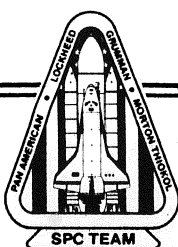


SPACE SHUTTLE MAIN ENGINES (SSMEs) SYSTEM ENGINEER HANDBOOK

Prepared by



For



SHUTTLE PROCESSING CONTRACT
John F. Kennedy Space Center

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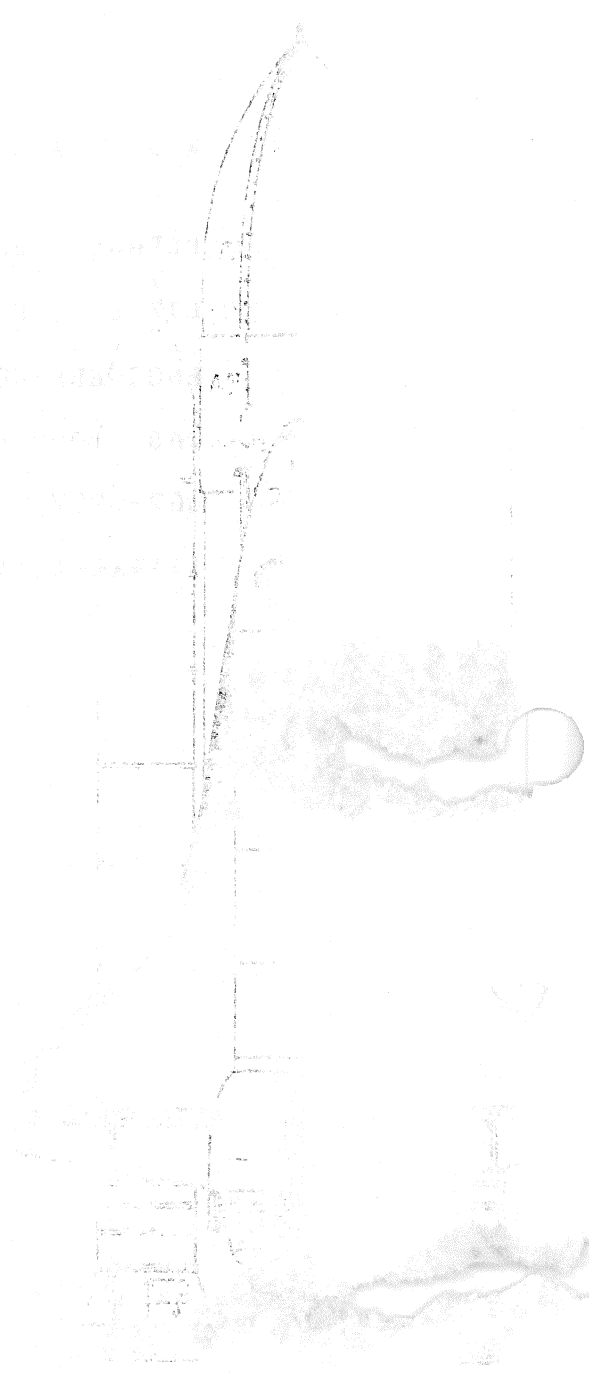
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1. The first part of the report is a general introduction to the subject of the study. It discusses the importance of the problem and the objectives of the research. It also mentions the scope of the study and the methods used.

2. The second part of the report is a detailed description of the experimental work. It includes a description of the apparatus used, the procedure followed, and the results obtained. It also discusses the errors involved in the experiment and the precautions taken to minimize them.

3. The third part of the report is a discussion of the results. It compares the results with the theoretical predictions and with the results of other workers. It also discusses the significance of the results and the conclusions drawn from them.

4. The fourth part of the report is a summary of the work. It states the main findings of the study and the conclusions drawn from them. It also mentions the limitations of the study and the suggestions for further work.



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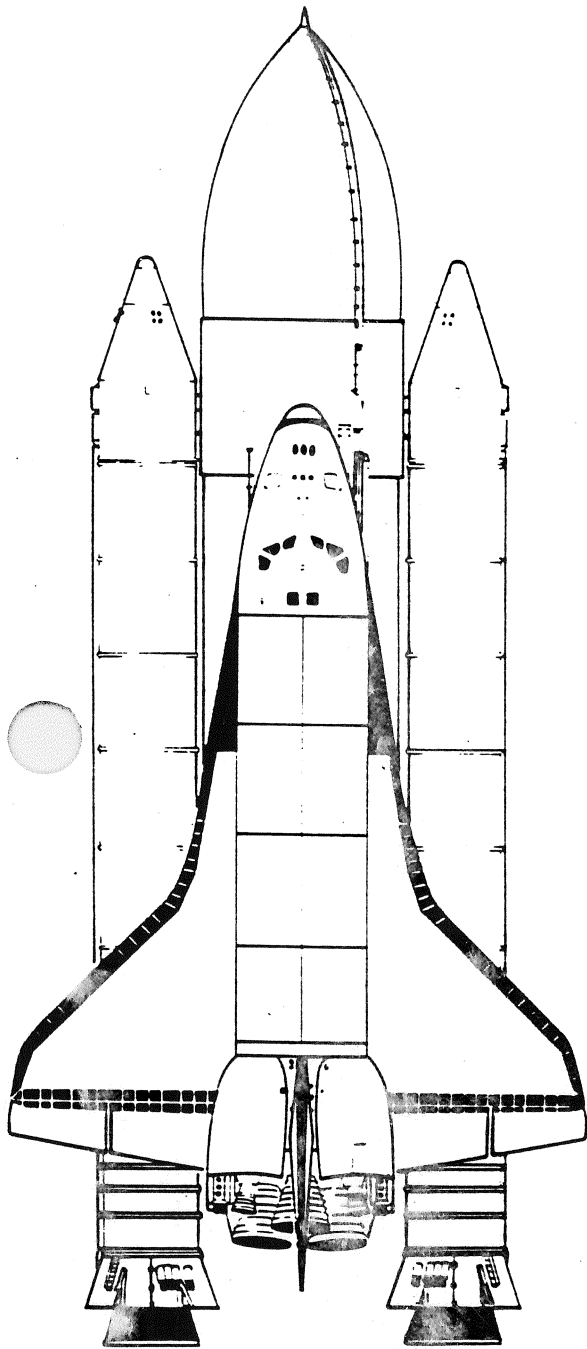
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SPACE SHUTTLE MAIN ENGINES (SSMEs) SYSTEM ENGINEER HANDBOOK

Prepared by

 **Lockheed**
Aeronautical Systems Company

For

 **Lockheed**
Space Operations Company

CHANGE 1 JANUARY 1989

LIST OF EFFECTIVE PAGES

<u>Page</u>		<u>Change</u>
1-1	through 1-7	0
1-8	through 1-17	1
1-18	through 1-22	0
1-23	through 1-24	1
1-25	through 1-34	0
1-35	through 1-40	1
1-41	through 1-96	0
2-1	through 2-191	0
3-1	through 3-26	0
4-1	through 4-36	0

RECORD OF CHANGES

CHANGE	DATE	DESCRIPTION OF CHANGE
Change 1	December 1988	Incorporation of LSS participation in Shuttle processing. Section 1 effected.

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1.0 INTRODUCTION.

1.1 PURPOSE AND SCOPE.

1.1.1 This handbook is designed as a guide to familiarize the new System Engineer with the system purpose, operational characteristics, and components. This handbook also provides references to associated system interfaces, ground support equipment (GSE), power requirements, and source documents containing detailed information necessary to provide a thorough understanding of overall system operation, maintenance requirements, failure modes, and results.

1.1.2 This handbook serves as an information reference source only and does not authorize any type of system operation or maintenance.

1.2 HOW TO USE.

1.2.1 This handbook is divided into four sections. Section 1 contains information of a general nature which is common to all System Engineers regardless of system assignments. All information in this section is covered in general terms leaving system specifics to Sections 2, 3, and 4.

1.2.1.1 Section 2 contains information on the system/subsystem(s). The information contained in Section 2 covers system descriptions, operations, and safety information, as well as information on interfacing/supporting systems. The section is presented in easily identifiable paragraph headings which lead the user to the pertinent topic. All illustrations follow the paragraph in which they are first called out. In order to alert the user to the fact that some information may be out-dated, the system drawings are presented with their original title/change block included and should not be considered as representing the latest configuration.

1.2.1.1.1 The material in Section 2 is to be used as an information source only, and DOES NOT AUTHORIZE OR DICTATE SYSTEM MAINTENANCE/OPERATION IN ANY WAY.

1.2.1.2 Section 3 is the Reference Material section and contains lists of operation and maintenance instructions (OMIs) and other similar data important to the System Engineer. This data is unique to the particular system covered in the handbook.

1.2.1.3 The last section in the handbook is Section 4, the Glossary. Terms, abbreviations, and symbols used throughout the handbook are defined in this section.

1.3 GENERAL INFORMATION.

1.3.1 SYSTEM ENGINEER.

1.3.1.1 Introduction. The following information is based on experience and reflects an understanding of the Shuttle processing system engineering job requirements. It is intended to provide the new System Engineer with tried and true guidelines for what are the most important elements of his/her work environment and to stimulate questions for discussion with his/her supervisor. The formal job description takes precedence over these guidelines in case of any disagreement.

1.3.1.2 Required Knowledge. Nothing is more fundamental in determining the value of a System Engineer than his/her in-depth knowledge of the assigned system or area of responsibility. Sufficient time and effort must be taken to extract thousands of technical details from existing documentation. Specialized technical information which cannot be memorized must be available at the work area for quick access from organized storage without a long search required. Familiarity with types of available information within the technical data files is an absolute requirement. The importance of maintaining an ongoing mental effort to acquire detailed technical knowledge cannot be overstressed. In order to retain this information, periodic personal review of current material must be undertaken. The

extent of self-motivation and self-discipline exercised in gaining and retaining this information as outlined above will in all probability be a major criterion in evaluating the net worth of the System Engineer to his/her assigned organization.

1.3.1.2.1 The System Engineer must strive to acquire an in-depth knowledge of the following:

- A. System design, design criteria, and specifications
- B. System design certification and qualification test requirements
- C. System operational modes: normal, integrated, emergency, redundancies, flight, and ground
- D. System supporting GSE: design and operational information, test requirements, interfaces, and structural limitations
- E. System interfaces with other flight systems/GSE and the possible interacting parameters
- F. System history: design changes, test failures, offsite problems, qualification, and certification test histories.
- G. Facilities, as designed to support an assigned system or test
- H. Support requirements: safety, special tools or equipment, and consumables.

1.3.1.3 Functions. The following functions are those which a System Engineer can expect to participate in as a normal part of his/her job:

- A. Keeping technically current with hardware, facilities, and other System Engineers
- B. Keeping supervision/management informed on activities, issues, and daily progress
- C. Supporting design reviews, onsite and offsite
- D. Evaluating and originating design changes/modifications
- E. Developing, planning or implementing any or all of the following products:

- 1. Facilities plans, layouts, and access requirements
- 2. Test requirements, design criteria specifications and operations and maintenance requirements and specifications documents (OMRSD)
- 3. Engineering support requests (ESRs)
- 4. OMIs
- 5. Software
 - a. Software applications programs and math models
 - b. Software verification procedures
 - c. Software requirements and specifications documents
- 6. Launch commit criteria (LCC) requirements
- 7. Measurement lists

8. Problem reports (PRs) and test preparation sheets (TPS)
 9. Troubleshooting plans
 10. Test evaluation reports
 11. Emergency/contingency plans and procedures
 12. Support requirements
 13. System checkout flows and test schedules.
 14. System assurance analysis (SAA)
 15. Hazard analysis report
- F. Supporting any related contractor effort with regard to adequacy, accuracy, and quality. This should be accomplished in a timely, personal, and professional manner. These needs may be:
1. Producing the preceding products when requested
 2. Timely implementation of planned procedures
 3. Conducting operations, checkouts, testing, and troubleshooting
 4. Concurring when possible, with requested deviations to OMI's or TPSS
 5. Adhering to safe operating requirements while satisfactorily completing and personally supporting the needed operations and tests,
- G. Support team meetings
- H. Support team assignments and obtain approval of section head on all written products before submitting them.

1.3.1.3.1 The primary responsibility of the System Engineer is to ensure the safe, smooth, efficient flow of flight hardware through KSC. This requires active participation in hardware use, operation, and/or testing. Meetings or paper work should never have a higher priority than personal involvement in testing or operating procedures.

1.3.1.4 Tools. The System Engineer must have immediate access to or be on permanent distribution for the following:

- A. System drawings, schematics, engineering orders (EOs), and modification packages
- B. Appropriate preliminary interface revision notices (PIRNs) and change requests (CRs)
- C. Systems technical manuals
- D. Facilities plans, drawings, and schedules
- E. OMRSDs and changes
- F. Appropriate ESRs for evaluation
- G. Appropriate OMIs and application programs
- H. LCC document
- I. Appropriate TPS or PR
- J. Baseline KSC plans for the system
- K. Test evaluation reports
- L. Measurements lists
- M. Troubleshooting plans
- N. Emergency contingency plans/procedures
- O. Support requirements documents (SRDs)

- P. Contact telephone numbers for worldwide technical counterparts and interfaces
- Q. Test data results for assigned system(s)
- R. Design center qualification and certification test requirements and results
- S. Notification of meetings, working groups, and other appropriate discussions in assigned technical area
- T. Process engineering computer system (PECS).

1.3.1.5 Operating Modes. To be of maximum value to the program and himself, the System Engineer must acquire a reputation as the recognized expert in his assigned technical area. A few personal and professional golden rules to follow are listed below:

- A. Seek out and establish a dialog with counterparts in Lockheed Space Operations Company (LSOC), National Aeronautics and Space Administration (NASA), design center engineers (LSS) Johnson Space Center (JSC), KSC, and George C. Marshall Space Flight Center (MSFC) on a first name, frequently contacted, mutually respectful basis.
- B. Be open minded to technical inputs, suggestions, other methods, and potential design changes, and evaluate each impartially, based on the best solution for the project.
- C. Develop a team spirit with contractor/NASA/LSS contacts and interfaces and recognize those members that are contributors.

- D. Be alert to information, problems, or rumors that should be made available to management.
- E. Recognize personnel who are exceptional and make it known to their supervisors; conversely for poor performers, except, inform your supervisor and take whatever action is appropriate.
- F. Be physically present during significant tasks, operations, and tests of the system. Maintain alertness and attention to each phase of the test. Be prepared to alert contractor or other test personnel quickly of any potential problem which could impact safety or schedule.
- G. When participating in design reviews, meetings with other directorates, or supporting any preplanned meeting, a System Engineer is expected to:
 - 1. Be prepared in detail prior to the meeting.
 - 2. Act and react with verbal assuredness in support of his/her technical position. The only limitations to verbal assuredness would be:
 - a. If his/her supervisor requests it
 - b. A common sense limitation in order to allow conducting the original purpose of the meeting.
- H. When requesting supervisory support on controversial issues, a thorough research of the issue should be made to prevent an over enthusiastic or bent-spear position resulting from uncertain information or incomplete

thinking through undermining the position he/she wishes to be supported.

1.3.1.6 Team Concept. A key ingredient to the success of the Apollo Program was the team concept. The Shuttle launch team members must develop a strong identification with the reality of being essential to the checkout and launch tasks. The achievement of the Shuttle launch team attitude requires:

- A. The acknowledgement that everyone is a key member of the team
- B. The consistent best performance of each person involved
- C. Active cooperation among all team members
- D. Vertical and horizontal communication flow.

1.3.1.6.1 LSOC/NASA/LSS Counterpart Relationship. The relationship between LSOC and NASA counterparts is that of contractor and customer. The relationship between LSOC and LSS is that of system operator and design technical representation. NASA system Engineers continuously monitor and evaluate LSOCs' effort in fulfilling the Shuttle Processing Contract (SPC). LSS System Engineers provide real time support to LSOCs' effort to ensure understanding and compliance with design center requirements. In addition, both NASA and LSS they perform many jobs independently to ensure that the proper checks and balances are maintained.

1.3.1.6.1.1 There are two key elements necessary for a successful LSOC/NASA/LSS counterpart relationship: teamwork and communication. At KSC a System Engineers function centers around this three member team.

1.3.1.6.1.2 Teamwork. Teamwork is required between LSOC/NASA counterparts in order to accomplish assigned tasks and to resolved problems. Counterparts are partners, not adversaries. Both learn to utilize the talents and resources of one another to get the job done correctly and efficiently. NASA monitors the following Lockheeds'efforts to:

- A. Prepare the system for launch operations
- B. Develop troubleshooting plans
- C. Analyze test data
- D. Update documentation such as OMIs, and SAAs.
- E. Evaluate OMRSD, LCC changes
- F. Improve the existing system hardware and software through modifications

1.3.1.6.1.2.1 NASA and LSS System Engineers participate in all phases of launch processing operations (with their LSOC counterparts). They are there to provide their system knowledge or expertise when needed as well as to ensure that operations proceed according to program and system requirements.

1.3.1.6.1.3 Communication. Communication between LSOC and NASA is paramount to achieving a safe, smooth launch processing flow for each system. Lack of information results in ignorance and misinformation, which can be dangerous especially when working in hazardous operations. LSOC System Engineers must status NASA regularly on a variety of topics such as:

- A. Daily checkout operations
- B. Hardware and software PRs and interim problem reports (IPRs)
- C. OMRSD/LCC changes
- D. Upcoming meetings and telecons
- E. Simulated launches
- F. Standard practice instruction (SPI) changes, additions or deletions
- G. Changes in operating procedures, materials or equipment
- H. Safety issues
- I. Schedule changes

1.3.1.6.1.3.1 Counterparts are encouraged to open the flow of communication, and challenged to improve upon it.

1.3.1.7 General. A supervisor is required to be aware of all activities taking place within the group and to maintain a current status of events. This means that a frequent and consistent information exchange must take place with all section personnel. If a significant change in status occurs, it is the

responsibility of the System Engineer to inform the lead or supervisor or, in their absence, the manager of this information.

A. Job satisfaction on a day-to-day basis comes primarily

through the initiative of the System Engineer to stay involved in work efforts. It may be easy to sit on the sidelines, but the primary person you are letting down is the guy you see in the mirror.

B. Several rules are non-negotiable and bring

counteraction if abused. These include arriving late, leaving early, excessively long lunch periods, and not being easily located during working hours.

C. The processing of the Shuttle does not always go smoothly.

Be prepared to come early and leave late to cover work assignments. Personal health, family commitments, and a transportation system should all be in the go mode to allow a heavy commitment of your time when required for support.

D. It is of particular importance to supervision, management,

and director-level organizations that intra-group cooperation, eager assistance, and recognition of other contributions be attained. You are not expected to do the job or assigned task of a fellow worker. You are expected, however, to lend your expertise to any effort that is important to your organization. All your actions, positive and negative, reflect upon your organization just as the reputation of your organization reflects upon you.

1.3.1.8 Conclusion. It is obvious from the preceding, that the System Engineer is the cornerstone of expertise and a motive force required for successful accomplishment of Shuttle engineering functions and goals. Without the System Engineer, the necessary depth of technical knowledge for systems development and testing would not be attained. Acknowledgement must be made that the System Engineer is the backbone upon which management is dependent for support. Recognition of this fact by the new System Engineer goes a long way toward making it happen.

1.3.2 LSOC ORGANIZATION.

1.3.2.1 General. The following paragraphs define some of the important organizations within LSOC with which the System Engineer may interface.

1.3.2.2 Launch Equipment Shop (LES). The LES comprises of various shops (machine, electrical, pneumatic equipment,) that support system engineering functions, such as system modifications and parts rework.

1.3.2.3 Operation Planning and Control (OP&C). OP&C is responsible for development and implementation of element and integrated space shuttle processing plans and schedules; development and release of supporting operations and maintenance documentation, including the operations and maintenance plan;

processing support plan and work authorization documents (WADs); and managing the Shuttle work control system.

1.3.2.4 Project Engineering (PE). PE is divided into three categories:

- A. GSE
- B. Flight hardware
- C. Test project engineering (TPE).

1.3.2.4.1 General. PE interfaces with the System Engineer in regard to software impact due to configuration changes/modifications, waivers required on deviations, test preparation sheets.

1.3.2.4.2 TPE. TPE is the technical interface of the System Engineer in the firing room. For further description of the TPE and their duties see the Firing Room Operations, Discipline, and Protocol paragraph in this section.

1.3.2.5 Quality. Quality consists of the following groups:

- A. Quality engineering (QE)
- B. Quality assurance (QA)/Quality control (QC).

1.3.2.5.1 Quality provides many functions that are of interest to the System Engineer. Good working relations between the System Engineer and quality is paramount.

1.3.2.6 Site Planning And Scheduling. Site planning and scheduling is responsible for maintenance and coordination of Shuttle inflow work and modification schedules for sites pad A/B, mobile launcher platforms (MLP), vehicle assembly building (VAB), flight GSE, orbiter processing facility (OPF), hypergol maintenance facility (HMF), rotation processing and surge facility (RPSF) and shuttle landing facility (SLF); coordination for KSC operations and other external agencies involved in work affecting inflow processing; and coordination and control of work schedules, work planning, and support requirements for all processing activities performed at the processing sites.

1.3.2.7 Technical Operations (Tech Ops). Tech Ops is the organization which provides the technicians that perform the system maintenance and launch support.

1.3.3 FIRING ROOM DISCIPLINE AND PROTOCOL.

1.3.3.1 General. This section is designed for test conductors (TCs) and System Engineers who are responsible for conducting tests on orbiter flight hardware and GSE. The section provides operating disciplines and protocol required within the firing

room during testing, maintenance, and launch of the Shuttle vehicle. This section also provides personnel with a common understanding of standard practices to be used in the firing room. Good firing room practices and adherence to protocol are necessary to ensure :

- A. The protection of lives and well being of personnel at the test sites
- B. The protection of flight and ground support hardware.

1.3.3.2 Assignment. An assigned firing room becomes dedicated to a particular orbiter vehicle the moment that the orbiter arrives at the OPF. That firing room monitors and controls all checkouts and tests for that vehicle up to and including launch. There are two working bays in the OPF, two assembly high bays in the VAB, two firing rooms [a third secured firing room for Department of Defense (DOD) payload launches], and two launch pads to allow for two shuttles to be in process at the same time.

1.3.3.3 Firing Room. The firing room configuration is determined by the KSCL-1735-035 Firing Room Utilization Plan, Appendix A, which defines responsibilities and console assignments for each System Engineering station. The System engineer must study this plan in detail prior to console allocation. The firing room layout is shown in figure 1-1.

FIRING ROOM 1 & 3

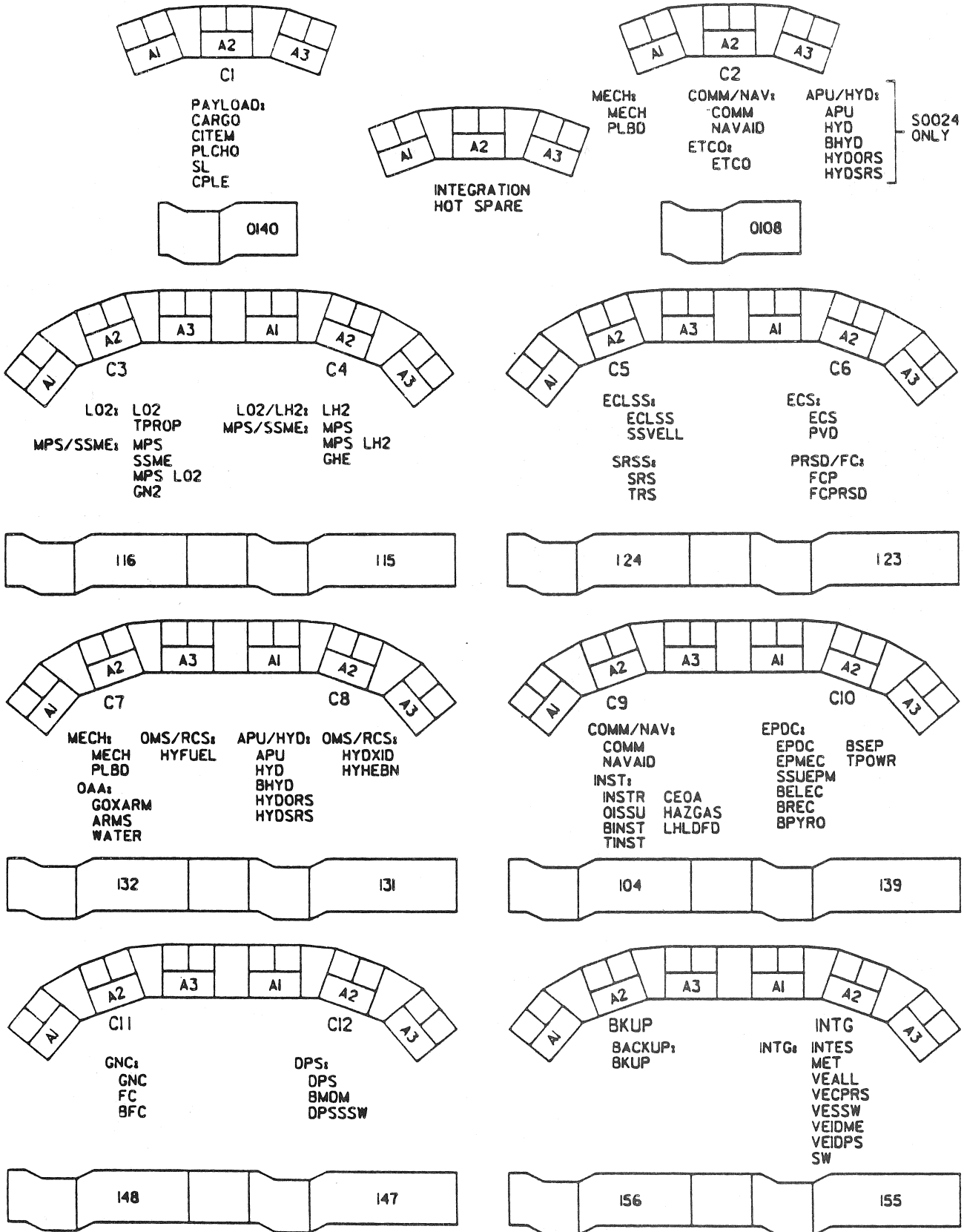


Figure 1-1. Firing Room Layout

1.3.3.4 Standboards. A standboard comprises experienced qualified personnel who conduct hands-on training and testing to assure that each assigned System Engineer is given the proper training to meet the minimum basic requirements necessary to function within the firing room environment without being a detriment to himself, to others, or to the test in progress.

1.3.3.4.1 Participants. Standboards are conducted on an informal basis with the following personnel in attendance:

- A. Orbiter test conductor (OTC)
- B. Test project engineer (TPE) and/or system specialist
- C. Quality engineer (QE)
- D. Safety
- E. Cognizant supervision.

1.3.3.4.2 Format. The System Engineer is given an oral and/or written quiz in his/her system discipline. All active stations are manned by qualified personnel certified for that position or by on-the-job (OJT) training personnel backed up by a certified console operator. A certificate of qualification is issued to the System Engineer upon completion of the minimum requirements.

1.3.3.5 Work Performed in the Firing Room. Only qualified personnel are permitted to operate the firing room. These personnel perform the following tasks:

- A. Payload processing
- B. Troubleshooting
- C. Test and maintenance operations on the orbiter hardware, GSE, and software.

1.3.3.6 Personnel. The personnel assigned to the firing room and their respective responsibilities are defined in the following paragraphs.

1.3.3.6.1 System Engineer. The System Engineer is responsible for conducting system/subsystem testing and troubleshooting, providing support for other system testing, and monitoring his/her system. The System Engineer is responsible for keeping the respective TC apprised of the progress of his/her testing/troubleshooting, and for making recommendations on any real-time changes which may improve operational conflicts which can occur from time to time. The System Engineer is also responsible for keeping his/her management apprised of the status of any testing and troubleshooting in process. The System Engineer is also required to report to his/her OTC or tank/booster test conductor (TBC).

1.3.3.6.2 Lockheed Test Director (LTD) and NASA Test Director (NTD). The LTD and the NTD are responsible for overall test operations within the firing room. This includes schedules, discipline, and safety of all operations. The LTD and NTD are also the direct interface with Safety in support of all hazardous operations. The LTD and NTD also interface with Security and outside agencies such as Houston Flight, White Sands, Merritt Island launch Area (MILA), etc.. The LTD and NTD are the single-point of contact for public address announcements relating to hazardous operations. The LTD/NTD is the prime executor of emergency procedures documents (EPDs). The LTD position is manned seven days a week and is the primary interface with offsites. The NTD primarily mans the firing room during tests or other procedures requiring formal crew involvement (S0007, S0017, S0014). Normally, the importance of the procedure determines the involvement of the NTD.

1.3.3.6.3 OTC. The OTC is responsible for the conduct, discipline, and safety of all personnel during orbiter related test operations. He/she is responsible to support the test team with the resources under his/her direction as well as execution of the schedule, including all firing room-initiated adjustments to that schedule. The OTC, like other element TCs, is responsible for updating the Shuttle processing contractor (SPC) management chain on schedule or test accomplishments, problems, and recommendations for schedule improvement. He/she is involved

in all OMI call-to-stations (CTS) and assurance that all personnel conduct their tests to the highest standards of safety both within the firing room and at the test site.

1.3.3.6.4 TBC. The TBC has a dual function, acting in the combined capacity of a tank and a booster test conductor who reports directly to the LTD.

1.3.3.6.5 Support Test Manager (STM). The STM is the primary interface within the firing room for support services such as operational intercommunication system (OIS), trucks, cranes, sampling labs, etc. The STM works through all TCs and the LTDs.

1.3.3.6.6 QC Runner. The QC runner is a person designated to distribute deviations to Test or control documents directly to the console operators within the firing room. He/she reports directly to QC.

1.3.3.6.7 Safety Console Coordinator (SCC). The SCC is the one person within the firing room who is responsible to coordinate the activities of all site Safety personnel in support of firing room operations. The SCC reports directly to the LTD.

1.3.3.6.8 Firing Room Quality Control Coordinator. The firing room QC coordinator is responsible to verify the accuracy and completeness of all documentation performed from the firing room. A QC representative, control monitor quality control (CMQC), is assigned to each System Engineer and TC on their OIS channels during the performance of firing room operations. The firing room QC coordinator reports directly to QC.

1.3.3.6.9 TPE. The TPE has the primary responsibility for technical integration within the firing room. He/she acts as the technical adviser to the OTC/Launch Test Conductor (LTC). He/she has system monitoring capability at his/her console and may serve as backup for some system personnel during breaks and lunch. The TPE reports directly to the OTC.

1.3.3.6.10 Pad Leader. The Pad Leader is an extension of the OTC at the work site. The Pad Leader is responsible for directing, controlling, statusing, and working out any problems at the test site. The Pad Leader provides technicians with local QC, equipment, etc., and works with Safety in support of operations which are directed from the firing room. The Pad Leader reports directly to the OTC.

1.3.3.6.11 Others. The following is a list of other personnel and their call signs connected to the firing room operation:

- A. System Engineer including NASA and LSS counterparts (see KVT-HB-0002, Call Sign Handbook for specific callsigns).
- B. LTD Channel 212 or 232
- C. OTC Channel 132
- D. TBC Channel 136
- E. STM (STM)
- F. Data coordinator
- G. LSOC SCC (SCC)
- H. LSOC cargo systems lead (CPLE)
- I. McDonnell Douglas Astronautics Company (MDAC) payload test conductor (PTC) including the payload customers [firing room and engineering support assembly (ESA)]
- J. NASA Landing and Recovery Director (LRD)
- K. Checkout, control, and monitor subsystem (CCMS) master console operator (LPS)
- L. Firing room test assembly inspection record (TAIR) station personnel (CMQC)
- M. Record/playback station personnel (JRPS)
- N. Firing room TV monitors (JYVO) Channel 138
- O. Firing room OIS (GYCC) Channel 117
- P. Orbiter Pad Leader (PAD)
- Q. TPE (TPE).

1.3.3.7 Test Team Organizational Charts. The Test Team Organizational Charts depicting day-to-day operations and the integrated test team are shown in figures 1-2 and 1-3. These charts show the hierarchy to which personnel working in the firing room must adhere. These can be found in KVT-OI-0001.A, STS Systems Operations Instructions, and SP-101 (2) K.

1.3.3.8 Equipment and Documents Required for Testing. Equipment and documents for the major test procedures in which the System Engineer or the test team may be involved at test time; OMIs which are subtasked to the system major OMI, include the following:

- A. Standard configuration OMIs which apply to the system of the System Engineer, including Shuttle/Orbiter standard powerup power down OMIs (V9001, S9001).
- B. Software listings for Downlink Downlist software requirements (These are available from the TPE.)
- C. Advanced electrical schematics
- D. System schematics for troubleshooting
- E. Call Sign/Word Handbook (KVT-HB-0002)
- F. Log book
- G. Current phone numbers of management and other members of your group

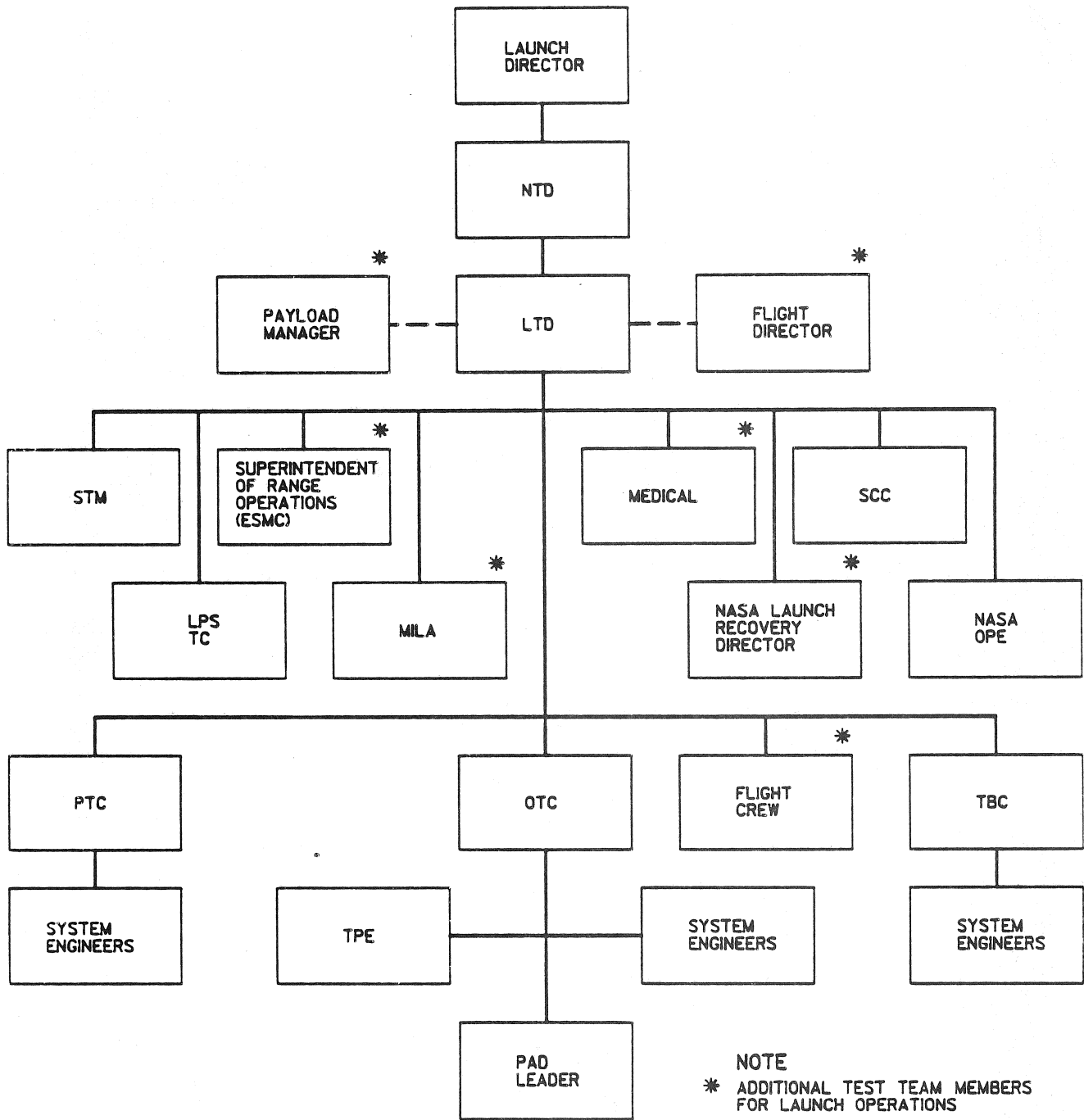


Figure 1-2. Test Team Organization Chart

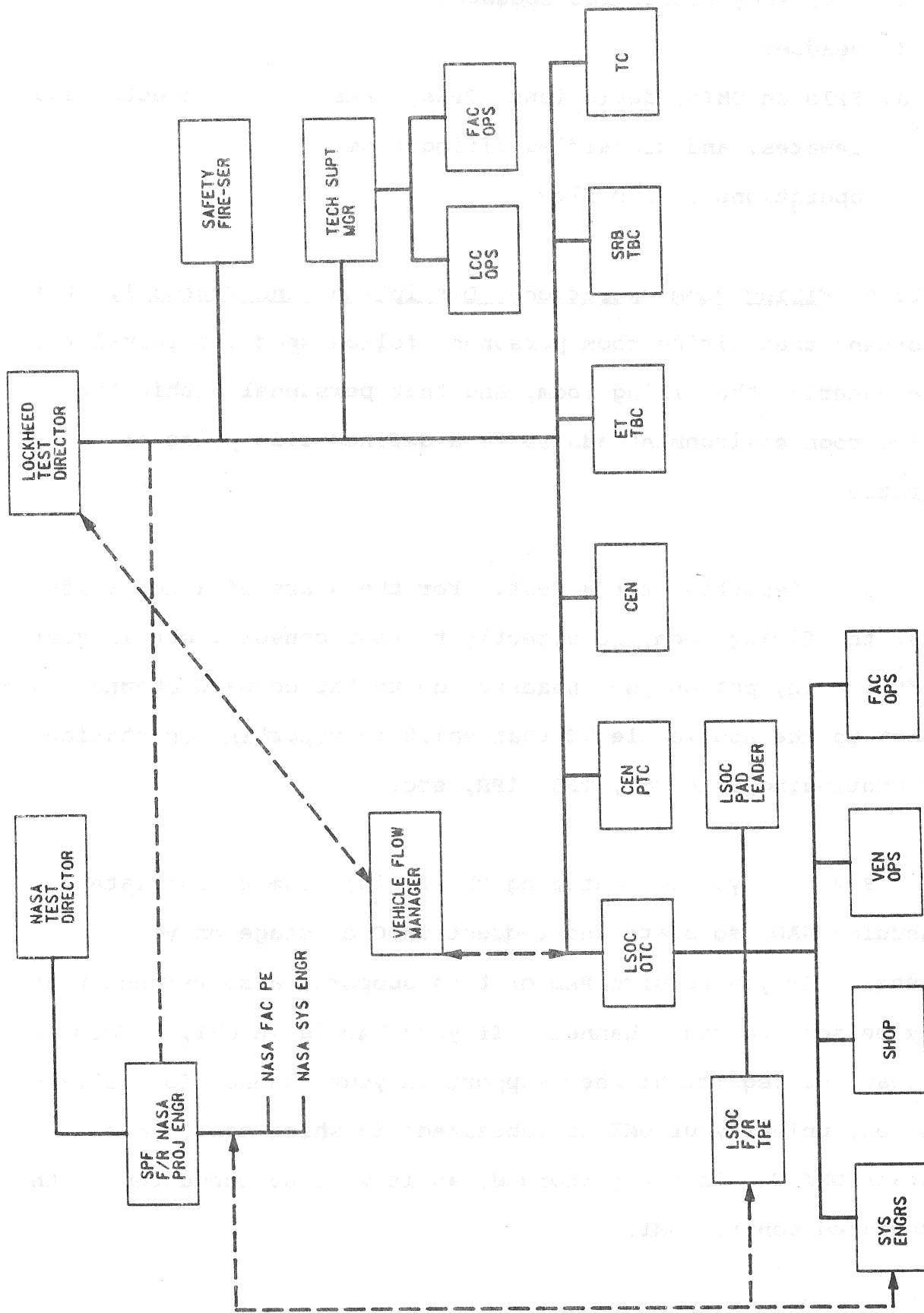


Figure 1-3. Test Team Day To Day Operation

H. Emergency Procedures Document

I. Headset

J. SPIs on OMIs, deviations, TPSs, IPRs, PRs, connector and demates, and classified firing room operations if DOD flow.

1.3.3.9 Firing Room Operations, Discipline, and Protocol. It is important that firing room personnel follow specific formalities when entering the firing room, and that personnel within the firing room environment adhere to a defined discipline of operation.

1.3.3.9.1 Reporting for a Test. For the start of a new shift, enter the firing room, go directly to your console, obtain your shift tie-in, put on your headset, go to the command channel, and report to the applicable TC that shift is reporting on station and continuing with OMI, TPS, IPR, etc.

1.3.3.9.2 If you are entering the firing room to initiate a scheduled WAD, so state and request CMQC coverage on your channel. If you require PAD or tech support, also request that they be sent to your channel. If your WAD is an OMI, inform the TC that you require his/her support on your channel for call-to-station, unless your OMI is subtasked; in which case, your subtask OMI CTS is not performed, as it will be conducted by the integrated/control OMI.

1.3.3.9.3 Use of the Firing Room as a Walkthrough. Because of their physical locations, firing room 1 and 2 are used as walkthroughs to gain access to other launch control center (LCC) and VAB locations. Under most conditions, it is acceptable to walk through without checking with the LTD/OTC, provided you travel a path in front of the firing room and along either one of the side walls and that you do not stop to chat along the way. It is unacceptable to walkthrough during full-up integrated tests, i.e., S0017, S0007, S0014, etc. There is usually controlled access if testing.

1.3.3.9.4 Visiting the Firing Room. With the preceding exceptions, visiting for business purposes is permitted; e.g. firing room paper cleanup, test coordination, technical discussions are permitted after you have checked through the LTD/OTC and obtained permission to visit a specific location. Conditions for walking into and out of the firing room TAIR station (QC) are considered the same as walk-through conditions.

1.3.3.9.5 Leaving Station. At shift change, it is not necessary for the relieved System Engineer to check off-station as the requirement is for the oncoming shift to report in. The System Engineer should check off-station through the applicable

TC when he/she terminates operations for that shift. Further, when checking off-station, he must give to the relieving System Engineer a thumbnail status of what has been accomplished during the shift.

1.3.3.9.6 Launch Complex Paging System. This paging system is to be used for test announcements only. Paging may be used, however, with Test Director concurrence, or as a last resort to establish communications. Normally, those who have paging capability on the local net include the LTD, OTC, TBC, and Safety.

1.3.3.9.7 OMIs. An OMI is a test document based on OMD Handbook S00000-2 formatting standards which compiles requirements for the purpose of accomplishing specific objectives.

A. Section I. Physically located in the front of an OMI, the information section. The major information within this section is:

1. Special tools and equipment, i.e., materials equipment requirement list (MERL)
2. GSE required for the OMI
3. Safety requirements which identify the hazardous operations within the OMI

4. Special instructions which identify operational information needed for OMI performance
5. OMRSD requirements.

B. Section II, Preoperations setups. Contains step-by-step setup instructions for nonpowered configuration, which must be established to start a test. Preoperations must be complete (unless identified otherwise) prior to CTS.

C. Section III, Operations Support Setups. Contains step-by-step instructions to establish a new configuration or move from a previous configuration to another configuration during the performance of the test. Operation support setups are those which are required after CTS.

D. Section IV, Operational Sequences/Steps. Contains the steps which are required to satisfy the test requirements and objectives of the OMI. This section also covers the hazardous operations performed during the test.

E. Section V, Postoperations Instructions. Contains the steps necessary to secure from a test.

F. Test appendices, data sheets, emergency sequences.

G. Hazardous OMI's are identified by the following:

1. The cover is highlighted in red and has the words this OMI contains hazardous operations.
2. Section I, Safety Instructions, specify the hazardous operations involved during OMI performance.

3. The use of Warning and Caution notes during OMI performance.
4. Specific emergency instructions in Appendix Z
5. Bar charts showing hazardous operations with bold diagonal lines.

H. Caution and Warning Notes:

1. Caution. A note which alerts personnel that the following sequence or steps if not properly performed could cause damage to hardware.
2. Warning. A note which alerts personnel that the sequence or steps which follow could, if not properly performed or due to an accidental condition, cause injury to personnel.

NOTE

During the performance of an OMI, it is mandatory that each Warning note be read by the test leaders over the OIS to all personnel supporting the test on that channel.

- I. Appendix Z. Contains instructions to put the system into a safe configuration from an emergency condition.
- J. GP 1098, Ground Safety Plan, contains information concerning clears and controls required during hazardous operations. This document must be supplemented by coordination with the Shuttle Processing Contractor Safety group during test document development.
- K. EPD. The EPD contains emergency instructions and directions for emergencies which occur during routine operations or major testing. There is an EPD for each test site (OPF, VAB, pad, etc.). The EPD ties in with Appendix Z in that Appendix Z safes from a specific condition which was created by the OMI containing Appendix Z. Appendix Z instructions are executed primarily by the TCs and systems personnel, with the instructions usually specific to hardware/software. After safing per Appendix Z, the EPD continues with the emergency condition in broader, more general terms, carrying the emergency to a final and safe conclusion. Appendix Z instructions are specific to active OMIs while EPDs are specific to conditions which may or may not be the result of an active OMI. EPDs are primarily executed/controlled by the LTD/NTD.
- L. X-OMIs. A classified OMI in its entirety. This normally has DOD payloads, trajectories, flight checks, etc.

M. Appendix Q. A classified portion of a Shuttle hardware/software (Shuttle/Payload integrated tests) OMI given to those personnel who have a need to know. When the console operator comes to a classified subject of the test within an unclassified OMI, Appendix Q picks up, and is in the possession of those personnel who have a need for it in running the test. After completion of the classified portion in Appendix Q, Appendix Q is then put away and safeguarded, and the remainder of the unclassified OMI is accomplished.

N. Hazardous Steps. Prior to the start of all hazardous operations, there is a Warning note stating: "Hazardous Steps Follow." At the completion of the hazardous operation, there is a Warning note stating " Hazardous Steps Complete." When performing hazardous operations, perform the following:

1. Prebrief the operation with all personnel supporting you on your OIS channel.
2. Review Appendix Z (if an OMI) or your prewritten Emergency Instructions (if IPR, TPS, or PR) with applicable personnel.
3. Read all Caution and Warning Notes as you progress through the test, time permitting; if not, prebrief.

4. All deviations written to hazardous OMIs require Safety signature. All hazardous OMIs/OM TOPS require Safety signature.
 5. If other than an OMI, those personnel wanting to perform hazardous operations from the firing room are responsible to supply the applicable TC or LTD with a copy of the paper, i.e., deviations, TPSSs, IPRs, etc.
- O. KMI 1710.13 (KSC Management Instruction). This document sets the guidelines for how hazardous requirements are satisfied. It contains the information on how hazardous operations are formulated.
- P. Repetitive task OMI (RTOMI). An OMI with tasks, operations, or configurations considered standard, usually repeated one or more times each flow, and performed exclusively as support to other tests or operations. This type OMI does not satisfy test requirements except those that are necessary to assure a correct support configuration.
- Q. Operations manual (OM). A manual, divided into tasks, that details the steps necessary to process hardware and associated ground support equipment (GSE).

1.3.3.10 Conducting Systems Tests. After completion of CTS, the System Engineer should give a brief description of the test about to be performed to those personnel on his/her test channel so that all supporting personnel are aware basically of why they are there. If it is a hazardous test, make sure that all Appendix Z participants have reviewed their Appendix Z requirements. As you progress through the test, you should state frequently what step you are performing. As each sequence is complete, so state, and announce the start of the next. All Caution and Warning notes must be read verbatim to all personnel supporting you on your channel. Prior to the start of each hazardous operation, you must conduct a briefing of the hazardous operation about to begin. Also review with the specific test participant(s) any specific Appendix Z steps that may apply to the test.

1.3.3.10.1 Declaration of an Emergency. If you have a degrading or malfunctioning condition that you feel requires immediate action by personnel on your channel (to prevent injury to personnel or damage to hardware), you must alert and execute as follows:

- A. "Break--Break", "This is an emergency," "OMTG," "057 Panel," "Close valve XX now."
- B. Recapping and paperwork comes later, after the emergency condition has been safed.

1.3.3.10.2 Stopping a Test. If you must stop the test for any reason, (break, paper processing, etc.), so inform the personnel supporting you. They may be able to break or have a personnel changeover in the meantime.

1.3.3.10.3 Continuous Testing. If you intend to continue testing through lunch or shift change, you must notify the OTC as much in advance as is known, so arrangements can be made to keep your personnel on-station. Obviously, you should notify your supporting personnel.

1.3.3.10.4 Breaks. If there is a need to take a break during active testing, or while you are in the monitor mode, notify the TC. If your system is down, the break may be taken without a relief. If your system is up, the TPE may have monitor capability; in which case, he/she monitors (no test activity) from his/her console. If there is hazardous test activity at the site, you have to wait until it is terminated before breaking, unless arrangements are made through the TC to cover it otherwise. (NASA can monitor but not test).

1.3.3.10.5 Reporting Problems. When do you request an IPR? When you are initially faced with your problem, check it out first. A certain amount of research and mental gymnastics is expected prior to requesting an IPR. However, whenever you are

in doubt or do not fully understand a condition you should take an IPR. To request an IPR, contact the TC (OTC, TBC) on his/her command channel. Give your callsign; give the document you are working; explain the problem; and give sequence, step, and constraint, if possible, and if you intend to stop testing to troubleshoot. The TC makes sure that CTPE and CMQC are monitoring. You are given an IPR number, at which time either you or QC fill out an IPR index card. The information on this card is what is fed into the central IPR system [problem reporting and corrective action (Praca) data base] for tracking purposes. He/she then uses the card to fill out the first page of the IPR, which he/she gives to you.

1.3.3.10.6 You should put a constraint statement on the IPR if possible/known. You should then write your troubleshooting plan and steps which satisfy this plan or continue with testing, depending on your original discussion with the TC/TPE.

1.3.3.10.7 Active Troubleshooting. The first order of business to initiate active troubleshooting on an IPR is a request through the OTC for PAD/OPS, etc. to come to your channel to discuss whatever special equipment is required to support your troubleshooting. This equipment should be listed on the IPR. The next item you should initiate is the Troubleshooting Plan. This is a plan that narratively describes what you intend to do for your first phase of troubleshooting. Also described is the

purpose of the plan. You then obtain signatures for the plan and proceed to write the technical/operational steps which execute your plan. At the completion of the steps which satisfy this first plan, write a summary of the results of these steps, again obtaining the appropriate signatures. If there is a need to continue with the troubleshooting, you must repeat the process i.e., plan, steps, summary. Continue to do so until you have solved the problem, or require an upgrade of the IPR. Keep in mind that your interim summary is very important for the recap.

