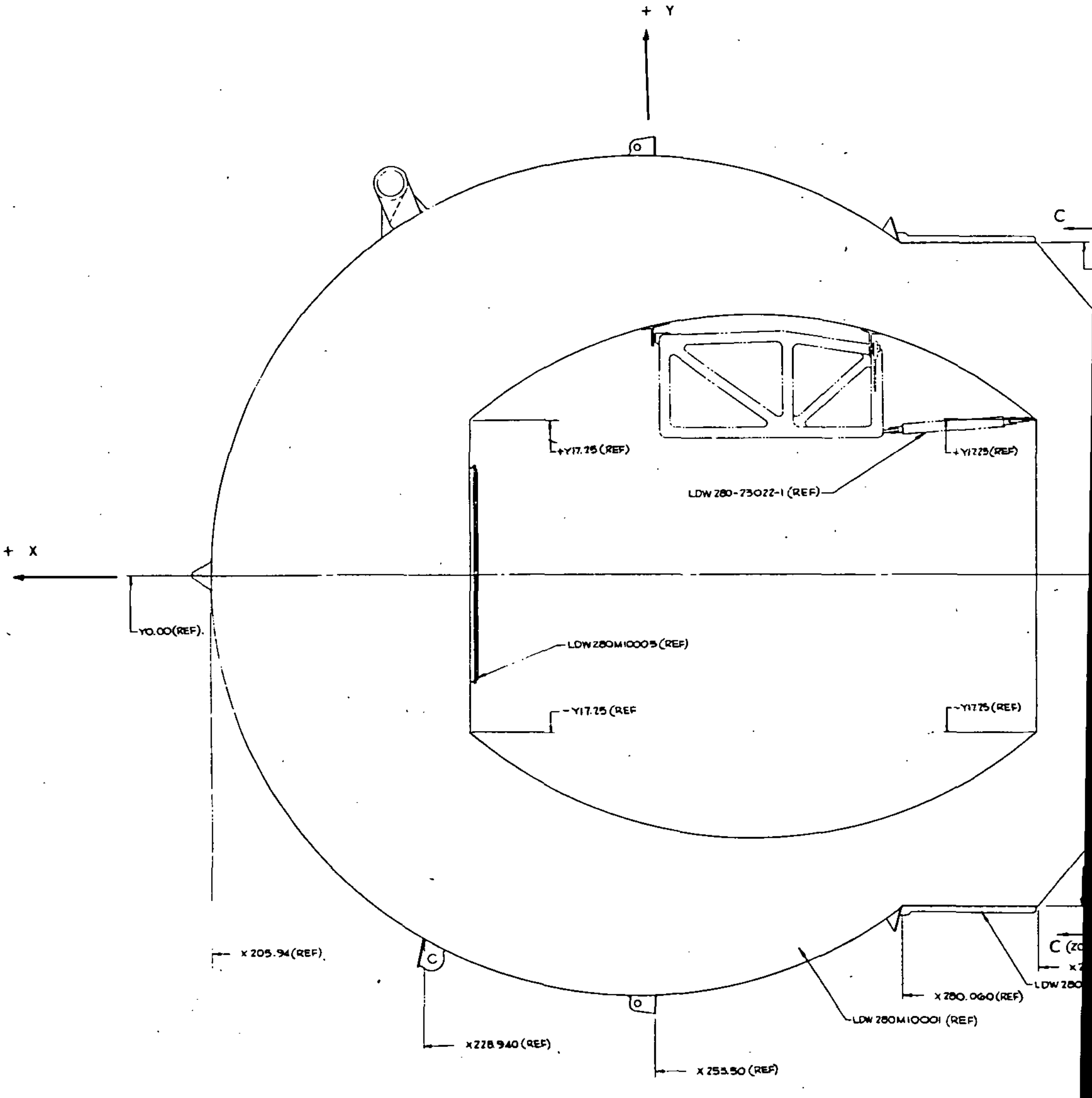


Fig. 6.1-1 LEM Structural Arrangement
Ascent Stage Forward Cabin



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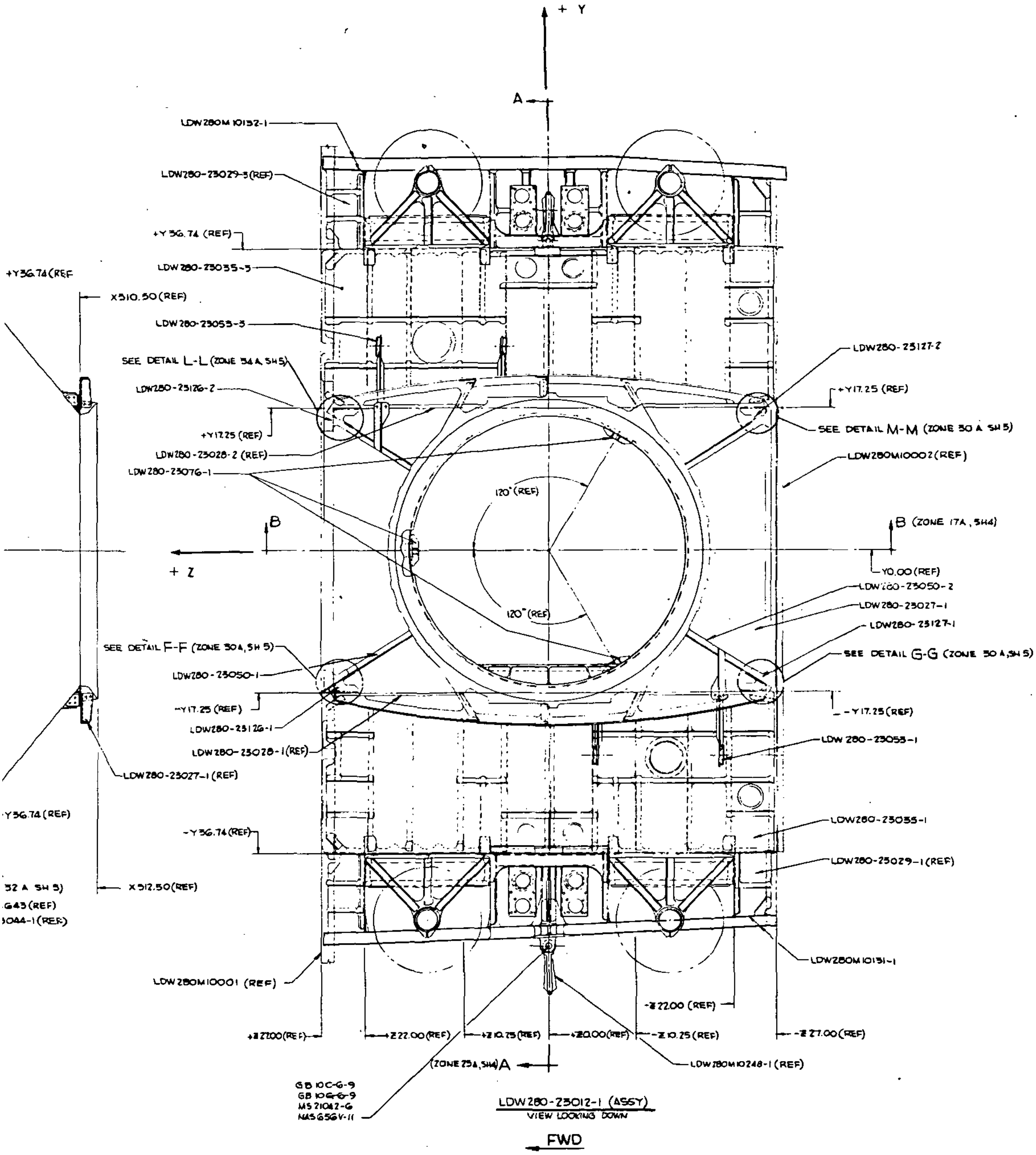
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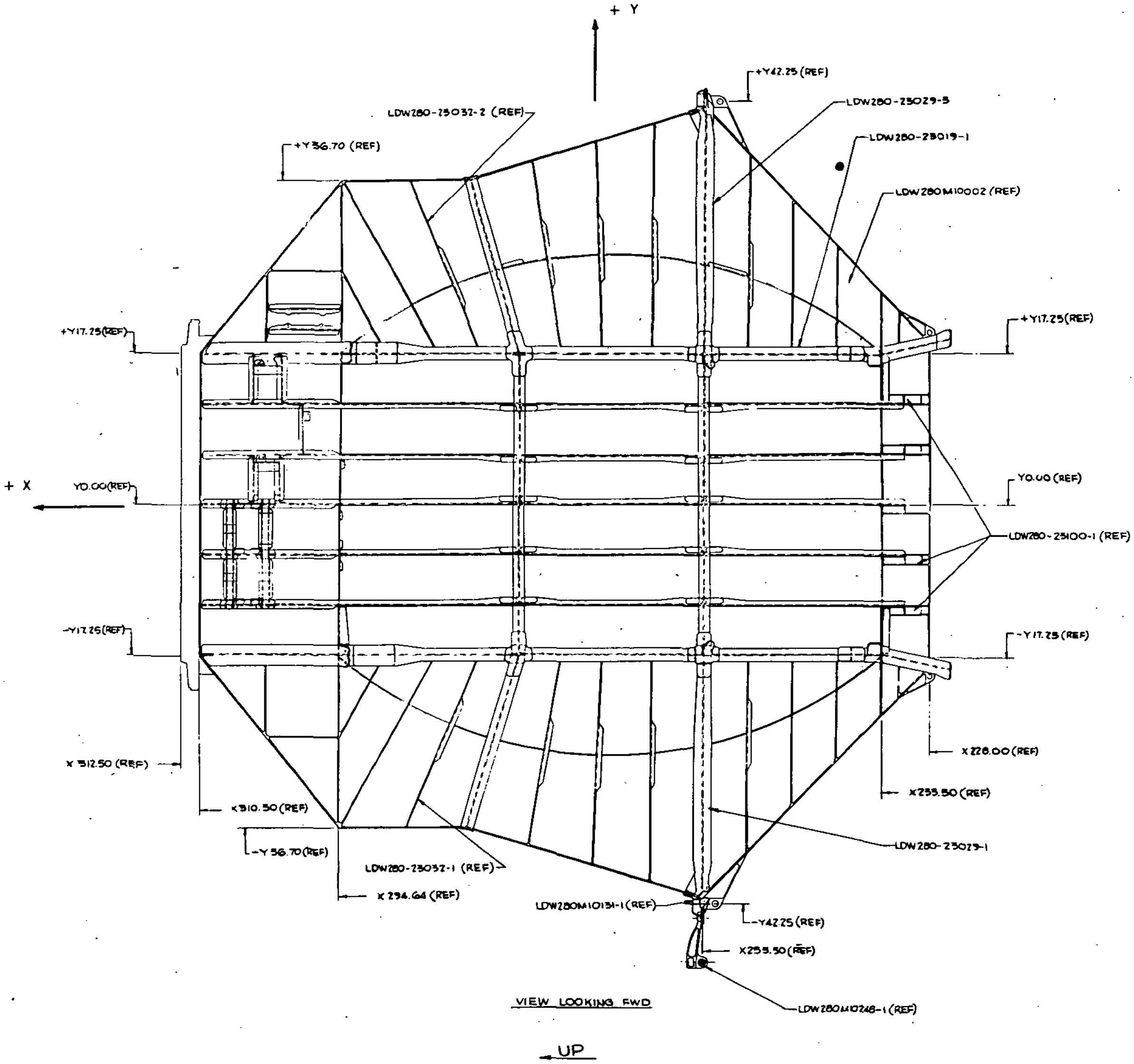

Fig. 6.1-2 LEM Structural Arrangement
Ascent Stage Aft Cabin

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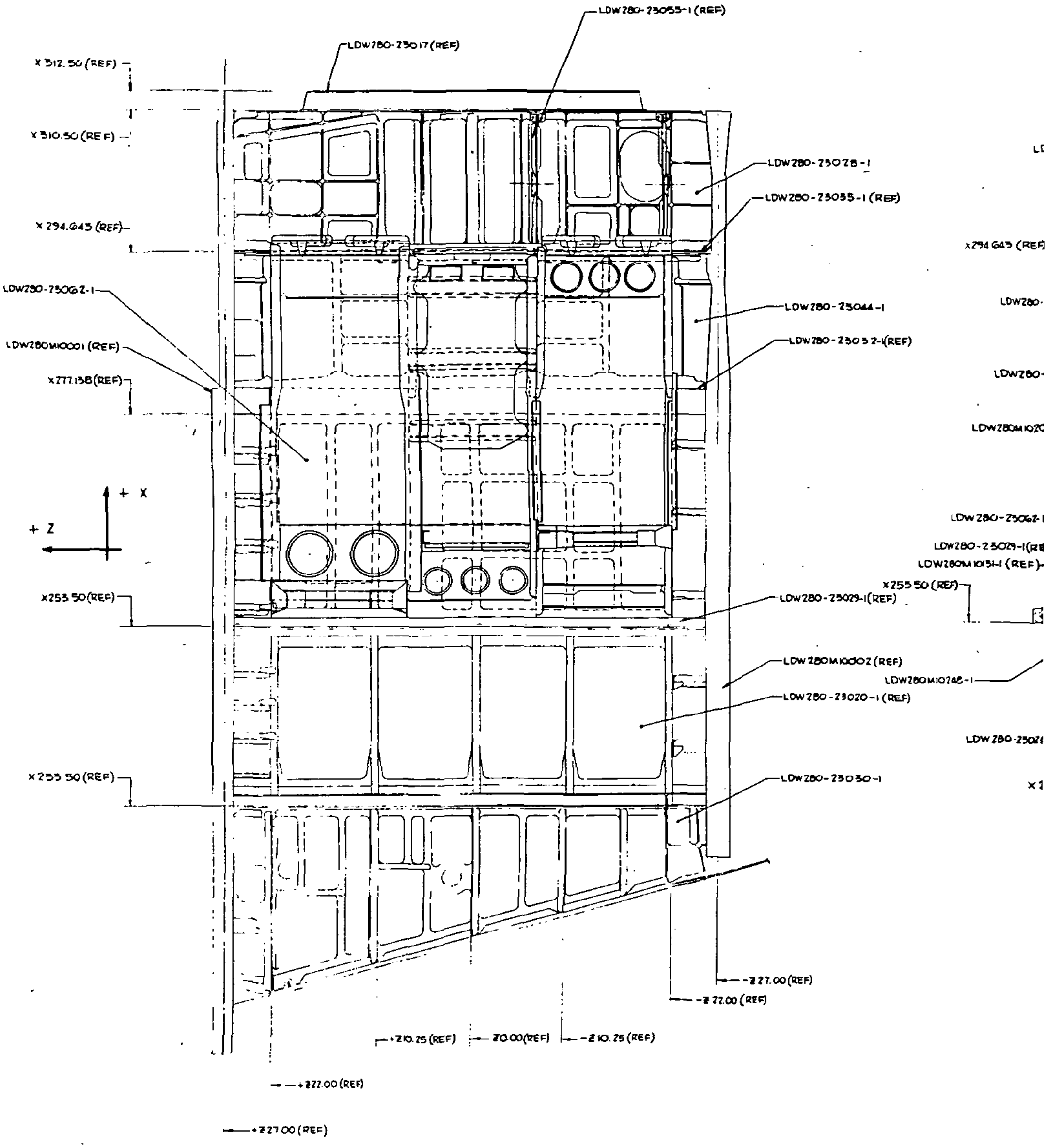

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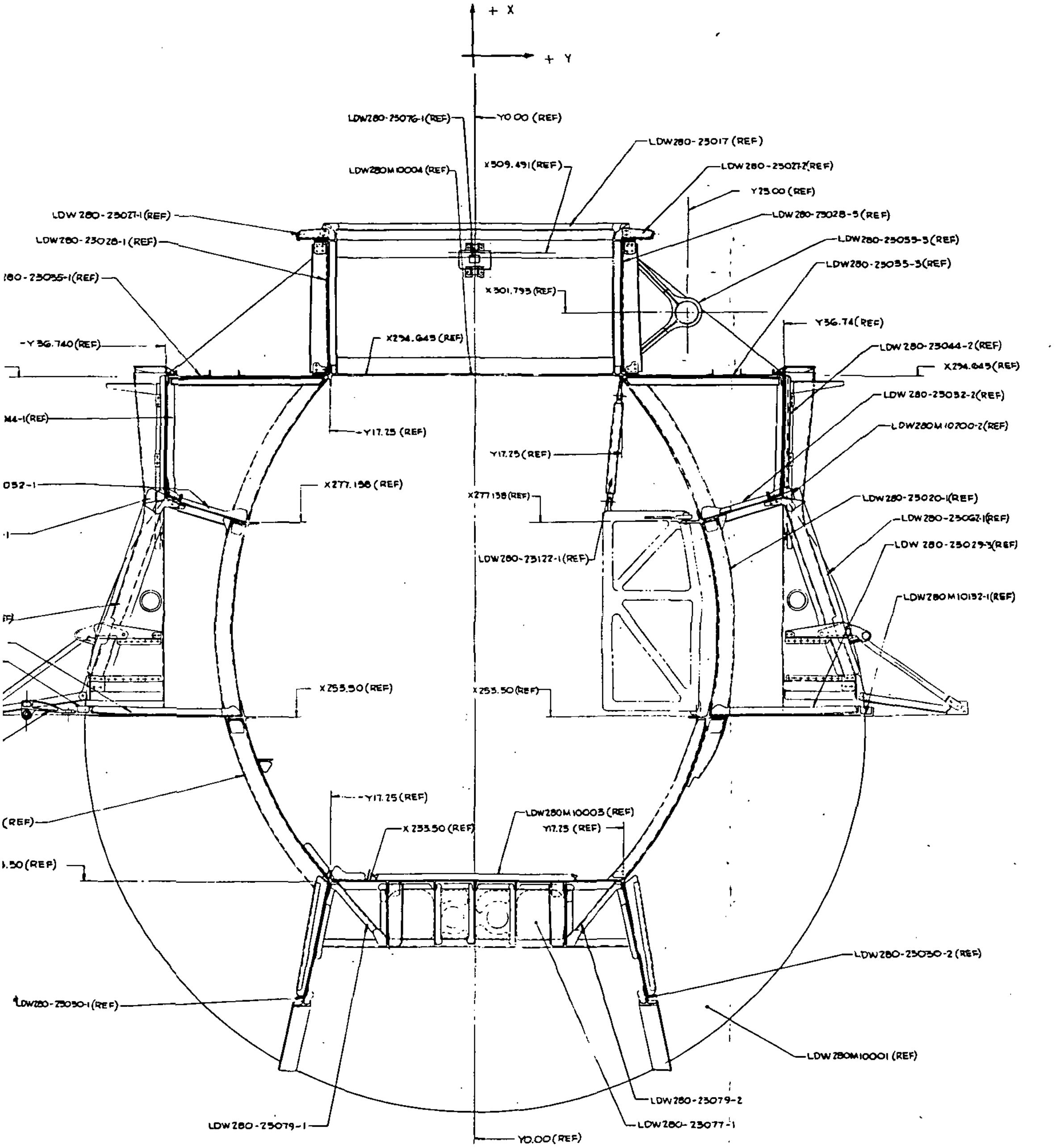

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(ROTATED CW 90°)
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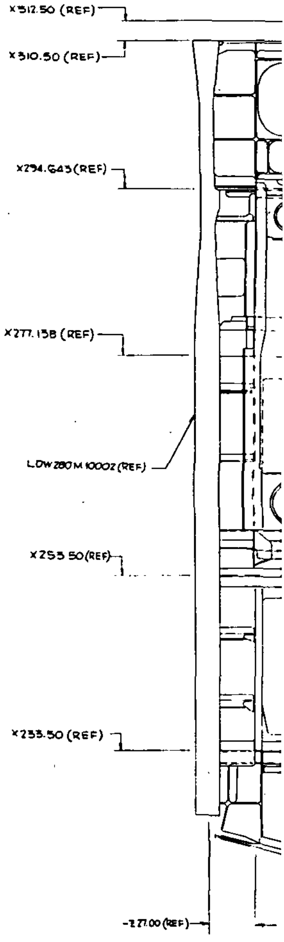


6.1-3

②

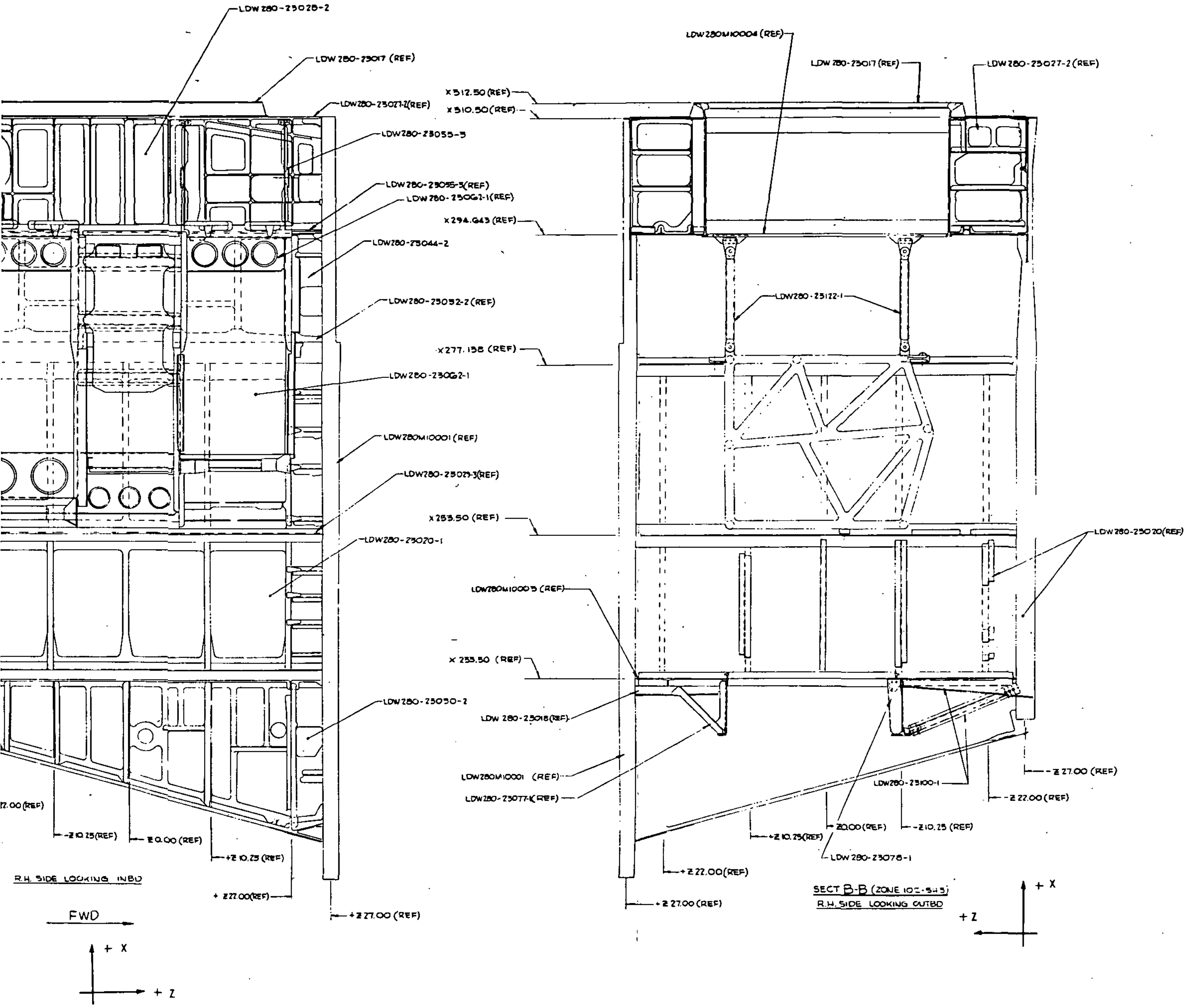


Fig. 6.1-3 LEM Structural Arrangement
Ascent Stage Aft Cabin

③

Grumman

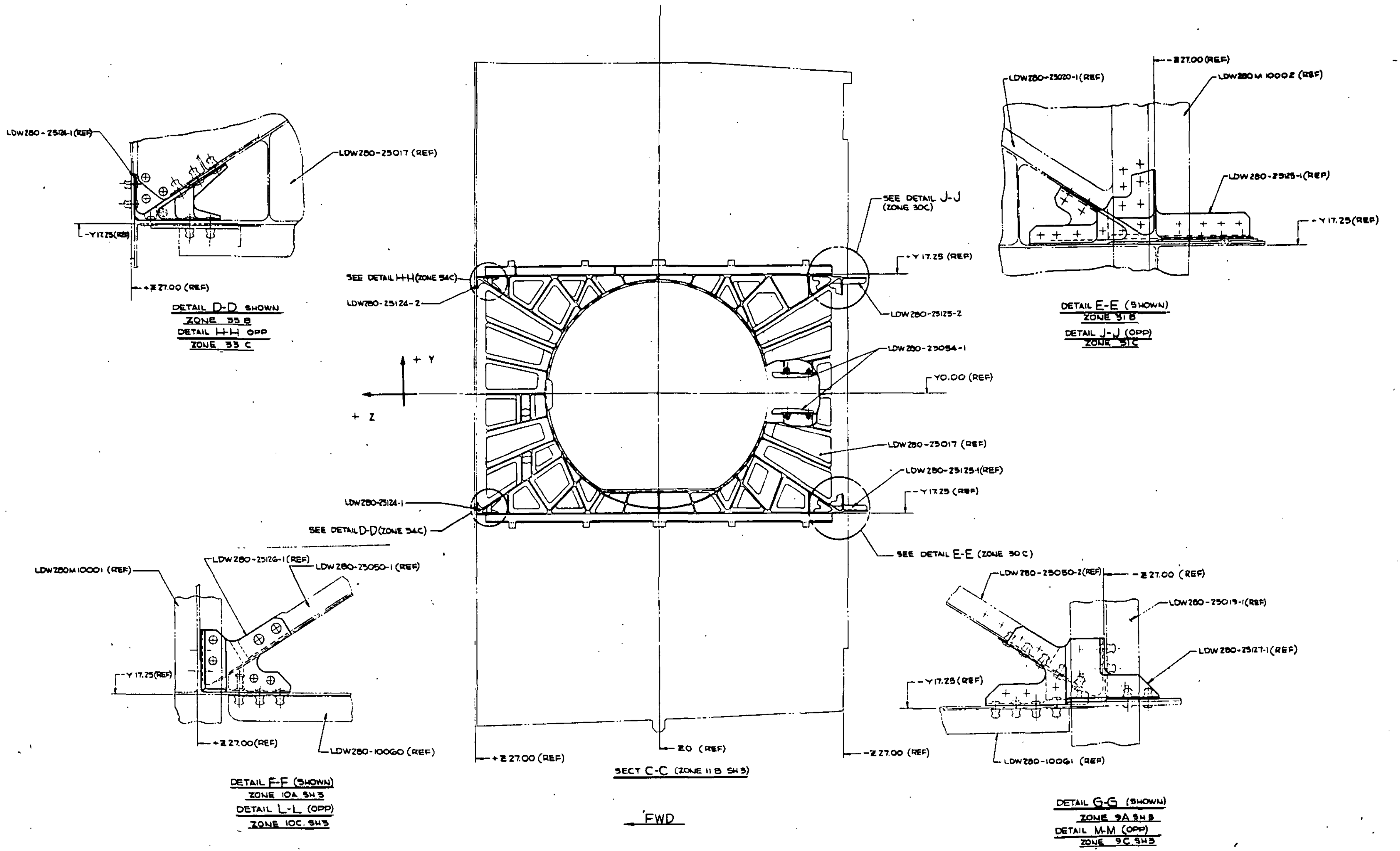
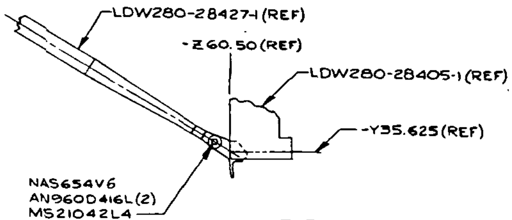


Fig. 6.1-4 LEM Structural Arrangement Ascent Stage Aft Cabin

(21)



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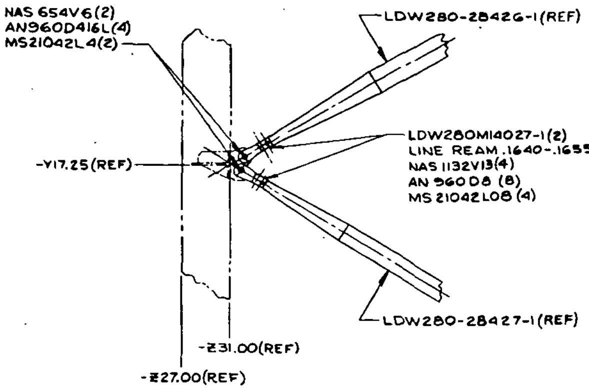
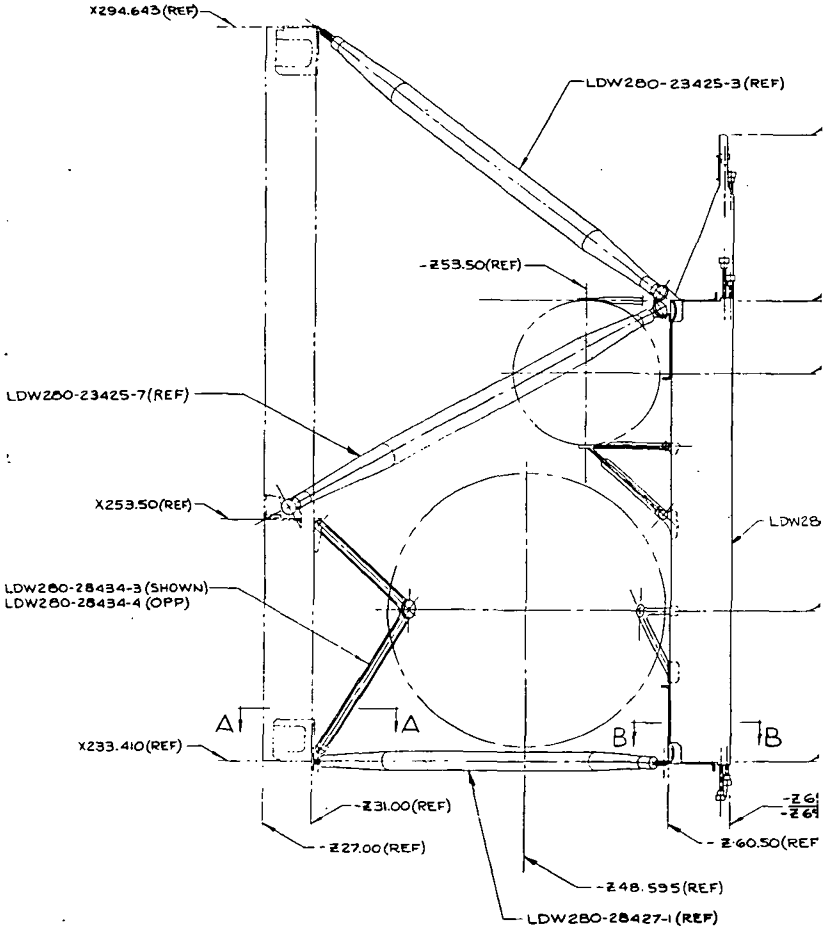
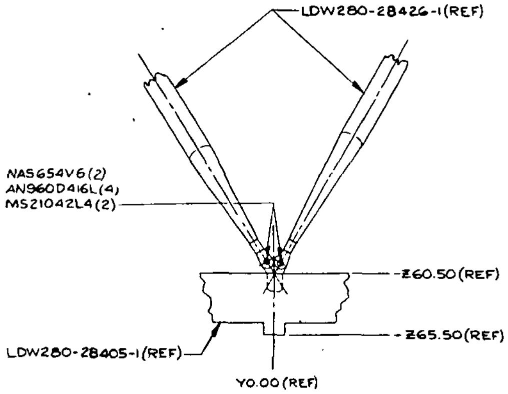
LH (SHOWN) RH (OPP)



VIEW A-A
LH (SHOWN) RH(OPP)





VIEW C-C

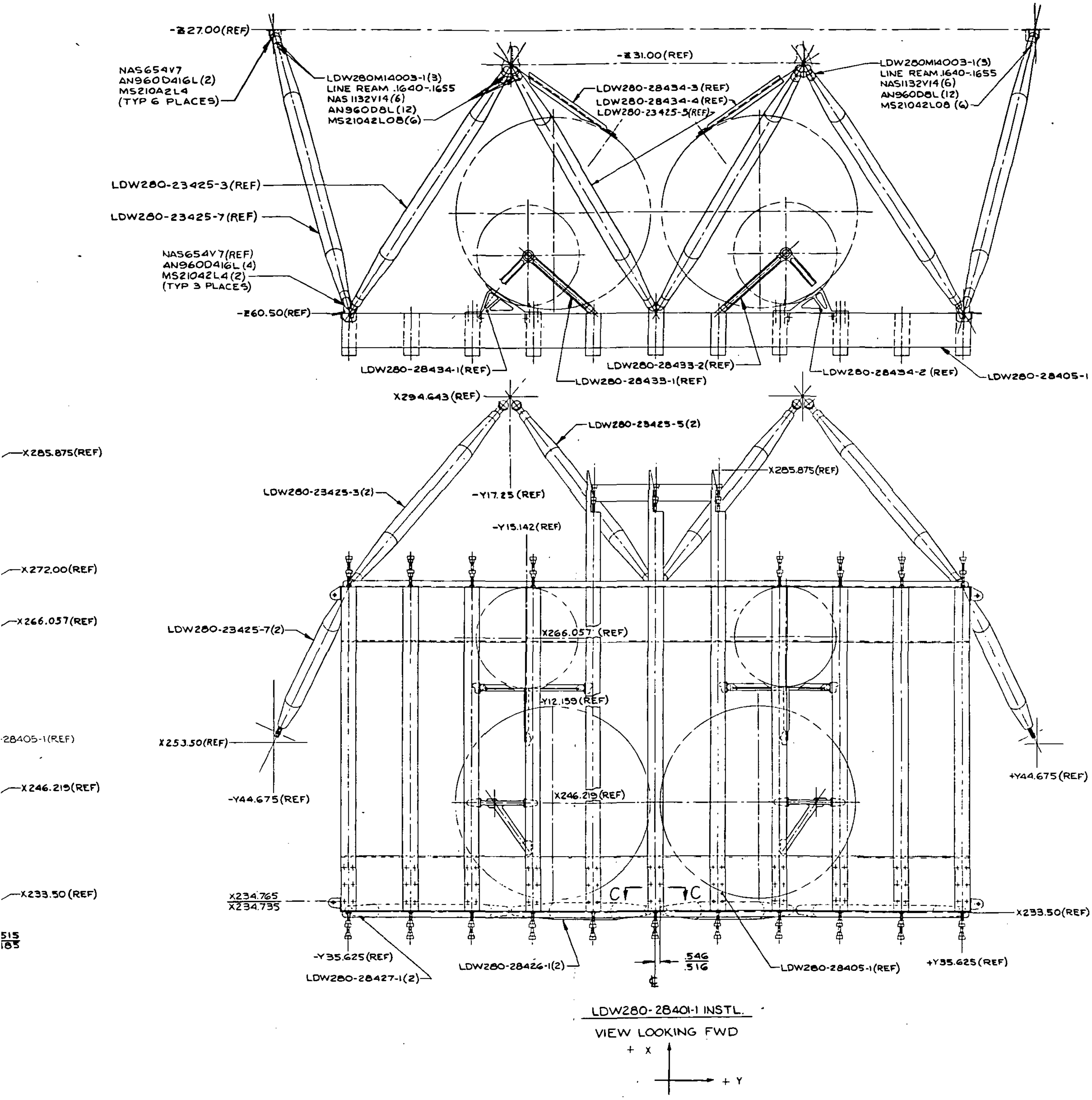
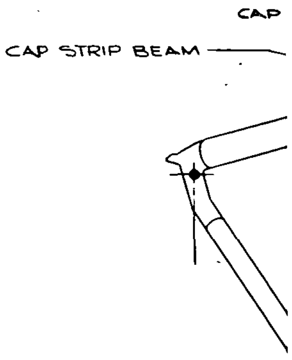
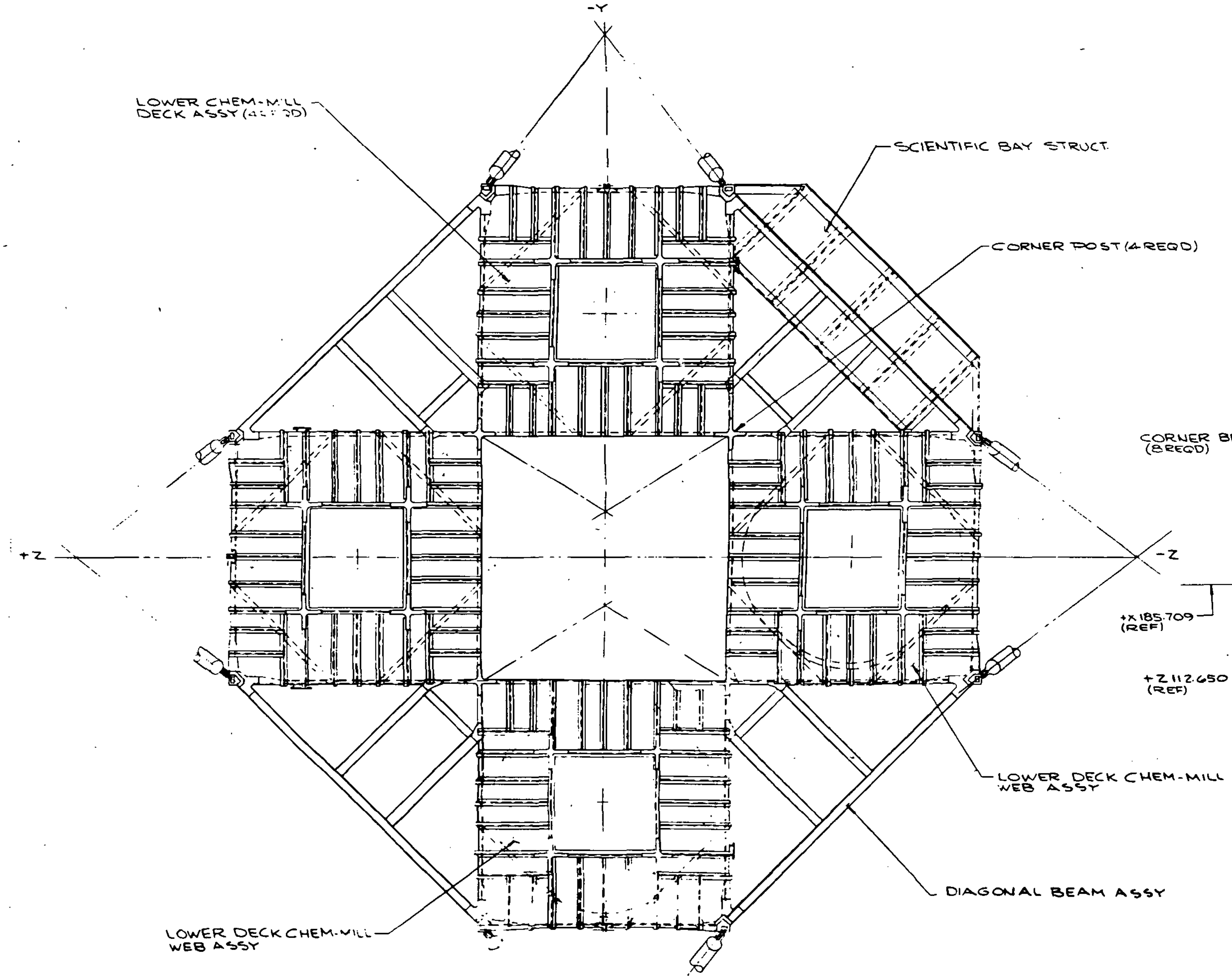
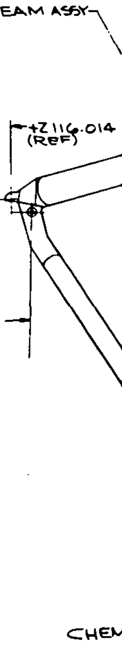


Fig. 6.1-5 LEM Structural Arrangement Ascent Stage Aft Equipment Compartment



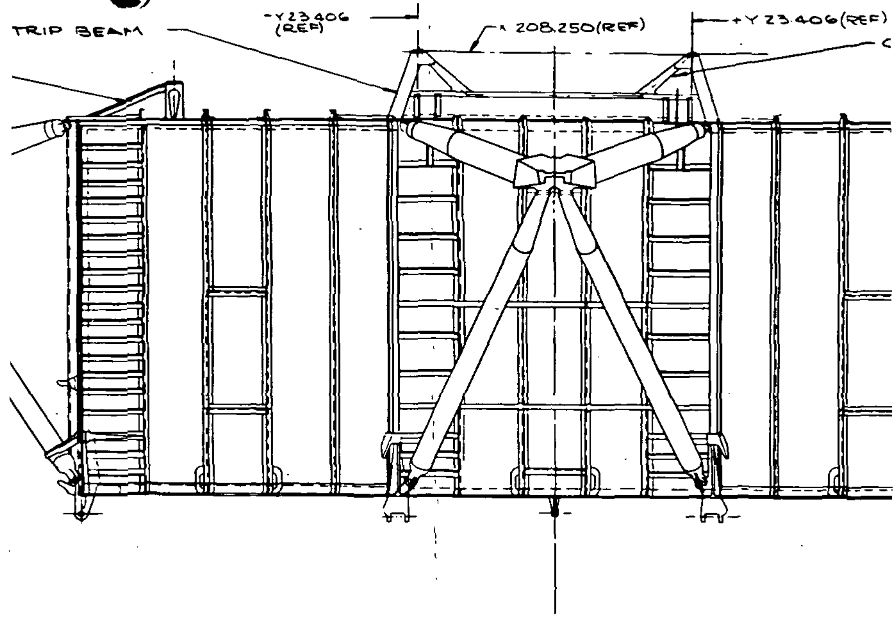




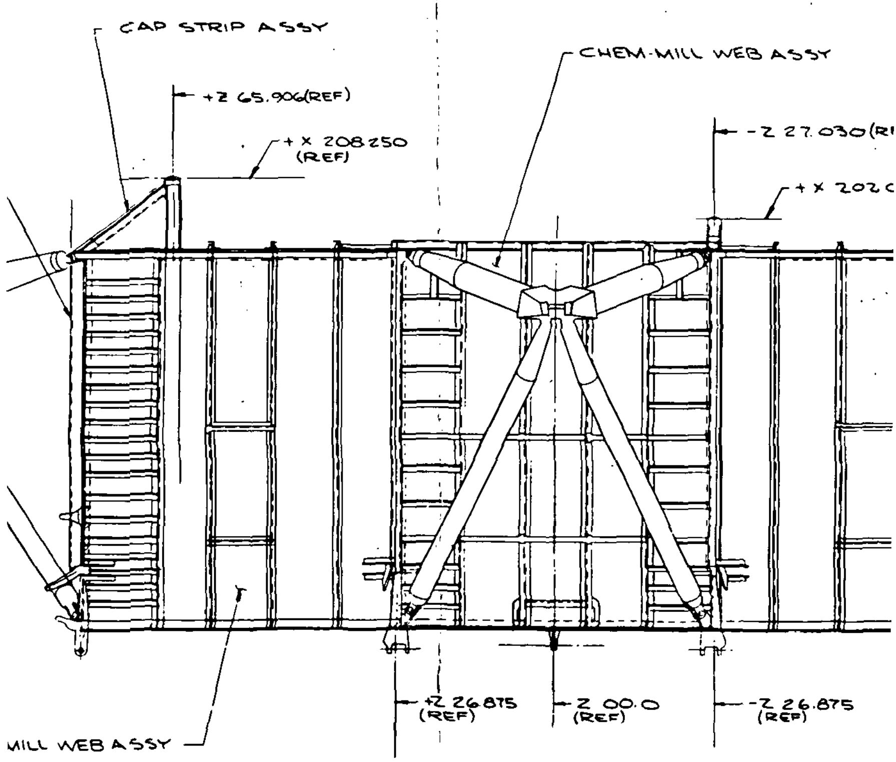
VIEW LOOKING UP
LOWER DECK

6-1-6

⑦

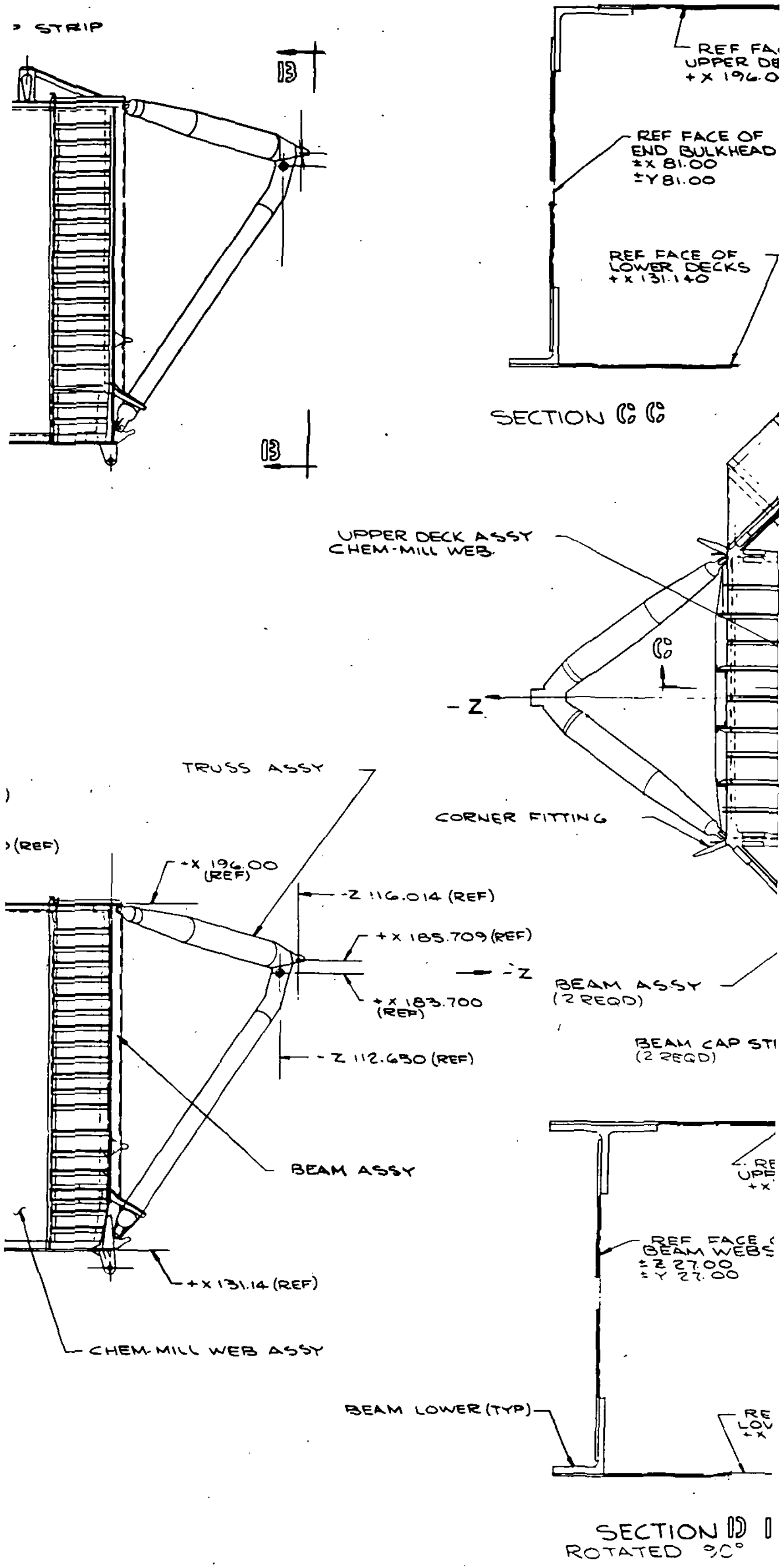


VIEW A-A
ROTATED 90°



B-B
VIEW LOOKING INBD
-Y 81.00 / -Y 27.00

6.1-6 ②


STRIP
B
B
REF FA
UPPER DE
+X 196.0
REF FACE OF
END BULKHEAD
±X 81.00
±Y 81.00
REF FACE OF
LOWER DECKS
+X 131.140
SECTION C C
UPPER DECK ASSY
CHEM-MILL WEB
C
-Z
CORNER FITTING
TRUSS ASSY
(REF)
+X 196.00
(REF)
-Z 116.014 (REF)
+X 185.709 (REF)
-Z
+X 183.700
(REF)
-Z 112.650 (REF)
BEAM ASSY
(2 REQD)
BEAM CAP STI
(2 REQD)
BEAM ASSY
+X 131.14 (REF)
CHEM-MILL WEB ASSY
RE
UPE
+X
REF FACE
BEAM WEBS
±Z 27.00
±Y 27.00
BEAM LOWER (TYP)
RE
LOV
+X
SECTION D D
ROTATED 90°

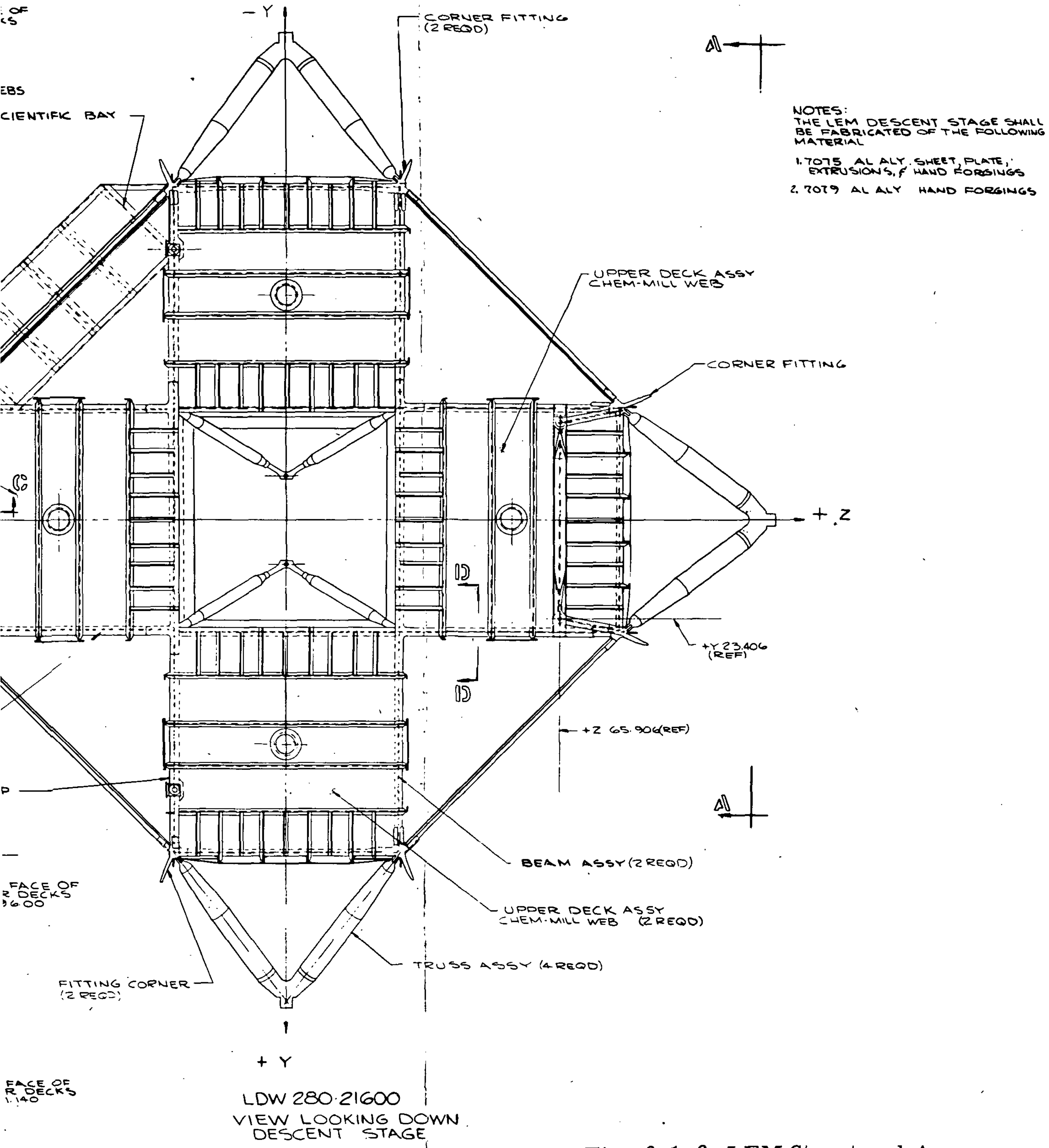
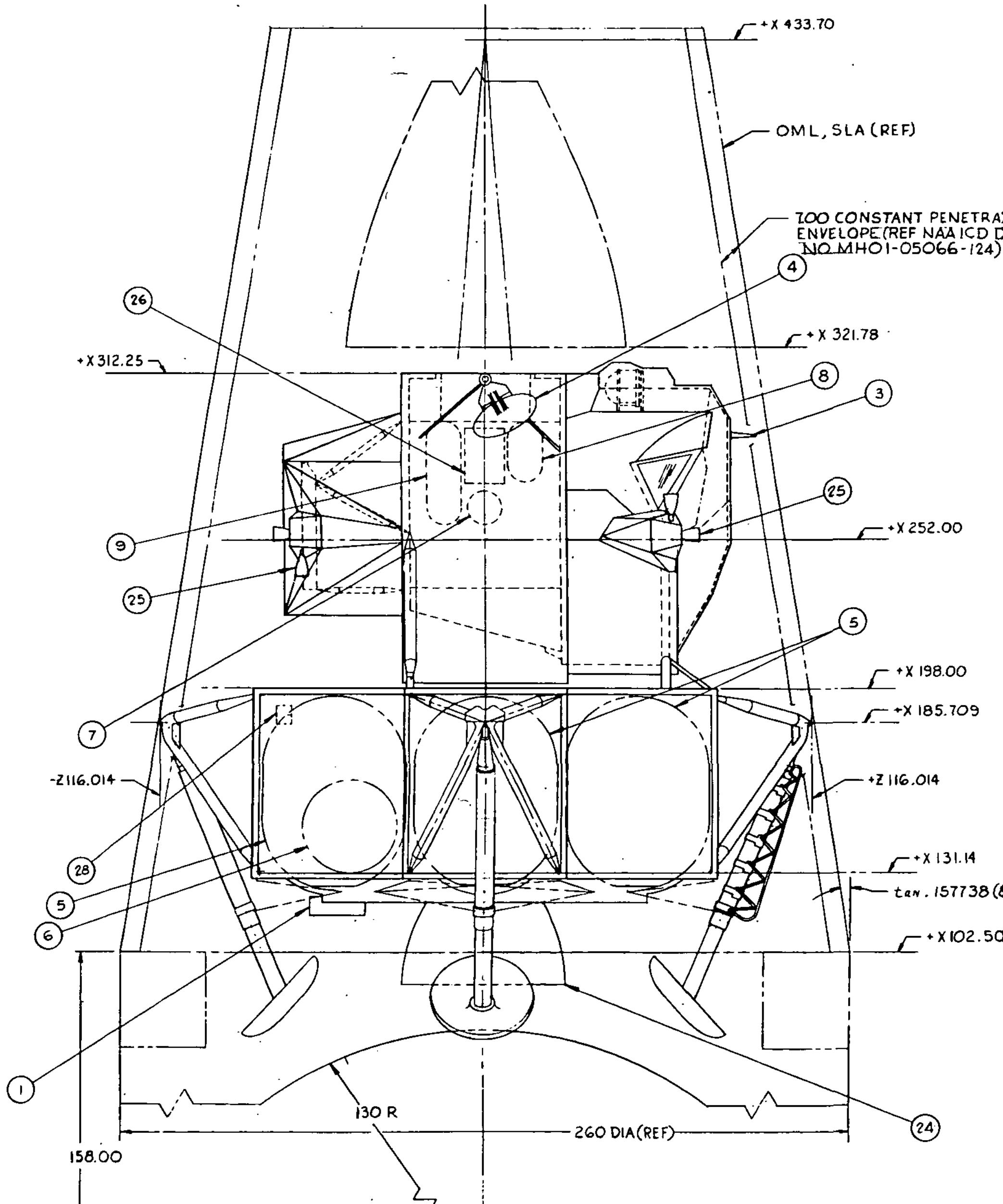