1.3.3.10.8 Requesting Support. Personnel who are not specifically assigned to your testing channel, JYVO (OTV-Channel 138) and GYCC (OIS-Channel 117) must be requested. All requests for other personnel or contractors to support your operations must be coordinated through the applicable TC (OTC, TBC, etc.,). No OMI is to specify direct contact with those not assigned to the testing channel. Direct OIS or phone contact with resources not assigned to your test is forbidden.

1.3.3.10.9 Master Alarms. Appropriate reactions to master alarms are:

- A. During a test, if your SCO reports a master alarm, and the master alarm is not specifically called out in your test document, notify the OTC. If you are the cause of the alarm and it is a normal occurrence, tell the OTC and he

will permit you to reset the master alarm. The OTC will ask you to write a step in your test document as verification. He/she also notifies the Instrumentation System Engineer, who is the keeper of the master alarm problems.

- B. If the master alarm is not immediately explained, the Caution and Warning (C&W) Instrumentation Engineer does a search pattern to identify the source of the master alarm.
- C. If the master alarm cannot be identified (source/system) an IPR is taken by the instrumentation group. For that reason, he/she is in control of master alarm reset. We consider master alarms as very important and we want to know why they occurred.
- D. If you are performing a test that causes master alarms (as normal occurrences), you should have steps in your WAD to notify the OTC that the following test causes master alarms.

NOTE

Reset of the master alarms does not get rid of the data. The master alarm does not silence until a button is pushed.

1.3.3.10.10 Firing Room Fire Alarm/Halon System. Appropriate reactions to firing room fire alarm are:

- A. If the fire alarm or Halon system goes off in the firing room and you are not monitoring powered systems or GSE hardware, evacuate the room in a very orderly manner.
- B. If you have powered equipment (an active station), notify personnel supporting you on your channel about the fire alarm. Safe or be prepared to safe your hardware and wait for instructions from the LTD/NTD/OTC. Do not leave until instructed to do so, unless of course you are in immediate jeopardy.
- C. When the Halon system flashing red indicator light is activated, there is an approximate 20-second time delay before the Halon is actually dispensed. Treat the same as in steps A and B.

1.3.3.10.11 The Schedule. There are only two official schedules which direct operations on the Shuttle program.

A. The KSC integrated control schedule (KICS) is commonly known as the 72 hour, 11 day schedule. The 72 hour portion of the KICS shows minimum detail of any specific operation. The 11 day portion generally only references an operation and is in less detail than the 72 hour portion.

1. The KICS schedule is the result of a scheduling meeting conducted each day and involves representatives of all systems, support. Cargo, and other contractor organizations working the Shuttle program.
2. The BULLDOG is the firing room final edition of the KICS schedule, printed and distributed each afternoon at the end of first shift.

B. The second schedule, the MINI (flags), is a detailed breakdown of the minimum detailed operation which is specified on the 72 hour portion of the KICS.

1.3.3.10.11.1 The Systems Engineers complete a Schedule Data Sheet and submit it to PP&C or LCC operations during the appropriate scheduling meetings, or at least 24 hours prior to WAD performance. Tasks are not scheduled in the KICS, Floor, or GSE schedules to be worked within 24 hours of the test unless the paper/parts are available with appropriate signatures.

1.3.3.10.11.2 If you want to put into work an operation that is not specified to be performed at that time, or you do not intend to perform an operation that is specified, you must coordinate these changes through the applicable TC. There is an operational and management chain that is charged with the responsibility of tracking, reporting, scheduling, and rescheduling these operations; the TC is the beginning of this chain.

1.3.3.11 Deviations. An OMI change is required during real-time OMI performance or a change written prior to the start of an OMI when there is insufficient time to process an ICR or conduct an OMI review.

A. Deviations are covered in detail in OG-306 OMI Dev Processing, and also in SPI SP-511 (2). There are four different categories of deviations, as follows:

1. Permanent Deviation. A change which is effective for all future flow performances of the OMI section to which it applies and includes all reruns on the same flow. If a deviation has been logged through Quality and later there is no intent on running the deviation, another deviation must be written to delete the original.

2. Temporary Deviation. A change which is effective one time only. Any future reruns of the applicable OMI section requires a rewrite of a temporary deviation if a rerun of the deviation is also intended.
 3. Temporary-Recycle Deviation. A temporary deviation which is rerun during recycles for subsequent launch or landing attempts (OMIs S0007, S0026, S0028) on the same space transportation system (STS) mission.
- B. The Processing Support Plan (PSP). This is a baseline for all inflow processing and maintenance required and approved for a specific STS mission. It is broken down alphanumerically. Only those tasks listed in the PSP are scheduled or have WAD released.
- C. PSP Deviations. Any additions or deletions to tasks or operations listed in the PSP must be authorized prior to the release of the paper to the site TAIR station. These deviations normally are written before the PSP is released on the street, but are written as required during real-time needs.
- D. Job Cards. Job cards list repetitive site local (primarily mechanical) tasks and are kicked off in OMIs, and in some instances, specified by schedule only. A particular job card may be called out in one OMI and then,

further on down the line, may be called out in another OMI. They are normally worked by technicians and are taken out to the work area with them. They also contain operations support and preoperations not contained in an OMI.

E. TPS. The procedures for TPSs are taught in course OG-141, OMD Familiarization, and are also found in SPI SP-504 (2). Generally speaking, TPSs are written usually for a one-time-only test or operation.

F. TOPS Handbook (S00000-2).

G. Engineers Buying Off Their Own Work. The following ground rules apply:

1. In some cases, engineers are allowed to proceed without firing room QC coverage during the execution of an OMI.
2. While this applies mostly to nonhazardous, single-system tests, it may also include the nonhazardous portions of hazardous OMIs. Keep in mind that although the firing room QC (CMQC) is not present, the technician at the work site may have a QC representative with him/her.
3. This agreed upon list of OMIs is located in SPI SP-519 (2), Appendix A. This list is also posted in the firing room (TAIR) work control station.

NOTE

As Quality takes over operation of the TAIR stations, there will be more personnel available to function as firing room quality. The preceding procedure may be scrapped at a later date as a result.

H. Types of Constraints.

1. Category I. Prohibits the power-up or CTS of an operation, or the operational step of an OMI not containing a power-up.
2. Category II. Prohibits the start of a specified sequence/step(s) after test start within the operational section of a WAD.
3. Category III. A constraints list addendum. The section of a constraints list which lists open work items whose constraint status for equipment hardware and software being used in support of, or being tested by a WAD is unknown. All category III items must be upgraded to category I or category II, or signed off as no constraint.

- ### I. Open Item Review (OIR).
- A meeting conducted to identify items which could constrain the start or performance of an OMI. All open items are reviewed against the flight

element, payload, and GSE to be used to conduct the WAD. Items identified as constraints are compiled into a document called a constraints list. OMs that must have OIRs are listed in a matrix in SPI SP-507 (2), Appendices A and B.

1. After the OIR, the constraints list is sent to the TAIR station so that each constraining item can be closed as worked off. Four (4) hours prior to CTS, the OIR/Constraints List is sent to the firing room TAIR station.
2. Category I constraints must be closed prior to CTS. Category II constraints are tracked during the OMI and must be closed/waived before the start of the applicable WAD sequence/step.
3. Engineers also provide a constraint disposition on all Category III items, constrain all flight hardware and software items in the open item status report (OISR) without a constraint, disposition all unconstrained GSE items in the OISR as a constraint to a specific WAD sequence and flight or as a none. If none, add supporting rationale in the OISR for transfer to the

constraints revision record (CRR) by OP&C. This information is covered thoroughly in SPI SP-507 (2).

- a. It is the primary responsibility of the System Engineer, TPE, and TC (for integrated OMIs) to see that their constraints are cleared.
 - b. If, after CTS, new paper is found, the engineer and TC must be immediately notified and a determination is made whether the paper is a constraining item. If it is a constraint, the sequence and step must be listed and it becomes a category II constraint.
4. CRR. This form is a traveler attached to all WADs which augments the constraint block and has ample space to list and change constraints.
- a. No WAD shall have a none constraint disposition unless supporting rationale is provided on the CRR (per Appendix E of SP-507 (2)). The none constraint category does not exist for flight elements.
 - b. A CRR is attached to each WAD upon constraint disposition. Any time a constraint changes, the new constraint(s) are recorded on the WADs CRR to provide traceability.

1.3.3.12 Logs. Logs provide continuity between shifts and act as adjuncts to troubleshooting. They shall contain an accurate record of events that transpire during the course of a shift, including dates, times and other information that would be helpful in retracing events to support troubleshooting operations.

A. Minimum requirements for logbook entries:

1. Major significant activity/events as per the schedule, test procedure, or WAD
2. Major realtime deviations from planned schedule, test procedure, or WAD
3. Real-time requirements, authorizations, concurrence
4. Problems including measurement or system outages
5. Information relevant to specific problems
6. Support activity information or communications to or from management or customer
7. Test area openings and closures (notification and actual clearing and accessing times)
8. Significant personnel changes (absenteeism that affects scheduled operations).

B. Log Entry Criteria.

1. All entries shall be made in black ink by ballpoint pen.
2. Entries should be self-explanatory and complete, but brief and to the point.

3. Entries should be grammatically correct and legible.
 4. Wrong entries shall be corrected as follows:
 - a. Neatly lineout incorrect portion using a single line.
 - b. Insert correct information.
 - c. Initial correction.
 5. Entries should be in chronological order.
 6. Open-ended entries shall be followed by subsequent entries to make them close-ended.
 7. After the last data entry in the log, the log book shall be retained as a permanent record for a period of 1 year.
- C. Data Playbacks. Requests for data playbacks should be made through the LSOC TPE (CTPE) and NASA Project Engineer (COPE).
- D. Firing Room Console Problems. If you have a problem with your console, contact the TC. If it occurs during a critical portion of your test, request that the CTPE call up your program and relocate yourself to the integration console until your console is reloaded or another console is assigned to you.
- E. General Problems Within the Firing Room. Contact the TC for the following:
1. For TV monitor problems, TC contacts JYVO (OTV/CCTV CTLR) on channel 138.

2. For OIS/Communications problems, TC contacts GYCC (Communications Control) on channel 117, or 867-4141.

If you are unable to report, get someone to report the information for you. State identification, location, type of equipment, and problem encountered.

1.3.3.13 General Emergencies. General emergencies in the firing room are classified as follows:

A. Loss of OIS. When we find we have lost OIS, all of the subsystems are polled by the OTC for their hold capability. Even if there is minimum activity in the firing room and you lose OIS, the OTC wants verification that you can hold in your present configuration until the OIS is reestablished.

1. Nonhazardous testing. The OTC polls the subsystems for holding capability and stops all tests.

2. Hazardous testing. Again, you are polled by the OTC for your hold capability. If you happen to be involved in a hazardous subsystem test, you have had on-net pretest briefings prior to the start of your hazardous test. In prebriefing you should discuss with all the personnel, who are remote to your location, but who

under this situation have responsibility and decision authority whether to safe their hardware, if it is dictated by the test, or maintain their present configuration.

NOTE

Once OIS is lost during a hazardous test, the responsibility of the hardware belongs to the people who have control of that hardware. If it is remotely controlled from the LCC, and you cannot hold, and you have the capability from the firing room for safing of that system, that is exactly what you do. No on-net discussion with the OTC/LTD/NTD is necessary. If you feel it must be safed, safe it.

B. Loss of Launch Procseeing System (LPS).

1. Nonhazardous testing. As in the case of loss of OIS, the test is stopped until LPS has been recovered.
2. Hazardous testing. This generally requires the subsystem to take immediate action to locally safe the system and is dictated by the configuration. If there is loss of LPS and you no longer have direct talk capability with the hardware, but you do have local capability, go ahead and use your local capability and safe your hardware. You do not have to go through the element test conductor if you feel your actions must be immediate.

C. General Injuries. Most of these situations are handled by the OTC/LTD/NTD. You should be familiar with the reporting procedures.

1. Nature of illness/injury
2. Seriousness
3. Specific location of injured party
4. Whether an ambulance is required.

NOTE

If you get a call regarding a mishap/injury, try to keep the person on the phone. If you are alone in the firing room, call 911 or the Duty Officer at X4910 to relay the necessary information.

D. Preliminary Evaluation Report (PER). This form is to be used in all cases of personnel injury or equipment damage. The back of the form itself has instructions on how to fill out the form. Once the form is completed and signed by the supervisor of the individual(s) involved, it is sent to Safety, and then sent to the Director of Operations in the LCC by the end of that shift.

E. Site Fire Alarms.

1. Nonhazardous testing. When a fire alarm sounds or you get a call from the test site that reports a fire alarm, and an emergency condition has not yet been reported, all of your supporting personnel at the test site are to be evacuated immediately and the LTD/NTD notified.
2. Hazardous testing. An attempt, if possible, should be made to safe prior to evacuation. If the LCC is controlling the operation, the site is to be evacuated immediately. Status the OTC/LTD/NTD as soon as possible.

F. Red Crew. The red crew is a group of individuals from numerous disciplines that are standing by during hazardous operations (OMIs), primarily for launch sequences, and pad entry in prelaunch conditions. They act in a very limited capacity/function and are not involved in troubleshooting. They are briefed prior to the start of hazardous operations as to what types of problems to expect, what to do, what not to do, and just what their limitations are. They may have to be in self-contained atmospheric protective ensemble (SCAPE) to help disabled/downed personnel out of certain areas, etc.

1.3.3.14 Reference Documents. The following is a list of reference documents:

- A. SP-010 (2)KV Test Team Operational Discipline
- B. SP-014 (2)KV Log Books
- C. SP-017 (2)KV Certification System
- D. SP-503 (2)KV Closed-Loop Feedback of OMRS Satisfaction
- E. SP-505 (2)KV Scheduling
- F. SP-507 (2)K Constraints and Open-Item Reviews
- G. SP-508 (2)KV OISRs
- H. SP-509 (2)K Job Card System
- I. SP-511 (2)K OMI/OM Deviation Processing
- J. SP-514 (2)K OMI Preparation and Release
- K. SP-519 (2)K Flight Element Operations OMI Implementation
- L. SP-526 (2)K Processing Support Plan
- M. QA-001 (2)KV Problem Reporting and Corrective Action
- N. SF-505 (8)KV Mishap Reporting
- O. KSCL-1735-035 LPS Firing Room Utilization Plan
- P. KVT-HB-0002 NASA/DDD Callsign/Work Handbook, Rev 14
- Q. KVT-OI-0001.A STS System Operations Instructions
- R. KVT-PL-0009 STS Operations Plan LC-39 Fallback Area
- S. S00000-2 TOPS Handbook
- T. NASA Ref Pub Space Transportation System and
1059 Revised Associated Payloads: Glossary,
Acronyms and Abbreviations

1.3.4 LPS (GENERIC).

1.3.4.1 General. The LPS is a computer-operated system used for support test, checkout, launch control, and operational management of launch site ground operations. The control, checkout, and monitor subsystem (CCMS) is the same for both orbiter and GSE systems with minor exceptions. The biggest difference is that GSE systems utilize a hardware interface module (HIM) and orbiter systems utilize a orbiter/LPS signal adapter (OLSA) to send/receive signals. The HIM or OLSA transfers control/status signals to/from the console and hardware. All LPS functions unique to a particular system covered in Section 2.

1.3.4.2 Operational Components. The following paragraphs identify the components used to process LPS data. Figure 1-4 shows the functional relationship between the components.

1.3.4.2.1 Consoles. The console functions are performed via Type I and Type II consoles and their associated software.

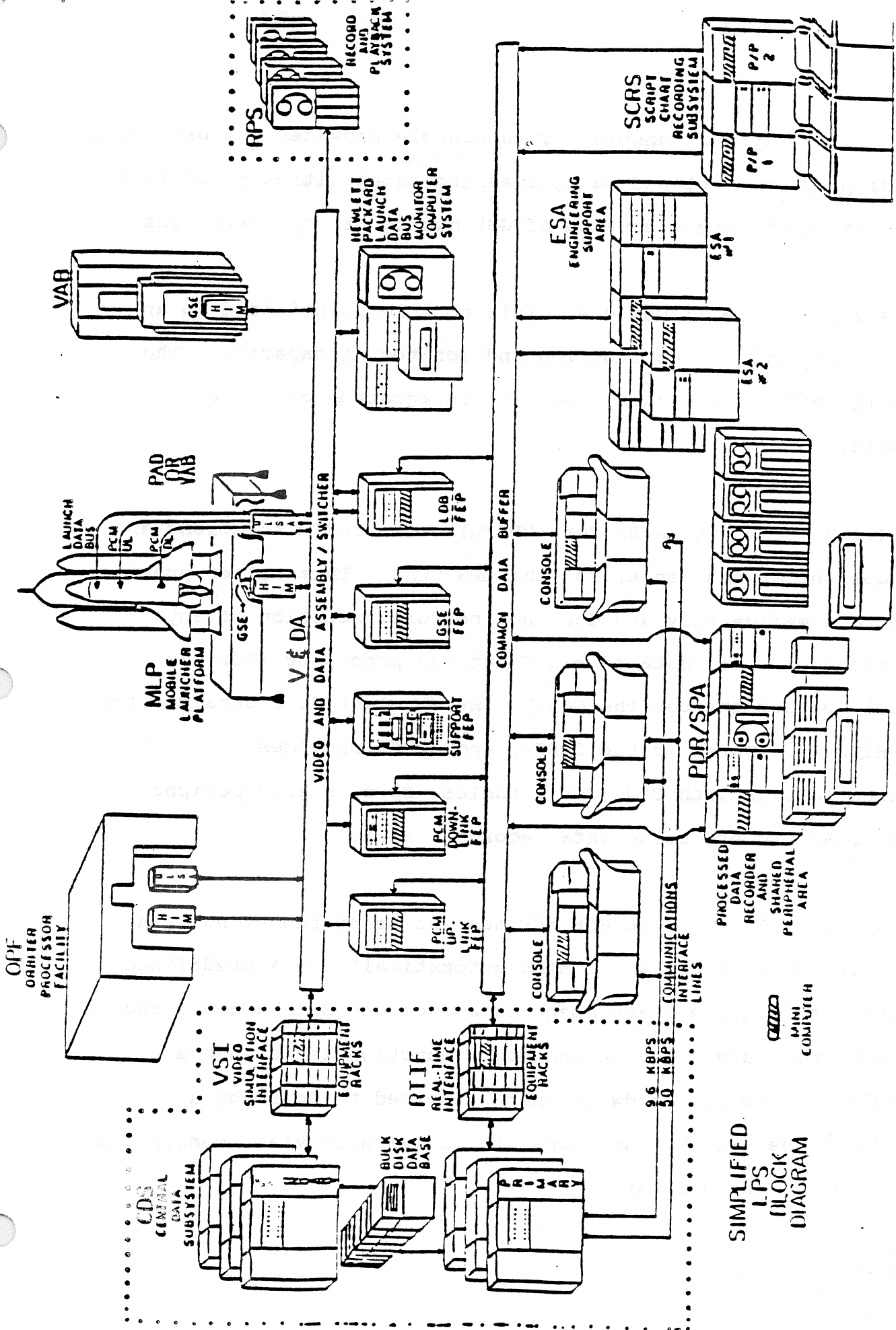


Figure 1-4. Simplified LPS Block Diagram

1.3.4.2.1.1 Type I Console. This console provides the user with the display, control and dataprocessing capabilities to control test, checkout, and execution of GSE during ground operations.

1.3.4.2.1.2 Type II Console. This console is utilized in an overall supervisory controlling and monitoring capacity. The Type II console is either a master, integration or spare console.

1.3.4.2.2 Common Data Buffer (CDBFR). The CDBFR functions as the communications center for the LPS CCMS. This buffer provides a storage medium only and does not perform execution of any instructions. All data from a front end processor (FEP) or console passes through the CDBFR. Measurement data obtained from the HIMs are stored in the CDBFR, and CDBFR provides interconnection with CPUs for consoles, FEPs, shared peripheral area (SPA) and processed data recorder (PDR).

1.3.4.2.3 GSE FEP. The GSE FEP has two major functions. The first is to interrogate the HIMs automatically in a predefined sequence to acquire measurement data from the GSE hardware and to process this data. The second major function is to ensure stimulus to the GSE hardware when requested to do so by a console. The GSE FEP functions are implemented via a combination of microcode and software.

1.3.4.2.4 HIM. The HIM is the interface between the GSE and the LPS. The HIM is an input/output (I/O) device that provides the required stimuli and monitoring capabilities enabling the LPS to communicate with various pieces of GSE.

1.3.4.2.4.1 The HIM assembly provides the CCMS with a versatile, general purpose interface with GSE. The HIM provides all the required signal conditioning, measurement, and command generation functions to permit remote monitoring and control of electrical and eletromechanical GSE. The HIM is basically a computer I/O device, operable remotely from the GSE FEP through the video and data processing assembly (V&DA) data transmission system. The HIM performs analog and discrete input and output, relay closure, and self-test functions. Typical HIM applications include remote operation under control of GSE FEP through a serial GSE data bus and local operation under control of the HIM control and display panel.

NOTE

The GSE data bus is sometimes called remote data bus (RDB).

1.3.4.2.4.2. The HIM is composed of:

- A. A transmitter/receiver module, which allows for signal communication between the HIM and V&DA

- B. A control card and master control card, which allows for HIM internal control as well as Manchester to non-return-to-zero (NRZ) conversion
- C. 30 I/O cards/HIM. These are subsystems GSE dedicated cards that allow for data conversion (analog to digital and digital to analog). Other HIM cards and functions are listed below:
1. Eight channel relay closure discrete
 2. 16 channel 5 volts logic source discrete measurement
 3. 16 channel 28 volts logic source discrete measurement
 4. 16 channel 5 logic sink discrete measurement
 5. 16 channel 28 volts logic sink discrete measurement
 6. 2 byte command, internal acknowledge
 7. 4 channel 0 to +50 mA current control command, Type II
 8. 4 channel 0 to 5 vdc analog command, Type I
 9. 4 channel -5 to +5 vdc analog command, Type I
 10. 4 channel 0 to 10 vdc analog command, Type I
 11. 4 channel -10 to +10 vdc analog command, Type I
 12. 8 channel 0 to 5 vdc analog measurement
 13. 2 byte command, external acknowledge
 14. 4 channel 0 to 50 mV dc analog measurement (isolated)
 15. 8 channel 0 to 50 mA dc current measurement
 16. 8 channel 20 to 40 vdc analog measurement
 17. 4 channel 0 to 5 vdc analog measurement (isolated)
 18. 8 channel 0 to 20 mA dc current measurement.

1.3.4.2.5 PDR. The PDR subsystem is responsible for recording the operational system data on tape and maintaining recent data on direct access storage (disk). All data recorded is retained on magnetic tape.

1.3.4.2.6 SPA. The SPA provides the retrieval function for other CCMS subsystems. The SPA can request printing or plotting to the printer plotter, recall PDR data from tape, and provide support to load, verify, or dump Shuttle memories. The SPA is also backup to the PDR.

1.3.4.2.7 Printer Plotter (P/P). The P/P provides the user the capability of plotting timed events relating to specific measurements. Data is retrieved from the CDBFRs and plotted against a timed function, along with identifying information.

1.3.4.3 CCMS Operations. The following paragraphs provide information pertaining to the system software which accomplishes system load, initialization, and operation as well as provides system messages to the user via the console.

1.3.4.3.1 CCMS Load and Initialization (CLAI). The CLAI software provides the means for calling up the operational software. The CLAI software receives its control information and

directives from operator inputs through the program function keys (PFKs) and cursor. CLAI also provides return status information to the success/failure of the execution of the selected options.

1.3.4.3.2 System Messages. Upon execution of a command word by the keyboard operation, the central processor (CP) issues a response message to the operator. The command word response messages are divided into four categories as follows:

NOTE

MM/SS = Minutes and seconds (GMTP).

XXXX = Four character command as keyed
in by the user.

A. FEP Error. This message signifies to the operator that the error condition was detected by the FEP. Examples are as follows:

1. MM/SS CPR0227 XXXX FAILED - FEP/INVALID CONSOLE
2. MM/SS CPR0228 XXXX FAILED - FEP/INVALID SSRN.

B. CP Error. This message signifies to the operator that the error condition was detected by the CP. Examples are as follows:

1. MM/SS CPR0300 XXXX FAILED - FDN NOT IN DATA- BANK
(DDMT RTRN = XXXX)
2. MM/SS CPR0301 XXXX FAILED - INVALID FUNCTION
DESIGNATOR TYPE (XXXX).

C. Success. This message signifies to the operator a successful command operation and the command information follows. Examples are as follows:

1. MM/SS CPR0401 XXXX SUCCESSFUL - FEP XXXX
2. MM/SS CPR0403 XXXX SUCCESSFUL - XXXXXXXXXXXX OS
XXXXXXXX NS XXXX.

D. Information. This message signifies to the operator additional information to execute the command. An example is as follows:

```
MM/SS CPR0450 XXXX INFO GOAL MONITORING FDN  
WILL BE TWO STEP
```

1.3.4.4 Console Utilization. The purpose of this section is to provide a description of the following concepts relative to the utilization of the console:

- A. Keyboard description
- B. Display paging
- C. Keyboard commands
- D. Ground rules
- E. Placard.

1.3.4.4.1 Keyboard Block Diagram and Description. (See figure 1-5.) The keyboard layout has been divided into five sections (areas) as an aid in referencing keyboard buttons during this description.

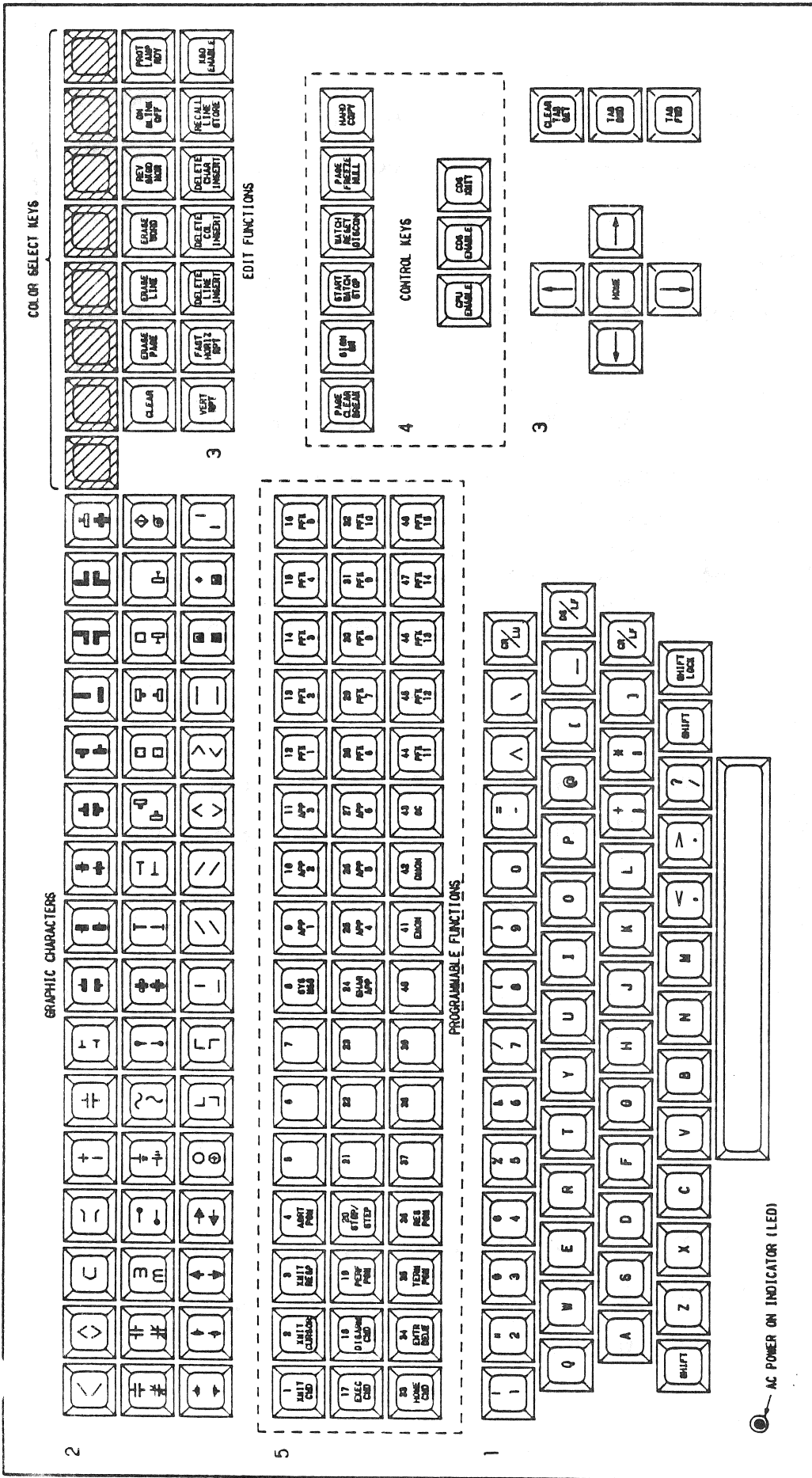


Figure 1-5. Keyboard Block Diagram

1.3.4.4.1.1 Areas 1, 2, and 3. Areas 1, 2, and 3 are described as follows:

- A. Area 1 of this keyboard is an alphanumeric keyboard.
- B. Area 2 is an extension of the alphanumeric keyboard. Area 2 has special graphic characters.
- C. Area 3 is a set of edit function keys. None of the keys in area 1, 2, or 3 cause information to be sent to the console computers. These keys are used to format display skeletons on the screen, position the cursor, and to put text on the screen for later entry.

NOTE

The explanation of the keyboard in areas 4 and 5 considers the interface with CCMS.

1.3.4.4.1.2 Area 4. Area 4 is described as follows:

- A. HARD COPY causes the cathode ray tube (CRT) image to be output to the local P/P.
- B. CDS ENABLE causes the CRT to switch to central data subsystem (CDS) mode. CDS is no longer considered as part of the console subsystem until it is switched back to CCMS.

- C. CPU ENABLE returns the CRT to CCMS. When this happens, the operator once again views the page that was being viewed when CDS mode was entered.
- D. CDS XMIT. This key is inoperable while in CCMS mode.
- E. PAGE CLEAR BREAK. This is a double labeled key. PAGE CLEAR is the CCMS label. This key clears the stored display page being viewed at the CRT as well as clearing the CRT. This key does not clear the third line of the CRT if there is an armed text command there. If there is a prompt outstanding on the page being cleared, the prompt is redisplayed. This key should be used with care. Clearing a page may cause problems in the program using that page, especially if the program is waiting on cursor inputs from a skeleton.
- F. SIGN ON. This key is inoperable while in CCMS mode.
- G. START WATCH STOP. This double labeled key starts and stops the stopwatch which is displayed in the status lines. This key stops the stopwatch if it is running and starts the stopwatch if it is not running.
- H. WATCH RESET DISCON. This is a double labeled key. WATCH RESET is the CCMS label. This key resets the stopwatch to zero.
- I. PAGE FREEZ NULL. This is a double labeled key. PAGE FRZ is the CCMS label. This key freezes or releases freeze on the CRT depending on whether it is already frozen or not. When a CRT is frozen, FRZN is written in

the status lines and no more output or input is accepted for that CRT until the freeze is released. Freeze is implemented to enable the operator to get a hardcopy without the screen being updated.

1.3.4.4.1.3 Area 5. Area 5 is described as follows:

- A. XMIT CMD. The transmit command key is used to enter test commands. When the XMIT CMD key is pressed, the test entered is text on the line with the cursor. The test command includes all text from the left margin up to but not including the cursor.
- B. XMIT-CURSOR. The transmit cursor key is a means of communication between the operator and the program supporting a display page. To use this key, the operator positions the cursor over target positions provided by the program (must be on lines 4 through 33 of CRT) and presses XMIT CRSR. The supporting program is notified of the action. The detailed use of cursor input is determined by each routine using it.
- C. XMIT RESP. This key is used to provide text information in response to a prompt from software. When a prompt is output to a page (i.e., "ENTER YES OR NO"), the operator enters text starting at the left margin of any line,

while the prompting page is being viewed, and presses XMIT RESP. The text up to but not including the cursor, is put into a buffer previously defined by the prompting software.

- D. ABRT PGM. This key aborts a program. To execute, the program name is entered starting at the left margin, of any line, on any page, and the ABRT PGM key is pressed. For GOAL procedures, this key and TERM PGM have the same meaning: terminate the program. Non-GOAL programs have the option to supply forced test end routines. ABRT PGM ignores the forced test end routines and terminates.
- E. EXEC CMD. The execute command key is used to execute armed, two-step test commands. This is accomplished by positioning the cursor to the third line of the CRT (the command line) and pressing the key. This key may also be used as an operation interface to the software, supporting a page if the software is set up to process an execute command input from specific coordinates on a page.
- F. DISARM CMD. The disarm command key is used to disarm previously entered two-step text commands by positioning the cursor to the third line of the CRT where the armed command is displayed and pressing the key. This key may also be used as an operator interface to the software supporting a page if the software is set up to process a disarm command input from specific coordinates on a page.

- G. PERF PGM. This key is used to perform a program. The program name to be performed, followed by any input parameters required by the program, are entered starting at the left margin of any line, on any page. Then the key is pressed. A message is output to the fourth line of the CRT, telling the operator in which slot the program is running.
- H. STOP/STEP. This key is used to stop the execution of a ground operational aerospace language (GOAL) procedure and to step through the execution of the procedure one step at a time. To use this function key, the operator must be viewing a page (A or B) which is assigned to the concurrency he wishes to stop or single step. If this key is used while on a page not assigned to GOAL, the operator receives an error response.
- I. HOME GMD. This key returns the cursor to the beginning of the third line. This key is an aid to the operator in positioning cursor for input.
- J. ENTER DEUE. This key simplifies entry of DEUE commands. When the key is pressed, the present DEUE parameters DEU #, link, and major function switch positions are output to the fourth line of the CRT, the first part of the DEUE command (DEUE) is output to the start of the third line, and the cursor is positioned after the DEUE command for the operator to enter the rest of the DEUE command.

- K. TERM PGM. This key terminates a program. The program name is entered, starting at the left margin of any line while viewing any page; then the TERM PGM key is pressed. A message is output to the fourth line, informing the operator the program is in terminal sequence. Nonline GOAL programs have their forced test end routine executed, if one is supplied, before termination.
- L. RES PGM. This key is used to resume the execution of a GOAL procedure which has been stopped. To use this function key, the operator must be viewing a page (A or B) which is assigned to the concurrency he wishes to resume. If the procedure was stopped due to a run time error, two strokes of the resume function key are required to continue the execution. The first stroke of the key clears the error and the second stroke causes the procedure to continue execution.
- M. SYS MSG. This is the page select key for the system message page.
- N. SHAR APP, This is the page select key for the shared application page.
- O. APP 1 through APP 6. Each of these keys is a page select key for the two pages associated with application programs 1 through 6. Each application has an A and a B page. While viewing a program on A or B page, the

operator presses the associated APP key to page select the other page in the pair. (While viewing page 1A press APP 1 to view 1 B, then press APP 1 to go back to 1A.) When the operator presses an APP key while not viewing one of the applications pages, the page selected is the last page viewed by the operator for that application. (While viewing page 6B, the operator presses any page key other than APP 6. The next time APP 6 is pressed, 6B is selected.)

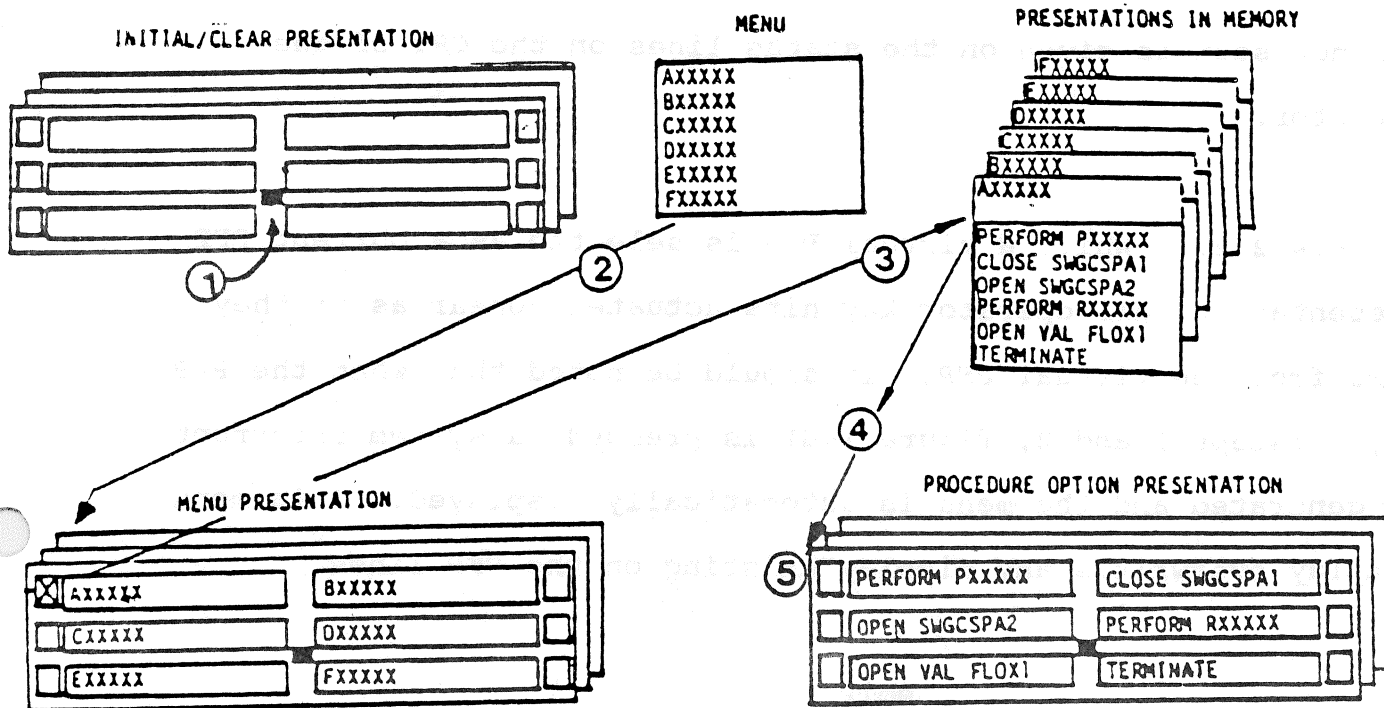
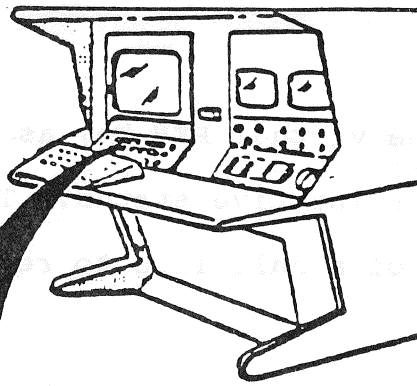
- P. EMON. This is the page select key for the three exception monitor pages: E1, E2, E3. When the system is initialized, pressing this key the first time at a CRT page selects E1 if at CRT 1, E2 for CRT 2, and E3 for CRT 3. After that, each EMON key hit, while viewing an EMON page, selects the next EMON page in sequence (ie, E1-E2-E3-E1...). While not viewing an EMON page and pressing EMON, the EMON page last viewed at this CRT is selected.
- Q. DMON. This is the page select key for the three DMON pages: D1, D2, and D3. This key follows the same rules as the EMON key.
- R. OC. This is the page select key for the three operator communications program pages: 01, 02, and 03. This key follows the same rules as the EMON key.
- S. PFK 1 through PFK 15. These keys are the programmable function keys 1 through 15. These keys are a means for a

program supporting a page to receive input from the operator. Individual programs define the results of pressing particular PFKs. PFK hits are routed to software based on the page being viewed when the key is pressed.

1.3.4.4.2 Programmable Function Panels (PFPs). (See figure 1-6.)

There is one PFP at each of the three operator positions at a CCMS console. Each PFP has three lines of light emitting diodes (LEDs) with a back lighted input key at each end of each line. There is a seventh input key without back lighting in the center of the panel. In CCMS, each line of the PFP is divided into two 17-character half-lines with one unused blank character separating them.

1.3.4.4.2.1 Applications software does not write directly to a PFP. Instead, all their PFP references are to a virtual PFP. A virtual PFP is a stored representation of a physical PFP, including text data and the state of the lights for the back-lighted keys. It is up to the operator to determine which virtual PFP is to be displayed at a physical PFP. To do this, the operator requests the PFP menu by pressing the DISARM AND MENU SELECT key in the center of the PFP. A menu is then displayed to the PFP. Each half-line of the menu has a program



PFP OPERATION

1. On performance of a concurrent program the computer assigns a presentation page, (one of six available) to store program entries to the Light Emitting Diodes (LEDs).

EXPLANATION OF ILLUSTRATIONS ABOVE

2. When PFP key 7 is activated ①, a menu of application programs is displayed ②. If the program has terminated, the word INACT appears after the program name.
3. The user may select the PFP presentation page he desires by depressing the the appropriate PFP key. When the key is depressed ③ the presentation page for program AXXXXX is selected from memory ④.
4. The options for AXXXXX are retrieved and are displayed, ⑤.

The user may now select the individual action to be performed by activating the associated PFP key.

Figure 1-6 . PFP Operational Flow

name, the virtual PFP key associated with that program, and its active or inactive status. The operator presses the button at the end of a half-line to request a virtual PFP.

1.3.4.4.2.2 Information about which virtual PFP is being viewed at a PFP and which unviewed virtual PFPs have data the operator has not seen is given on the status lines on the CRT of the operator.

1.3.4.4.2.2.1 While a virtual PFP is selected as a current PFP presentation, all operator key hits actuated appear as if they came from the virtual PFP. It should be noted that when the PFP key 7 (steps 1 and 2, figure 1-6) is pressed, a system interrupt is generated and the menu is automatically displayed. This menu display overwrites any display existing on the PFP lines.

NOTE

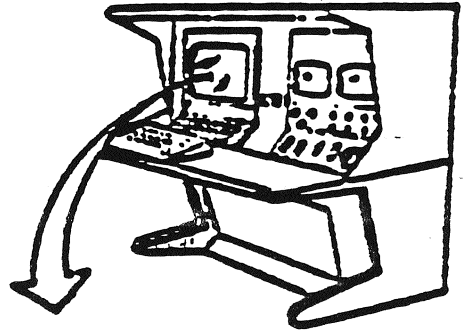
If the program of the user contains armed two-step commands specifying the PFP keys, the user may elect to utilize PFK 7 to specify a programmed disarm command for these interrupts. Therefore, when PFK 7 is pressed, the armed command is disarmed automatically and the menus redisplayed. This prevents the user from retaining any armed commands on an unviewed virtual PFP.

1.3.4.4.2.2.2 One virtual PFP is allocated to each of the six application procedure slots. These slots may be assigned to a GOAL procedure or to a non-GOAL application. GOAL procedures have the option of overriding this assignment and of using any of the six virtual PFPs for output or input.

1.3.4.5 Display Information. The following paragraphs provide a general description of the displays associated with LPS console in the firing room:

1.3.4.5.1 CRT. (See figure 1-7.) The following characteristics are associated with the display generator (DG) CRT display:

- A. Each CRT display is composed of 34 lines (lines 0 through 33) and each line has 72 character positions (characters 0 through 71).
- B. The display characters that may be presented on these lines may be in one of the following colors:
 1. Red
 2. Green
 3. Yellow
 4. Dark blue
 5. Magenta
 6. Cyan (light blue)
 7. White
 8. Black (not visible).



001: 1455/48E SH 0000/02 COT -99:2359/59 ~~XXXXXXXXXXXX~~ CPU ~~XXXX~~ 11
 SA 0123 0123 E123 1AB 2AB 3AB 4AB 5AB 6AB TASKNAME\LEVLNAME P123456
 2 3 13 12

(OSINIT) PRINTER/PLOTTER INITIALIZATION SUCCESSFUL.
 (OSINIT) DIRECTORY MANAGEMENT INITIALIZATION SUCCESSFUL.
 (OSINIT) BULK MEMORY INITIALIZATION SUCCESSFUL.
 (OSINIT) DISPLAY GENERATOR INITIALIZATION SUCCESSFUL.
 (OSINIT) COBFR INITIALIZATION SUCCESSFUL.
 (OSINIT) PFP INITIALIZATION SUCCESSFUL.
 (OSINIT) TIMING CONTROL INITIALIZATION SUCCESSFUL.
 (OSINIT) CONSOLE SUBSYS INIT INITIALIZATION SUCCESSFUL.
 (OSINIT) TCB BUILD INITIALIZATION SUCCESSFUL.
 (OSINIT) SYSTEM INTEGRITY INITIALIZATION SUCCESSFUL.
 (OSINIT) 50KB TC&MM INITIALIZATION SUCCESSFUL.
 (OSINIT) COMPLETE REV 010 06267. DISK REV=3025HZ011

Figure 1-7 . Simulated CRT Display

C. Data displayed on the CRT screen may be caused to blink or to be inverted.

D. All data outputs by the system software meet the following conventions:

1. Normal message color is light blue (cyan).

NOTE

System software definitions are:

A caution requires operator attention to a possible problem or abnormal condition exists. Operator execution of a function displayed in yellow changes hardware or software configuration.

2. Caution data color is yellow.

NOTE

A warning requires operator attention to and or action if a possible problem or abnormal condition exists. Operator execution of a function displayed in red changes hardware or software configuration. Consequences of a warning condition are probably more serious than caution conditions.

3. Warning data color is red.
4. Caution or warning data which has been restored to normal and go condition data color is green.
5. Colors may be used to highlight displayed data or make it more readable.

6. Blink is used to call operator attention (as a guide the use of blink should be restricted).
7. Invert is used to remind operator of existing condition or highlight data.
8. Black is not normally used.

1.3.4.5.1.1 CRT Display Status Lines. (See figure 1-7.) The two top lines of each display are status lines. The third line is used to display two-step text commands. Additionally, the third line is used to display the first line of two-line responses. The fourth line of each CRT is used to display error or informational messages that are direct responses to operator action. Functional descriptions of status line elements are as follows:

NOTE

The numbers in parentheses () correspond to the index numbers on figure 1-7.

- A. Page Status Indicators (1). These indicators are displayed inverted when that page is being viewed by the user. They are displayed yellow when a page is not being viewed and new data has been output to the page. The indicators are displayed blinking when a prompt is outstanding or when a program has requested the page indicator to blink, indicating operator action required.

- B. Task/Level (2,3). This area of the status lines depicts the eight-character program name associated with the display page. Item 3 displays the current level name if the task name is a GOAL procedure. Otherwise, the area is blank.
- C. Names (4). They are displayed in yellow if it is a critical GOAL procedure. Names are displayed inverted if the task associated with the page has terminated.
- D. Greenwich mean time (GMT), countdown time (CDT) (5,7). When the console subsystem is running on internal time, the clocks are displayed in yellow. Format for GMT is HHMM/SS. Format for CDT is +/-DD:HHMM/SS. When time is synchronized to CDBFR time, the synchronized time is displayed in cyan.
- E. Stopwatch (6). Stopwatch time is displayed to the nearest second while running and to the nearest 1/10 second when stopped. Maximum stopwatch time equals 24 hours.
- F. Microcode Message (8). This is a message area for the DG microcode.
- G. DG Option Plane (9). This is a message area for the DG option plane. The RETRY message is displayed in yellow when the operator hits a key before the previous key hit has been processed. RETRY stays on until another good key hit is made.

- H. FRZN (10). This message is displayed inverted and yellow when the operator freezes the CRT.
- I. CRT (11). CRT indicates position 1, 2, or 3 and also shows the approximate percentage of system utilization by means of the color of this inverted indicator.
- J. PFP Status Indicator (12) These indicators are displayed inverted when that virtual PFP is being viewed at a PFP. They are displayed yellow when unviewed virtual PFPs have data the operator has not seen.

1.3.4.5.1.1.1 Status Line Functional Requirements. The status line is outputted once a second while a CRT is not frozen and not in CDS mode. The status line includes:

- A. GMT (displayed with 1-second precision)
- B. CDT (displayed with 1-second precision)
- C. Stopwatch:
 - 1. Outputs to 1-second precision on 1-second updates.
 - 2. Outputs to 1/10-second precision when it is stopped.
 - 3. Wraps back to 0 after 24 hours.
 - 4. May be reset to 0 while running or reset to blanks while stopped.
 - 5. When restarted after a stop, the stopwatch continues counting from its present value.
- D. CRT number
- E. CRT frozen indicator

F. Page status indicators

1. There is an indicator on each CRT status line for each stored page.
2. The default state of this indicator is cyan, no blink, and noninverted.
3. The indicator is inverted when the page is being viewed.
4. While the page is not being viewed and there is a prompt outstanding or software has requested that the indicator of the page be blinked, the indicator blinks.
5. While the page is not being viewed and new data is written to the page or attributes are changed on the page, the indicator is displayed in yellow.
6. New data is maintained separately for each CRT.

G. TASK name associated with the viewed page

H. For GOAL pages:

1. Present level name to be associated with the page
2. Indicator that the task assigned that page is critical
3. For critical GOAL procedures, the program name associated with a page is displayed in yellow.

I. PFP presentation status indicators:

1. There is an indicator on each CRT status line for each PFP presentation.

2. The default state of this indicator is cyan, no blink, and noninverted.
3. The indicator is inverted for the PFP presentation being viewed on the PFP associated with a CRT.
4. When a PFP presentation is not being viewed and text is written to it, its indicator is yellow.
5. The new data indicator is maintained separately for each CRT PFP.

1.3.4.5.1.1.1.1 When the task associated with a page is not active, the program name displayed in the status line is displayed inverted.

1.3.4.5.2 Display Paging Description. (See figure 1-7.) The bottom 30 lines of display on a CRT are used to view display pages. Display pages exist within bulk memory and are stored representations used by the software to format the display data. The user has the capability to select the specific display page to be viewed. Figure 1-7 illustrates the display page status line (line 2). The existing pages available to the user and their status line designators are as follows:

- A. System message (SM) page
- B. Exception monitoring (EMON) page (E123)
- C. Display monitoring (DMON) page (D123)
- D. Shared application (SA) page

- E Application pages (1AB through 6AB)
- F. Operator communication pages (01 through 03)

NOTE

When selecting the desired page, the operator should view the display status lines. If the desired page status indicator does not come on, continue to press the appropriate key until the desired page is indicated by the inverted status light.

1.3.4.5.2.1 SM Page. This page accumulates messages relating to system execution and status. These messages are available to all CCMS systems and may be viewed at any CRT position. Initiate display of the SM page by pressing SYS MSG key on the console keyboard.

NOTE

Many SMS indicated significant CCMS problems that may compromise the ability of the system function. A yellow SM page indicator should be responded to.

1.3.4.5.2.2 EMON Page (E123). There are three EMON pages assigned to each console and they continuously accumulate measurement exceptions for display. These pages are updated by the system software regardless of whether they have been selected for viewing.

1.3.4.5.2.2.1 When a measurement exception occurs, the exception status indicators E123 blink yellow indicating operator attention is required. The operator may select this page for viewing by pressing the EMON keyboard select key. When the desired EMON page is displayed, the E1, E2, or E3 character on the display screen appears inverted. (For a detailed description of the EMON page see the EMON paragraph under Real-Time Measurement Monitor (RTMM in this section.)

1.3.4.5.2.3 DMON Page. Three of these DMON pages are provided each console. These pages provide continuous monitoring of selected measurement. The user must select the page to view by utilizing the DMON keyboard select key. (For a detailed description of the EMON page, see the EMON paragraph under Real-Time Measurement Monitor (RTMM) in this section.)

1.3.4.5.2.4 SA Page. The SA page is available for viewing at either CRT. No user (operator) actions can be input to this page since it provides a single intergrated display of multiple procedure operations. This page is available to any application

procedure. This page may be selected for viewing by pressing the SHAR APP display keyboard button.

1.3.4.5.2.5 Application Pages (1AB through 6AB). There are 12 of these pages available for use by the application of the user program. Two of these pages are assigned to an executing GOAL procedure with the execution BEGIN PROGRAM GOAL statement of the procedure. These pages display in a typewriter mode or to any line or character position on the display (from line 4 through line 33). The usage of these pages allows only one active prompt per page. The user may view any application page by pressing the appropriate application display keyboard button.

1.3.4.5.2.6 Operator Communication Pages (01 through 3). There are three of these pages assigned to a console. These pages are utilized by the operator and are used to retrieve, format, and display data at request of the operator. These pages are selected by pressing the OC display keyboard button.

1.3.4.6 Real-Time Measurement Monitor (RTMM). The RTMM capability of CCMS allows the operator to simultaneously monitor many different measurements. The measurements may be monitored by DMON and/or EMON. DMON allows the operator and/or application software to request 3 pages of 30 measurements each. EMON allows the display of 3 pages of 15 measurements each that are outside of prescribed limits.

1.3.4.6.1 DMON. Measurements to be monitored may be selected by specifying a function designator name for operator inputs or a system software reference number (SSRN) for applications software. Values are read from the CDBFR, and DMON pages are updated every 9 seconds. Once activated, measurements are monitored continuously until operator or applications software action is taken to deactivate the measurement, or the DMON page is deselected. Application software can only deactivate measurement monitoring that was initiated by application software. When the DMON page is reselected, processing resumes.

1.3.4.6.1.1 Functional Description. DMON supports monitoring of analog, discrete, pseudo discrete, and digital pattern measurements. Each measurement is displayed in CYAN, on one display line, containing the 10-character function designator identification, the 34-character nomenclature, the present value (variable length with the maximum of 20 characters), and the 8-character engineering units. New measurements are written to the next available line. For operator input activations, the page specified will be the DMON page from which the input was received, or if a DMON page is not viewed, it will be the CRT form which the entry was made.

1.3.4.6.1.1.1 When a transit cursor is entered from the line containing the measurement to be terminated, monitoring of a particular measurement is terminated. When the DMON page is cleared, all measurement monitoring for a DMON page is terminated. When monitoring of an individual measurement is terminated, the measurement data is deleted from the display page, and the vacated slot is filled by moving lower lines up.

1.3.4.6.1.1.2 Automatic suspension occurs when the DMON page is deselected; an automatic resumption occurs when the DMON page is reselected.

1.3.4.6.2 EMON. The EMON capability controls the visual display of preselected measurements that are not within established tolerances. Exception detection is performed by the FEP subsystem which notifies the console for display. Data bank information from the online data bank (OLDB) is used to generate the visual display.

1.3.4.6.2.1 Functional Description. EMON receives and saves exception data from the FEP via the computer-to-computer communications component of the operating system. EMON supports a maximum of 15 exceptions per EMON page (2 lines used for each exception). The display shows exception information for analog, discrete, and digital pattern data types. Digital pattern data is displayed in either hexadecimal, decimal, octal, or binary as

specified in the OLDB. If neither decimal, octal, nor binary is specified, the data is formatted in hexadecimal. All exceptions are displayed on the EMON page specified in the FEP-generated exception message.

1.3.4.6.2.1.1 The initial occurrence of an exception for any supported data type displayed on the next two available lines of the appropriate EMON page. It is considered an active exception until the operator clears the exception.

1.3.4.6.2.1.2 For active exceptions, the second and subsequent occurrences are treated as updates to the initial occurrence. The EMON count and/or the exception criteria of the initial display are/is modified to reflect the number of times the measurement transitions to the exception state and also to reflect the current exception criteria. In addition (for discrete and digital patterns), the latest report state or value and the time it occurred are displayed or updated.

1.3.4.6.2.1.3 For active analog exceptions, the CDBFR is read periodically, and the three latest samples are maintained on the second line of the exception message whenever the applicable EMON page is being viewed. Individual analog exceptions are updated once every 9 seconds. All analog values to be displayed are checked against the upper and lower transducer values from the

OLDB. If the value to be displayed is not within the specified transducer range, the characters UL or LL are displayed in place of the two least significant digits of the measurement value.

1.3.4.6.2.1.4 If a new exception occurs and the applicable EMON page is full, the overflow condition is logged on the system message page, and the operator is notified. In this case, the measurement does not become an active exception. Whenever a new exception is written to an EMON page, the control and display (C&D) blink count is incremented. This causes the status line indicator for that EMON page to blink whenever it contains unacknowledged exceptions and it is not being viewed.

1.3.4.6.2.1.5 If any active exception transitions to the defined exception condition more than 10 times in a 1-second period, EMON in the FEP is deactivated, and the operator is informed of this action by the blinking of the exception monitoring count (EMC).

1.3.4.6.2.1.6 The console operator is provided with the capability to acknowledge, clear, or deactivate individual exceptions, and to clear all exceptions for an individual EMON page.

1.3.4.6.2.1.7 Information for each measurement on an EMON display is as follows:

A. First line, left to right (all data displayed in cyan except as noted):

1. A = Acknowledge cursor position, initially displayed inverted; changes to normal when acknowledged.
2. C = Clear cursor position
3. D = Deactivate cursor position, yellow
4. 34-character measurement name
5. Value at time of initial exception condition, red if out of tolerance
6. For analog measurements only, engineering units
7. Time.

B. Second line, left to right (all data displayed in white except as noted):

1. Function designator, if control logic was also notified of this exception, this field is displayed in green.
2. Exception criteria:
 - a. For analogs:
 - (1) L = lower limit identifier, low limit value
 - (2) H = high limit identifier, high limit value.
 - b. For discrete
 - (1) Normal state identifier (NORMAL =)
 - (2) Normal state.

c. For digital patterns:

- (1) Test condition (change from, equal to, and not equal to). The binary, octal, and hexadecimal identifiers `B`, `T`, `#`.
 - (2) Comparison value.
3. Exception monitor counter, this field blinks when automatically deactivated.

NOTE

EMC field is a count of the number out-of-tolerance notifications received from the FEP for this measurement. If more than 10 out-of-tolerance notifications are received for the same measurement in a 1-second period, EMON in the FEP is deactivated and the operator is informed by blinking the EMC.

4. Binary, octal, and hexadecimal identifiers `B`, `1`, and `#` for digital pattern data.
5. Latest measurement value(s), red if out of tolerance.
 - a. For analogs, this field contains three periodically obtained samples (9-second sample period); oldest to newest and read left to right.

b. For discrete and digital patterns, this field contains the value contained in the latest exception message received from the FEP.

6. Time of latest exception (discrete and digital patterns only).

1.3.4.7 CDS. CDS is a multidimensional information system. CDS provides online, real-time processed (by CCMS) data recording and recall; maintains engineering technical files; supports pretest and posttest data analysis; supports goal program development; maintains a program library; supports program simulation, debug, and validation; and supports operator training. The major elements within CDS are:

A. Data processing and storage (data bank) consists of three main frame Honeywell Model 66/80 computers which form the kernel of the CDS system. These computers contain the shared data management system (DMS), I/O multiplexers, front-end network processors (FNPs), and engineering terminals (located at KSC as well as other NASA sites). The CDS computers also share a one megabyte online high speed memory and 1.2 gigabyte offline disk storage memory.

B. Real-Time Interface (RTIF). Allows the user to access the data bank for measurement updates in real time. It utilizes four microcomputers, each of which is initialized, supported, and serviced by a 64K MODCOMP minicomputer. The RTIF interfaces with the CDBFR through the MODCOMP computers and processes the CDS data through the microcomputers.

C. Video Simulation Interface (VSI). Provides for data interface between the CCMS FEPs and the Shuttle ground operations simulator (SGOS) modules executing on the LPS computers. The primary function of the VSI is to provide simulation of the GSE and orbiter systems by allowing the users to run their programs against a math model. VSI hardware consists of 64K MODCOMP computers, pulse code modulation (PCM) equipment, data bus simulators, PCM uplink decommutators, I/O multiplexer front end loaders, channel I/F adapters, and block transfer processors.

1.3.5 PRACA SYSTEM

1.3.5.1 General. Every task involved in Shuttle processing requires a document to authorize the work. This document provides step-by-step technical instructions required to

accomplish a task, whether it be a simple paint touchup, or the more complicated preparations for launch. Each document is approved and signed by representatives of several responsible organizations and then the work is actually performed by technicians, Quality inspectors, TCs, and System Engineers, alike. Refer to SPI QA 001(3) for procedures and guidelines pertaining to PRACA.

1.3.5.1.1 WADs are required not only as instruction manuals, but also for historical record. Each document provides configuration accountability for all Shuttle processing activities. The completed procedure is kept on record at KSC to provide traceability and ensured by ink stamp verifications by the responsible individuals at each work step on the official document.

1.3.5.1.2 The requirements for preparation and processing of these documents are set forth in the SPIs). There are separate SPIs dictating different formats for each of these documents, depending on whether the work is routine, a special action or modification, or a response to a problem.

1.3.5.1.3 Systems Engineers are responsible for preparation of the largest percentage of these WADs. Checklists have been developed to help the Systems Engineer verify that the procedure he or she has prepared is accurate, complete, and meets all program requirements.

1.3.5.2 Discrepancy Report (DR). A DR is nonconformance that can be described and corrected to drawing/specification requirements, and does not meet problem report (PR) requirements.

1.3.5.3 IPR. An IPR is a document to record an apparent nonconformance, failure or unsatisfactory hardware/software condition which usually requires troubleshooting.

1.3.5.4 Line Replaceable Unit (LRU) PR. An LRU PR is generated against hardware removed from or not yet assigned to a specific GSE or flight element end item, when the hardware requires a disposition, or hardware has been removed due to a JSC Building 45 investigation. See SPI BM322 (2) KV.

1.3.5.5 PR. A PR is any nonconformance that is a failure, or unsatisfactory condition that has been isolated to an end item or LRU that usually requires/affects one or more of the following:

- A. A retest that requires or causes a break in functional configuration other than retests called out within preplanned preapproved procedures

- B. Engineering involvement by launch site personnel
- C. Engineering resolution and corrective action (beyond the specific article under consideration) by the sustaining or design engineering organization [recurrence control (RC) action].
- D. System level problems
- E. Material review or deviation/waiver action not including standard repair
- F. Configuration change
- G. Use of equipment/material out of calibration/hydrostat/validation, proof test, or shelf life.
- H. Suspect condition which may conform to drawing or specification, but represents a potential problem
- I. Unauthorized connector mate/demate cable integrity group (CIG) log.

2.0 SPACE SHUTTLE MAIN ENGINES (SSMEs).

2.1 OVERVIEW.

2.1.1 SSME OVERVIEW.

2.1.1.1 General. The SSME is a staged combustion cycle engine which operates at extremely high pressures to reduce engine envelope while attaining efficiencies previously unknown in rocket engine technology. Burning liquid hydrogen and liquid oxygen, the three engines in the shuttle orbiter provide the majority of the total impulse (thrust time duration) required to attain orbital velocity. Lift-off thrust is provided by solid rocket boosters, which are dropped after two minutes operation and later recovered from the sea. The SSMEs are shut down prior to reaching orbital velocity and the external tank, which provides the hydrogen and oxygen propellants, is dropped into the ocean.

2.2 DESCRIPTION.

2.2.1 SSME DESCRIPTION. (See figure 2-1.)

2.2.1.1 General. The main engines are reusable, high-performance liquid-propellant rocket engines with variable thrust. The propellant fuel is liquid hydrogen (LH₂) and the

oxidizer is liquid oxygen (LO₂). The propellants are carried in separate tanks in the external tank and supplied to the main engines under pressure. Each engine can be gimbaled plus or minus 10.5 degrees in pitch and plus or minus 8.5 degrees in yaw for thrust vector control by hydraulically powered gimbal actuators.

2.2.1.1.1 The main engines can be throttled over a range of 65 to 109 percent of their rated power level (RPL) in one percent increments. A value of 100 percent corresponds to a thrust level of 375,000 lbs. at sea level and 470,000 lbs. in a vacuum. 104 percent corresponds to 393,800 lbs. at sea level, 488,800 lbs. in a vacuum. 109 percent corresponds to 417,300 lbs. at sea level or 513,250 lbs. in a vacuum.

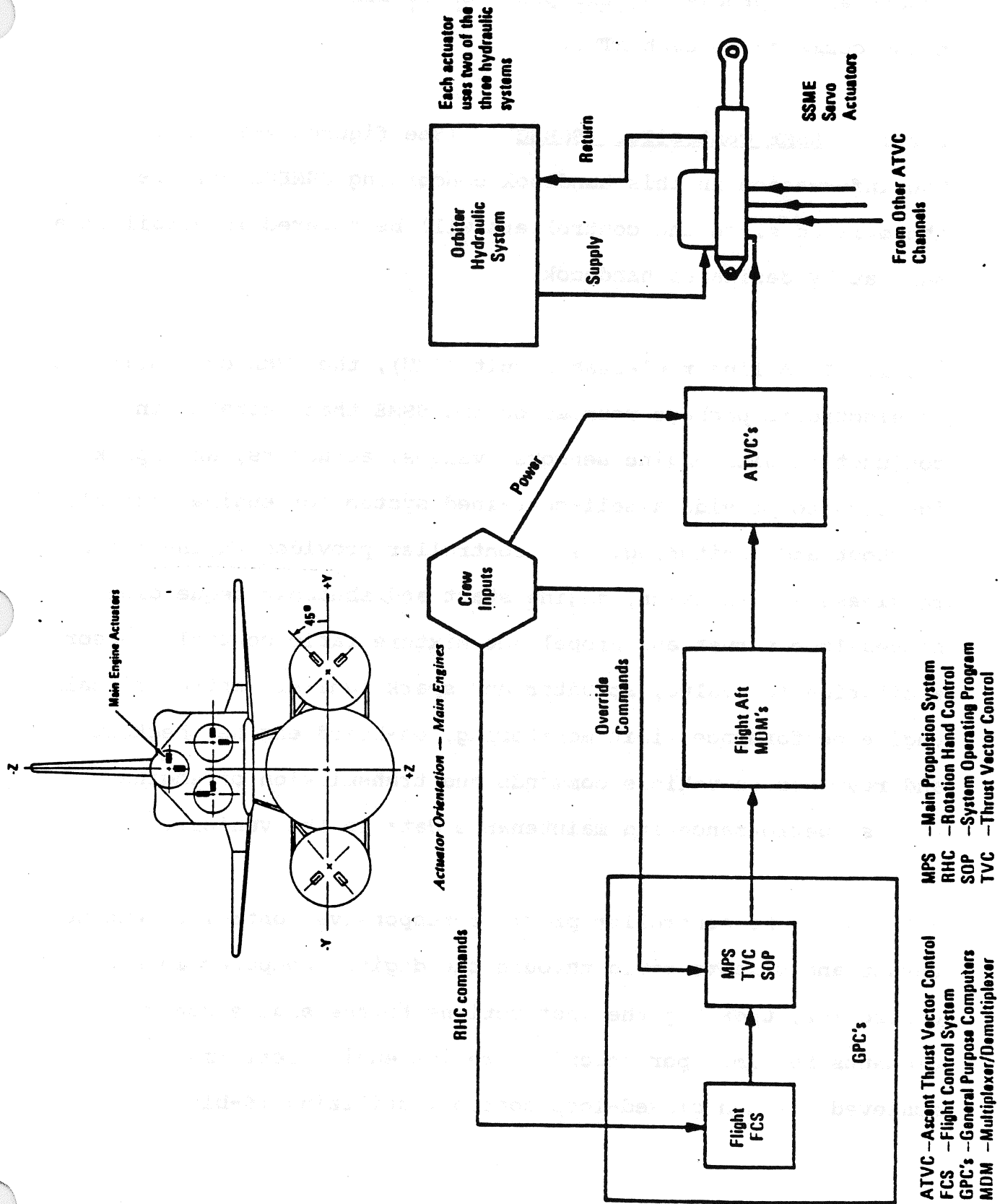
2.2.1.1.2 At sea level, the engine throttling range is reduced due to flow separation in the nozzle, which prohibits operation of the engine at its 65 percent throttle setting, currently referred to as the minimum power level (MPL). All three main engines receive the same throttle command at the same time. Normally these come automatically from the general purpose computers (GPCs) through the engine controllers. During certain contingency situations, manual control of engine throttling is possible by use of the speed brake/engine throttle controller handle. The throttling ability reduces vehicle loads during maximum aerodynamic pressure, limits vehicle acceleration to

three gs maximum during boost, and makes it possible to abort with all main engines thrusting or one engine out.

2.2.1.1.3 Each engine is designed for 7.5 hours of operation over a life span of 55 starts. Throughout the throttling range, the $\text{LO}_2\text{-LH}_2$ mixture is 6:1. Each nozzle area ratio is 77.5:1. The engines are 167 inches long and 94 inches in diameter at the nozzle exit, and weigh 6953 lbs. dry. The diameter of the powerhead is 105 by 94.5 inches.

2.2.1.2 Thrust Vector Control (TVC). (See figure 2-2.) TVC provides attitude control and trajectory shaping by SSME and SRB gimbaling.

2.2.1.2.1 The major subsystems comprising TVC are the hydraulic servoactuator, the Ascent Thrust Vector Control (ATVC), and the MPS Thrust Vector Control Command Subsystem Operating Program (MPS TVC CMD SOP). The hydraulic servoactuators are the hardware subsystems which gimbal the main engines. There are two actuators per SSME, one for yaw motion and one for pitch motion. Each actuator is fastened to the orbiter thrust structure and to the powerhead of one of the three SSMEs. The ATVC is an avionics hardware package which provides gimbal commands and fault detection for each hydraulic gimbal actuator. There are four ATVCs, each of which receives position commands from the MPS TVC CMD SOP which resides in the GPCs. The MPS TVC CMD SOP is



- ATVC - Ascent Thrust Vector Control
- FCS - Flight Control System
- GPC's - General Purpose Computers
- MDM - Multiplexer/Demultiplexer
- MPS - Main Propulsion System
- RHC - Rotation Hand Control
- SOP - System Operating Program
- TVC - Thrust Vector Control

SSME Thrust Vector Control Interface Flow

Figure 2-2. Ascent Thrust Vector Control

essential in processing the position commands before issuing these commands to each ATVC.

2.2.1.3 SSME Controller (SSMEC). (See figures 2-1 and 2-3.)

The information in this handbook concerning SSMECs will be abbreviated since the controllers will be covered in detail in a separately dedicated handbook.

2.2.1.3.1 A line replaceable unit (LRU), the SSME controller is an electronic package mounted on the SSME that operates in conjunction with engine sensors, valves, actuators, and spark igniters to provide a self-contained system for engine control, checkout and monitoring. The controller provides engine flight-readiness verification, engine start and shutdown sequencing, closed-loop thrust and propellant mixture ratio control, sensor excitation for valve, actuator and spark igniter control signals, engine performance limit monitoring, on-board engine checkout, and response to vehicle commands and transmission of engine status, performance and maintenance data to the vehicle.

2.2.1.3.2 The controller provides responsive control of engine thrust and mixture ratio through the digital computer in the controller, updating the instructions to the engine control elements 50 times per second. Precise engine performance is achieved through closed-loop control, utilizing 16-bit

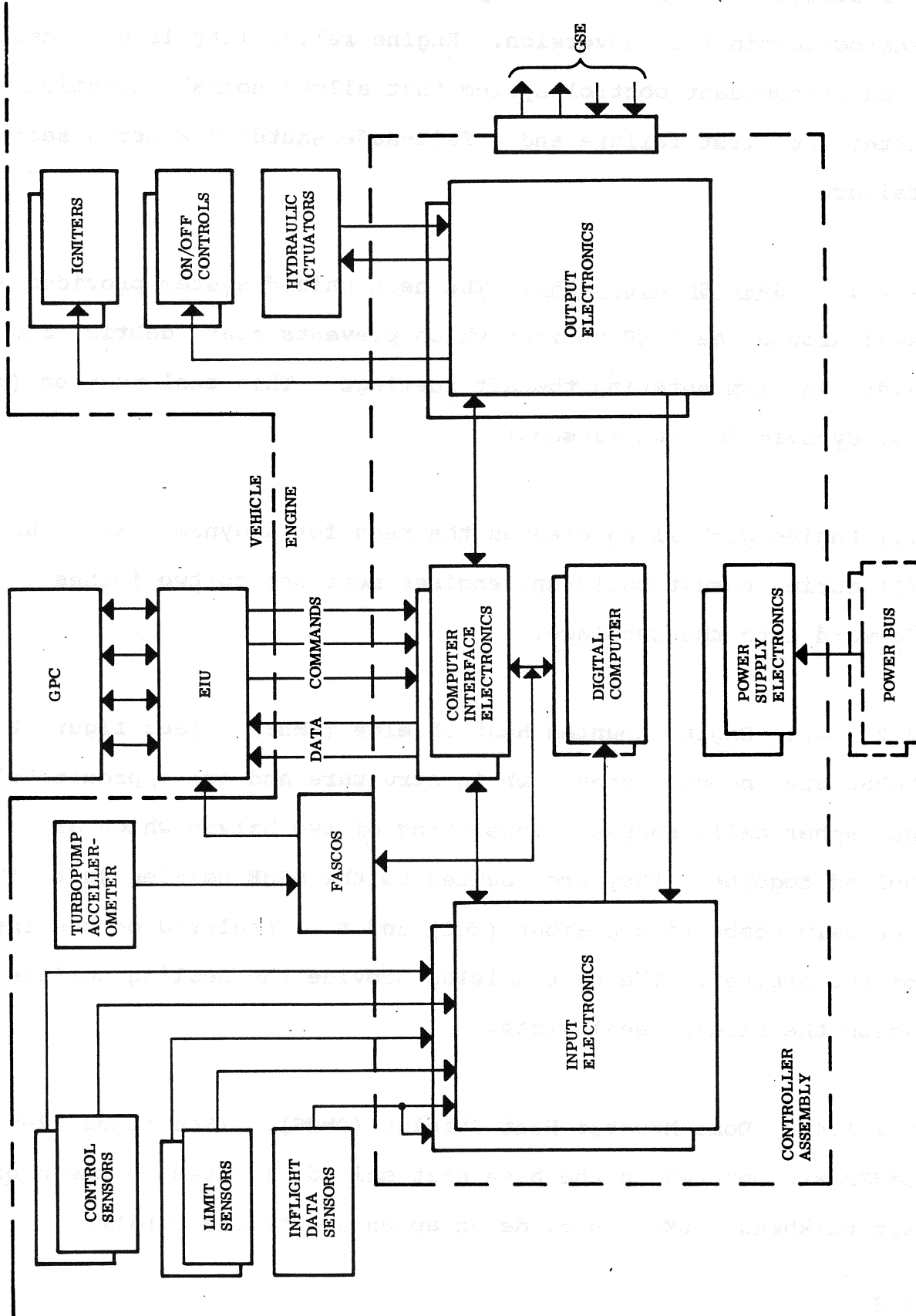


Figure 2-3. Controller Organization

computation, 12-bit input/output resolution, and self-calibrating analog-to-digital conversion. Engine reliability is enhanced by a dual-redundant control system that allows normal operation after the first failure and a fail-safe shutdown after a second failure.

2.2.1.4 Heat Shields (HS). The heat shield system provides a seal around the SSME nozzles which prevents heat, debris, and hydrogen from entering the aft fuselage. This seal must be (and is) dynamic for two reasons:

- (1) Engine gimbaling creates the need for a dynamic seal, and
- (2) during thrust build-up, engines move one to two inches forward into the fuselage.

2.2.1.4.1 Engine-Mounted Heat Shields (EMHS). (See figure 2-4.) EMHSs are inconel honey-comb in structure and are approximately hemispherically shaped. Consisting of two halves which are bolted together, they are mounted to the SSME nozzles just aft of the main combustion chamber (MCC) and are insulated on the inside of the orbiter. The heat shields provide the sealing surface on which the sliding seal rests.

2.2.1.4.2 Dome-Mounted Heat Shields (DMHS). (See figure 2-5.) DMHSs are mounted to the base heat shield, located on the orbiter aft bulkhead. DMHSs provide an appendage to the orbiter

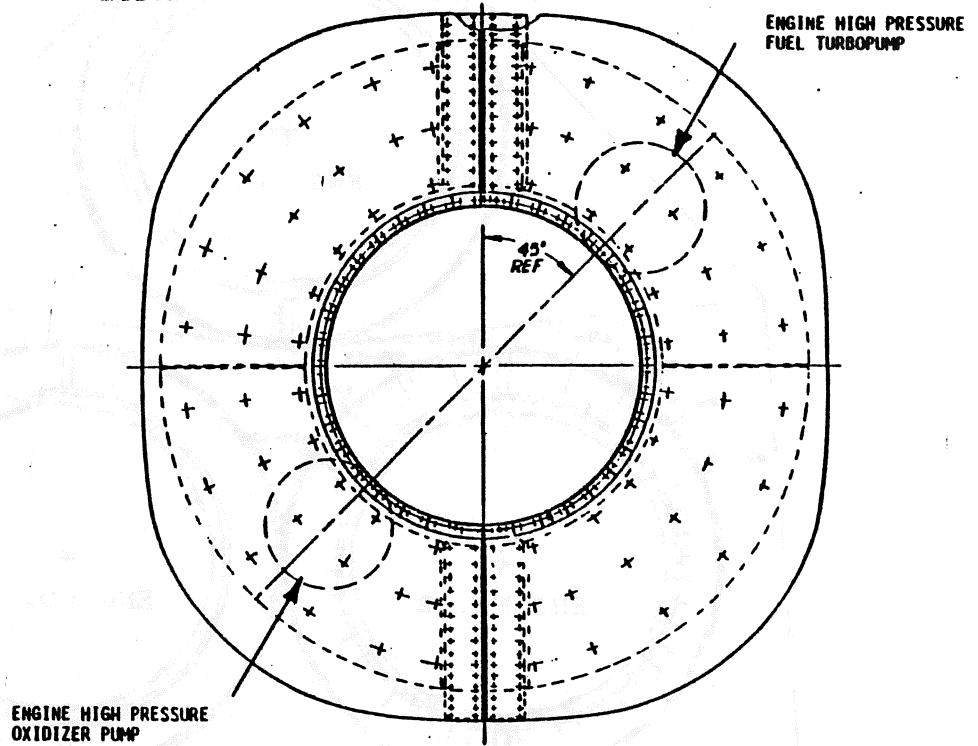
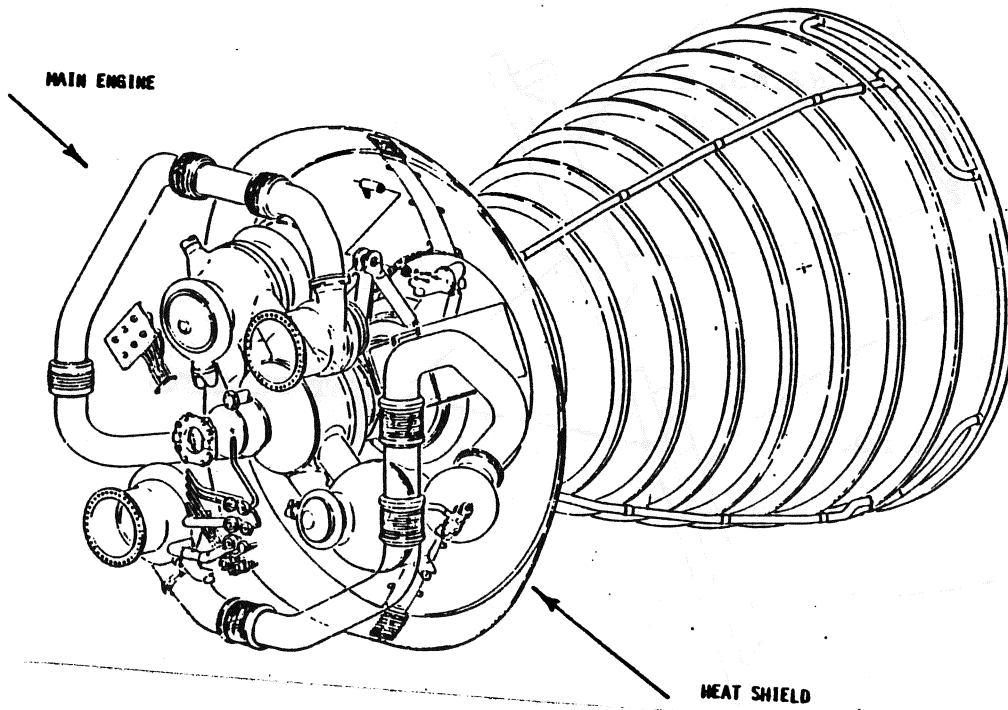
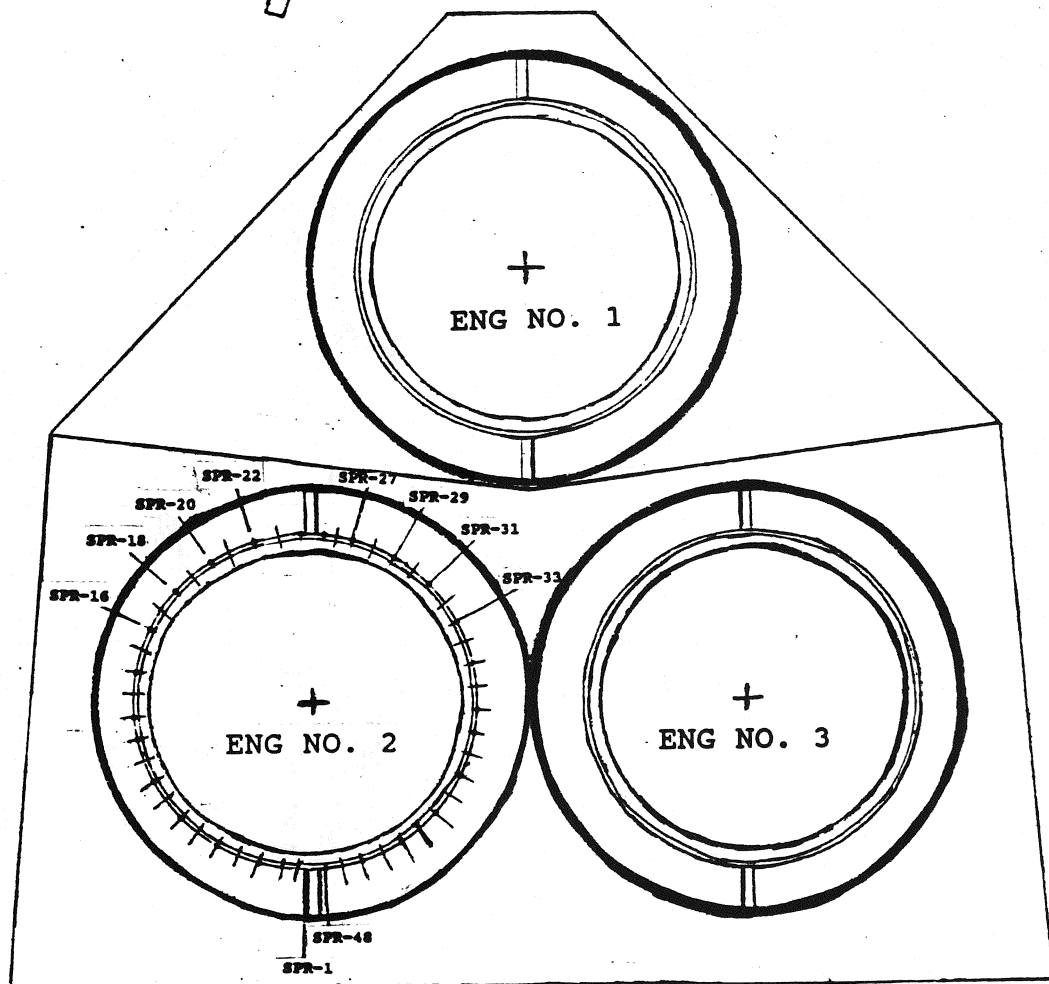
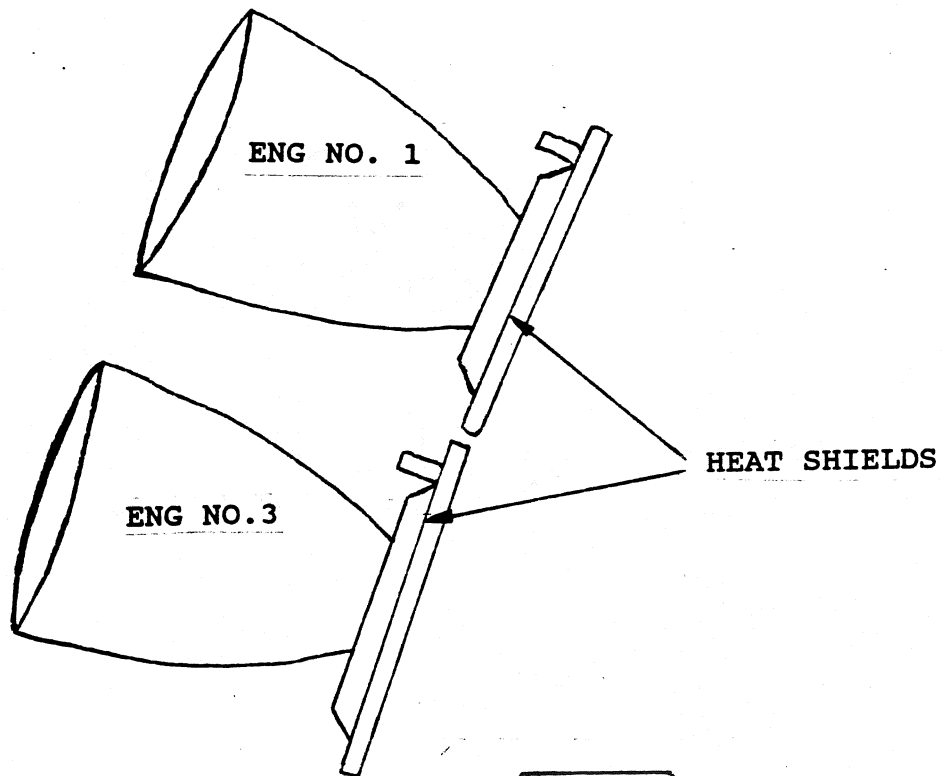


Figure 2-4. Engine-Mounted Heat Shields



structure for mounting the sliding seal assembly. Consisting of two halves which are bolted together, the DMHSSs contain 48 spring cans, each of which provide spring force to maintain contact between the sliding seal and the EMHS. The actual location of the DMHSSs depends on the position of the SSMEs in relation to the orbiter.

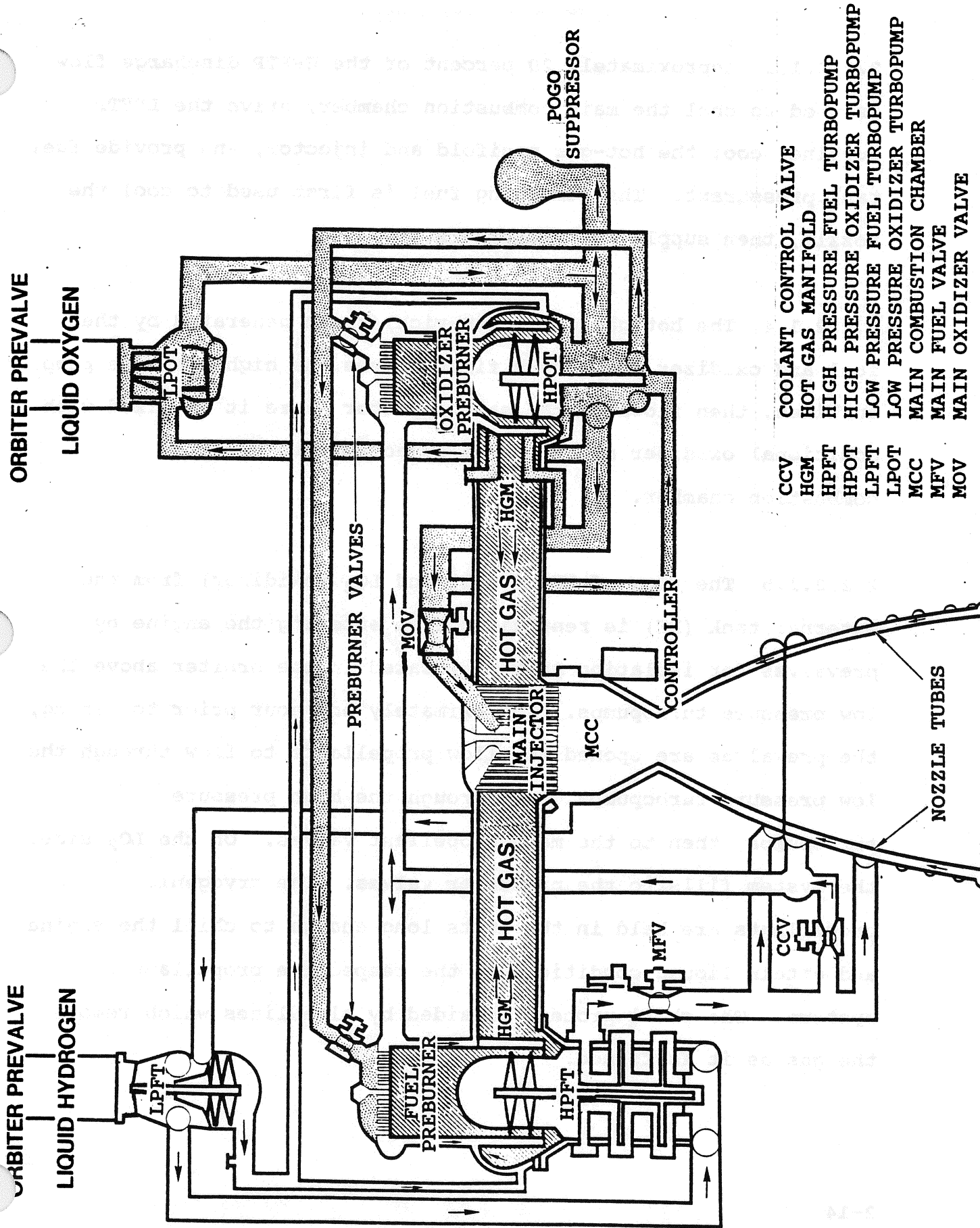
2.2.1.4.3 The SSME System Engineer is responsible for the installation, removal, and modification of both the engine- and dome-mounted heat shields, as well as the performance of corrective action on same where needed, since both shield types are removed after each flight for SSME powerhead servicing. The heat shields are held on by lockout tools which drive the spring cans inward to release tension. There are 24 spring cans, maintaining approximately 100 lbs. of force each. Care must be observed at all times in the immediate area as the lockout tools can dislodge, causing damage to the sliding seal assembly or personal injury. See Section 3 for a list of heat shield job cards.

2.2.2 OPERATION.

2.2.2.1 General. (See figure 2-6.) The SSMEs use a staged combustion cycle in which propellants are partially burned at low mixture ratio, high pressure, and relatively low temperature in the preburners and then completely burned at high mixture ratio, high pressure, and high temperature in the main combustion chamber.

2.2.2.1.1 The propellant system uses four turbopumps. The two low-pressure turbopumps operate at relatively low speed to permit low pressures in the vehicle tanks. The function of these pumps is to provide sufficient pressure increase at the inlets of the high-pressure turbopumps to permit them to operate at high speeds. The discharge from the low-pressure turbopumps is fed to the inlets of the high-pressure turbopumps.

2.2.2.1.2 Approximately 75 percent of the flow from the HPOTP goes to the main combustion chamber. Approximately 10 percent is directed to the preburner pump, which raises the pressure to that required by the preburners. Small quantities are bled through the heat exchanger for oxidizer tank pressurization and pogo suppression pressure. The balance of the oxidizer drives the hydraulic turbine powering the LPOTP and is then recirculated to the inlet of the HPOTP.



- CCV COOLANT CONTROL VALVE
- HGM HOT GAS MANIFOLD
- HPFT HIGH PRESSURE FUEL TURBOPUMP
- HPOT HIGH PRESSURE OXIDIZER TURBOPUMP
- LPFT LOW PRESSURE FUEL TURBOPUMP
- LPOT LOW PRESSURE OXIDIZER TURBOPUMP
- MCC MAIN COMBUSTION CHAMBER
- MFV MAIN FUEL VALVE
- MOV MAIN OXIDIZER VALVE

Figure 2-6. MPS Propellant Flow Schematic

2.2.2.1.3 Approximately 20 percent of the HPFTP discharge flow is used to cool the main combustion chamber, drive the LPFTP turbine, cool the hot-gas manifold and injector, and provide fuel tank pressurant. The remaining fuel is first used to cool the nozzle, then supply the preburners.

2.2.2.1.4 The hot-gas (hydrogen-rich) steam generated by the fuel and oxidizer preburners first drives the high-pressure pump turbines, then flows to the main injector where it is mixed with additional oxidizer and fuel and injected into the main combustion chamber.

2.2.2.1.5 The flow of LH_2 (fuel) and LO_2 (oxidizer) from the external tank (ET) is restrained from entering the engine by prevalues (or isolation valves) located in the orbiter above the low pressure turbopumps. Approximately one hour prior to firing, the prevalues are opened to allow propellants to flow through the low pressure turbopumps, and through the high pressure turbopumps, then to the main propellant valves. On the LO_2 side, the system fills to the preburner valves. The cryogenic propellants are held in the ducts long enough to chill the engine and attain liquid conditions in the respective propellant systems. The chill process is aided by bleedlines which remove the gas as it is formed.

2.2.2.1.6 The LH₂ and LO₂ sides operate almost simultaneously in the start sequence. The following paragraphs describe the operation of each side separately.

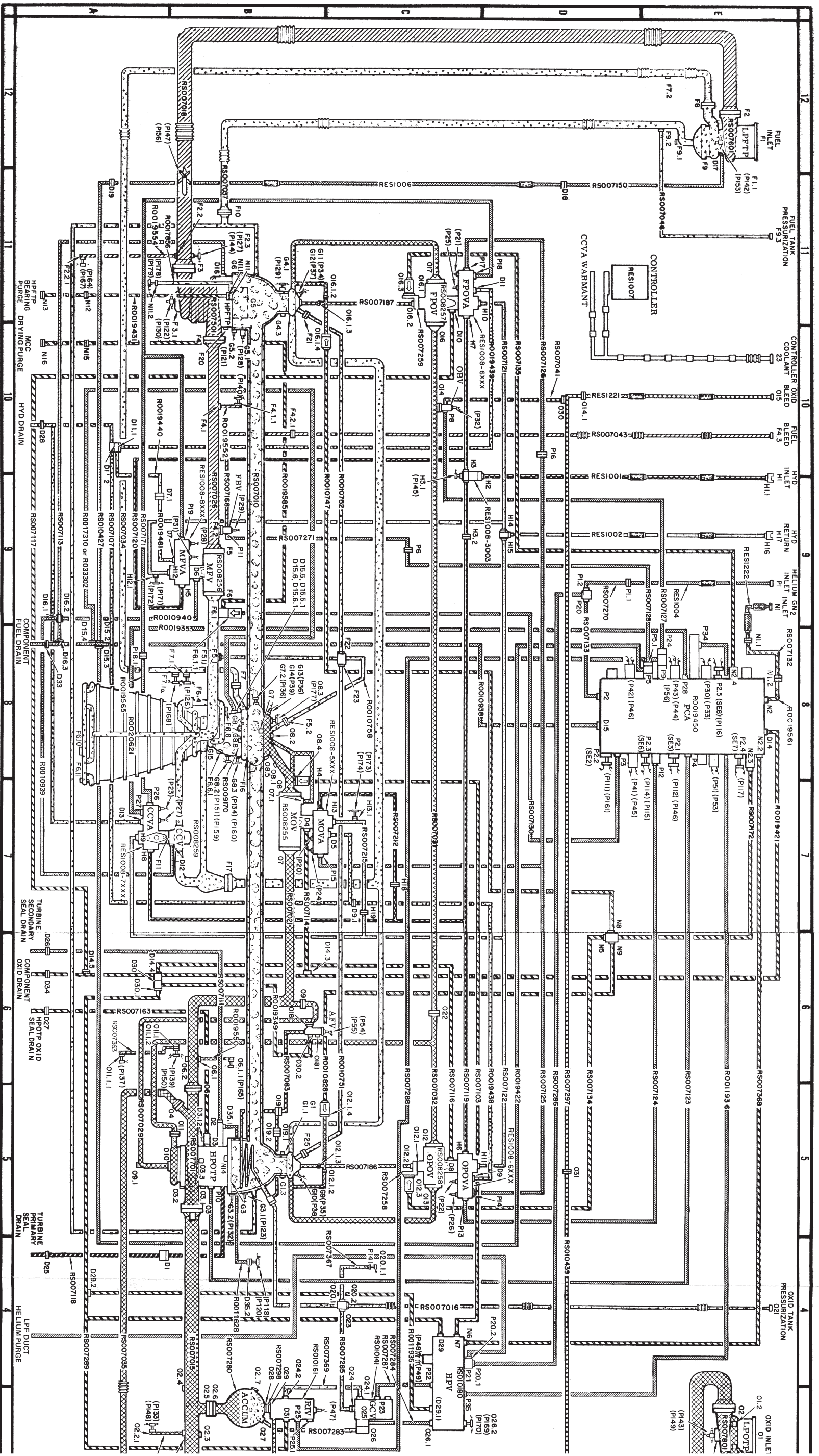
2.2.2.1.6.1 On the LH₂ side, upon receipt of the ignition command from the orbiter, the main fuel valve (MFV) is opened. This permits LH₂ to flow into the coolant loop, through the nozzle tubes, and through channels in the main combustion chamber (MCC). Part of this coolant loop flow is diverted by the coolant control valve (CCV) to the preburners, for combustion and cooling of the preburner walls. Some of the LH₂ used in the coolant loop is warmed in the process to virtually ambient conditions and is tapped off at the MCC for routing back to the low pressure turbopump to drive the turbine for that pump. This flow passes through the turbine and is returned to the walls of the hot gas manifold (HGM), and the main injector to provide cooling.

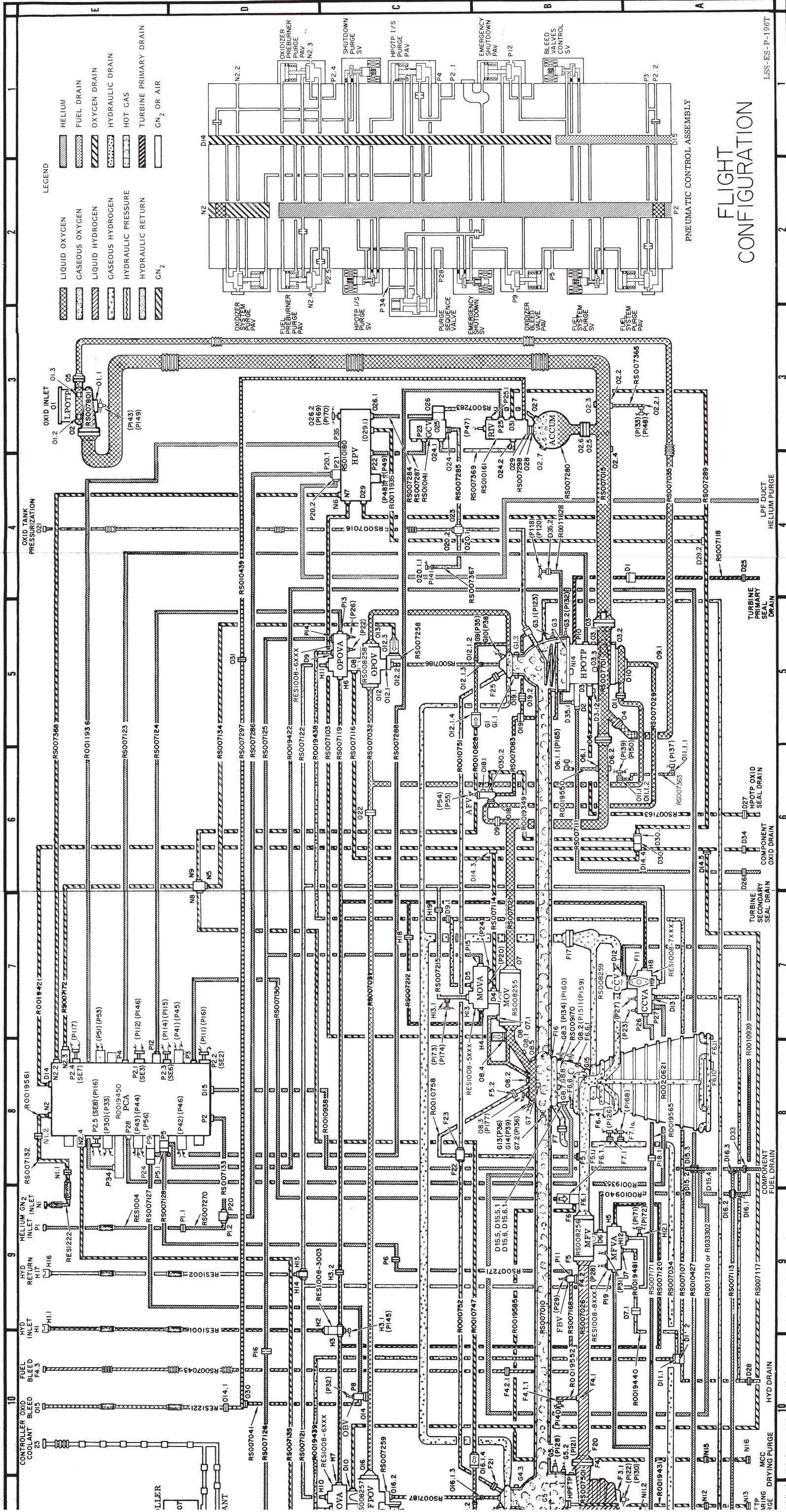
2.2.2.1.6.2 On the LO₂ side, the ignition command opens the main oxidizer valve (MOV). The LO₂ flows through the two turbopumps to the main injector and also, through valves, to the two preburners. Oxygen, tapped off downstream of the high pressure oxidizer turbopump (HPOT), is routed to the low pressure turbopump and serves as the turbine-drive fluid for that pump. This flow continues through the low pressure oxidizer turbopump (LPOT), thus reentering the circuit.