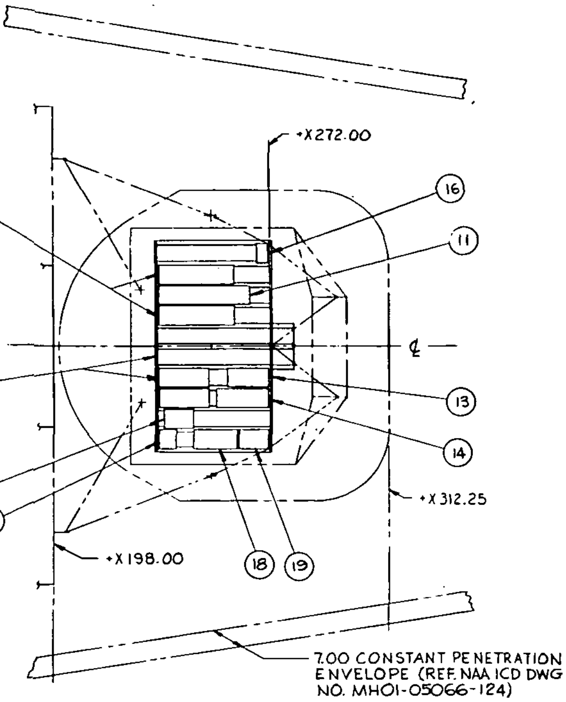
Fig. 6.1-6 LEM Structural Arrange - Descent Stage

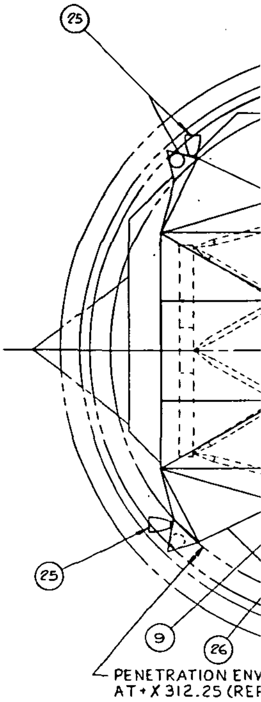
4


+X 433.70
OML, SLA (REF)
7.00 CONSTANT PENETRA
ENVELOPE (REF NAA ICD D
NO MH01-05066-124)
4
26
+X 321.78
+X 312.25
8
3
25
9
+X 252.00
25
5
+X 198.00
7
+X 185.709
-Z116.014
+Z 116.014
28
+X 131.14
5
tan. 157738 (
6
+X 102.50
1
130 R
260 DIA (REF)
24
158.00

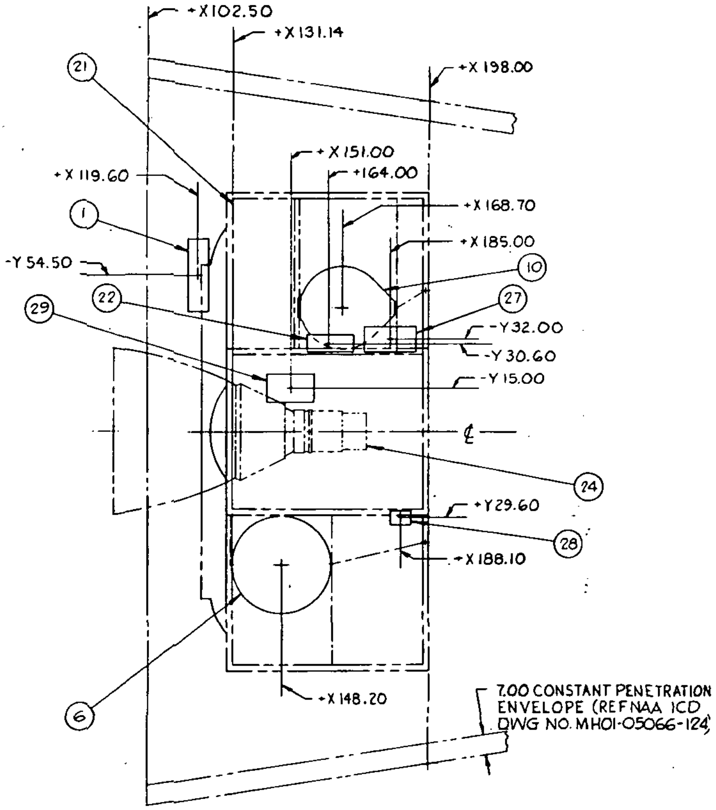
6-1-7
0

ON
NG


+X 272.00
15
16
11
12
13
14
17
20
18
19
℄
+X 312.25
+X 198.00
7.00 CONSTANT PENETRATION ENVELOPE (REF. NAA ICD DWG NO. MH01-05066-124)


25
25
9
26
PENETRATION ENV
AT +X 312.25 (REF

58"


+X 102.50
+X 131.14
+X 198.00
21
+X 151.00
+164.00
+X 119.60
+X 168.70
1
+X 185.00
-Y 54.50
10
22
27
29
-Y 32.00
-Y 30.60
-Y 15.00
℄
24
+Y 29.60
28
+X 188.10
6
+X 148.20
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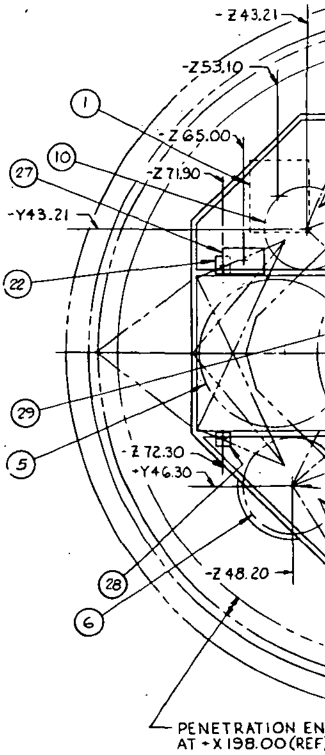
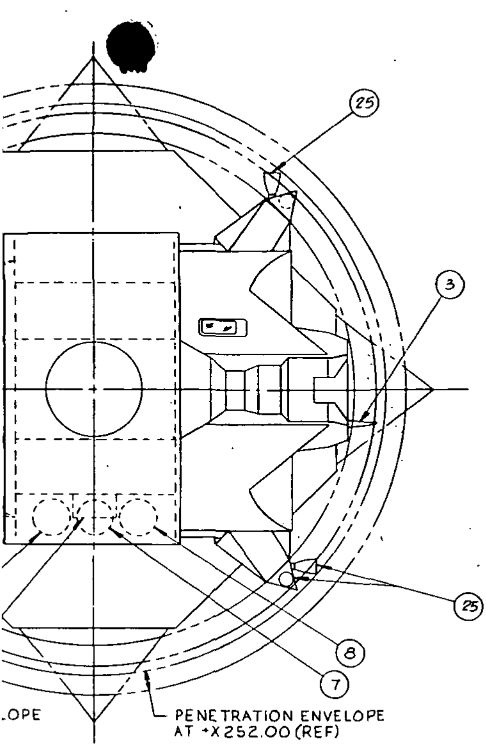

-Z 43.21
-Z 53.10
1
-Z 65.00
10
-Z 71.90
27
-Y 43.21
22
29
5
-Z 72.30
+Y 46.30
28
6
-Z 48.20
PENETRATION EN
AT +X 198.00 (REF

6.1-7

(2)



KEY

ANTENNAS
1. LANDING RADAR
2. S-BAND ERECTABLE
3. S-BAND IN-FLIGHT
4. S-BAND STEERABLE

TANKS
5. FUEL (DESC. PROPUL)
6. He (DESC. ENGINE)
7. He (RCS)
8. RCS FUEL
9. RCS OXIDIZER
10. WATER

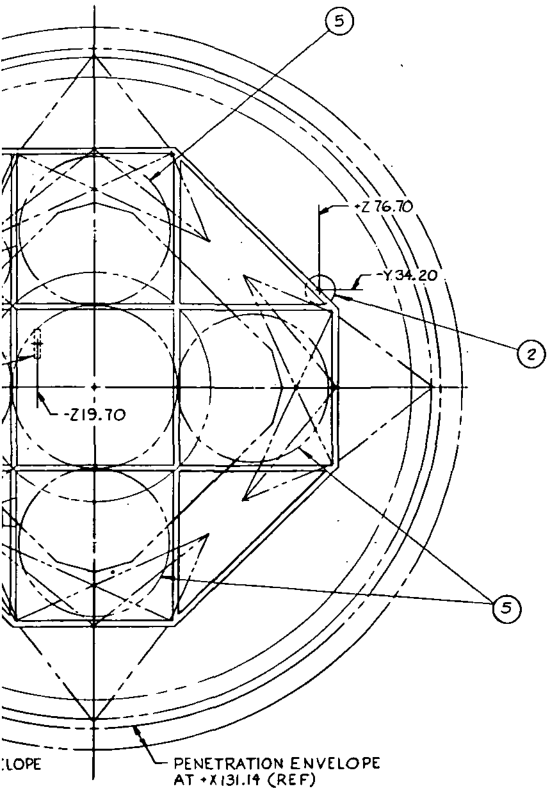
ELECTRONIC REPLACEABLE ASSYS
11. PULSE CODE MODULATION
12. INVERTER
13. CAUTION & WARNING ELECTRONIC ASSY
14. ATTITUDE & TRANSLATION CONTROL ASSY
15. SIGNAL CONDITIONER ELECTRONICS ASSY
16. PROPELLANT QUANTITY GAUGING SYSTEM
17. VHF COMMUNICATION ASSY
18. S-BAND TRANSCEIVER
19. S-BAND POWER AMPLIFIER
20. SIGNAL PROCESSOR

PAYLOAD
21. PRESENT LEM SCIENTIFIC EQUIPT BAY

MISCELLANEOUS
22. LANDING RADAR ELECTRONIC ASSY
23. IMU
24. DESCENT ENGINE
25. RCS
26. RCS He PRESSURE UNIT
27. He PRESSURE MODULE (DESC. PROPUL. SYSTEM)
28. DESCENT ENGINE CONTROL ASSY
29. He HEAT EXCHANGER

0 20 40 60 80 100

Scale, in.



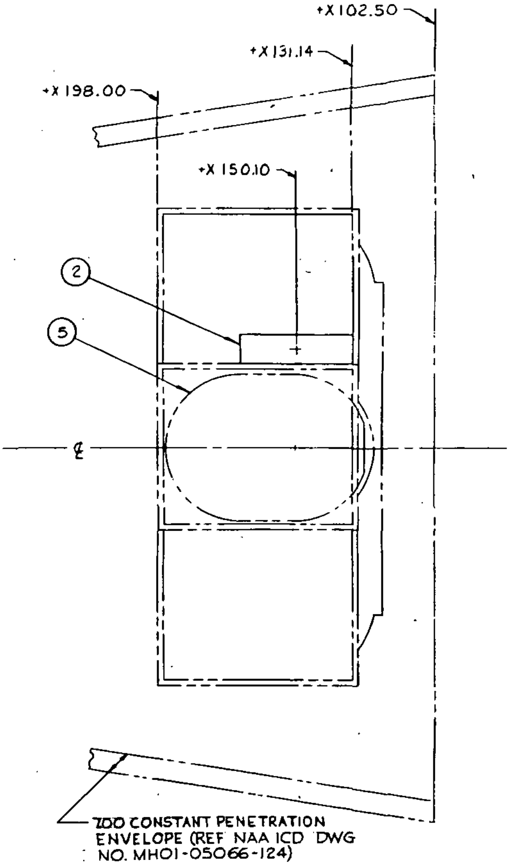


Fig. 6.1-7 Stripped Shelter - General Arrangement

3

Key

Antennas

1 Landing*
2 S-Band Erectable*
3 S-Band In-Flight**
4 VHF In-Flight**
5 S-Band Steerable**
6 Erectable EVA*

Tanks

7 Fuel (Desc Propul)*
8 GOX(For Detail See Fig. 6.1-10)
9 He (Desc Eng)*
10 He (RCS)*
11 RCS Fuel*
12 RCS Oxidizer*
13 Gaseous H_2 For Detail See Fig. 6.1-9)
14 Water*
15 FCA Water Storage***
(For Detail See Fig. 6.1-12)

Crew Provisions

16 PLSS Supplementary GOX Tank
17 Cabin LiOH
18 PLSS Cartridges*
19 PLSS Units (2) +
} For Detail See Fig. 6.1-21

Electrical Power Supply

20 Fuel Cell Assy(For Detail See Fig. 6.1-11 & -12)
21 Modified Desc Stg Batt's
22 ECA**
23 Pyro Batt's
24 Pyro Relays**
} For Detail See Fig. 6.1-13

Thermal Insulation & Protection

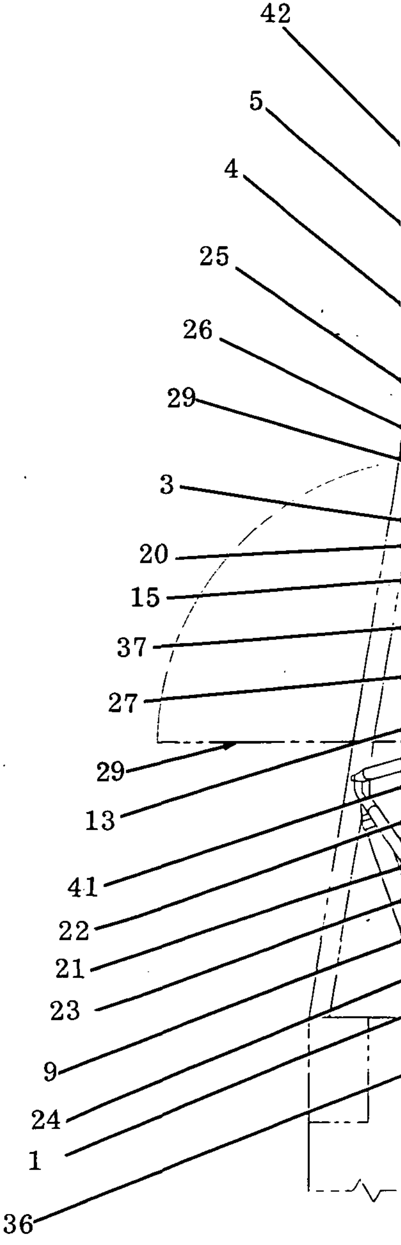
25 Thermal Shield(For Detail See Fig. 6.1-16 & -17)
(Upper Hatch & Windows)
26 Radiators
27 Fuel Cell Radiators
} For Detail See Fig. 6.1-18
28 Heat Pipe(For Detail See Fig. 6.1-15)
29 Shade (Radiator)

Payload

30 Exper Payload Envelope (For Detail See Fig. 6.1-22 & -23)
31 Scientific Equipt Stowage/Shelter Growth Requirement

Miscellaneous

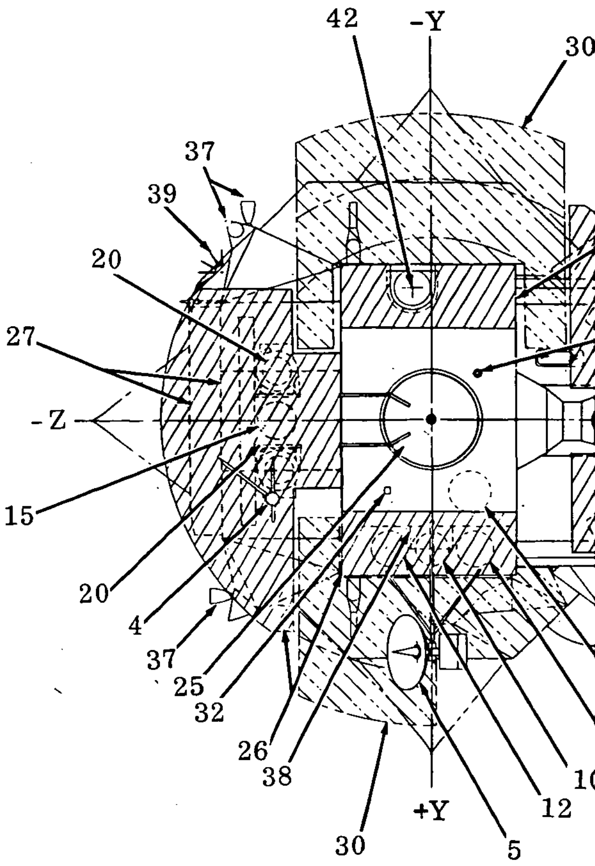
32 X-Band Antenna Xponder
33 Airlock(For Detail See Fig. 6.1-19)
34 Ldg Radar Electronic Assy*
35 IMU* Auto Tracker
36 Descent Engine*
37 RCS*
38 RCS He Press Unit*
39 RTG (For Detail See Fig. 6.1-14)
40 He Press Module*
41 Descent Engine Control Assy*
42 Docking Target*
43 Water Boiler (For Detail See Fig. 6.1-14)

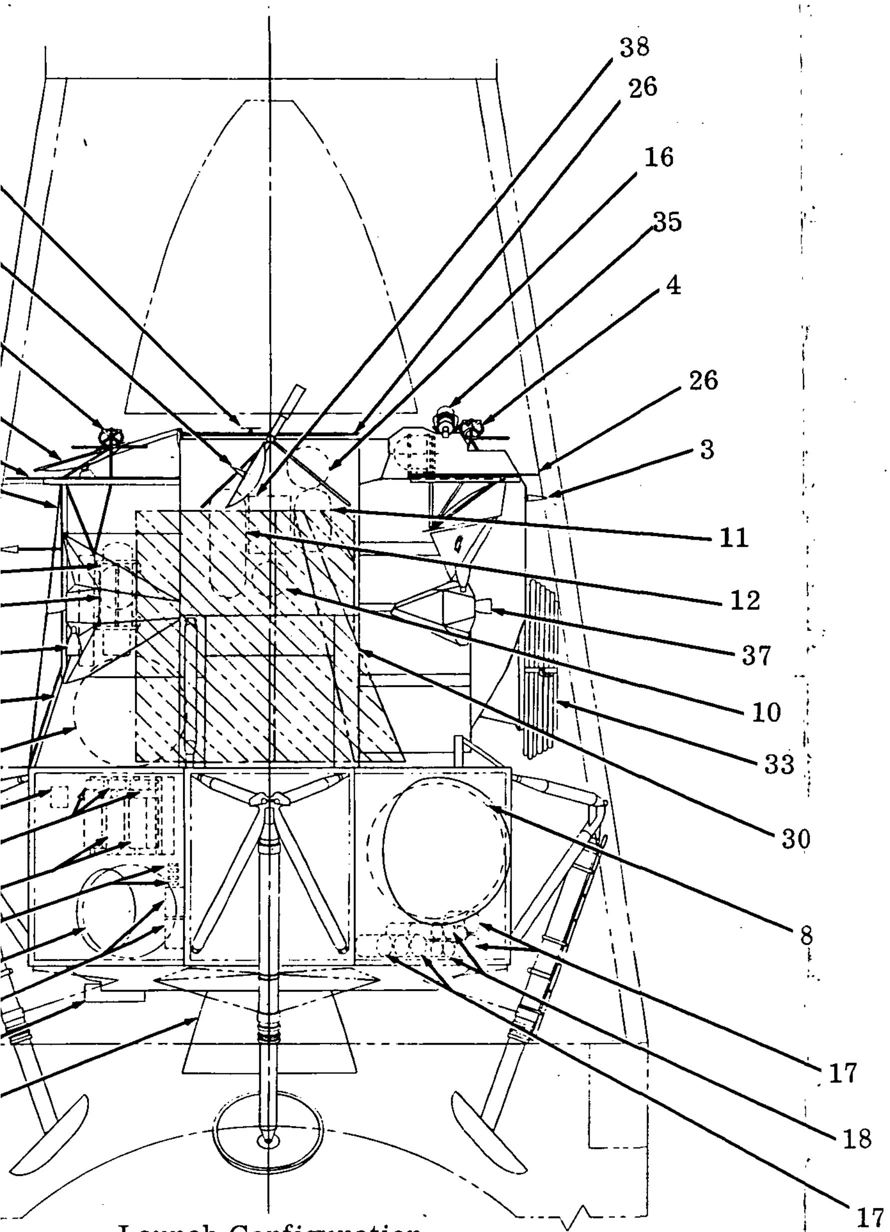


6.1-8
0

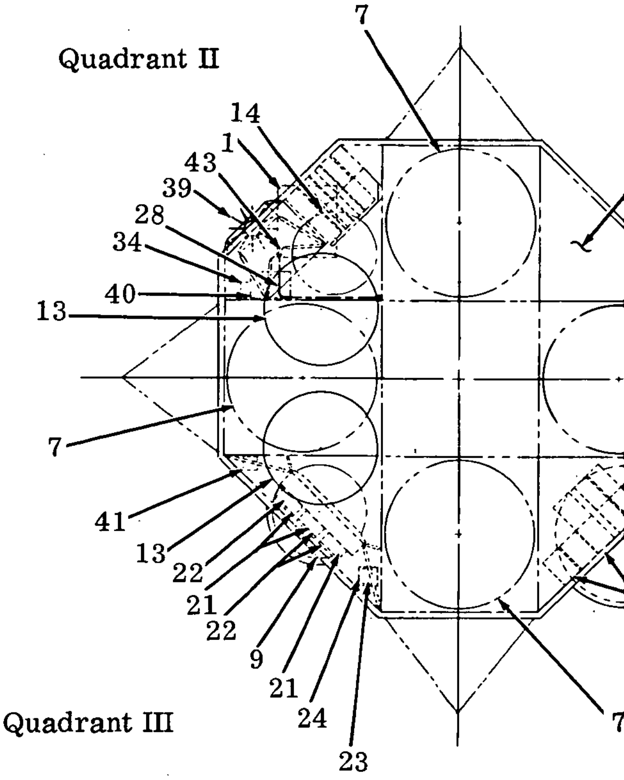
Notes

Existing LEM Hardware
Relocated
Stowed Internally in Ascent Stage
Until Man Arrives
Existing Apollo Hardware (CSM)

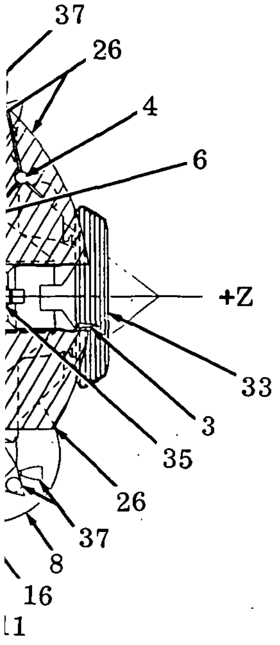




Launch Configuration



6.1-8
(2)



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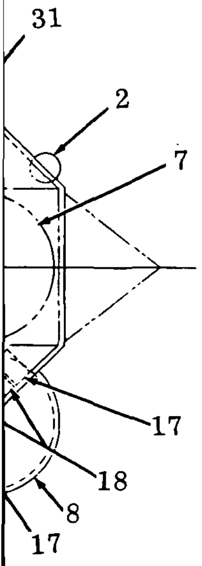
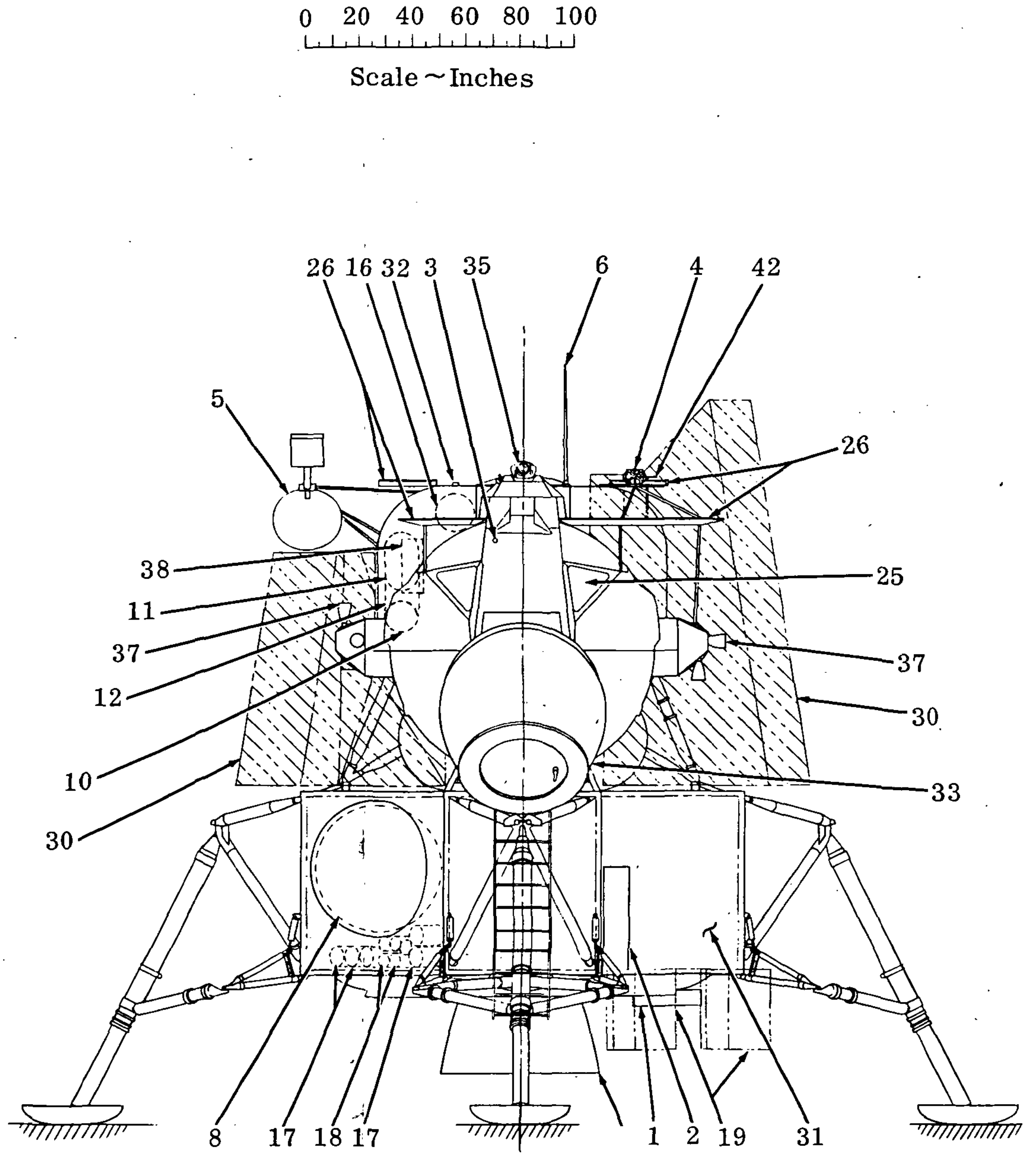


Quadrant IV

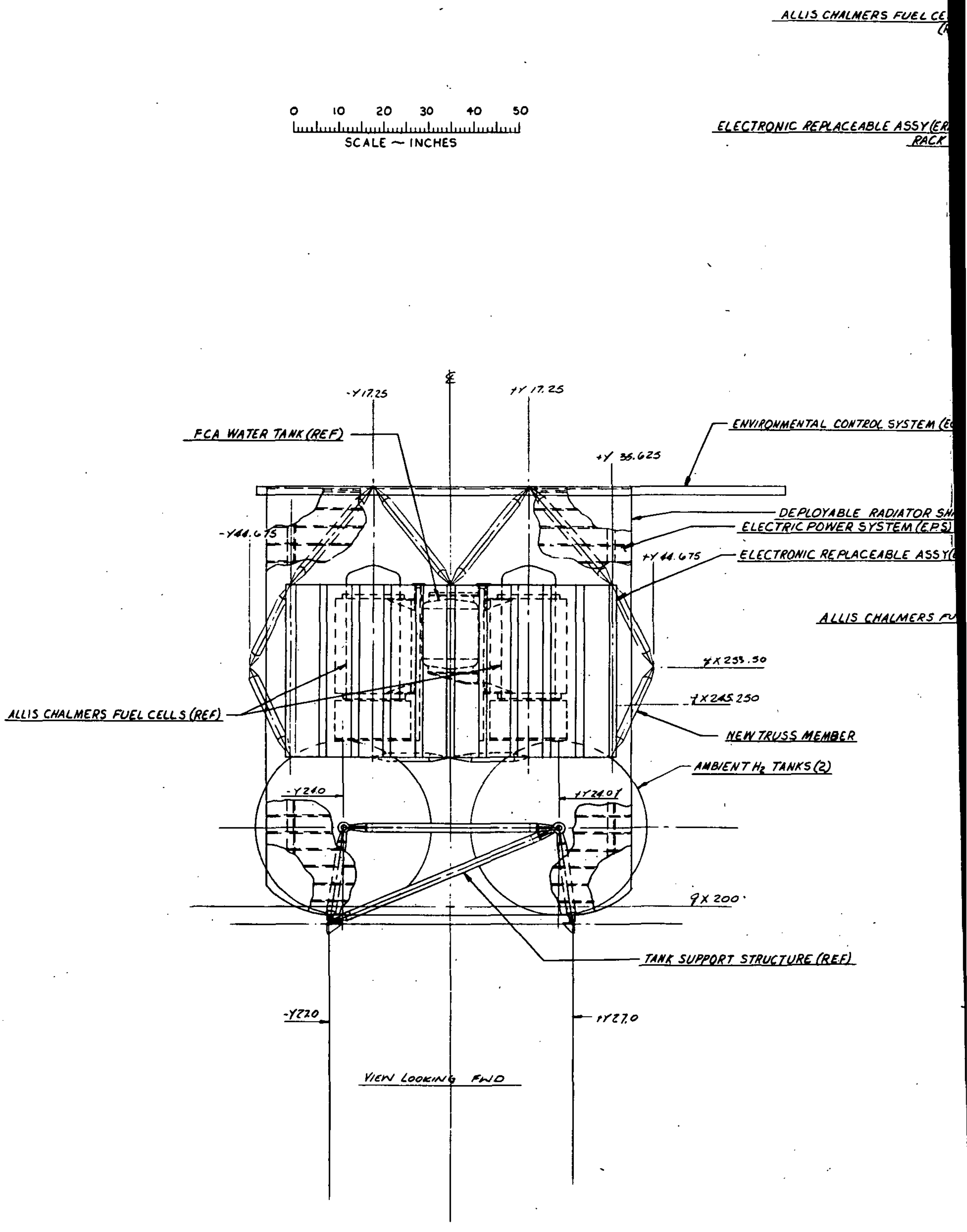


Landed Configuration

Fig. 6.1-8 Recommended Shelter General Arrangement

③

29



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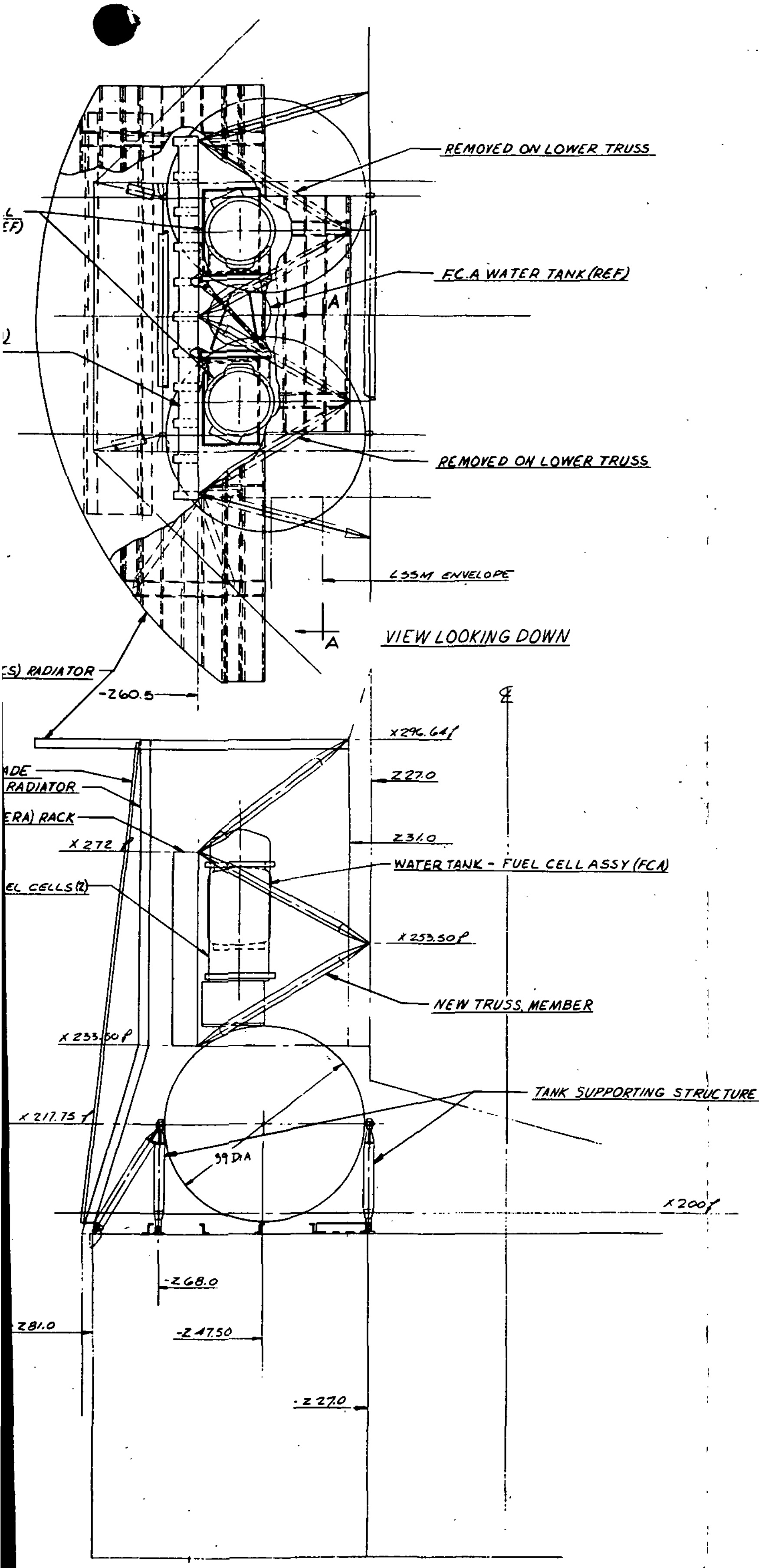


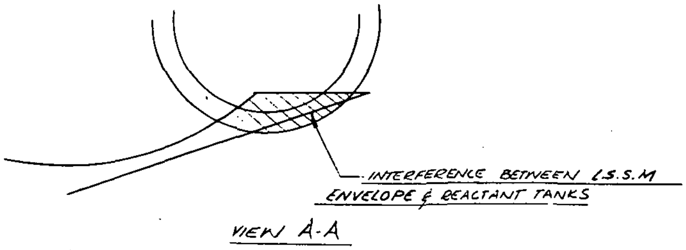


Fig. 6.1-9 Structural Arrangement - Recommended H_2 Tanks

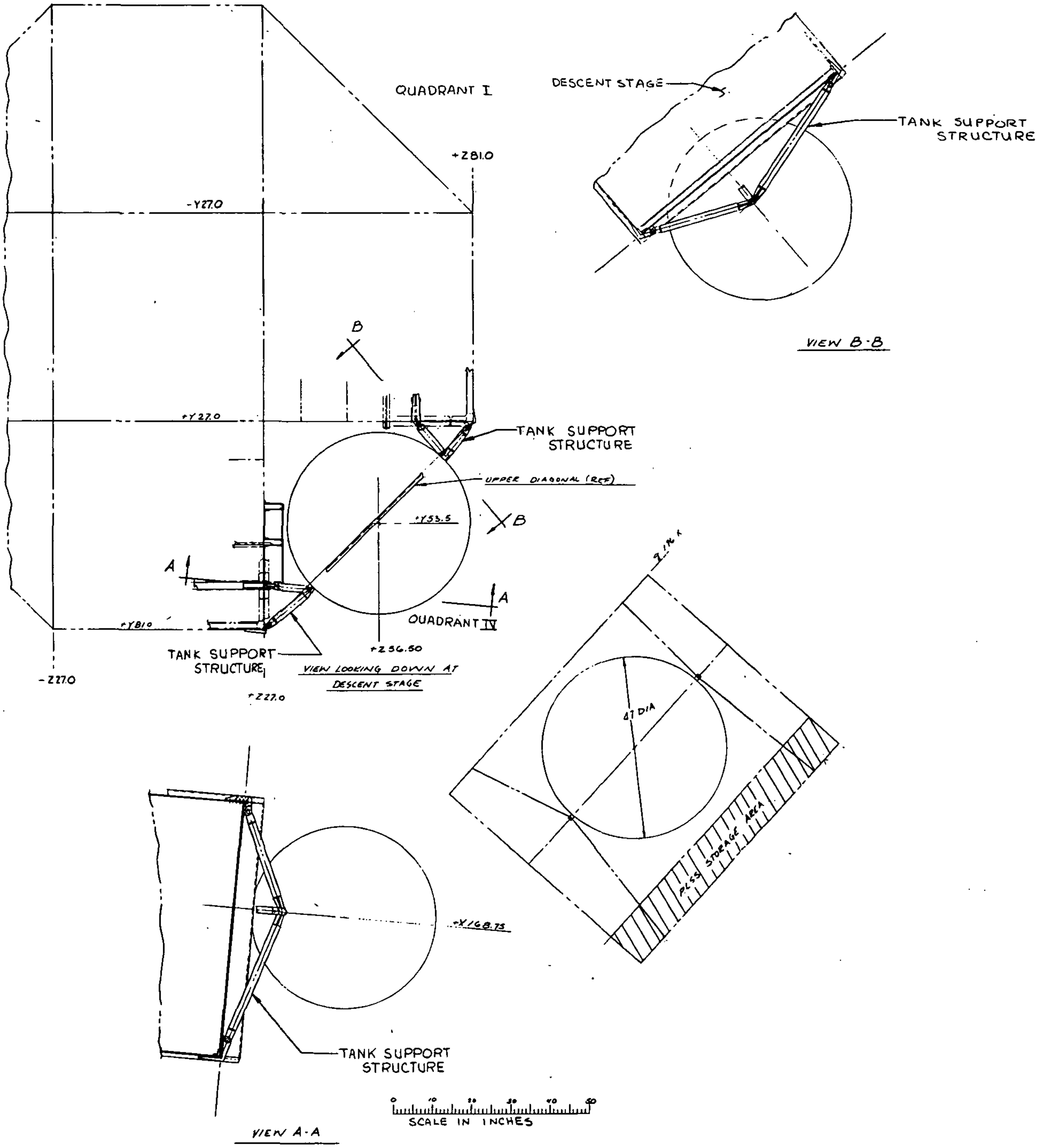
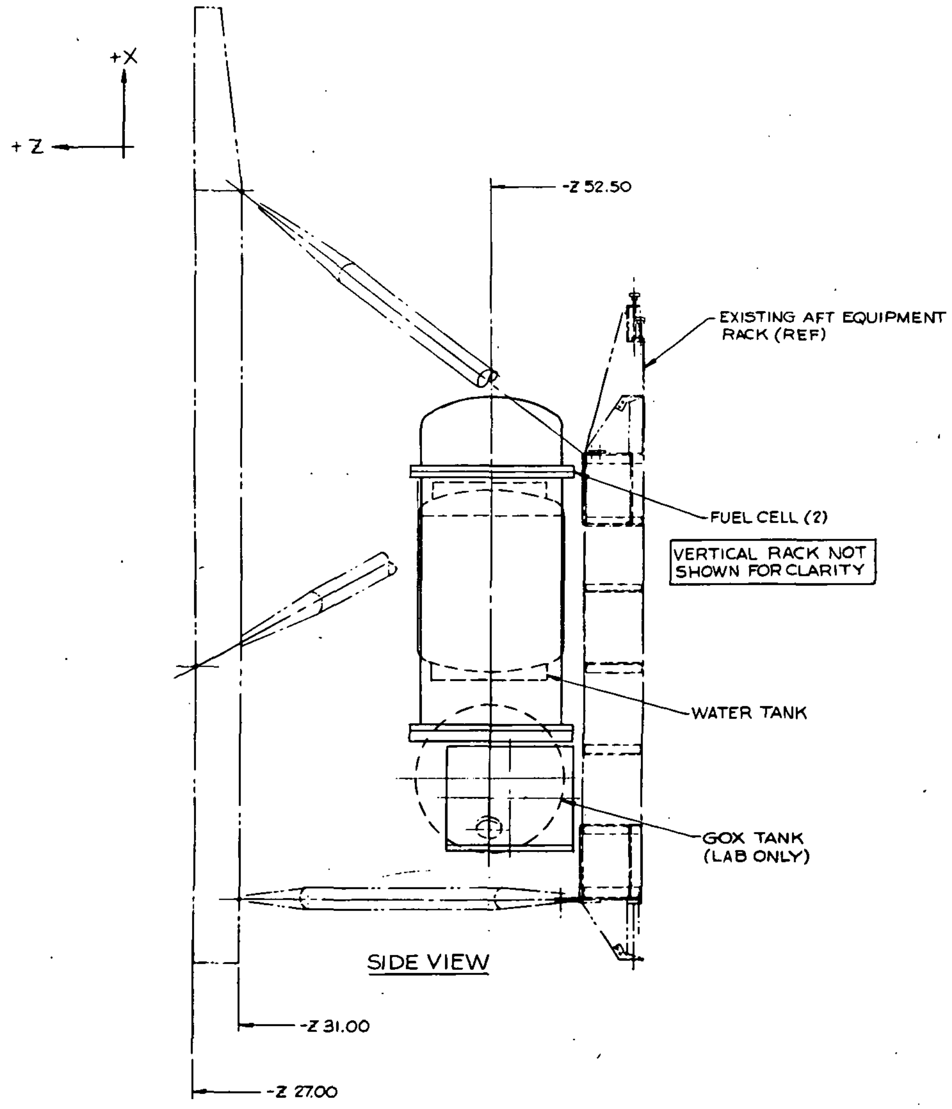
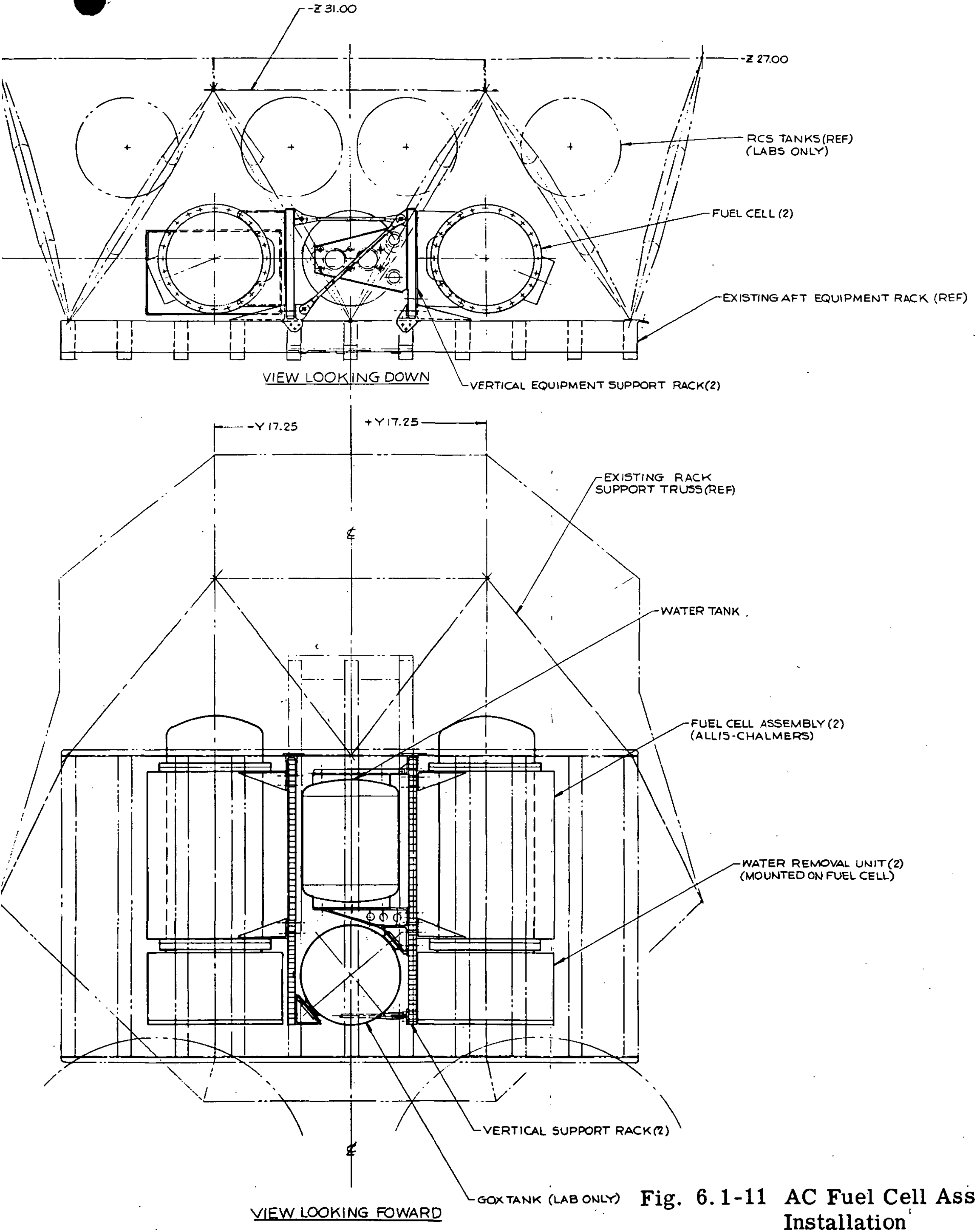


Fig. 6.1-10 Structural Arrangement - Recommended O_2 Tank

-Z 52.5

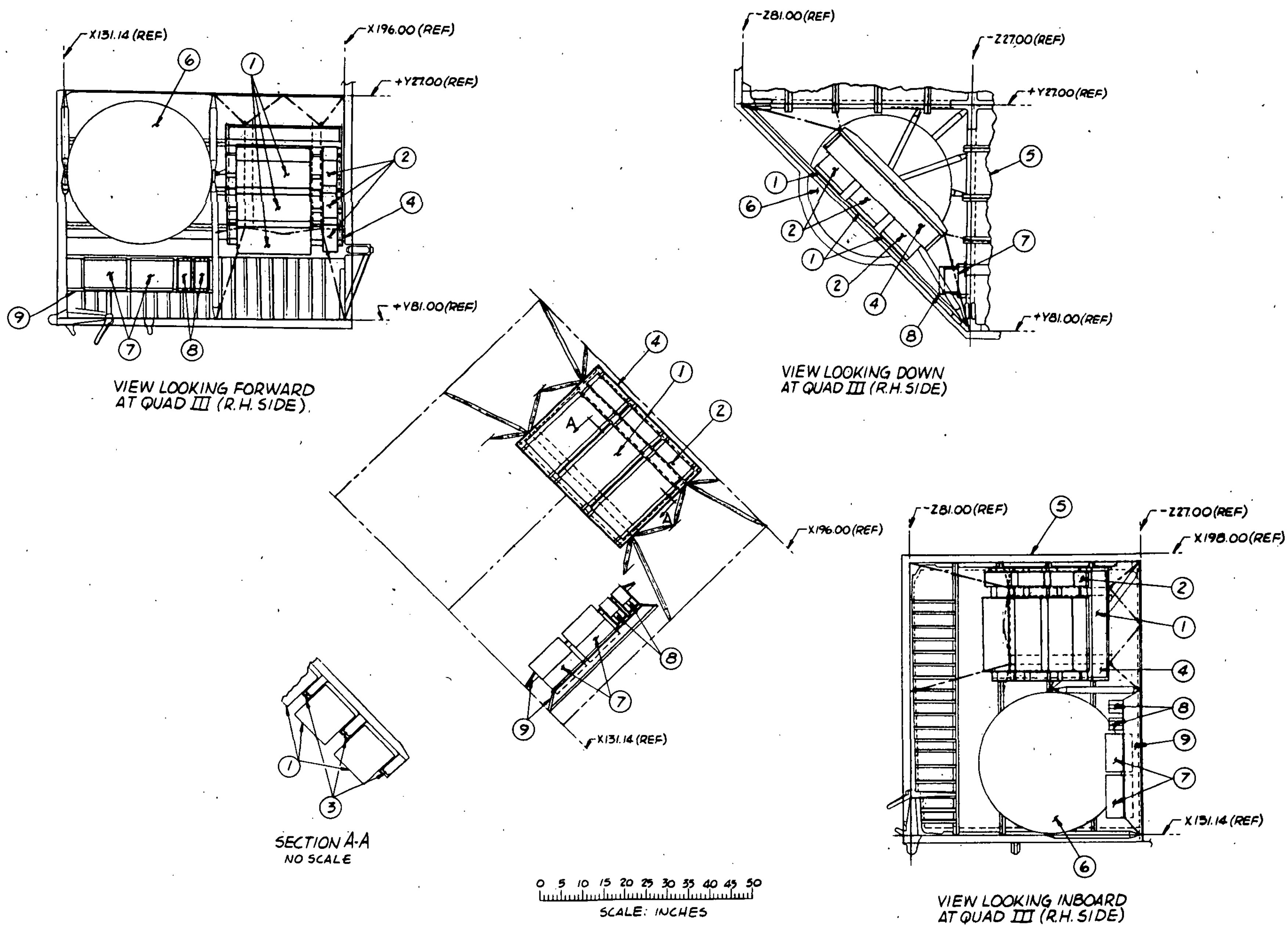


SIDE VIEW


VIEW LOOKING DOWN

VIEW LOOKING FOWARD

Fig. 6.1-11 AC Fuel Cell Assembly Installation



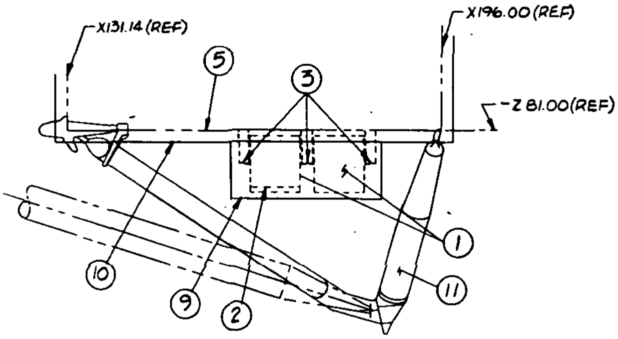
VIEW LOOKING FORWARD AT QUAD III (R.H. SIDE).