2.2.2.1.7 Spark igniters located in the dome of both preburners and the MCC initiate combustion. The two preburners are operated at mixture ratios of less than one part oxygen to hydrogen to produce hot gas. The hot gas is used to drive the turbines of the two high pressure turbopumps before entering the HGM. This gas is transferred by the HGM from the turbines to the main injector where it is mixed with additional LO_2 from the HPOT for combustion. This combustion process is completed at a mixture ratio of six parts LO_2 to one part LH_2 .

2.2.2.1.8 A pogo suppressor is provided to absorb any closed-loop, longitudinal dynamic oscillations that might be generated between vehicle structural dynamics and the engine combustion process. A suppressor is not required on the LH_2 side of the engine because the inherent low density of LH_2 is insufficient to transmit any appreciable dynamic oscillations. This system is discussed further in paragraph 2.2.3.8, below.

2.2.2.2 Flight Operations. (See figure 2-7.) At T minus 00:00:06.6, the GPCs issue the engine start command, opening the main fuel valve in the engine. Between main fuel valve opening and main engine cut off (MECO), LH_2 flows out of the ET through the ET LH_2 umbilical and the LH_2 feedline disconnect valve into the LH_2 feedline manifold. From this manifold, LH_2 is distributed to the engines through the three engine LH_2 feedlines. In each line, LH_2 passes through the pre valve and





PNEUMATIC CONTROL ASSEMBLY
FLIGHT CONFIGURATION

LSS-ES-P-196T

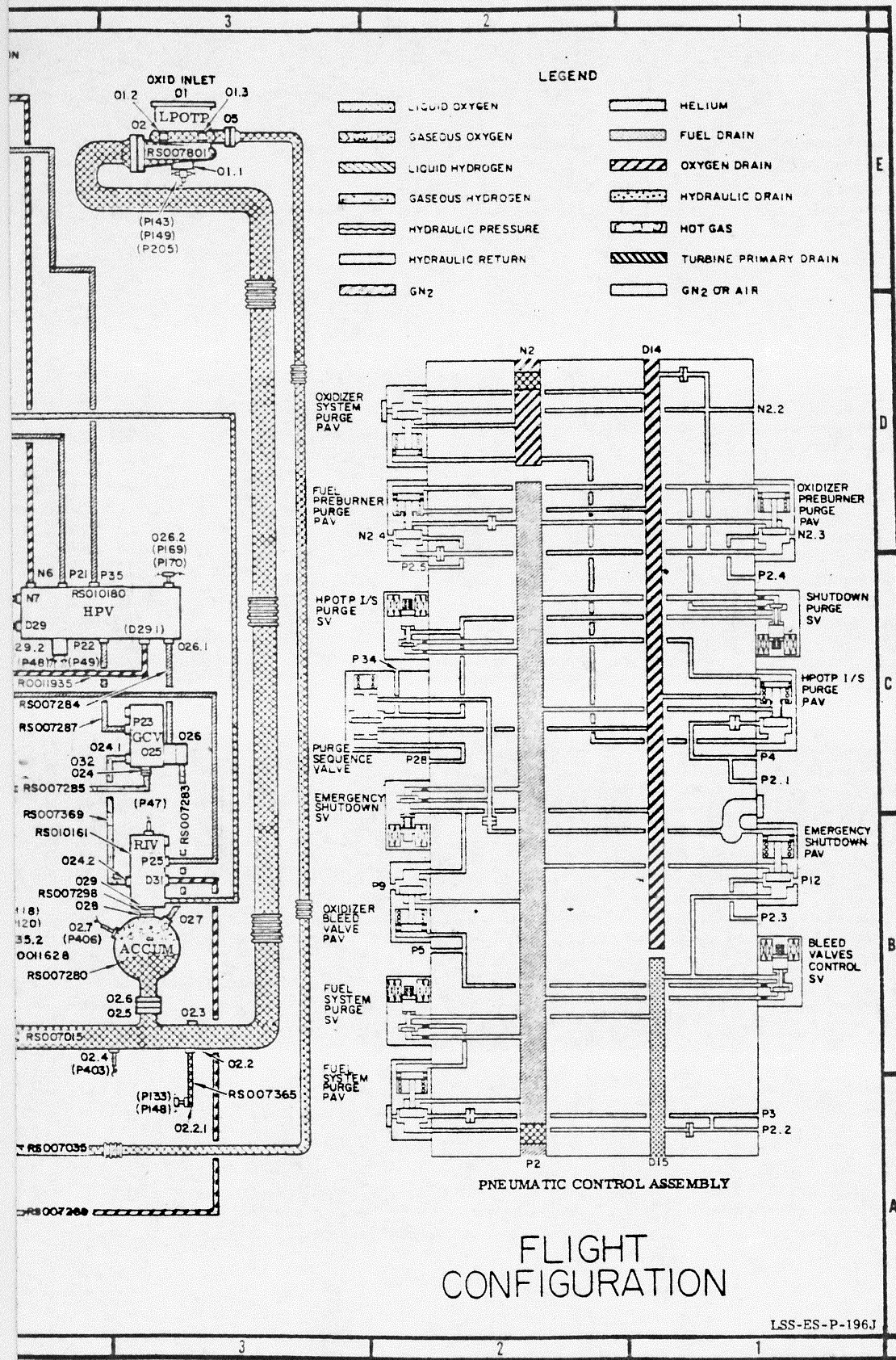


Figure 2-7. Propellant Flow - Flight Configuration

Change 1

2-17/(2-18 Blank)



enters the main engine at the inlet to the low-pressure fuel turbopump (LPFT). In the engine, the LH₂ is used to cool various engine components and in the process is converted to gaseous hydrogen (GH₂). The majority of this GH₂ is burned in the engine; a smaller portion is directed back to the ET to maintain LH₂ tank pressure. GH₂ flowback to the ET begins at the turbine outlet of the LPFT. GH₂ tapped from this line first passes through a check valve and then splits into two paths, each containing a flow control orifice. One of these paths also contains a valve normally controlled by one of three pressure transducers located in the LH₂ tank.

2.2.2.2.1 If all three SSMEs reach 90 percent of their rated thrust at T minus 3 seconds after the ignition command was issued, and approximately 3 seconds have elapsed from the time when all engines are at 90 percent to permit vehicle base bending load models to return to a minimum, the GPCs will issue the commands to fire the SRB ignition PICs, the hold-down release PICs, and the T-0 umbilical release PICs. At T-0 liftoff occurs almost immediately because of the rapid thrust of the SRBs.

2.2.2.2.2 If one or more of the three SSMEs do not reach 90 percent of their rated thrust in less than 4.6 seconds from the SSME ignition command, all SSMEs will be shutdown, the SRBs will not be ignited, and a countdown hold condition will exist. Between liftoff and MECO, as long as the SSMEs perform nominally,

all MPS sequencing and control functions will be executed automatically by the GPCs. During this time period, the flight crew will monitor MPS performance, back up automatic functions, if required, and provide manual inputs in the event of MPS malfunctions.

2.2.2.2.3 Beginning at T-0, the SSME gimbal actuators, which were locked in their special pre-ignition positions, are commanded to their null positions for SRB start and then allowed to operate as needed for thrust vector control.

2.2.2.2.4 During ascent, LH₂ tank pressure is maintained between 33 and 35 psia through the orifices in the two lines and the action of the flow control valve. When pressure in the LH₂ tank reaches 35 psia, the valve closes. The tank relieves through the tank vent valve if pressure drops below 33 psia. If tank pressure falls below 33 psia or rises above 35 psia, the flight crew will position the MPS LH₂ ULLAGE PRESS switch on panel R2 to the OPEN position. This allows the three flow control valves to go to the full-open position. Normally the MPS LH₂ ULLAGE PRESS switch is in the AUTO position. Downstream of the two flow control orifices and the flow control valves, the GH₂ lines empty into the ET GH₂ pressurization manifold. This single line then exits the orbiter at the GH₂ pressurization disconnect and passes through the ET GH₂ umbilical into the top of the LH₂ tank. During ascent LO₂ tank pressure is maintained between 20 and 22

psia by the orifices in the two lines and the action of the flow control valve. When pressure in the tanks reaches 22 psia, the valve closes. When pressure drops below 20 psia, the valve opens. LO₂ tank pressure greater than 25 psia will cause the tank to relieve through the tank vent and relief valves.

2.2.2.2.5 The SSME thrust level setting is dependent upon individual flight requirements. It may be 100 or 104 percent for some high-orbit missions, while missions involving heavy payloads may require the maximum thrust setting of 109 percent. The initial thrust level is normally maintained until approximately 31 seconds into the mission, when the GPCs throttle the engines to a lower thrust percent setting which also is dependent upon the needs of the individual flight. The purpose of the lower throttle setting is to minimize structural loading when the orbiter is passing through the region of maximum aerodynamic pressure (max Q). This normally occurs around 63 seconds mission elapsed time. At approximately 65 seconds, the engines are once again throttled to the applicable higher percent and remain at that setting.

2.2.2.2.6 Beginning at approximately 00:07:40 mission elapsed time, the engines are throttled back to maintain vehicle acceleration at, or less than, three gs. The three g limit is an operational limit devised to prevent physical stresses on the

flight crew. Approximately eight seconds before MECO, the engines are throttled back to 65 percent.

2.2.2.2.7 Although MECO is based on the attainment of a specified velocity, the engine can also be shutdown due to LO₂ depletion before the specified velocity of MECO is reached. LO₂ depletion is sensed by four oxidizer depletion sensors located in the LO₂ feedline manifold. Any two of the four sensors indicating a dry condition will cause the GPCs to issue a MECO command to the engine controller.

2.2.2.2.8 The engine can also be shutdown by LH₂ depletion should it occur before the specified velocity is reached. LH₂ depletion is sensed by four fuel depletion sensors located in the bottom of the LH₂ tank. Any two of the four sensors indicating a dry condition will cause the GPCs to issue a MECO command to the engine controller.

2.2.2.3 Operational Phases and Modes. The six key SSME operational phases and their subordinate modes are discussed in the paragraphs below.

2.2.2.3.1 Checkout Phase. This phase requires that the controller operational program be initiated to begin active control, monitoring, or checkout, and utilizes both a standby and

component checkout mode as required. The modes utilized to advance this mode are discussed in the paragraphs below.

2.2.2.3.1.1 The standby mode is a waiting mode during which active control sequence operations are not in process. However, monitoring functions that do not affect engine hardware component status are continually active. Such functions include processing of vehicle commands, status update, and controller self-test. During the checkout phase, data and instructions can be loaded into computer memory. This permits updating of the software program and data as necessary to proceed with engine firing operations or checkout operations.

2.2.2.3.1.2 While in the component checkout mode, a checkout or engine leak test is performed on an individual engine system component using overlay modules. These functions include a sensor calibration and checkout, a pneumatic checkout, a hydraulic actuator checkout, redundancy verifications, and a flight readiness test (FRT).

2.2.2.3.2 Start Preparation Phase. During the SSME start preparation phase, engine system purges and propellant conditioning are performed. There are five modes used for this phase, each of which is covered in one of the following paragraphs.

2.2.2.3.2.1 The purge sequence number 1 mode (see figure 2-8) is the first purge sequence of the start preparation phase. The ground-supplied GN₂ purge of preburners, oxidizer dome, and HPOTP intermediate seal is initiated in this mode, and propellant valve positions are verified.

2.2.2.3.2.2 The purge sequence number 2 (figure 2-9) mode is the second purge sequence of the start preparation phase. The on-board helium purge of the fuel system is initiated in this mode, and the GN₂ purges initiated in purge sequence number 1 are continued.

2.2.2.3.2.3 The purge sequence number 3 mode (figure 2-10) is the third purge sequence of the start preparation phase. Propellant recirculation (bleed valve operation) is initiated in this mode, and the fuel system helium purge is suspended. (Note: During purge sequence number 3, the fuel system helium purge is reapplied for 3 minutes each 60-minute period.) While in this mode, GN₂ purges initiated in purge sequence number 1 are continued.

2.2.2.3.2.4 The purge sequence number 4 mode (figure 2-11) is the fourth purge sequence of the start preparation phase. The fuel system helium purge is reinstated. All fail-safe solenoid valves are energized. The GN₂ purges initiated in purge sequence number 1 are continued.

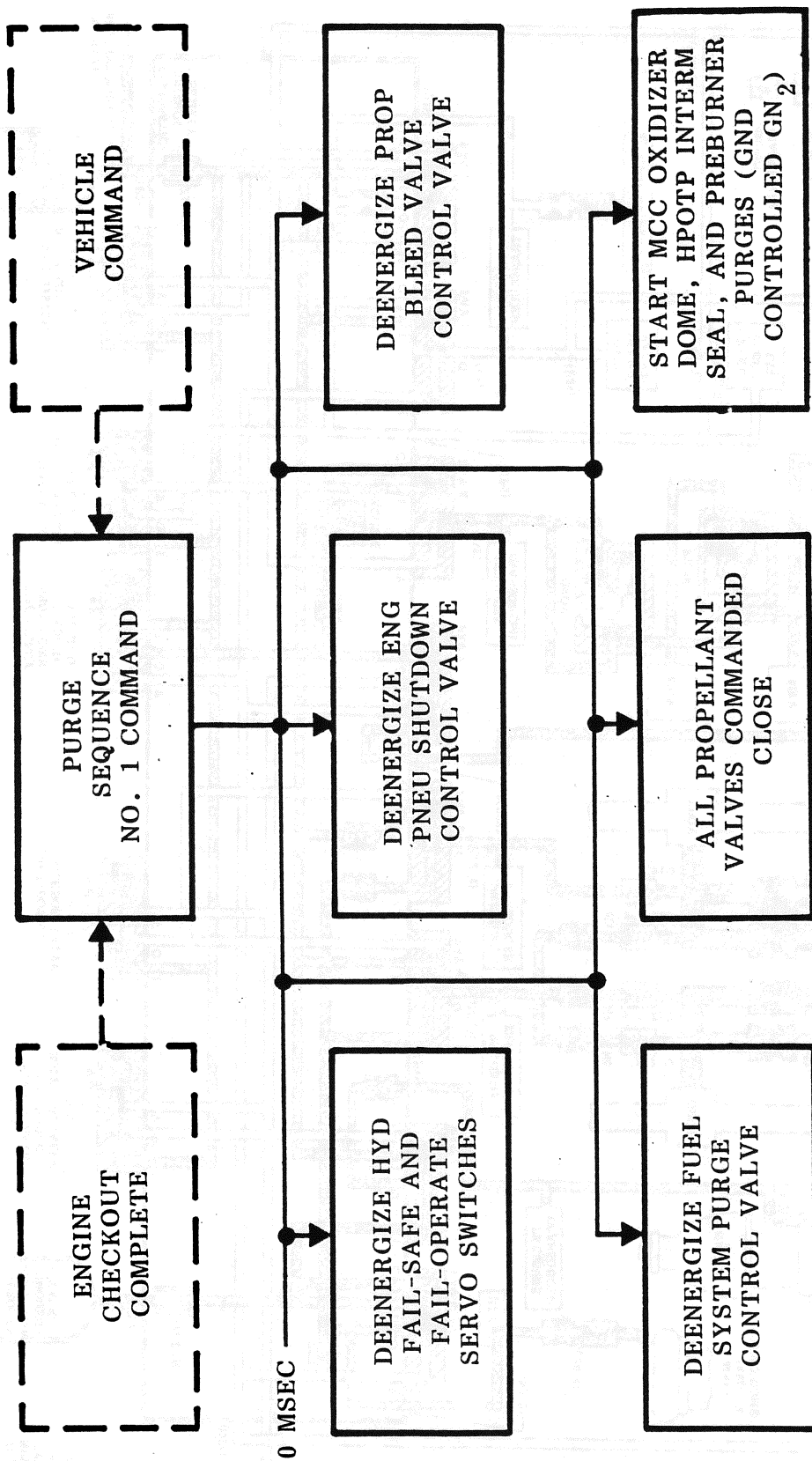


Figure 2-8. SSME start preparation phase Purge Sequence 1
(Sheet 1 of 2)

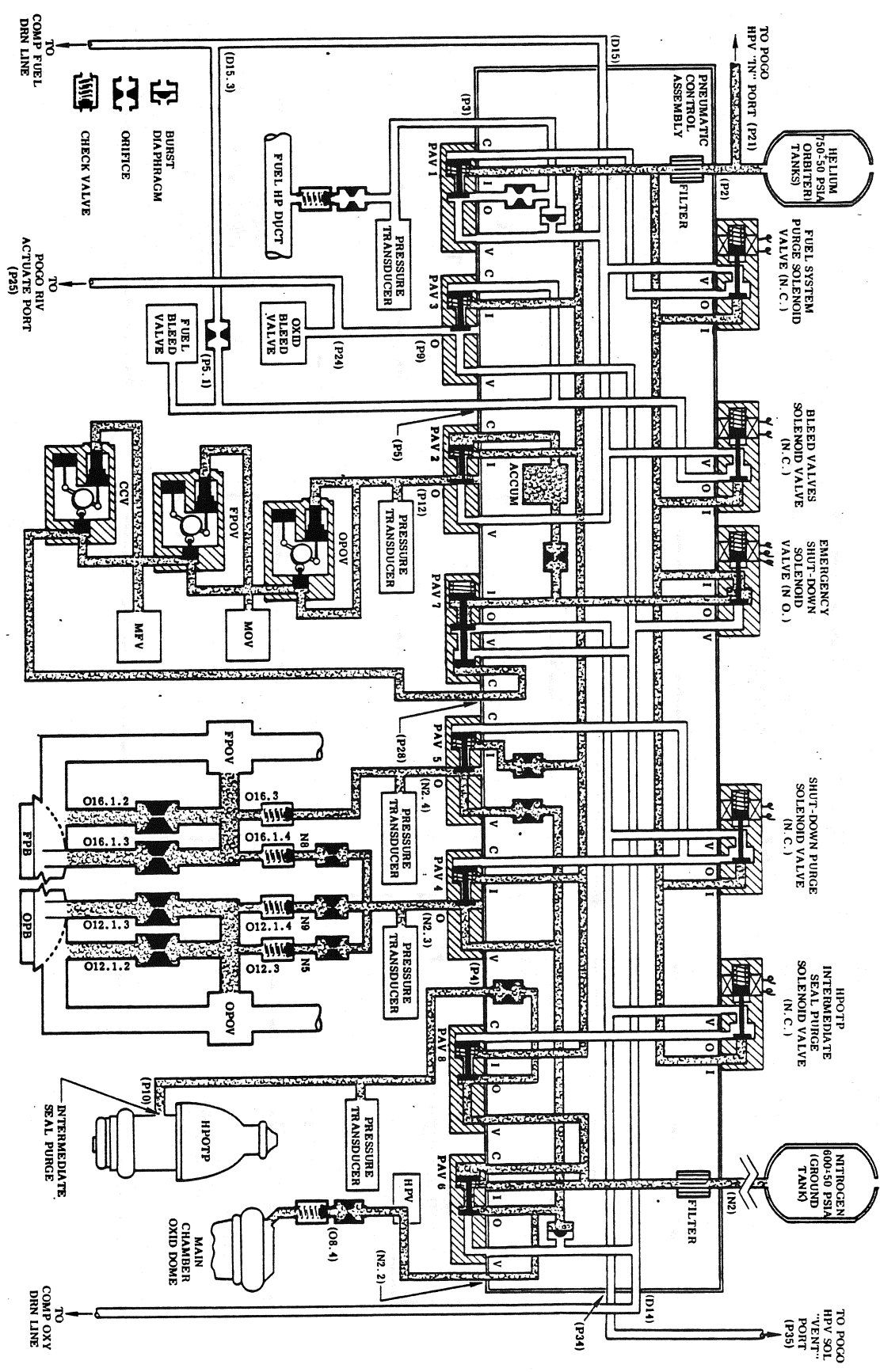


Figure 2-8. SSME Start Preparation Phase Purge Sequence 1

(Sheet 2 of 2)

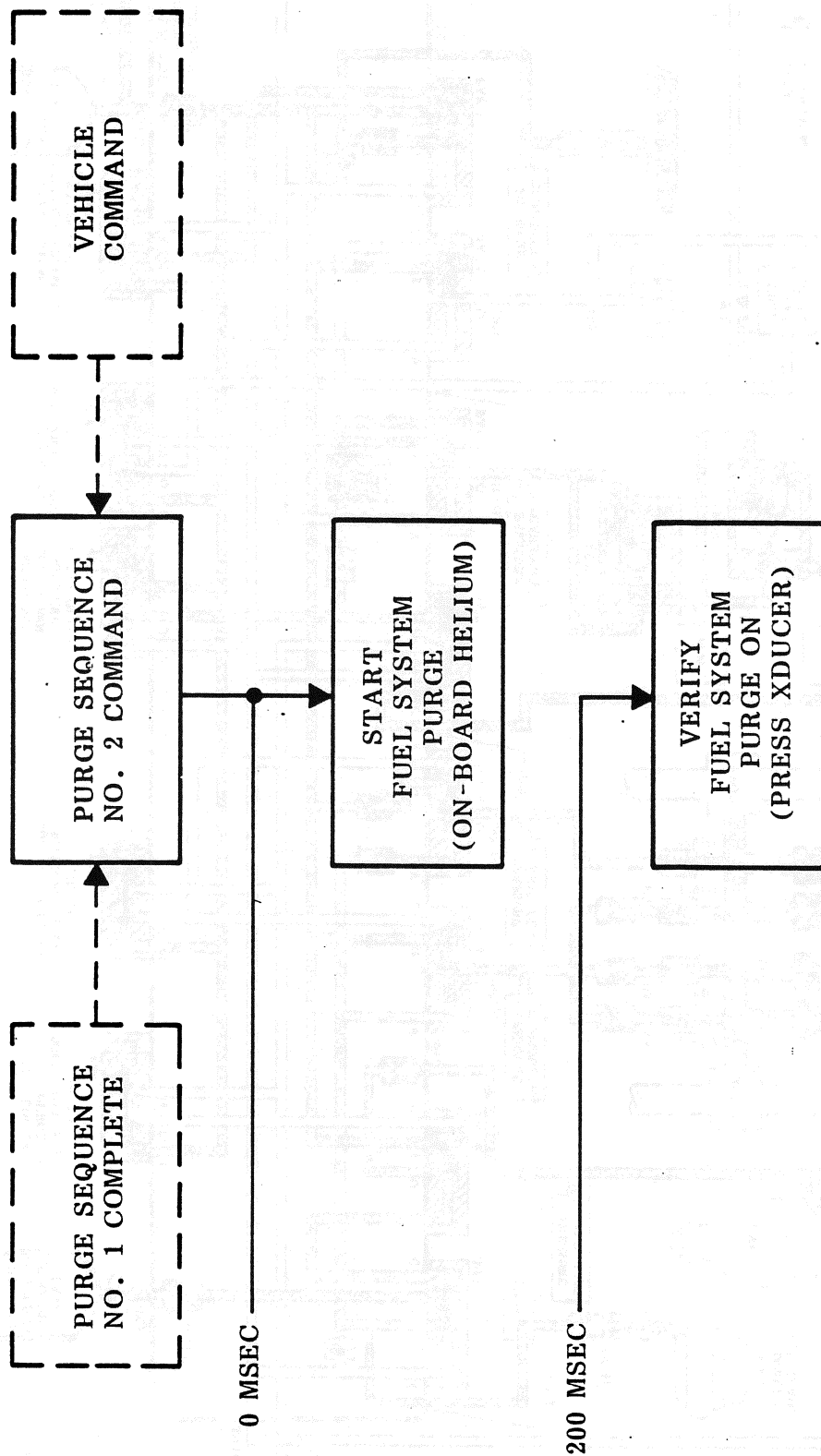
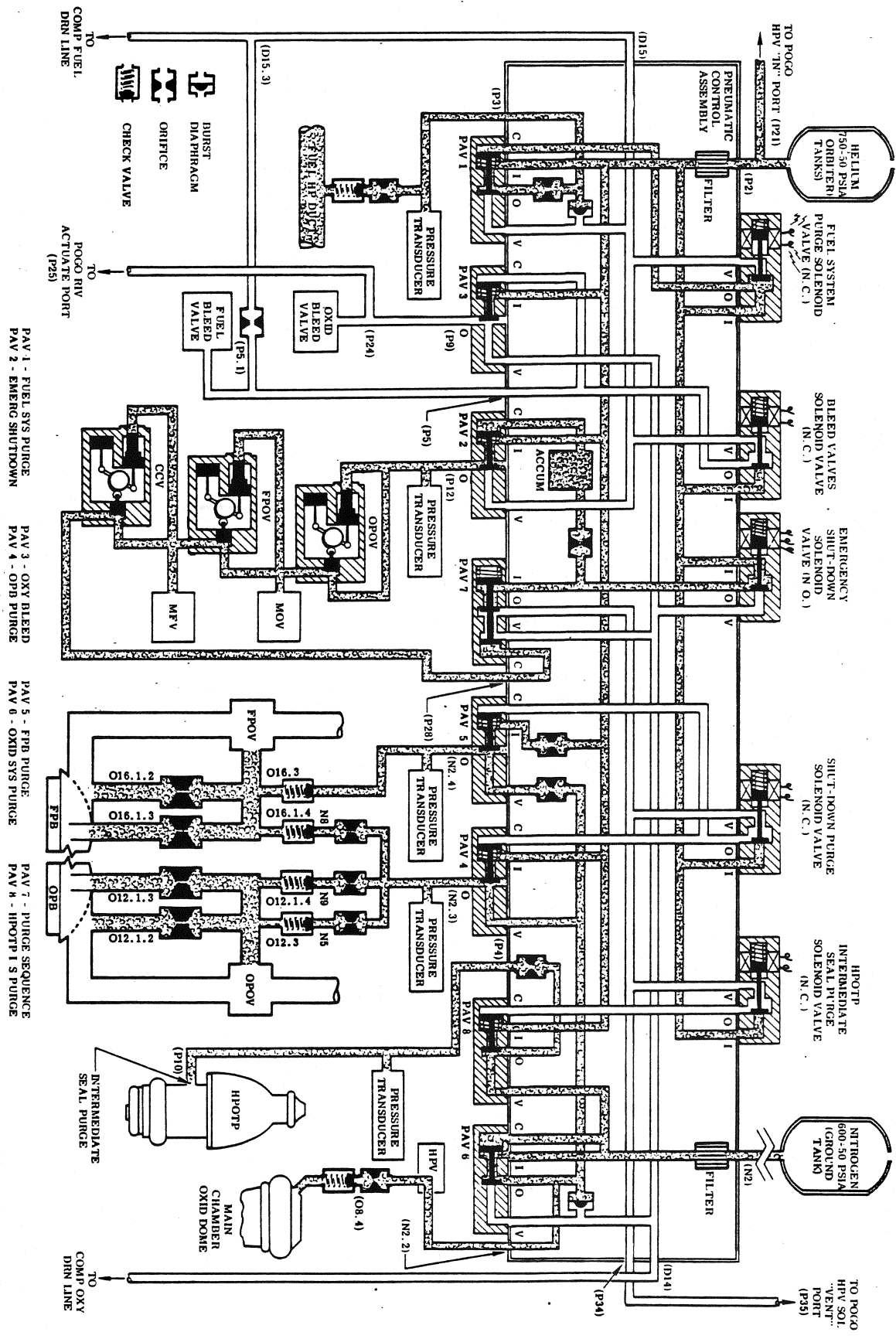


Figure 2-9. SSME Start Preparation Phase Purge Sequence 2



- PAV 1 - FUEL SYS PURGE
- PAV 2 - EMERG SHUTDOWN
- PAV 3 - OXY BLEED
- PAV 4 - OPB PURGE
- PAV 5 - FPB PURGE
- PAV 6 - OXID SYS PURGE
- PAV 7 - PURGE SEQUENCE
- PAV 8 - HPOTP I S PURGE

Figure 2-9. SSME Start Preparation Phase Purge Sequence 2

(Sheet 2 of 2)

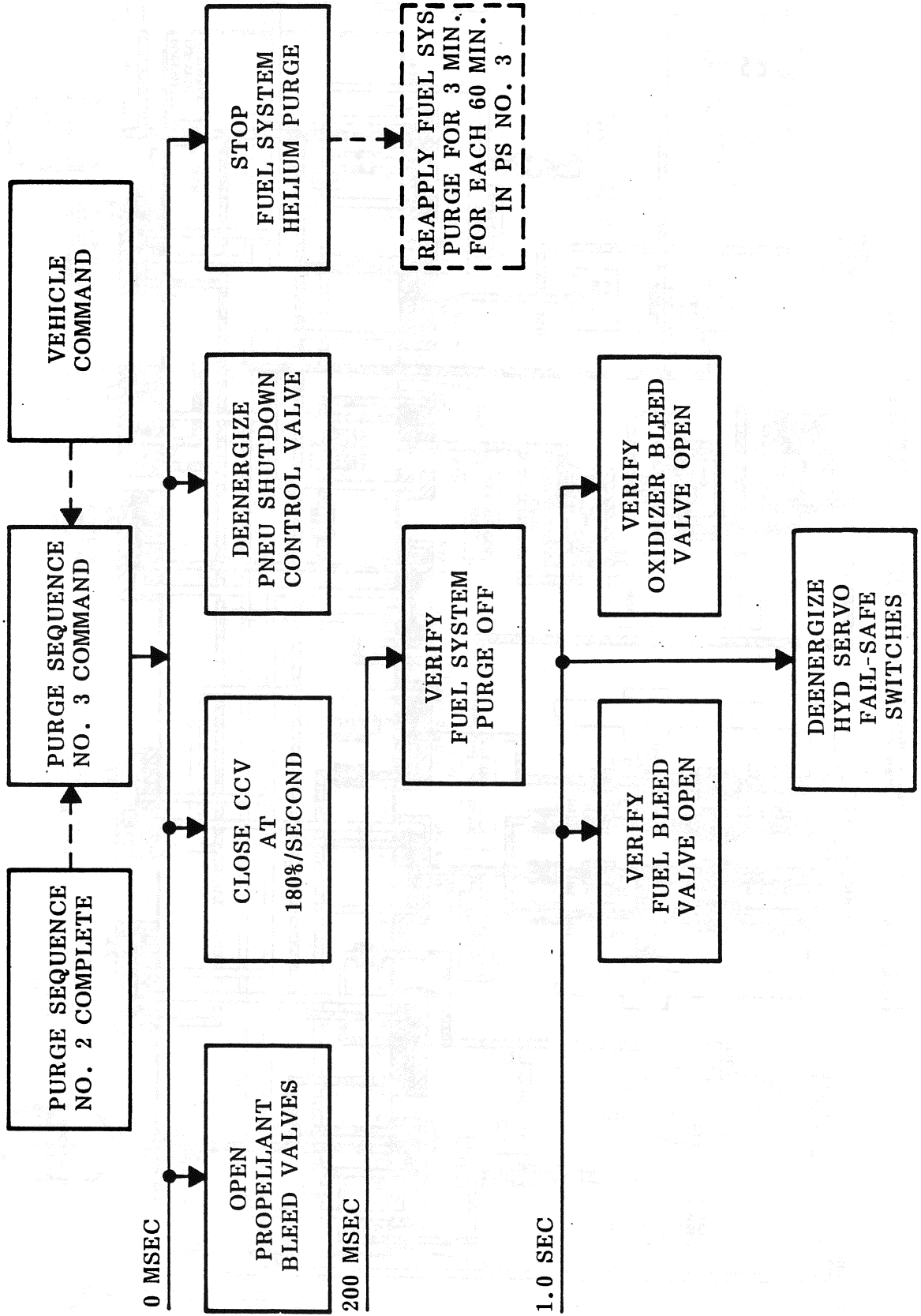
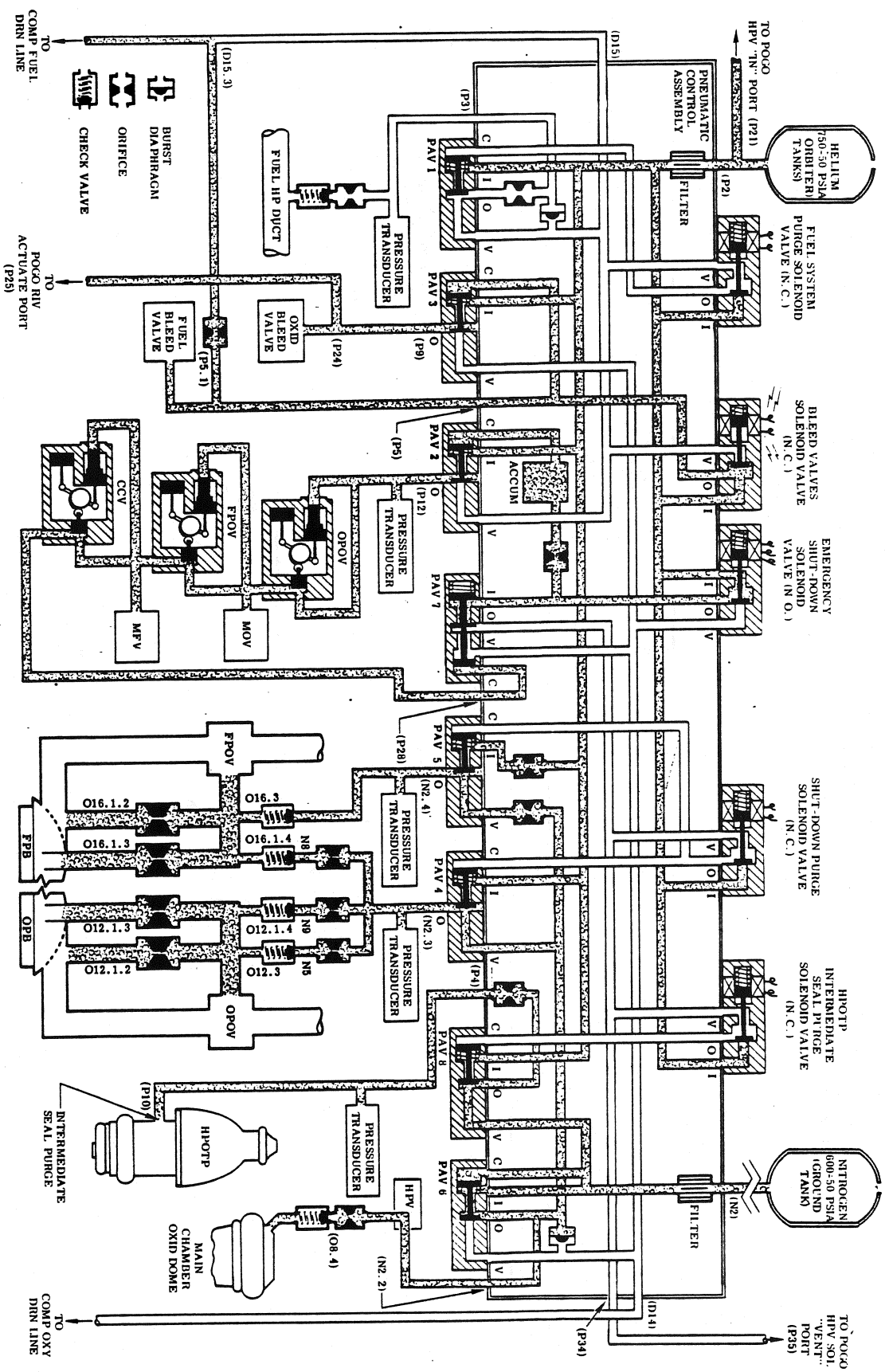


Figure 2-10. SSME Start Preparation Phase Purge Sequence 3

(Sheet 1 of 2)



- PAV 1 - FUEL SYS PURGE
- PAV 2 - EMERG SHUTDOWN
- PAV 3 - OXY BLEED
- PAV 4 - OPD PURGE
- PAV 5 - FPA PURGE
- PAV 6 - OXID SYS PURGE
- PAV 7 - PURGE SEQUENCE
- PAV 8 - HPOTP 1 S PURGE

Figure 2-10. SSME start Preparation Phase Purge Sequence 3

(Sheet 2 of 2)

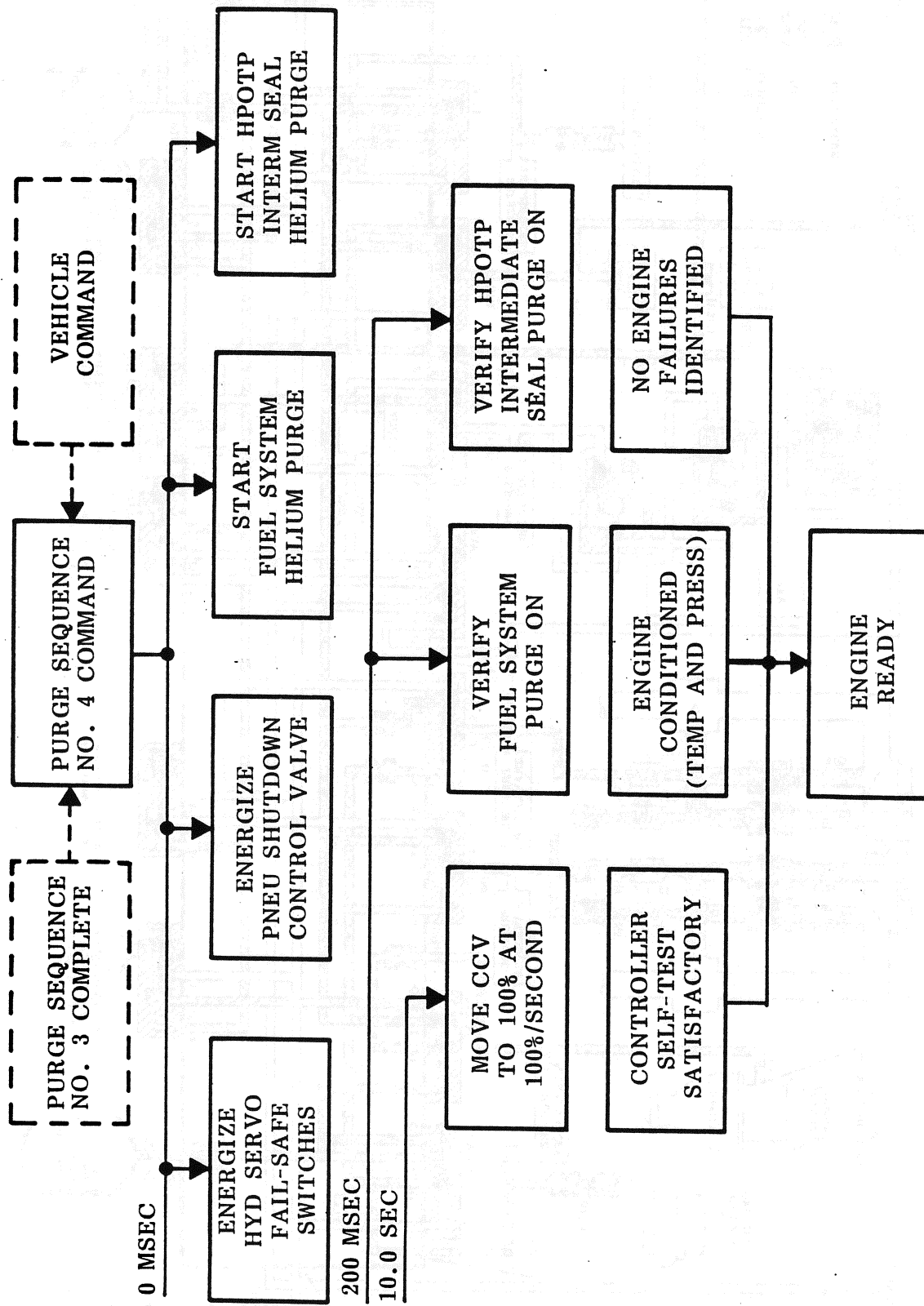


Figure 2-11. SSME Start Preparation Phase Purge Sequence 4

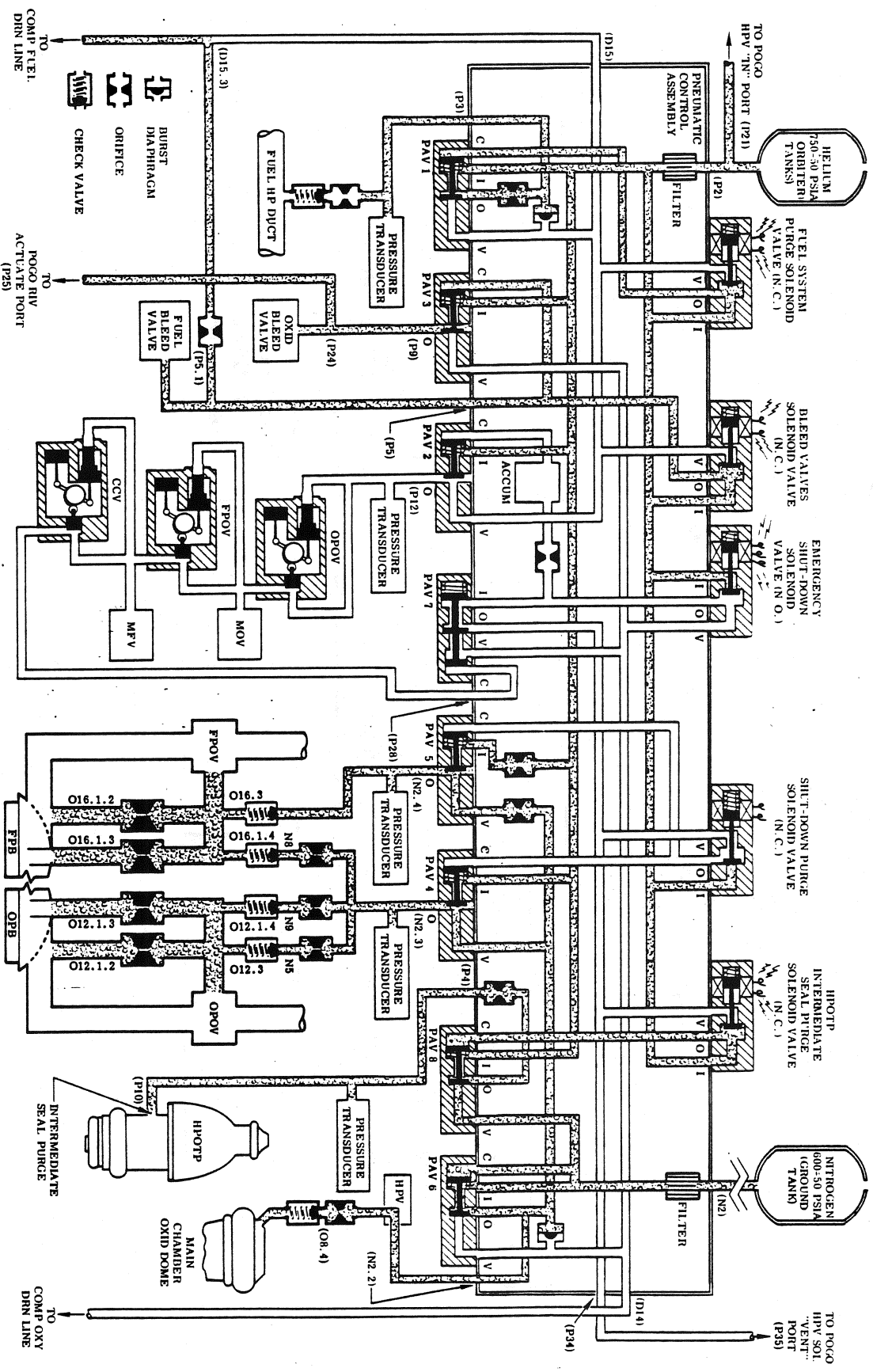


Figure 2-11. SSME start Preparation Phase Purge Sequence 4

2.2.2.3.2.5 The engine ready mode verifies that proper thermal and pressure conditions for start have been attained and that other criteria for start have been satisfied. Purges from purge sequence number 4 are continued.

2.2.2.3.3 Start Phase. In this phase, operations for propellant ignition and thrust buildup are in progress, beginning with scheduled (open-loop) operation of all five propellant valves. The modes applicable to this phase are described in the paragraphs below.

2.2.2.3.3.1 During the start initiation mode, the initial functions prior to ignition confirmed are in progress. All purges are off and verified. Bleed valves are closed and verified. Igniters are energized and verified. The thrust control loop is closed. (See figure 2-12.)

2.2.2.3.3.2 In the thrust buildup mode, ignition has been detected by monitoring main combustion chamber pressure and closed-loop thrust buildup sequencing is in progress. The mixture ratio control loop is closed. The pogo suppression accumulator is helium pre-charged for 2 seconds. MFV, MOV, and CCV are scheduled I/A/W MCC pressure (thrust). (See figure 2-13.)