VIEW LOOKING DOWN AT QUAD III (R.H. SIDE)

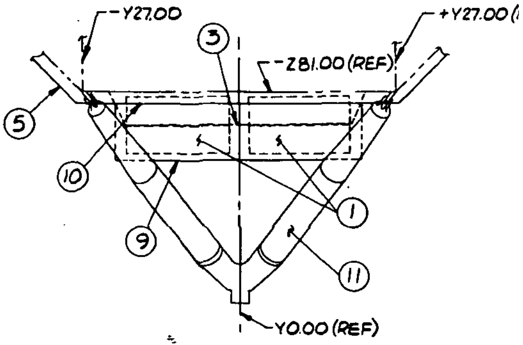
SECTION A-A
NO SCALE

VIEW LOOKING INBOARD AT QUAD III (R.H. SIDE)

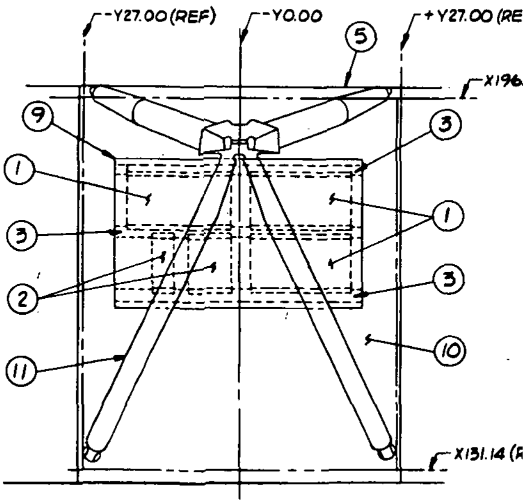
Fig. 6.1-12 Descent Battery Installation



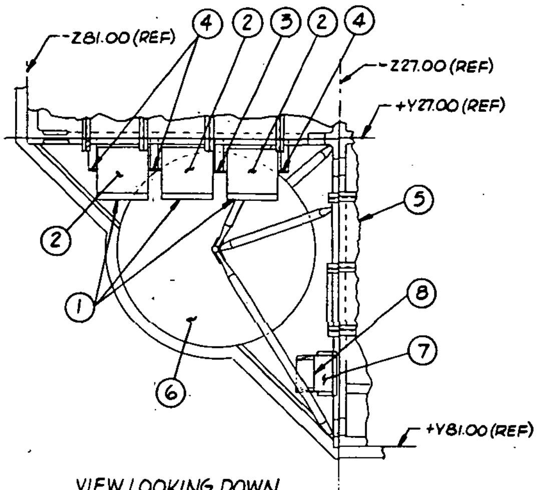
VIEW LOOKING INBOARD (L.H. SIDE)



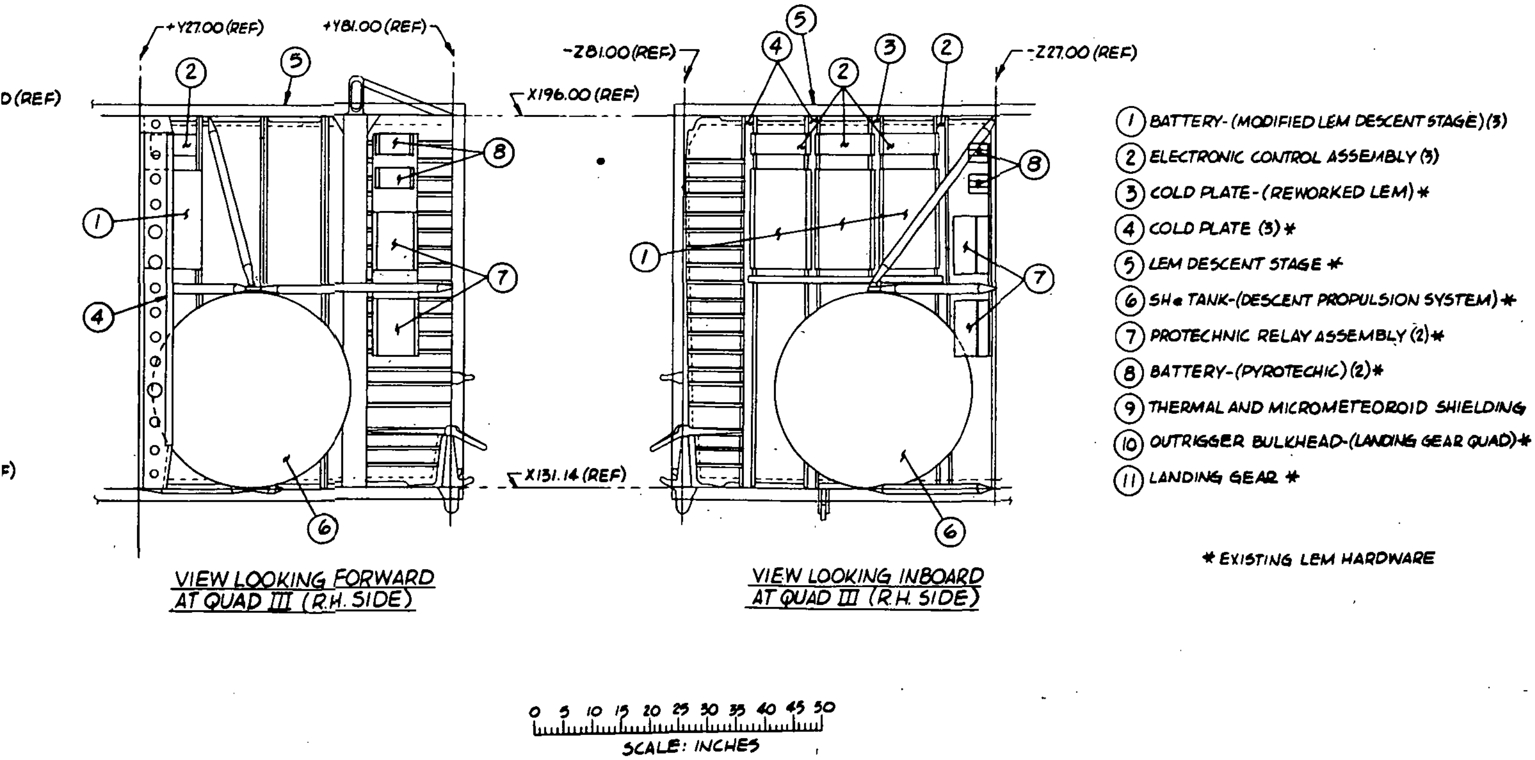
VIEW LOOKING DOWN



VIEW LOOKING FORWARD AT -Z END BULKHEAD TYPICAL AT +Z, +Y & -Y END BULKHEADS



VIEW LOOKING DOWN
AT QUAD III (R.H. SIDE)

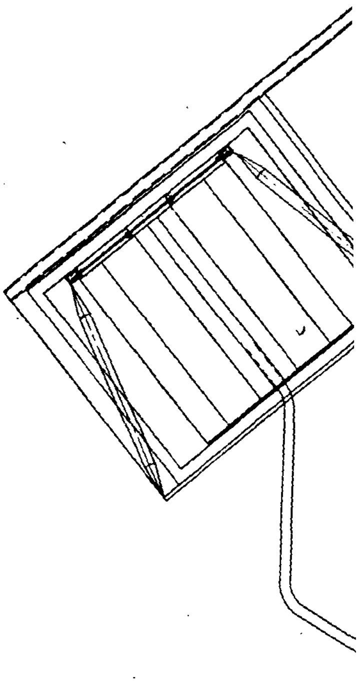


VIEW LOOKING FORWARD
AT QUAD III (R.H. SIDE)

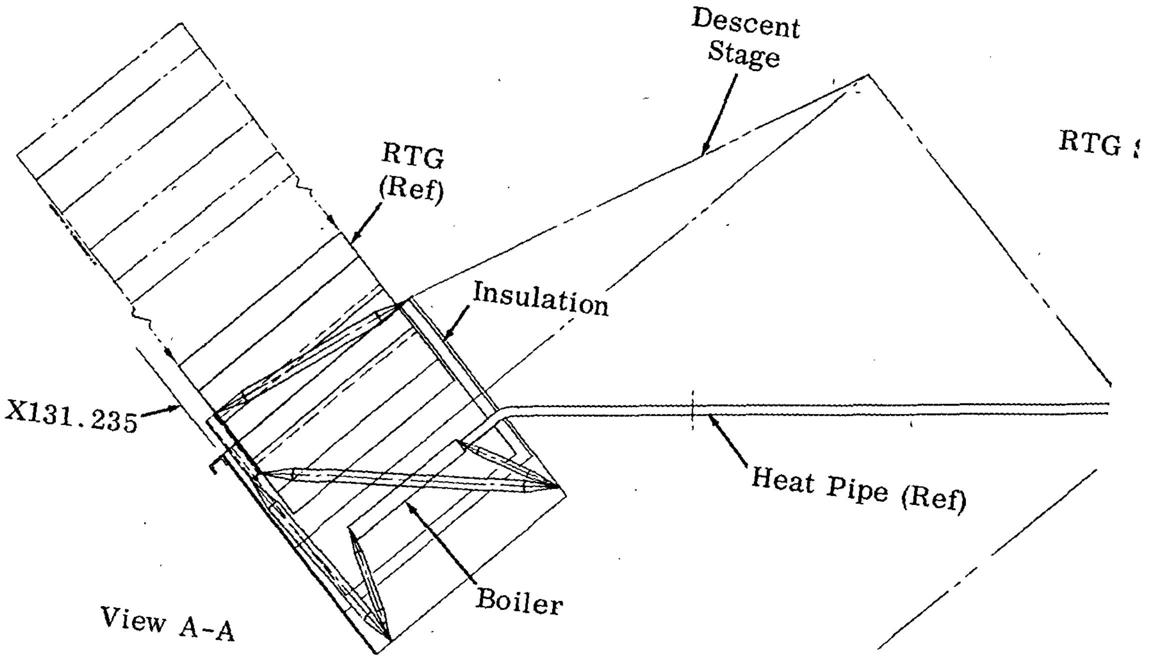
VIEW LOOKING INBOARD
AT QUAD III (R.H. SIDE)

Fig. 6.1-13 Alternate Descent Battery Installations

㊴



RTG & S
Removed fro



View A-A

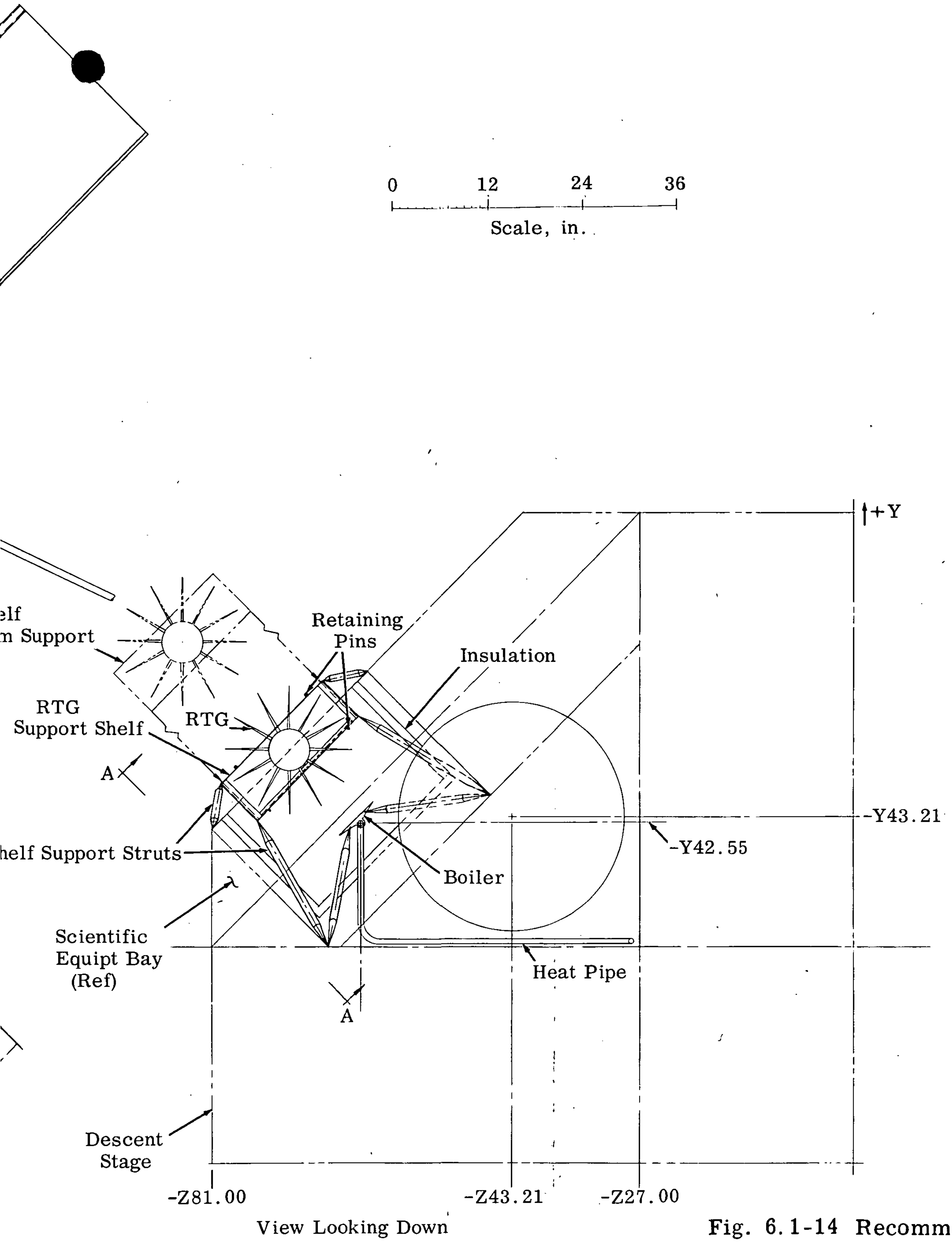
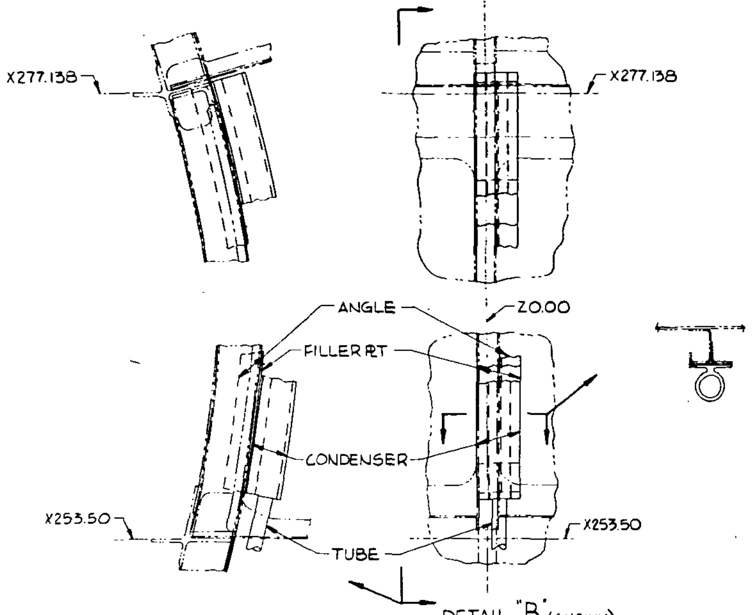
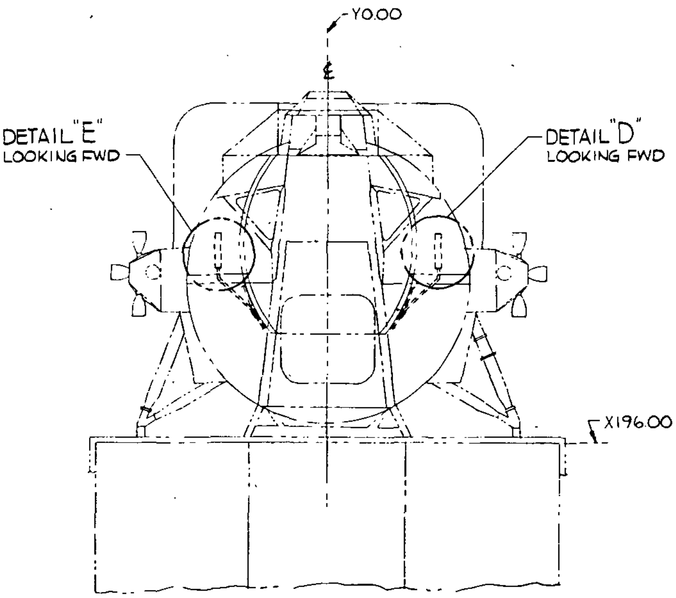


Fig. 6.1-14 Recommended RTG Installation



DETAIL "B" (SHOWN)
DETAIL "C" (OPP OF ℄)
HALF SIZE



VIEW LOOKING AFT

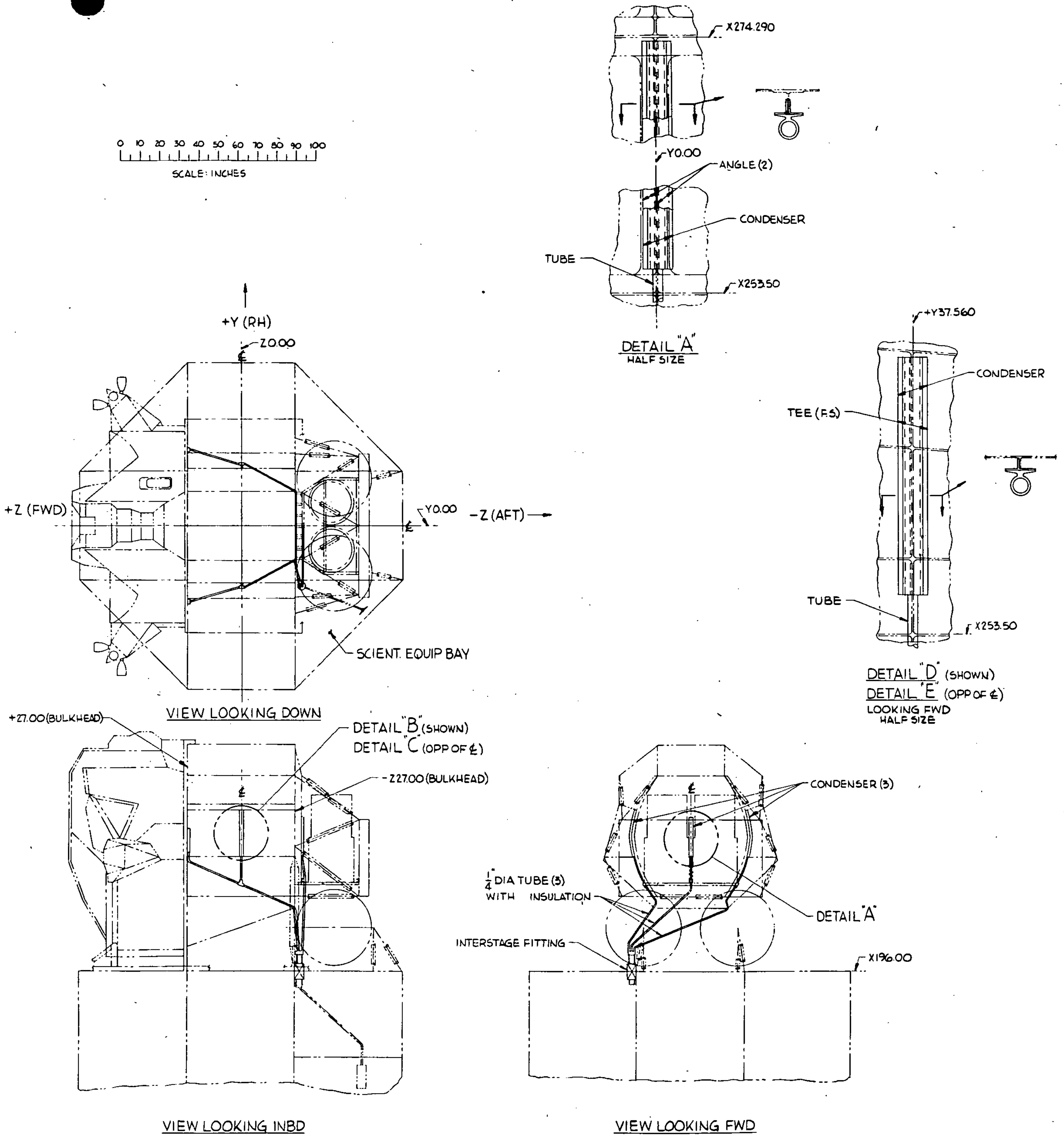
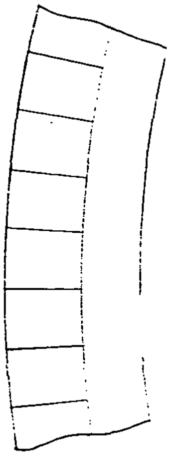
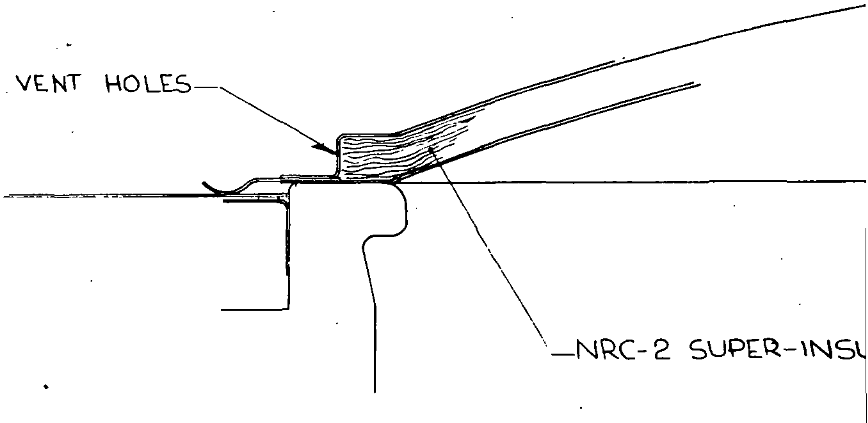
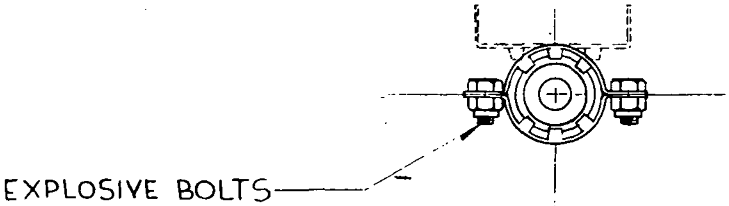


Fig. 6.1-15 RTG Heat Pipe Installation



SECTION OF RIM. SH
SEALING STRIP FIN

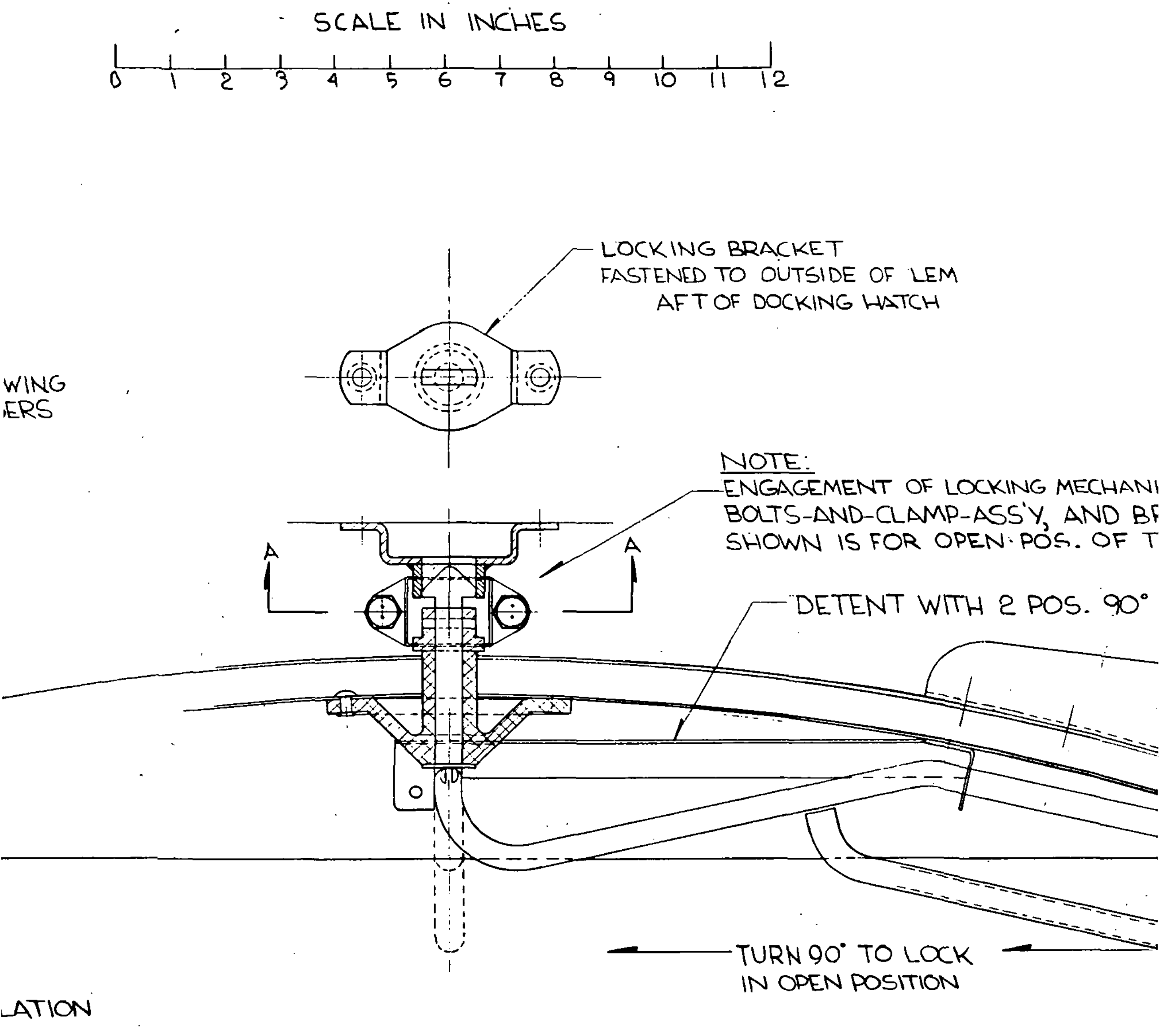


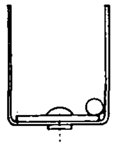


SECTION A - A

6.1-16

①





SECTION B -B

6.1-16

②

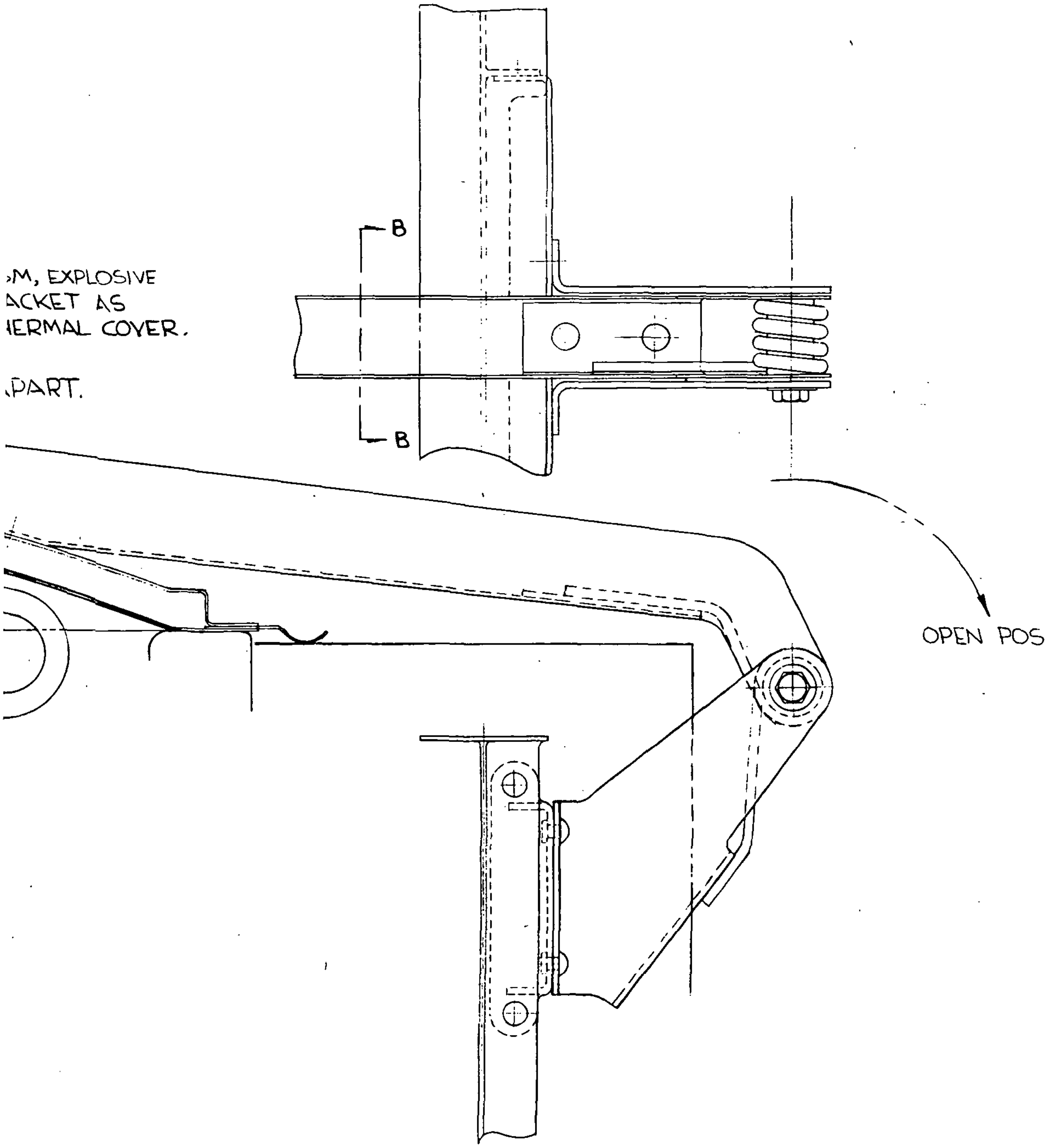
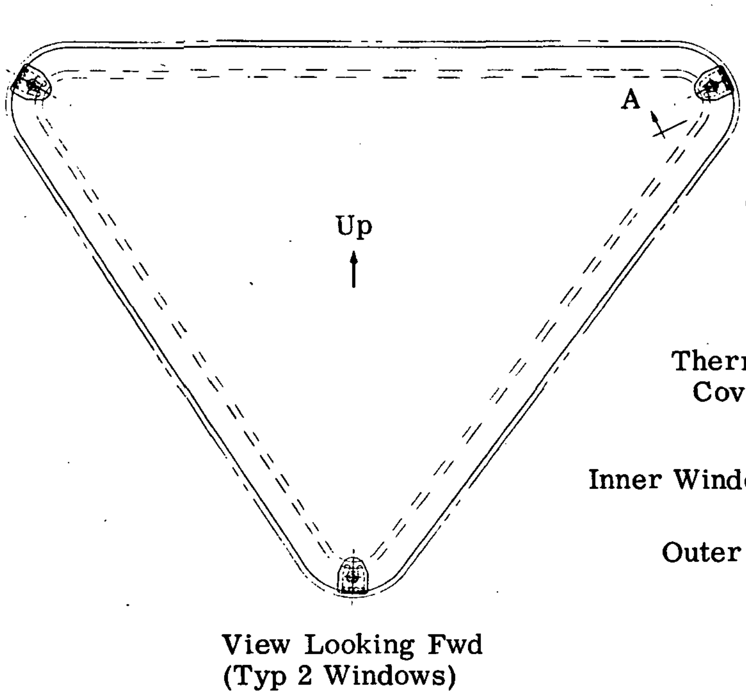


Fig. 6.1-16 Recommended Top Tunnel Thermal Cover

3



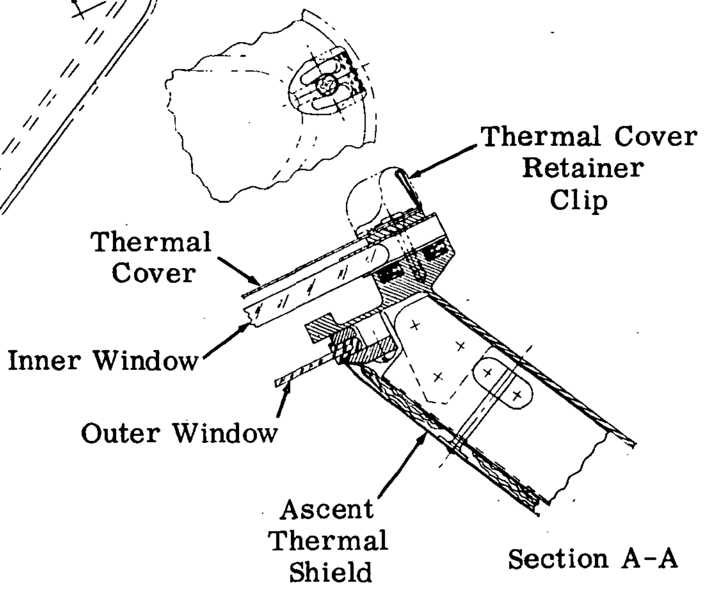
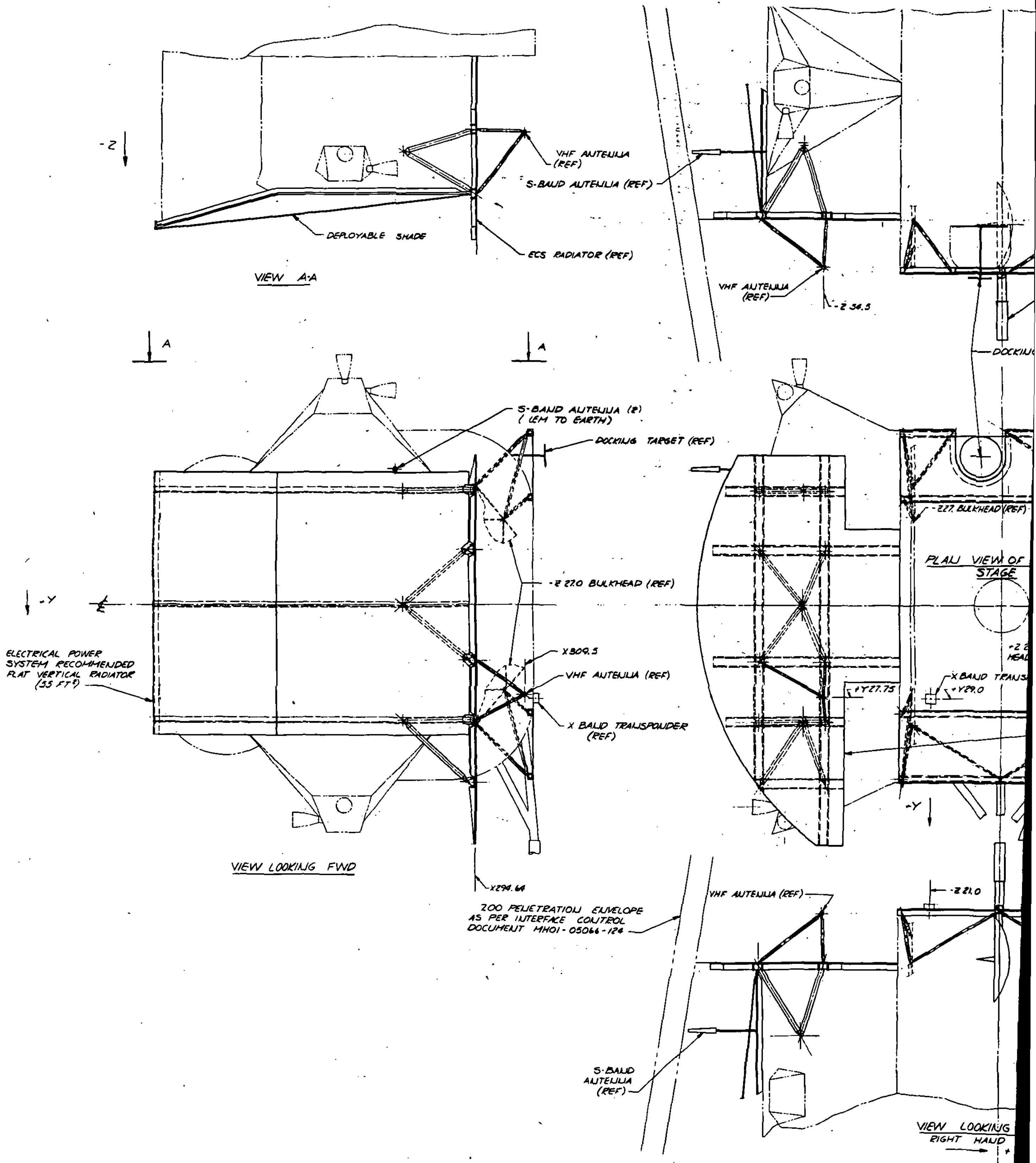


Fig. 6.1-17 Window Thermal Covers

㊼


-Z
VHF ANTENNA (REF)
S-BAND ANTENNA (REF)
DEPLOYABLE SHADE
ECS RADIATOR (REF)
VIEW A-A
VHF ANTENNA (REF)
-Z 54.5
DOCKING
A
A
S-BAND ANTENNA (2) (LEM TO EARTH)
DOCKING TARGET (REF)
-Z 27.0 BULKHEAD (REF)
-Y
℄
ELECTRICAL POWER SYSTEM RECOMMENDED FLAT VERTICAL RADIATOR (55 FT²)
X 309.5
VHF ANTENNA (REF)
X BAND TRANSPONDER (REF)
VIEW LOOKING FWD
X 294.64
200 PENETRATION ENVELOPE AS PER INTERFACE CONTROL DOCUMENT MH01-05066-124
-Z 27. BULKHEAD (REF)
PLAN VIEW OF
STAGE
+Y 27.75
X BAND TRANS
+Y 29.0
-Y
VHF ANTENNA (REF)
-Z 21.0
S-BAND ANTENNA (REF)
VIEW LOOKING
RIGHT HAND

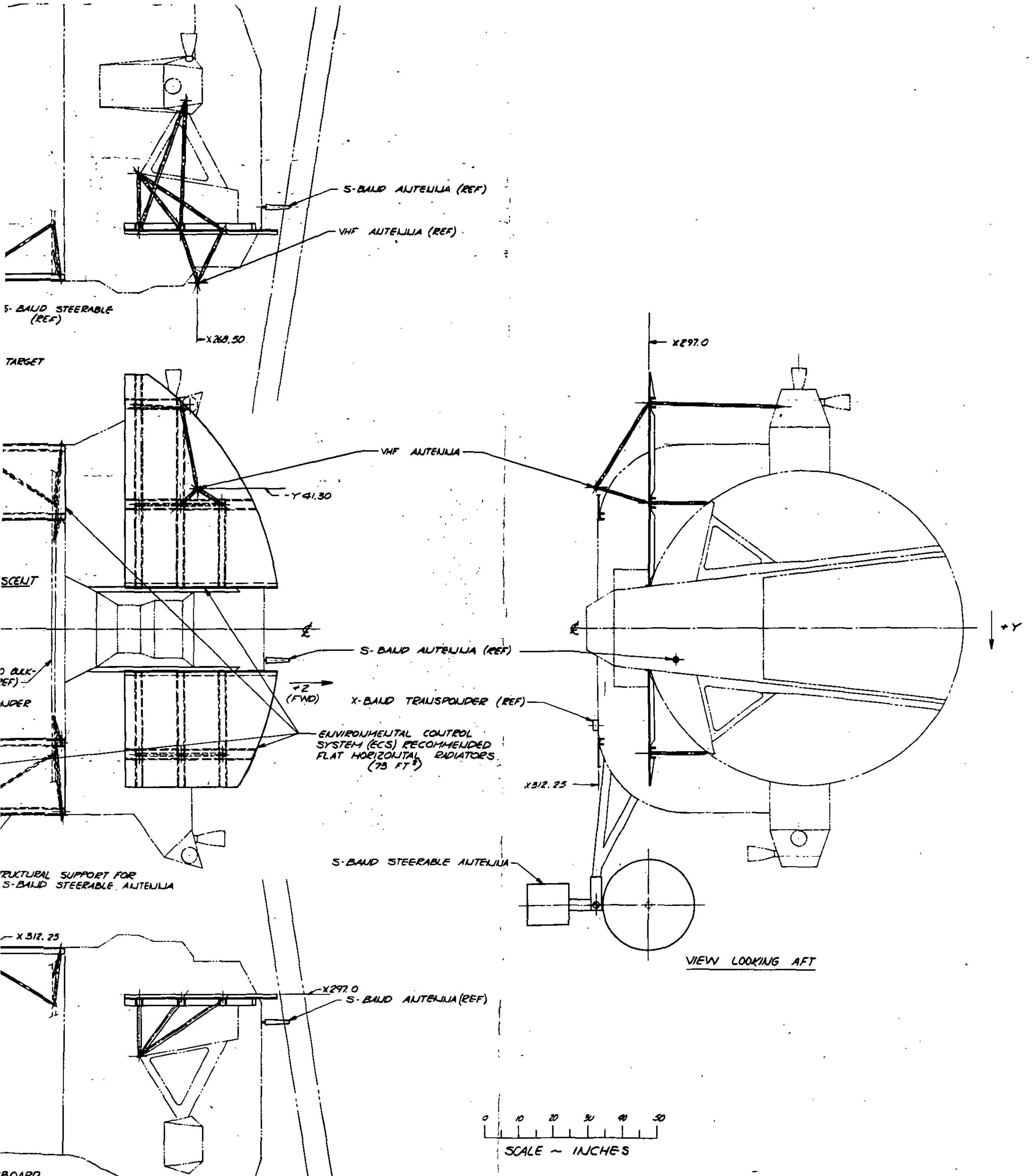
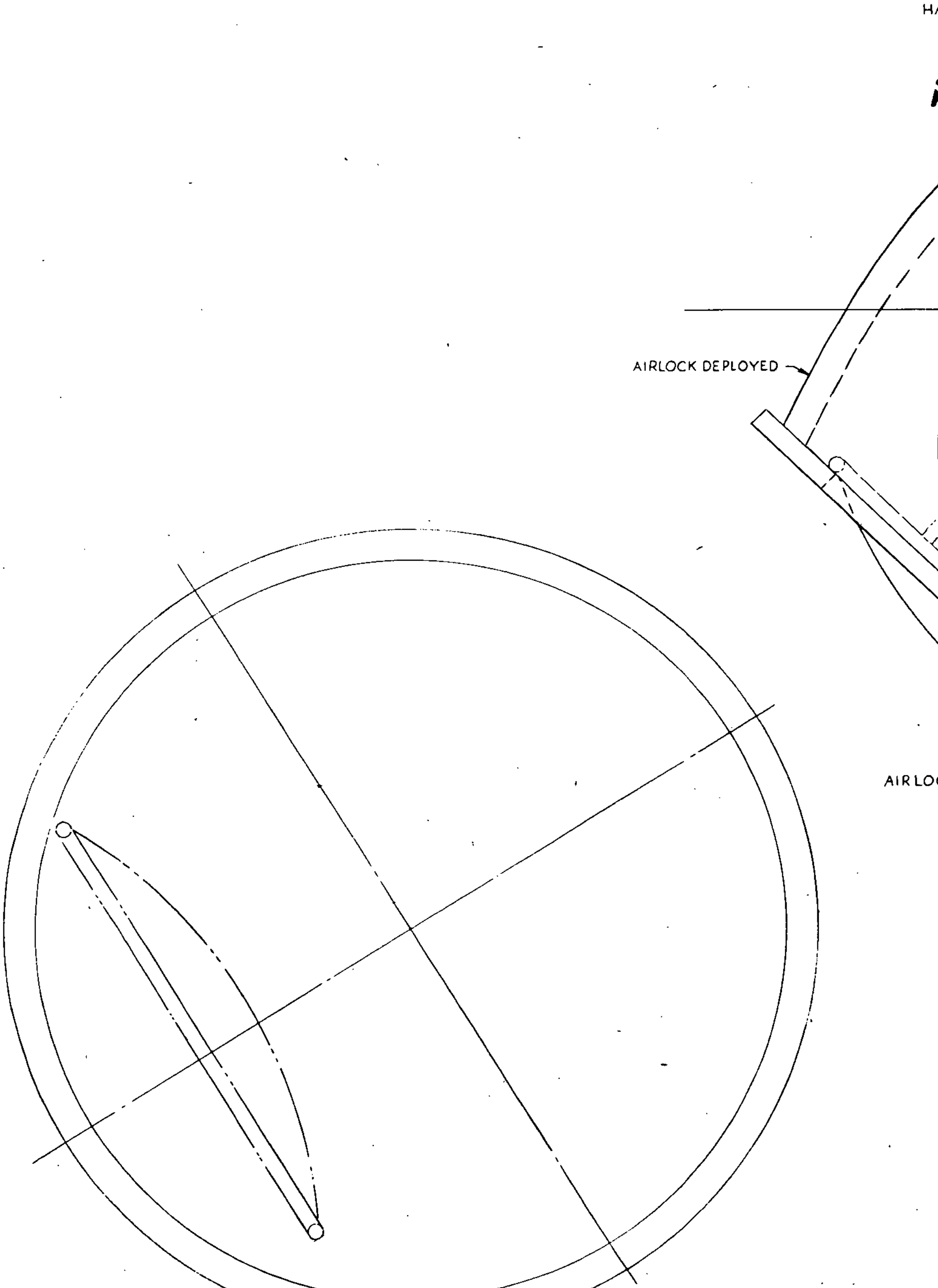
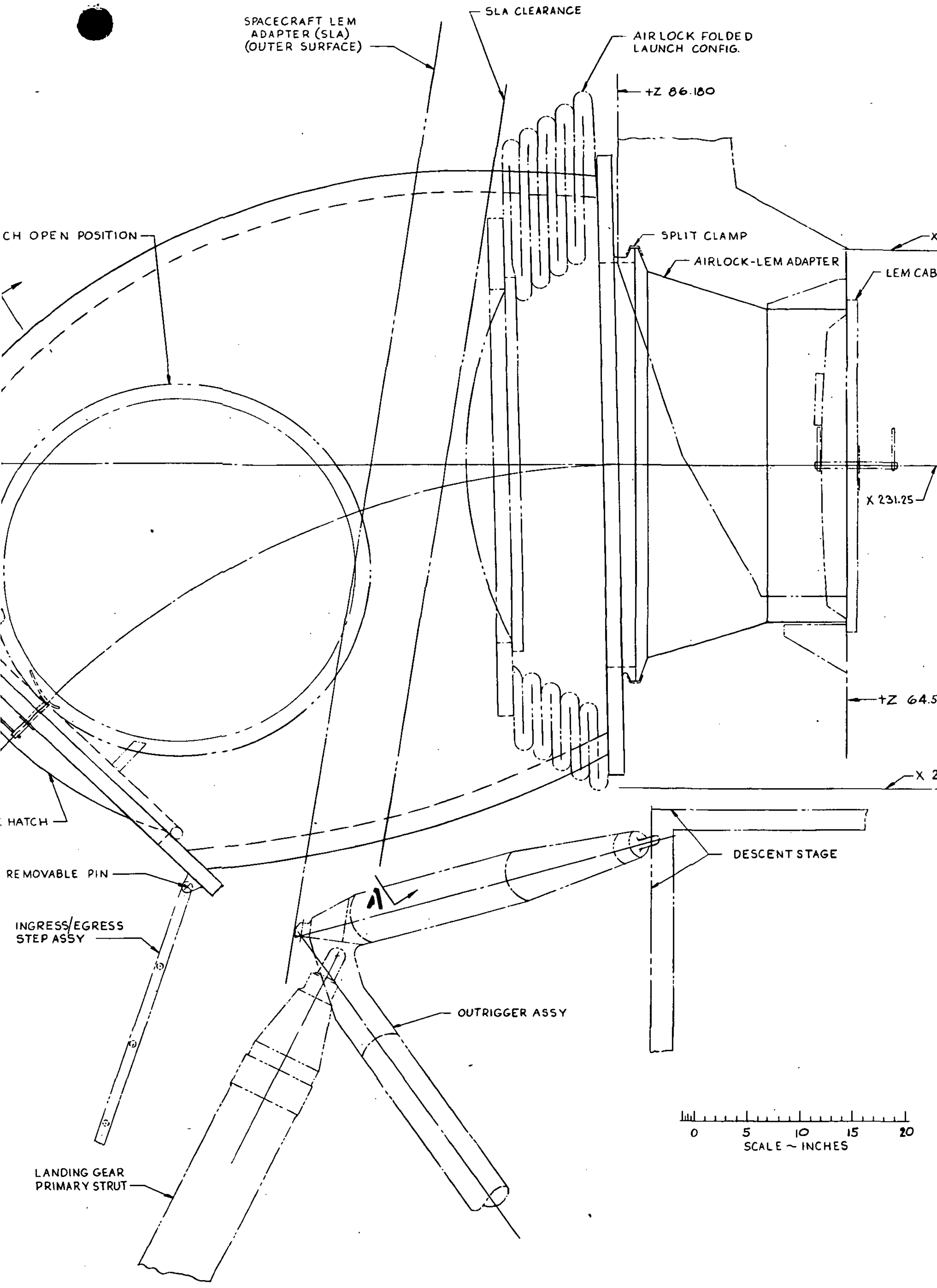


Fig. 6.1-18 Recommended Radiator Installation



SECT. A-A

6.1-19


SPACECRAFT LEM ADAPTER (SLA) (OUTER SURFACE)
SLA CLEARANCE
AIR LOCK FOLDED LAUNCH CONFIG.
+Z 86.180
CH OPEN POSITION
SPLIT CLAMP
AIRLOCK-LEM ADAPTER
X
LEM CAB
X 231.25
+Z 64.5
X 2
HATCH
REMOVABLE PIN
INGRESS/EGRESS STEP ASSY
A
DESCENT STAGE
OUTRIGGER ASSY
LANDING GEAR PRIMARY STRUT
0
5
10
15
20
SCALE ~ INCHES

6.1-19
②

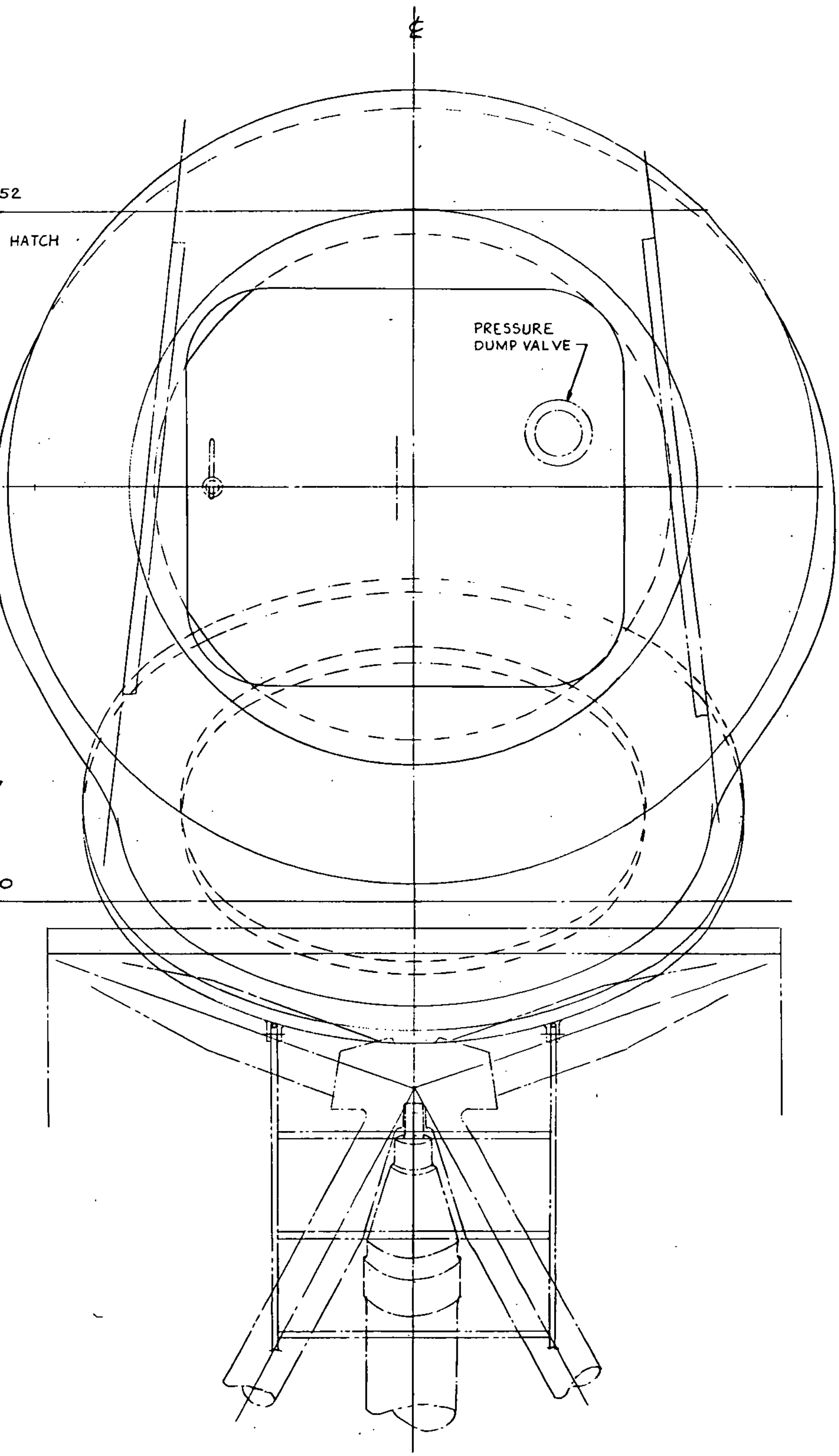
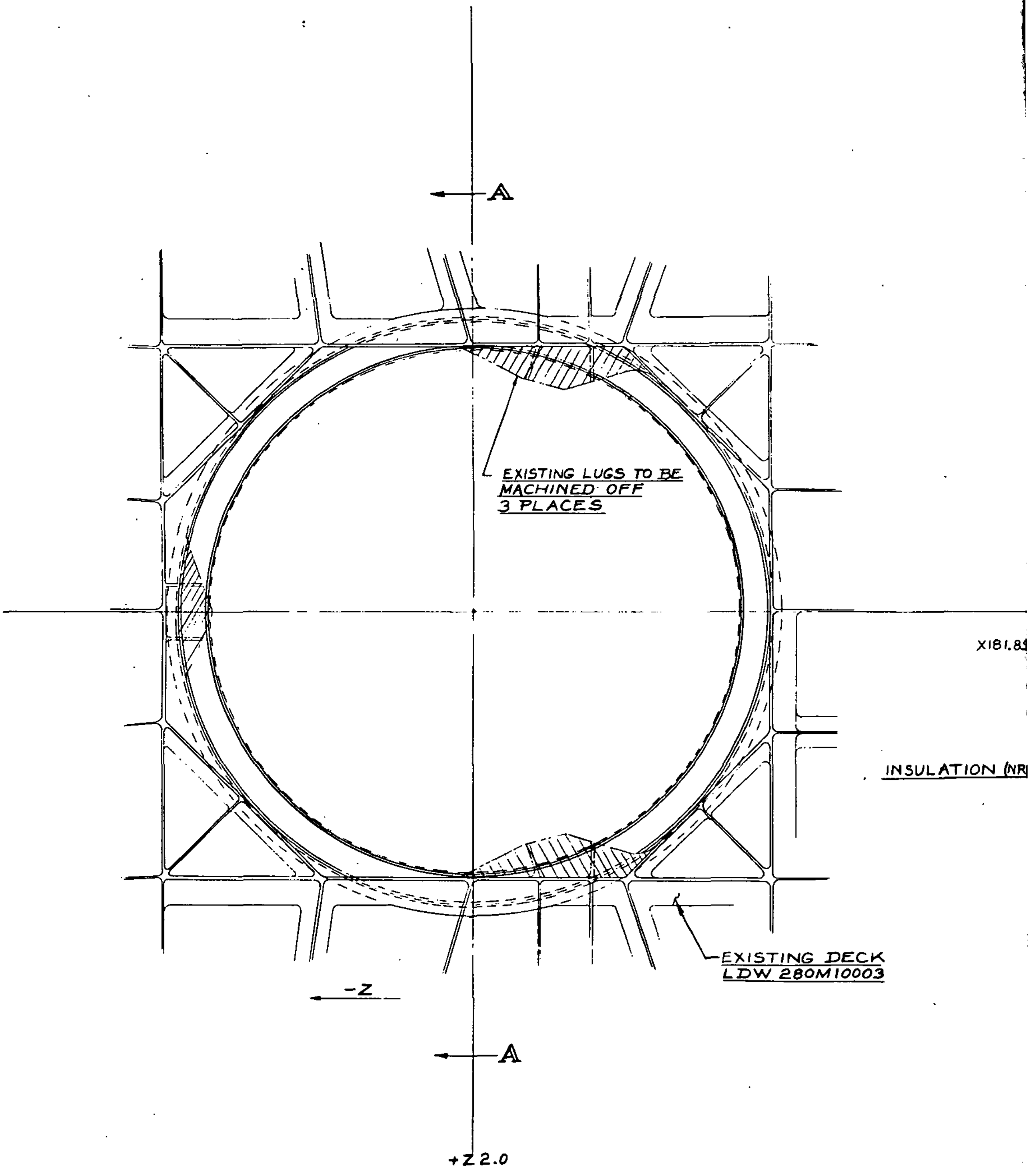


Fig. 6.1-19 Recommended Airlock Installation

3



VIEW LOOKING UP AFT CABIN DECK

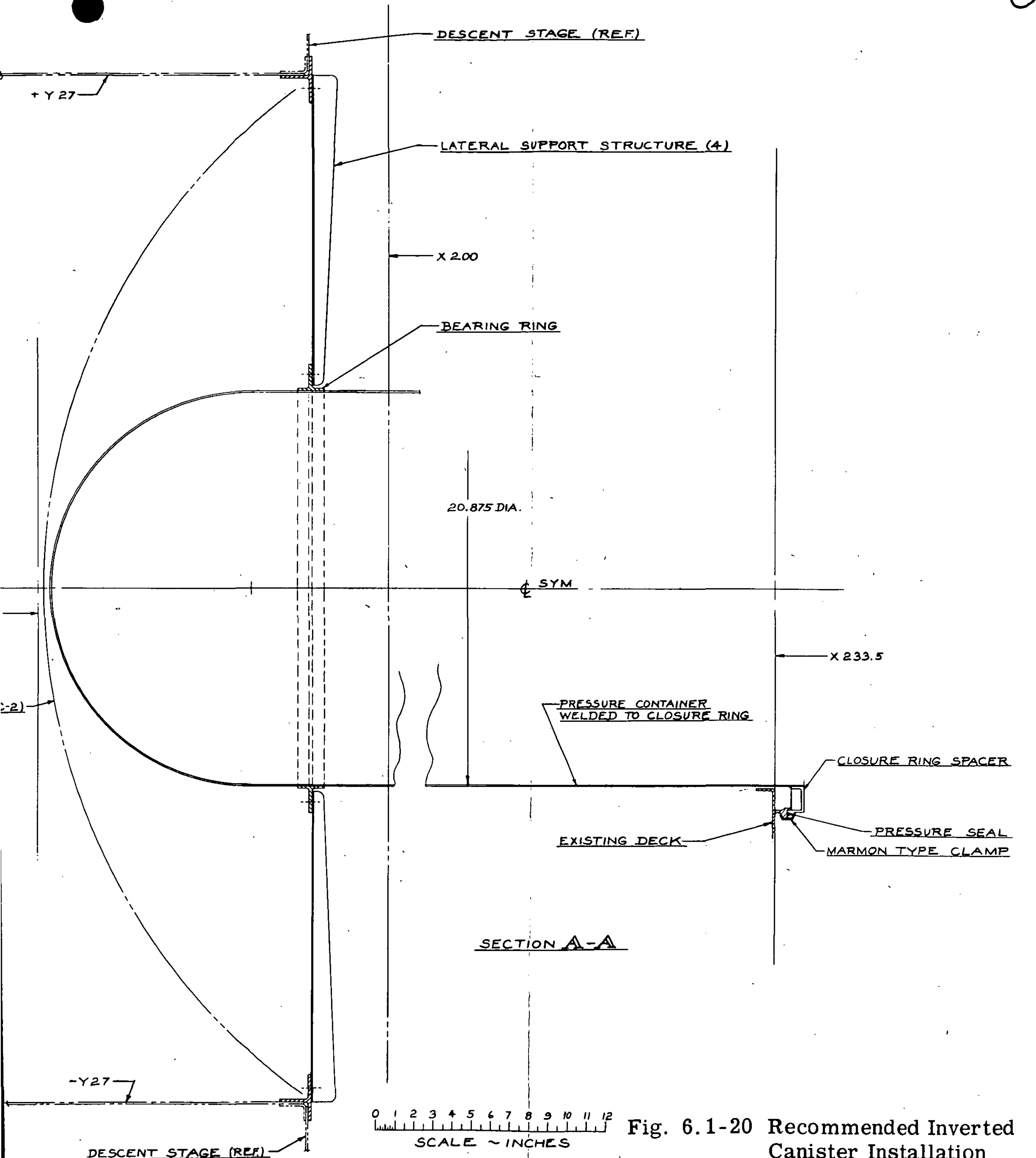
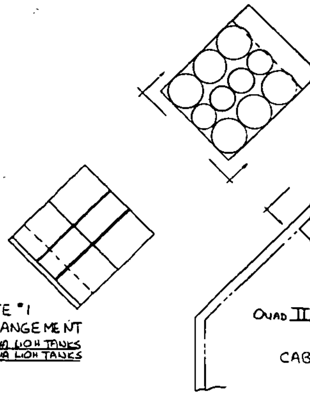


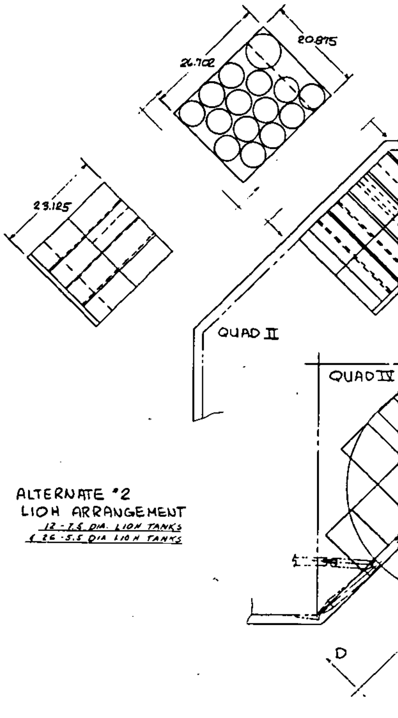
Fig. 6.1-20 Recommended Inverted Canister Installation

(53)



ALTERNATE #1
LIOH ARRANGEMENT
12 - 7.5 DIA LIOH TANKS
8 - 5.5 DIA LIOH TANKS

RECOMMENDED
LIOH ARR
6 - 7.5 DIA
& 17 - 5.5 DIA



ALTERNATE #2
LIOH ARRANGEMENT
12 - 7.5 DIA. LIOH TANKS
& 26 - 5.5 DIA LIOH TANKS

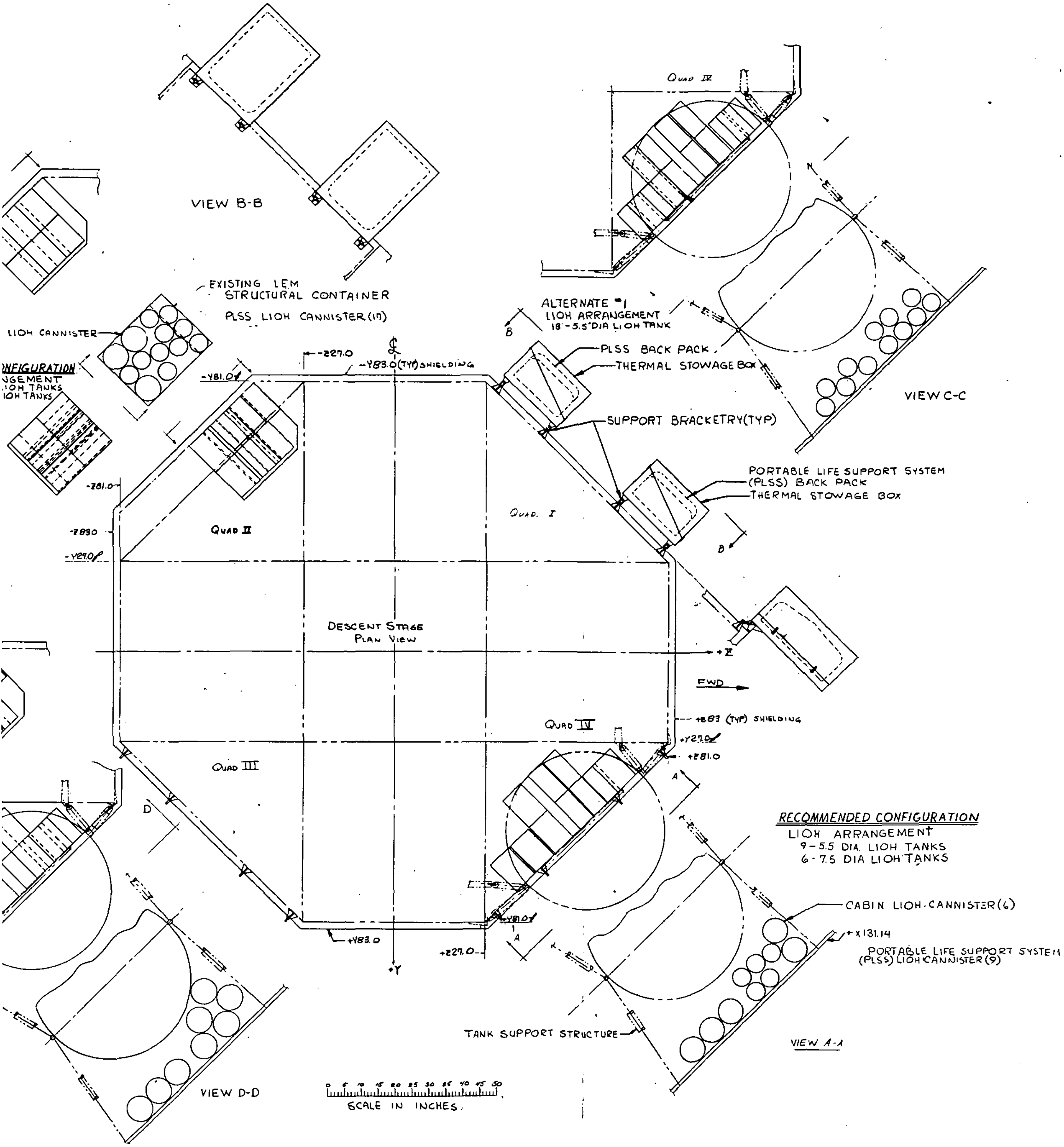
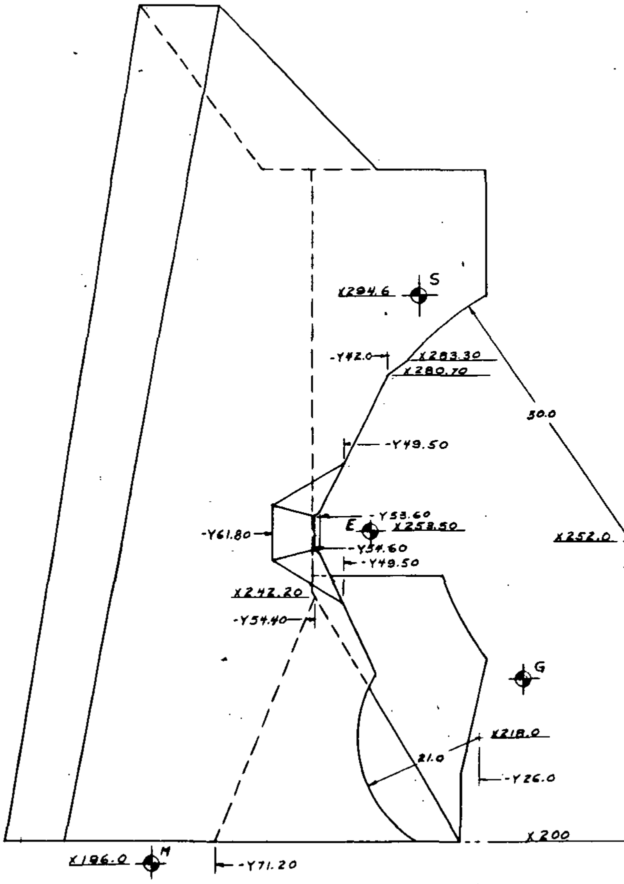
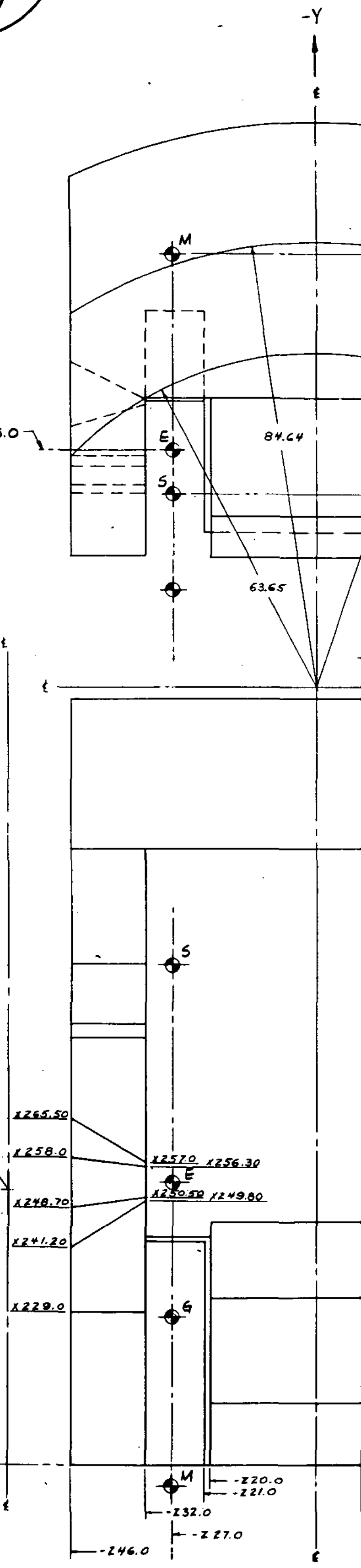


Fig. 6.1-21 Backpack & LiOH Storage

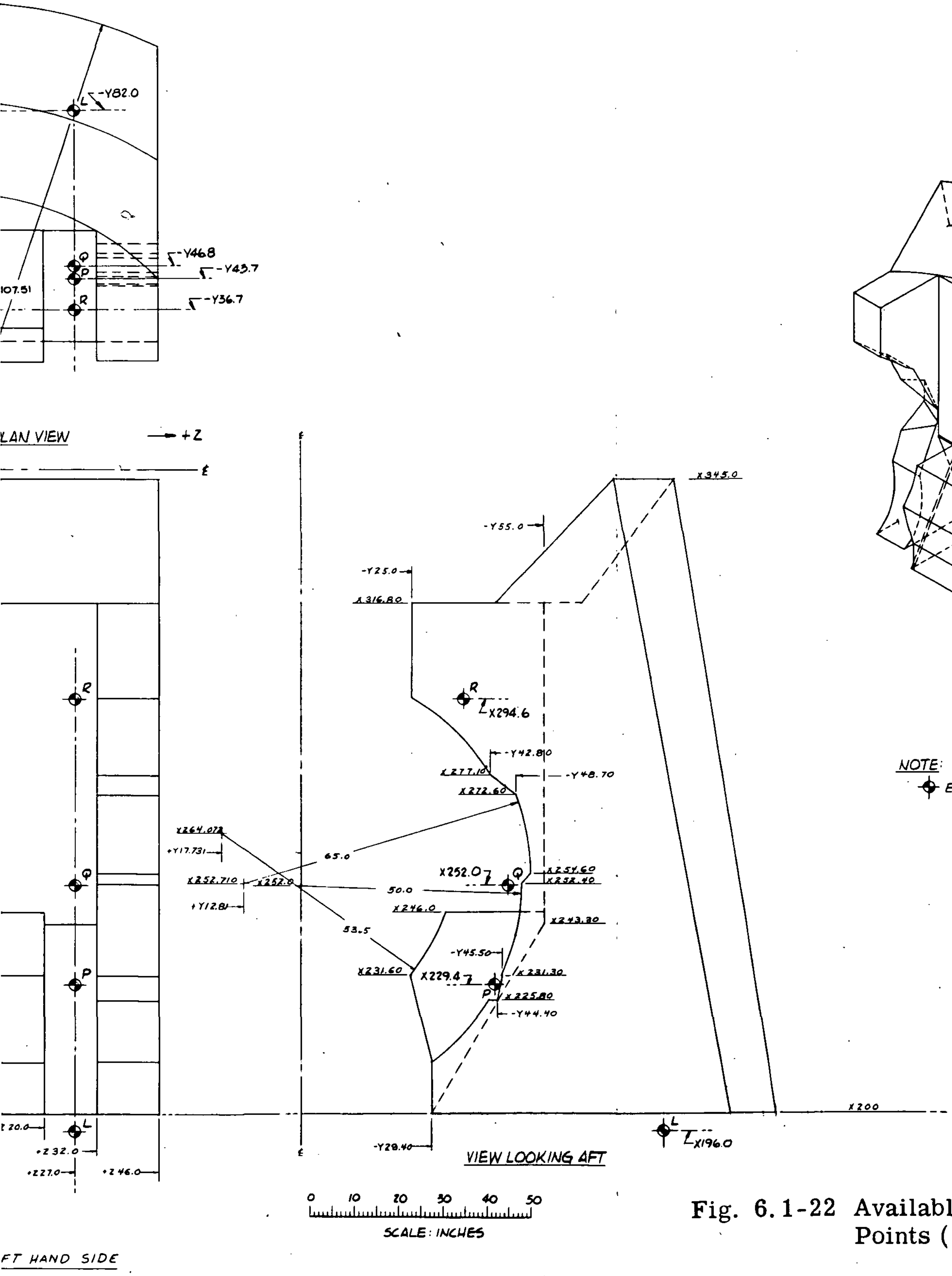
55

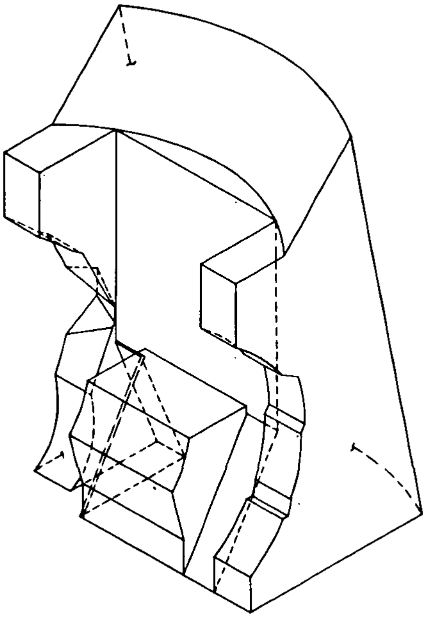


VIEW LOOKING FWD



VIEW LOOKING OUTB'D L

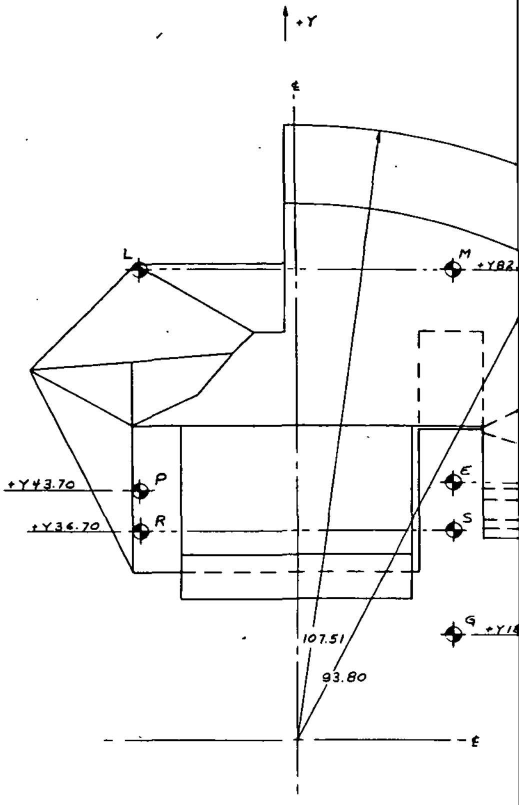




NOTE:
⌖ EXISTING HARDPOINTS

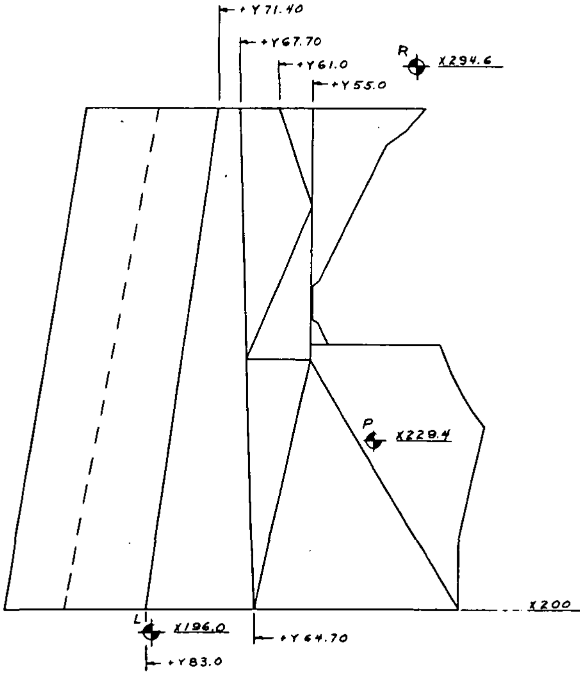
Fig. 6.1-22 Available Volume & Hard Points (-Y) Left-Side

57

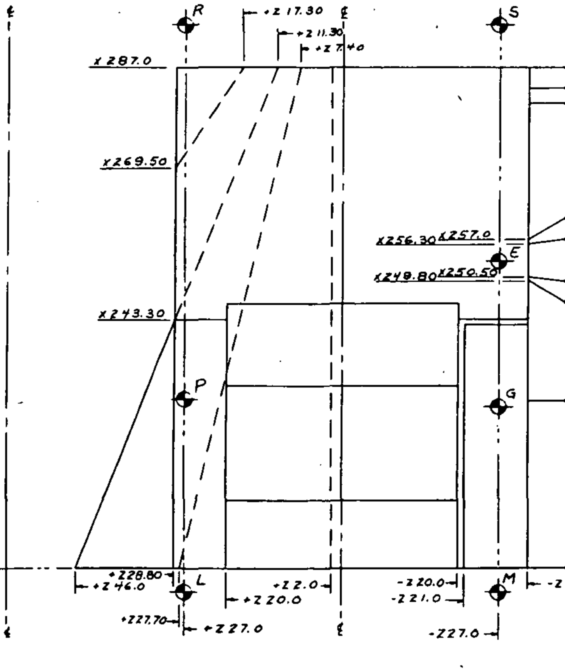


PLAN VIEW

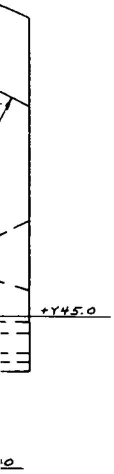
+Z

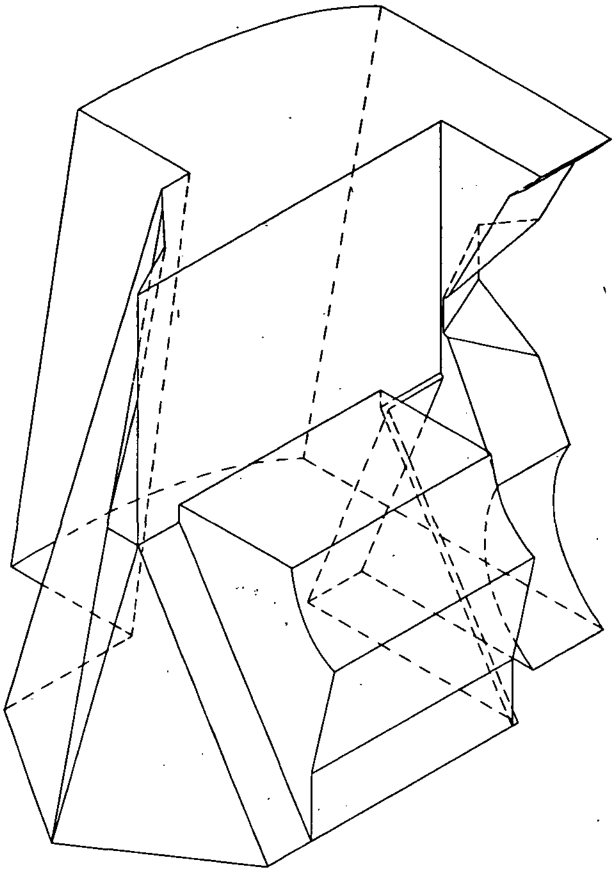


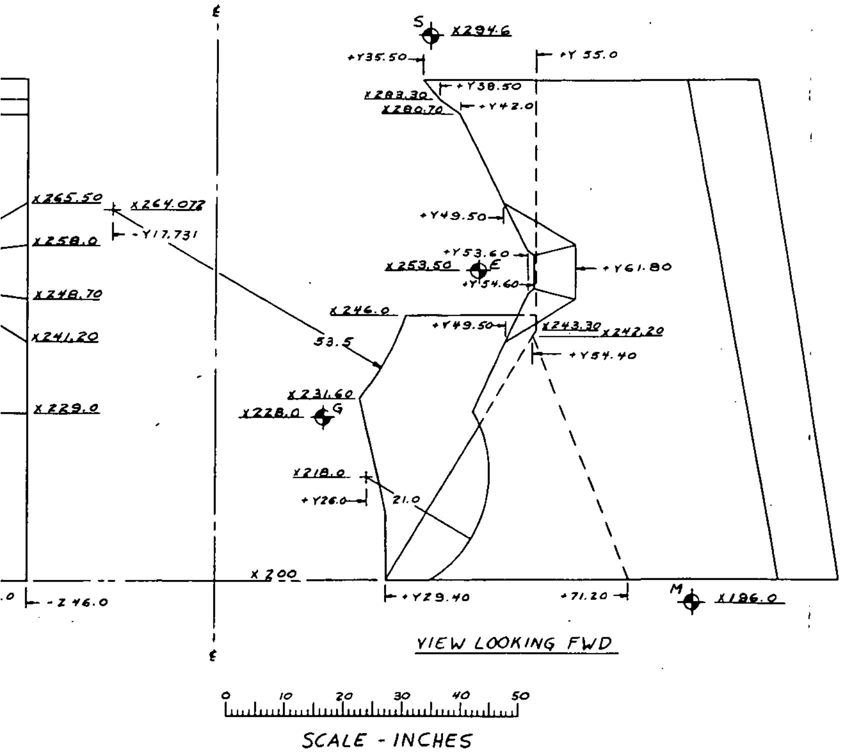
VIEW LOOKING AFT



VIEW LOOKING OUTB'D RIGHT HAND SID



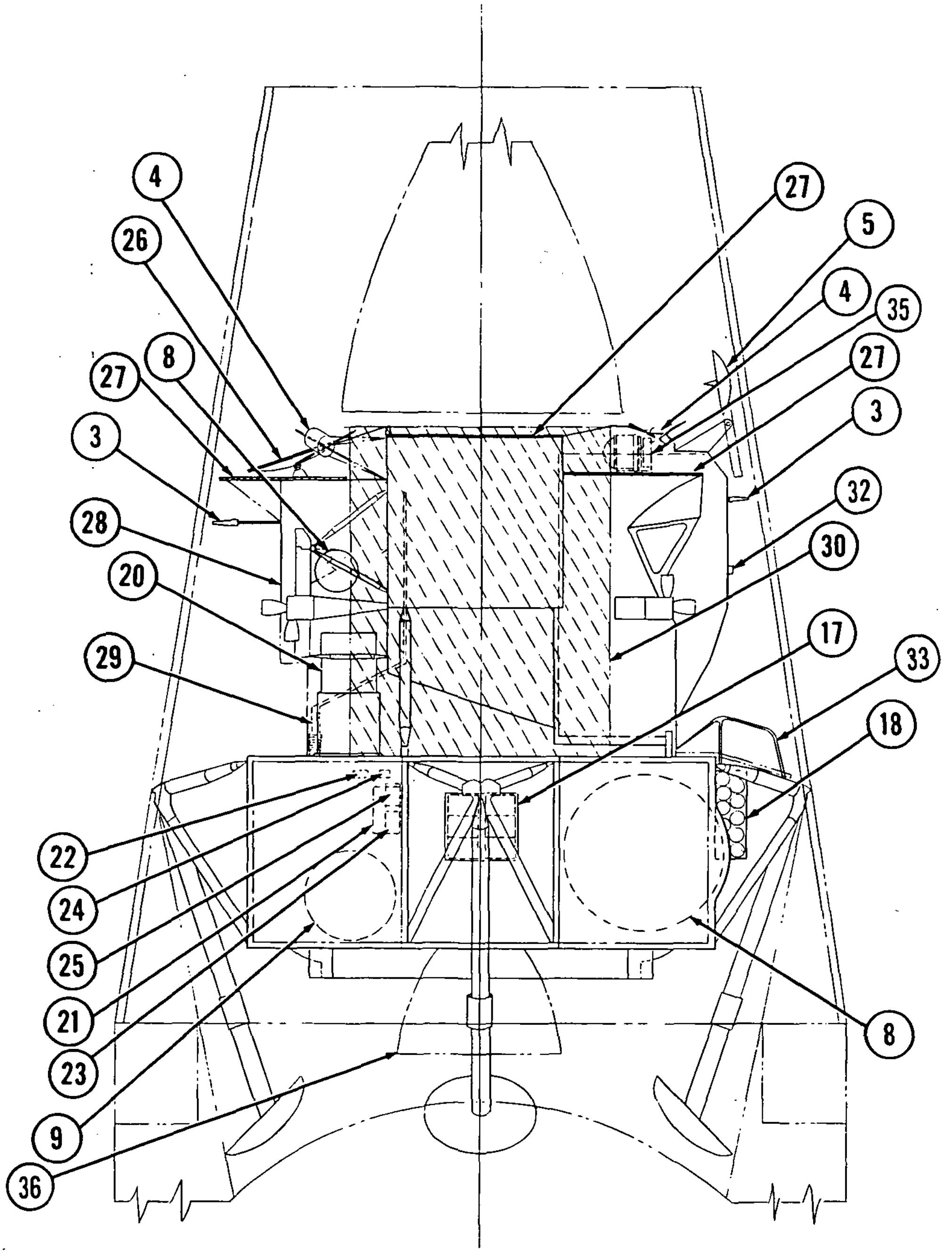




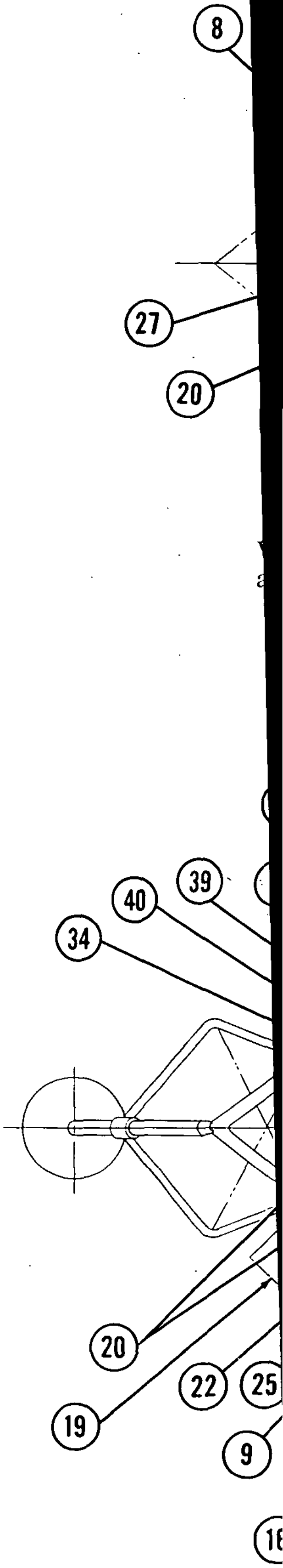
NOTE:

⌖ EXISTING HARD POINTS

Fig. 6.1-23 Available Volume & Hard Points (+Y) Right-Side

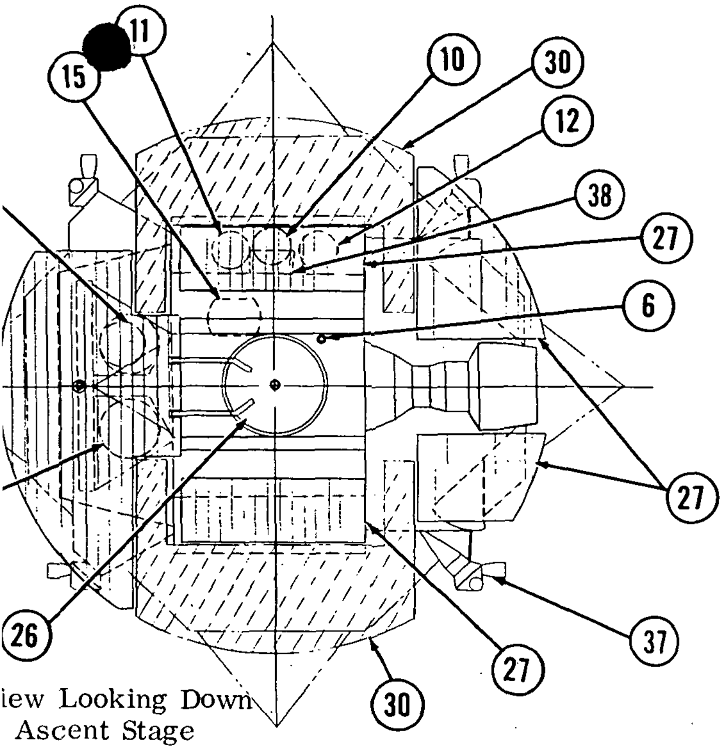


Launch Configuration

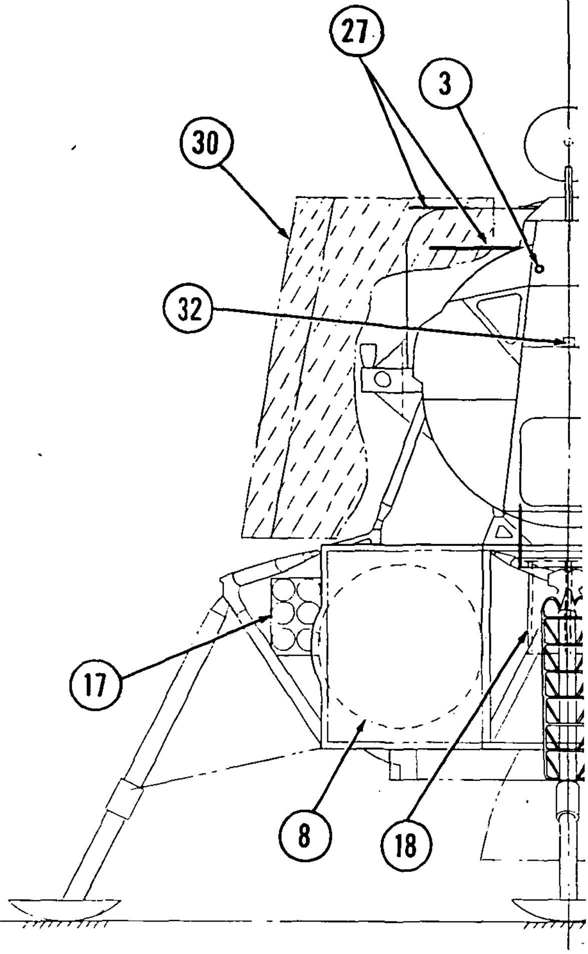


6.1-24

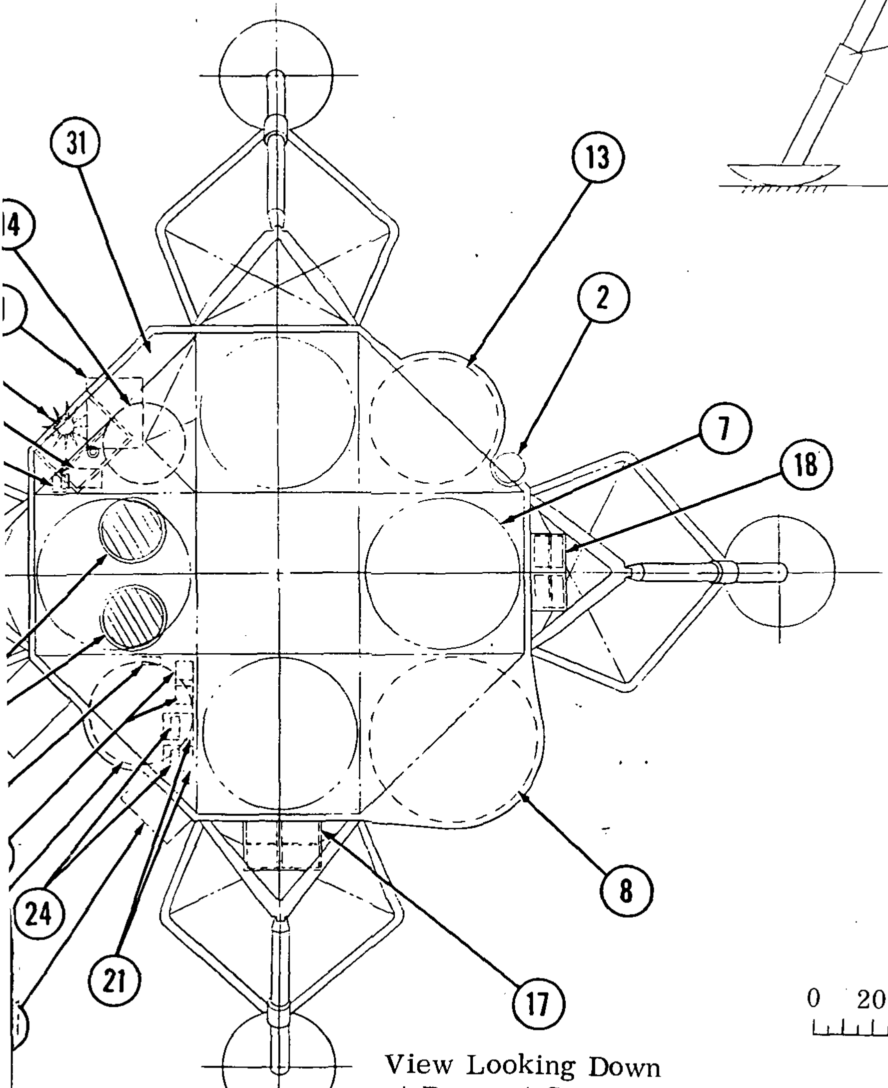
7



iew Looking Down
Ascent Stage



Landed Con



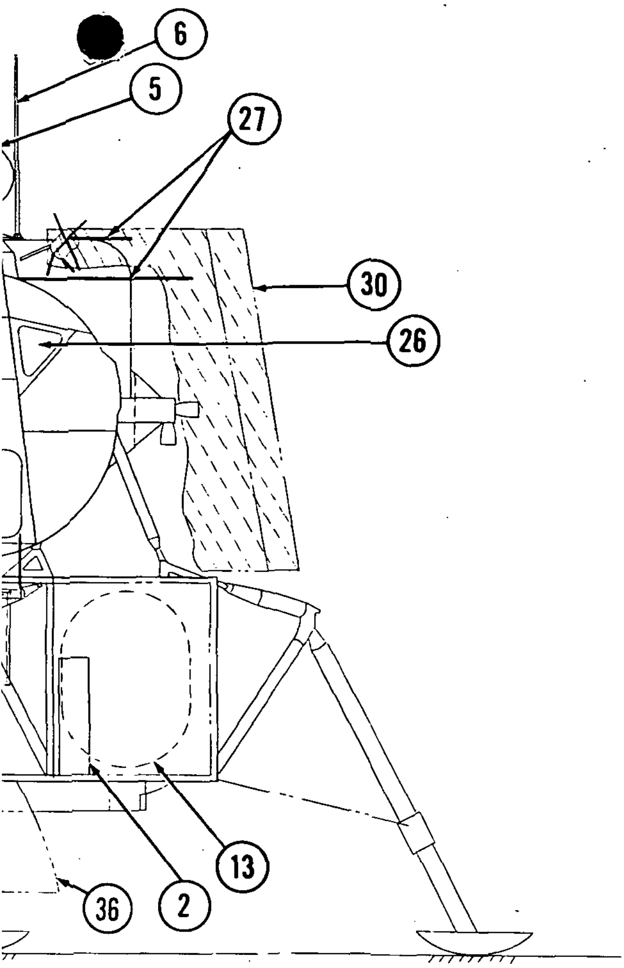
View Looking Down
at Descent Stage

Notes

* Existing LEM Hardware
** Relocated
\+ Stowed Internally in Asc
Until Man Arrives

0 20 40 60 80 100
Scale, in.

② 6.1-24



iguration

nt Stage

Key

Antennas

1 Landing*
2 S-Band Erectable*
3 S-Band In-Flight**
4 VHF In-Flight**
5 S-Band Steerable**
6 Erectable EVA*$^+$

Tanks

7 Fuel (Desc Propul)*
8 GOX
9 He (Desc Eng)*
10 He (RCS)*
11 RCS Fuel*
12 RCS Oxidizer*
13 Gaseous H_2
14 Water*
15 FCA Water Storage*

Crew Provisions

16 Hard Suit$^+$
17 Cabin } LiOH
18 PLSS } Cartridges*
19 PLSS Units (4)$^+$

Electrical Power Supply

20 Fuel Cell Assy
21 Desc Stg Batt's
22 Storage Batt
23 ECA*
24 Pyro Batt's*
25 Pyro Relays*

Thermal Insulation & Protection

26 Thermal Shield (Upper Hatch & Windows)
27 Radiators
28 Fuel Cell Radiators
29 Heat Pipe

Payload

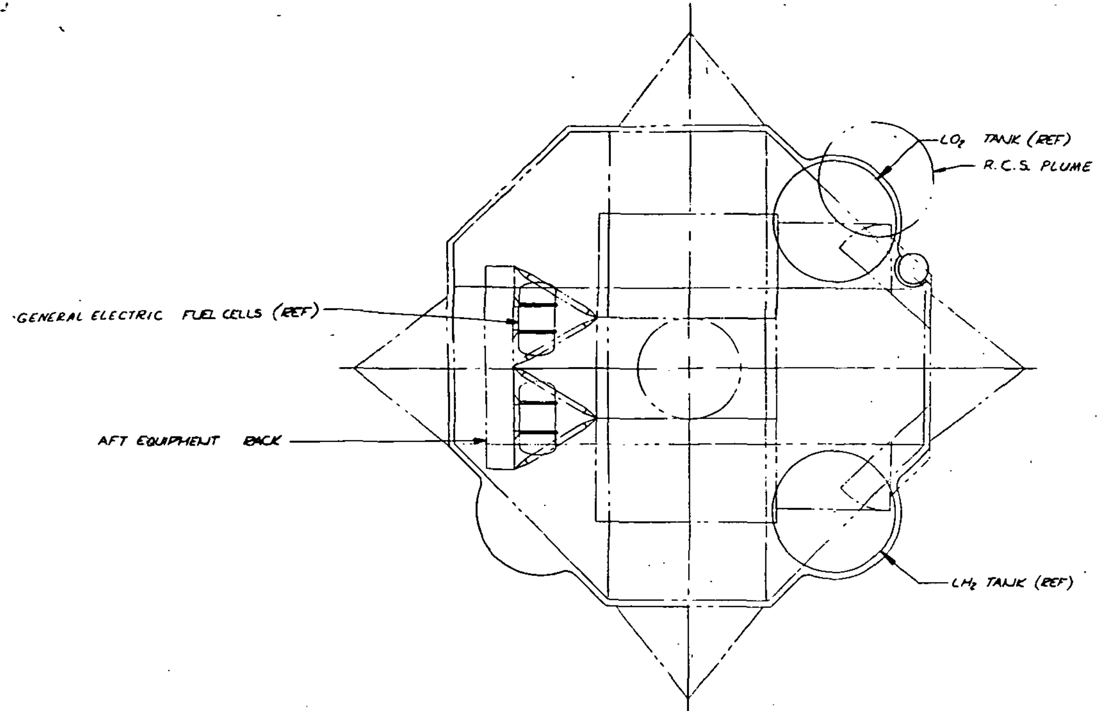
30 Exper Payload Envelope
31 Scientific Equipt Bay

Miscellaneous

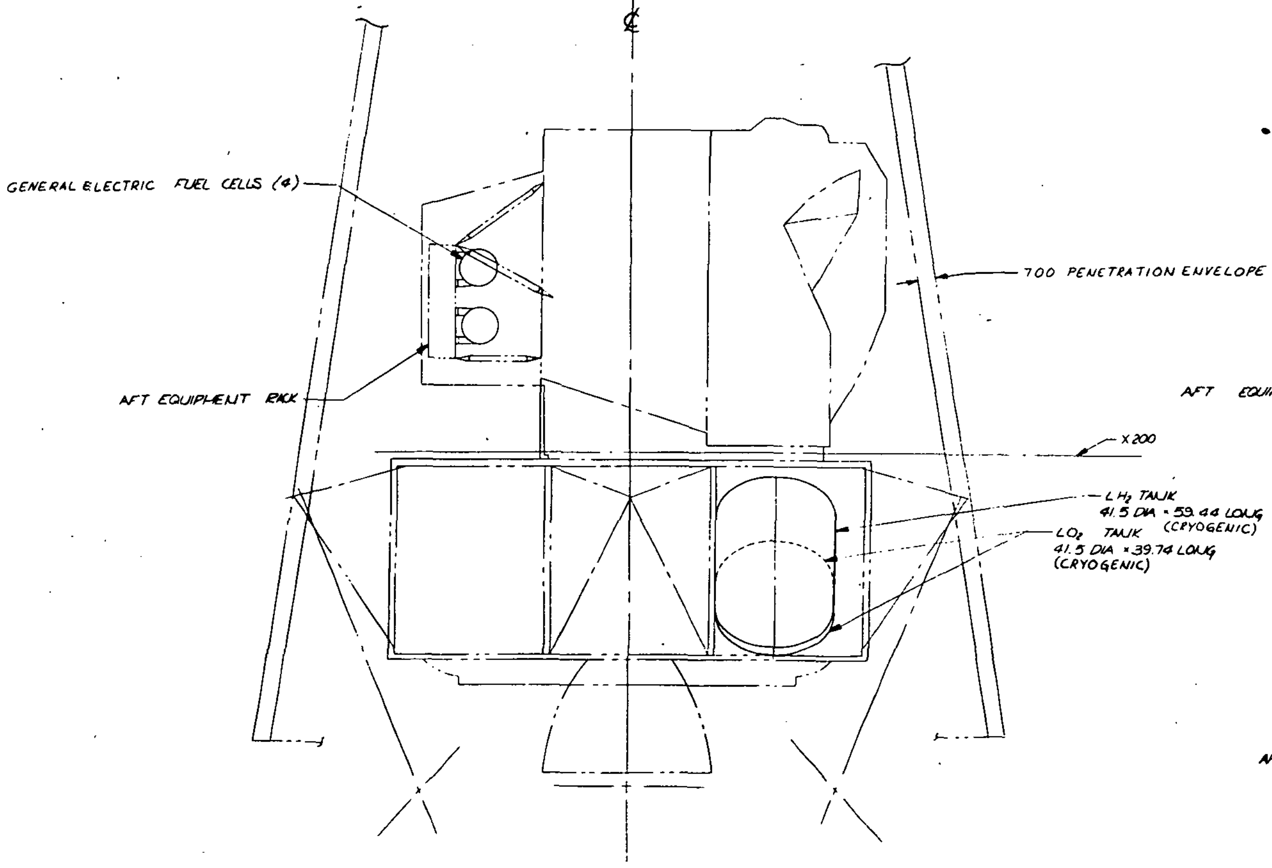
32 X-Band Antenna Xponder
33 Ingress/Egress Platform*
34 Ldg Radar Electronic Assy*
35 IMU-AOT*
36 Descent Engine*
37 RCS*
38 RCS He Press Unit*
39 RTG
40 He Press Module*

Fig. ~~6.~~1-24 Baseline Shelter General Arrangement

3



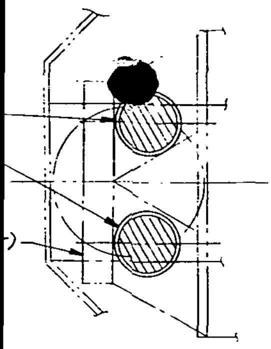
VIEW LOOKING DOWN



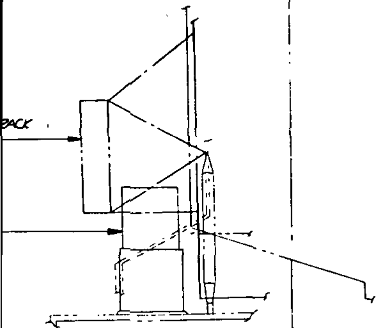
VIEW LOOKING INB'D
CRYOGENIC TANK ARRANGMENT

6.1-25

①

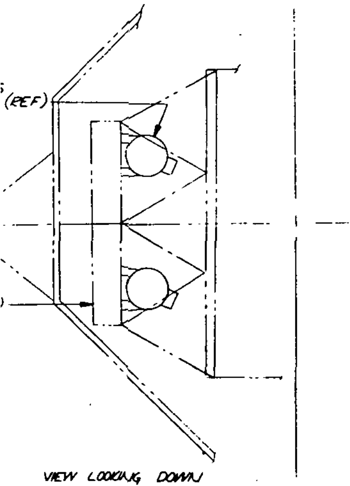


VIEW LOOKING DOWN

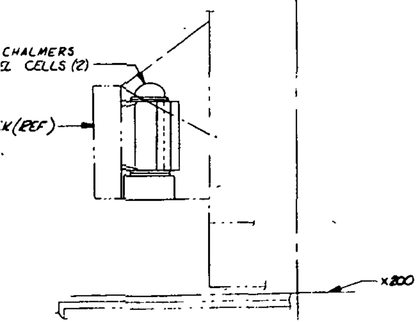


VIEW LOOKING INB'D

ALTERNATE FUEL CELL ARRANGEMENT
P&W FUEL CELLS (2)

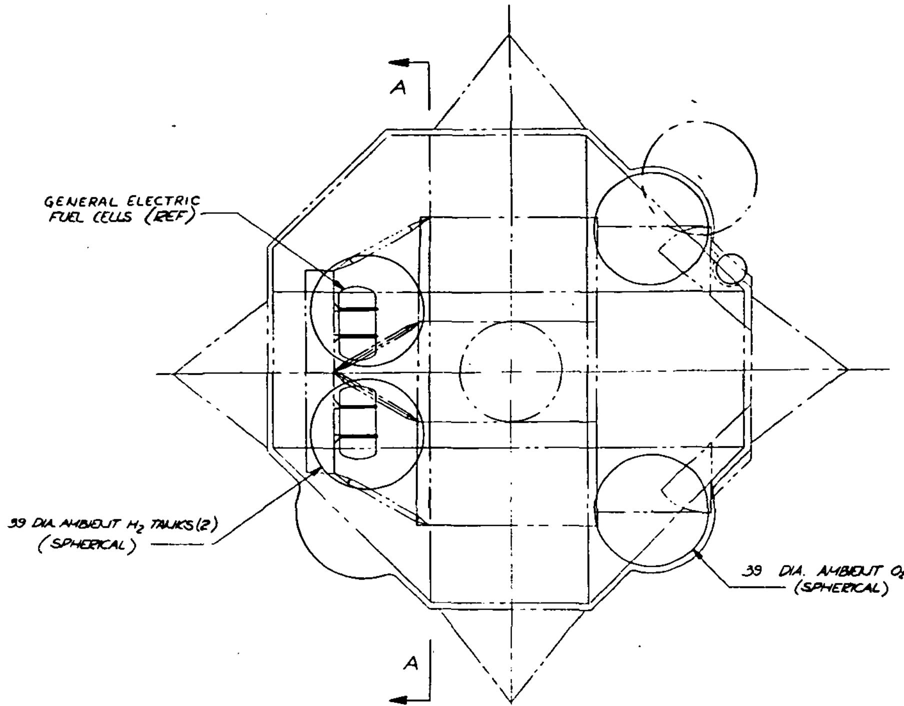


VIEW LOOKING DOWN

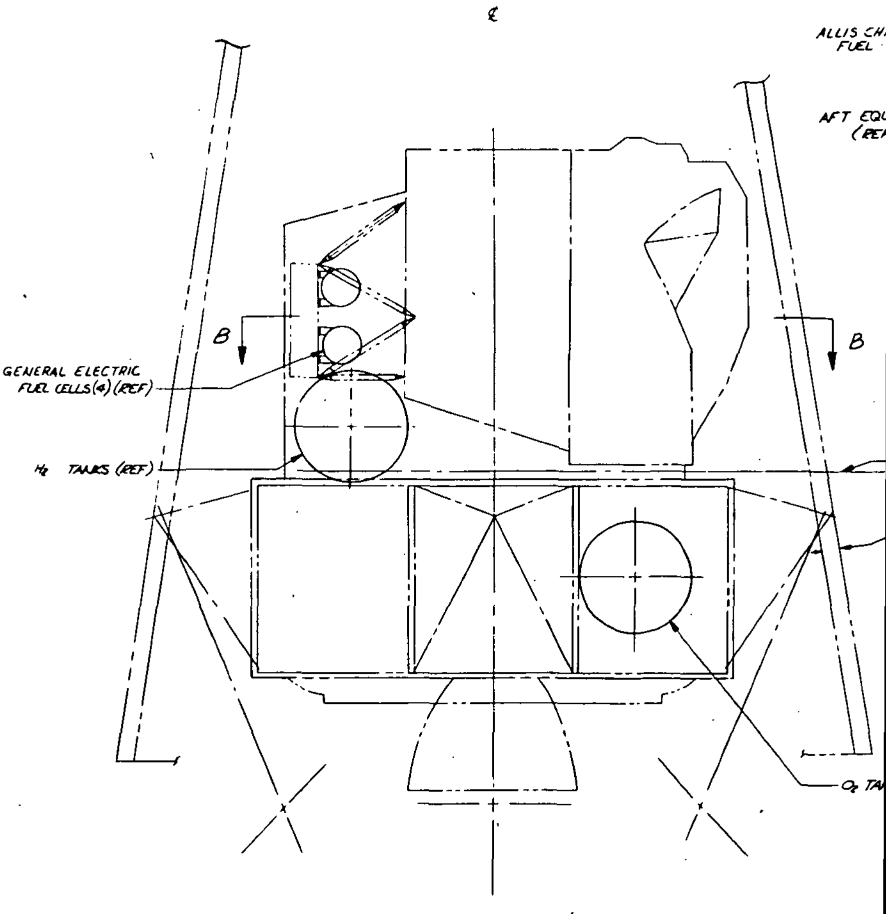


VIEW LOOKING INB'D

ALTERNATE FUEL CELL ARRANGEMENT
A.C. FUEL CELLS



SECTION B-B
VIEW LOOKING DOWN



VIEW LOOKING INBD
AMBIENT TANK ARRANGEMENT

Scale, in.