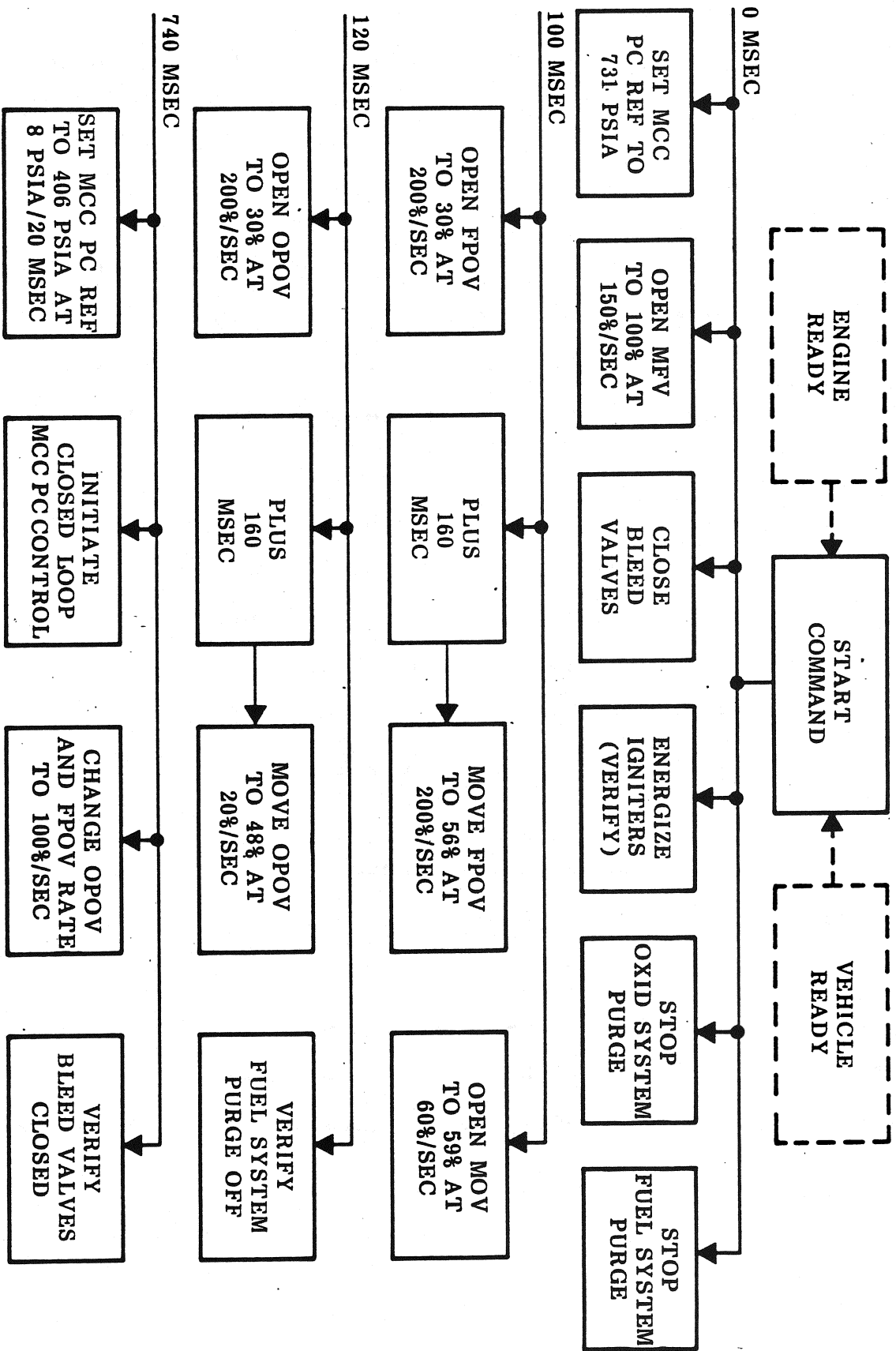


Figure 2-12. SSME Start Phase (Sheet 1 of 2)

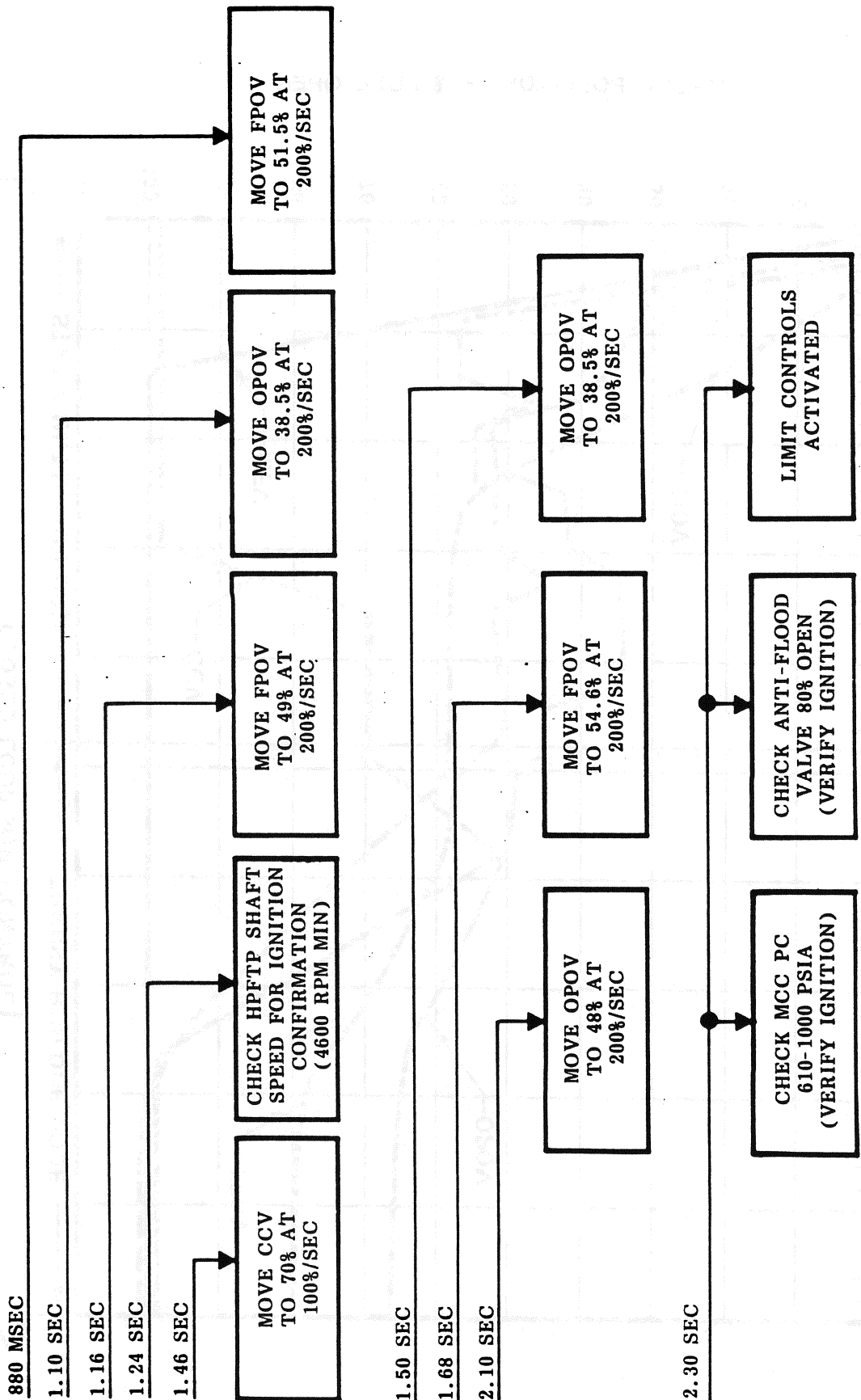


Figure 2-12. SSME Start Phase (Sheet 2 of 2)

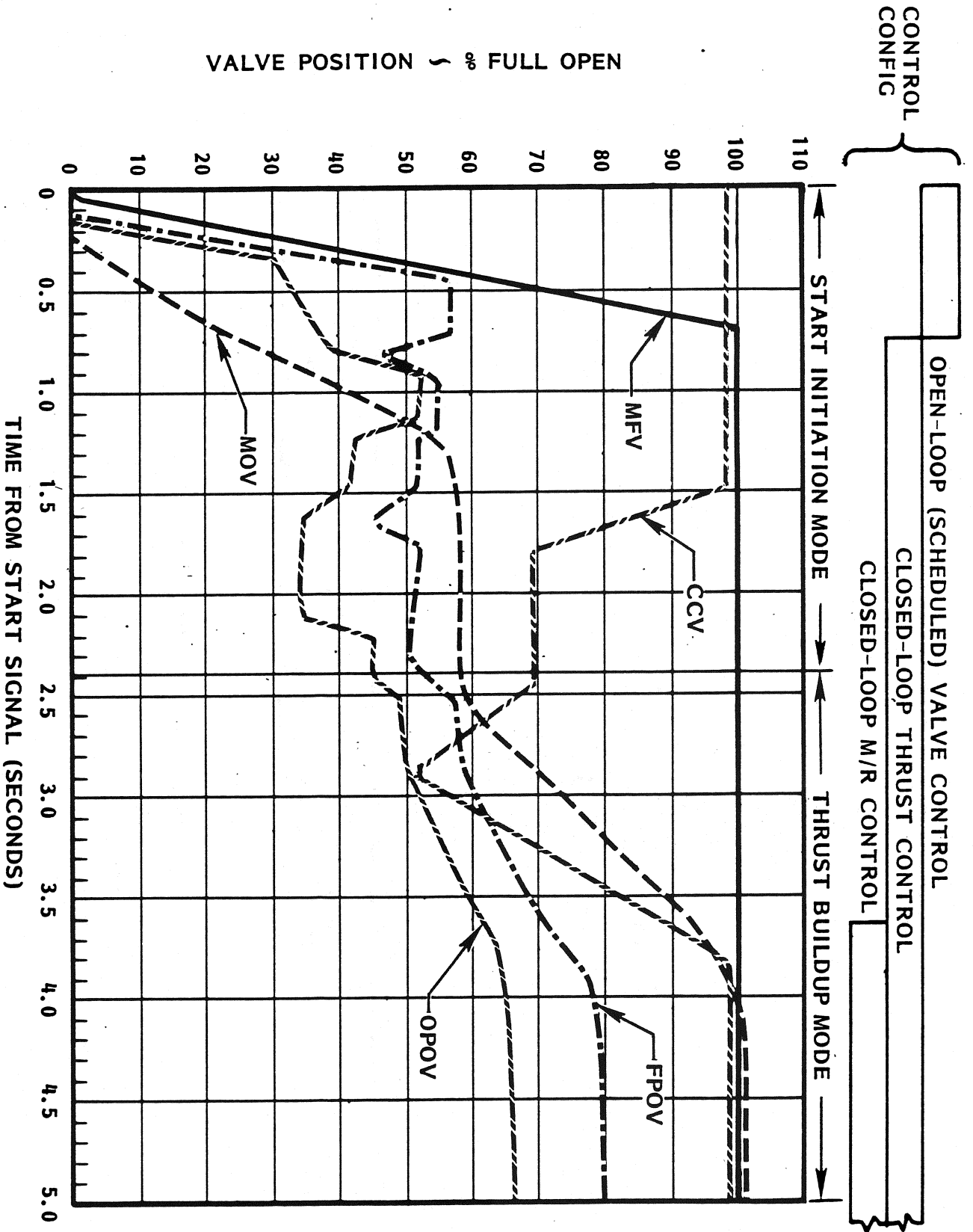


Figure 2-13. Engine Start Valve Sequence (Sheet 1 of 2)

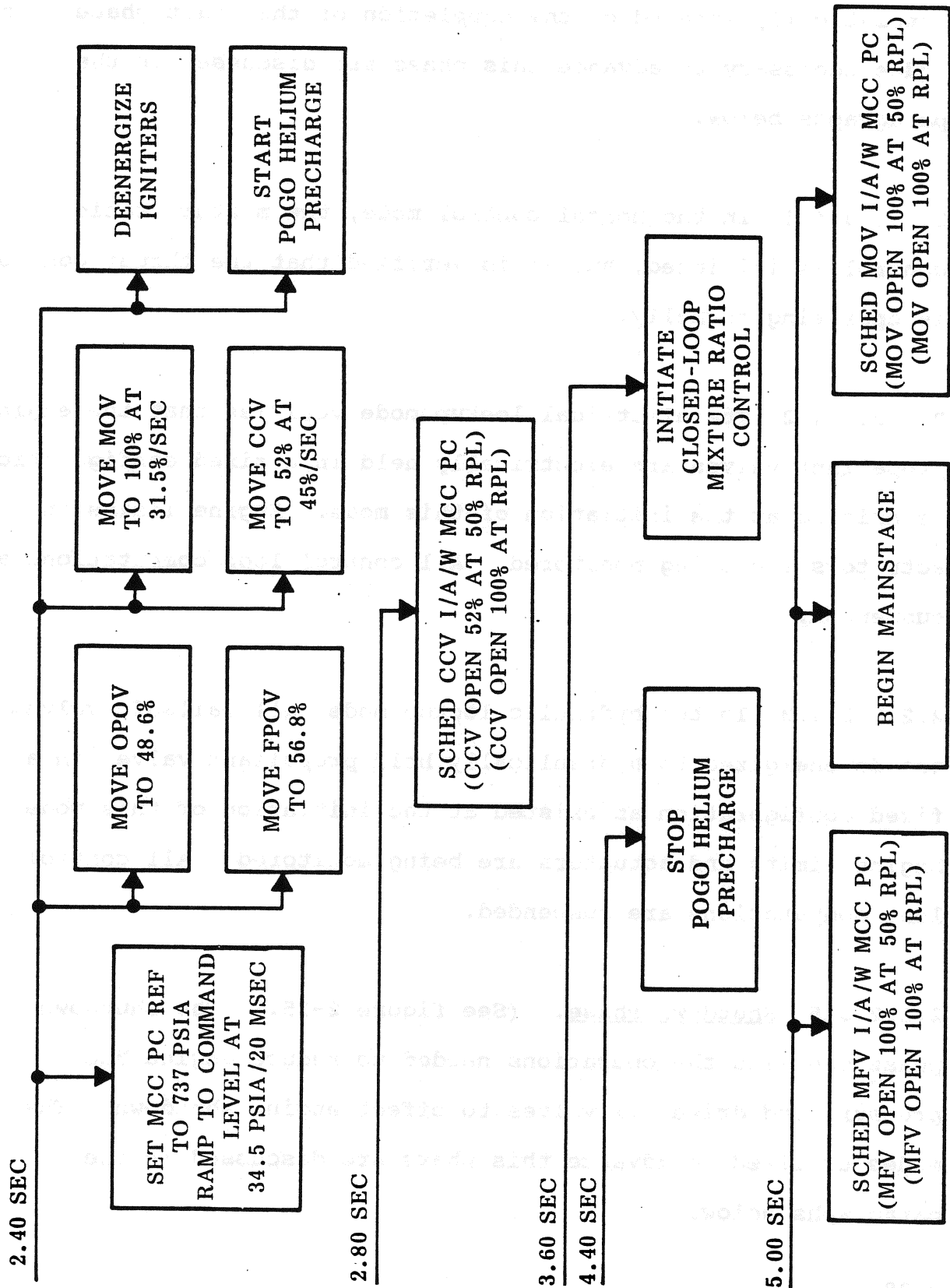


Figure 2-13. Engine Start Valve Sequence (Sheet 2 of 2)

2.2.2.3.4 Mainstage Phase. (See figure 2-14.) This phase is automatically entered on the completion of the start phase. The modes necessary to advance this phase are discussed in the paragraphs below.

2.2.2.3.4.1 In the normal control mode, the mixture ratio control is initiated, and it is verified that the thrust control is operating normally.

2.2.2.3.4.2 The electrical lockup mode verifies that the engine propellant valves are electrically held in a fixed configuration, as existed at the initiation of this mode. Engine limits and actuators are being monitored. All control loop computations are suspended.

2.2.2.3.4.3 In the hydraulic lockup mode, all failsafe valves are de-energized to hydraulically hold propellant valves in a fixed configuration as existed at the initiation of this mode. Engine limits and actuators are being monitored. All control loop computations are suspended.

2.2.2.3.5 Shutdown Phase. (See figure 2-15.) The shutdown phase contains the operations needed to reduce engine MCC pressure and drive all valves to effect engine shutdown. The modes utilized to advance this phase are discussed in the paragraphs below.

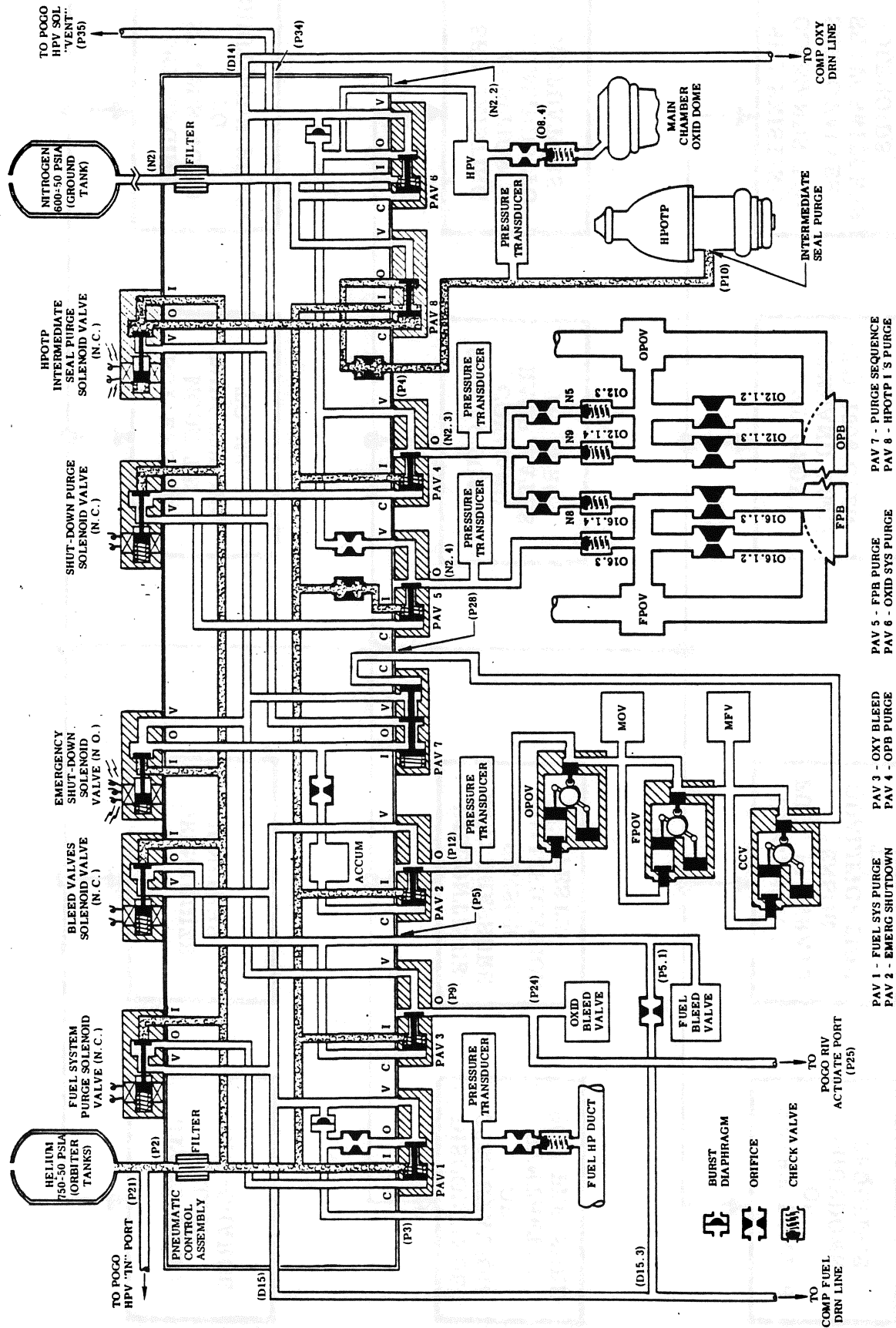


Figure 2-14. SSME Main Stage Phase

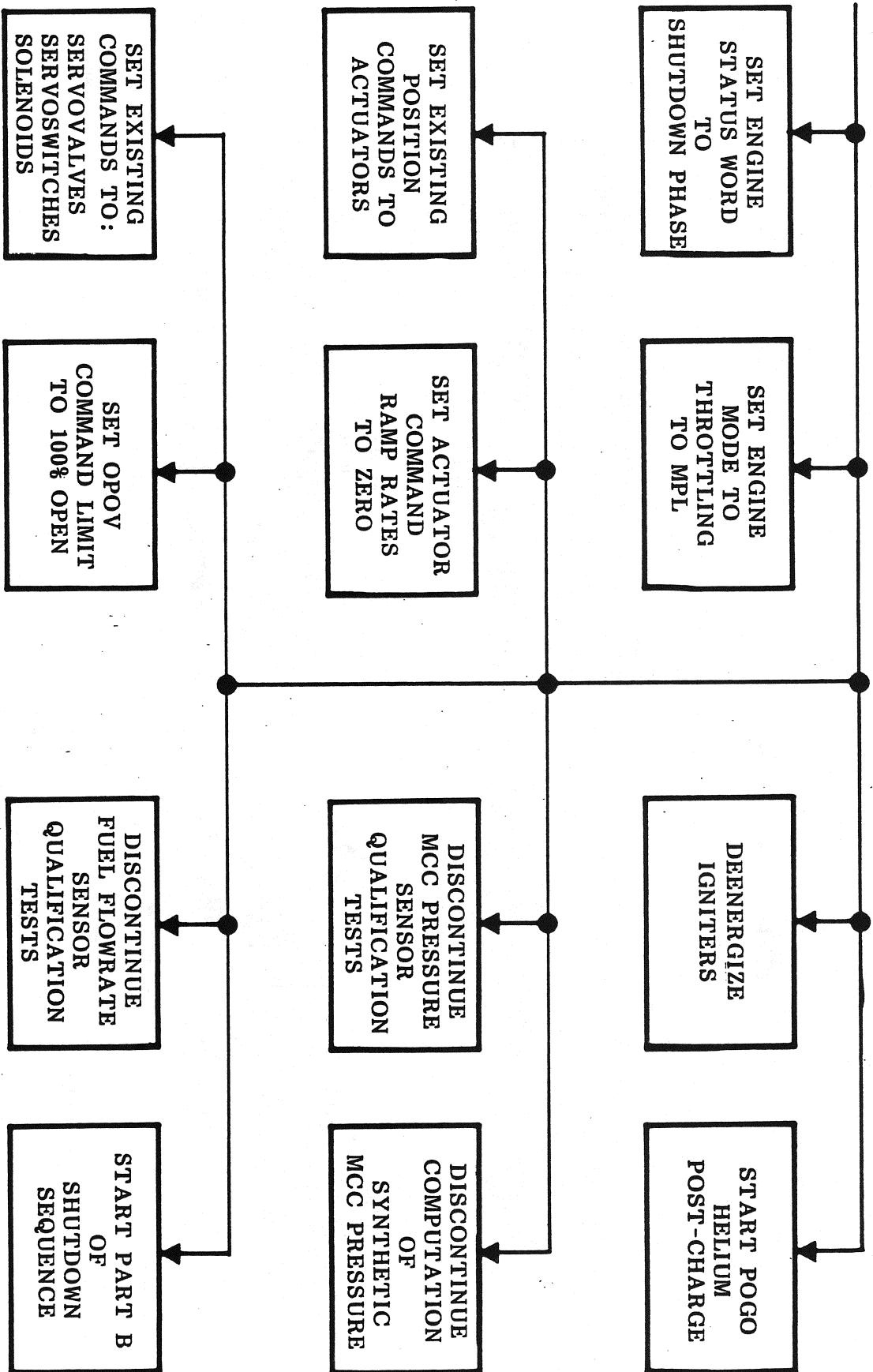


Figure 2-15. SSME Shutdown Phase (Sheet 1 of 8)

TIME T_b

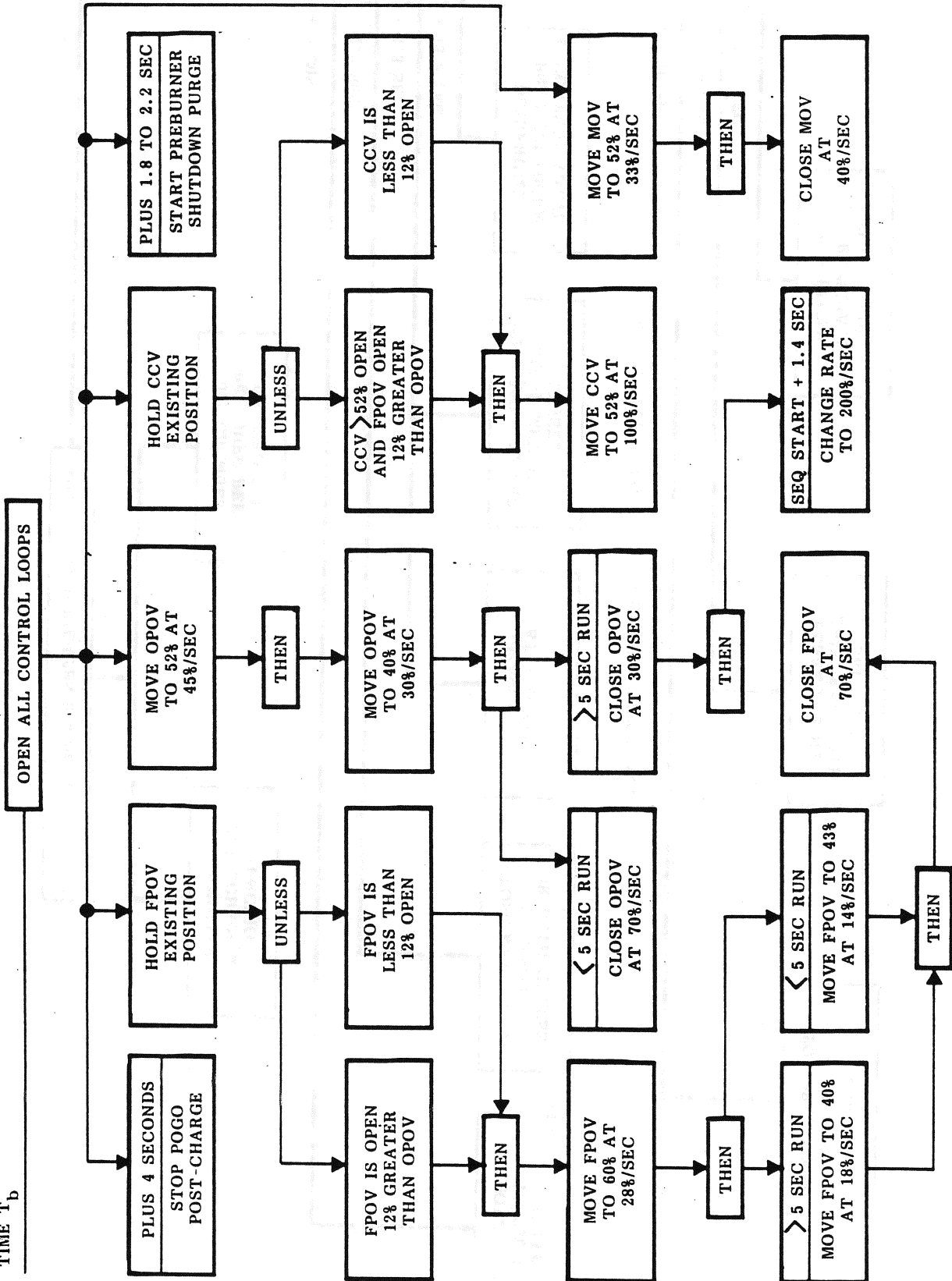


Figure 2-15. SSME Shutdown Phase (Sheet 2 of 8)

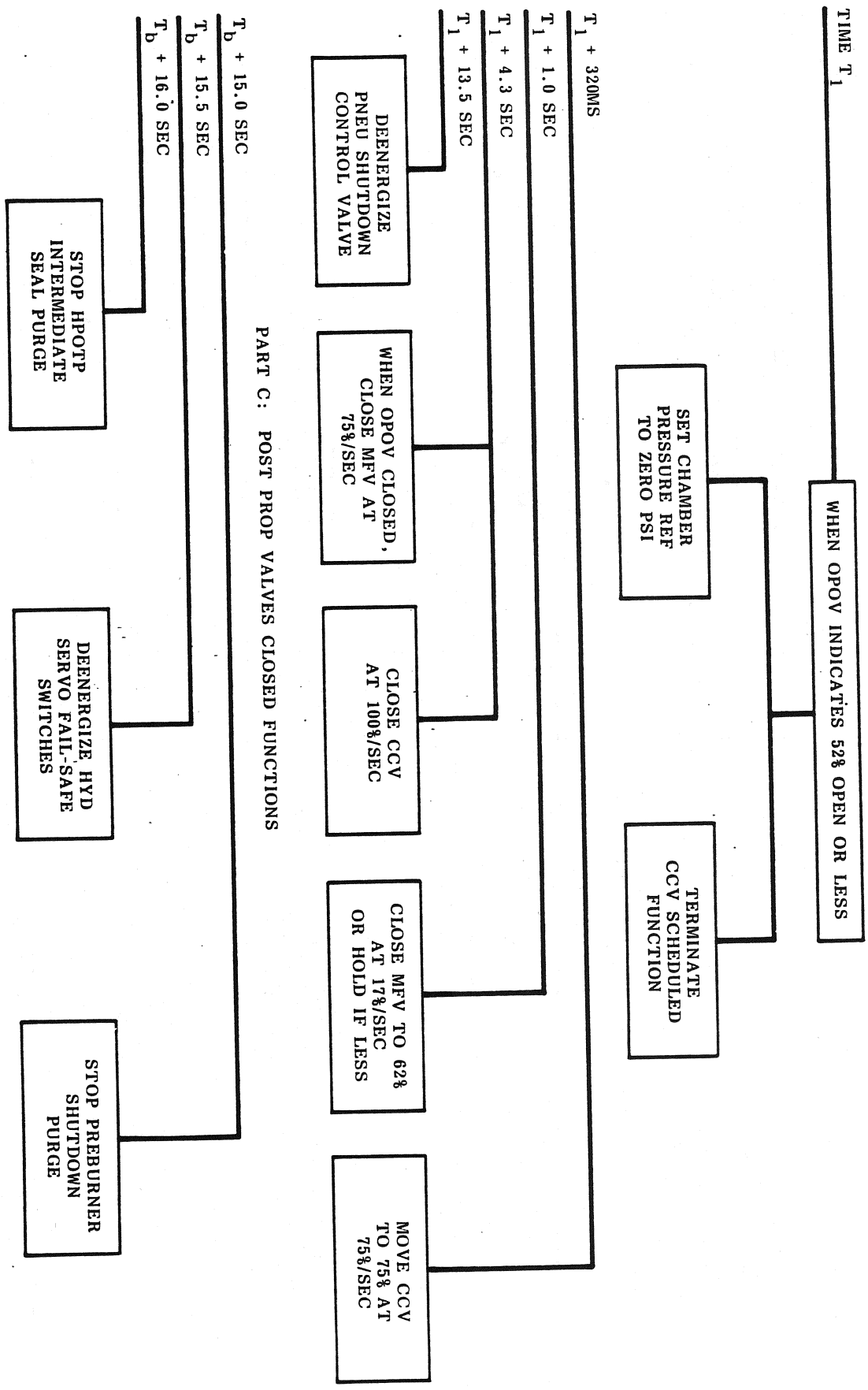


Figure 2-15. SSME Shutdown Phase (Sheet 3 of 8)

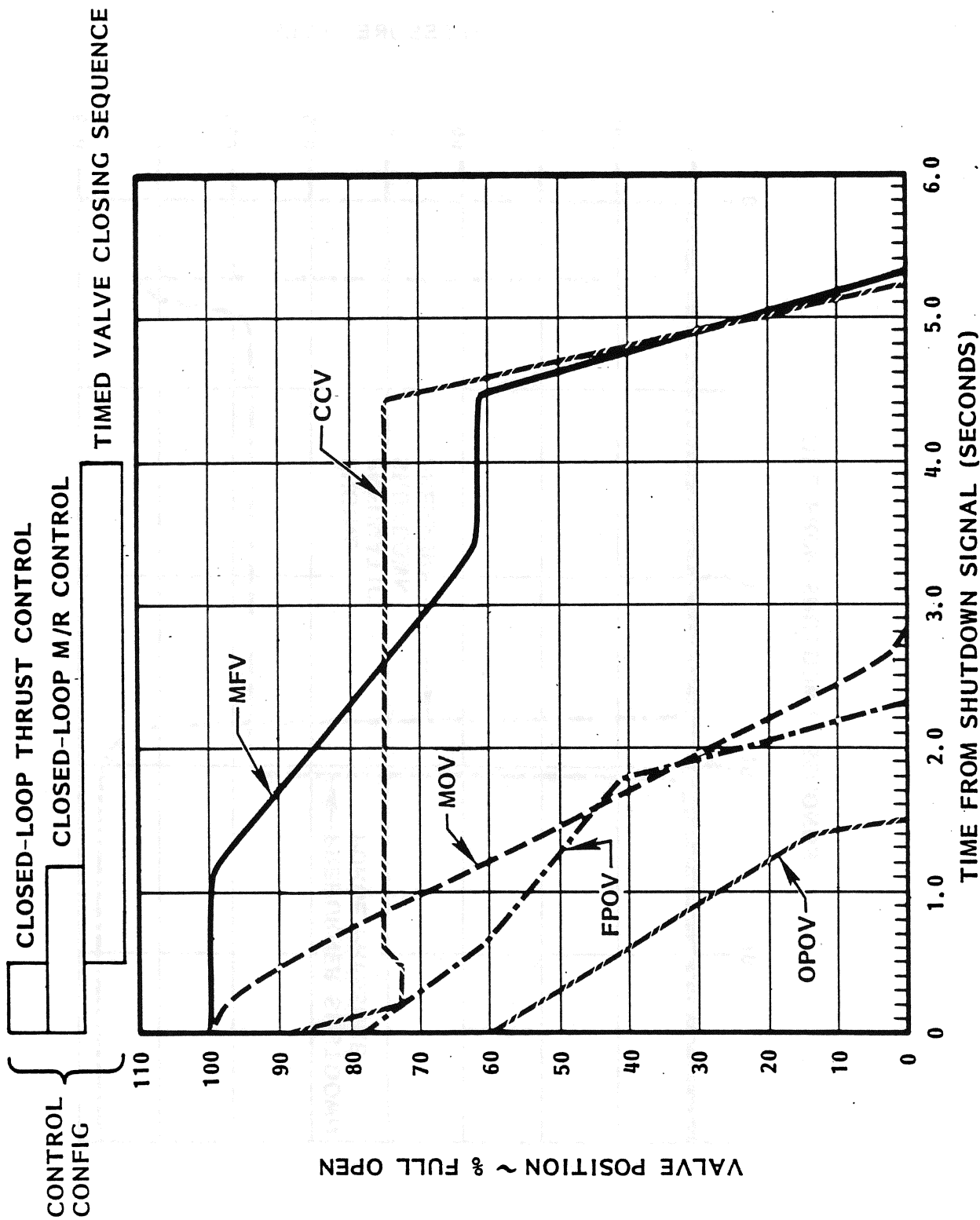


Figure 2-15. SSME Shutdown Phase (Sheet 4 of 8)

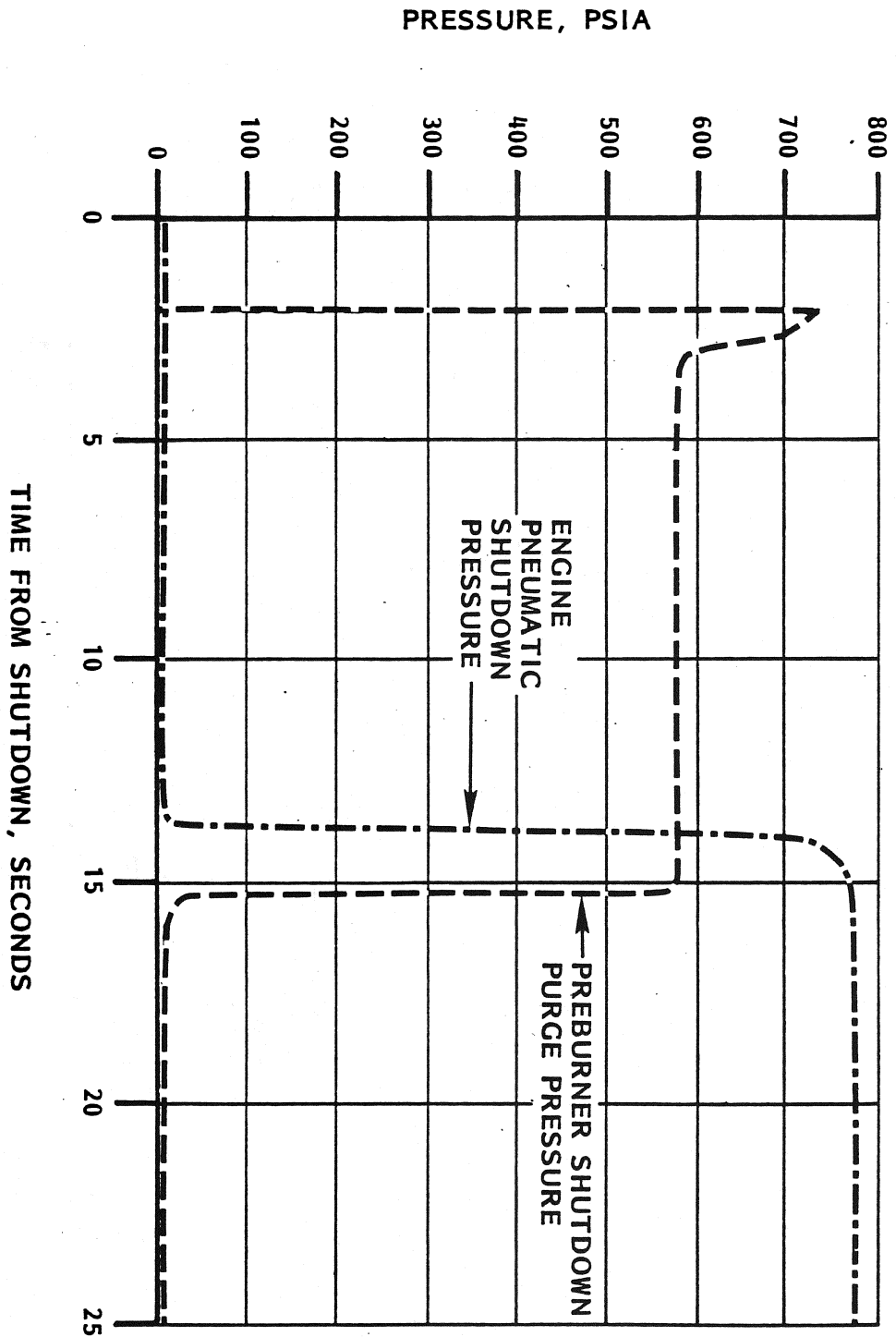
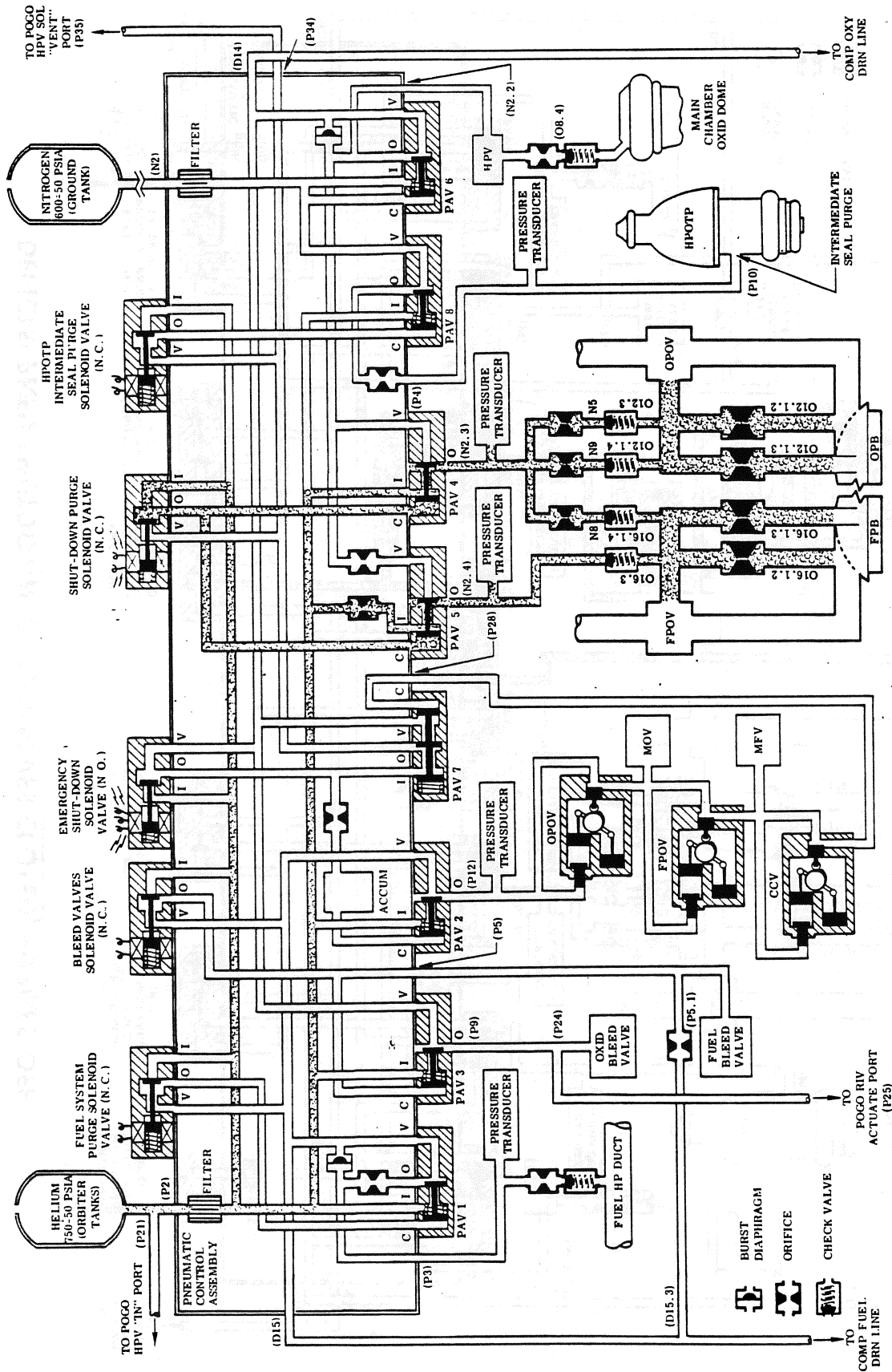


Figure 2-15. SSME Shutdown Phase (Sheet 5 of 8)

DEPICTS: PREBURNER PURGE (NORMAL SHUTDOWN)



- PAV 1 - FUEL SYS PURGE
- PAV 2 - EMERG SHUTDOWN
- PAV 3 - OXY BLEED
- PAV 4 - OPB PURGE
- PAV 5 - FPB PURGE
- PAV 6 - OXID SYS PURGE
- PAV 7 - PURGE SEQUENCE
- PAV 8 - HPOTP I S PURGE

Figure 2-15. SSME Shutdown Phase (Sheet 6 of 8)

DEPCTS: PNEU SHUTDOWN; PROP VALVES CLOSED, PURGES OFF

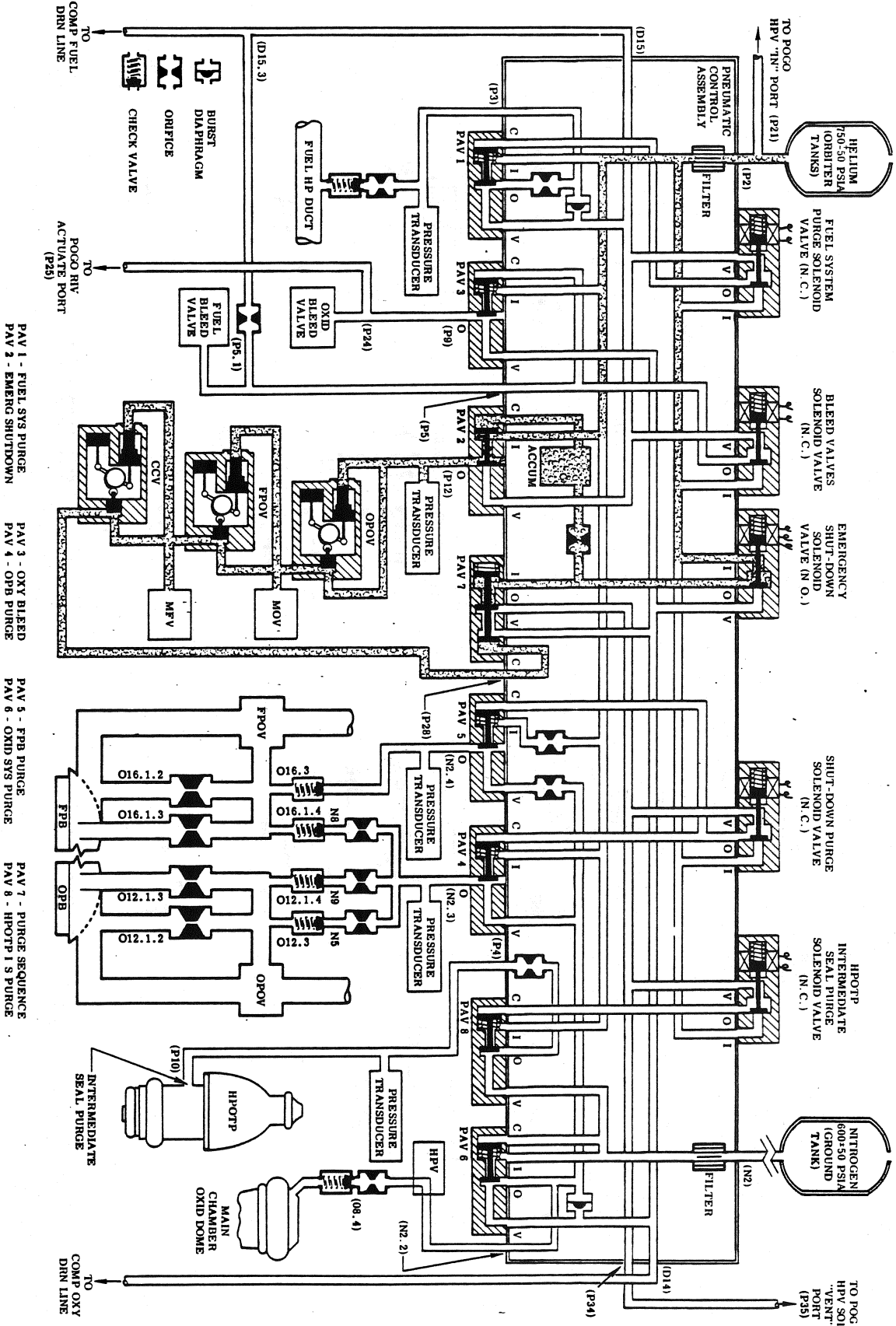
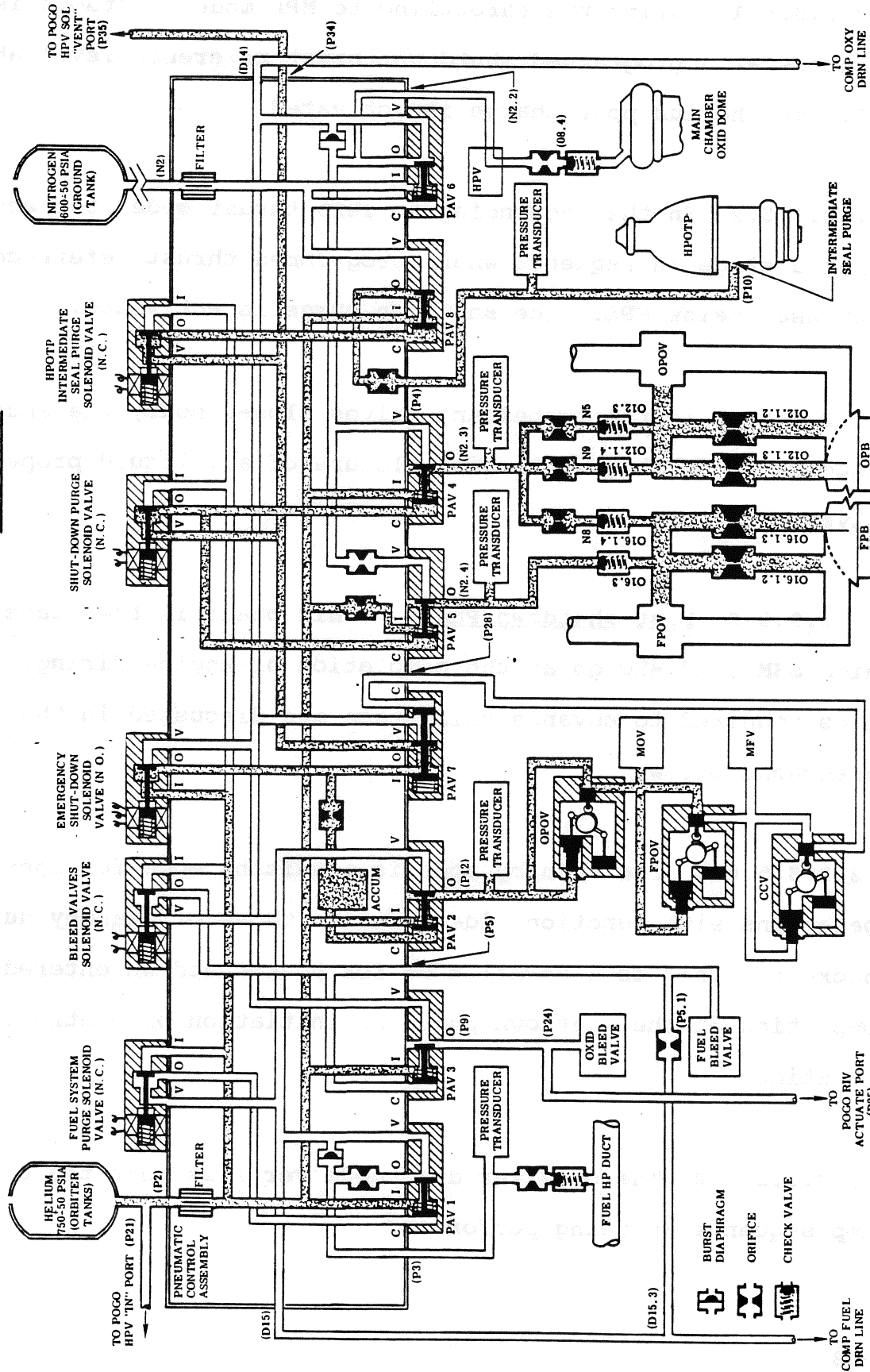


Figure 2-15. SSME Shutdown Phase (Sheet 7 of 8)

DEPICTS: PNEU SHUTDOWN; PROP VALVES CLOSING, PURGES ON



PAV 1 - FUEL SYS PURGE PAV 3 - OKY BLEED PAV 5 - FPB PURGE PAV 7 - PURGE SEQUENCE
 PAV 2 - EMERG SHUTDOWN PAV 4 - OPB PURGE PAV 6 - OKID SYS PURGE PAV 8 - HPOTP I S PURGE

Figure 2-15. SSME Shutdown Phase (Sheet 8 of 8)

2.2.2.3.5.1 During the throttling to MPL mode, shutdown is in progress at a programmed shutdown thrust reference level above MPL. The helium post-charge is activated.

2.2.2.3.5.2 In the sequencing to zero thrust mode, the shutdown is at a stage in sequence where programmed thrust reference has decreased below MPL. The shutdown purge is activated.

2.2.2.3.5.3 In the propellant valves closed mode, the shutdown sequence is in stage following closure of all liquid propellant valves.

2.2.2.3.5.6 Post-shutdown Phase. This phase is the state to which SSME and MEC go at the completion of engine firing. The modes required to advance this phase are discussed in the paragraphs below.

2.2.2.3.5.6.1 The standby mode is a waiting mode for controller operations with functions identical to those of standby during checkout. This is a normal mode for post-shutdown entered after completion of the shutdown phase or initiation of controller operation.

2.2.2.3.5.6.2 The oxidizer dump mode verifies that the oxidizer dump sequence is being performed.

2.2.2.3.5.6.3 During the termination sequence mode, termination of a purge or dump sequence by a command from the vehicle is in progress. All propellant valves are closed, and all solenoid and failsafe servo switches are de-energized.

2.2.3 COMPONENTS.

2.2.3.1 General. (See figure 2-16.) The major SSME components are described in the following paragraphs.

2.2.3.2 SSME Powerhead. (See figure 2-17.) The powerhead is a structural arrangement consisting of eight major engine components. These components are: two preburners, two turbopumps, a hot-gas manifold (HGM), a main injector, a heat exchanger, and a main combustion chamber (MCC).

2.2.3.2.1 The HGM serves as the structural base for the powerhead. This manifold also ducts the turbine exhaust gases from both turbines to the main injector, providing uniform flow across the injector face - a major factor in achieving high performance.