② 6.1-25

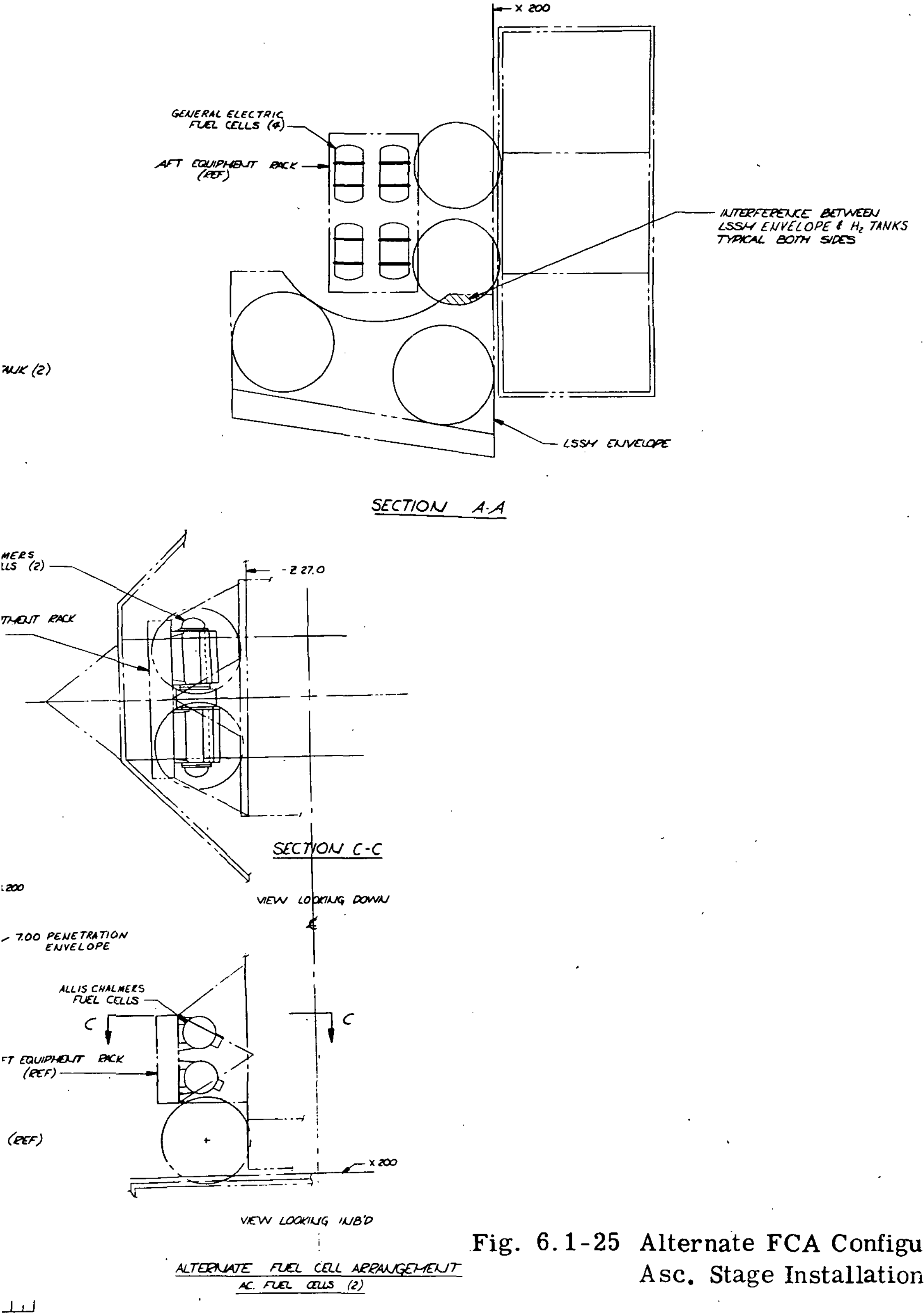
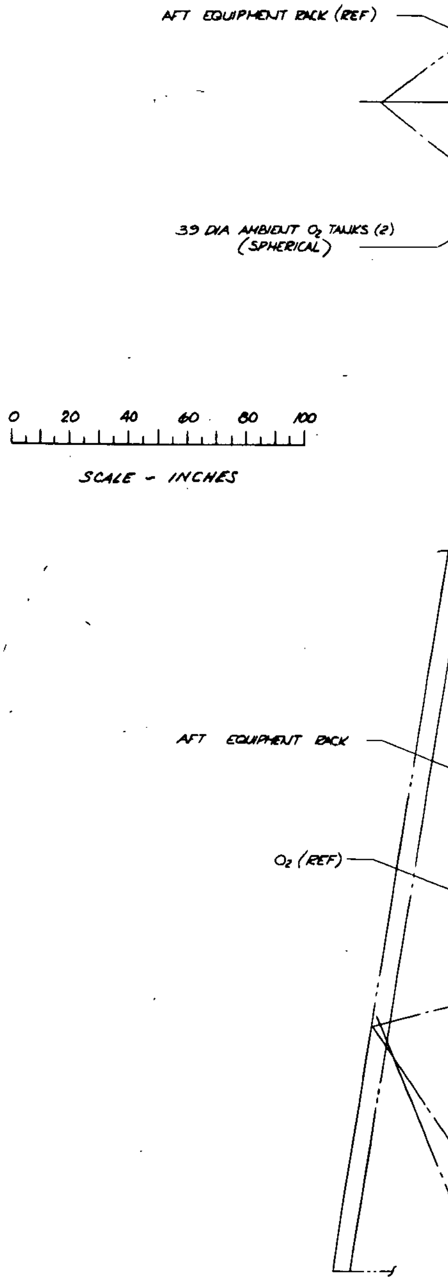


Fig. 6.1-25 Alternate FCA Configuration Asc. Stage Installation


AFT EQUIPMENT RACK (REF)
39 DIA AMBIENT O_2 TANKS (2) (SPHERICAL)
0 20 40 60 80 100
SCALE - INCHES
AFT EQUIPMENT RACK
O_2 (REF)

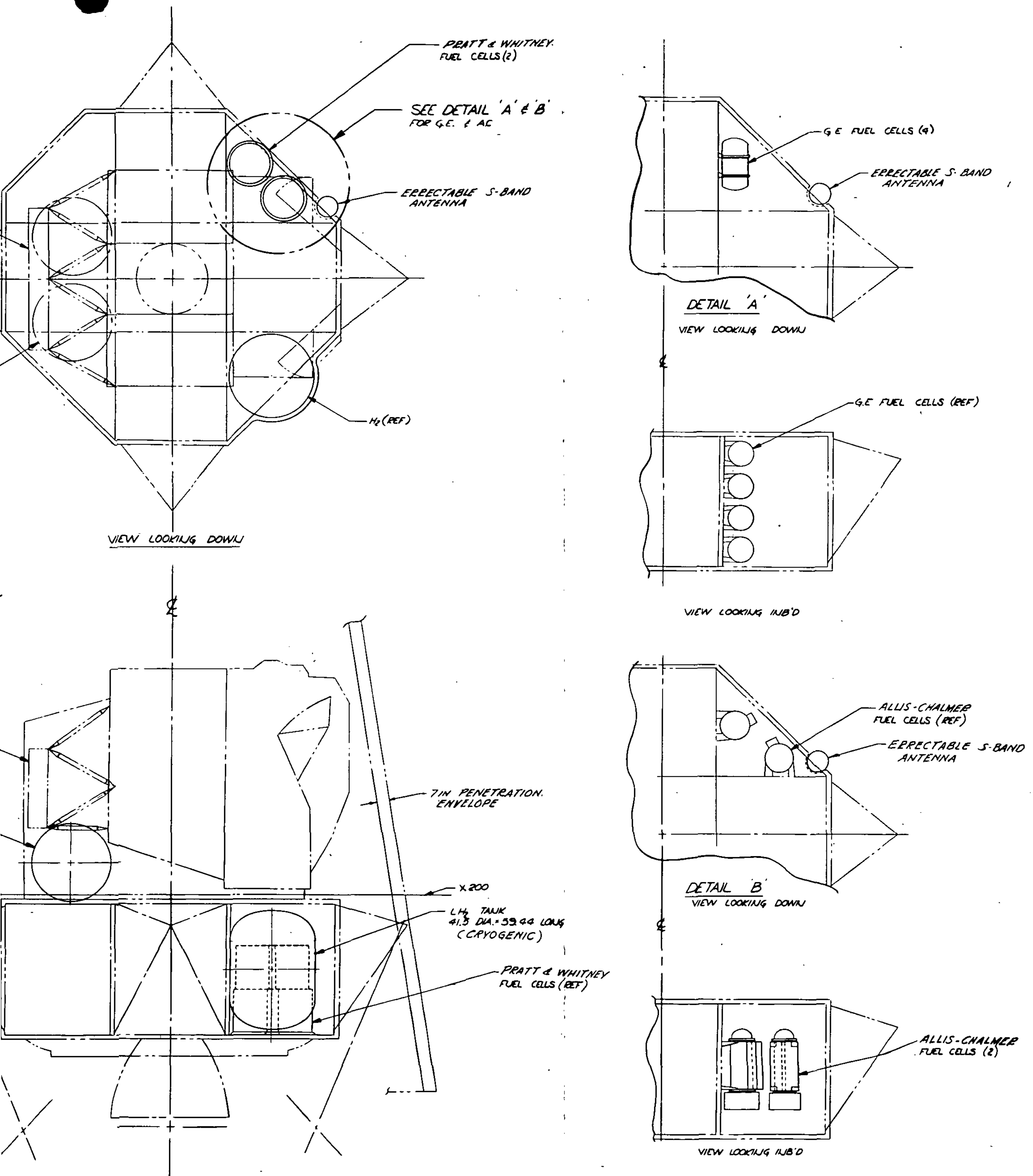
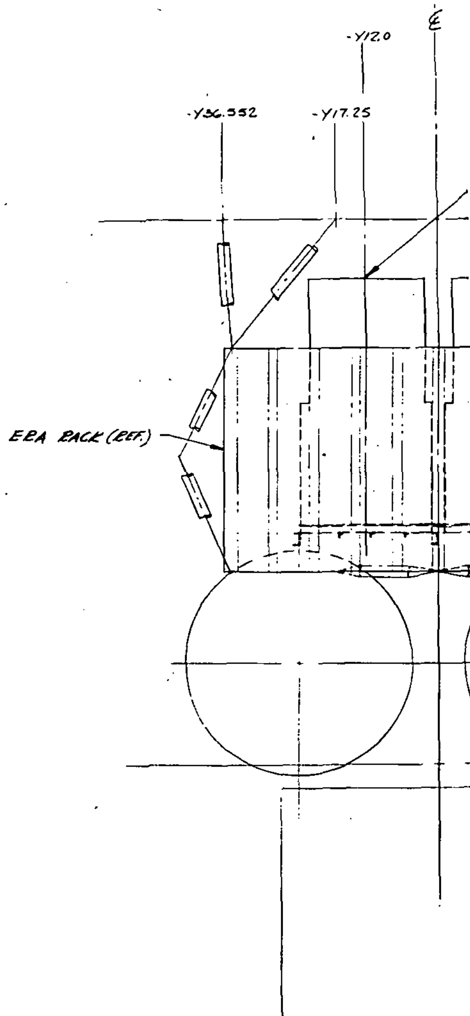


Fig. 6.1-26 Alternate FCA Configuration - Desc. Stage Installation

65



VIEW LOOKING
AFT EQUIPMENT

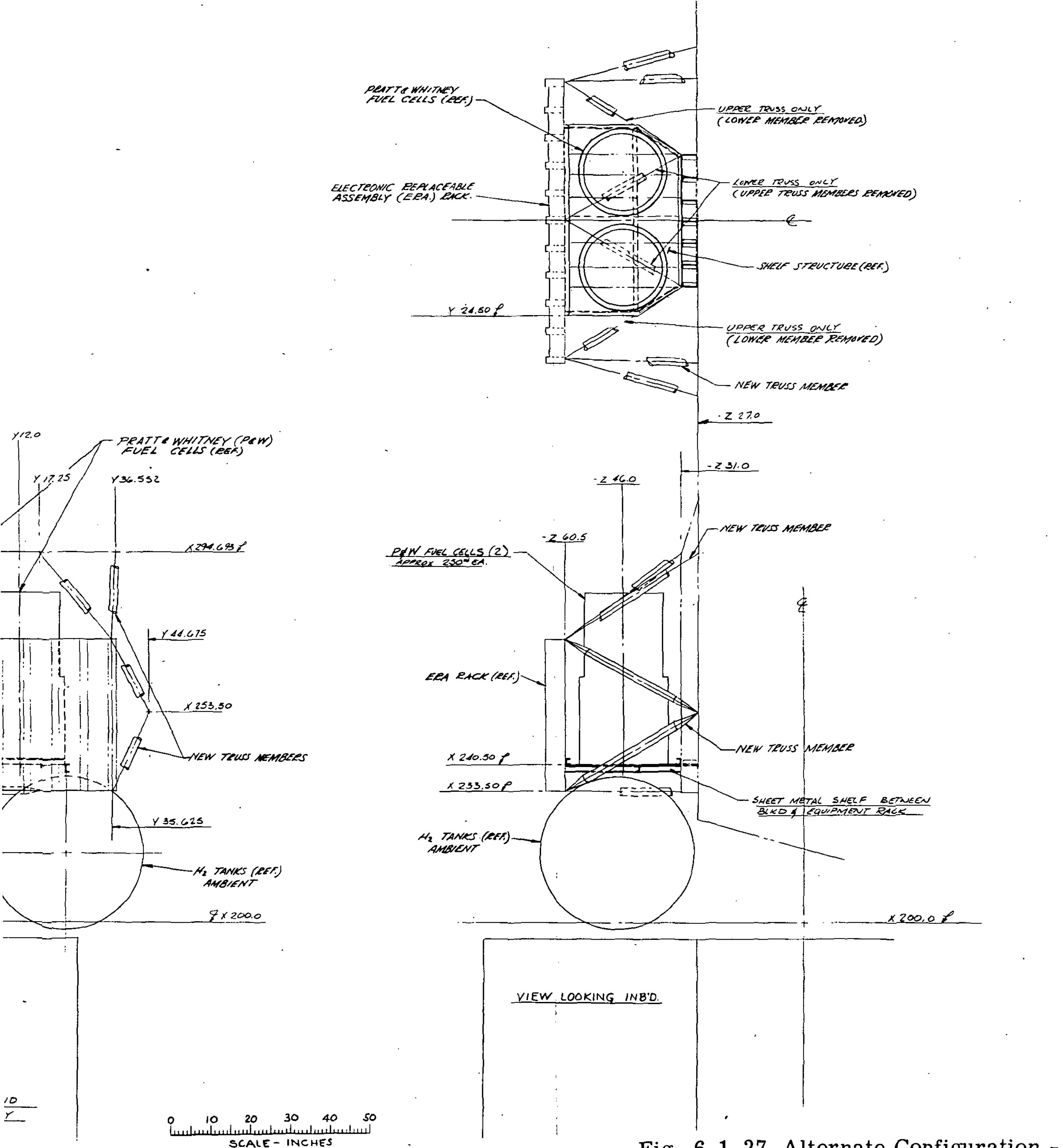
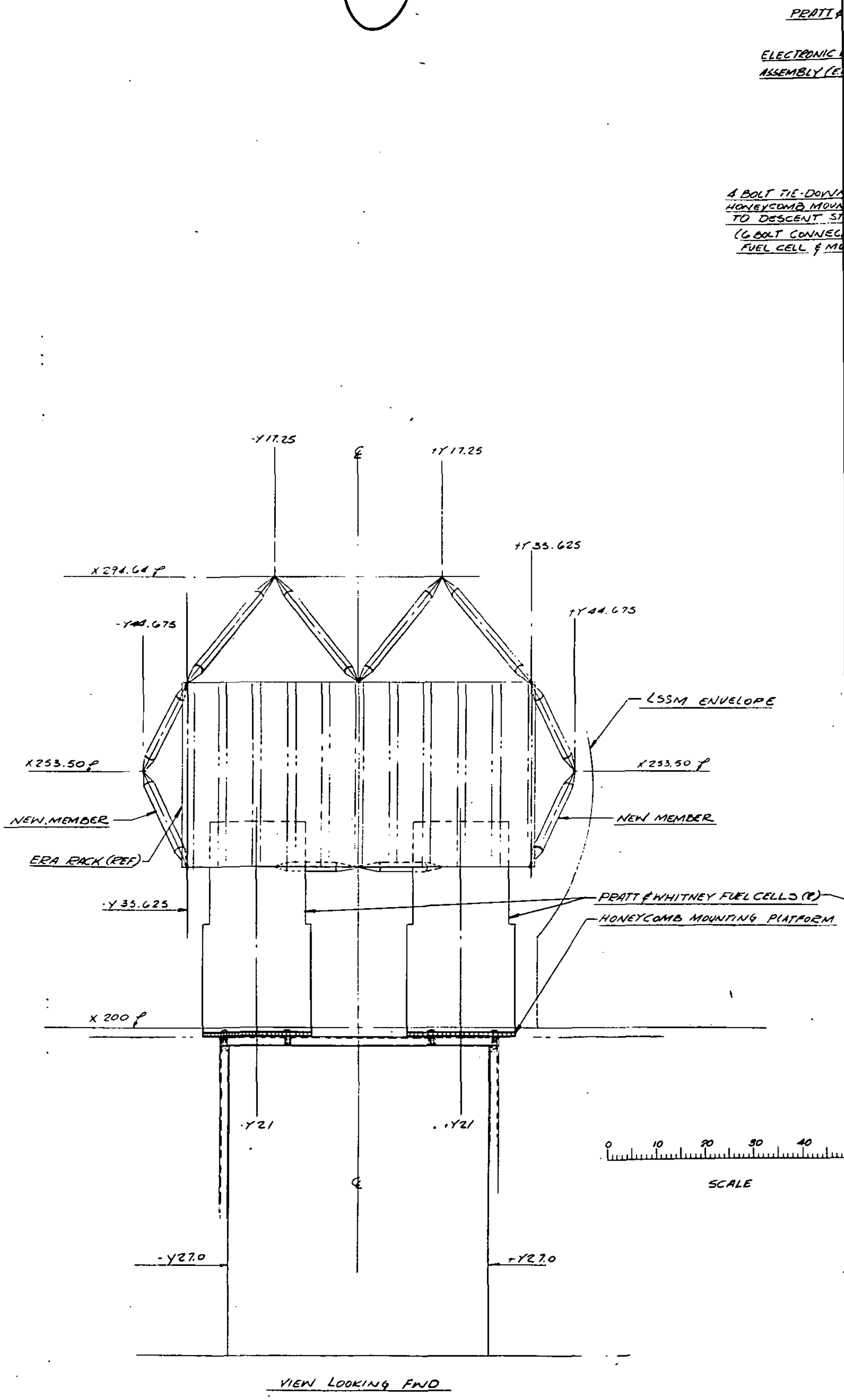


Fig. 6.1-27 Alternate Configuration - P&W FCA Shelf Mounted

67



VIEW LOOKING FWD

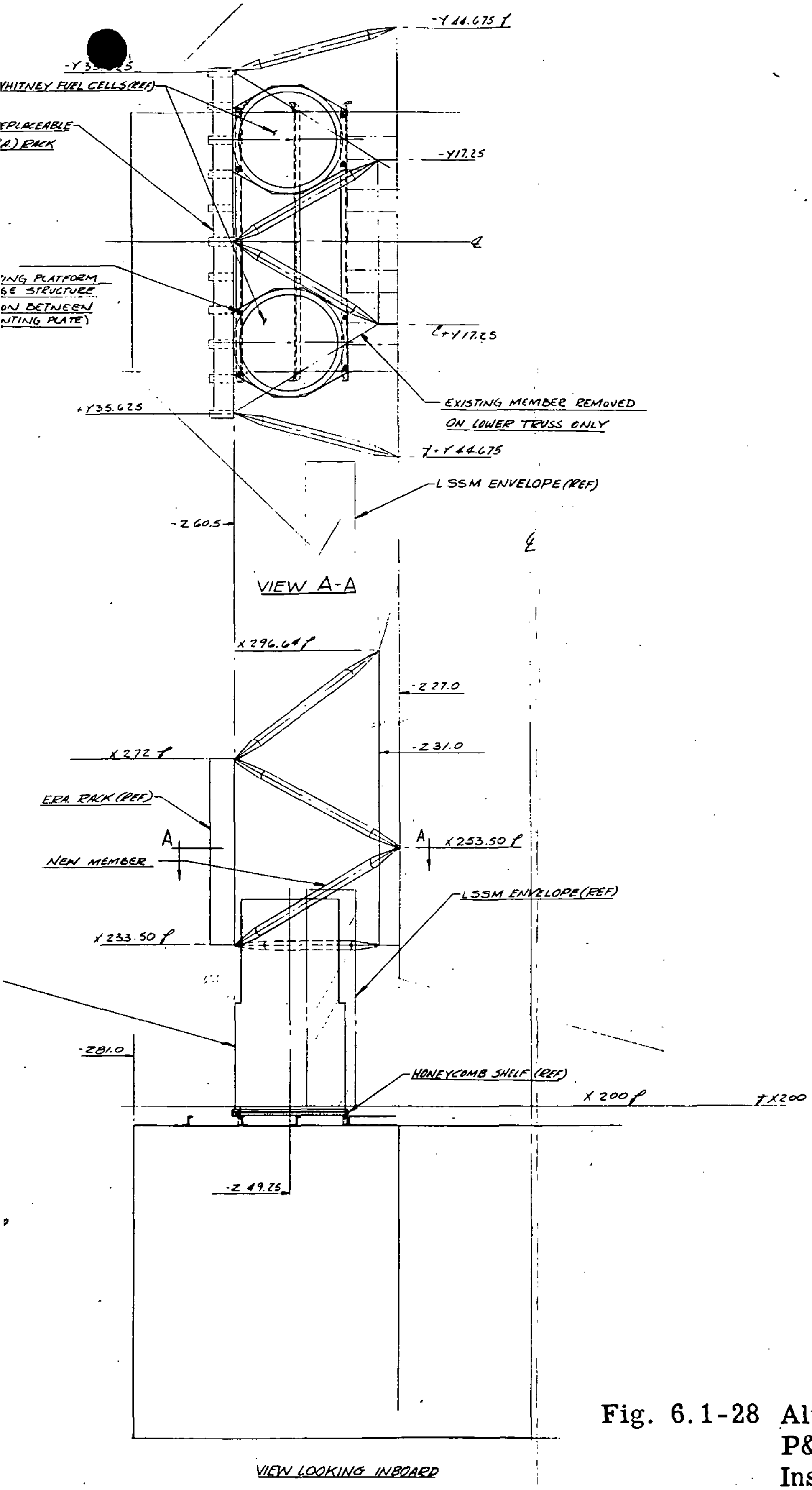
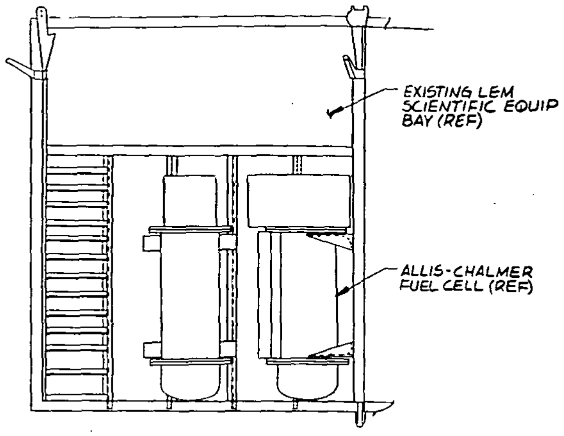
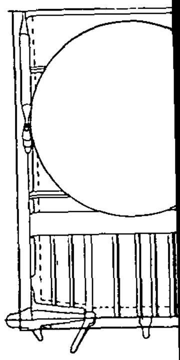


Fig. 6.1-28 Alternate Configuration - P&W FCA Desc. Stage Installation

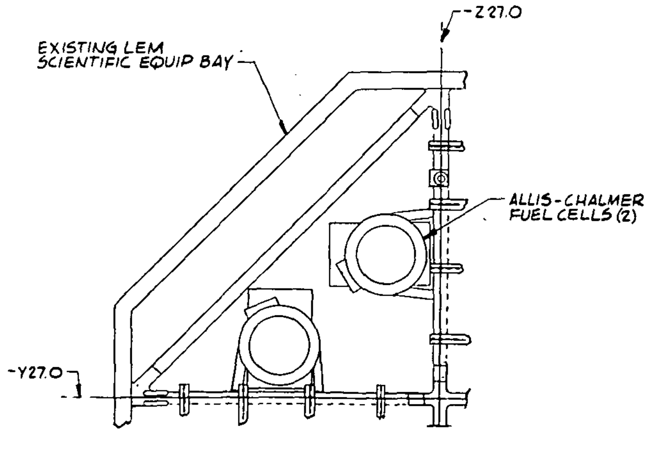
69



VIEW LOOKING INBOARD
QUADRANT II



VIEW LO
QUAD



VIEW LOOKING DOWN
QUADRANT II

0 5 10 15

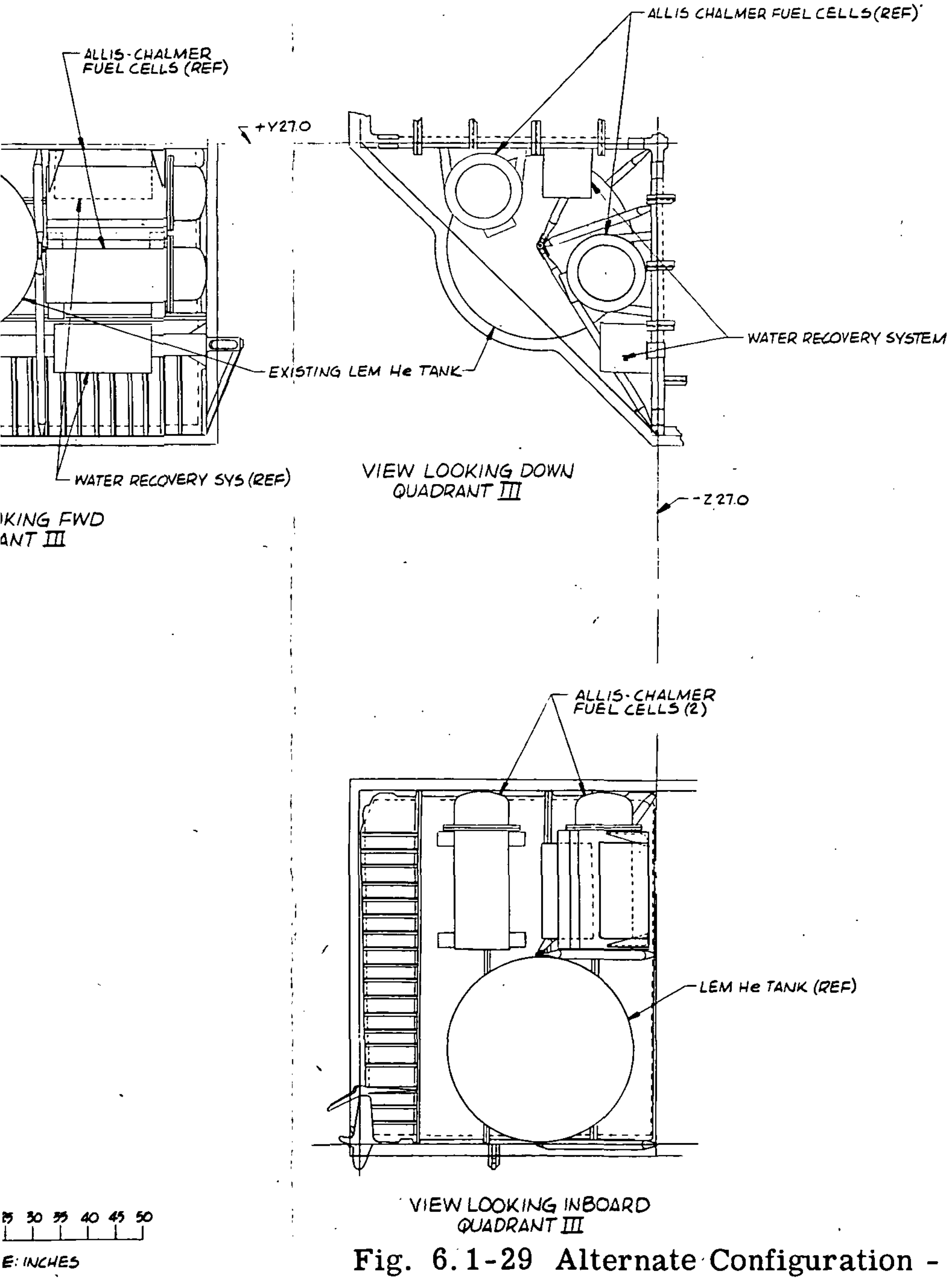


Fig. 6.1-29 Alternate Configuration - AC FCA Quadrant I Installation

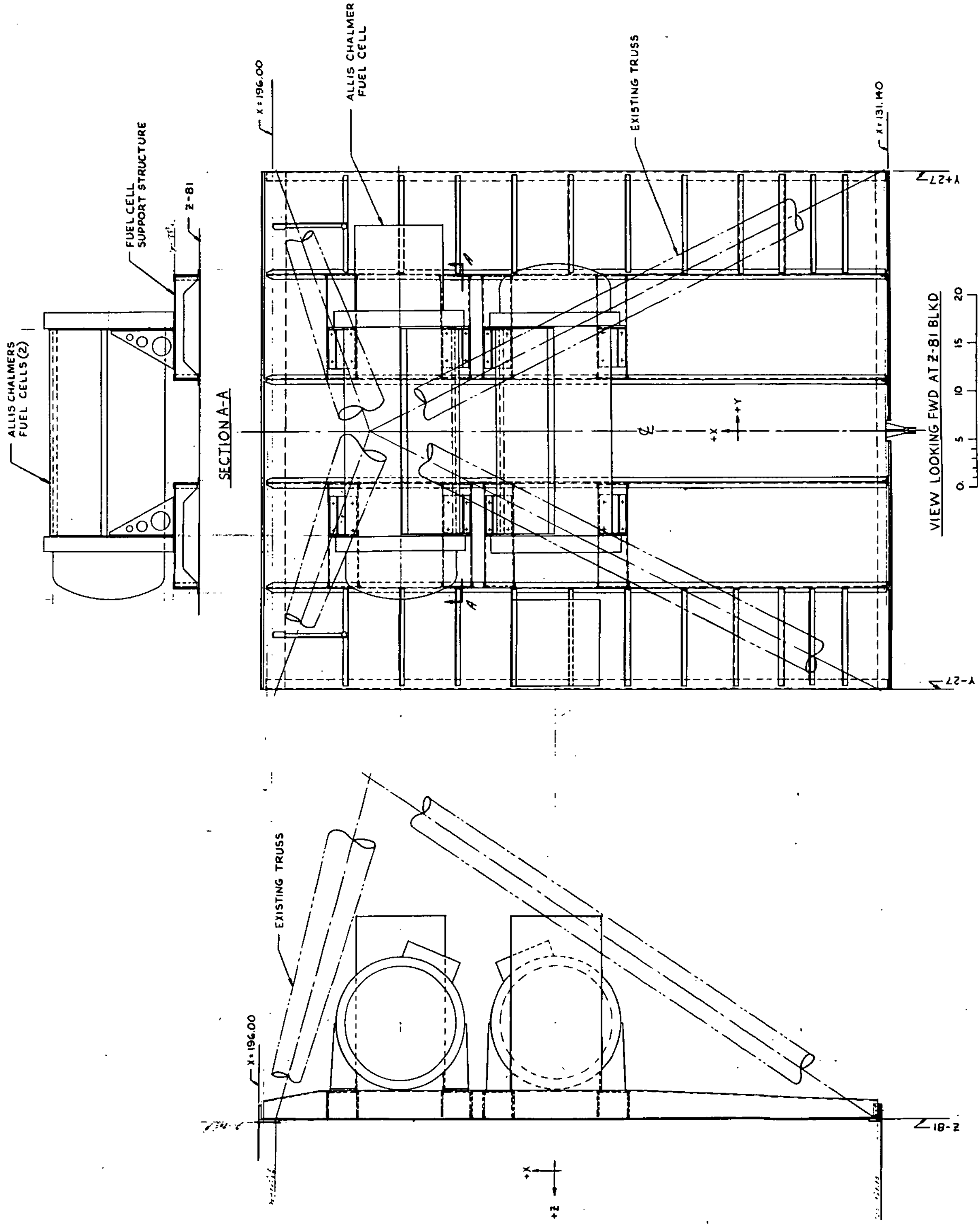
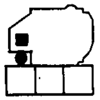
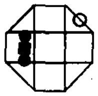
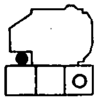
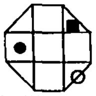
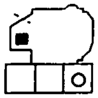
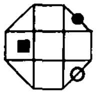
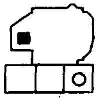
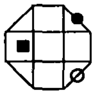
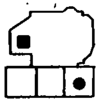
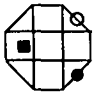
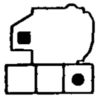
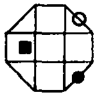
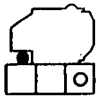
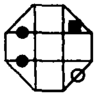
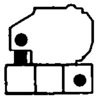
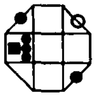
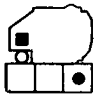
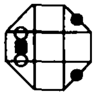
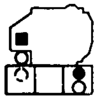
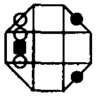
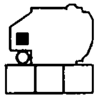
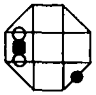


Fig. 6.1-30 Alternate Configuration - AC FCA Outrigger Installation

				1	S-46D							Quad IV to III.
9			C	2 2	S-38D S-41D	N	E,S	MOD	S	QUAD I	F	Same as 8.
10			C	1 1	C-41.5DX39.7L C-41.5DX59.4L	N *	E,S	E	S	NONE	G	Batteries & pyrorelays relocated from Quad IV to Quad III truss support for ERA rack slightly modified *Being considered for AES Phase II Lab.
11			C	1 1	C-41.5DX39.7L C-41.5DX59.4L	N *	E	MOD	S	QUAD I	F	Batteries & pyrorelays relocated from Quad IV to Quad III. ERA rack revised to support FCA. *Being considered for AES Phase II Lab.
12			C	1 1	S-44D S-46D	N	E	MOD	S	QUAD 1	G	Same as 11.
13			C	1 1	S-44D C-41.5DX59.4L	N *	E	MOD	S	QUAD I	G	Same as 11. *Being considered for AES Phase II Lab.
14			H	1 1	S-55D C-41.5DX59.4L	N *	E,S	MOD	S	QUAD I	G	Same as 11. Ambient O_2 tank. *H_2 tank is Cryo (AES Phase II Lab).
15			H	2 1	S-39D C-41.5DX59.4L	N *	E,S	MOD	S	NONE	G	Truss support for ERA rack revised. Batteries & pyrorelays relocated from Quad IV to III. O_2 tanks are ambient. *H_2 tank is Cryo (AES Phase II Lab)
16			H	2 3 1	S-40.9D S-21.69D C-41.5DX59.4L	* **	E,S	E	S	QUAD I	F	Batteries & pyrorelays relocated from Quad IV to III. *40.9D O_2 tank is existing NAA He Tank (possible incompatibility between Ti tank & O_2). **21.69D O_2 tank is existing LEM D/S Tank. FCA & three 21.69D GOX tanks in same location as Phase I Lab. H_2O tank relocated. ±H_2 tank is Cryo (AES Phase II Lab)
17			A	2 2	S-44D S-40.9D	N *	E,S	E	S	QUAD I	F	O_2 Press = 3000 psi, H_2 press 4200 psi, temp 130°F. Batteries & pyrorelays relocated from QUAD IV to III. ERA rack modified to support FCA & truss support for ERA rack slightly modified. *H_2 tanks are NAA 5000 psi He tanks reworked.
18			A	2 5	S-44D S-33.6	N *	E	MOD	S	QUAD I	F	Batteries & pyrorelays relocated from QUAD IV to III. ERA rack modified to support FCA. H_2O tank relocated. *H_2 tanks are LEM D/S He tanks reworked.
19			A	1 2	S-55D S-40.9D	N *	E,S	MOD	S	NONE	F	Batteries & pyrorelays relocated from Quad IV to III. ERA rack modified to support FCA & truss support modified slightly. *H_2 tanks are NAA 5000 psi He tanks reworked. H_2 press = 4200 psi, O_2 press = 3000 psi, temp 130°F.

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SUMMARY OF ALTERNATE TANK CONFIGURATIONS

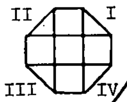
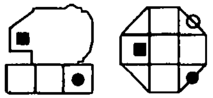
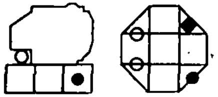
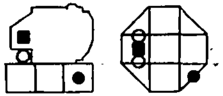
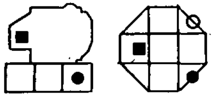
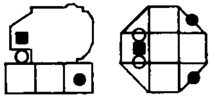
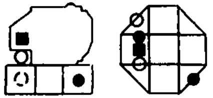
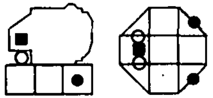
Tankage & FCA Location ■ F.C.A. ○ H_2 Tank ● O_2 Tank	 Type of System Cryo(C)-Ambient(A)-Hybrid(H)	No. of Tanks O_2	No. of Tanks H_2	Tank Dimensions Spherical(S) Cylindrical (C)	Tank Status Existing (E); New (N)	Modifications Req'd Equip. Relocation(E) Struct.(S)	Structural Modifications M(Minimal)Mod(Moderate)E(Extens.)	Supporting Structure Straight Fw'd(S)Complex(C)	R.C.S. Impingement	On-Pad Accessibility Good(G)-Fair(F)-Poor(P)	Comments (General); Specifics in Boxes Below • 8-Jet RCS System Used • Ambient Reqmts H_2: 42.5 lb O_2: 786.5 lb (Based on No Airlock) • In configs 1, 4, 8, & 11 thru 14, the FCA can be located as shown or in the same area, but on top of the descent stage. • FCA location on ERA rack common with Lab.
1 	A	1	1	S-55D S-48.5D	N	E,S	MOD	S	QUAD I	G	O_2 Press = 3000 psi, H_2 Press = 5000 psi Temp 130°F. Batteries & pyrorelays relocated to Quad III from Quad IV. Mod to ERA rack to support F.C.A.
2 	A	1	2	S-55D S-38.5D	N	E,S	MOD	S	NONE	G	O_2 Press = 3000 psi, H_2 Press = 5000 psi Temp 130°F. Batteries & pyrorelays relocated from Quad IV to Quad III. Truss support for E.R.A rack modified slightly. Battery structure revised
3 	A	1	2	S-55D S-38.5D	N	E,S	MOD	S	NONE	F	Same as 2, except FCA stored in aft equipment bay. Mod to ERA rack to support FCA.
4 	A	1	1	S-55D C-40DX60L	N	E,S	MOD	S	QUAD I	G	O_2 Press = 3000 psi, H_2Press = 5000 psi, temp 130°F Batteries & pyrorelays relocated from Quad IV to III. Battery structure revised.
5 	A	2	2	S-39D S-39D	N	E,S	M	S	QUAD I	F	O_2 Press = 4300 psi, H2 Press = 4800 psi, temp 130°F. ERA rack modified to support FCA. Slight Mod to truss supporting ERA rack. Batteries & pyrorelays relocated from Quad IV to III.
6 	A	2	2	S-39D S-39D	N	E,S	E	S	NONE	F	Same as 5, except add'l structural Mod req'd to mount tank in Quad II. H_2O in Quad II relocated.
7 	A	2	2	S-46D S-38.5D	N	E,S	M	S	QUAD I	F	O_2 Press = 3000 psi, H_2 Press = 5000 psi, temp 130°F. Batteries & pyrorelays relocated from quad IV to III. ERA rack & truss support slightly modified.
8 	C	2		S-38D	N	E.S	MOD	S	NONE	F	ERA rack modified to support FCA. Truss support for ERA rack modified slightly. Batteries & pyrorelays relocated from

Fig. 6.1-31 Alternate Tank Configurations

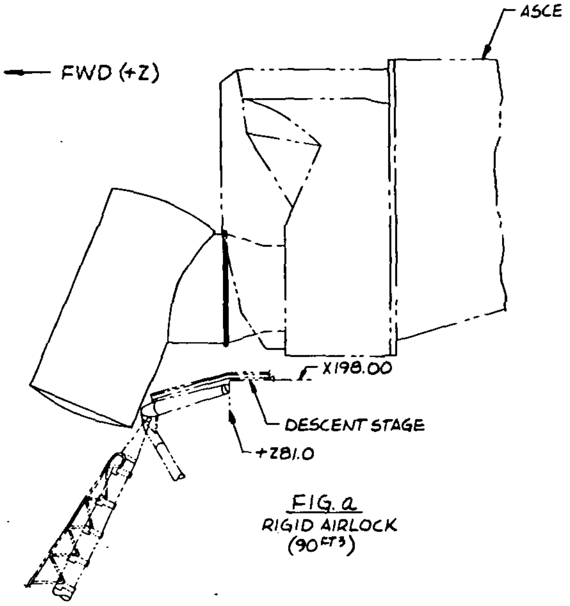


FIG. a
RIGID AIRLOCK
(90$^{FT^3}$)

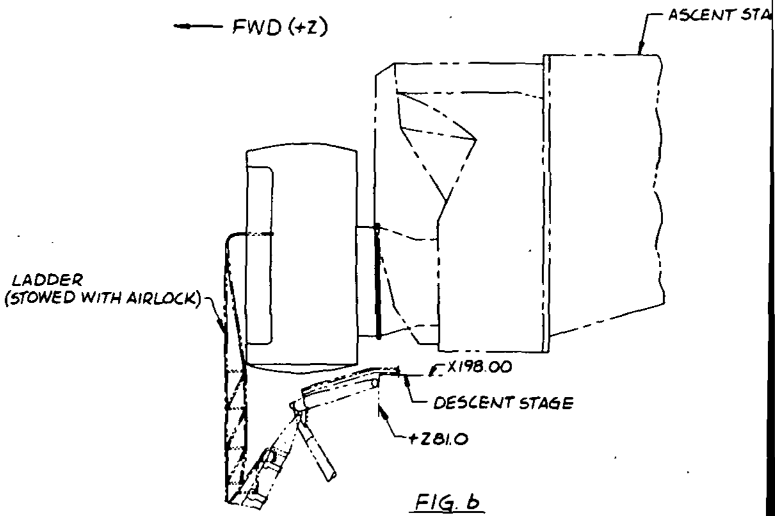


FIG. b
RIGID AIRLOCK
(90$^{FT^3}$)

STAGE

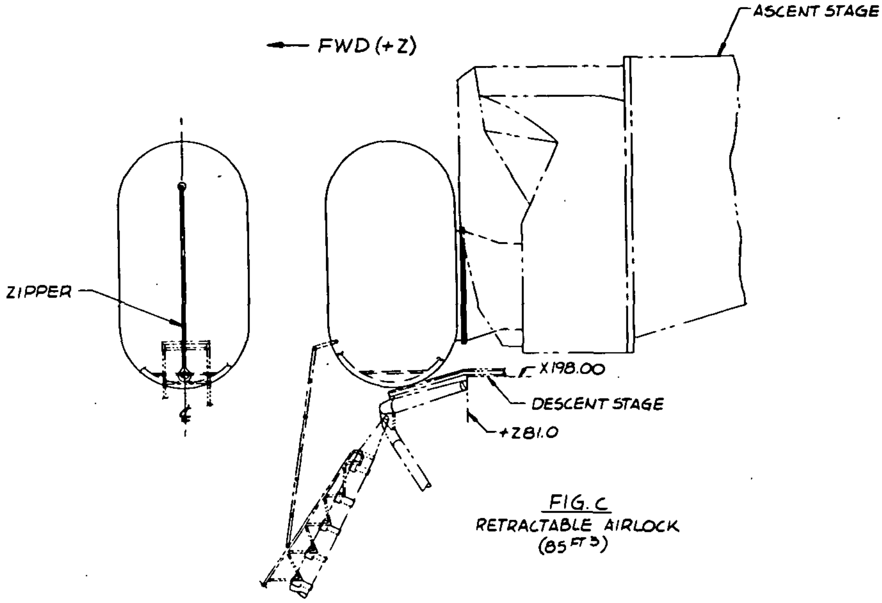


FIG. c
RETRACTABLE AIRLOCK
(85^{FT^3})

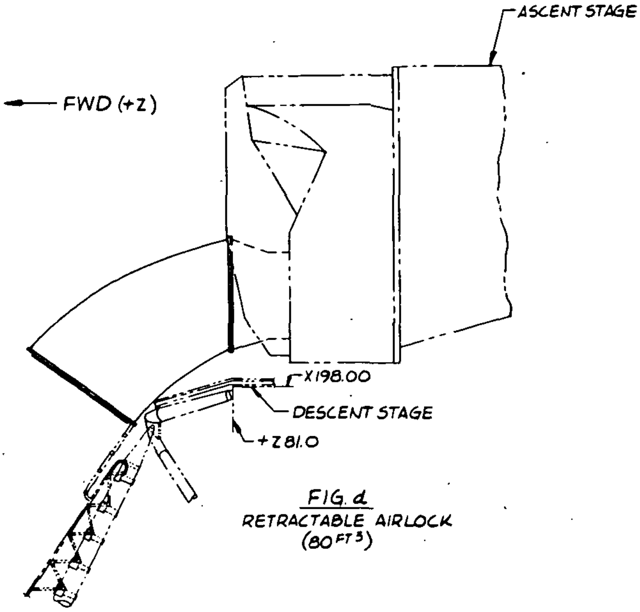


FIG. d
RETRACTABLE AIRLOCK
(80^{FT^3})

6.1-32
②

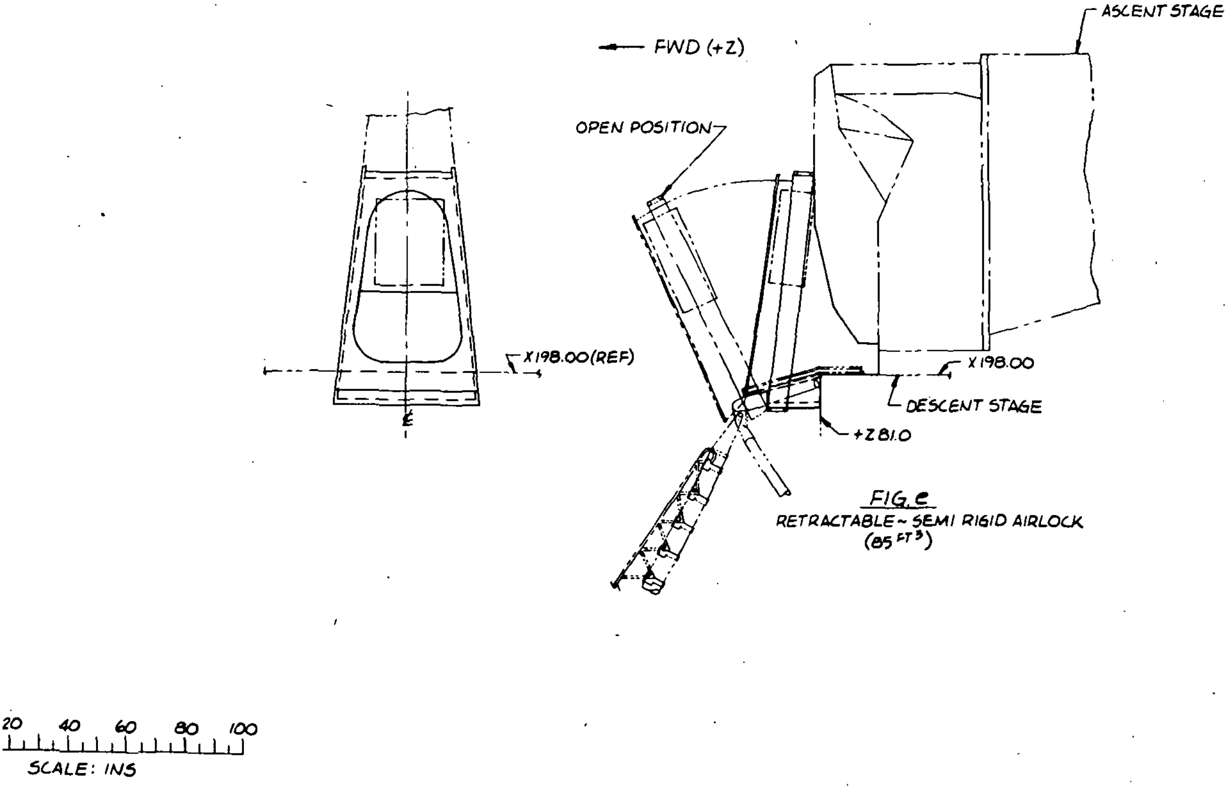
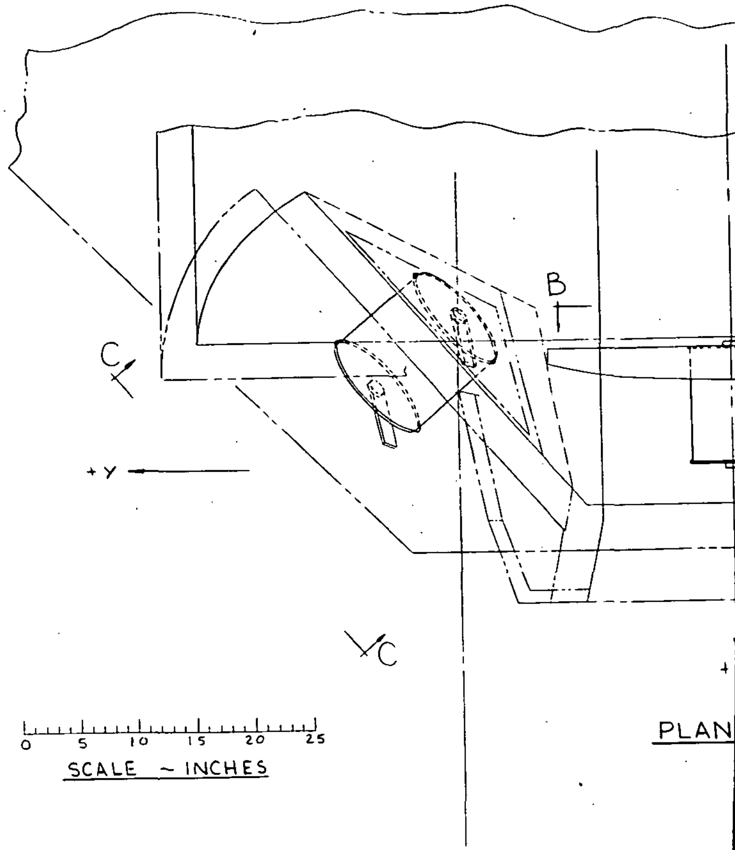


FIG. e
RETRACTABLE ~ SEMI RIGID AIRLOCK
(85 FT^3)

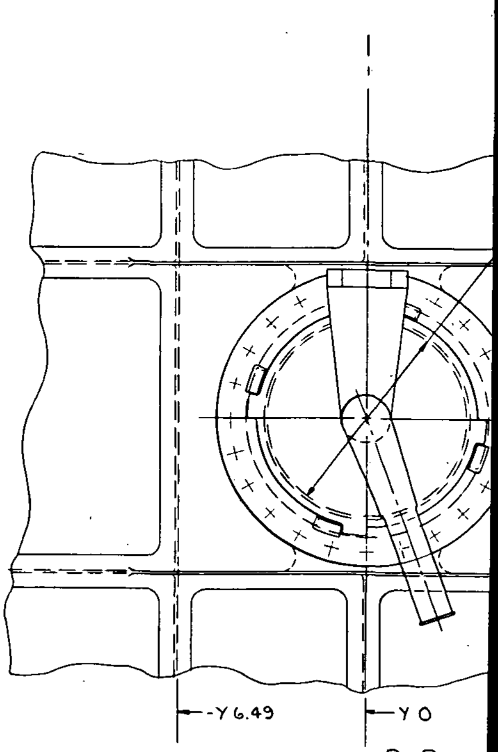
Fig. 6.1-32 Alternate Airlock Configurations

3

77



PLAN



VIEW B-B

VIEW LOOKING FW

FORWARD HATCH

ROTATED 180°

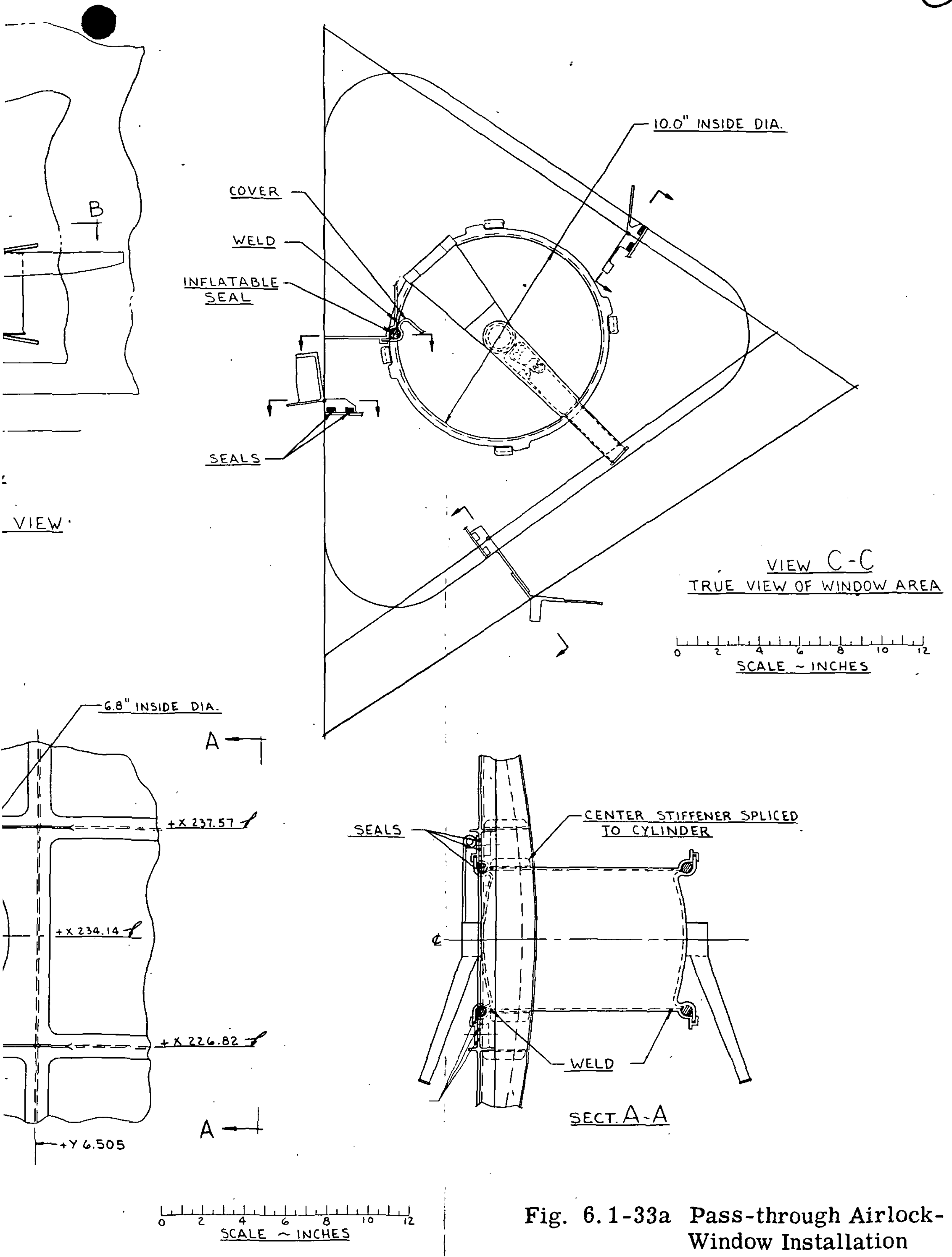
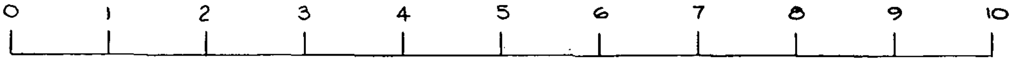
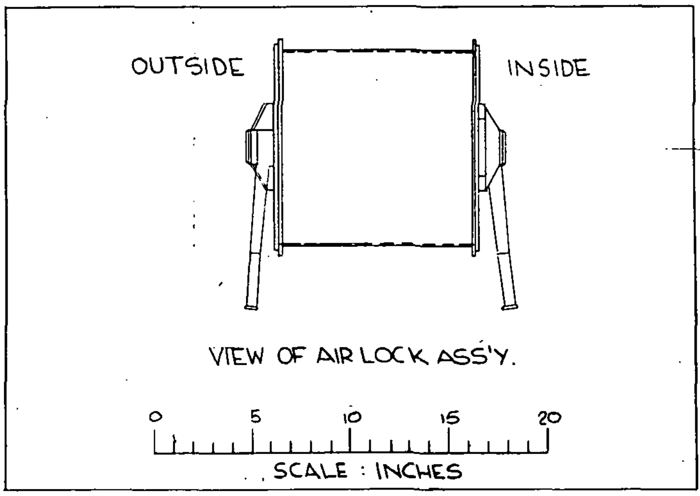


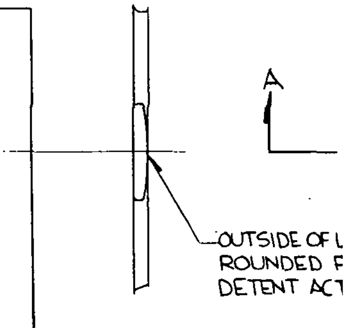
Fig. 6.1-33a Pass-through Airlock-Window Installation

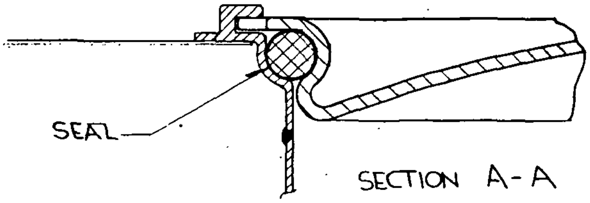


SCALE : INCHES



VIEW OF AIR LOCK ASS'Y.





SECTION A-A
TYPICAL FOR 4 LUGS
90° APART

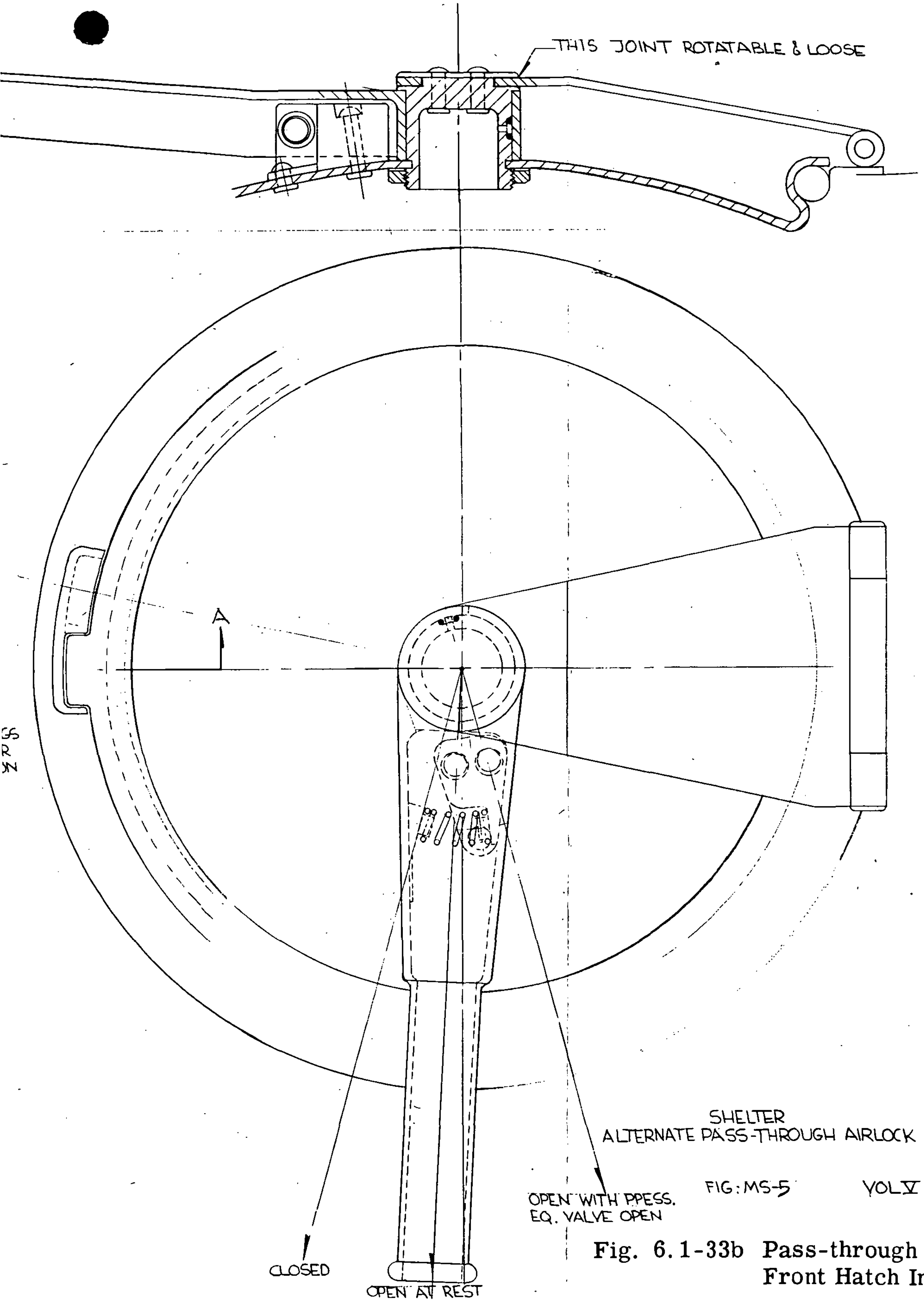
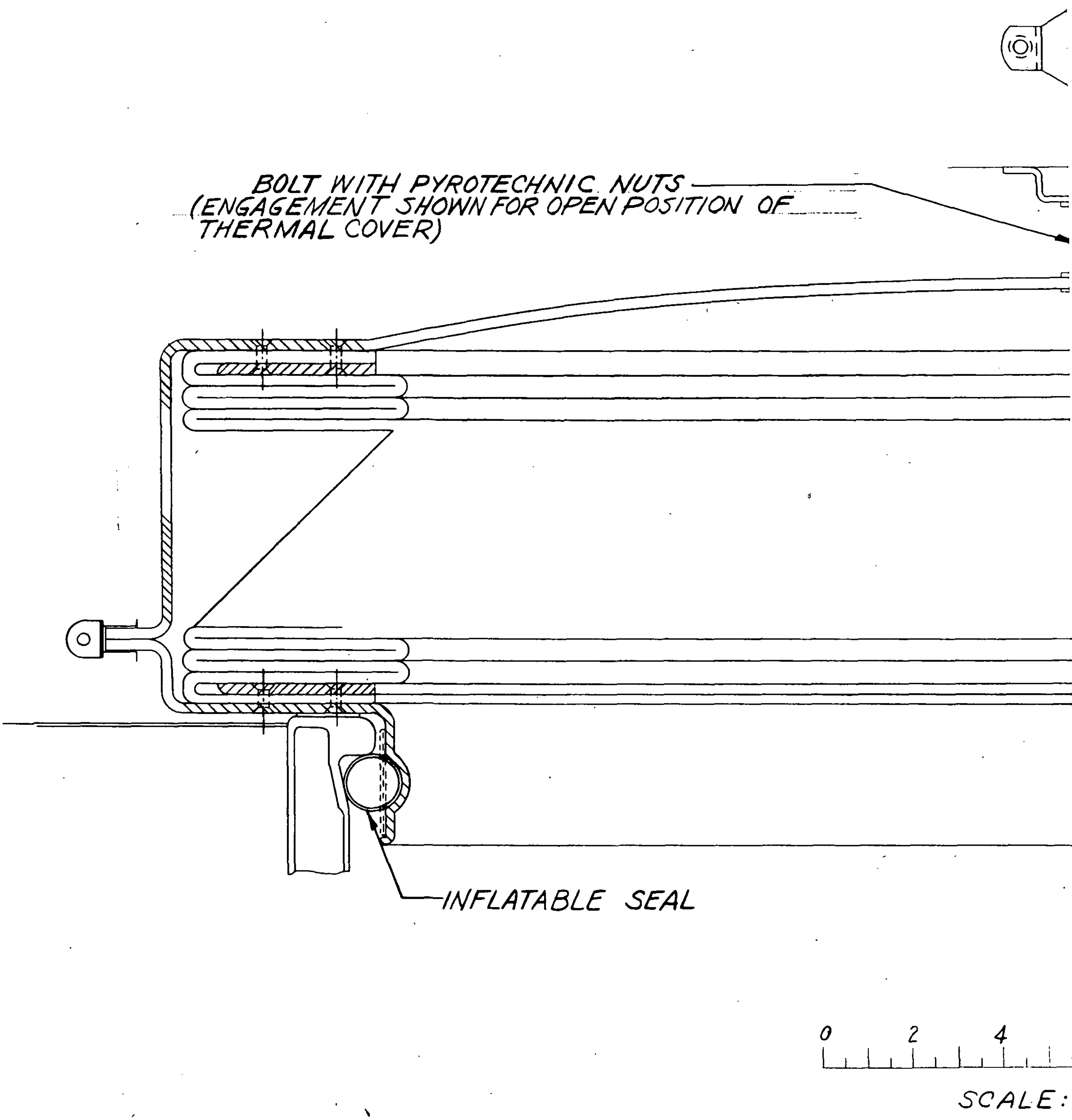
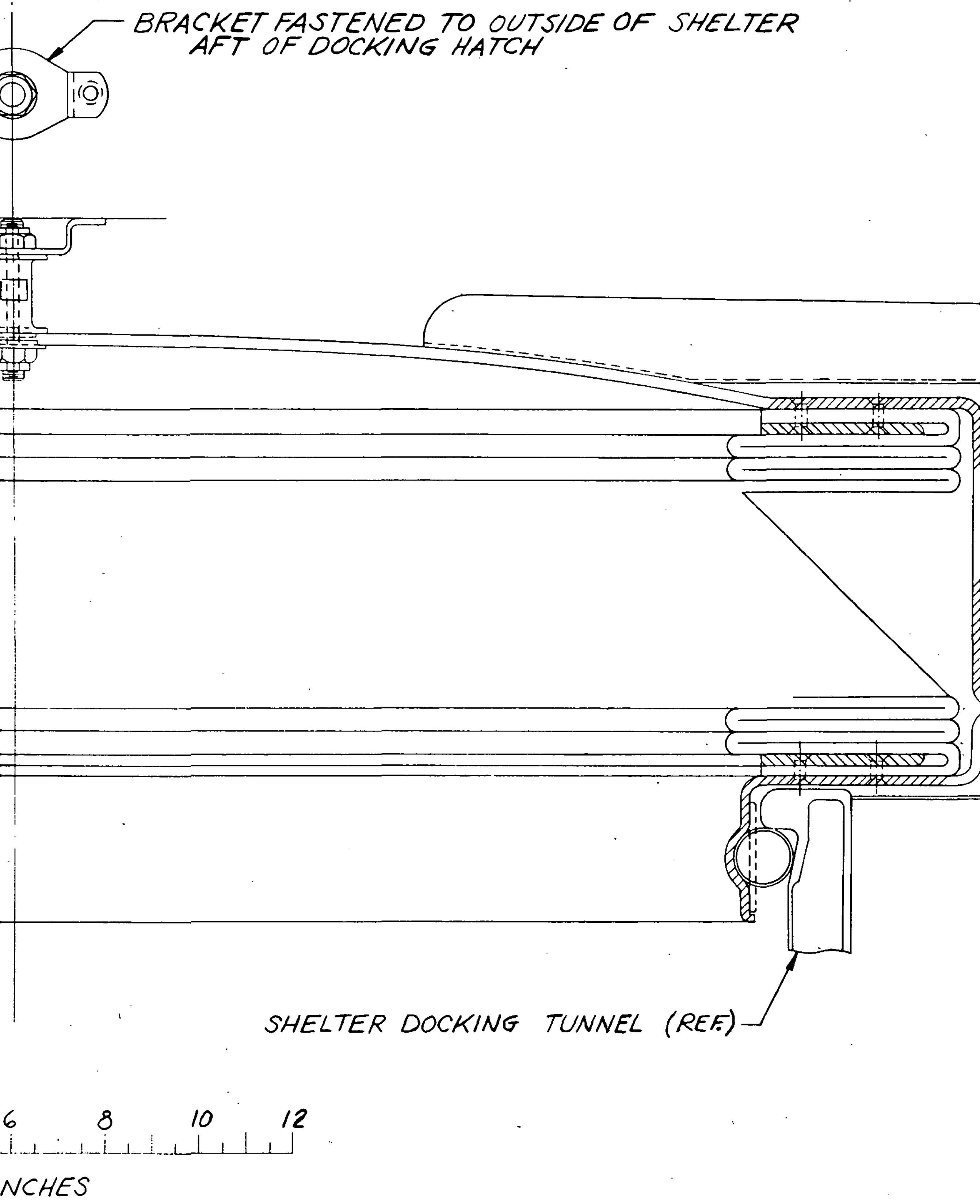


Fig. 6.1-33b Pass-through Airlock-Front Hatch Installation


BOLT WITH PYROTECHNIC NUTS
(ENGAGEMENT SHOWN FOR OPEN POSITION OF
THERMAL COVER)
INFLATABLE SEAL
0
2
4
SCALE:


BRACKET FASTENED TO OUTSIDE OF SHELTER
AFT OF DOCKING HATCH
SHELTER DOCKING TUNNEL (REF.)
6
8
10
12
NCHES

6.1-34

②

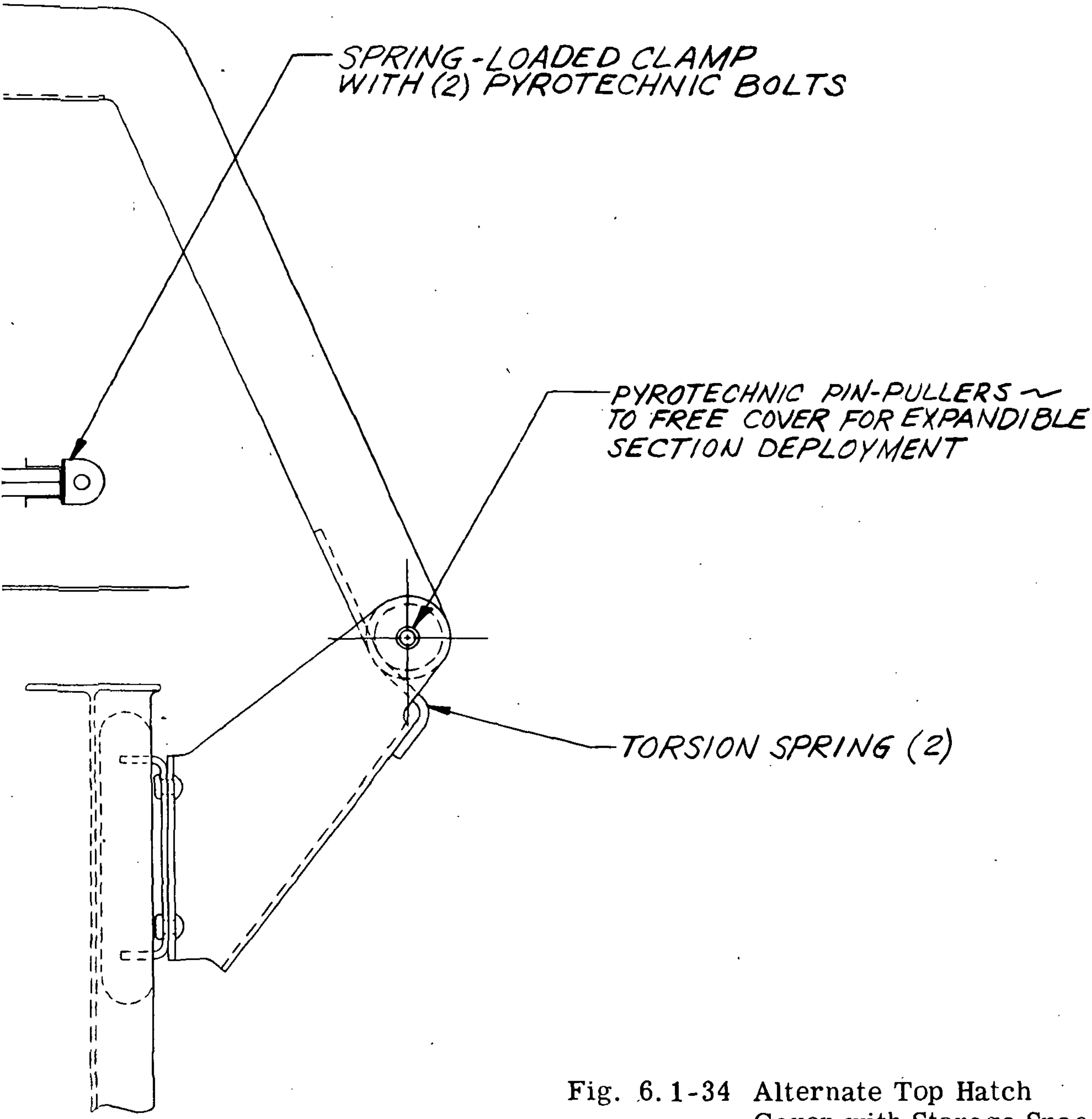
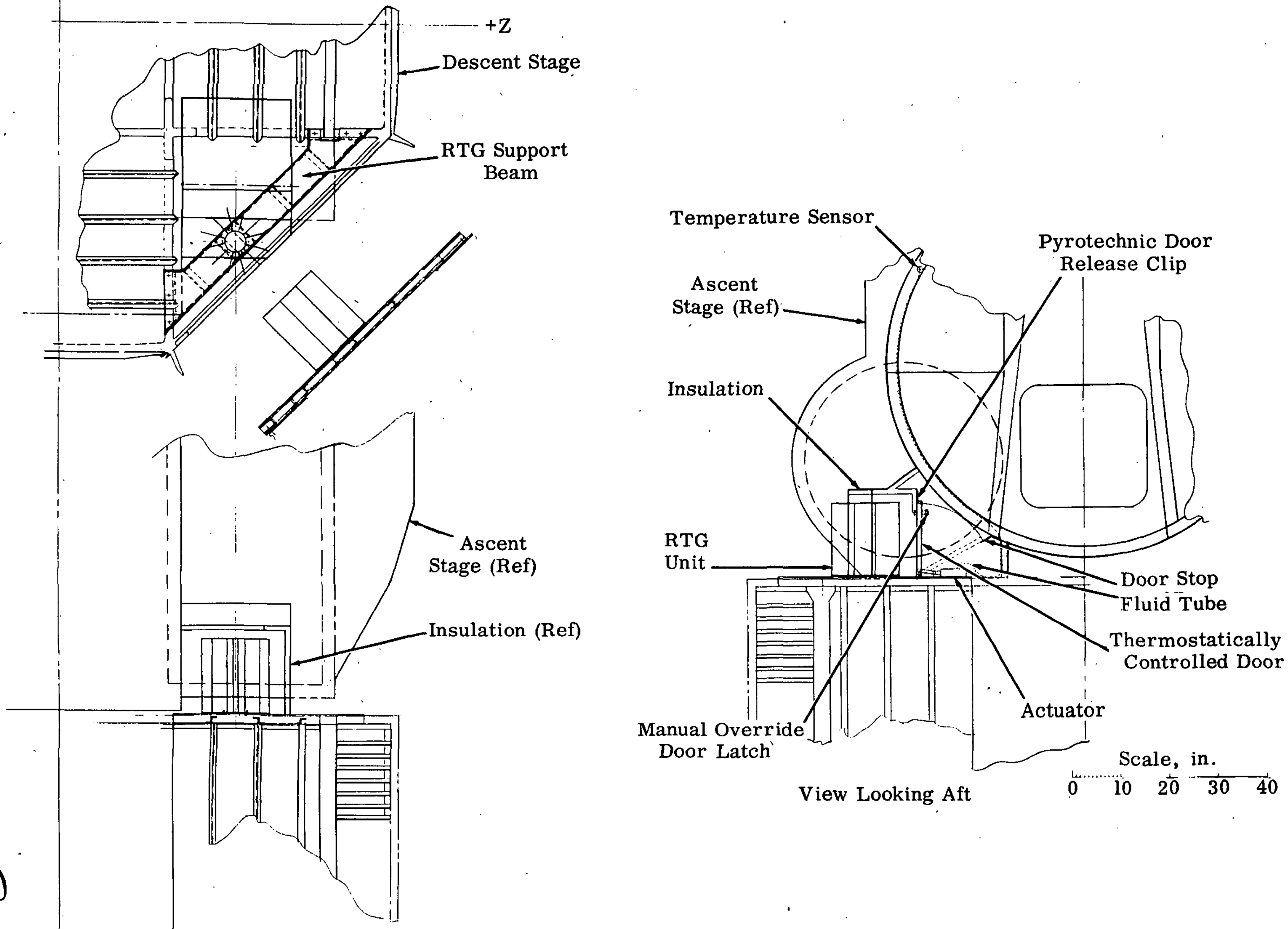


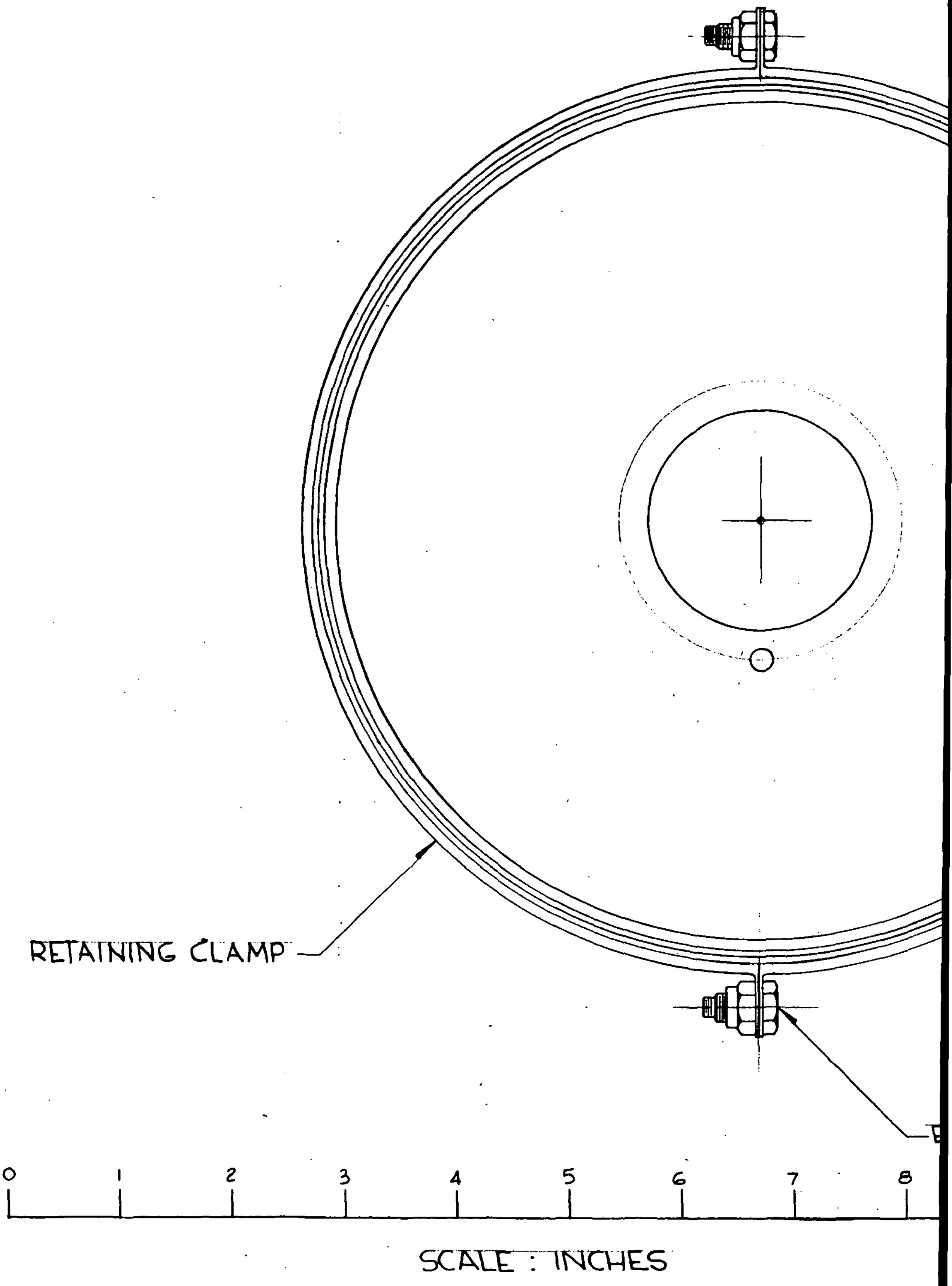
Fig. 6.1-34 Alternate Top Hatch Cover with Storage Space

③

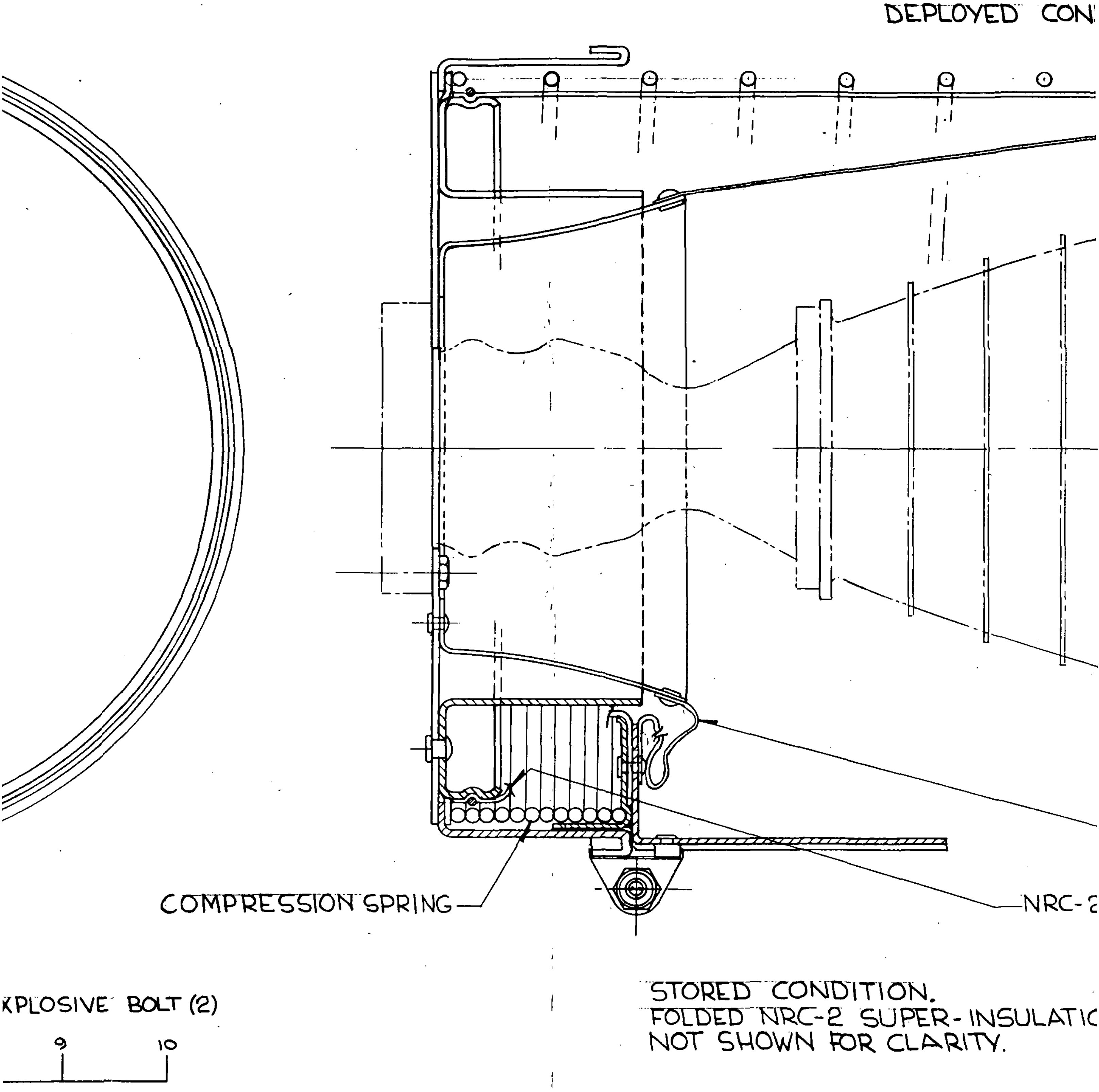


View Looking Aft

Fig. 6.1-35 Alternate RTG Installation



6.1-36
0



STORED CONDITION.
FOLDED NRC-2 SUPER-INSULATI
NOT SHOWN FOR CLARITY.

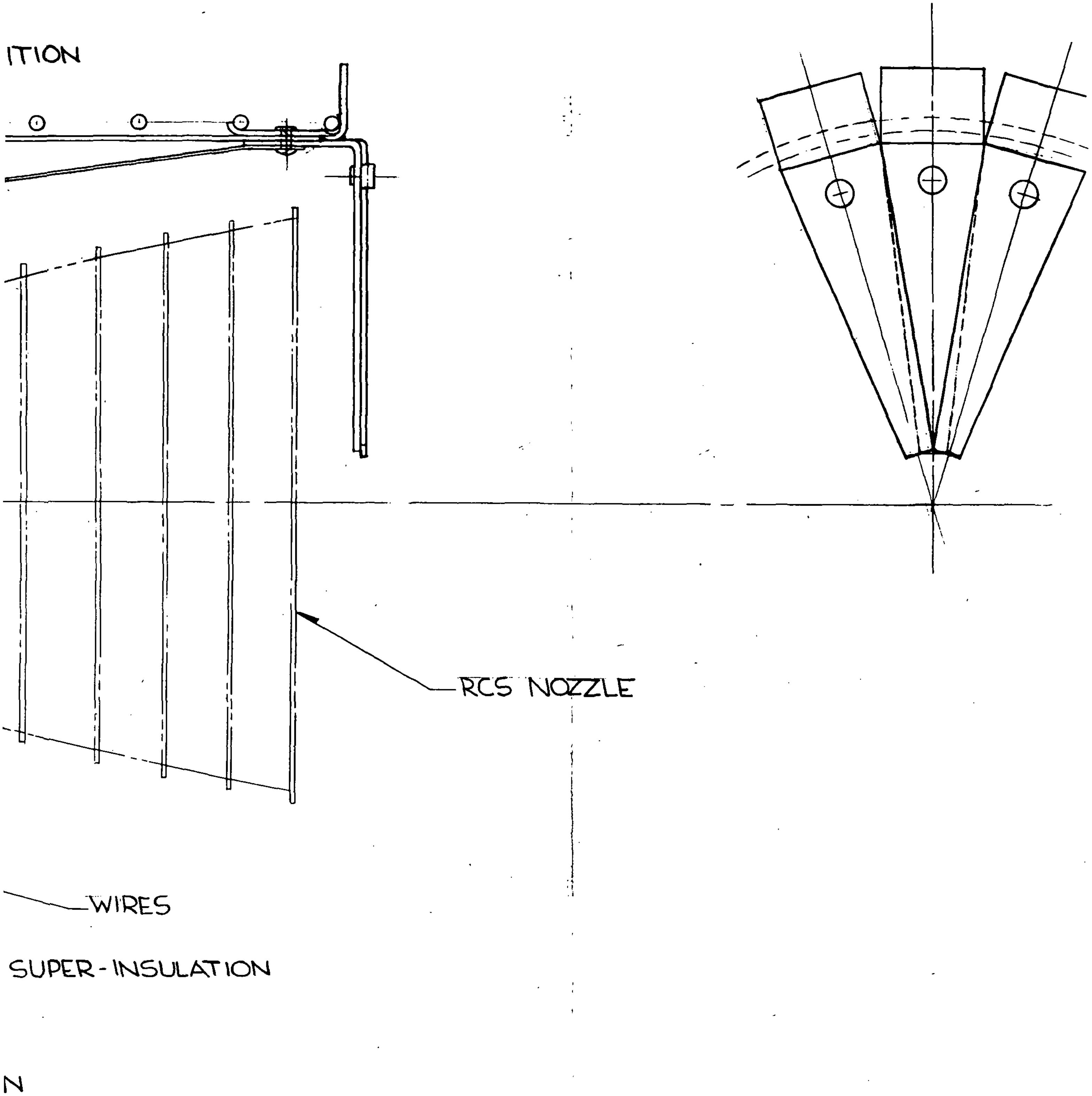


Fig. 6.1-36 RCS Thruster Cover - Individual Thruster

③

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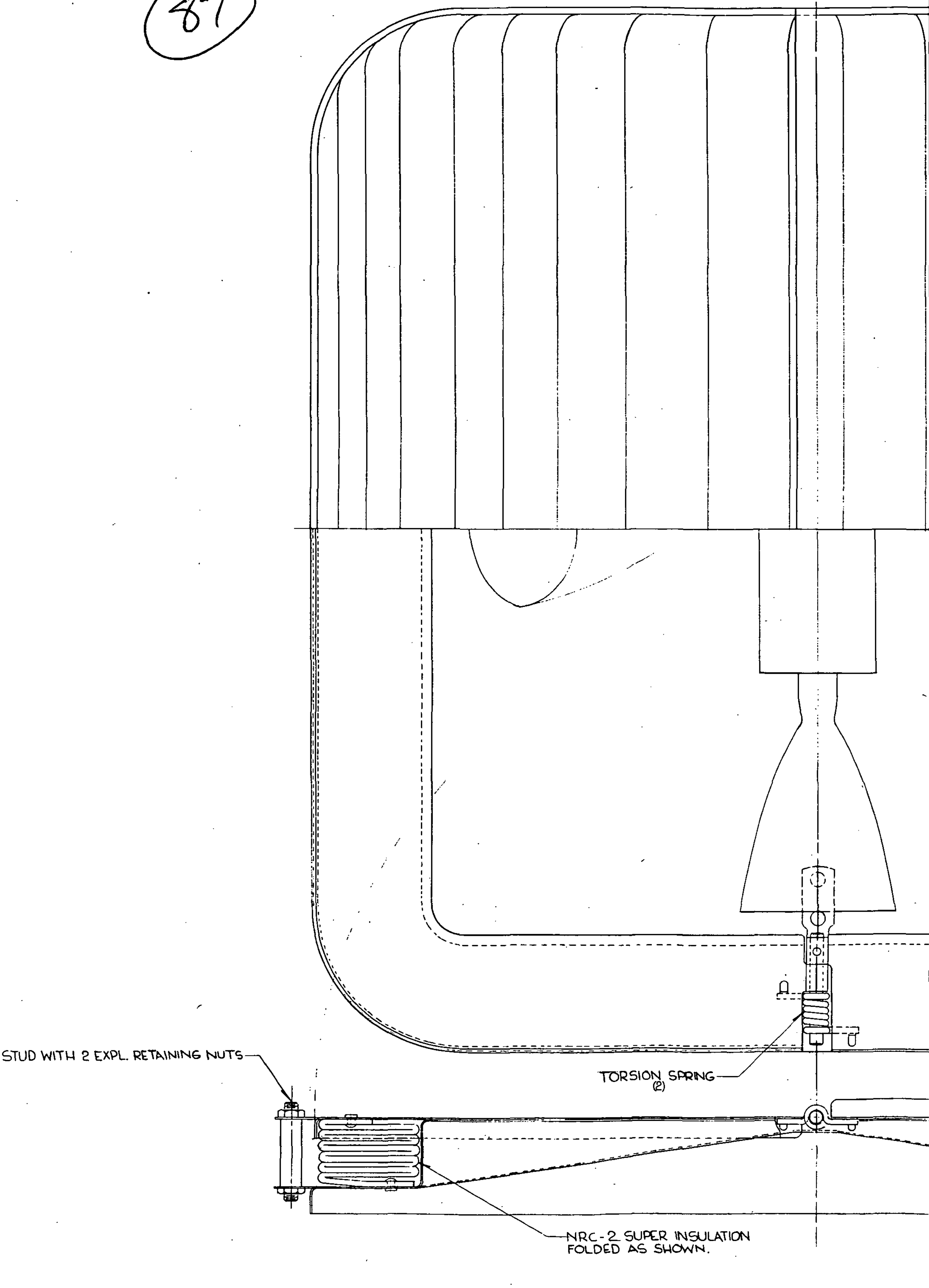
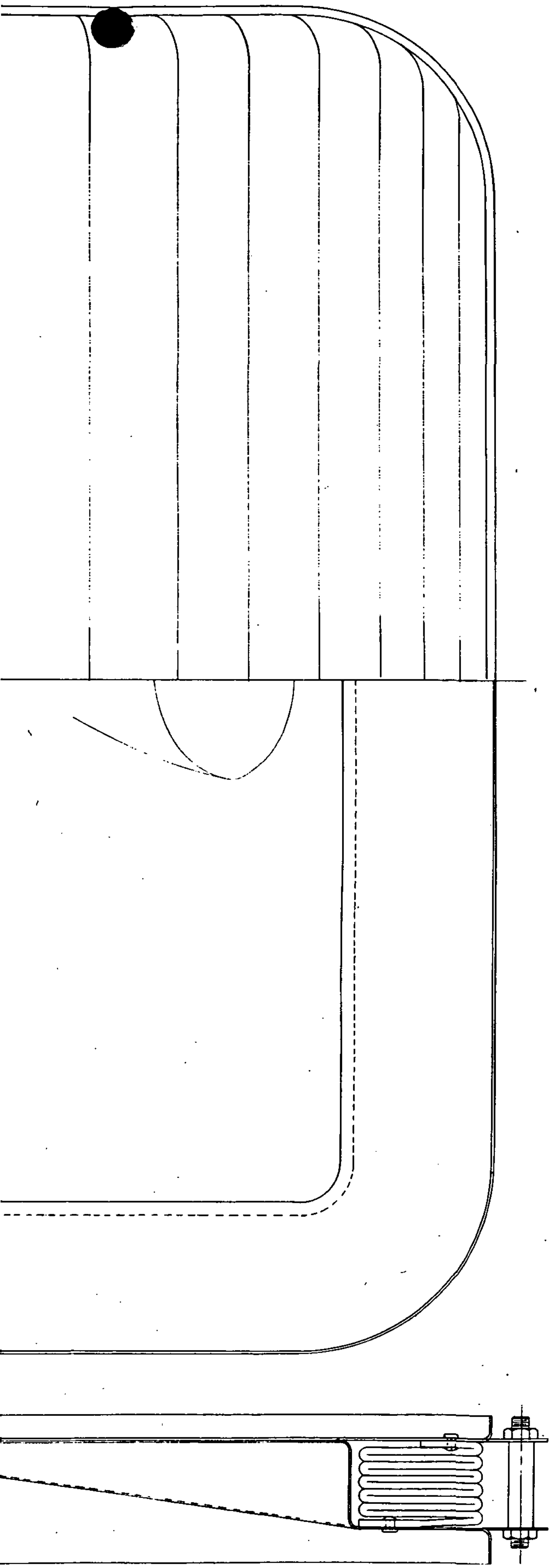
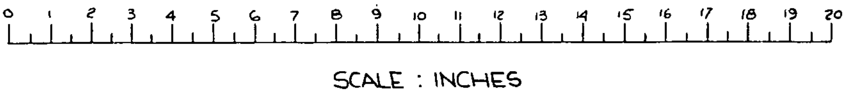
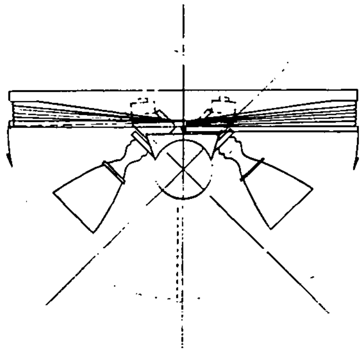

STUD WITH 2 EXPL. RETAINING NUTS
TORSION SPRING (2)
NRC-2 SUPER INSULATION FOLDED AS SHOWN.



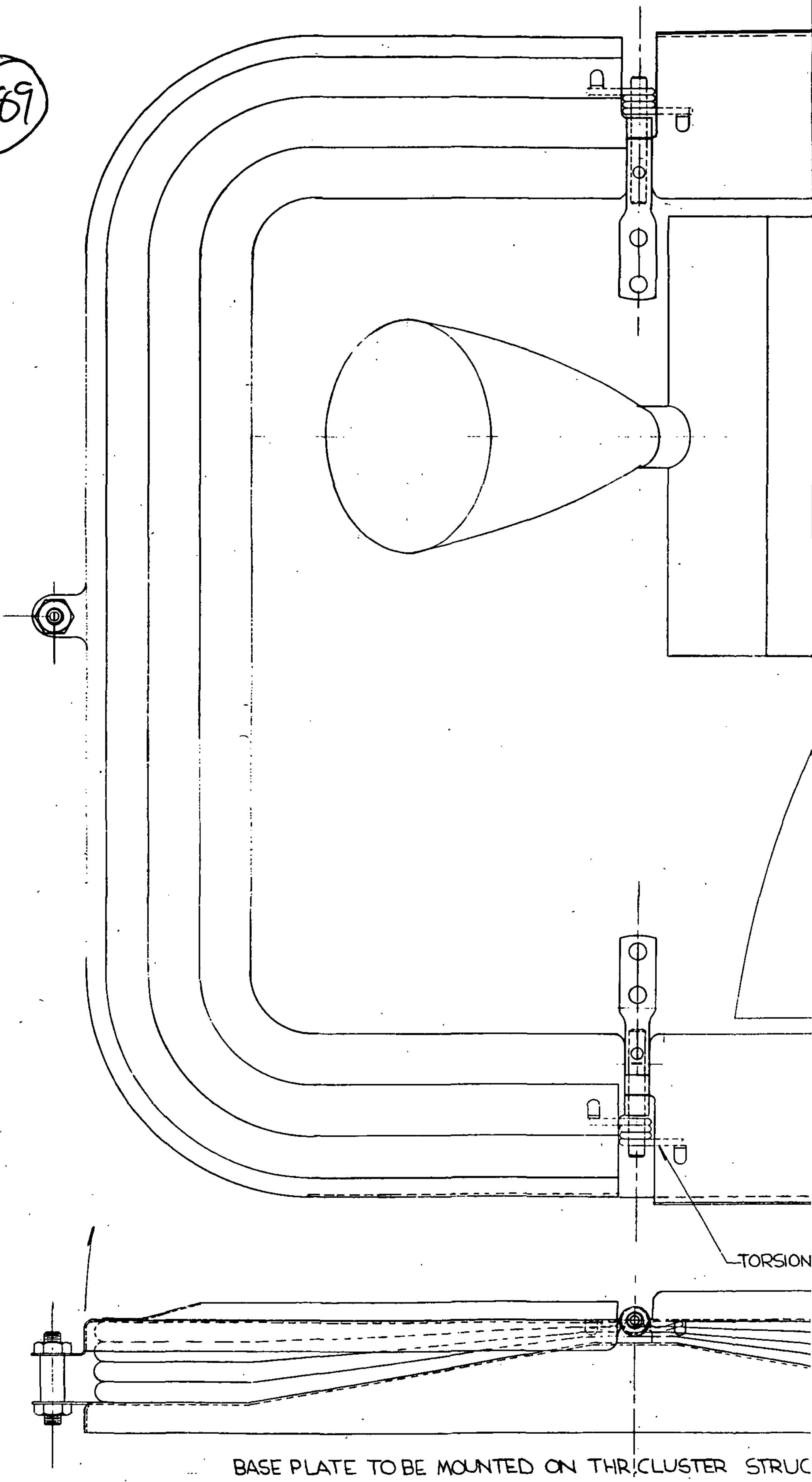




TYPICAL TOPVIEW
(REDUCED SCALE)

Fig. 6.1-37 RCS Thruster Cover - 4 Thruster Clam Shell

89



BASE PLATE TO BE MOUNTED ON THR CLUSTER STRUC

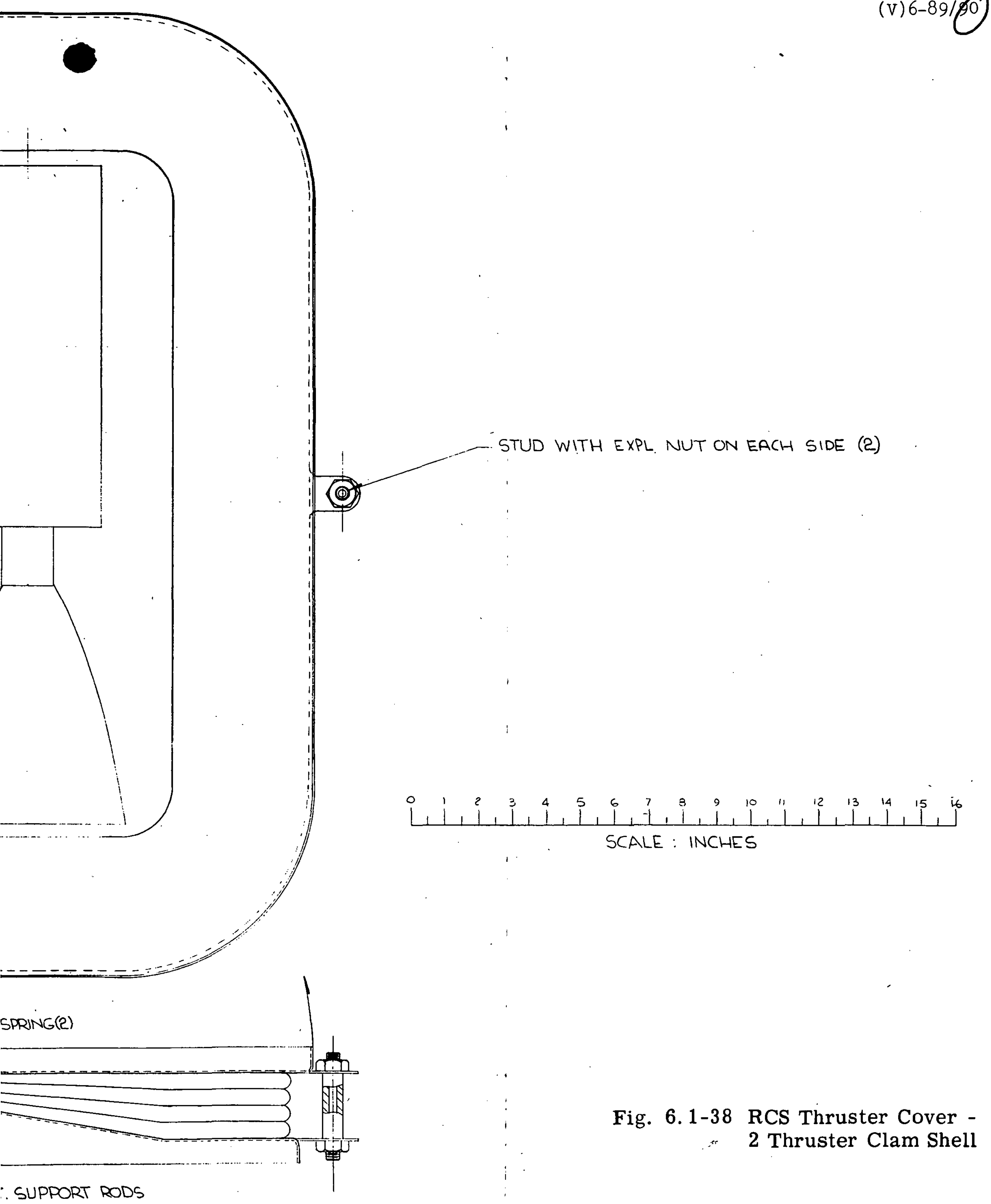
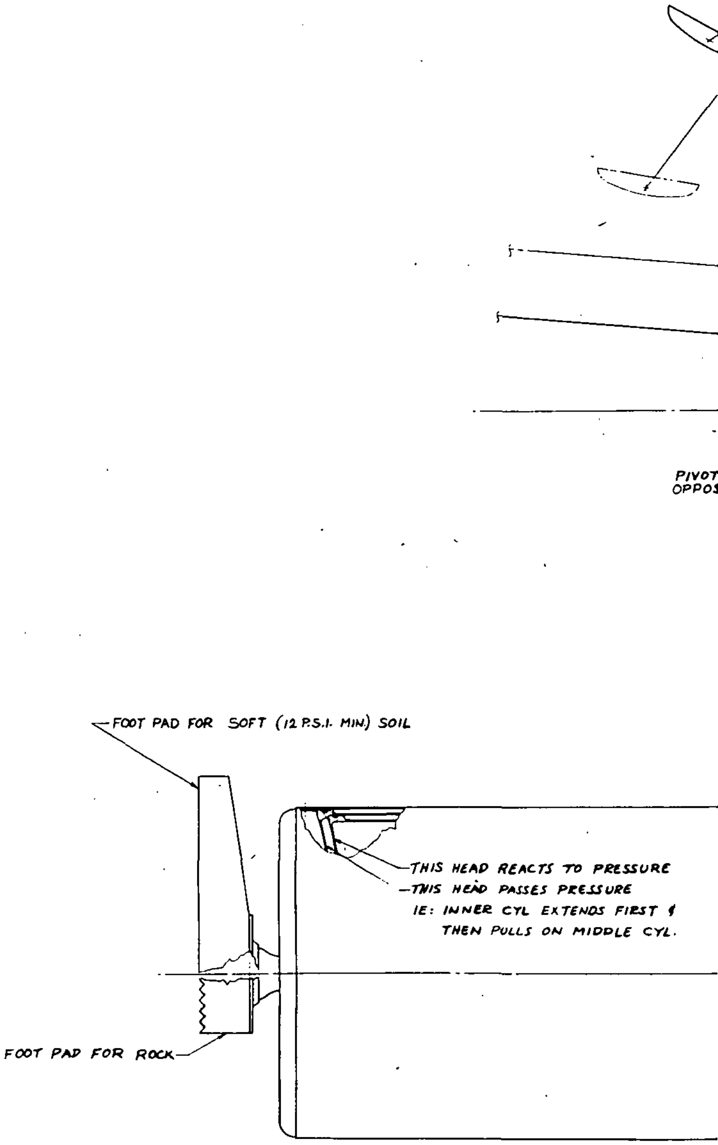


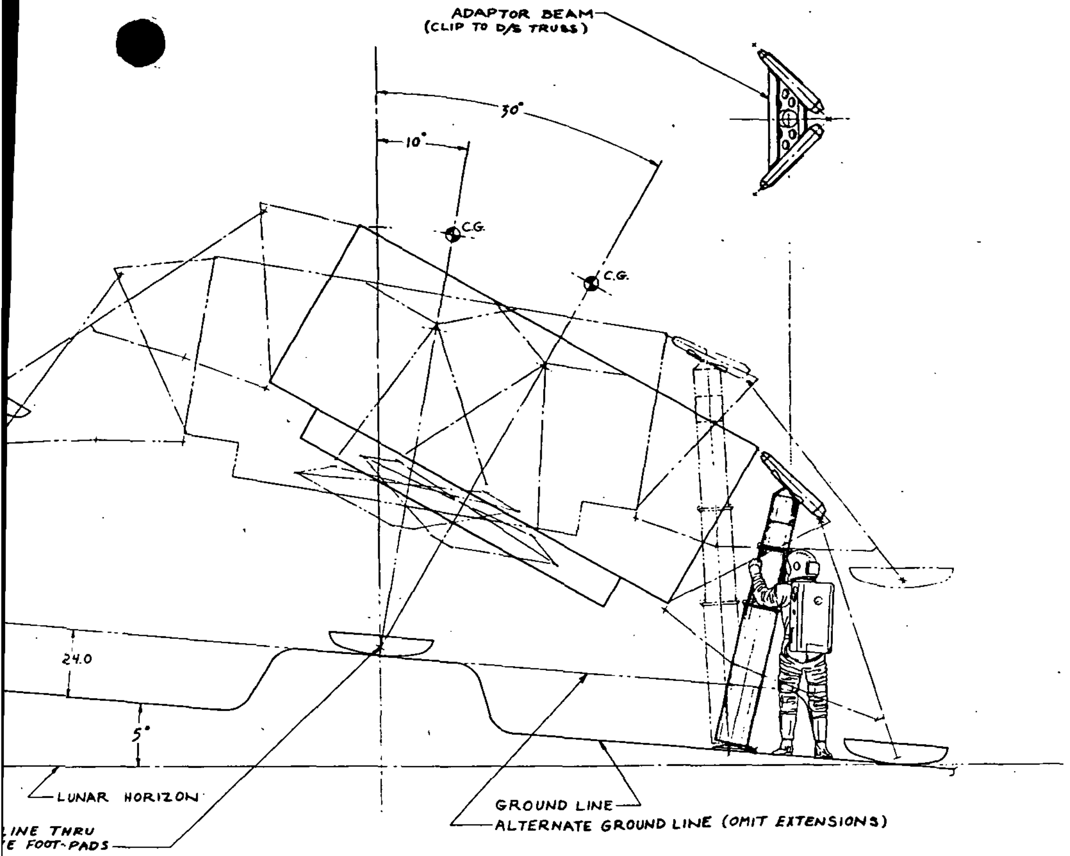
Fig. 6.1-38 RCS Thruster Cover - 2 Thruster Clam Shell

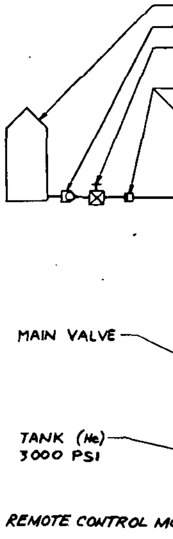
Grumman


PIVOT
OPPOS
FOOT PAD FOR SOFT (12 P.S.I. MIN) SOIL
THIS HEAD REACTS TO PRESSURE
THIS HEAD PASSES PRESSURE
IE: INNER CYL EXTENDS FIRST & THEN PULLS ON MIDDLE CYL.
FOOT PAD FOR ROCK

6.1-39

8





CONDITION I (1/20 SIZE)

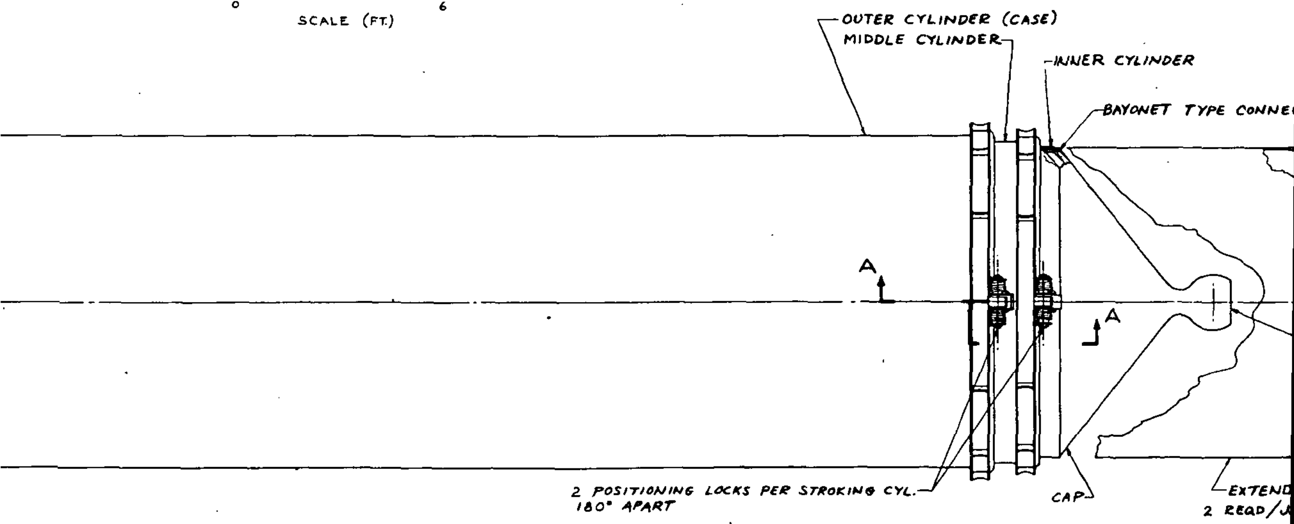
MAX 'WORST GEOMETRIC'

POST LANDING ATTITUDE

1-2-1 TOUCHDOWN

ONE JACK REQUIRED SEE NOTE #1

0 6
SCALE (FT.)