2.2.3.2.2 The preburners are close-coupled to their turbines, resulting in minimum-length hot-gas ducting. The turbopumps are mounted to the HGM to provide a compact package and are canted

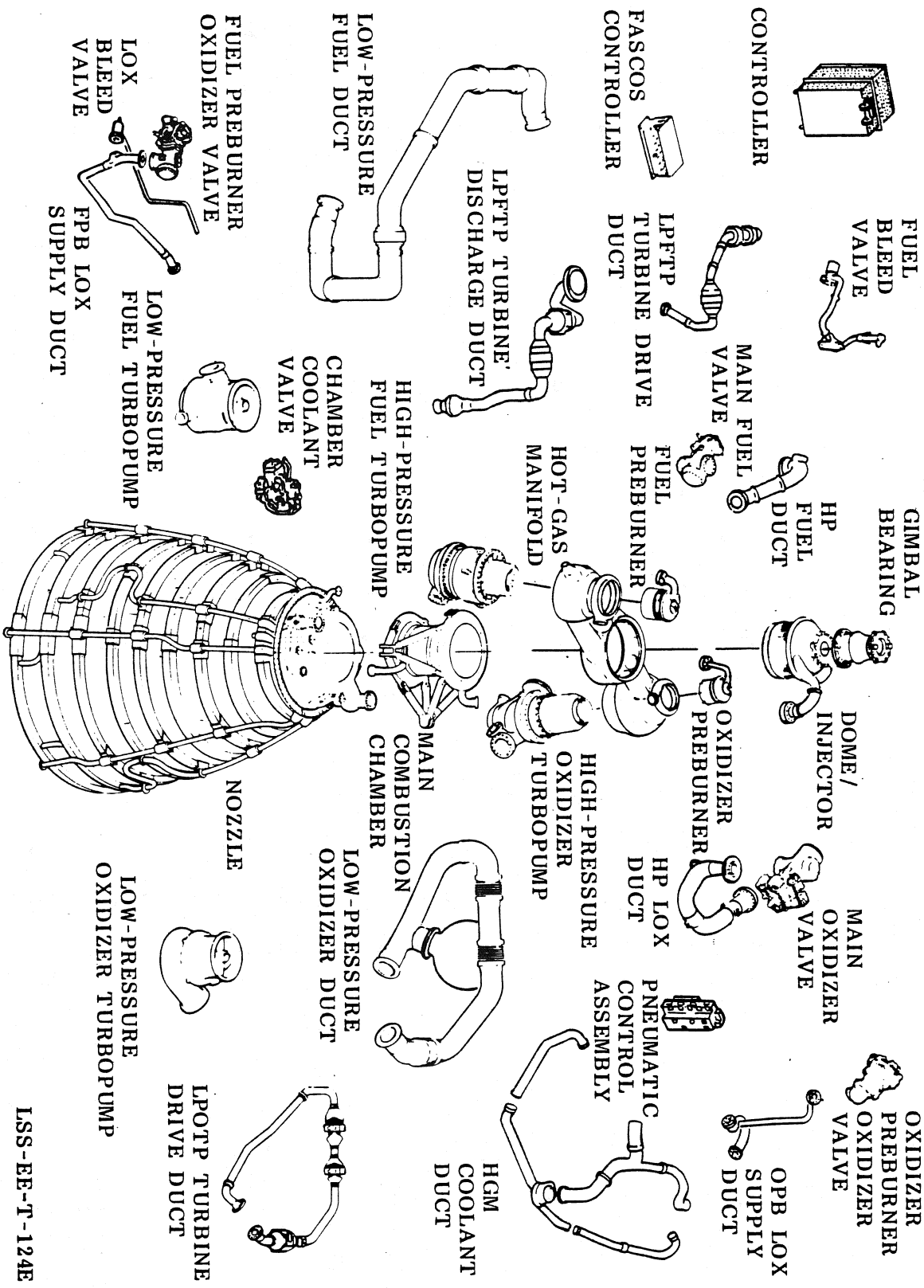


Figure 2-16. SSME Major Components

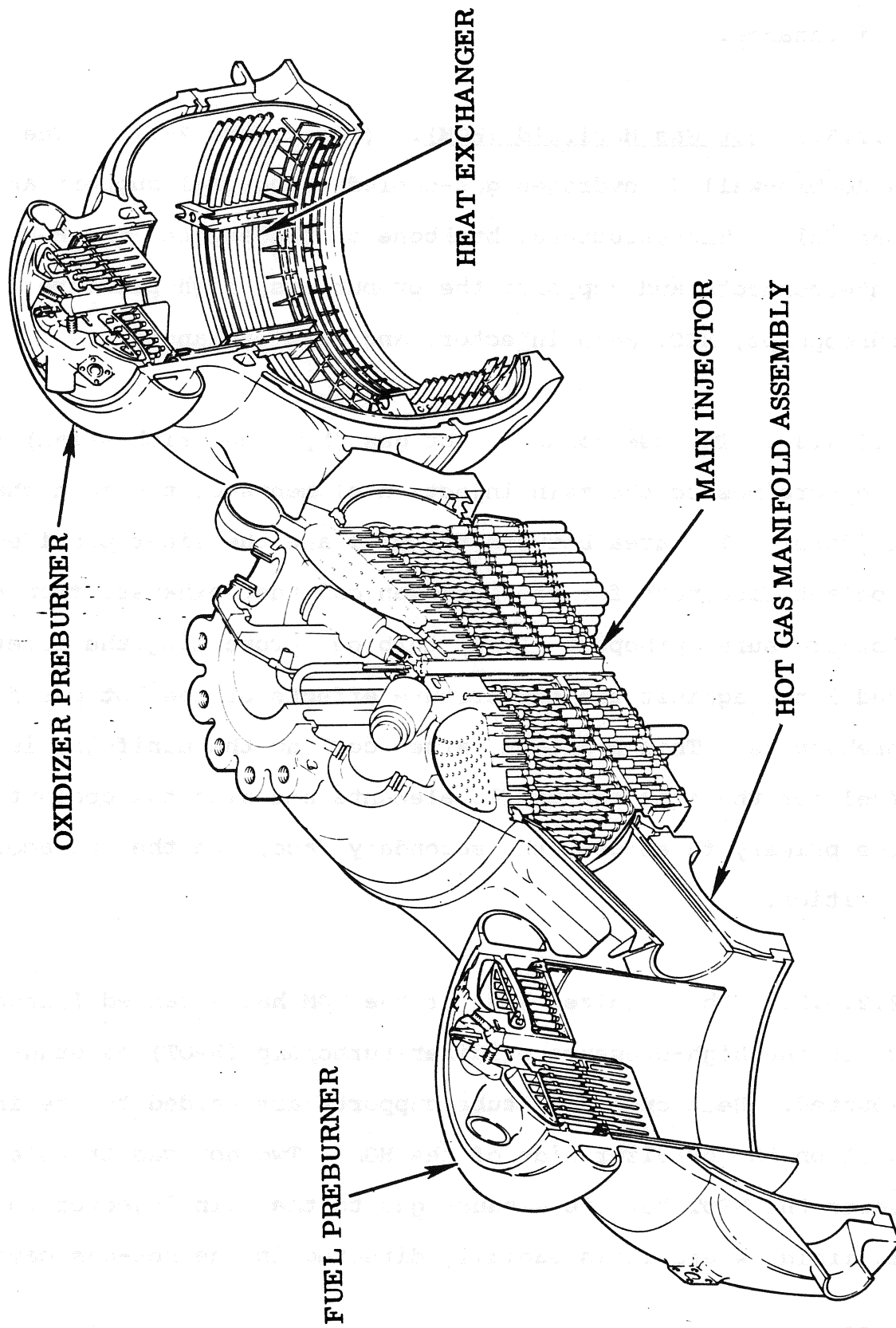


Figure 2-17. Powerhead Assembly

outboard from the vertical to permit easy removal for maintenance.

2.2.3.3 Hot-Gas Manifold (HGM). (See figure 2-17.) The HGM is a double-walled, hydrogen gas-cooled structural support and fluid manifold. The structural backbone of the engine, the HGM interconnects and supports the preburners, high-pressure turbopumps, MCC, main injector, and heat exchanger.

2.2.3.3.1 The HGM conducts hot gas (hydrogen-rich steam) from the turbines to the main injection elements of the main chamber injector. The area between the wall and the liner provides a coolant flow path for the hydrogen gas that exhausts from the low-pressure turbopump (LPFT) turbine, protecting the outer wall and liner against the temperature effects of the hot gas from the preburners. This hydrogen, after cooling the manifold, is the fuel for the injector baffle elements and also the coolant for the primary faceplate, the secondary face, and the MCC acoustic cavities.

2.2.3.3.2 The oxidizer side of the HGM has a canted flange to which the high-pressure oxidizer turbopump (HPOT) is stud-mounted. Heat exchanger tube supports are welded to the inner wall on the oxidizer side of the HGM. Two hot-gas transfer tubes route the HPOT turbine exhaust gas to the main injector torus manifold, where it is radially directed in the hot-gas cavity of

the main injector. The oxidizer preburner (OPB) is welded to the upper end of the oxidizer side of the HGM.

2.2.3.3.3 The fuel side of the HGM also has a canted flange, to which the high-pressure fuel turbopump (HPFT) is stud-mounted. Three hot-gas transfer tubes route the HPFT turbine exhaust gas to the main injector torus manifold, where it is radially directed into the hot-gas cavity of the main injector. The fuel preburner (FPB) is welded to the upper end of the fuel side of the HGM. Instrumentation ports, which are also used for internal inspection of the injectors and turbines, are located throughout the HGM.

2.2.3.4 Preburners and Injection Elements. Two preburners are used in the SSME, both of which burn hydrogen and oxygen to generate a variable hot gas supply to power the HPTs. The preburners operate at a low mixture ratio with gaseous hydrogen from the nozzle coolant circuit combined with hydrogen bypassed through the chamber coolant valve and liquid oxygen from the preburner oxidizer pump. Specific operating levels of the preburners are controlled by regulating the oxidizer flow rate with the preburner oxidizer valves. The preburner injector is a baffled, coaxial-element injector that mixes the gaseous hydrogen and liquid oxidizer in correct proportions and uniformly distributes and injects the propellants into the combustion chamber. The coaxial elements are contained in the upper

interpropellant plate and a lower faceplate in a pattern of closely spaced concentric rows. Each element consists of an orificed center tube (oxidizer post) and an outer fuel sleeve that has a series of orifices in its periphery. Oxidizer entering the oxidizer manifold is uniformly distributed within the oxidizer dome over the interpropellant plate and enters the oxidizer post through the post orifice. Hydrogen from the fuel manifold passes radially into the injector fuel cavity formed by the interpropellant plate and faceplate. From the fuel cavity, the hydrogen enters the annulus of the coaxial elements through the fuel sleeve orifices. The high velocity of the low-density fuel (relative to the density and velocity of the oxidizer) produces a high rate of atomization and thorough mixing. Coaxial injection and baffles maintain stable combustion in the preburners. Hydrogen flows through axial passages in each baffle for cooling and is discharged radially into the combustion chamber.

2.2.3.4.1 Fuel Preburner (FPB). (See figure 2-18.) The FPB is supported by the HGM, to which it is welded, and is close-coupled to the HPFT. The FPB consists of these three major parts: (1) the injector, (2) the augmented spark igniter (ASI) chamber, and (3) the combustion chamber.

2.2.3.4.1.1 The ASI unit, a small injector and combustion chamber with two spark igniters located in the center of the

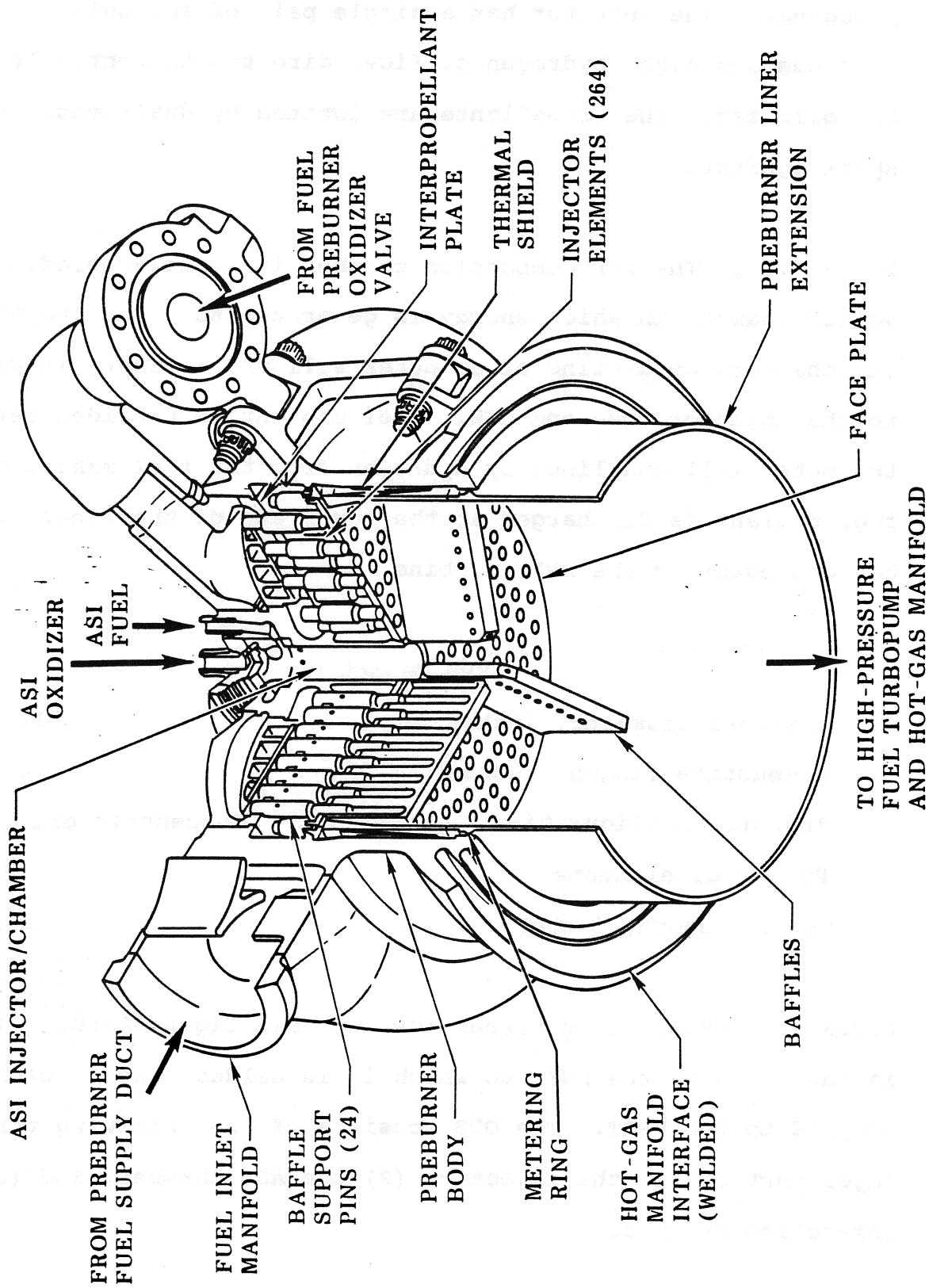


Figure 2-18. Fuel Preburner

injector, initiates the ignition of propellants in the preburner. The injector has a single pair of impinging oxidizer orifices and eight hydrogen orifices directed tangentially around the oxidizer. The propellants are ignited by dual-redundant spark igniters.

2.2.3.4.1.2 The FPB combustion chamber is a fuel-cooled, double-walled chamber in which energy is generated to power the HPFT. The chamber, consisting of an outer wall and a liner, is welded to the injector/dome and HGM. Fuel coolant is provided between the outer wall and liner by hydrogen from the fuel manifold. The fuel coolant is discharged at the lower end of the liner into the hot gas powering the HPFT turbine.

FPB Geometry

Internal diameter, inches	10.43
Combustion length, inches	4.37
Injector configuration.	Concentric orifice
Number of elements.	264
Baffle length, inches	2.25

2.2.3.4.2 Oxidizer Preburner (OPB). (See figure 2-19.) The OPB is supported by the HGM, to which it is welded, and is close-coupled to the HPOT. The OPB consists of the following three major parts: (1) the injector, (2) the ASI chamber, and (3) the combustion chamber.

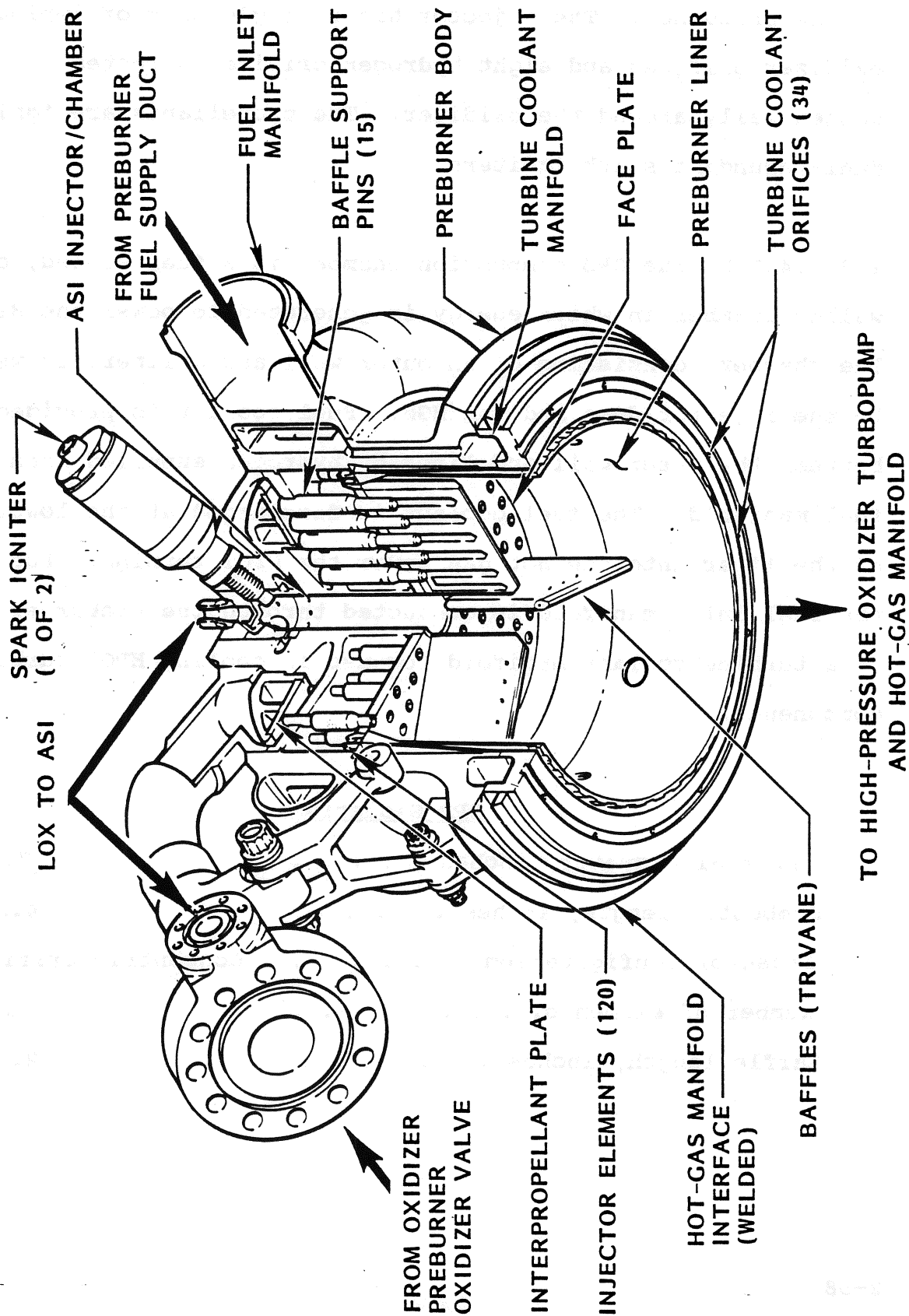


Figure 2-19. Oxidizer Preburner.

2.2.3.4.2.1 The ASI unit initiates the ignition of propellants in the preburner. The injector has a single pair of impinging oxidizer orifices and eight hydrogen orifices directed tangentially around the oxidizer. The propellants are ignited by dual-redundant spark igniters.

2.2.3.4.2.2 The OPB combustion chamber is a fuel-cooled, double-walled chamber in which energy is generated to power the HPOT. The chamber, consisting of an outer wall and a liner, is welded to the injector/dome and the HGM. Fuel coolant is provided between the outer wall and liner by hydrogen supplied from the fuel manifold. The fuel coolant is discharged at the lower end of the liner into the hot gas power the HPOT turbine. Fuel from the fuel inlet manifold is conducted through the preburner body to a turbine coolant manifold for use in cooling HPOT turbine components.

OPB Geometry

Internal diameter, inches	7.43
Combustor length, inches	4.25
Injector configuration.	Concentric orifice
Number of elements.	120
Baffle length, inches	2.25

2.2.3.4.3 Main Injector. (See figure 2-20.) The main injector is a baffled, coaxial-element-type injector that efficiently mixes and uniformly distributes propellants to the MCC. The injector body is welded to the HGM. A gimbal bearing mounts to the forward end of the injector and transmits thrust loads to the vehicle thrust structure. Basically, the injector assembly is an all-welded assembly consisting of a structural body, injection elements, two porous metal plates, and the ASI assembly. The ASI unit initiates ignition of propellants in the MCC. The injector has a single pair of impinging oxidizer orifices and eight hydrogen orifices directed tangentially around the oxidizer. The propellants ignited by dual-redundant spark igniters. The coaxial injection elements consist of 525 main injection elements and 75 baffle elements. The main and baffle injection elements are supplied with oxidizer from the injector oxidizer manifold. The main injection elements are supplied with fuel-rich hot gas from the turbine exhaust of the high-pressure turbopumps through the HGM. The baffle elements are supplied with gaseous hydrogen used in the HGM coolant circuit. Both primary and secondary porous metal plates are supported by the injector elements and form the cavity from which part of the HGM cooling circuit hydrogen is supplied to the baffle elements. The primary plate separates the cooling hydrogen from the combustion chamber, and the secondary plate separates the cooling hydrogen from the hot gas that is supplied as fuel to the main injector elements. Both

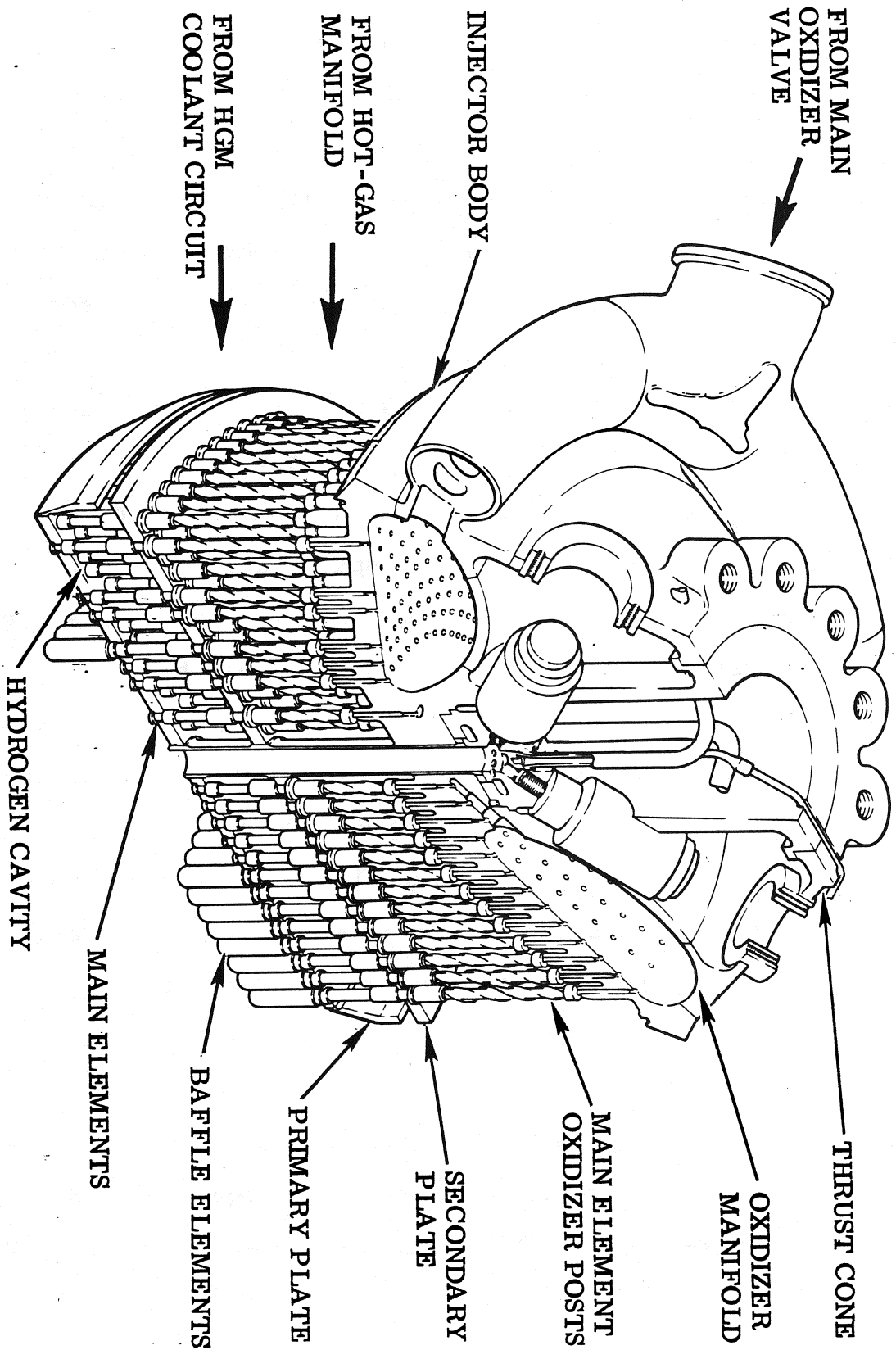


Figure 2-20. Main Injector Assembly

plates are transpiration-cooled by part of the HGM cooling circuit hydrogen.

Main Injector Geometry

Face diameter, inches.	17.74
Injector configuration.	Concentric orifice
Number of elements.	525
Number of flow shields.	42
Number of baffle elements	75
Baffle length, inches	2

2.2.3.4.3.1 Main Injector Elements. (See figure 2-21.) The main injector elements are bipropellant, gas/liquid, coaxial, fluid-injection devices. They meter, mix, and distribute propellants into the MCC by providing a flow field consisting of a low-velocity liquid oxygen core that is surrounded by a high-velocity, hydrogen-rich hot-gas shroud. The main injector uses 525 main injector elements and 75 baffle elements, uniformly spaced radially and circumferentially across its face.

2.2.3.4.3.1.1 Each main injector element assembly consists of a hollow post within a sleeve that is secured by a retainer and nut between the primary and secondary plates of the main injector. Each post is welded to the injector body and is ported to the injector oxidizer manifold through a metering orifice in the injector body. The posts are recessed from the primary face-plate to provide initial contact between the liquid oxygen stream

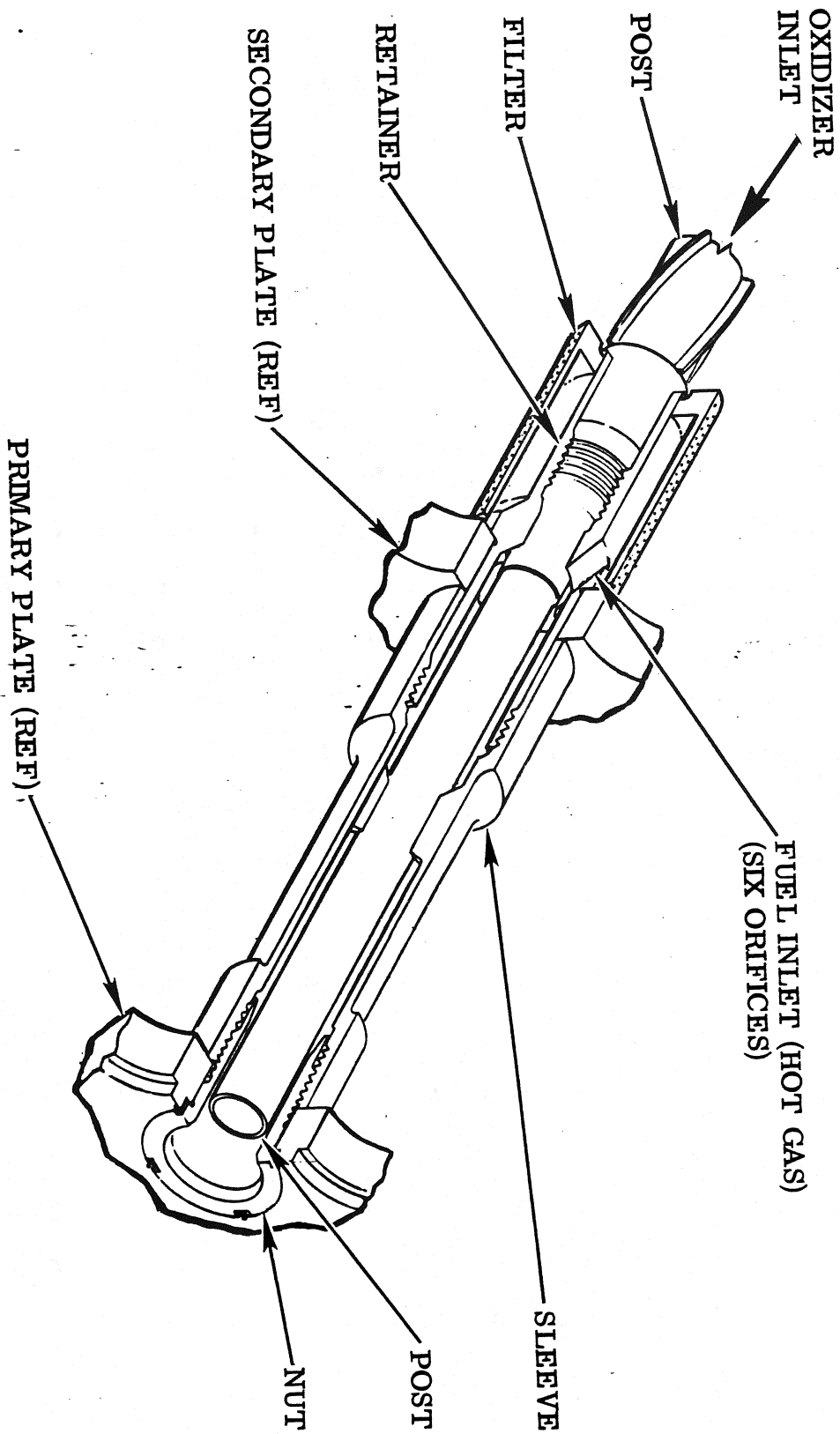


Figure 2-21. Main Injector Element

and hot gas at a region on maximum velocity ratio. The upper ends of the posts have four helically wound spoilers machined in their outer perimeters to eliminate vibration induced by the hot-gas flow.

2.2.3.4.3.1.2 The retainer clamps the secondary plate to the sleeve and contains six equally spaced orifices that direct the hot gas into the annulus surrounding the post. The sleeve with the post forms the annulus for the hydrogen-rich hot gas. Centering lugs are machined in the sleeve to insure concentricity of the post and hot-gas annulus. A nut secures the primary faceplate to the sleeve and forms the cup in which the initial contact between the liquid oxygen and hot gas takes place.

2.2.3.4.3.2 Main Injector Baffle Elements. (See figure 2-22.) The main injector baffle elements are bipropellant, gas/liquid, coaxial, fluid-injection devices that divide the face of the injector into six combustion compartments to prevent combustion instability modes below a frequency of 4680 Hz. Seventy-five baffle elements, along with 525 main elements, meter, mix, and distribute propellants into the MCC. The baffle elements extend 2 in. below the primary faceplate and provide a flow field consisting of a low-velocity liquid oxygen core that is surrounded by a high-velocity, cold hydrogen gas shroud.

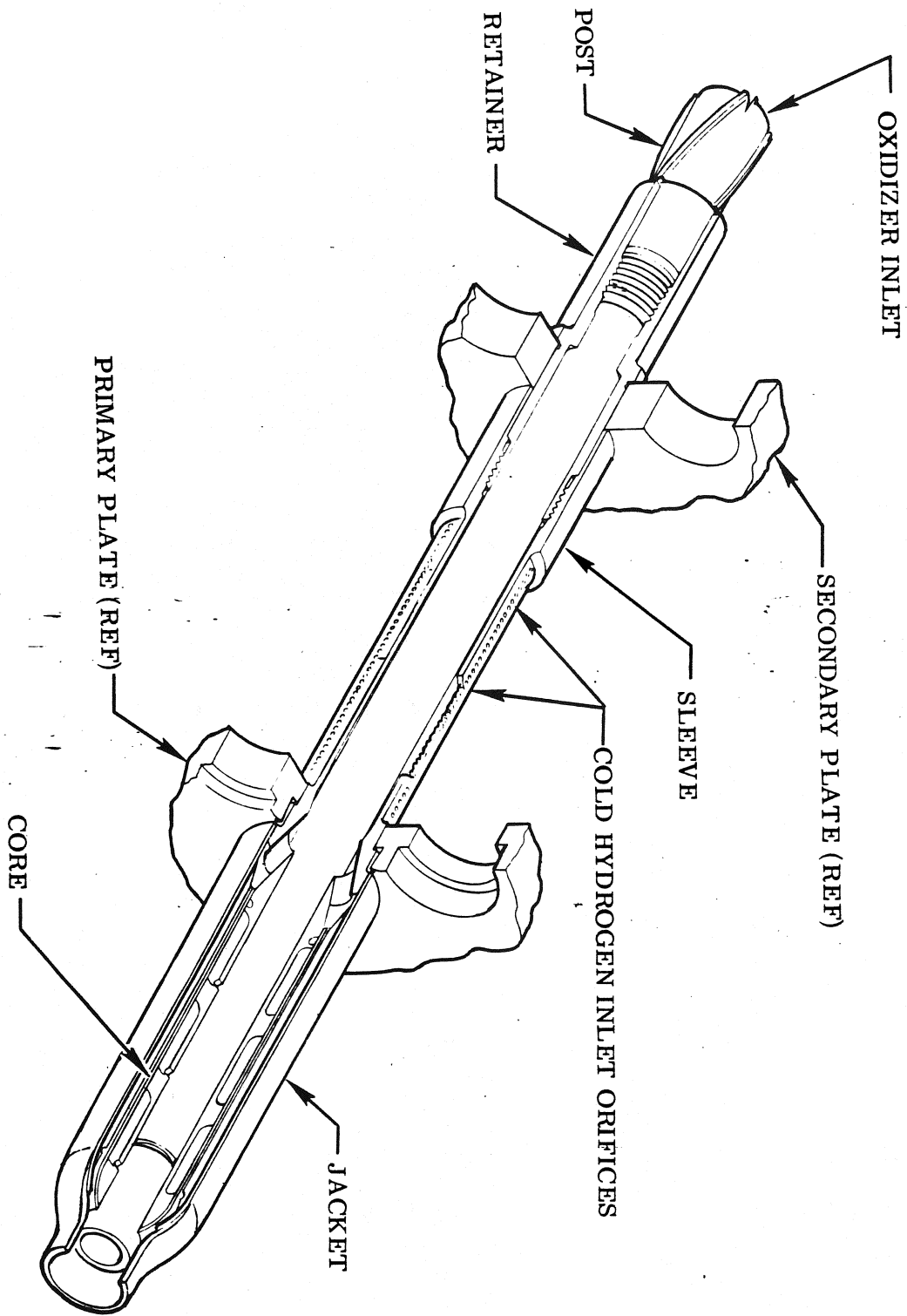


Figure 2-22. Main Injector Baffle Element

2.2.3.4.3.2.1 Each main injector baffle element assembly consists of a post, retainer, sleeve, jacket, and core. The sleeve, jacket, and core are brazed together into an integral component. Each post is hollow, welded to the injector body, and ported to the injector oxidizer manifold through a metering orifice in the injector body. The upper ends of the posts have four helically wound spoilers machined into their outer perimeters to eliminate vibration induced by the hot gas flow to the main injector elements.

2.2.3.4.3.2.2 The retainer threads (LH) to the posts and clamps the secondary plate to the sleeve, which is threaded (RH) to the retainer. The sleeve is hollow throughout its length and has 16 rows of orifices, which direct the cold hydrogen gas into the annulus formed by the post and sleeve. From this annulus, the cold hydrogen gas is redirected through holes in the sleeve and into the annulus formed by the jacket and core.

2.2.3.4.3.2.3 The inner wall of the jacket has milled rectangular channels to provide convective cooling of the baffle element exposed to the high temperature in the MCC. The geometry of the baffle tip both provides a smooth external gas transition and initiates early propellant interaction at the baffle tip.

2.2.3.5 Main Combustion Chamber. (See figure 2-23.) The MCC is a cylindrical, regeneratively cooled structural chamber that contains the burning propellant gases and initiates their expansion from the chamber throat to a ratio of 5:1. It is flange-attached to the HGM. The MCC consists of a coolant liner, a high-strength structural jacket, coolant inlet and outlet manifolds, a throat ring, and two actuator struts.

2.2.3.5.1 The chamber coolant liner provides the coolant flow path for the MCC. It consists of a chamber machined to the same contour as the inside diameter of the structural jacket. The outer surface has 390 milled axial coolant channels that are closed out by an electroforming process that deposits a chopper barrier followed by a nickel closeout over the coolant channels. The channels are ported to coolant inlet and outlet manifolds of the chamber jacket to provide an up-pass circuit for MCC fuel coolant. Thirty acoustic cavities that damp out high-frequency baffle compartment oscillations are at the upper end of the liner near the injector face.

2.2.3.5.2 The chamber jacket provides the structural strength of the MCC. The jacket is approximately 20 inches long and is formed and machined in two matched halves. The halves are placed around the liner and welded to each other and to inlet and outlet coolant manifolds, which in turn are welded to the liner. A throat ring is welded to the structural jacket to provide

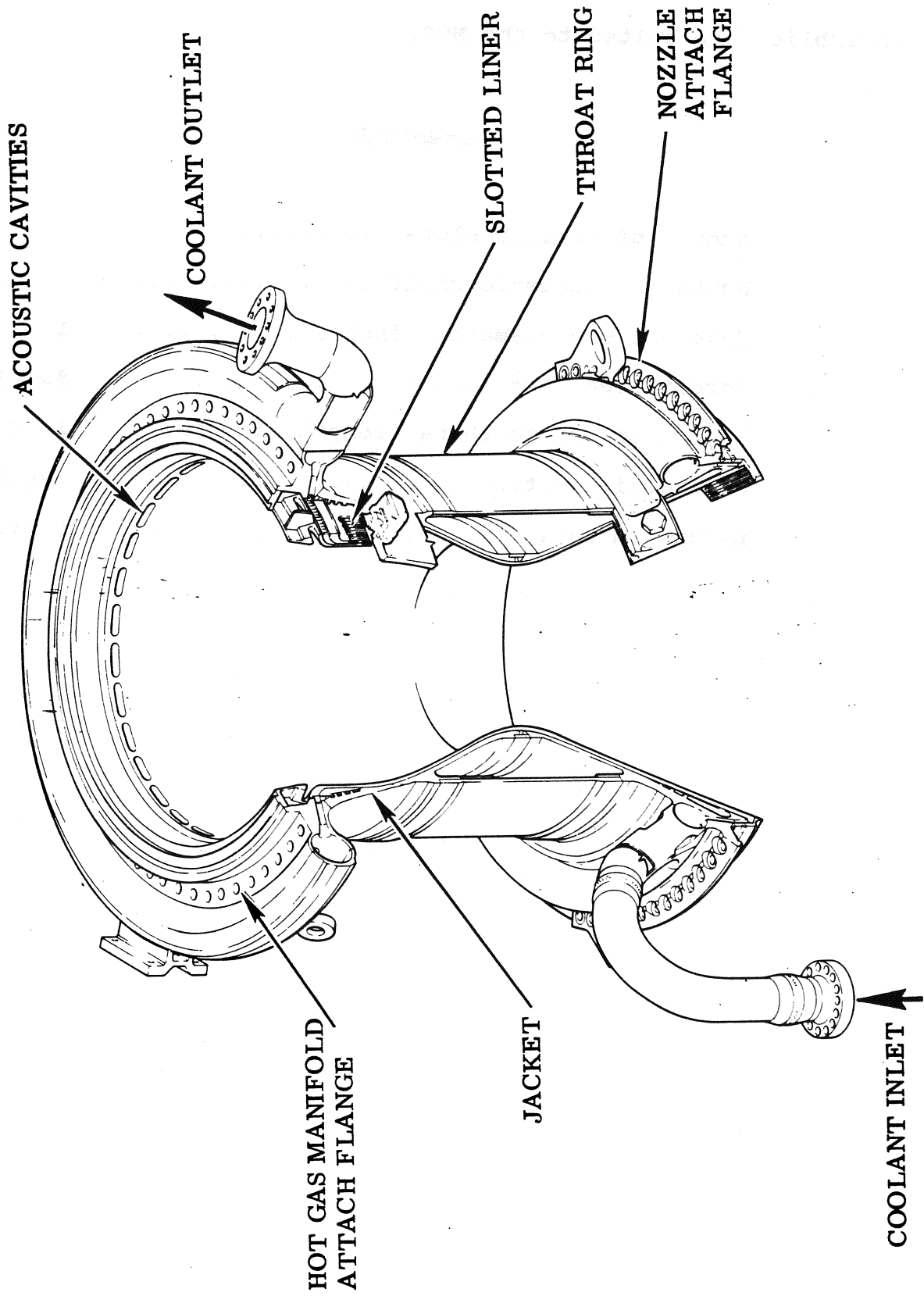


Figure 2-23. Main Combustion Chamber

additional strength. Two thrust vector control actuator strut assemblies are bolted to the MCC.

Geometry

Number of coolant slots	390
Number of acoustic cavities	30
Injector end diameter, inches.....	17.74
Throat area, in ²	83.41
Injection end to throat length, inches..	14.00
Contraction ratio	296:1
Expansion ratio	5.0:1

2.2.3.6 Nozzle Assembly. (See figure 2-24.) The nozzle assembly is a fuel-cooled, 80.6-percent bell nozzle that provides a 77.5:1 thrust chamber expansion ratio. It is approximately 113 inches long and has a 94-inch exit outside diameter. It is bolted to the MCC at the 5:1 expansion ratio plane. The nozzle assembly consists of a forward manifold subassembly and a stacked nozzle subassembly. The forward manifold subassembly distributes hydrogen to the main chamber and nozzle cooling circuits, and provides the flanges for attaching the nozzle assembly to the MCC, MFV, and preburner fuel supply duct. The nozzle assembly allows continued expansion of the combustion gases exiting the MCC to provide the maximum thrust efficiency possible.

2.2.3.6.1 Forward Manifold Subassembly. The forward manifold subassembly is welded to the stacked nozzle subassembly. The forward manifold subassembly consists of the manifold shell, diffuser, mixer Chamber Coolant Valve (CCV) housing, and the CCV duct. The diffuser inlet interfaces with the downstream end of the MFV and distributes hydrogen to the fuel circuits. The diffuser directs fuel to the nozzle coolant inlet manifold, the MCC coolant inlet manifold, the CCV, and the ASIs. The fuel system purge check valve is attached to the diffuser. The mixer mixes fuel from the CCV with fuel from the nozzle coolant outlet and directs it to the OPB and FPB.

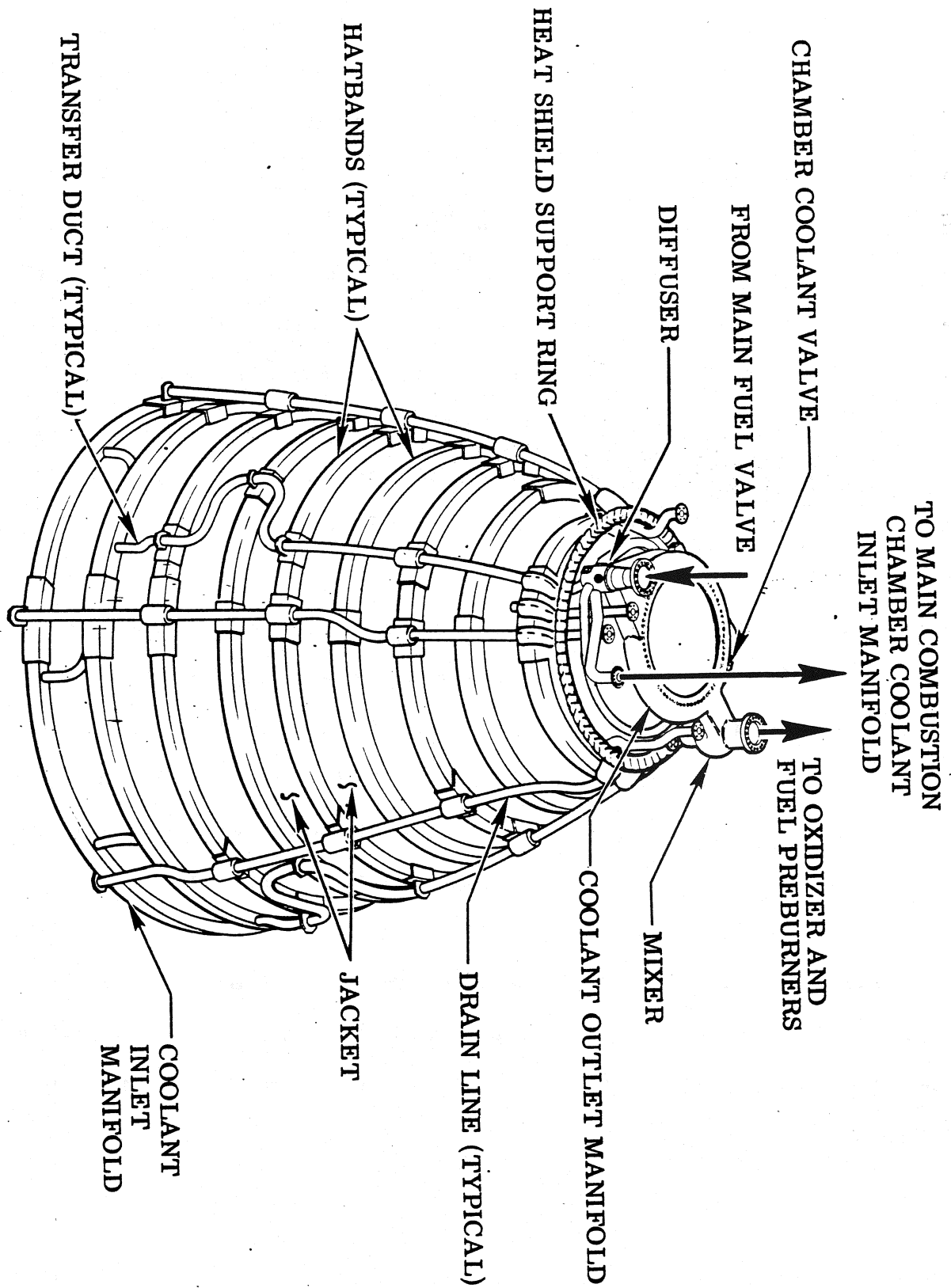


Figure 2-24. Flight Nozzle (Sheet 1 of 2)

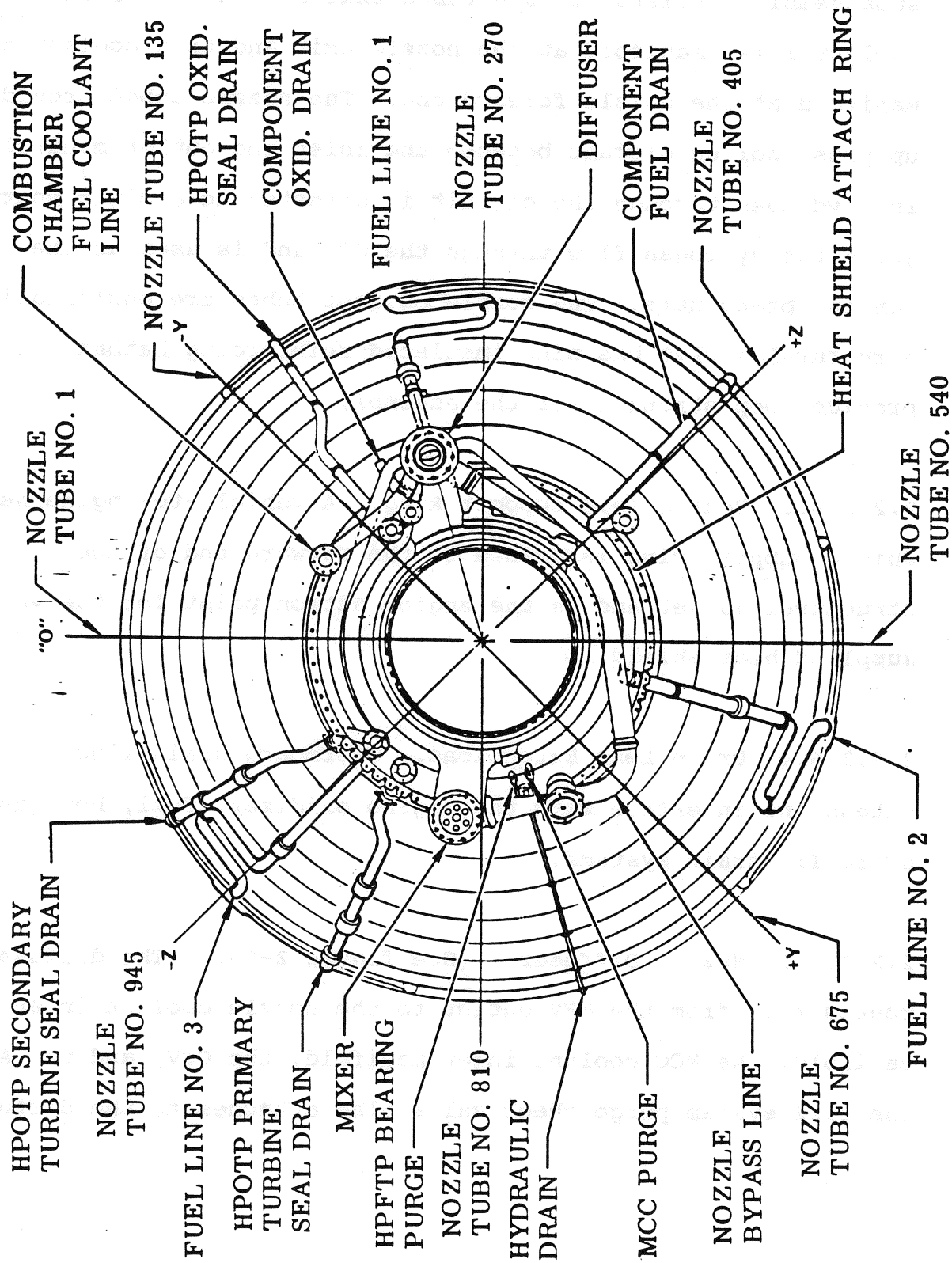


Figure 2-24. Flight Nozzle (Sheet 2 of 2)

2.2.3.6.2 Stacked Nozzle Subassembly. The stacked nozzle subassembly consists of 1080 tubes that are connected to a coolant inlet manifold at the nozzle exit and to a coolant outlet manifold at the nozzle forward end. The nozzle tubes provide an up-pass cooling circuit between the inlet and outlet manifolds. The hydrogen through the circuit is directed to a mixer where it joins the hydrogen flow through the CCV and is used as the fuel for the preburners. The nozzle coolant tubes are enclosed in a structural jacket has nine insulated reinforcing hatbands to provide hoop strength for the assembly.

2.2.3.6.3 Heat Shield Support Ring. A vehicle-to-engine heat shield support ring is welded to the forward end of the structural jacket and is the engine attach point for the vehicle-supplied heat shield.

2.2.3.6.4 Drain Line Extensions. Overboard drain line extensions interface with the engine oxidizer, fuel, hot-gas, and hydraulic drain systems.

2.2.3.6.5 Nozzle Diffuser. (See figure 2-25.) The diffuser routes fuel from the MFV outlet to the nozzle coolant inlet manifold, the MCC coolant inlet manifold, the CCV, and the ASIs. The fuel system purge check valve also attaches to the diffuser.

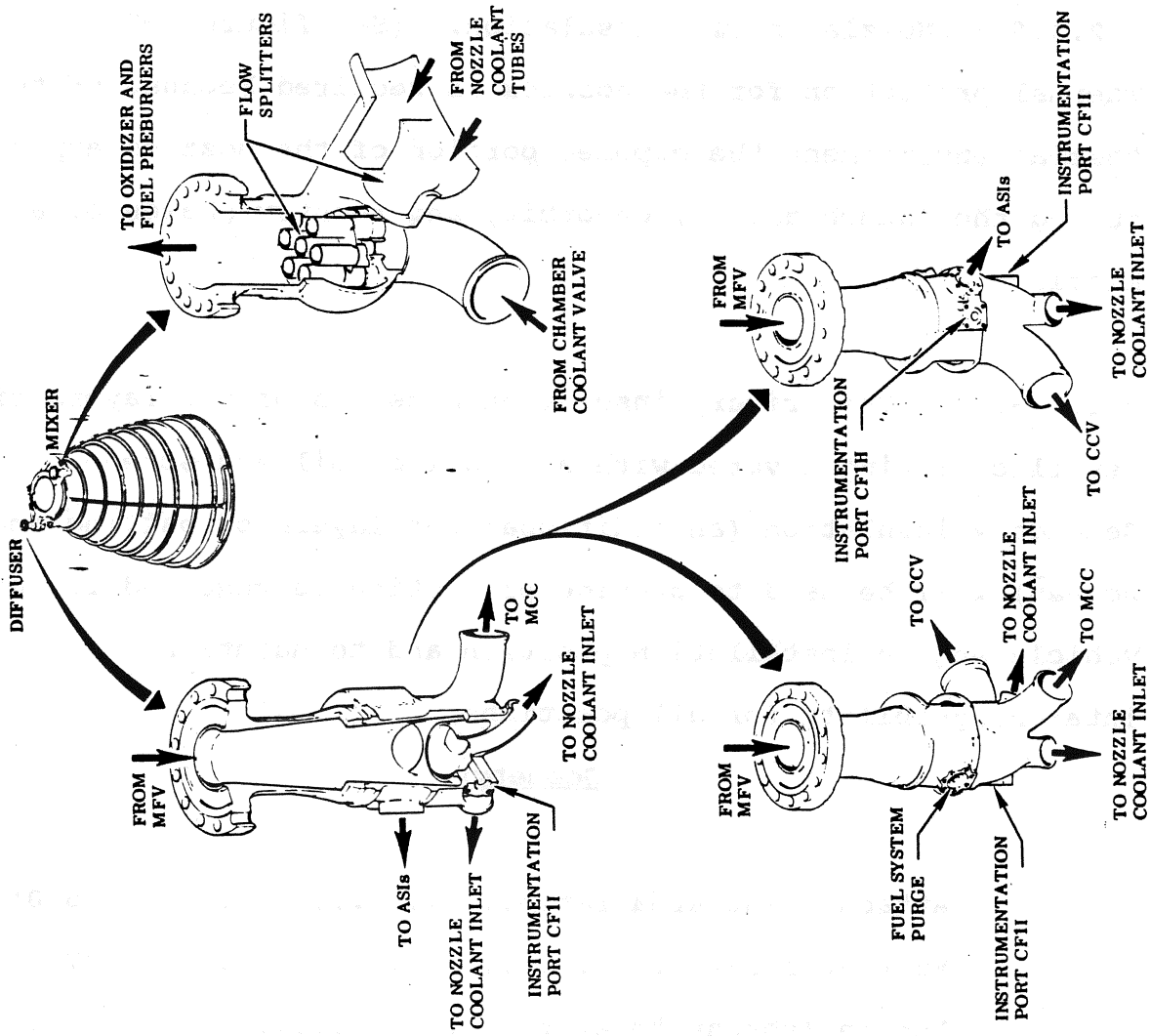


Figure 2-25. Nozzle Diffuser and Mixer

2.2.3.6.6 Nozzle Mixer. (See figure 2-25.) The mixer receives cold fuel from the CCV and mixes it with fuel from the nozzle coolant outlet manifold. The mixed fuel is then routed to the oxidizer and fuel preburners. The diffuser and mixer are integral parts of the nozzle forward manifold assembly.

2.2.3.6.7 Nozzle Thermal Insulation. (See figure 2-26.) Thermal protection for the nozzles is required because of the thermal environment the exposed portion of the nozzles experience during the launch ascent, on-orbit, and reentry phases of a mission.

2.2.3.6.7.1 The primary insulation consists of two layers of metallic batting covered with a metallic foil and screen. Secondary insulation (an additional two layers of batting and screen) will be used to provide protection as required for each vehicle engine installation position and to maintain interchangeability for all positions.

Geometry

Attach point area ratio.....	5.0:1
Exit area ratio.....	77.5:1
Length (throat to exit)	121
Exit diameter (inside/outside), inches..	90.7/94
Number of tubes	1080
Number of feed ducts	3

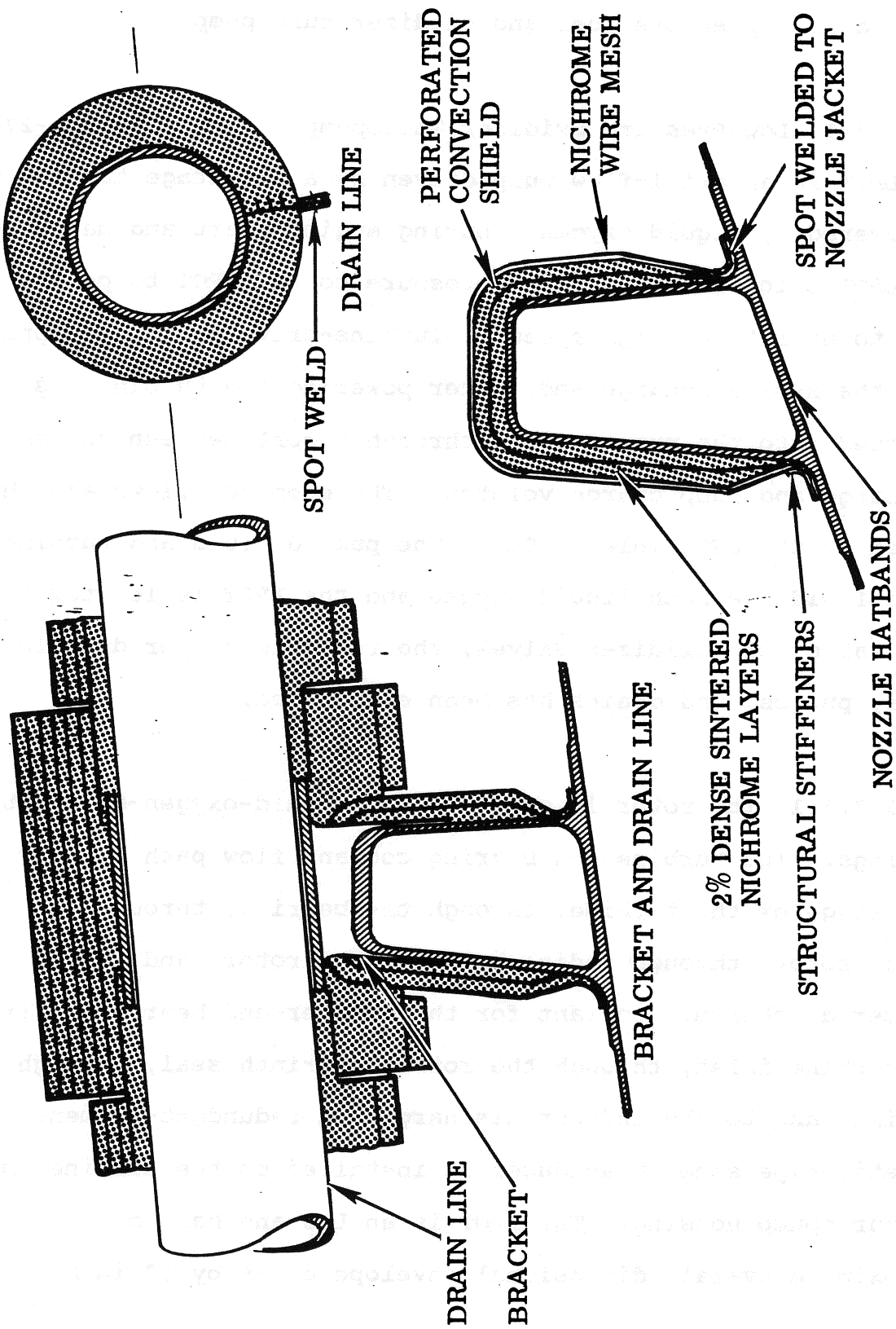


Figure 2-26. SSME Nozzle Thermal Protection Insulation Configuration

2.2.3.7 SSME Turbopumps. The following paragraphs describe the low and high pressure fuel and oxidizer turbopumps.

2.2.3.7.1 Low-Pressure Oxidizer Turbopump. (See figure 2-27.) The LPOT is an axial-flow pump driven by a six-stage turbine that is powered by liquid oxygen. During engine start and mainstage, the LPOT maintains sufficient pressure to the HPOT to permit the HPOT to operate at high speeds. Turbine-drive fluid is tapped from the HPOT discharge and, after powering the turbine, is injected into the pumped fluid through a port between the turbine discharge and pump charge volutes. The combined flows are then routed to the HPOT inlet. Since the pumped fluid and turbine drive fluid are both liquid oxygen and the LPOT is located upstream of the oxidizer valves, the requirement for dynamic seals, purges, and drains has been eliminated.

2.2.3.7.1.1 The rotor is supported by liquid-oxygen-cooled ball bearings. The turbine-end bearing coolant flow path is from the last stage of the turbine, through the bearing, through the hollow rotor, through radial holes in the rotor, and to the inducer discharge. Coolant for the inducer-end bearing is from the turbine inlet, through the rotor labyrinth seal, through the bearing, and to the inducer discharge. A redundant-element, magnetic-type speed transducer is installed on the turbine end of the turbopump housing. The LPOT is an LRU and has an approximate overall dimensional envelope of 18 by 18 inches.

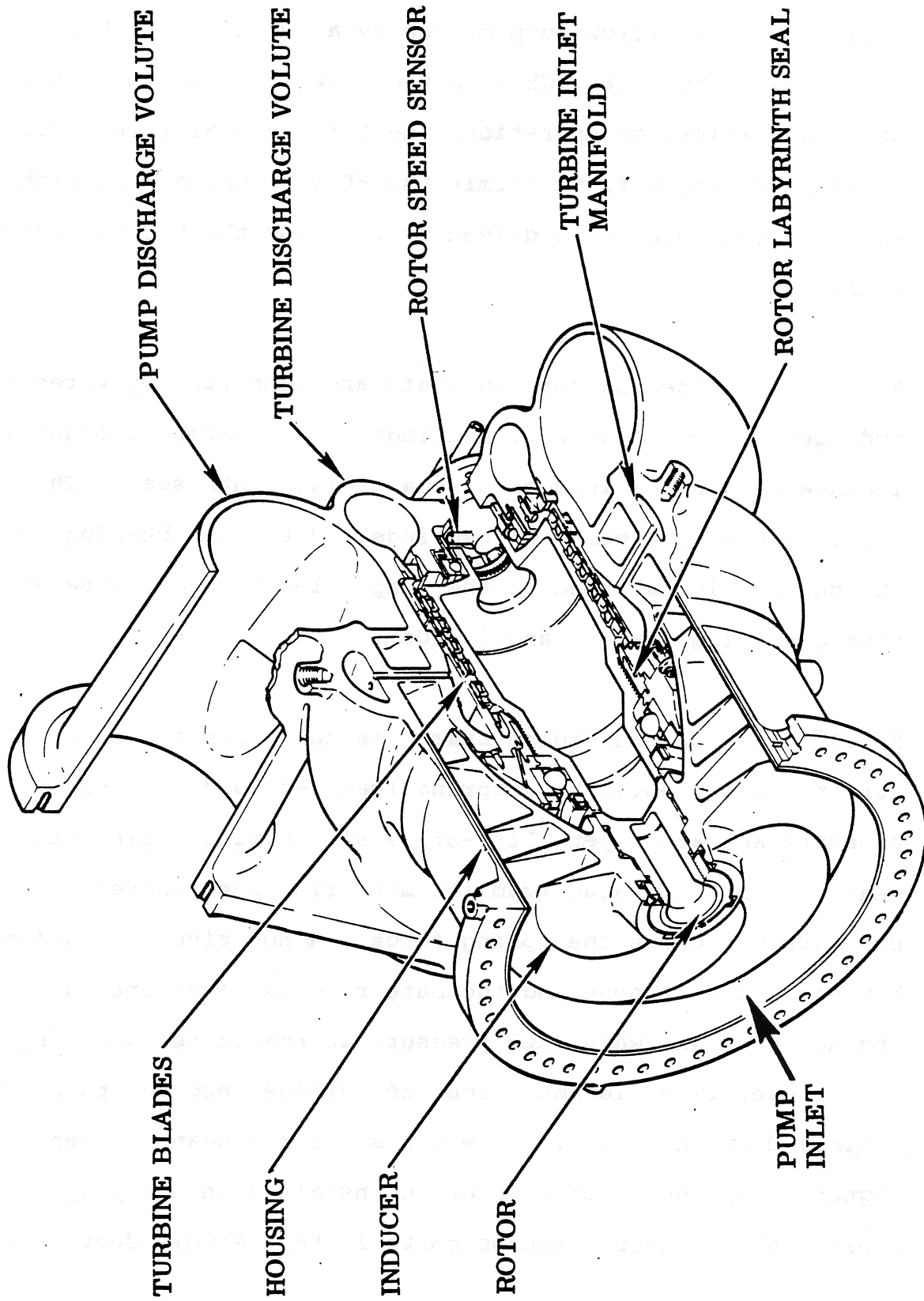


Figure 2-27. Low-Pressure Oxidizer Turbopump

2.2.3.7.2 Low-Pressure Fuel Turbopump. (See figure 2-28.) The LPFT is an axial-flow pump driven by a two-stage turbine that uses gaseous hydrogen (GH_2) as the power medium. During engine start and mainstage operation, the LPFT maintains sufficient pressure to the HPFT to permit the HPFT to operate at high speeds. The turbine is driven by GH_2 from the MCC coolant valve manifold.

2.2.3.7.2.1 The inducer and shaft are supported by three liquid-hydrogen-cooled (LH_2) ball bearings. The bearing coolant is the leakage across the inducer discharge labyrinth seal. The coolant flows through the pump end bearings and turbine bearing. Then the coolant is returned to the pump inlet through passages in the shaft, bearing spacer, and inducer.

2.2.3.7.2.2 Before engine start, leakage from the pump into the turbine is prevented by a spring-loaded-closed, propellant pressure-actuated-open, lift-off seal. During engine start, the seal nose is separated from its mate ring when increasing fuel pressure overcomes the spring force. A positive separation between the seal nose and the mate ring is maintained until engine shutdown, when fuel pressure decreases below spring force. During operation, leakage from the turbine into the pump is minimized by the pump turbine seals. A redundant-element, magnetic-type speed transducer is installed in the pump volute to monitor shaft speed. Access ports in the vehicle duct allow

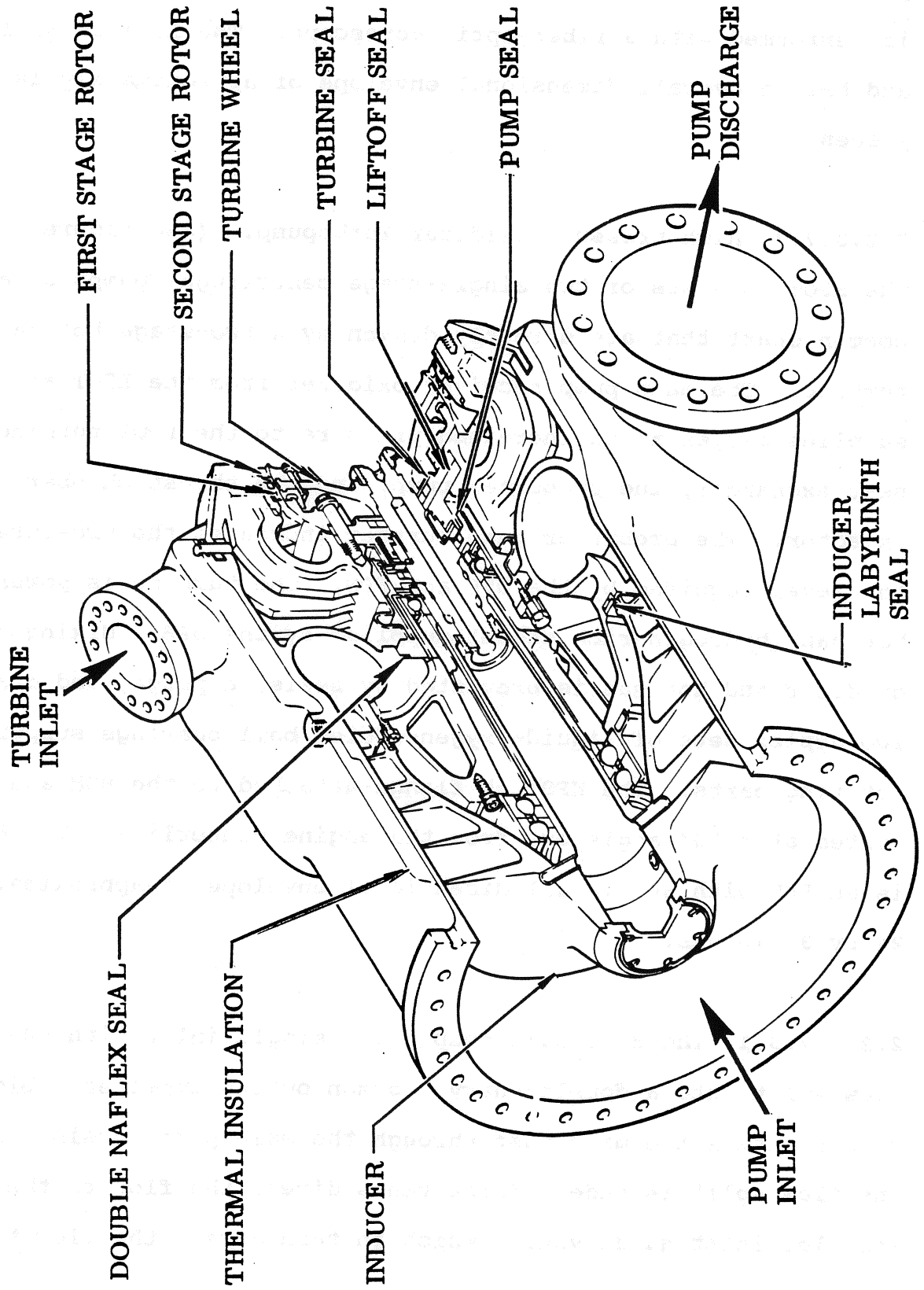


Figure 2-28. Low-Pressure Fuel Turbopump

periodic inspection of the inducer blades for damage. Inspection is performed with a fiber-optic borescope. The LPFT is an LRU and has an overall dimensional envelope of approximately 18 by 24 inches.

2.2.3.7.3 High-pressure Oxidizer Turbopump. (See figure 2-29.)

The HPOT consists of two single-stage centrifugal pumps on a common start that are directly driven by a two-stage hot-gas turbine. The main pump receives oxidizer from the LPOT and supplies oxygen at an increased pressure to the LPOT turbine, the heat exchanger, the preburner pump, and the thrust chamber injector. The preburner pump further increases the pressure to the level required by the OPB and FPB. The turbine is powered by hot gas (hydrogen-rich steam) supplied by the OPB. Mixing of oxidizer and hot gas is prevented by seals, a purge, and drains. Two duplex sets of liquid-oxygen-cooled ball bearings support the rotating parts. The HPOT is flange-attached to the HGM and is canted at a 10° angle out from the engine centerline. The HPOT is an LRU with an overall dimensional envelope of approximately 24 by 36 inches.

2.2.3.7.3.1 The HPOT main pump has a single inlet with 50-50 flow split into a double-entry, common outlet impeller. Liquid oxygen enters the main pump through the main pump housing, where the flow split is made. Inlet vanes direct the flow to the impeller inlet guide vanes, which in turn direct the flow to the

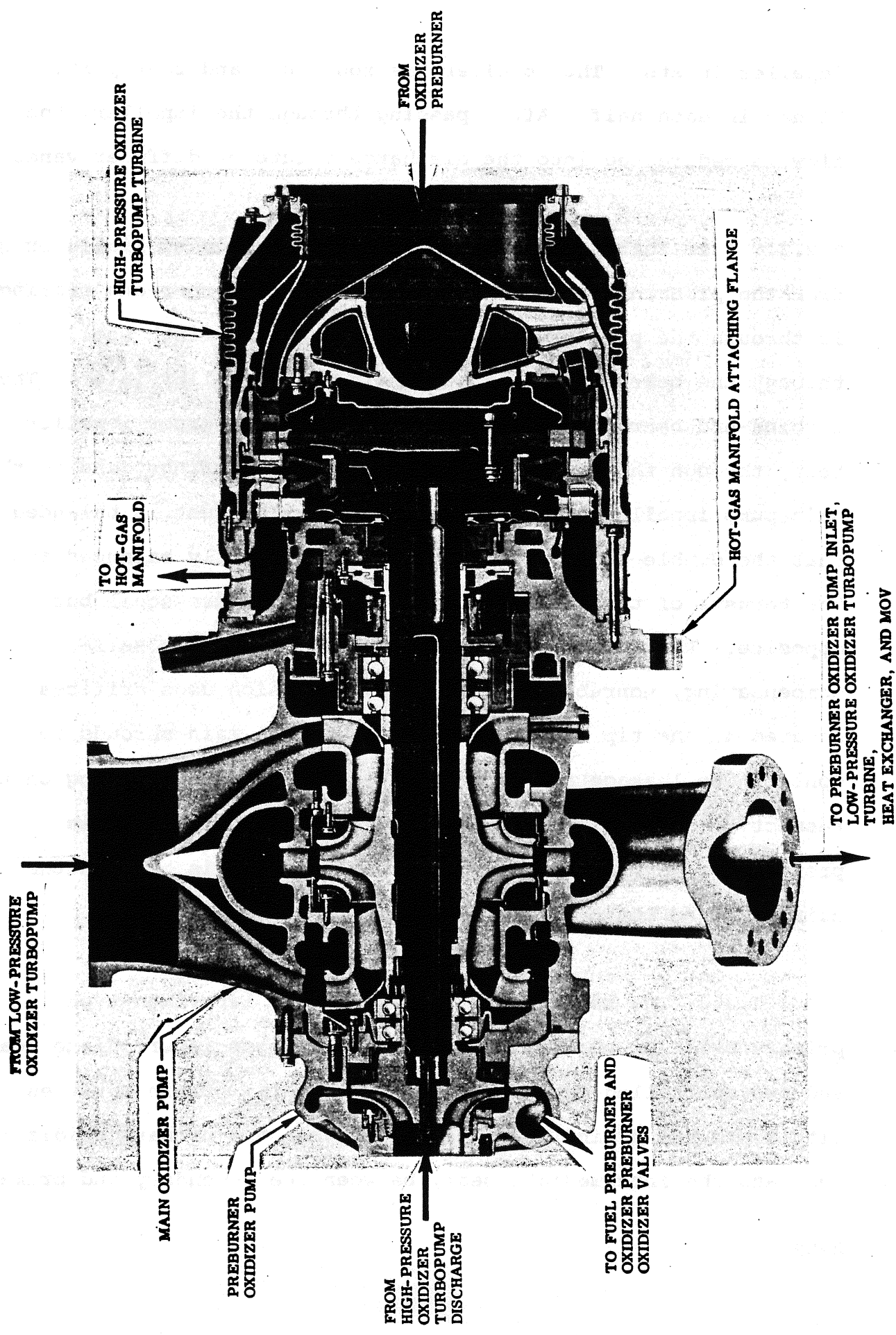


Figure 2-29. High-Pressure Oxidizer Turbopump

impeller inlets. The impeller has four full and four partial blades in each half. After passing through the impeller, the flow is redirected into the discharge volute by diffuser vanes.

2.2.3.7.3.2 Turbopump shaft bearings are cooled by liquid oxygen from the preburner pump. Coolant for the preburner-end bearings is through the preburner pump impeller hub labyrinth seal, through the bearings, and to the main pump impeller inlet. The turbine-end bearing coolant flows through the burner impeller bolt, through the hollow shaft, through the bearings, and to the main pump impeller inlet. Pump shaft axial thrust is balanced that the double-entry main impeller is inherently balanced and the thrusts of the preburner pump and turbine are equal but opposite. Residual shaft thrust is controlled by a self-compensating, nonrubbing, balance piston which uses orifices located at the tip and inner diameter of the main shrouds to control the leakage and, consequently, the pressure acting on the respective shrouds. Mixing of oxidizer and turbine gas is prevented by a dynamic shaft seal package that is between the main pump and the turbine.

2.2.3.7.3.3 The seal package consists of a labyrinth-type primary oxidizer seal, a purged controlled-gap intermediate seal, and two controlled-gap turbine hot-gas seals. Drain cavities with overboard drain lines located between the primary oxidizer seal and the intermediate seal, between the secondary and primary

turbine seals. To further ensure against the mixing of oxidizer and turbine gas, a helium purge is applied between the elements of the intermediate seal during engine operation.

2.2.3.7.3.4 The preburner pump has a single-entry impeller that discharges oxidizer through diffuser vanes into the discharge volute. The preburner pump housing is flange-mounted to the main pump housing. Impeller seals interface with labyrinths cut in the outside diameter of the impeller shroud and hub to minimize leakage back to the pump inlet and control the flow for cooling the preburner pump-end bearings.

2.2.3.7.3.5 High-Pressure Oxidizer Turbopump Turbine. (See figure 2-30.) The high-pressure oxidizer turbopump turbine is powered by hot gas generated by the OPB. Hot gas enters the turbine and flows across the shielded support struts, through the first- and second-stage nozzle and blades, and is discharged into the HGM. The turbine rotors are mated through a cubic coupling and are held together with a circle of bolts. The second-stage rotor is integral with the pump shaft. Turbine blade-to-house leakage is minimized by lands on the outer perimeter of the blade shrouds that run against seals in the turbine housing.

2.2.3.7.3.5.1 All components of the turbine are cooled by gaseous hydrogen flowing over or through them. Coolant is supplied from the OPB coolant jacket. After cooling the turbine

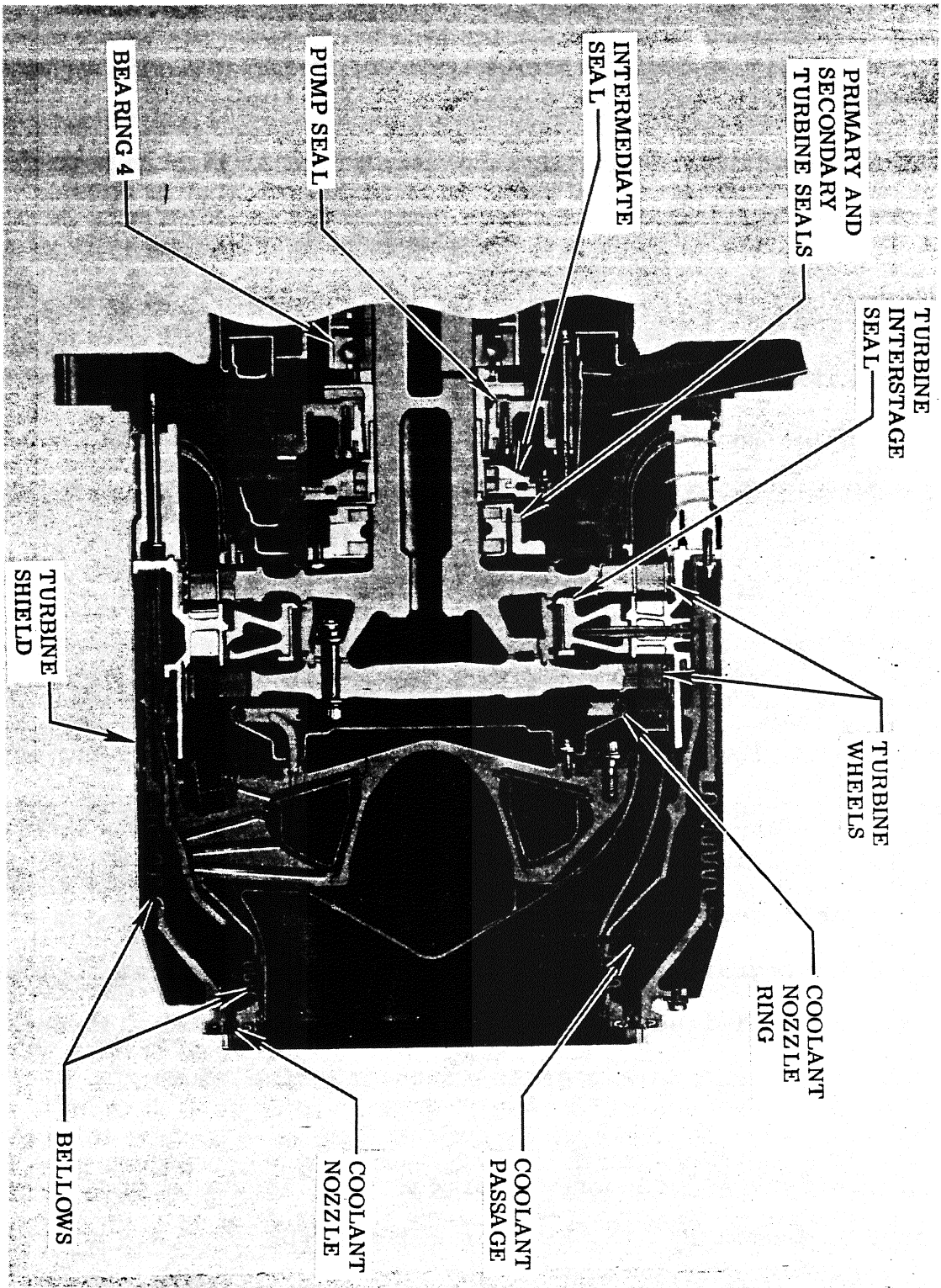


Figure 2-30. HPOTP Turbine Section

components, the coolant is exhausted into the hot-gas flow stream.

2.2.3.7.3.5.2 Turbine-to-OPB sealing is accomplished by a pair concentric bellows that load dual seals in the turbine inlet flange to the OPB. Turbine component materials are primarily nickel- and cobalt-base alloys. The diameter of the turbine rotors with blades approximately 11 inches.

2.2.3.7.4 High-Pressure Fuel Turbopump. (See figure 2-31.) The HPFT is a three-stage centrifugal pump that is driven by a two-stage hot-gas turbine. The pump receives fuel from the LPFT and supplies it at increased pressure, through the MFV, to thrust chamber assembly coolant circuits. The turbine is powered by hot gas (hydrogen-rich steam) generated by the FPB. Fuel flows in series through the three impellers from pump inlet to outlet, with flow redirected between the impellers by interstage diffusers.

2.2.3.7.4.1 Coolant flow across the pump-end bearings is provided by the first-stage impeller backplate wear-ring flow. The coolant is returned to the inlet of the first-stage impeller. Coolant flow to the inlet of the first-stage impeller. Coolant flow to the turbine-end bearings is supplied from the pump balance piston cavity through the shaft static lift-off seal.

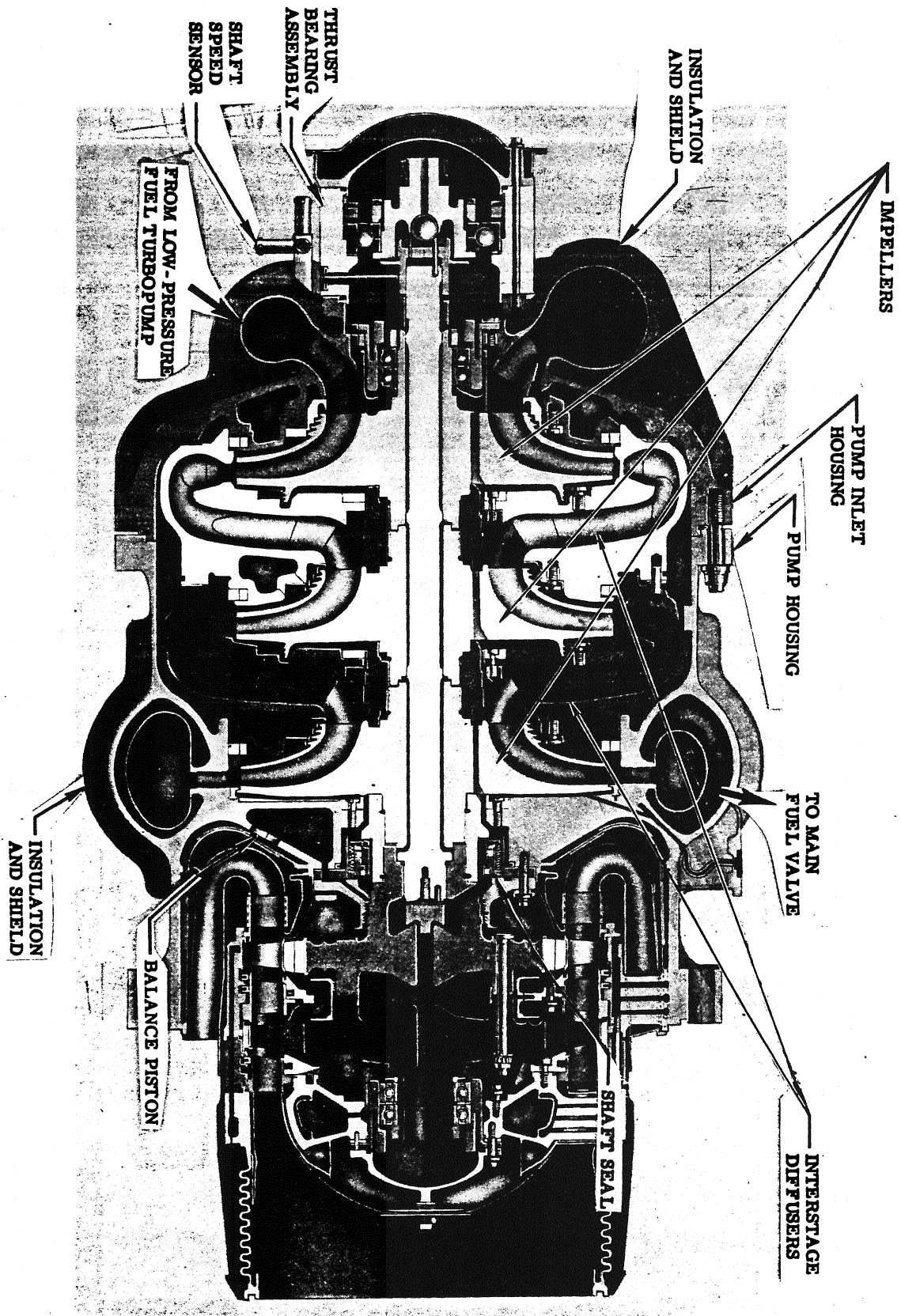


Figure 2-31. High-Pressure Fuel Turbopump

2.2.3.7.4.2 Axial rotor thrust is controlled by a self-compensating, double-acting balance piston that operates between high- and low-pressure orifices to maintain thrust at zero during normal operation. A thrust bearing located at the pump inlet end of the rotating assembly controls rotor thrust during start and cutoff transient operations.

2.2.3.7.4.3 Before engine start, leakage from the pump into the turbine is prevented by a spring-loaded-closed, propellant pressure-actuated-open, lift-off seal. During engine start, the seal nose is separated from its mate ring when increasing fuel pressure overcomes the spring force. A positive separation between the seal nose and mate ring is maintained until engine shutdown, when actuating pressure decreases below spring force. Propellant flow through the seal and mate ring is used to cool the turbine-end bearings and the turbine components.

2.2.3.7.4.4 The HPFT is flange-attached to the HGM and is canted out from the engine centerline at a 10 degree angle. The HPFT is an LRU with an overall dimensional envelope of approximately 22 by 44 inches.

2.2.3.7.4.5 HP Fuel Turbopump Turbine. (See figure 2-32.) The high-pressure fuel turbopump turbine is powered by hot gas generated by the FPB. Hot gas enters the turbine and flows across the shielded support struts, through the first- and

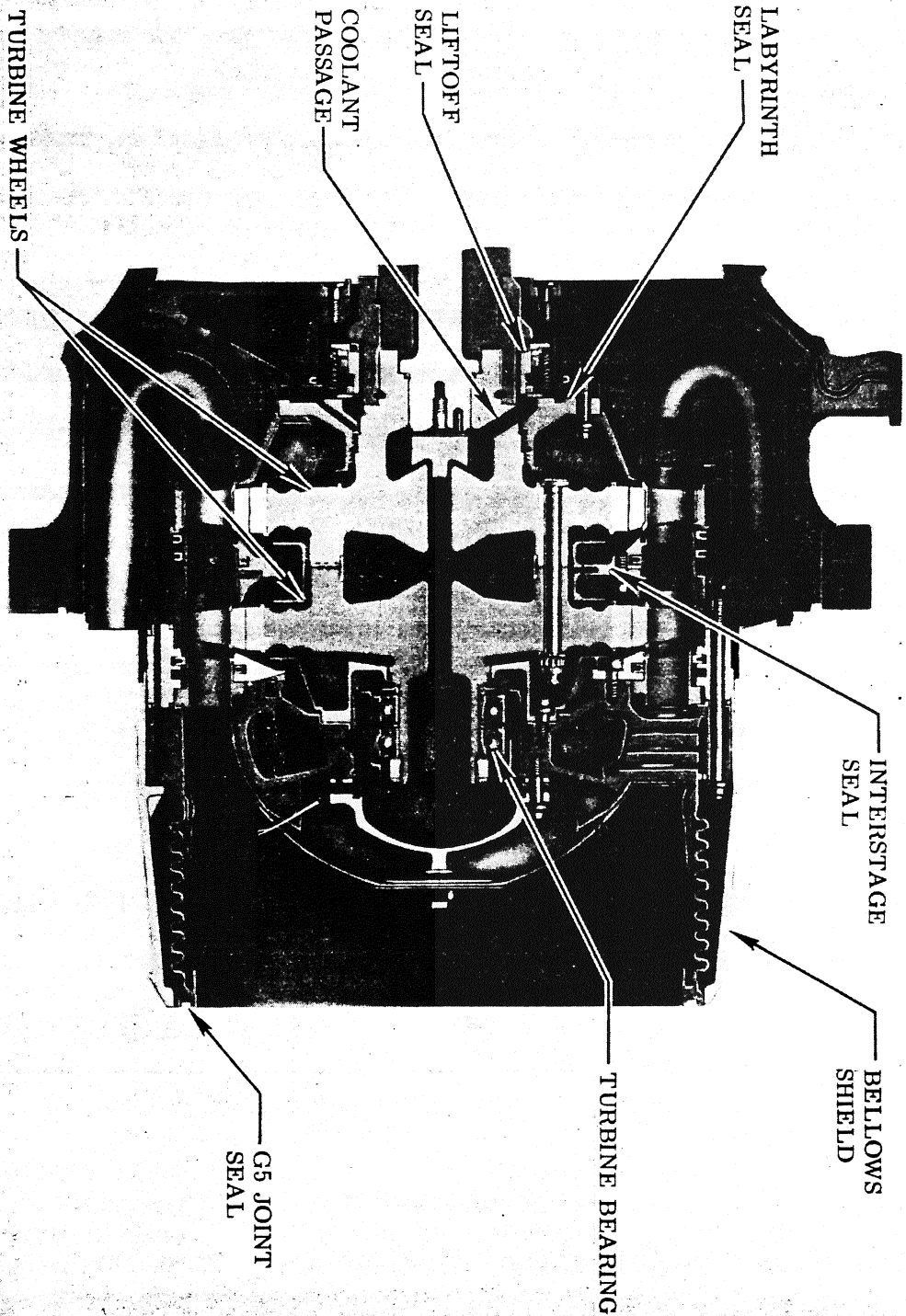


Figure 2-32. HPFTP Turbine Section

second-stage nozzles and blades, and is discharged into the HGM. The turbine disks are mated through a curved coupling and are held together with a circle of bolts. The two-stage turbine transmits torque to the pump by a splined coupling between the second-stage wheel and the pump third-stage impeller.

2.2.3.7.4.5.1 Bearing and turbine coolant is supplied through the shaft static lift-off seal when the seal is actuated at engine start. The turbine coolant flows over or through the hot-gas components and is then exhausted into the hot-gas flow stream. Turbine-to-FPB sealing is accomplished by a bellows that loads a Naflex seal against the FPB flange.

2.2.3.8 Heat Exchanger. (See figure 2-33.) The heat exchanger has a multipath, single-pass coil pack installed in the oxidizer side of the HGM and an orificed bypass line directly outside. It converts liquid oxygen to gaseous oxygen for vehicle oxygen tank pressurization and the pogo system accumulator. The coil pack consists of a helically-wound small tube approximately 30.6 inches long, in series with two larger, parallel tubes each approximately 310 inches long. The tubes are attached to supports welded to the HGM coolant jacket inner wall. The crossflow of hot turbine exhaust gases from the HPOT provides the heat source.

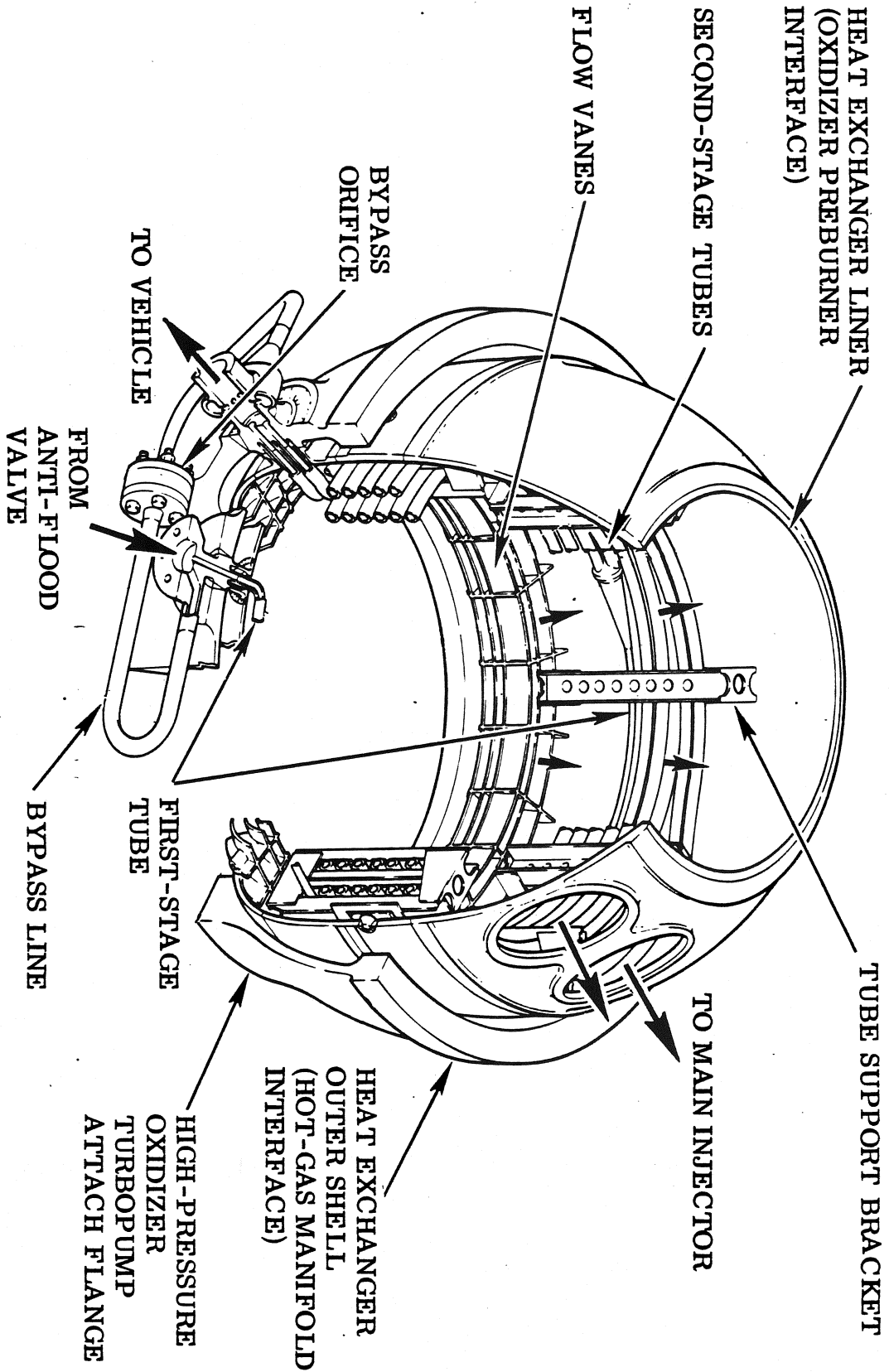


Figure 2-33. Heat Exchanger

2.2.3.8.1 Liquid oxygen tapped off the discharge side of the HPOT is supplied to the inlet of the heat exchanger through an Anti-Flood Valve (AFV). The oxygen is heated to a gas in the small tube (first stage) and nearly to the heating gas temperature in the two larger tubes (second stage). The orificed bypass line injects an unheated portion (approximately 35 percent) of the total oxygen flow into the outlet of the coils for control of temperature/flow-rate operating characteristics. Orifice in the vehicle and pogo system control the total heat exchanger oxygen flow rate.

2.2.3.9 Pogo Suppression System. (See figure 2-34.) Pogo is a regular surge and drop and thrust, which causes a pogo-stick-like ride. A pogo suppression system is provided to prevent the transmission of low-frequency flow oscillations into the high-pressure turbopump, and ultimately to prevent main combustion chamber pressure (engine thrust) oscillations. Flow oscillations transmitted from the Space Shuttle vehicle are suppressed by a gas-filled accumulator, which is flange-attached to the HPOT inlet duct. The system consists of a 0.6-ft³ accumulator with an internal standpipe, helium precharge valve package, gaseous oxygen (GO₂) supply valve package, and two recirculation isolation valves (one recirculation isolation valve is located on the Orbiter). Gaseous oxygen provided to the accumulator from the heat exchanger discharge is used as the compliant medium following an initial helium precharge. A continuous GO₂ flow is

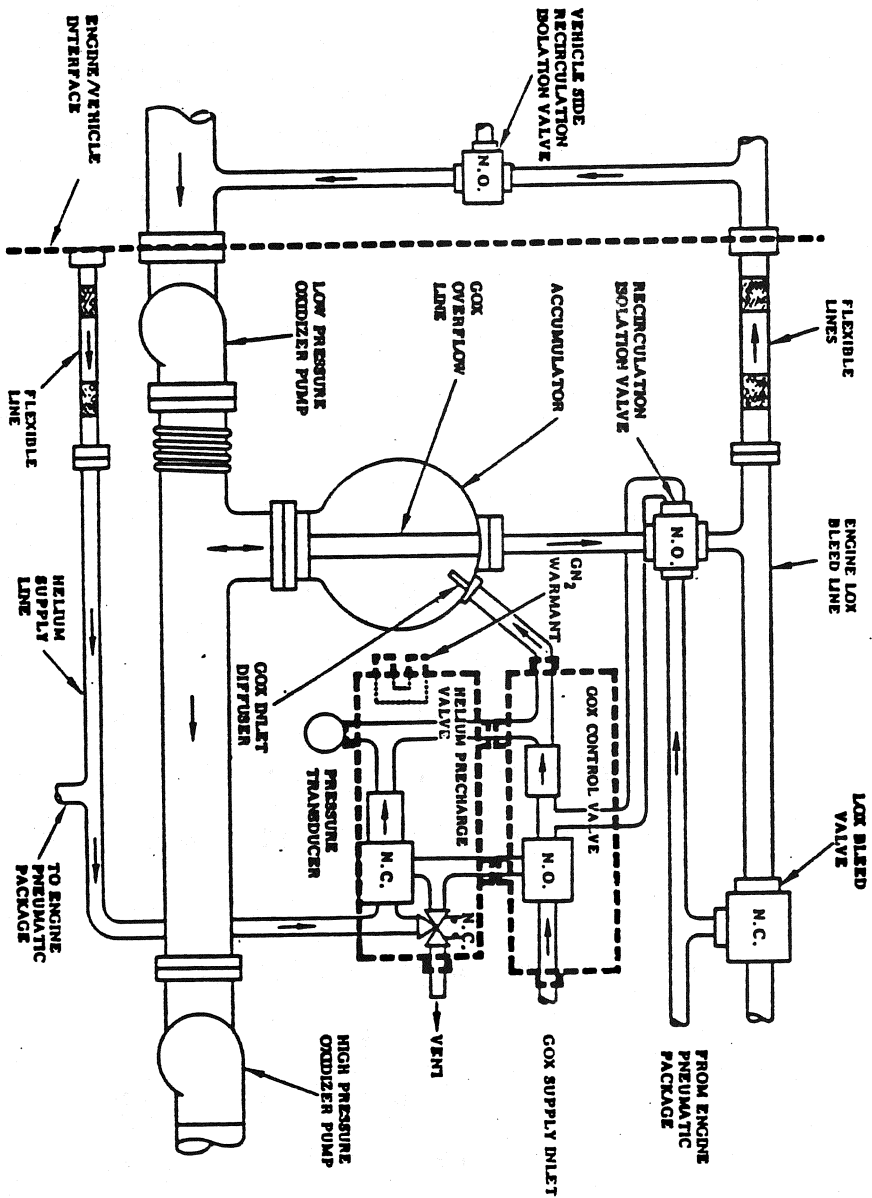


Figure 2-34. Pogo Suppression System Schematic

maintained at a rate governed by the engine operating point. Liquid level in the accumulator is controlled by a standpipe in the accumulator, which is orificed to regulate the GO_2 overflow over the engine operating power level range. The system is sized to provide sufficient GO_2 to replenish condensation at the minimum GO_2 flow rate and to permit sufficient GO_2 overflow at the maximum decreasing pressure transient in the LPOT discharge duct. At all other conditions, excess gaseous and liquid oxygen are recirculated to the LPOT inlet through the engine oxidizer bleed duct.

2.2.3.9.1 Pogo Suppressor. (See figure 2-35.) The pogo suppressor is a gas-filled accumulator that serves as a capacitance in the liquid oxygen (LO_2) flow circuit and prevents low-frequency flow oscillations from being transmitted into the HPOT. During engine operation, GO_2 is obtained from the heat exchanger discharge. During engine start, the accumulator is charged with helium 1.5 sec after the start command to provide pogo protection until the heat exchanger is operational and GO_2 is available.

2.2.3.9.2 The accumulator is partially chilled with LO_2 during the engine chilldown operation. Prestart actuation of the recirculation isolation valve allows the accumulator to fill to the overflow line inlet level. This level is sufficient to preclude gas ingestion at start.