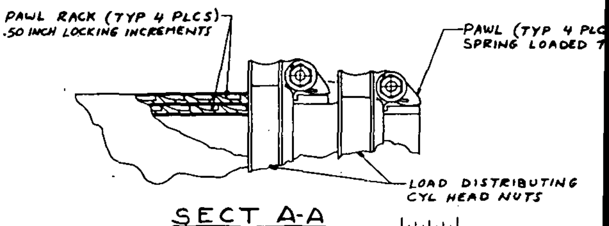
JACK (1/2 SIZE)

TELESCOPING PNEUMATIC

RETRACTED —— 62.00
MAX STROKE —— 64.00
EXTENDED —— 126.00
(WITH 2 EXTENSIONS) 145.00

.5 = DIA CYL ENGAGEMENT

0 6
SCALE (IN.)



SECT A-A
(FULL SIZE)

0 1
SCALE (IN.)

6.1-39 ②

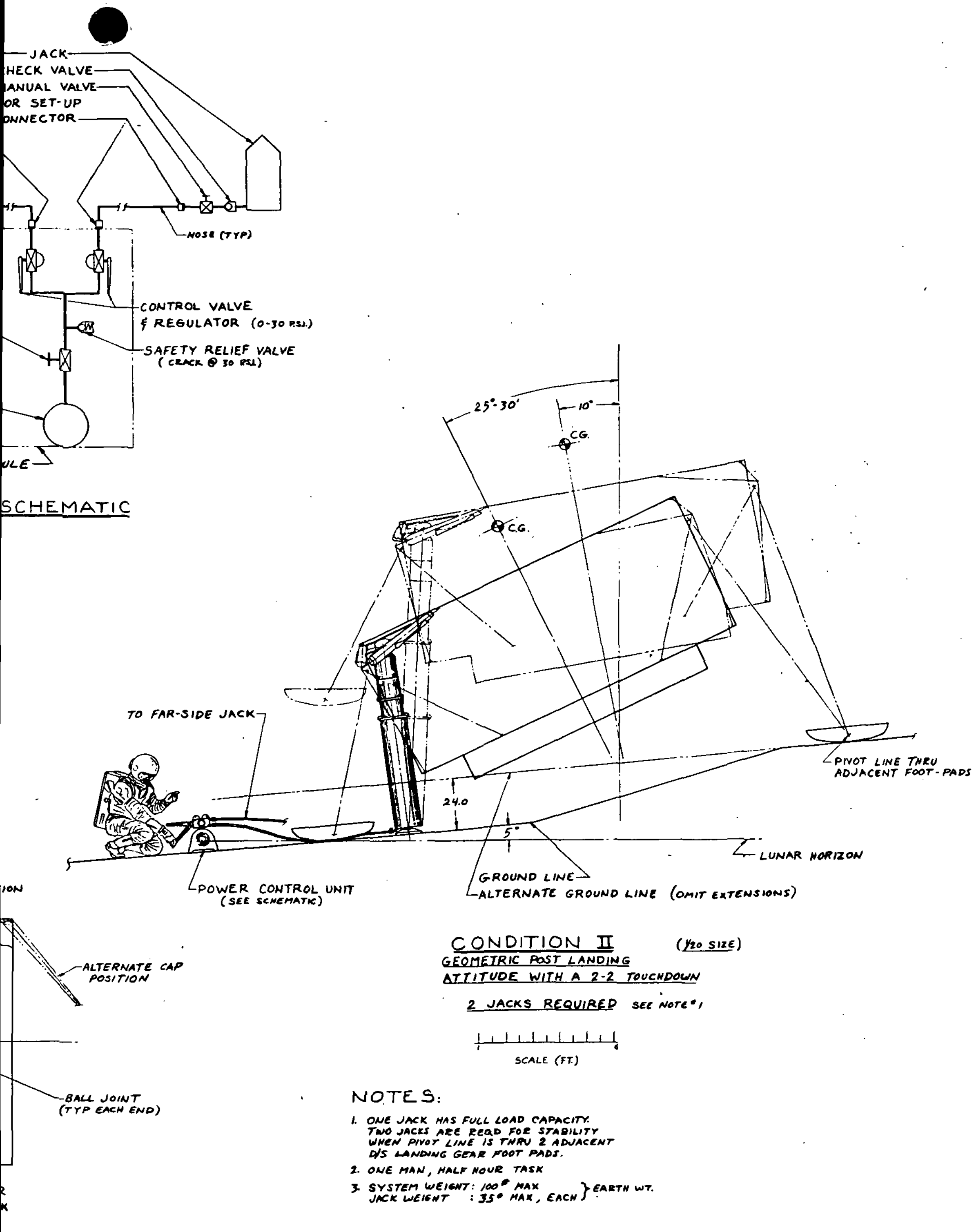


Fig. 6.1-39 Shelter Leveling System

③

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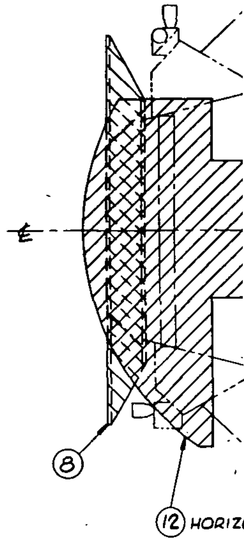
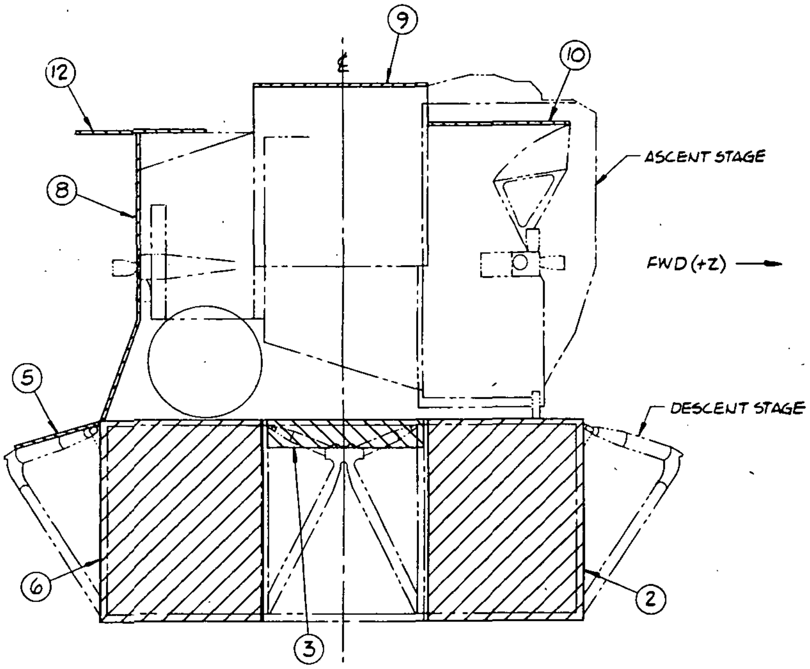
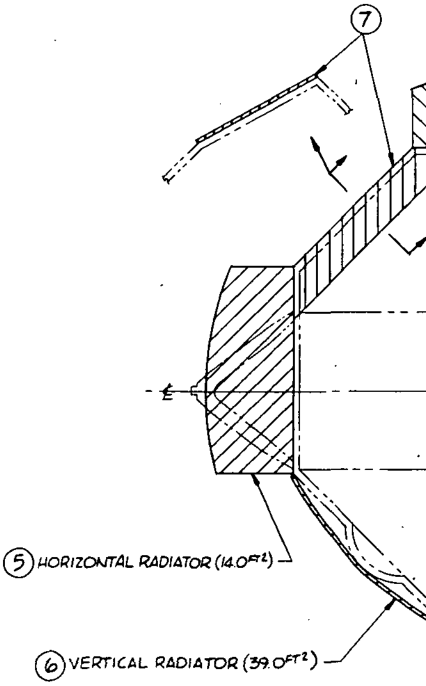
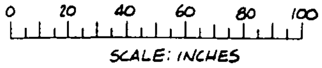


PLA

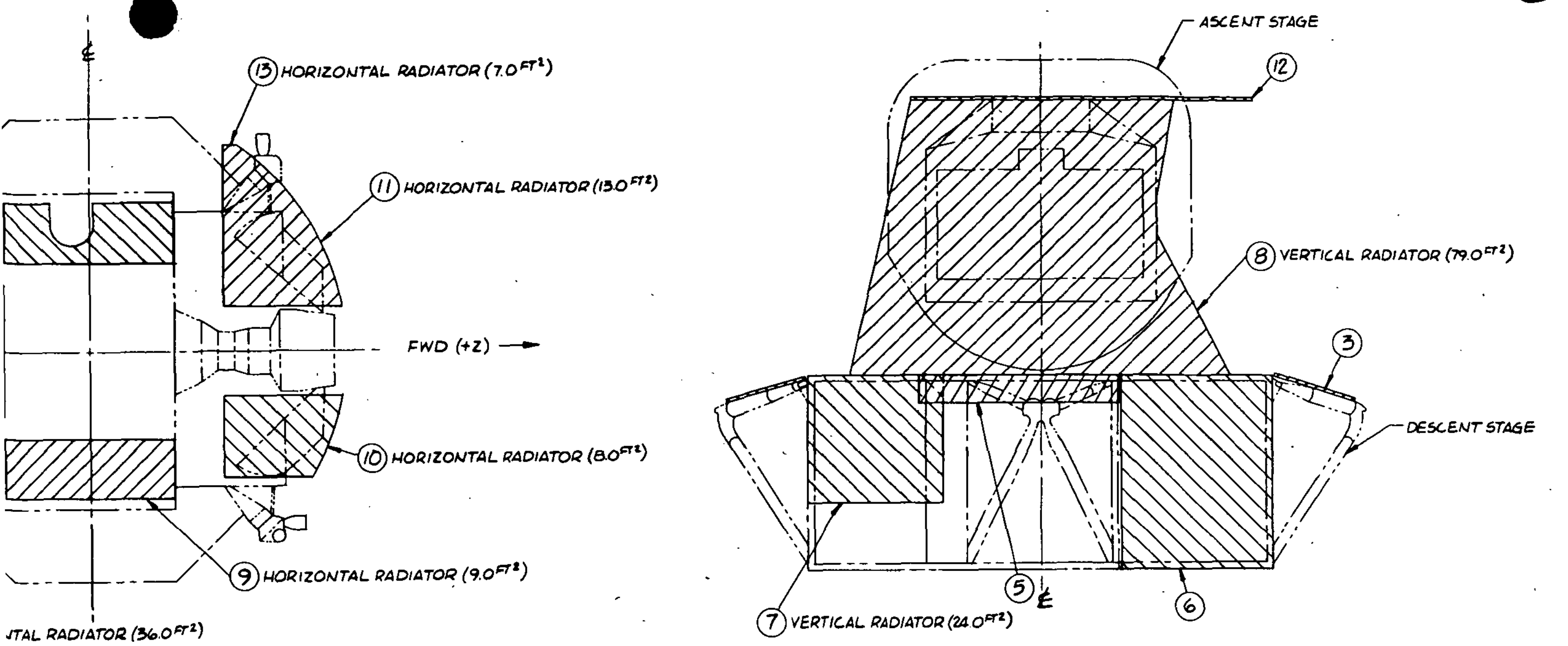


VIEW LOOKING INBOARD RIGHT HAND SIDE



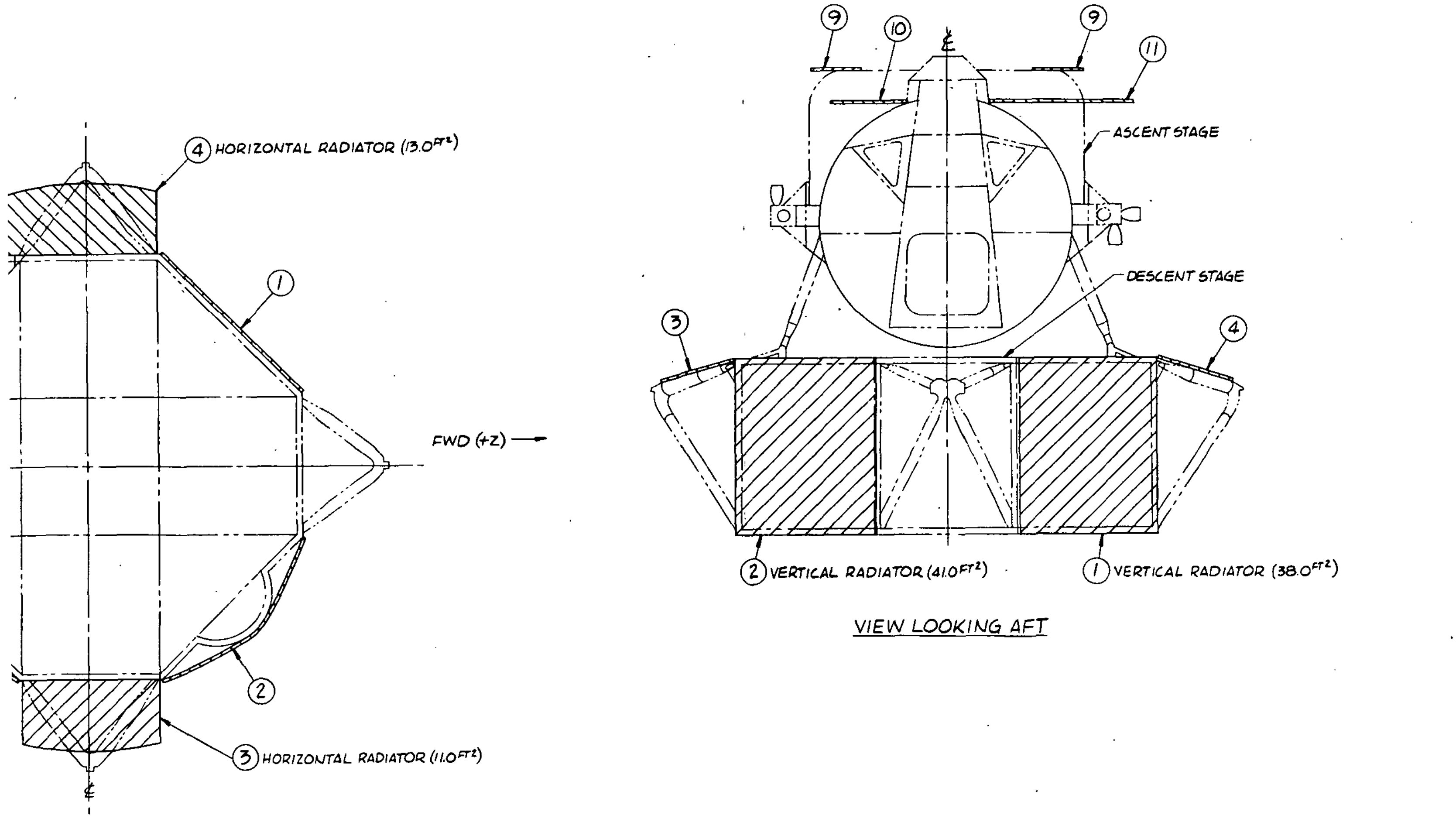


PLAN



VIEW OF ASCENT STAGE

VIEW LOOKING FWD



VIEW LOOKING AFT

EW OF DESCENT STAGE

Fig. 6.1-40 Alternate Radiator Locations

6.2 CREW PROVISIONS

6.2.1 Ground Rules

The following ground rules were applicable to this area:

- Untreated biological wastes shall not be allowed to become free residue on the lunar surface
- One hard suit will be placed in the Shelter, but consideration will be given to the possibility of incorporating two hard suits.

6.2.2 Assumptions and Background Data

It was assumed that the Shelter would be provided with the following items for the 14-day manned phase:

- Work, rest, exercise, and recreation facilities
- First aid supplies
- Personal hygiene facilities
- Waste management system
- Food, water, and food preparation facilities; the food and water quantity is based on an individual caloric intake of 3200 K calories/day
- Sleeping accommodations based on both astronauts sleeping simultaneously in soft suits.

6.2.3 Recommended Configuration

Figure 6.2-1 shows those items required for crew provisions during the lunar surface stay for the recommended Shelter. This paragraph describes how the Shelter differs from the basic LEM in those items added and removed and those items transferred from the Taxi.

The following Shelter items were added, since they are not carried on the LEM:

- Airlock
- Hard suit (1) and spare parts
- Rechargeable PLSS batteries (total 12)
- PLSS battery charger
- PLSS units (2)
- Constant wear garments (14)
- Intra-vehicular slippers (2 pairs)
- Exercise and recreation equipment
- Bunks (2)
- Work tops w/seats (2)
- Work top lights (2)
- Mid-section dome light
- Additional PLSS LiOH (total 38)
- Additional PLS LiOH (total 38)
- Additional ECS LiOH (total 14)
- Modified Apollo waste management system
- Medical supplies
- Hygienic equipment
- Housekeeping equipment
- External flood lights (2)

The following LEM components were not included in the Shelter:

- Soft suits (2) including helmets, gloves, and boots
- Liquid cooled garments (2)
- Anti-meteoroid/thermal garments (2)
- Suit repair kits & spare parts
- Crew restraints
- Bio-instrumentation
- Radiation dosimeter packages (2)
- LEM waste management
- Portable lights
- Arm rests (3)
- Translational controller (2)
- Attitude controller (1)
- TV cameras and lenses
- Cameras, film, and tape
- Specimen return containers
- Water probe.

The following is a list of items transferred from the Taxi by the crew on the Lunar surface. These items are necessary for the Taxi mission and are therefore not duplicated in the Shelter. Storage provisions, however, have been included in the Shelter for these items which are used during the 14-day lunar stay.

- Soft suits (2) including helmets, gloves, and boots
- Radiation dosimeter package (2)
- PLSS backpacks (2)
- Anti-meteoroid/thermal garments (2)
- Liquid cooled garments (2)
- Suit repair kits and spare parts
- Emergency O_2 systems (2)
- Water probe

Descriptions and discussions of pertinent equipments and concepts of the Shelter are presented in the following paragraphs.

6.2.3.1 Airlock and Spacesuits

The airlock presented is an example of the expandable type and is deployed by the crew upon activation of the Shelter. The total internal volume is 88.5 cu ft which provides sufficient room for ingress/egress and turn around in the soft or hard suit with backpack on. The design was dictated by the limited limb mobility of the soft suit and the larger size of the hard suit. The airlock is also used for storage during the surface operation phase for the hard suit.

Two soft suits are required, to be worn from the Taxi, around the Shelter, and for safety during sleep. These will be hung in front of the back wall in the midsection together with the liquid cooled garments. This will give the equipment a chance to dry out when not in use.

6.2.3.2 Controls and Displays

The panels of the cabin section consoles have been modified to accommodate the Shelter requirements as shown in Fig. 6.2-2. The console structural design has not been changed. Certain functions have been removed while others relocated to provide available area for experiment controls and displays. This available area is listed below by panel number:

Panel Number	Available Area (in.^{2})
I	327
II	41
V	149
VI	274
XII	110
Total	901

6.2.3.3 Work Stations and Seats

A lift-up work top and an adjustable, stowable, swivel seat are provided on both sides of the cabin. Lights are provided for illuminating these work tops. The work top will serve many uses, as a writing surface, for reading and recreation, for food preparation and consumption, for the performance of experiments, and any other demands that may exist.

It is felt that a 1/6g environment will necessitate the use of seats for work and rest. They may be conveniently swiveled to assume a forward, side, or rear facing position with proper console clearances. When not in use the seats may be swung to the side for storage.

It should be noted that the work tops and seat installations are common with the Phase I and Phase II Labs.

6.2.3.4 Anti-Meteoroid/Thermal Garments

Provisions for the storage of one anti-meteoroid/thermal garment with spare suit parts and repair kit is available below the right side console in the cabin section. After arriving from the Taxi, it will be necessary for the crew to remove the Program Coupler Assembly (PCA) on the left side and stow the second garment.

6.2.3.5 Food and Water

Based on 3200 K-calories/man/day, approximately 3.1 cu ft of food will be required for two men for 14 days. Water for food reconstitution, drinking, and hygiene will amount to a total of 252 lb or 4 cu ft.

Food will be the freeze-dried variety and packaged in the same manner as for LEM. Although eating will be done under 1/6g conditions, food will be reconstituted and dispensed in the same manner as for zero-g, using a water pistol. All food will be stored under the cabin section floor with lift-up panels provided. Used packaging material may be returned to the floor cavities or deposited in the waste management storage container.

Potable water will be drawn from a storage tank and will be heated or cooled as desired before reaching the water probe. If proven potable, fuel-cell generated water may be diverted to this system as required.

6.2.3.6 Bunks

Two bunks are stowed in the cabin section. They are shaped hammock-type sleeping facilities capable of being deployed quickly and simply. These are made of webbing mounted on plastic coated catenary cables without any rigid members. This permits compact rolling into a cylinder for storage. Pick-up attachment points in the Shelter and the attachment fittings or latches on the cables can be color coded for ease of assembly. Essentially, the sleeping attitude of the bunks will take the form of an inclined couch and will accept an astronaut in either a soft suit or shirtsleeve mode.

6.2.3.7 Exercise Equipment

The exercise equipment currently envisioned consists of a bicycle ergometer, hand ergometer, and bungee cord. The bicycle ergometer is mounted to the post of one seat and is stowed by swinging the main body of the unit to one side, removing the handle bars and shaft, and storing these in the left side of the mid-section of the Shelter. The hand ergometer and bungee cord will also be stored in the mid-section.

6.2.3.8 PLSS Units

Six back packs will be used for the mission. One will be stowed in the charging station in the mid-section, one in the airlock with the hard suit, and 4 outside the Shelter. As an additional consideration, two of the externally stored units may be located in the LSSM.

6.2.3.9 Lithium Hydroxide

Fourteen cabin ECS LiOH cartridges will be carried. One will be stored in the mid-section, one in the ECS unit, and 12 stored externally. Of the 38 PLSS backpack cartridges, six will be stored in the mid-section, six in the backpacks and 26 stored externally. All external storage will have suitable protection (Fig. 6.2-1).

6.2.3.10 Additional Mid-section Equipment

The following equipment will be stowed in the Shelter mid-section:

- PLSS batteries - six batteries and one charger will be carried internally, and six in the back packs
- Helmets and boots - two helmets and two pairs of boots are stowed.
- Constant wear garments - One suit/man/2 days will be provided for a total of 14. These garments will be worn while in the Shelter or under the soft suit when the back pack is not used
- Housekeeping equipment - this package shall be GFE and occupy approximately 0.25 cu ft
- Recreation equipment - this package shall be GFE equipment and occupy approximately 0.3 cu ft
- Medical supplies - this shall be GFE equipment and occupy approximately 0.5 cu ft. It is assumed that a minimum amount of "physicians handbag" equipment and clinical first aid supplies will be included

- Personal hygiene - this shall also be GFE and occupy approximately 0.6 cu ft of storage space. Shavers, cleansing pads, oral detergent agents, and other hygienic supplies will be included
- ECS - The cabin ECS and suit loop shall be retained together with the blower/heat exchanger
- Mid-section dome light - This light will be added to the ceiling on the right side behind the docking hatch. It will be used to illuminate the storage area.

6.2.3.11 Waste Management System

A modified 14-day Apollo waste management system is substituted for the LEM waste management system. The modification primarily will be in the method of packaging. In place of the ascent engine, a pressurized container approximately 21-in. dia and 40-in. deep (7.3 cu ft) is installed below the floor of the mid-section. Its cover opens aft into the Shelter. This container accommodates a lift-up fecal canister with urine flex hose, urine disposal lock with disinfectant, blower, check valves, back-up valve, selector valve, piping, plastic fecal bags, and a waste storage compartment for solids. Lines will run to the ECS package and to a special heated nozzle for ejecting treated urine overboard. Sufficient storage can be provided in the waste compartment to take other solid wastes accumulated during the 14 days; 1.6 cu ft would be sufficient for all wastes.

6.2.3.12 Storage During Liftoff

Items such as the hard suit and externally stored LiOH back packs, and other units will be tied down at various locations inside the Shelter, during lift-off. Since the Shelter will be remotely landed, a clear path through the vehicle must be provided for the manned checkout which is conducted prior to separation.

6.2.4 Baseline Configuration

The baseline configuration is the same as the recommended configuration less the following:

- Airlock
- Emergency O_2
- Work top lights
- Hygienic equipment
- External flood lights.

6.2.5 Alternate Configuration - Airlocks

The recommended configuration provides an airlock which will save cabin air and serve as storage for the hard suit and one back pack. An alternate to this is no airlock. In this case, additional storage would have to be provided outside the Shelter to accept the hard suit or back pack, or the back pack could be mounted on the inside of the front hatch which requires structural modification. A second alternative would be to store the hard suit internally which will be discussed later.

A series of alternate airlock designs are presented in Fig. 6.1-31; structural aspects are discussed in Paragraph 6.1. The man/machine relationship is as follows:

- Fig. 6.1-31a defines a cylindrical airlock volume of 90 cu ft. Ingress is made head first from the bottom of the cylinder through a hatch diameter of approximately 36 in. Tests have shown that 32 in. is the acceptable minimum with back pack on. Aside from structural, stowage, and erection problems,, remote operation of the external hatch would be necessary.
- Fig. 6.1-31b also represents a cylindrical airlock. Its volume is between 85 and 90 cu ft. Improved stand-up entry is made through the front. Shoulder clearance through the rectangular hatch measures about 30 in., which would be sufficient for this type of entry. However, kneeling down to crawl forward to the Shelter hatch would be tight. Structural, stowage, and erection problems are the same as the first airlock. In addition, a second ladder would be required for entry.
- Fig. 6.1-31c airlock defines a volume of 85 cu ft. The relative position and mode of entry of this airlock is the same as the airlock shown in Fig. 6.1-31b. It differs, however, in the fact that it utilizes an expandable material and provides a pressure zipper for stand-up side entry. This would present ingress problems in passing the body and back pack. However, a rigid hatch could be substituted.
- Fig. 6.1-31d airlock is a variation of the recommended expandable airlock. It contains a minimum internal diameter of 34 in. and a volume of 80 cu ft as compared to the 40 in. and 88.5 cu ft of the recommended airlock. Turn-around would not be possible, however, even at the largest diameter.
- Fig. 6.1-31e presents a departure from the designs illustrated thus far. Ingress is made into the 85 cu ft volume in a stand-up position. Its shape lends well to internal maneuvering as well as donning and doffing the back pack. However, this configuration involves structural redesign of the forward face beams.

6.2.6 Alternate Configuration - Expandable Pressurized Storage Container

Fig. 6.2-3a presents an expandable-type pressurized storage volume added above the docking tunnel. This unit also acts as a heat shield during storage time and is deployed when the crew arrives. Structural aspects have been discussed in Paragraph 6.1. A total volume of approximately 50 cu ft is available. The hard suit and both soft suits could be hung in this volume. This compartment will also have sufficient volume to accommodate the storage of two hard suits and their associated spare parts as illustrated.

6.2.7 Alternate Configuration - Urine Storage Facility

The recommended waste management system will have treated urine dumped overboard through a heated nozzle in conjunction with the fuel cell water dump line. If further study shows that it is not necessary to dump fuel cell water, it is suggested that urine be stored aboard the Shelter. This would eliminate the water dumping hardware, save power, and avoid penetrating the pressure shell. Fig. 6.2-3b illustrates the incorporation of a treated urine storage tank in the waste management system. This tank would accept only urine and would be properly sealed and vented internally. A total of approximately 89.6 lb of urine would be accumulated for the 14 days, and would require a storage volume of 1.6 cu ft which includes a 10% safety margin.

6.2.8 Alternate Configuration - External PLSS Recharging Station

Four back packs will be stored outside of the Shelter and used for the scientific excursions. Recharging will be required periodically inside the Shelter, which necessitates carrying the packs in and out. This forces extra repressurizations. As a supplement to the internal charging station Fig. 6.2-3c illustrates the addition of an external charging station. Additional hardware would include an external water and oxygen tap. Reloading of the LiOH would be simplified since 26 cartridges are externally accessible.

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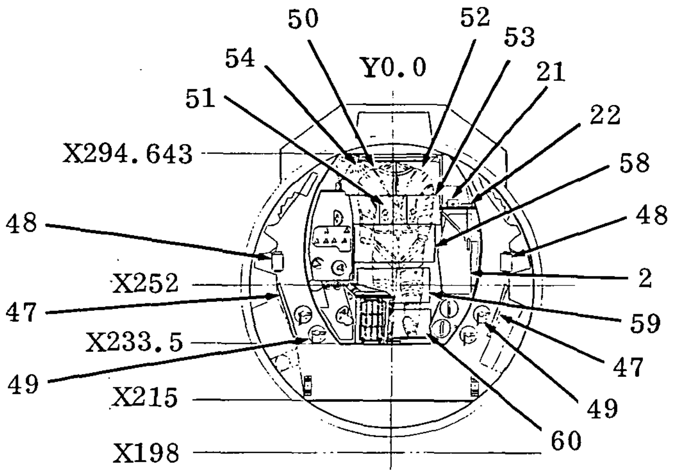
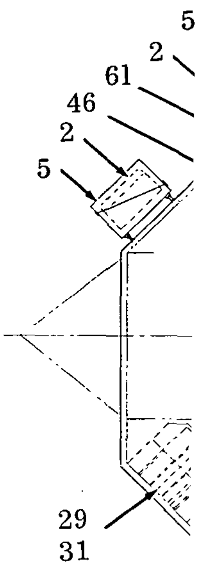
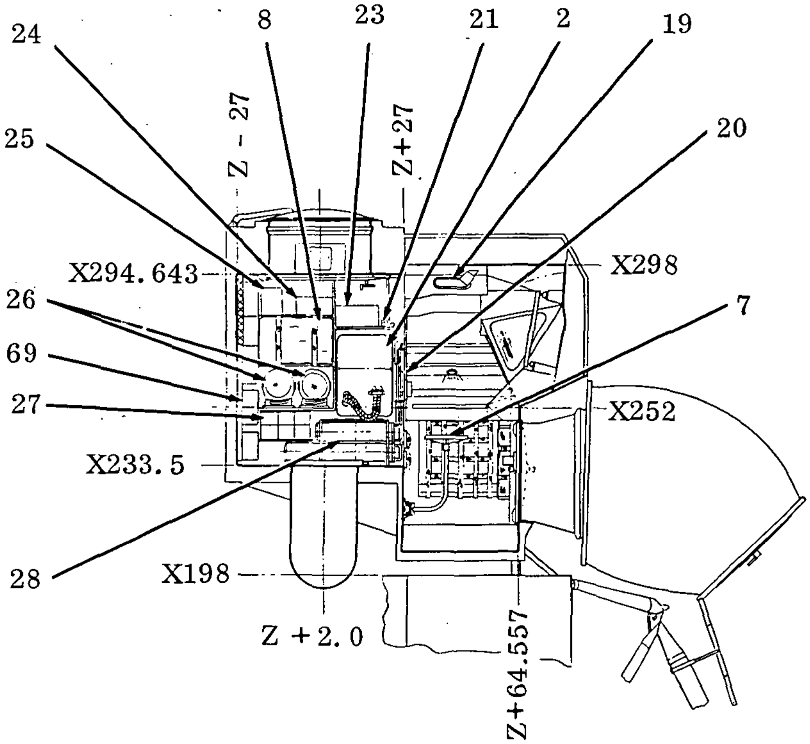
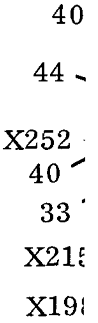


View Looking Aft At Z + 27.0







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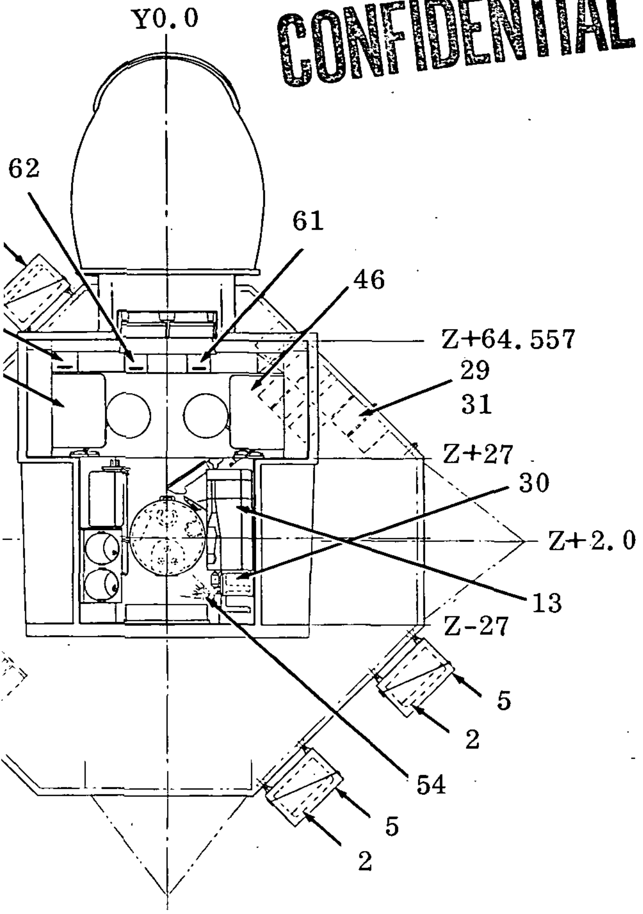
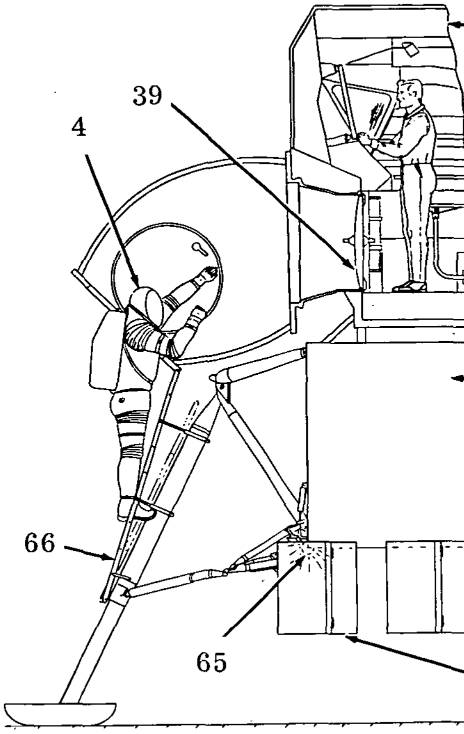
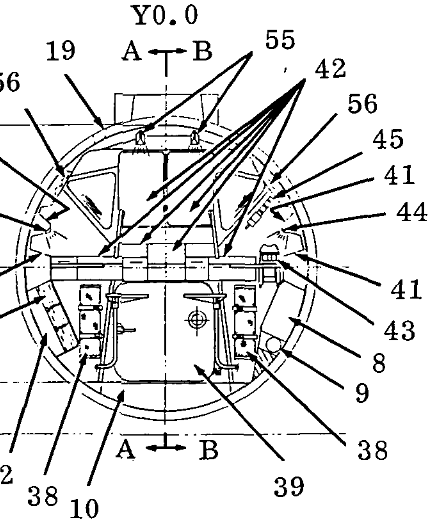


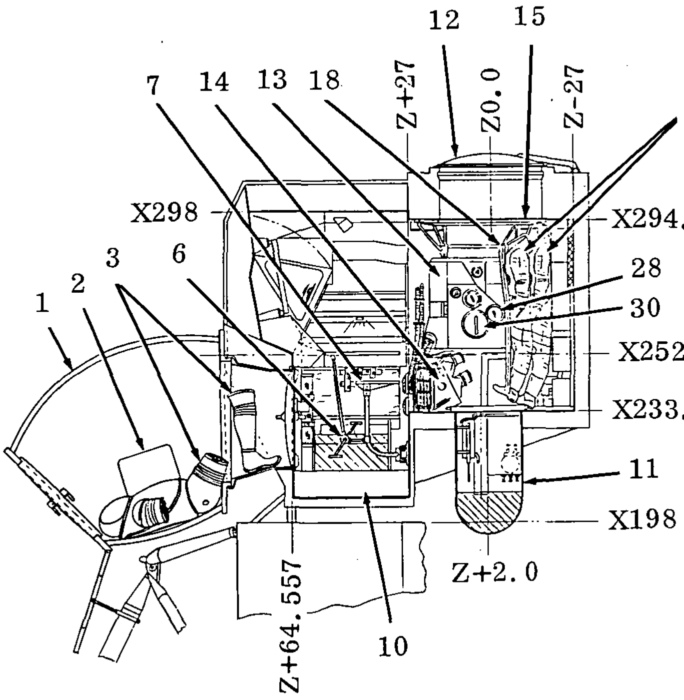
Plan View



Entering Airlock



Looking Fwd At Z+27.0



Section B-B View Looking Outb'd - R. H. Sid

6.2-1
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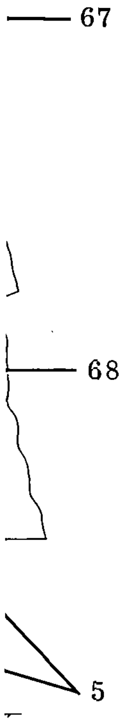
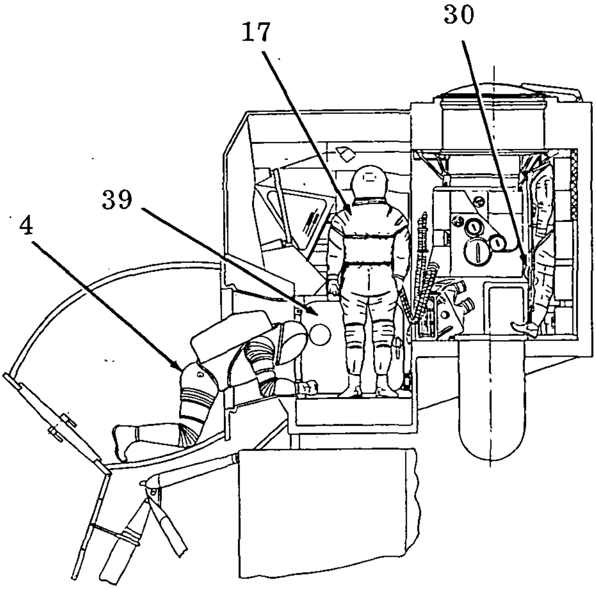
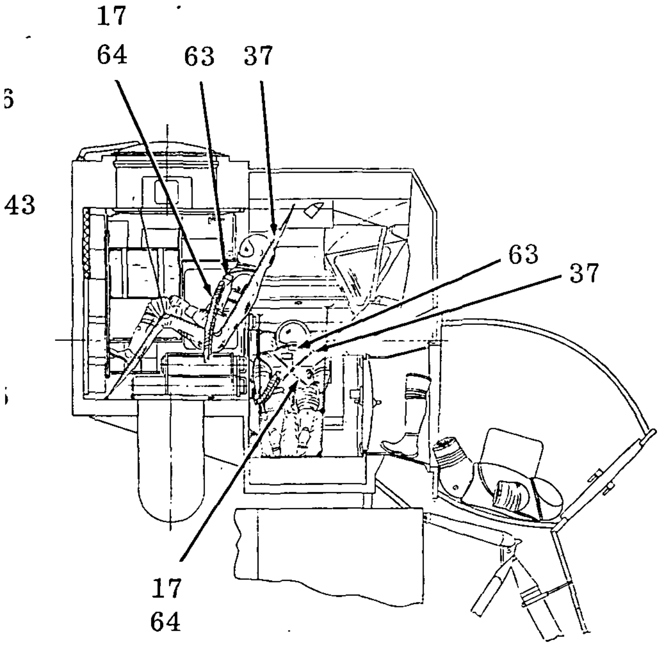
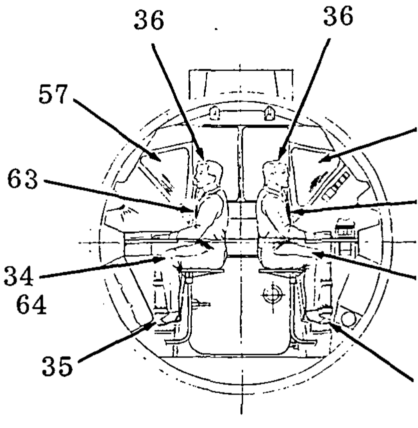




Entering Cabin Through Airlock



Sleeping Arrangement
In Mid and Cabin Section



Crew At Work Stations

6.2-1

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Key

1. Airlock (Expandable Type)
2. PLSS (6, Including Six Batteries & Six LiOH)
3. Hard Suit (Stored)
4. Hard Suit (Worn)
5. PLSS External Storage Facility (4)
6. Exercise Equipment - Bicycle Ergometer
7. Adjustable & Stowable Swivel Seat (2)
8. Anti-Meteroid/Thermal Garment (2 Stored)
9. Suit Servicing Kit (2)
10. Food Storage (3.1 cu. ft.)
11. Waste Management System
12. Upper Thermal Hatch
13. ECS Pkg (Suit And Cabin)
14. Blower/Heat Exchanger
15. Upper Hatch (Docking)
16. Soft Suit (2, Stored)
17. Soft Suit (Worn)
18. Water-Cooled Garment (WCG, 2, Stored)
19. Docking Window
20. PLSS Recharging Umbilical (2)
    Waste Management Urine Umbilical
21. PLSS Calibration Unit
22. Water Probe
23. EVA Boots (2 Pairs Stored)
24. Intravehicular Slippers (2 Pairs, Stored)
25. Exercise Equipment (Stored)
    - Bungee Cord
    - Hand Ergometer
26. Soft Suit Helmet (2, Stored)
27. PLSS Batteries (6, Stored)
28. PLSS LiOH Cartridge (6, Stored Internally)
29. PLSS LiOH Cartridge (26, Stored Externally)
30. ECS LiOH Cartridge (2, Stored Internally)
31. ECS LiOH Cartridge (12, Stored Externally)
32. Program Coupler Assembly Structure
33. Constant Wear Garments (CWG, 14, Stored)

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6.2-1

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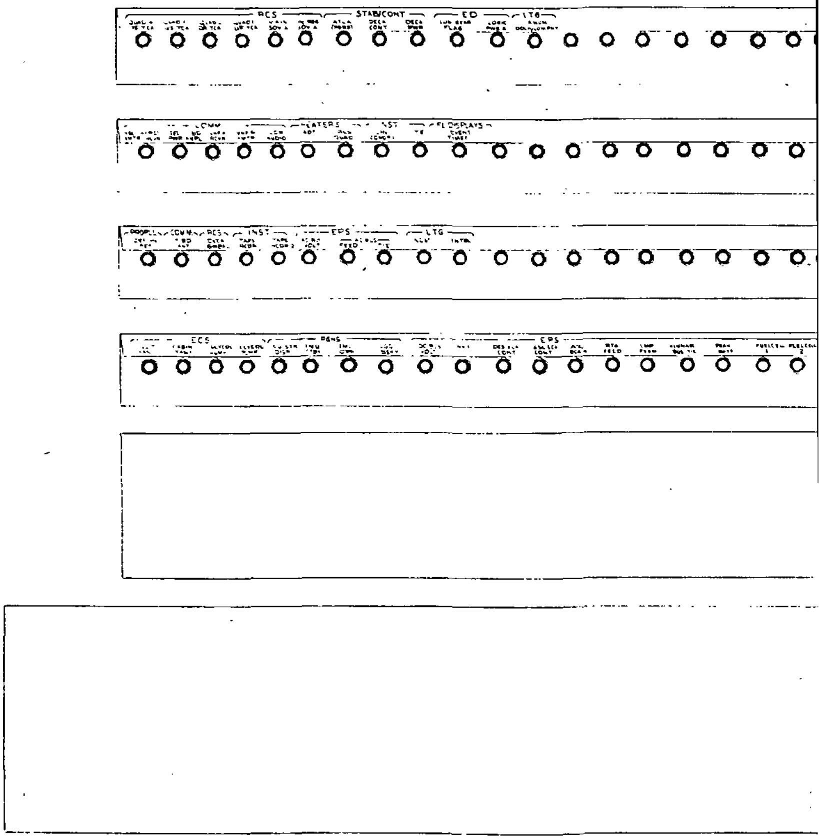
4. CWG (Worn)
5. Intravehicle Slippers (Worn)
6. Crew (2) In CWG
7. Bunk (2, Deployed)
8. Bunks (Stored)
9. Front Hatch (Ingress/Egress)
0. L. H. Control Panels
1. R. H Control Panels
2. Front Control Panels
3. Attitude Controller & Arm Rest
4. Work-Top Light (2)
5. Radiation Survey Meter
6. Work-Top (2) Deployed
7. Work-Top (Stored)
8. Voice Storage Recorder (2)
9. Emergency Oxygen Equipment (4)
0. Personal Hygiene Equipment (Stored)
1. Housekeeping Equipment (Stored)
2. Medical Equipment (Stored)
3. Recreation Equipment (Stored)
4. Mid-Section Dome Light
5. Cabin Section Flood Lights (2)
6. Circuit Breakers (L. & R. Side)
7. Windows (2)
8. LGS
9. CDU
0. PSA
1. Tissue Equivalent Ionization Chamber (Rate Meter, 2, Stored)
2. Tissue Equivalent Ionization Chamber (Rate Meter Charger, Stored)
3. Tissue Equivalent Ionization Chamber (Integrating, 2, Worn)
4. Passive Dosimeter (7 Per Man, Worn)
5. External Flood Light (2, Front And Rear)
6. Adjustable Ladder
7. Shelter
8. Descent Stage
9. Cold Plate

Fig. 6.2-1 Inboard Profile - Shelter Recommended Config.

⑤


RCS
STAB/CONT
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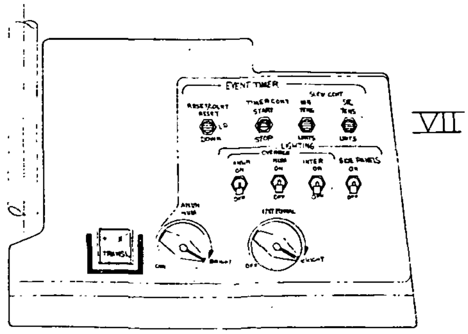
ECS
PGNS
EPS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SLEW CONT
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UNITS
SEC
TENS
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OVERRIDE
INTER
SIDE PANELS
ON
OFF
INTEGRAL
OFF
BRIGHT
VII

6.2-2

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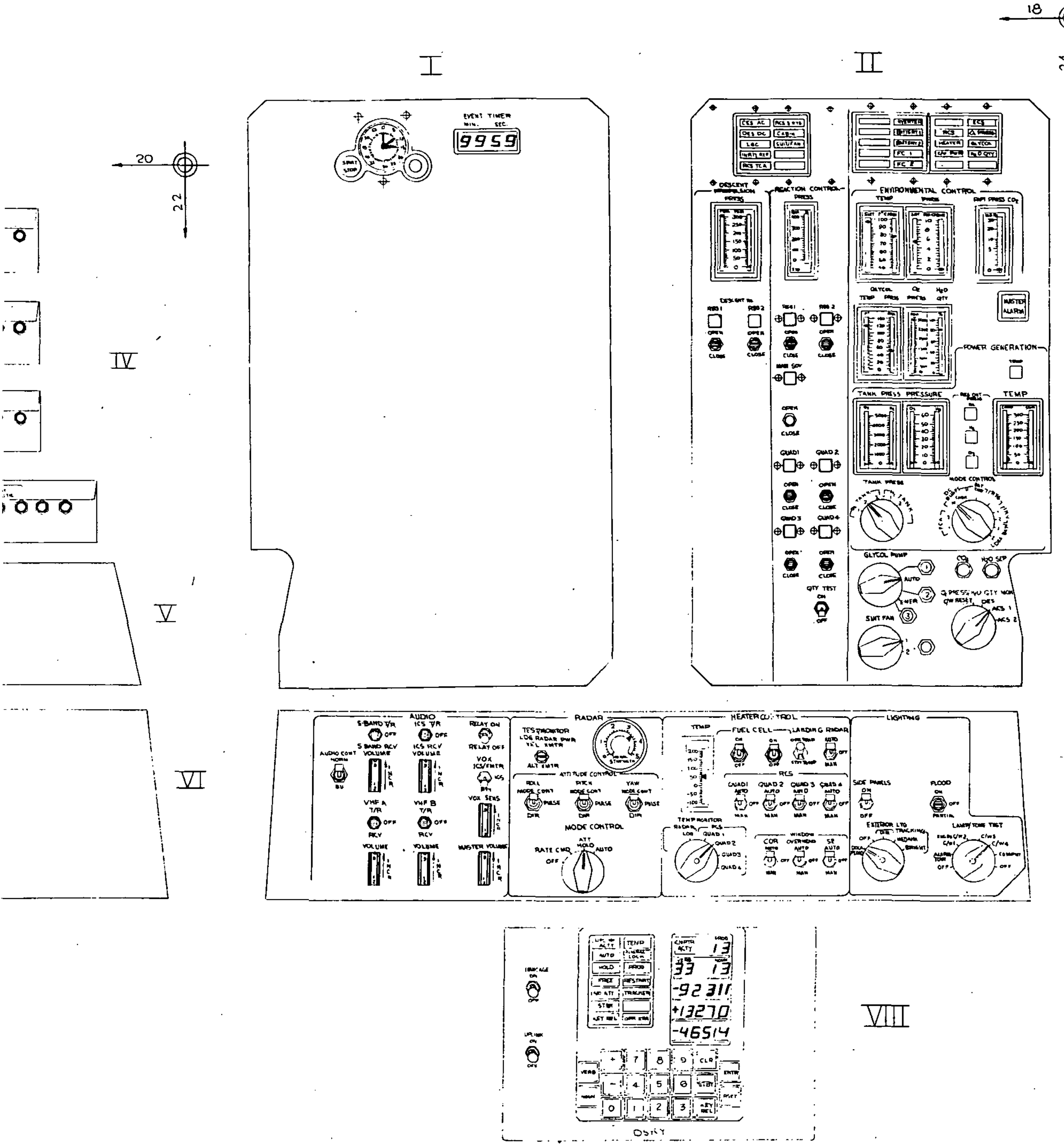

SHELTER

6-2-2

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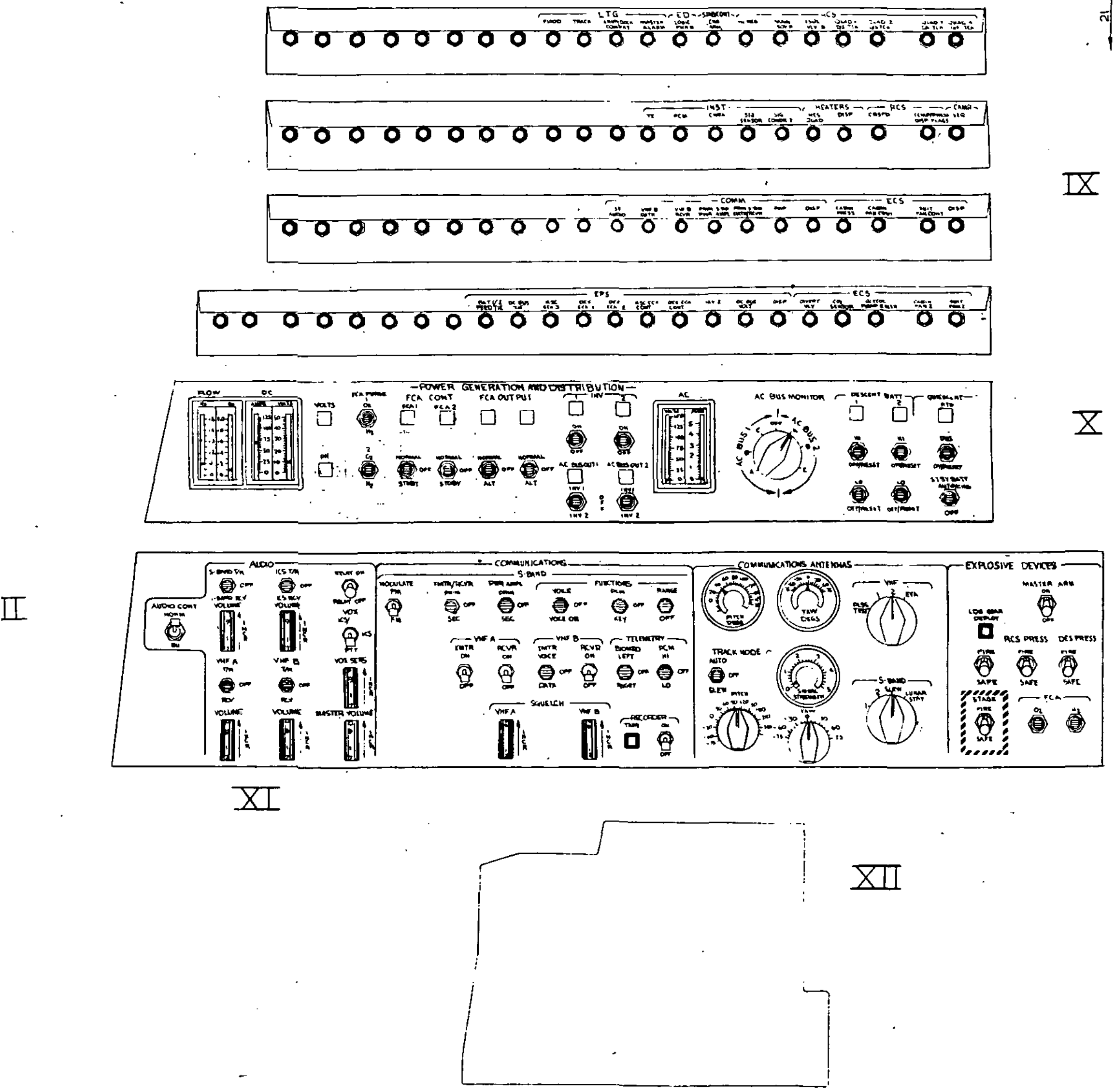

Fig. 6.2-2 Controls & Displays - General Arrangement

3

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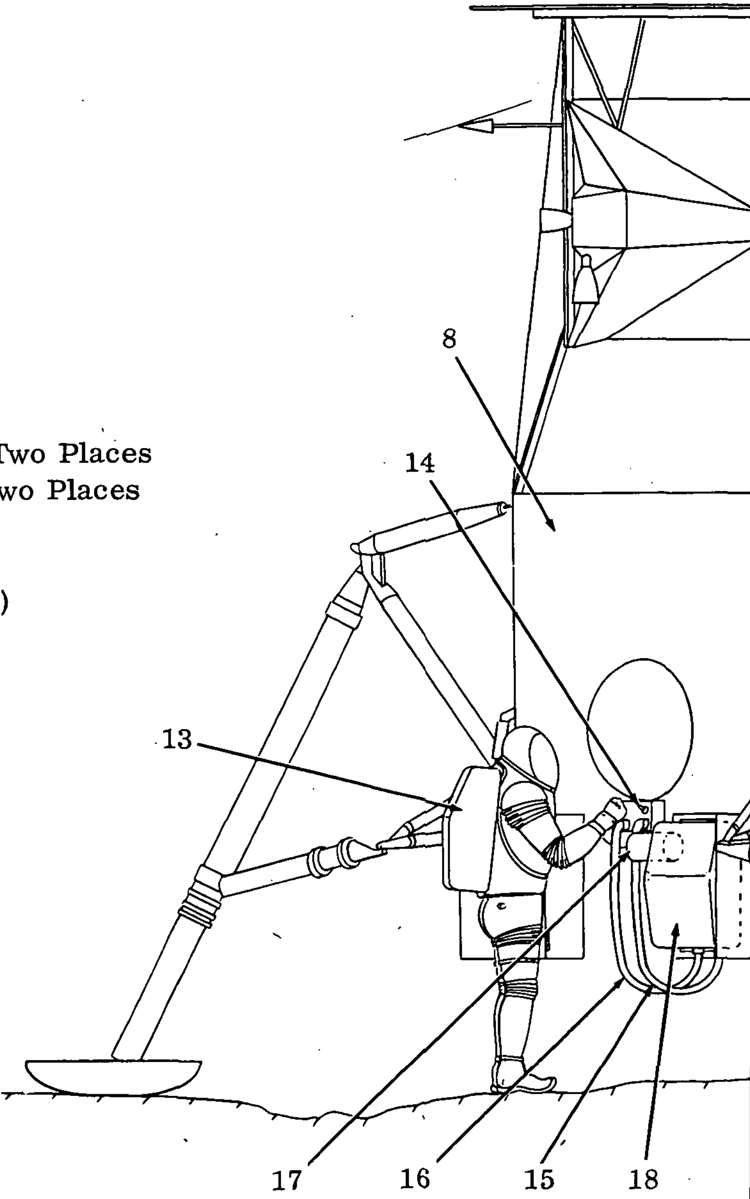
KEY

1. Storage Container (Stored)
2. Storage Container, 50 cu ft (Deployed)
3. Hard Suit & Spares (2, Stored)
4. PLSS (Stored)
5. Soft Suit (2, Stored)
6. Water Cooled Garment (2, Stored)
7. Shelter
8. Descent Stage
9. Airlock (Expandable Type)
10. Waste Management System
11. Urine Storage Tank (1.6 cu ft)
12. Solid Waste Storage Tank (1.6 cu ft)
13. Man in Hard Suit & PLSS
14. PLSS Recharging Control Panel
15. Oxygen Recharging Umbilical
16. Water Recharging Umbilical
17. PLSS LiOH Cartridge
18. PLSS (Stored In Recharging Position)
19. PLSS External Storage Facility (4)
20. PLSS LiOH Cartridge (26) Stored in Two Places
21. ECS LiOH Cartridge (12) Stored in Two Places
22. Gaseous Oxygen Storage
23. Adjustable Ladder
24. External Floodlight (2, Front & Rear)



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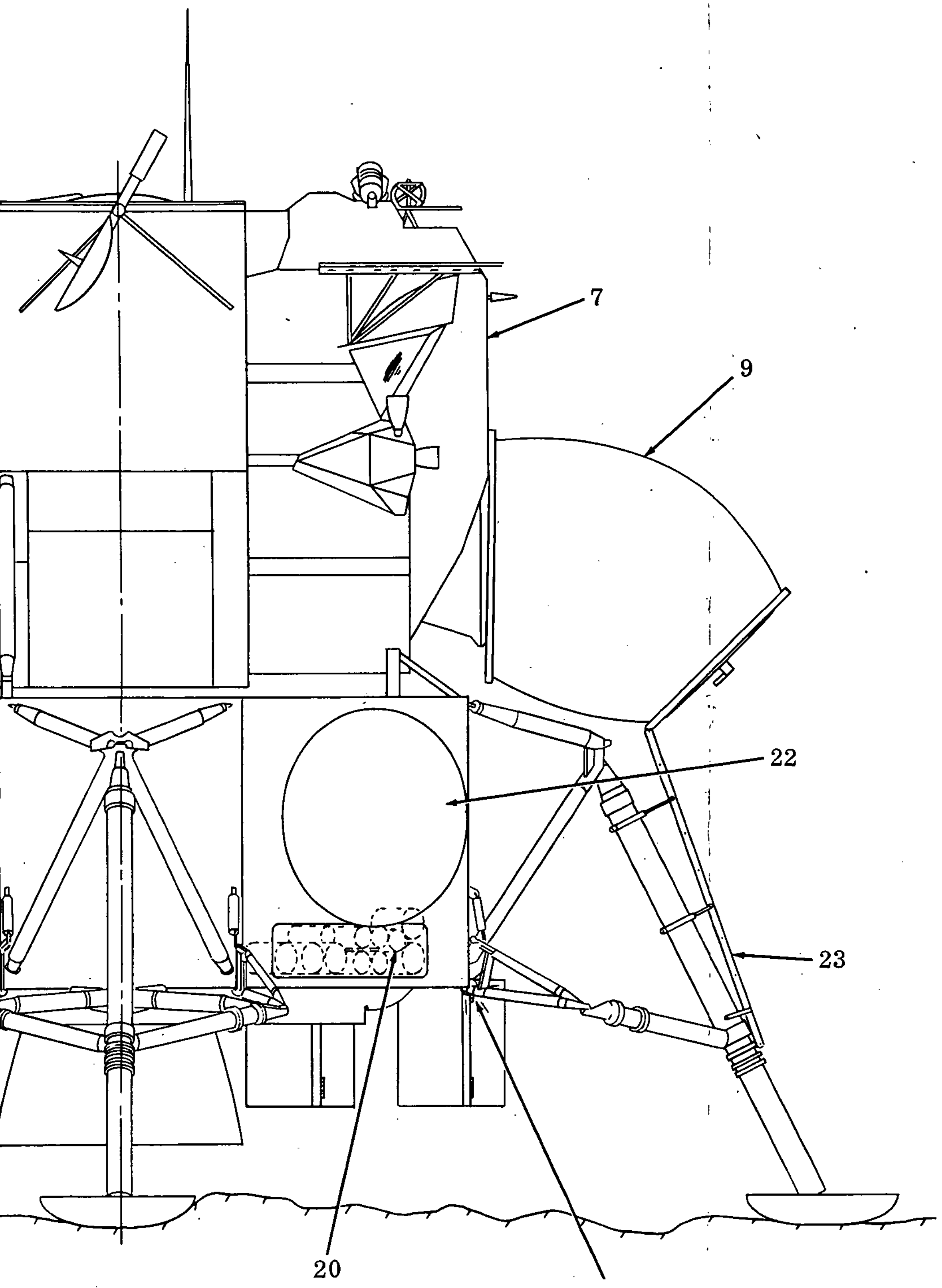

xternal PLSS Recharging Station

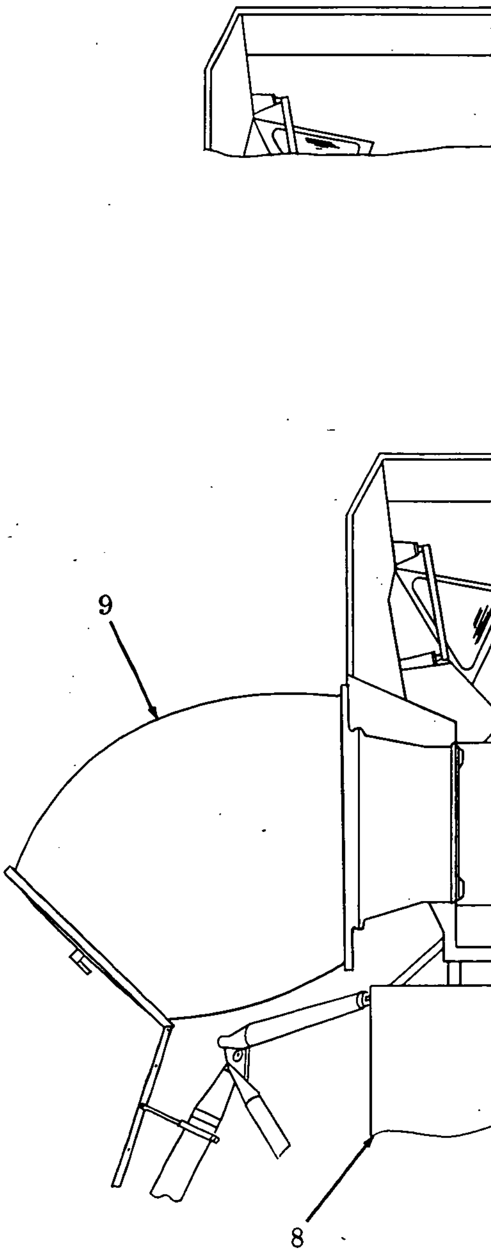

Fig. b - Uri

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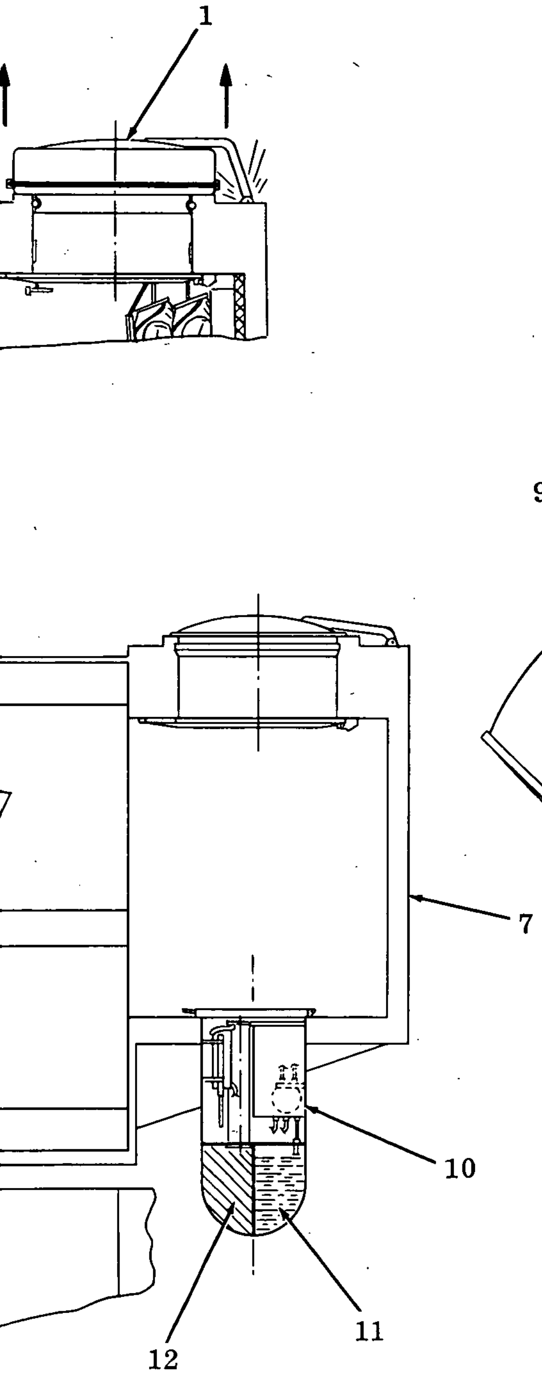

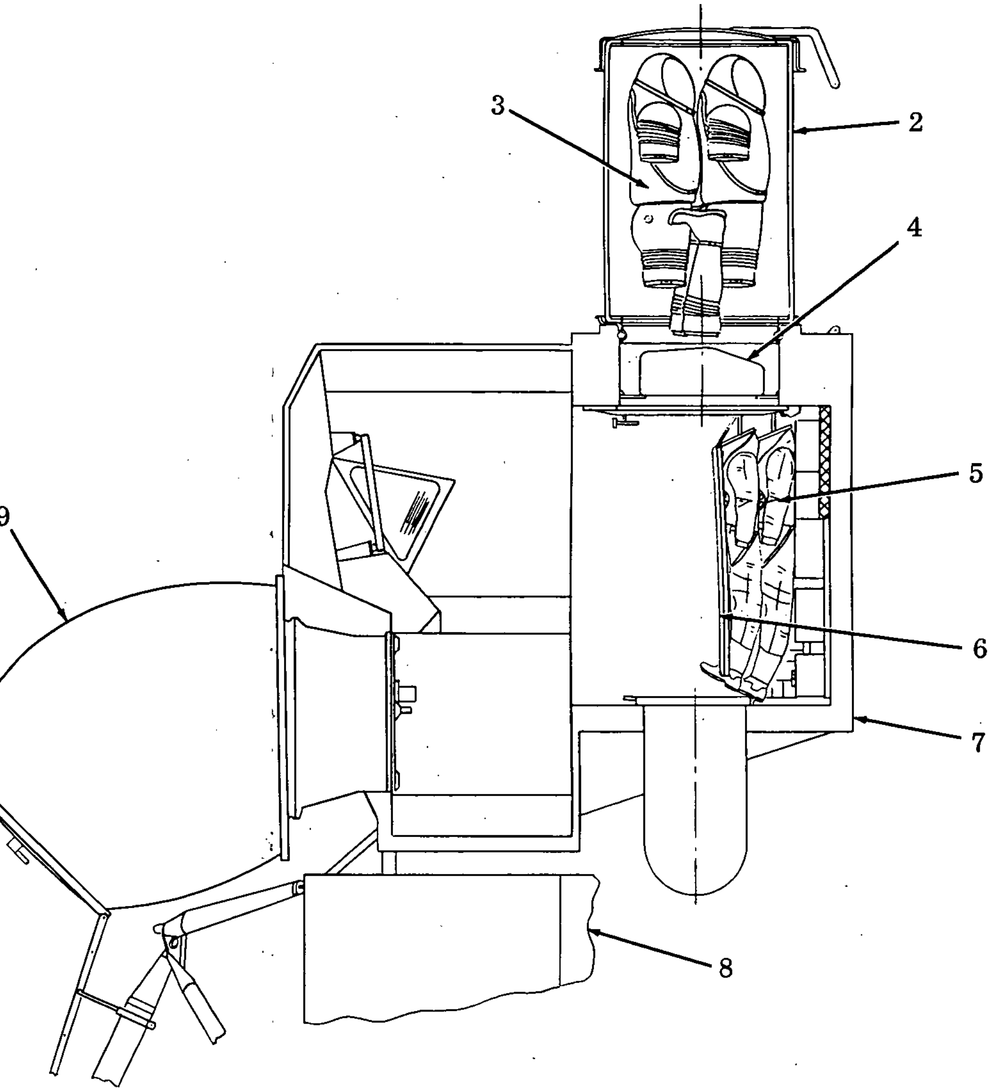

Fig. a - Expandable Pressurized Storage Container

e Storage Facility

Fig. 6.2-3 Inboard Profile - Alternate Configurations

6.3 STRUCTURAL ANALYSIS

6.3.1 Ground Rules

The following ground rule is unique to this portion of the study:

- Structural and dynamic interface between spacecraft and launch vehicles for all AES missions shall be compatible with the basic Apollo Program.

6.3.2 Assumptions and Background Data

The design criteria and environments established for the LEM have been used to establish subsystem design concepts and feasibility for this study. It is anticipated that these conditions will not be exceeded when the final configurations, including experiments and payloads, have been determined.

Inasmuch as the total LEM launch, separation, and landing gross weights will not be exceeded by the Shelter, it may be assumed that the basic structure will not require modification.

Tables 6.3-1 through 6.3-7 summarize the pertinent LEM design requirements which have been used to establish the integrity of the basic vehicle and subsystems. A safety factor of 1.50 is applied to the limit conditions to obtain ultimate loads. Figure 6.3-1 shows the Shelter reference axes.

An estimate of docking loads for the CSM and LEM with the S-IVB stage is given below for the indicated masses, moments of inertia, and criteria.

- Probe Contact
  Axial velocity = 0.1 to 1.0 fps
  Radial velocity = 0.0 to ±0.5 fps
  Angular misalignment = ±10 deg
  Angular velocity = ±1.0 deg/sec
  Miss Distance at probe = ±1 ft
- Loads
  F_x = 2235 lb
  F_z = 3118 lb
  M = 8134 ft-lb
- Mass Properties
  Active vehicle
    (CSM)
    M = 2000 slugs
    I = 74000 slug-ft^2
  Target vehicle
    (S-IVB + LEM)
    M = 2200 slugs
    I= 1,150,000 slug-ft^2
- Final Hard Surface Contact
  (Max permissible for single-point contact on non-parallel surfaces)
  Axial velocity = 0.15 fps
  F_x = 5000 lb

6.3.3 Recommended Configuration

6.3.3.1 General

The basic LEM structure will not require modification. However, because of the longer mission time, the micrometeoroid protection requirements may necessitate an increase in material thickness as well as a change in its structural configuration.

While micrometeoroid penetration considerations will determine the minimum average gage and skin spacing from the protected structure, the shielding must be designed for its ability to withstand sonic fatigue during the launch and boost condition.

For LEM, the micrometeoroid shielding, which also acts as thermal shielding, is 0.006-in. aluminum alloy skin, held away from the main structure by nylon standoffs. The standoffs offer point support and are spaced approximately 12 in. apart. For the Shelter shielding, it is recommended that a stiffened skin be used to provide the necessary micrometeoroid protection, as well as to withstand the acoustic environment. Additional studies must be carried out to optimize the stiffening requirements and support spacing.

While the basic structure will not require modification, there may be particular materials used by LEM which will not satisfy the longer mission time and revised environment.

Non-metallic materials are currently evaluated for a total of 3 days in contrast to the 104-day Shelter mission time. Since the quantity of outgassed products per material may be unacceptable for the increased mission time and increased degradation may also take place, retesting may be necessary. Other areas apart from a toxicity standpoint where testing may be necessary are: (1) compatibility effect of extended exposure of both metallic and non-metallic materials to propellants, oxygen, and hydrogen; (2) effect of prolonged UV radiation on visibility through window material; (3) extended mission times combining high and low temperature cycling and hard vacuum could have detrimental effects on sealants and non-metallics; and (4) stable thermal control coatings. The extent to which these potential problem areas will alter the original materials chosen will be studied further in Phase C.

6.3.3.2 Hardpoint Provisions for Payload and Experiment Support Structure

A basic requirement for the integration of experiments and payloads onto the spacecraft is that the primary structure will not require major modification. Some preliminary studies and analysis have been carried out to determine the magnitude of additional local load capability at various potential hardpoints on the ascent and descent stage structures.

In general, these hardpoints may be characterized into two groups. The first are those points at which no fittings or local stiffeners exist currently for LEM, but which may be adapted for concentrated load application through the use of attachment fittings, stiffeners, and skin doublers. By this means, concentrated payload support structure reaction forces can be delivered into the primary structure for internal load equilibrium without over-loading the existing members. The second group are those hardpoints at which fittings and stiffeners currently exist on LEM.

These points may be used to react additional concentrated loads, providing enough strength exists for the combined input loads. When necessary, it may be possible to increase the strength of these attachments by adding material thickness.

The current studies are based solely on static load conditions to determine structural feasibility. In later phases of the program, dynamic response analysis of equipment and payload items with support structures will be conducted to verify structural integrity. In addition to analyzing each payload and experiment local input into the primary structure, each flight configuration must be checked for the critical loading environments to ensure the overall structural integrity of the primary structural members.

6.3.3.2.1 Ascent Stage Hardpoints. Figures 6.3-2 and 6.3-3 show existing hardpoints in the LEM ascent stage. The loads shown applied to these hardpoints are ultimate allowable loads with the fuel and oxidizer propellant tanks removed. These loads may be used for local design, but are not necessarily applied simultaneously. The loads shown may be combined with the interstage loads from the descent stage for this loading condition only when applied in the directions shown. Hardpoints R and S do not have existing fittings, but may be adapted for the concentrated loads shown with minor modification. The remaining hardpoints have existing truss members joined to them by fittings or bulkhead lugs and may be readily picked up. Tables 6.3-8 shows the design loads on the aft equipment truss structure.

6.3.3.2.2 Descent Stage Hardpoints - For effective usage of the LEM descent stage, hardpoint load distribution should remain unchanged. Basic hardpoints on the existing LEM are located at coordinates such as engine mounts, tank mounts, and equipment shelf mounts. The descent stage primary structure, as well as the local structure, is designed for these loads. The loads are transmitted by the structure to the trunnion points which provide reactions for the boost conditions. Obviously, any new hardpoint requirement has to be analyzed utilizing the above constraints. As previously outlined, both a structural and dynamic analysis would be required to verify integrity. Any Shelter must remain within the weight and inertia envelope dictated by the LEM structure. Figure 6.3-4 shows the load capability of the descent stage when the ascent stage equipment listed below is removed. This reduction in ascent stage equipment affects the descent stage load capability, since the interstage forces are reduced.

-Y (Left side)	W (lb)	Y (in.)	M (in.-lb)
MM Shield	6	50	300
Supports	11	50	550
Fuel	1920	71	136,200
Tanks	93	71	6603
Plumbing	7	71	497
	2037 lb		144,150

+Y (Right side)	W (lb)	Y (in.)	M (in.-lb)
MM Shield	6	50	300
Supports	11	50	550
Oxid	3080	45	138,500
Tanks	93	45	4180
Plumbing	7	45	315
	3197		143,845

Tables 6.3-9 and 6.3-10 show the load carrying capability of available hardpoints.

6.3.3.3 Aft Equipment Bay Installation

The installation of the aft rack on the Shelter includes the various battery installations, as well as two radiators for heat dissipation. These radiators are located on top of the rack, in the Z-Y plane and on the back face of the rack in the X-Y plane. The top radiator weighs approximately 50 lb, while the one on the back face weighs approximately 100 lb. Besides the various batteries, there are three units installed in the space between the -Z27 bulkhead and the inner face of the rack; these are: one CSM water tank (15 lb) and two AC fuel cells (164 lb each). The Shelter aft rack assembly is essentially the same as the LEM configuration; however, the following items have been deleted for the Shelter:

	Weight (lb)
Two ECA units -	28
Two batteries -	260
One AFA unit -	34
One R/R unit -	30
Tanks -	150
Total Deleted	502

The following units are added on the Shelter rack structure:

	Weight (lb)
Two AC fuel cells -	325
One CSM water tank -	15
Two radiators -	150
Total Added	490

No structural modifications are anticipated for the Shelter, since the overall weight of the rack structure has decreased by about 9 lb. Figures 6.3-6 and 6.3-7 show the aft equipment rack and the AC fuel cell installation, respectively.

6.3.4 Baseline Configuration

The Shelter structures for the baseline configuration was essentially the same as for the recommended.

6.3.5 Alternate Configuration - Micrometeoroid Shielding

Alternate methods of construction for the micrometeoroid shielding were investigated using the techniques of Ref. 6.3-2. A general comparison was made of the following types of construction which are listed in order of preference from a weight standpoint:

- Honeycomb panels
- Skin and bonded doublers and ribs
- Skin and rib
- Corrugated panels
- Beaded panels

Since the design reference data used were developed for aircraft applications, the lowest number of design cycles considered were a factor of 10 to 100 times greater than those anticipated during the launch and boost conditions. The gages required were, therefore, 5 to 30 times greater than that used for LEM. An exception was the honeycomb construction where the sum of the two face gages was only 1.5 to 2 times as great.

6.3.6 Potential Modifications Per Flight

Where necessary, additional localized stiffeners and/or attachment fittings could be provided to accommodate specific per-flight payload items.

6.3.7 Discussion of Configuration Choices

For micrometeoroid shielding, the LEM-type construction with stiffening was selected for the Shelter with an increase of skin gage as required for the 104-day mission period. Although the increase in gage is usually beneficial with regard to fatigue, a change in dynamic characteristics, especially of the substructure, will occur. Therefore, acoustic testing of the new configuration would be required later in the program.

Table 6.3-1

LAUNCH & BOOST ACCELERATIONS

Condition	N_x (g)	N_y or N_z (g)
Lift-off	1.6	0.65
Max q α	2.07	±0.30
End boost	4.9	±0.10
1st-stage cut-off	1.7	±0.10
End 2nd-stage boost (engine hard-over)	2.15	±0.40

Table 6.3-2

VIBRATION INPUT TO EQUIPT SUPPORTS FROM EXTERIOR PRIMARY STRUCTURE

Random		Sinusoidal	
10 - 23 cps	12 db/oct rise	5 - 18.5 cps	0.154 in. D. A.
23 - 80 cps	0.0148 g^2/cps	18.5 - 100 cps	2.69 g peak
80 - 105 cps	12 db/oct rise		
105 - 950 cps	0.0444 g^2/cps		
950 - 1250 cps	12 db/oct decrease		
1250 - 2000 cps	0.0148 g^2/sec		

Table 6.3-3

VIBRATION INPUT TO EQUIPT SUPPORTS FROM INTERIOR PRIMARY STRUCTURE

Random		Sinusoidal	
10 - 23 cps	12 db/oct rise	5 - 16 cps	0.154 in. D. A.
23 - 80 cps	0.0148 g^2/cps	16 -100 cps	1.92 g peak
80 - 100 cps	12 db/oct rise		
100 - 1000 cps	0.0355 g^2/cps		
1000 - 1200 cps	12 db/oct decrease		
1200 - 2000 cps	0.0148 g^2/cps		

Table 6.3-4

ACOUSTIC ENVIRONMENT

Octave Band, cps	C-5 at Max q Level, db
9 - 18.8	136
18.8 - 37.5	142
37.5 - 75	146
75 - 150	143
150 - 300	139
300 - 600	135
600 - 1200	130
1200 - 2400	125
2400 - 4800	119
4800 - 9600	113
overall	150

(Sound pressure levels in db external
to LEM, Re: 0.0002 dynes/sq cm)

Table 6.3-5

SPACE FLIGHT ACCELERATION

Axis / Acceleration	X		Y		Z	
	g	$\frac{rad}{sec^2}$	g	$\frac{rad}{sec^2}$	g	$\frac{rad}{sec^2}$
SM Propul Sys Operating	-0.36	-	±0.062	±1.99	±0.062	±1.99
Not Operating	0	0	0	0	0	0

Table 6.3-6

DESCENT ACCELERATIONS

Phase	Vertical Accel, Earth g $\bar{X}$	Lateral Accel, Earth g Y&Z	rad/sec^2 about Y&Z	rad/sec^2 about $\bar{X}$
At Separation	+0.368	±0.0378	±0.192	±0.091
Elliptic Orbit	+0.372	±0.0383	±0.193	±0.092
Start of Hover	+0.707	±0.0728	±0.448	±0.166
End of Hover	+0.815	±0.084	±0.645	±0.189
Transfer Orbit	0	0	0	0

Table 6.3-7

LANDING ACCELERATIONS

Axis / Landing Accelerations at LEM cg	X		Y		Z	
	g	$\frac{rad}{sec^2}$	g	$\frac{rad}{sec^2}$	g	$\frac{rad}{sec^2}$
Case 1	.798	±.036	±1.778	-0.16	0	±14.56
Case 2	.798	0	0	17.60	1.778	0
Case 3	.857	±15.82	±.095	9.05	-.421	±.573
Case 4	2.74	0	0	±28.1	±.514	0
Case 5	2.74	.01	±.514	-.055	0	±23.3

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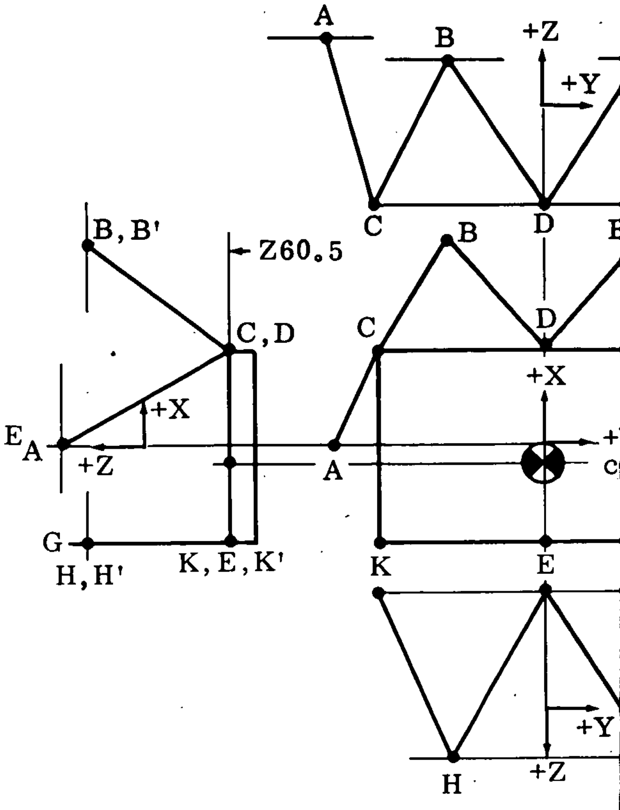
Table

DESCENT LOADS -

Axial Loads in Rack Tru

Truss Member	Landing Conditions								Boost		
									7.35g		n
	IA	IC	IIB	IIC	IIIA	IIID	IVB	IVC	A_1	A_2	
AC	-1484	+2163	-1713	-2083	-1539	-2020	-2370	-2613	-3029	-3053	+
BC	+2270	-3094	+2471	+2776	+1560	+1957	+3150	+3351	+3688	+3687	-
BD	+ 932	-1013	+1429	+ 55	+ 461	-1325	+1114	+ 212	+ 343	+ 373	+
KH	+ 340	- 317	+ 261	+ 144	- 316	- 469	+ 144	+ 67	- 91	- 118	+
HE	+ 529	- 477	+1801	-1213	+1278	-2638	+1112	- 866	- 299	- 165	+
A'C'	-1484	+2163	-2083	-1713	-2020	-1539	-2613	-2370	-3006	-3077	+
B'C'	+2270	-3094	+2776	+2471	+1957	+1560	+3351	+3150	+3669	+3706	-
B'D'	+ 932	-1013	+ 55	+1429	-1325	+ 461	+ 212	+1114	+ 431	+ 285	+
K'H'	+ 340	- 317	+ 144	+ 261	- 469	- 316	+ 67	+ 144	- 83	- 125	+
H'E'	+ 529	- 477	-1213	+1801	-2638	+1278	- 866	+1112	- 107	- 357	+



6.3-8
FT EQUIP. STRUCTURE

s Members (Gross Wt = 990 lb)

		Vibratory Conditions, *Random gs							
$=+.1g$	$n_z=-.1g$	$n_y=+3.5g$	$n_y=-3.5g$	$n_x=+3.5g$	$n_x=-3.5g$				
F_{1a}	F_{1b}	F_{2a}	F_{2b}	F_{4a}	F_{4b}	F_{3a}	F_{3b}		
168	-1996	- 689	- 138	-1862	+1034	-2662	+1782		
97	+1101	+ 729	+ 274	+2258	-1254	+1423	- 391		
986	-1888	- 975	+1072	+ 219	- 122	-2787	+2787		
137	-1165	- 102	+ 73	- 64	+ 35	-1478	+1478		
389	-1952	-2277	+2213	- 142	+ 79	-2320	+2320		
168	-1996	- 138	- 689	-1862	+1034	-2662	+1782		
97	+1101	+ 274	+ 729	+2258	-1254	+1423	- 391		
986	-1888	+1072	- 975	+ 219	- 122	-2787	+2787		
137	-1165	+ 73	- 102	- 64	+ 35	-1478	+1478		
389	-1952	+2213	-2277	- 142	+ 79	-2320	+2320		

* All Conditions Include N_x = +1g

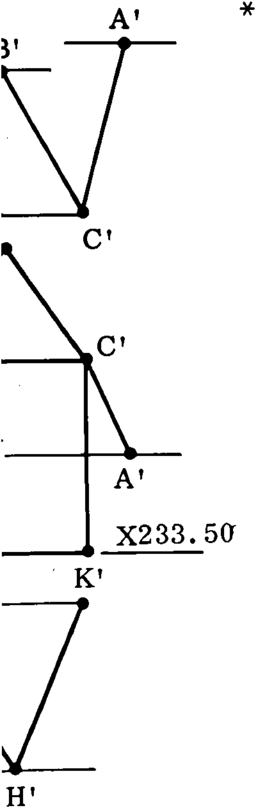


Table 6.3-9

LOAD-CARRYING CAPABILITIES OF AVAILABLE EQUIPMENT MOUNTING POINTS ASCENT/DESCENT STAGES

Component	Weight	X	X	Z	Comment
					All g's are ultimate
Ascent Engine	215	58g	37g	37g	XYZ vibratory LLD (1)
Ascent					
Oxidizer	3300	8g	8g	8g	Single-axis max. LLD*
Fuel	2000	8g	8g	8g	Single-axis max. LLD
Water	44	69g	69g	69g	Lab load design SAM*
He	62	2400lb	2400lb	2400lb	Lab load design SAM
Descent					
Engine	365	28000lb	±8600lb	±8600lb	X static thrust Y-Z vibratory
Oxidizer	5600	7.35g	±2.4g	±2.4g	Y-Z vibratory
Fuel	3500	7.35g	±2.4g	±2.4g	Y-Z vibratory
He -Y +Z	183	16g	16g	16g	Single-axis max.
He -Z -Y	183	21g	21g	21g	Single axis max.

Most mounts are designed by vibratory environment on discreet anchor points. If revised equipment packages are installed, anchor points should be investigated for more favored geometry permitting higher dead weight capacities.

A rack carrying equipment on the descent stage (under the ascent stage) would be in an environment of 16 to 21g. Again, discreet pickup points need be investigated and ultimate loadings would probably have vibratory dependence.

*LLD: LEM Load Design; SAM: Single-axis max.

Table 6.3-10

DESCENT STAGE HARD POINTS

				ΔP, lb		
Hard Point	X	Y	Z	X	Y	Z
U	+196	+82	+27	±900	±750	±1030
U1	+196	+82	-27	±900	±750	±1030

Notes:

1. ΔLoads are load increments which may safely be added to existing loads without requiring major re-analysis. Values shown are 1g (Earth) values and will be valid for all loading conditions.

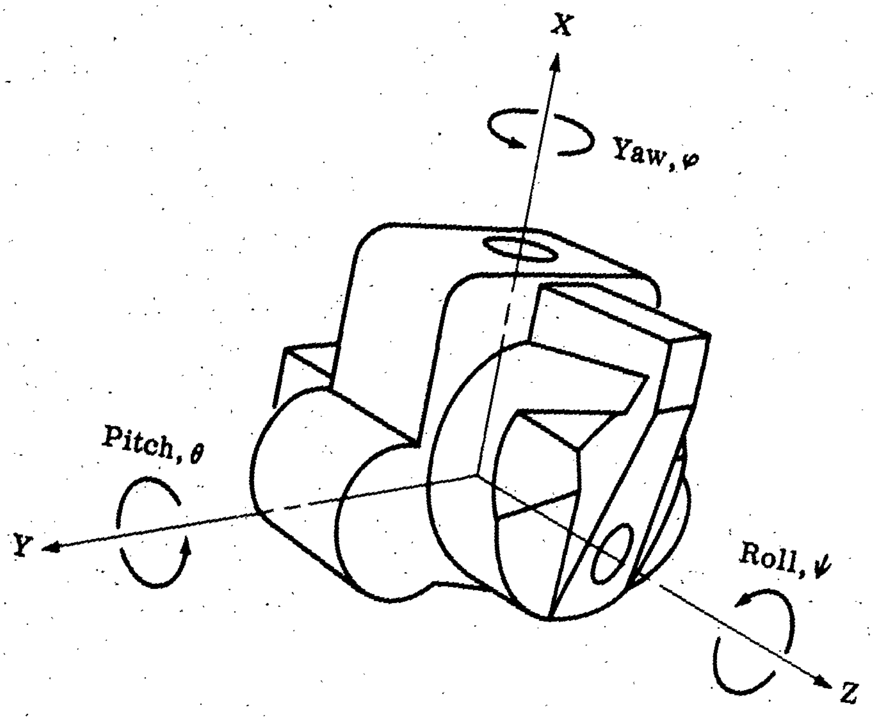
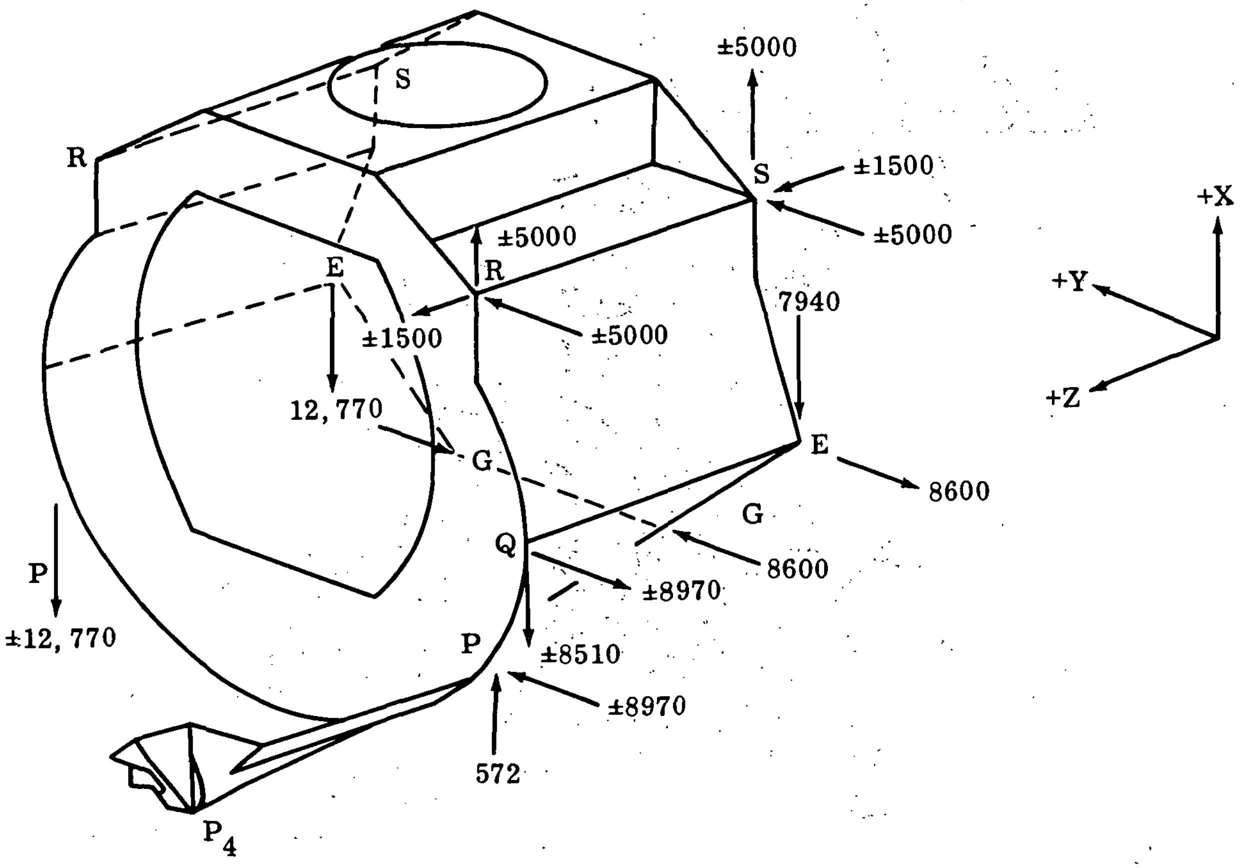


Fig. 6.3-1 Shelter Reference Axes

Hard Pt.	X	Y	Z
E	253.5	±45.0	-27
G	228.0	±18.4	-27
S	294.6	±36.7	-27
R	294.6	±36.7	+27
Q	252.0	-46.8	+27
P	229.4	±43.7	+27
P_4	211.3	±22.5	+64.6



Note: Loading (in lb) is symmetrical except where shown.

Fig. 6.3-2 Asc. Stage Hardpoints - Mid Section

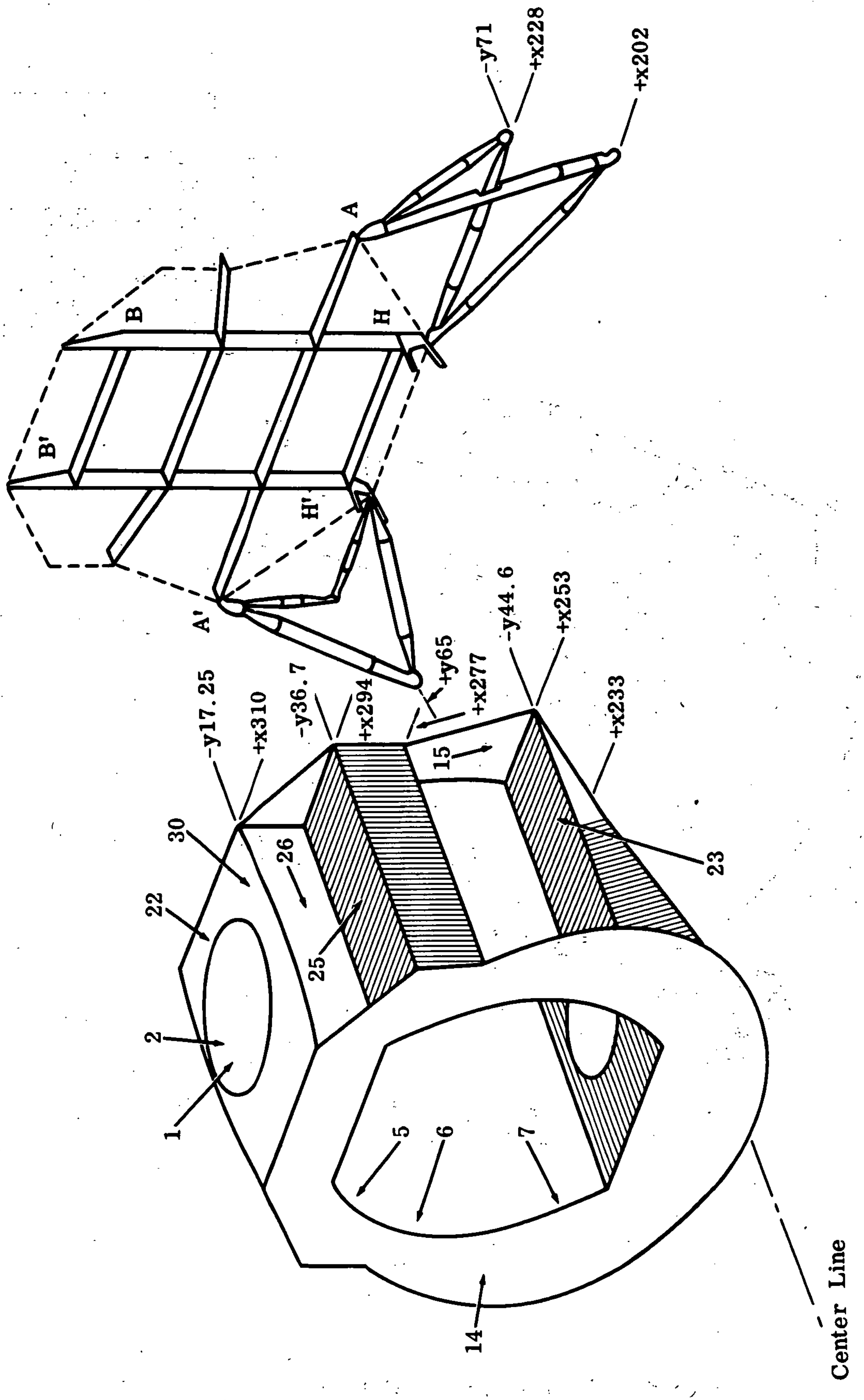
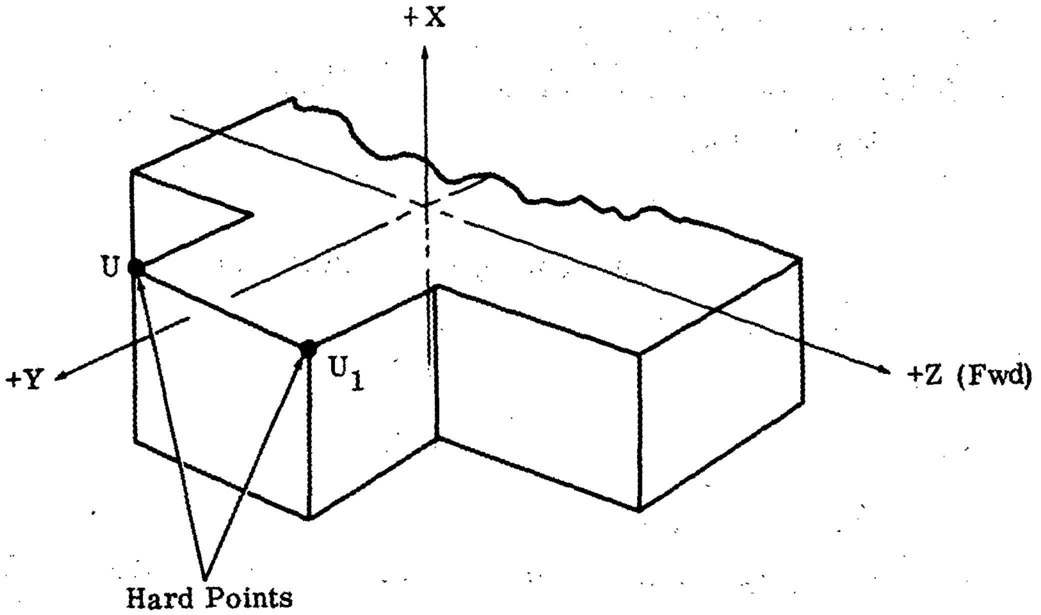
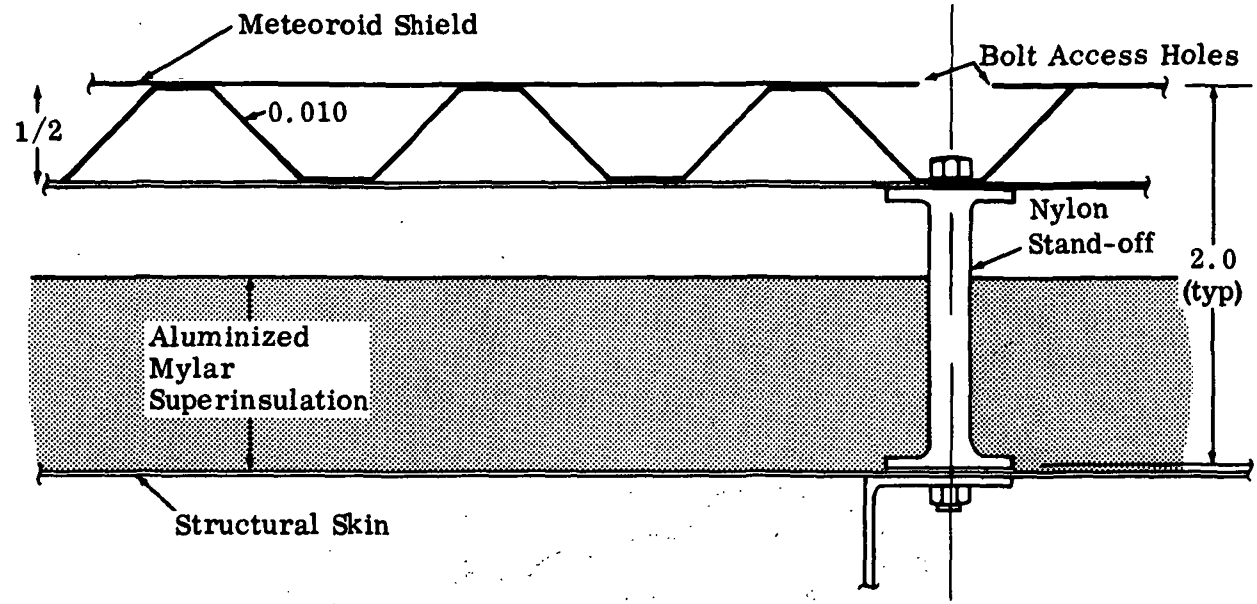


Fig. 6.3-3 Ascent Stage Hardpoints-Mid-Section

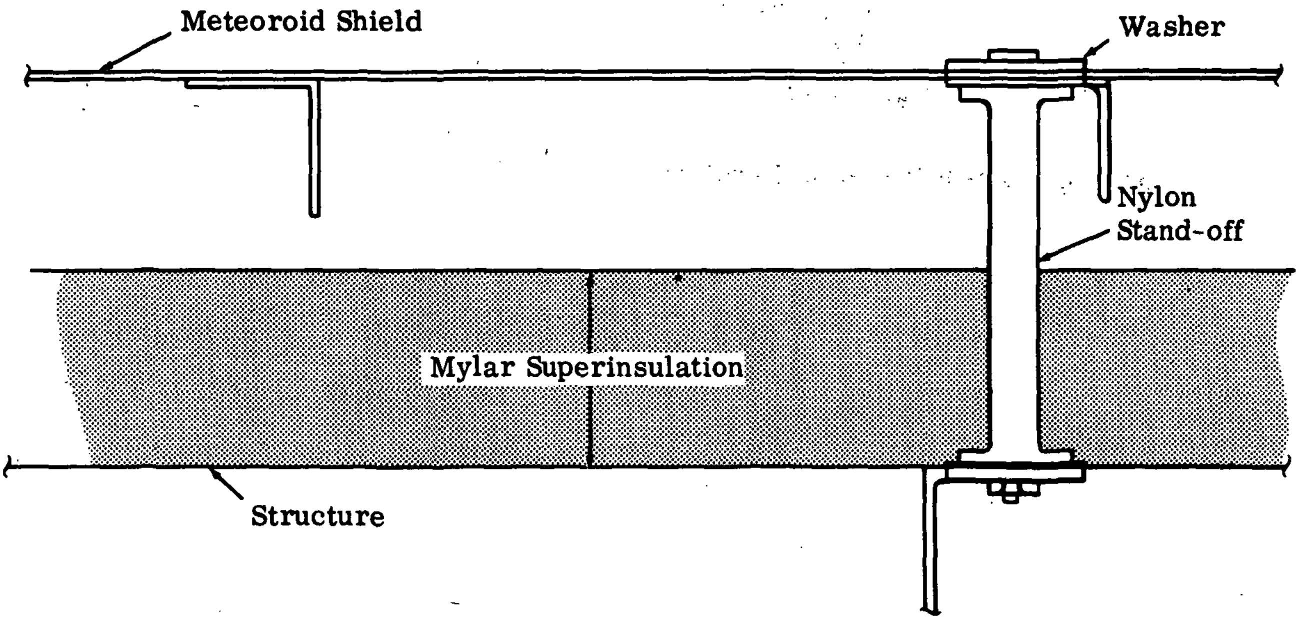


Descent Stage Hard-Point Location

Fig. 6.3-4 Load Capability - Descent Stage



A. Corrugation-Stiffened Shield



B. Sheet - Stiffener Shield

Fig. 6.3-5 Micrometeoroid Shielding Arrangements

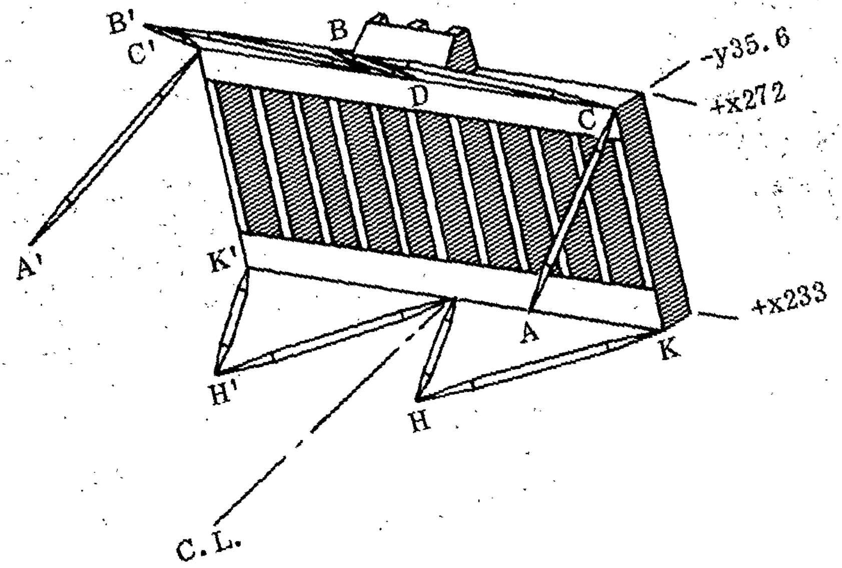
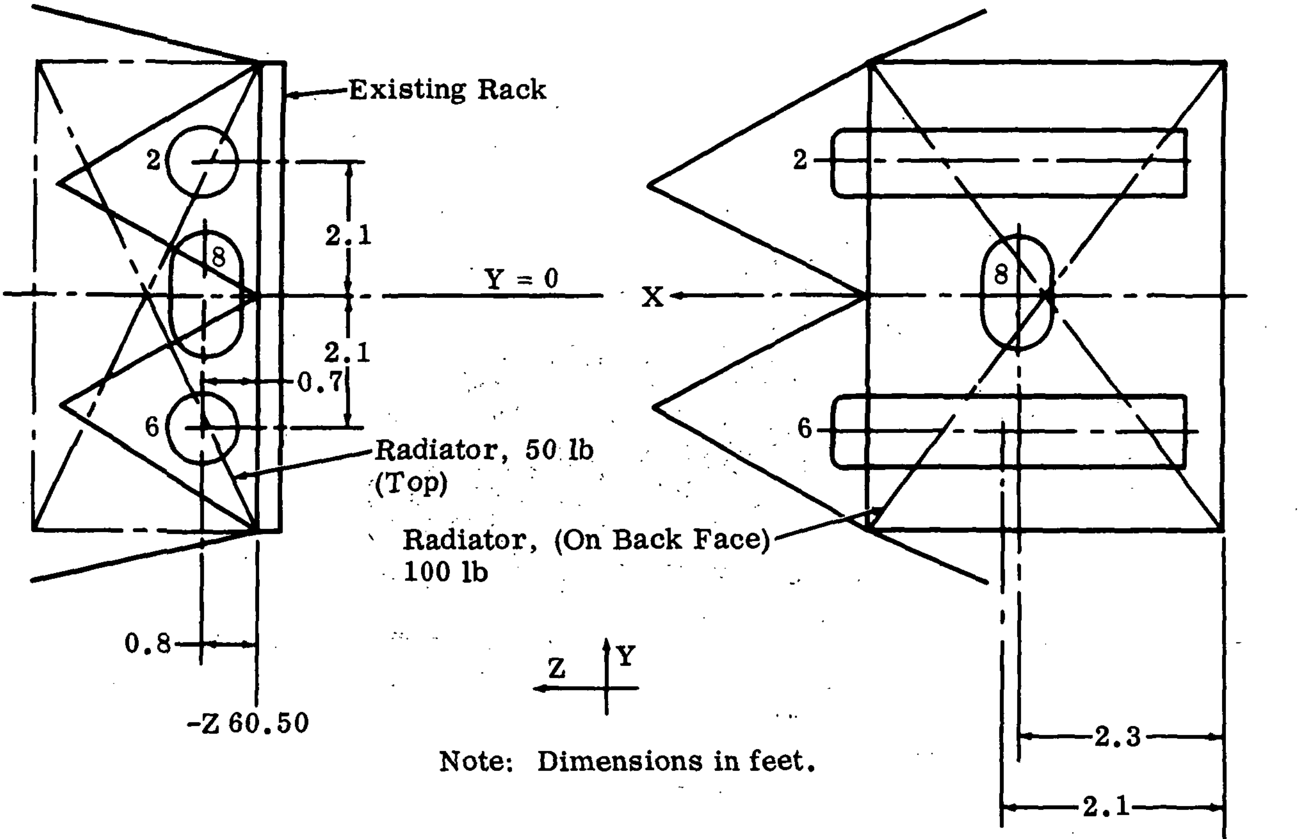


Fig. 6.3-6 Aft Equipment Rack



Note: Dimensions in feet.

Ref. No.		Wt, lb
2 6	Fuel Cell	164 ea.
8	CSM Water Tank	15

Fig. 6.3-7 AC Fuel Cell Installation - Aft Equip. Bay

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