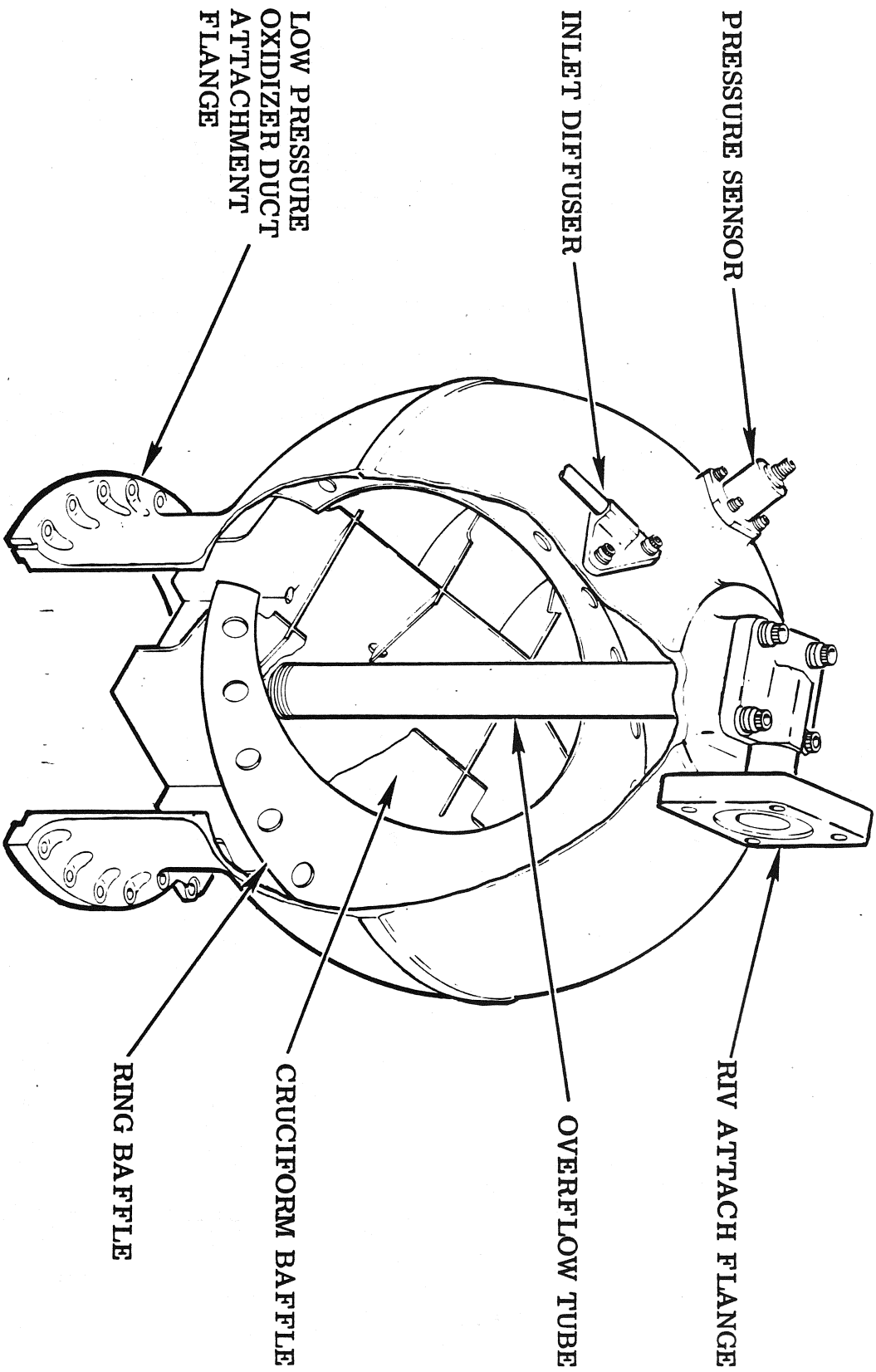


Figure 2-35. Pogo Suppression Accumulator

2.2.3.9.3 The overflow line in the accumulator controls the liquid level at all engine operating points. The orifices are sized to accept the maximum overflow (GO_2) occurring within the engine operating range. This flow is routed through the engine LO_2 bleed line across the gimbal plane to a point upstream of the LPOT. For most operating conditions, the recirculated GO_2 will condense before reaching the LPOT inlet.

2.2.3.9.4 The accumulator contains an annular ring and cruciform baffles to minimize sloshing of the liquid and is flange-mounted to the low-pressure oxidizer duct at the inlet of the HPOT. The pogo suppressor is an LRU.

2.2.3.9.5 Pogo Helium Precharge Valve. (See figure 2-36.) The Helium Precharge Valve (HPV) assembly provides helium pressurant to the pogo accumulator during engine start until gaseous oxygen is available from the engine heat exchanger. The HPV is a spring-loaded-closed, pneumatically actuated-open, poppet valve. It has an integral check valve at its outlet port. The helium supply is filtered by a 15 absolute filter at the HPV inlet.

2.2.3.9.6 A dual-coil, normally closed solenoid valve is mounted on the HPV and provides pilot control of the normally closed HPV and the normally open Gaseous Oxygen Control Valve (GCV).

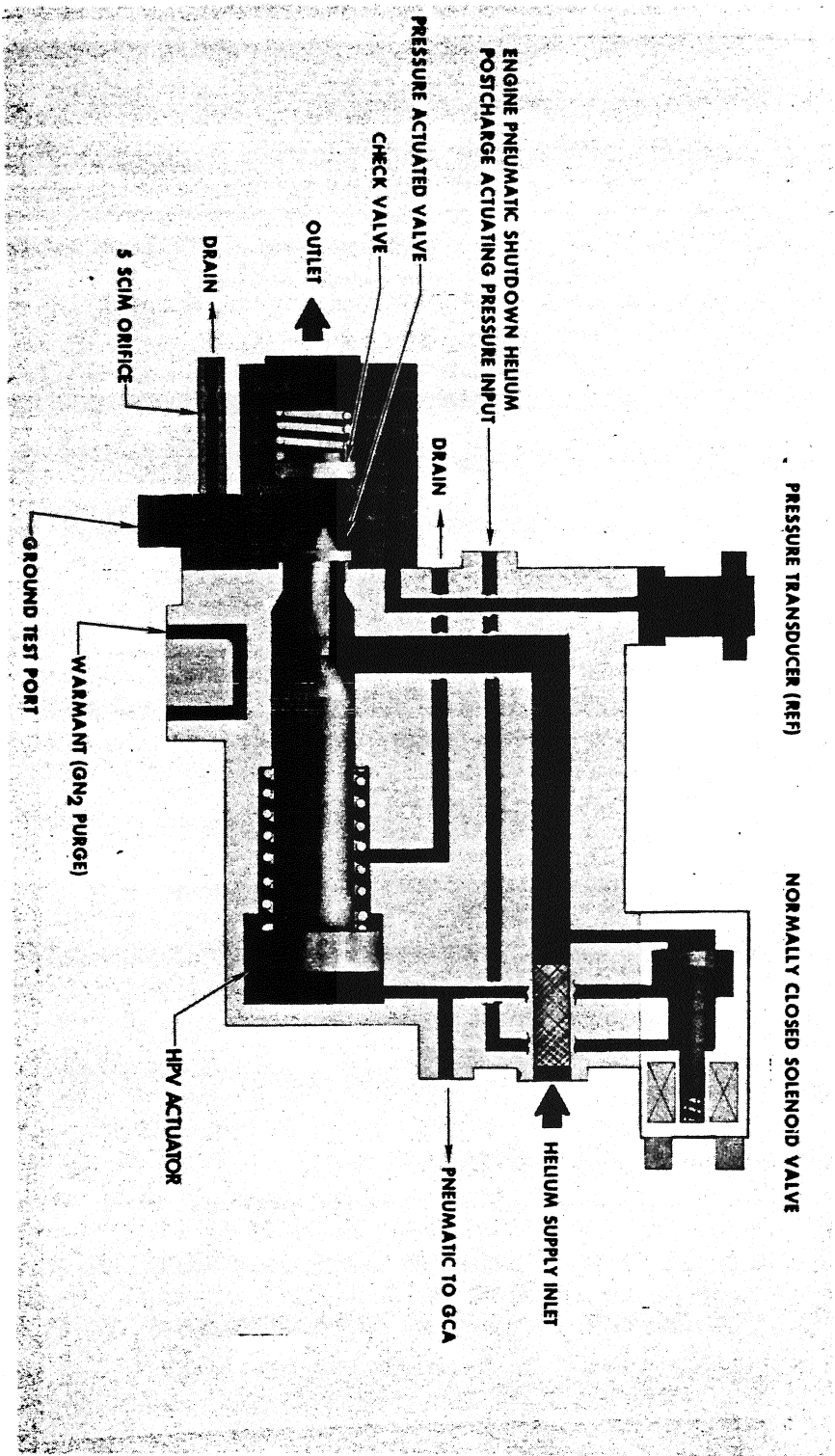


Figure 2-36. Helium Precharge Valve Assembly Schematic

2.2.3.9.7 During the engine start preparation phase, the HPV body is warmed by the main injector oxidizer dome nitrogen purge that flows through the HPV before being routed to the main injector. The HPV is an LRU.

2.2.3.9.8 Pogo Gaseous Oxygen Control Valve. (See figure 2-37.) The GCV provides gaseous oxygen pressurant to the pogo accumulator during engine operation after the engine heat exchanger begins functioning.

2.2.3.9.9 The GCV is a bellows-loaded-open, pneumatically actuated-closed, poppet valve. It has an integral check valve at its outlet port. The pilot solenoid valve mounted on the HPV controls the operation of the normally closed HPV and the normally open GCV.

2.2.3.9.10 A bleed orifice provides fail-operate valve actuation to the open position. Pneumatic pressure to the closing side of the actuator is also applied to the opening side through a bleed orifice. This will cause the valve to reopen approximately 2 sec after the application of closing pressure.

2.2.3.9.11 Operation of the recirculation Isolation Valve (RIV) is ensured by routing gaseous oxygen from the GCV to the override port of the RIV. The GCV is an LRU.

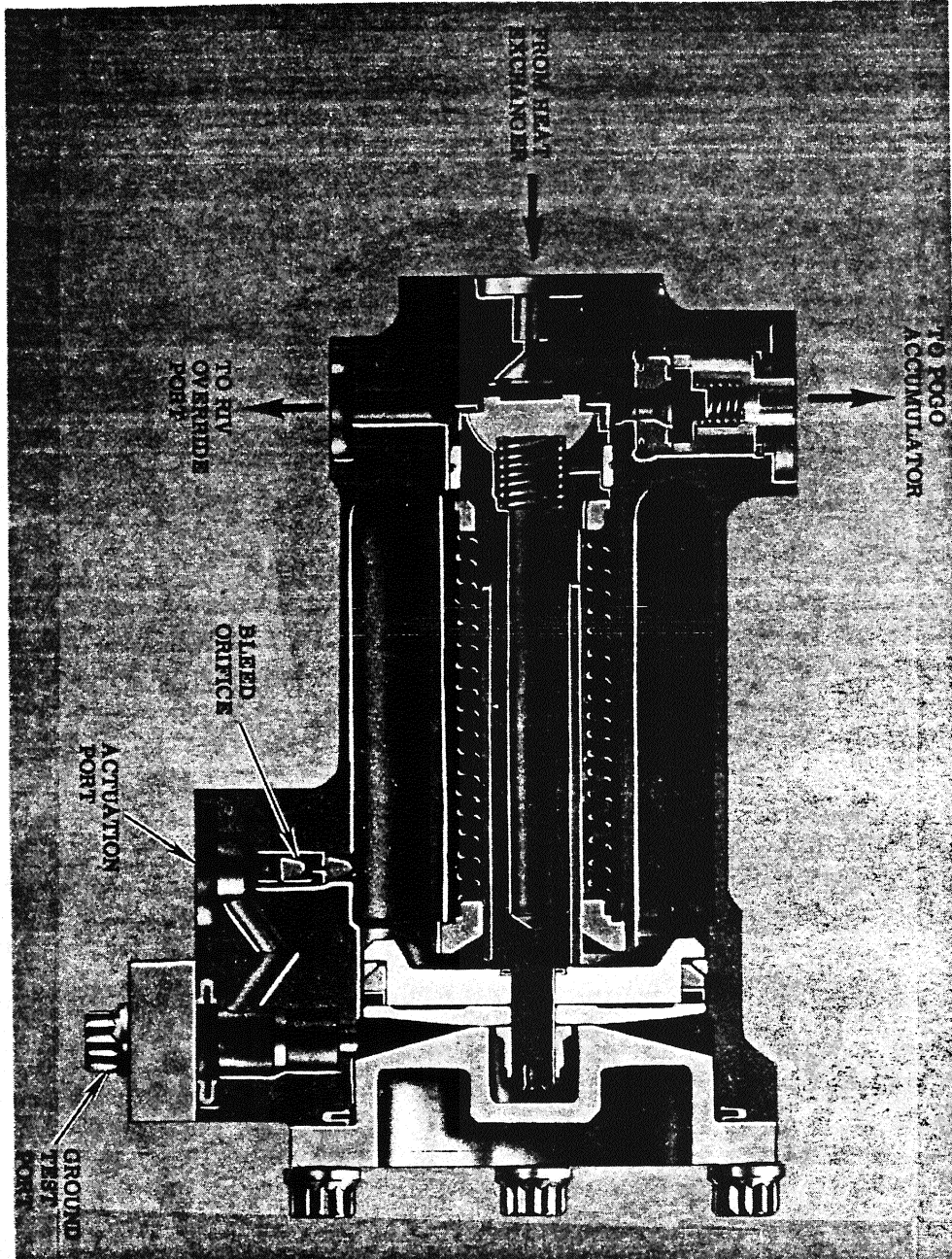


Figure 2-37. GOX Control Valve

2.2.3.10 SSME Valves. The following paragraphs describe the SSME valves.

2.2.3.10.1 Recirculation Isolation Valve. (See figure 2-38.) The RIV prevents a short circuit in the engine oxidizer system during the propellant conditioning mode of engine start preparation. The normally open RIV is actuated closed by the same pneumatic pressure that opens the normally closed oxidizer bleed valve.

2.2.3.10.1.1 The RIV is a bellows-loaded-open, pneumatically actuated-closed, poppet valve. Operation is ensured by routing gaseous oxygen from the override port of the GCV to the opening side of the RIV actuator when the GCV is opened. A Linear Variable Differential Transformer (LVDT) is used for valve position indication. The RIV is an LRU.

2.2.3.10.2 Main Oxidizer Valve. (See figure 2-39.) The Main Oxidizer Valve (MOV) is a ball-type valve with a 2.5-inches propellant flow passage flange-mounted between the main chamber oxidizer dome and the high-pressure oxidizer duct. The valve controls oxidizer flow to the main chamber LO₂ dome and main chamber ASI and is operated by a hydraulic servoactuator mounted to the valve housing. The servoactuator receives its control signals from the controller.

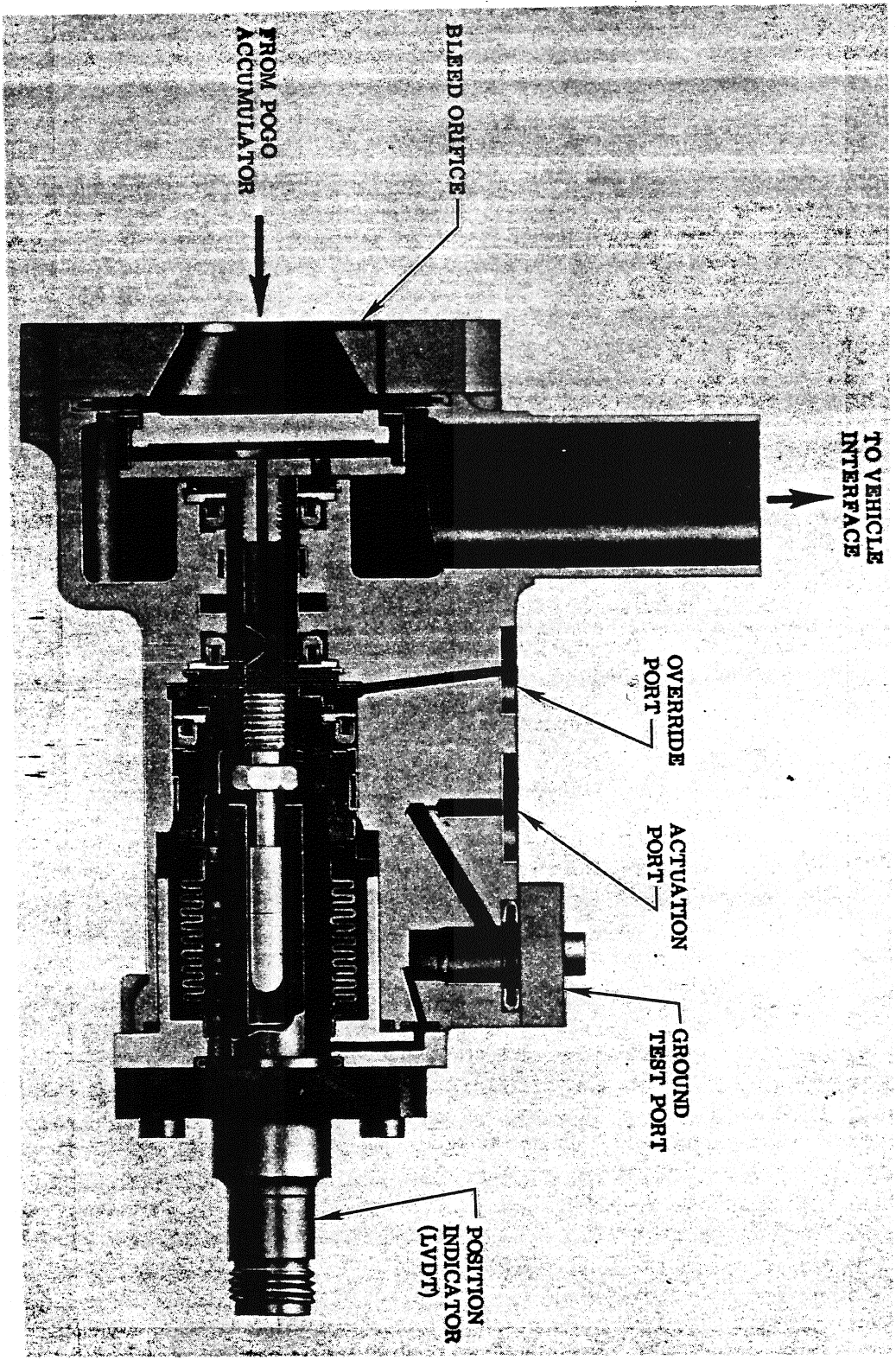


Figure 2-38. Recirculation Isolation Valve

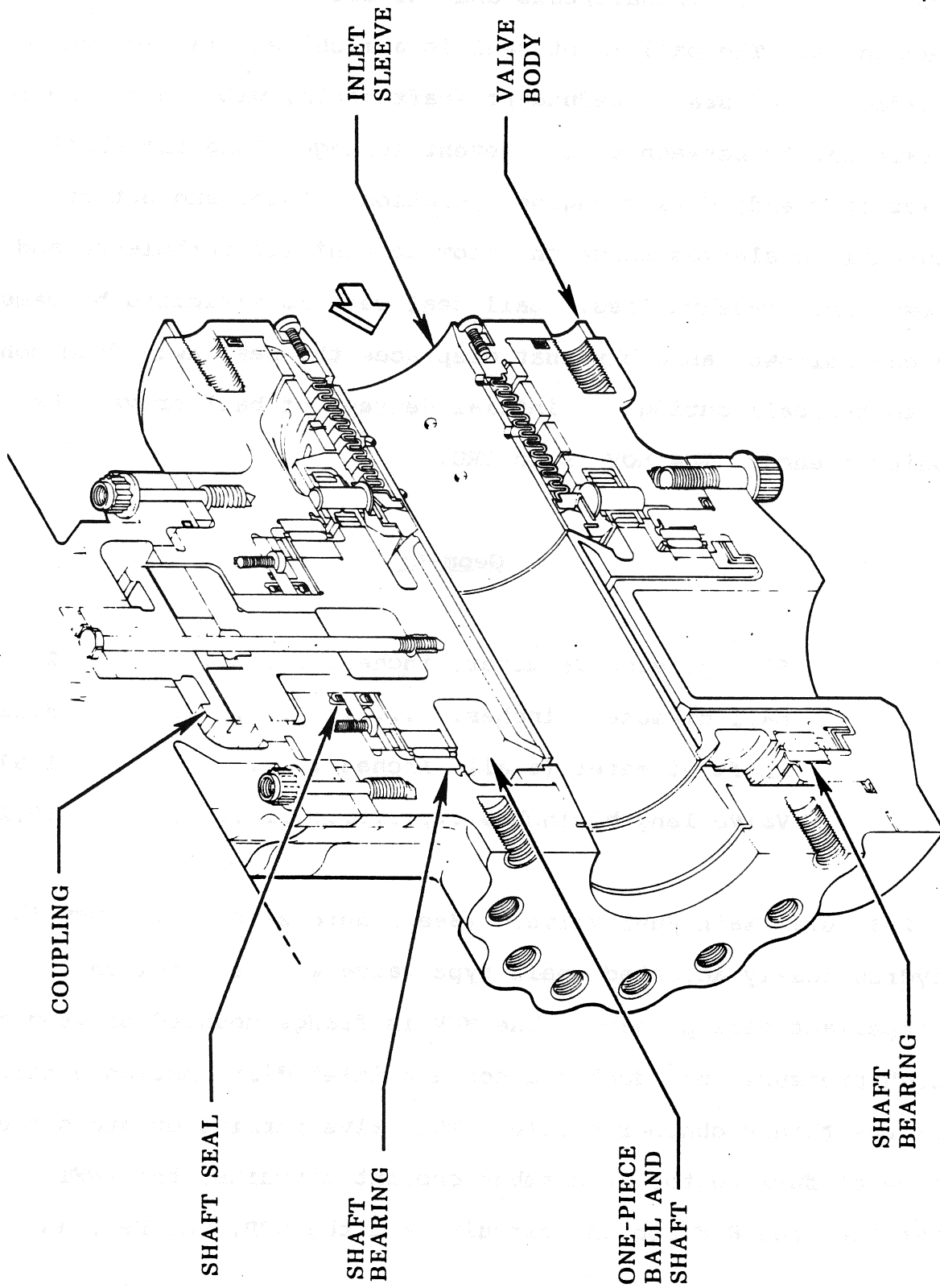


Figure 2-39. SSME Main Oxidizer Valve Assembly

2.2.3.10.2.1 The valve consists of two major moving components: the integral ball/shaft/cams and the ball seal retracting mechanism. The ball inlet seal is a machined plastic, bellows-loaded closed seal. Redundant shaft seals, with an overboard drain cavity between them, prevent leakage along the shaft (actuator end) during engine operation. Inlet and outlet throttling sleeves align the flow to minimize turbulence and the resultant pressure loss. Ball seal wear is minimized by cams and a cam follower assembly that displaces the seal away from contact with the ball during the initial degrees of ball travel when being opened. The MOV is an LRU.

Geometry

Flow passage diameter, inches.....	2.500
Ball diameter, inches.....	5.125
Shaft diameter (seal), inches.....	1.875
Valve length, inches.....	10.25

2.2.3.10.3 Main Fuel Valve. (See figure 2-40.) The MFV is a hydraulically actuated, ball-type valve with a 2.5-inch propellant flow passage. The MFV is flange-mounted between the high pressure fuel duct and coolant inlet distribution manifold of the thrust chamber nozzle. The valve permits or stops the flow of fuel to thrust chamber coolant circuits, the LPFT turbine, the HGM coolant circuit, and the OPB, the FPB, and

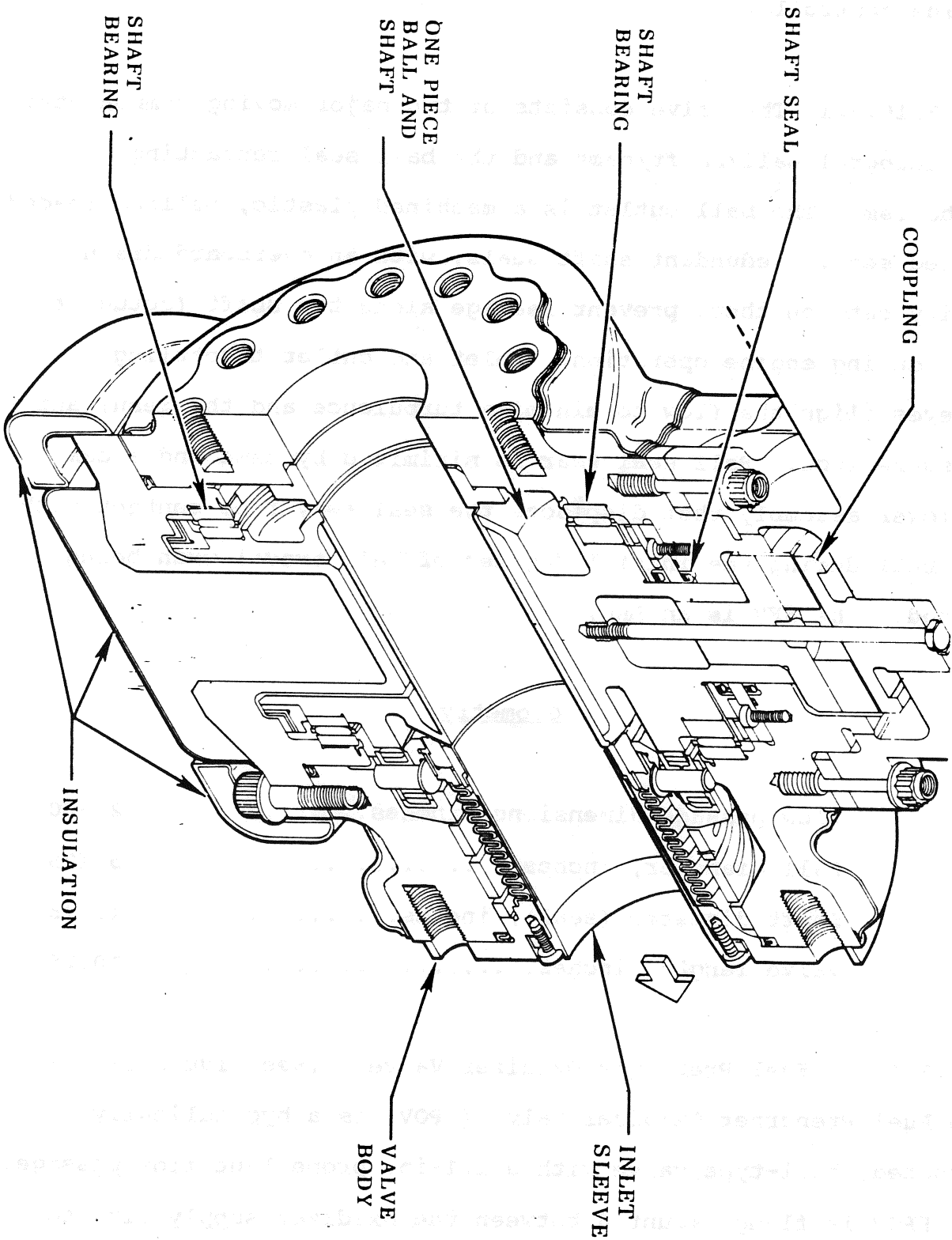


Figure 2-40. SSME Fuel Valve Assembly

the three ASIs. Valve position is controlled commands from the engine controller.

2.2.3.10.3.1 The valve consists of two major moving components: the integral ball/shaft/cams and the ball seal retracting mechanism. The ball outlet is a machined plastic, bellows-loaded closed seal. Redundant shaft seals, with an overboard drain cavity between them, prevent leakage along the shaft (actuator end) during engine operation. Inlet and outlet throttling sleeves align the flow to minimize turbulence and the resultant pressure loss. Ball seal wear is minimized by cams and a cam follower assembly that displaces the seal away from contact with the ball during the initial degrees of ball travel when being opened. The MFV is an LRU.

Geometry

Flow passage dimensions, inches.....	2.500
Ball diameter, inches.....	5.125
Shaft diameter (seal), inches.....	1.875
Valve length, inches.....	10.25

2.2.3.10.4 Fuel Preburner Oxidizer Valve. (See figure 2-41.) The Fuel Preburner Oxidizer Valve (FPOV) is a hydraulically actuated, ball-type valve with a 1.1-in. propellant flow passage. The FPOV is flange-mounted between the oxidizer supply line to

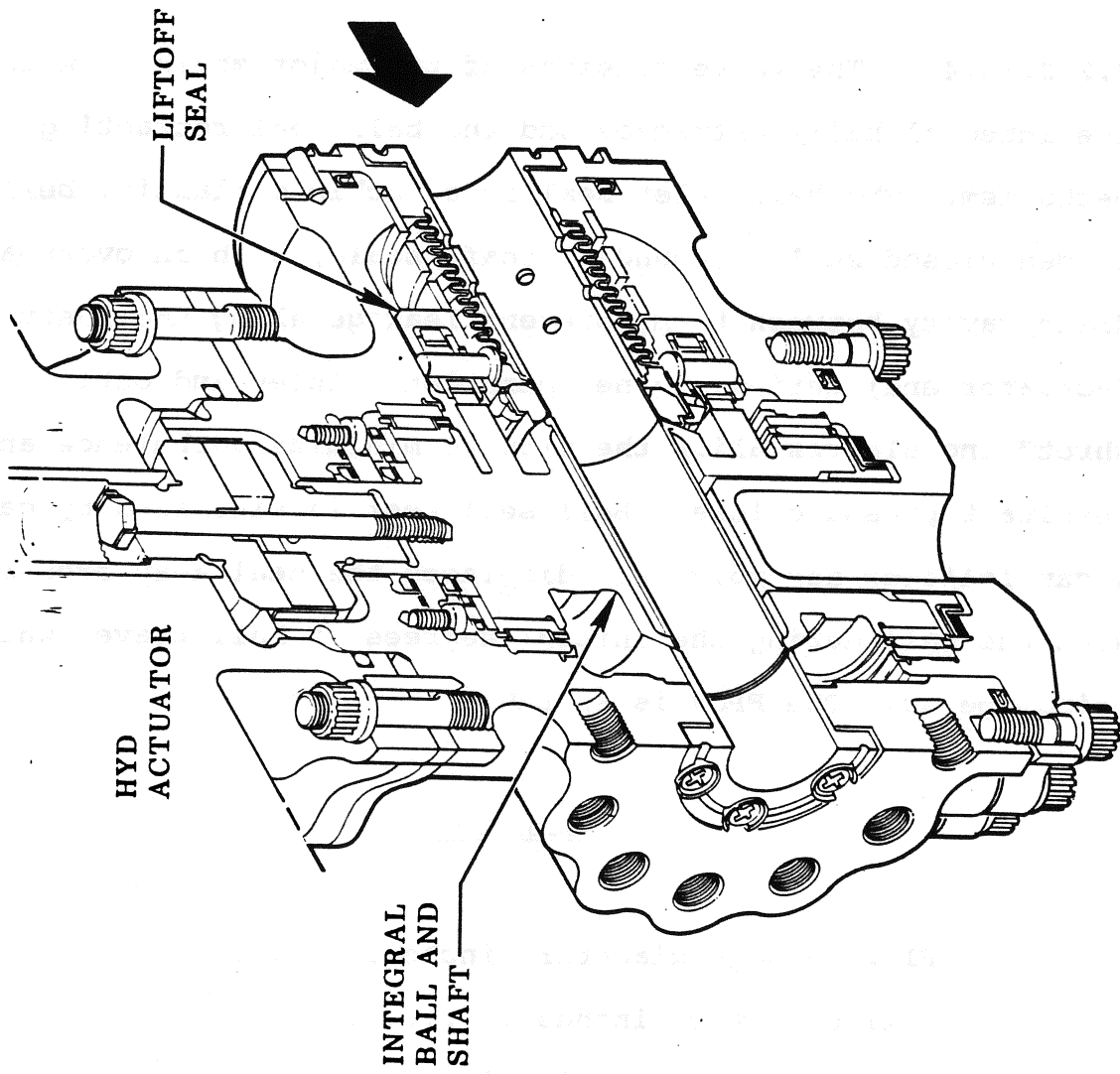


Figure 2-41. SSME Fuel Preburner Oxidizer Valve Assembly

the FPB and the FPB oxidizer inlet. The valve permits or stops the flow of oxidizer to the FPB and the FPB ASI. Valve position is controlled by commands from the engine controller; during mainstage operation, the valve is modulated to maintain the desired engine mixture ratio.

2.2.3.10.4.1 The valve consists of two major moving components: the integral ball/shaft/cams and the ball seal retracting mechanism. The ball inlet seal is a machined plastic, bellows-loaded closed seal. Redundant shaft seals, with an overboard drain cavity between them, prevent leakage along the shaft (actuator end) during engine operation. Inlet and outlet throttling sleeves align the flow to minimize turbulence and the resultant pressure loss. Ball seal wear is minimized by cams and a cam follower assembly that displaces the seal away from contact with the ball during the initial degrees of ball travel when being opened. The FPOV is an LRU.

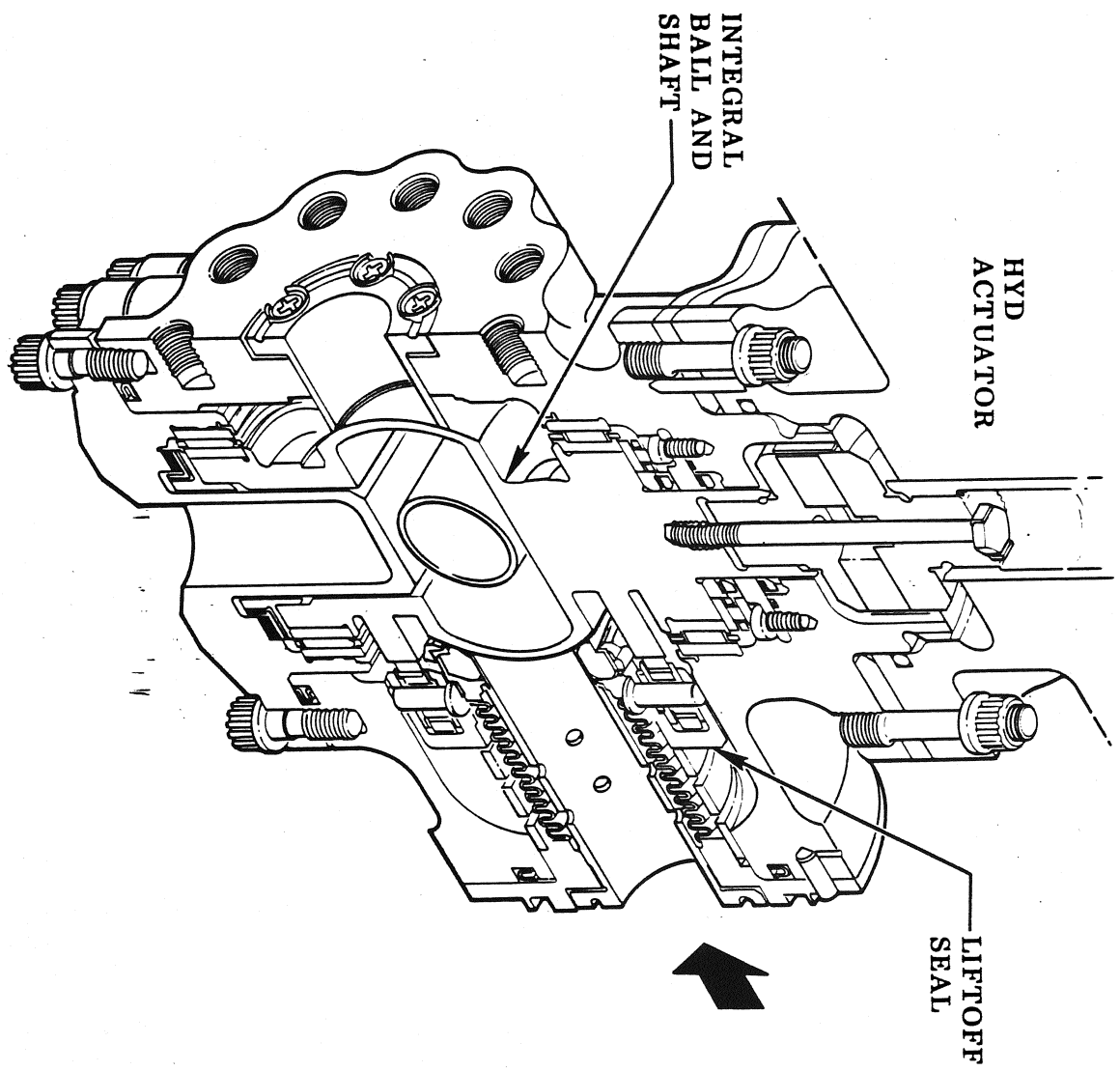
Geometry

Flow passage diameter, inches.....	1.100
Ball diameter, inches.....	2.968
Shaft diameter (seal), inches.....	1.100
Valve length, inches.....	6.812

2.2.3.10.5 Oxidizer Preburner Oxidizer Valve. (See figure 2-42.) The Oxidizer Preburner Oxidizer Valve (OPOV) is a hydraulically actuated, ball-type valve with a 1.1- by 0.285-in. propellant flow slot. The OPOV is flange-mounted between the oxidizer supply line to the OPB and the OPB oxidizer inlet. The valve permits or stops the flow of oxidizer to the OPB and the OPB ASI. Valve position is controlled by commands from the engine controller; during mainstage operation, the valve is modulated to control engine thrust between Minimum Power Level (MPL) and Full Power Level (FPL).

2.2.3.10.5.1 The valve consists of two major moving components: the integral ball/shaft/cams and the ball seal retracting mechanism. The ball inlet seal is a machined plastic, bellows-loaded closed seal. Redundant shaft seals, with an overboard drain cavity between them, prevent leakage along the shaft (actuator end) during engine operation. Inlet and outlet throttling sleeves align the flow to minimize turbulence and the resultant pressure loss. Ball seal wear is minimized by cams and a cam follower assembly that displaces the seal away from contact with the ball during the initial degrees of ball travel when being opened. The OPOV is an LRU.

Figure 2-42. SSME Oxidizer Preburner Oxidizer Valve Assy



Geometry

Flow passage dimensions, inches.....	1.100 x 0.374
Ball diameter, inches.....	2.968
Shaft diameter (seal), inches.....	1.100
Valve length, inches.....	6.812

2.2.3.10.6 Chamber Coolant Valve. (See figure 2-43.) The CCV is a hydraulically actuated, gate-type valve that serves as a throttling control to maintain proper fuel flow through the main combustion chamber and nozzle coolant circuits. The valve is installed in the chamber coolant valve duct, which is an integral component of the nozzle forward manifold assembly and provides the housing for the valve.

2.2.3.10.6.1 The gate has a 1.6 inch flow passage. The CCV does not have a gate seal, as it is located downstream of the main fuel valve and is not required to be positive shutoff valve. Redundant shaft seals, with an overboard drain cavity between them, prevent leakage along the shaft (actuator end) during engine operation.

2.2.3.10.6.2 The valve gate is positioned by commands from the engine controller. Its position is scheduled linearly with thrust reference so as to be 50 percent open at MPL and full open at Rated Power Level (RPL). The valve is an LRU.

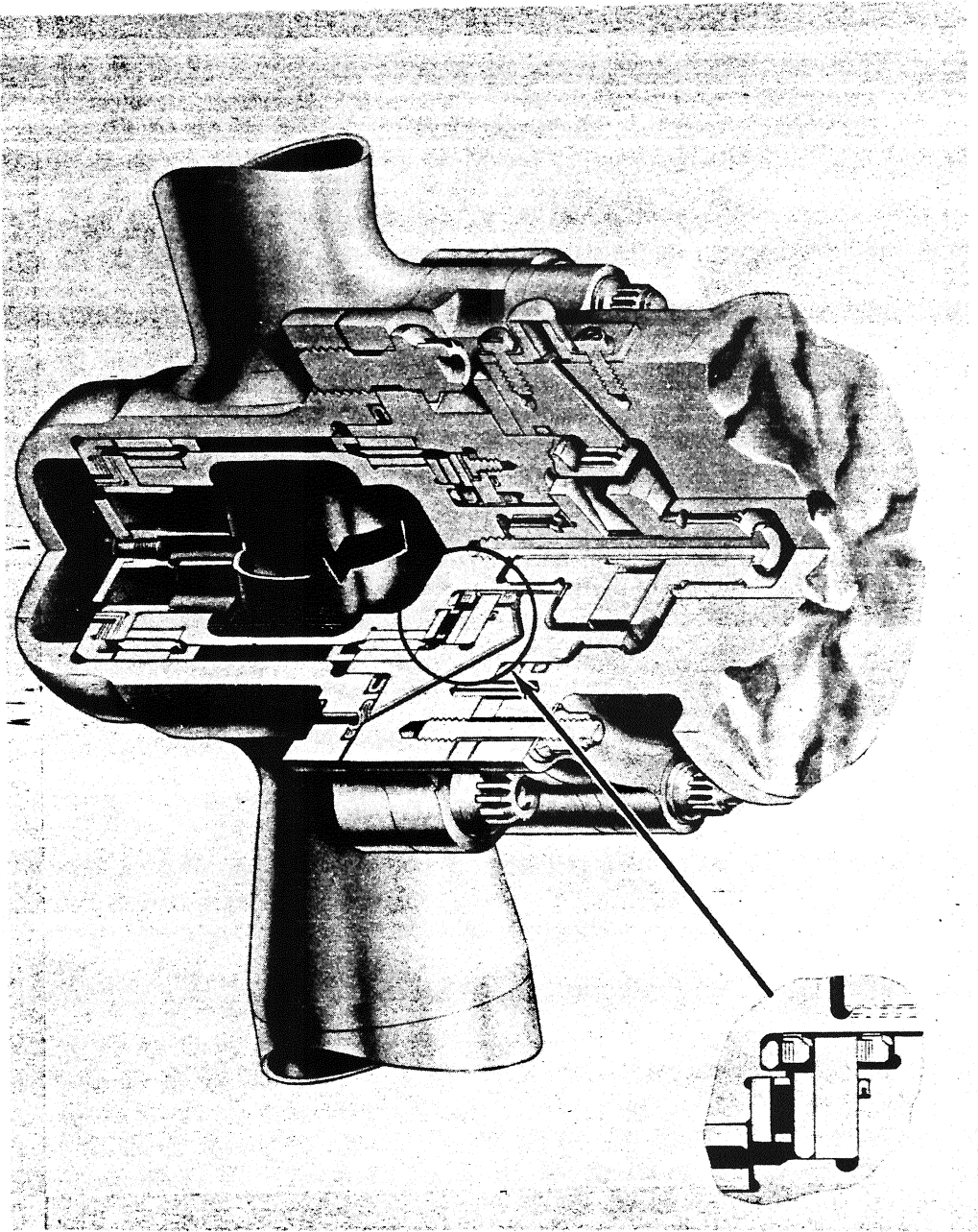


Figure 2-43. Chamber Coolant Valve

Geometry

Flow passage diameter, inches.....	1.600
Gate diameter, inches.....	2.500
Shaft diameter (seal), inches.....	1.100
Valve length, inches.....	7.729

2.2.3.10.7 Propellant Bleed Valves. (See figure 2-44.) The Oxidizer Bleed Valve (OBV) and the Fuel Bleed Valve (FBV) are spring and bellows-loaded-closed, pneumatically actuated-open, unbalanced-area, metal-to-metal seat, poppet valves. The valves are opened by pneumatic pressure from the Pneumatic Control Assembly (PCA) during engine start preparation to provide a recirculation flow for propellants through the engine to ensure that propellants in the engine are at the required temperatures for engine start. At engine start, the valves are closed by venting the actuation pressure. The valves are fail-safe in pressure acting on the unbalanced-area poppet, combined with spring and bellows forces to overcome the actuation pressure. The valves have LVDTs for full-open or full-closed position indication.

2.2.3.10.7.1 The OBV inlet is flange-mounted to the preburner oxidizer supply duct at the FPOV location and the oxidizer bleed duct is welded to the valve outlet. The FBV inlet is flange-mounted to the fuel high-pressure duct and the fuel bleed duct is

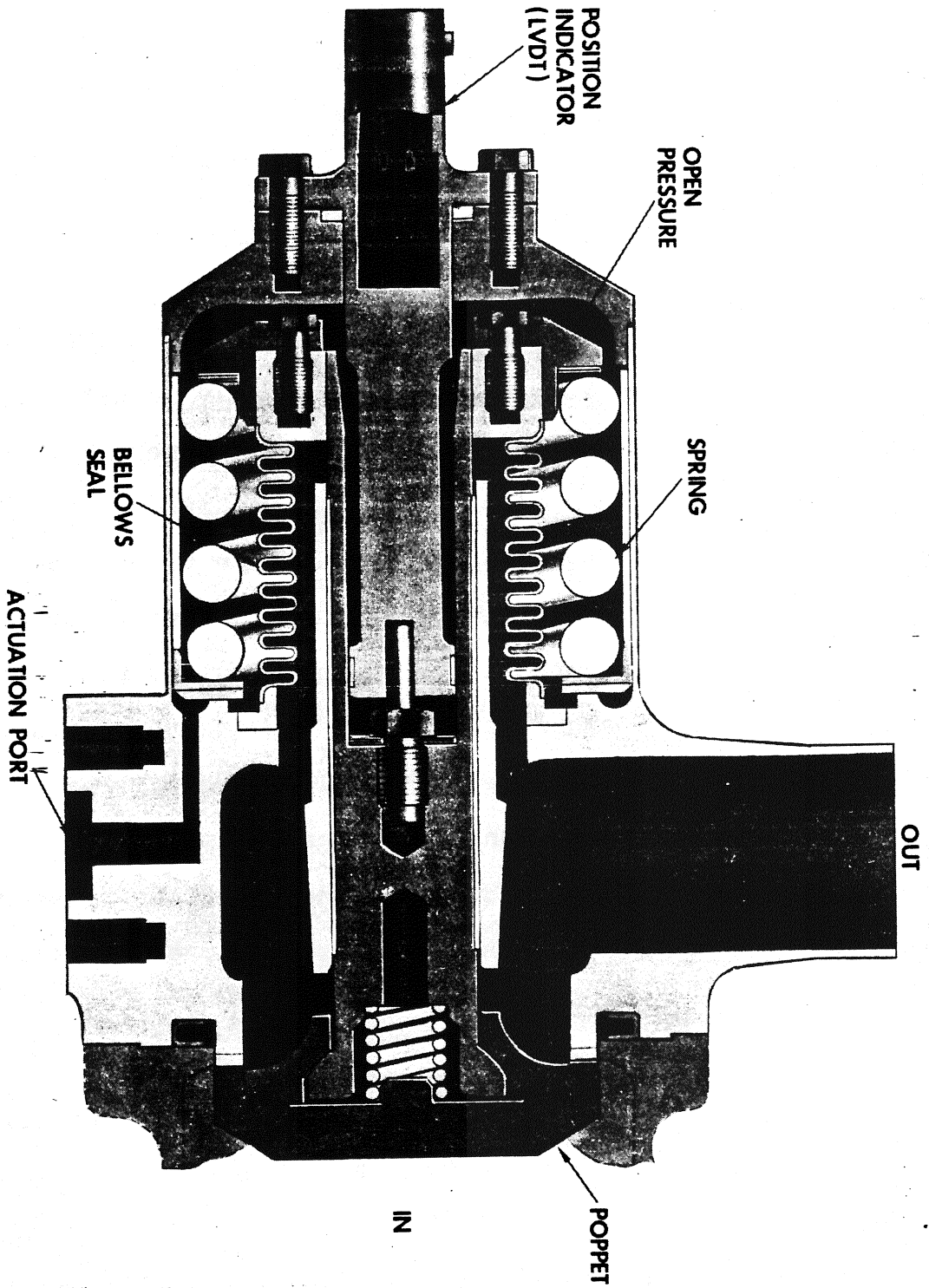


Figure 2-44. Propellant Bleed Valve

welded to the valve outlet. The valve assemblies, with their ducts, are LRUs as are the position indicators.

2.2.3.10.8 Anti-flood Valve. (See figure 2-45.) The AFV is a spring-loaded normally closed, poppet-type valve. It prevents the flow of liquid oxygen into the heat exchanger until there is sufficient heat applied to the heat exchanger during engine start to convert the liquid oxygen to gaseous oxygen.

2.2.3.10.8.1 The AFV can be checked out on the ground without disturbing line connections, and an LVDT that serves as a valve dual-position indicator. The valve assembly, with its duct, is an LRU.

2.2.3.10.9 Purge Check Valves. (See figure 2-46.) The pneumatic control system purge check valves are spring-loaded, normally closed, pressure-actuated-open, poppet valves that isolate propellants from the pneumatic systems. The purge check valves, with their attached lines, are LRUs.

2.2.3.10.10 Propellant Valve Hydraulic Actuators. (See figure 2-47.) Hydraulic power is provided for the operation of five valves in the propellant feed system (oxidizer preburner oxidizer, fuel preburner oxidizer, fuel preburner oxidizer, main oxidizer, main fuel, and chamber coolant valves). Servoactuators mounted to the propellant valves convert vehicle-supplied

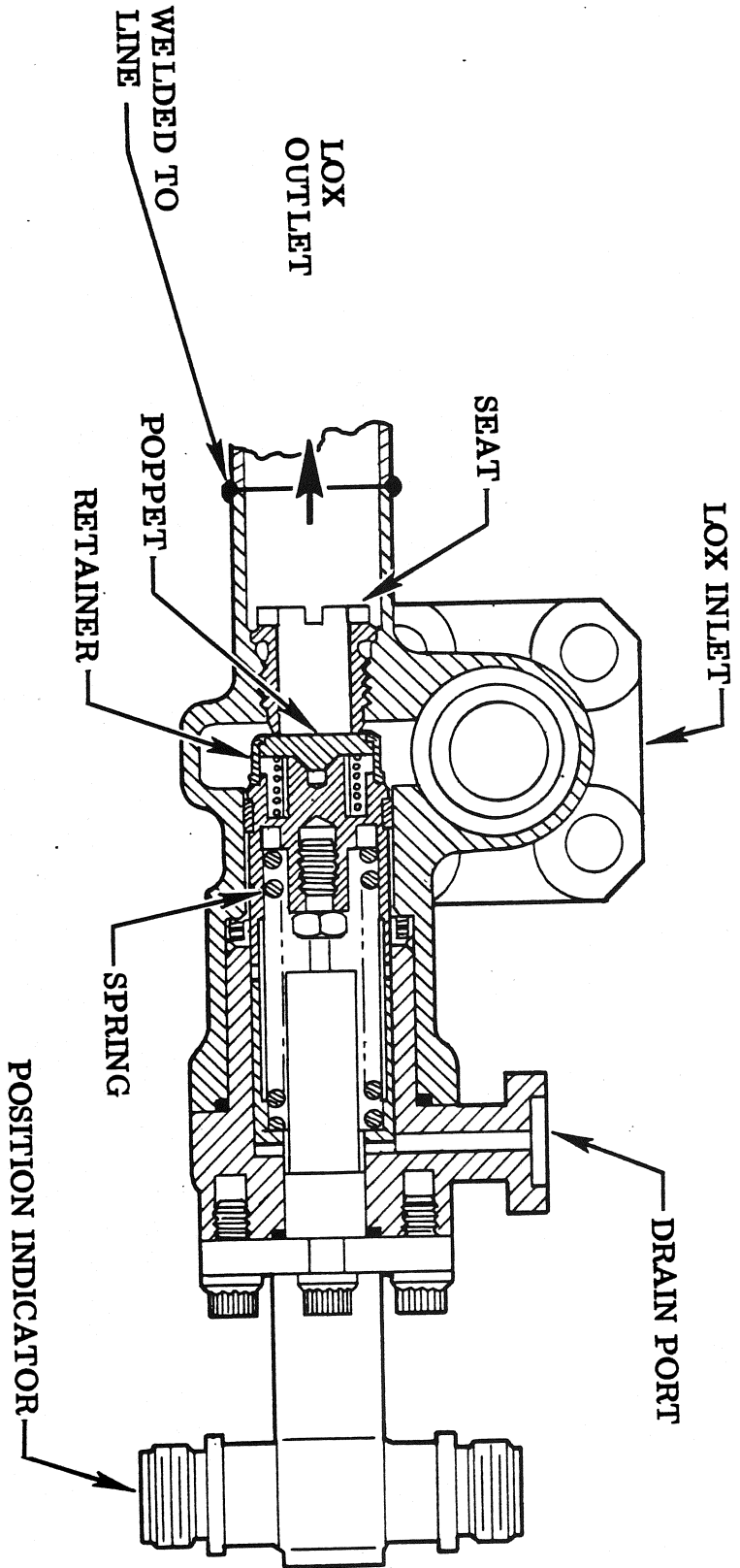


Figure 2-45. Anti-Flood Valve

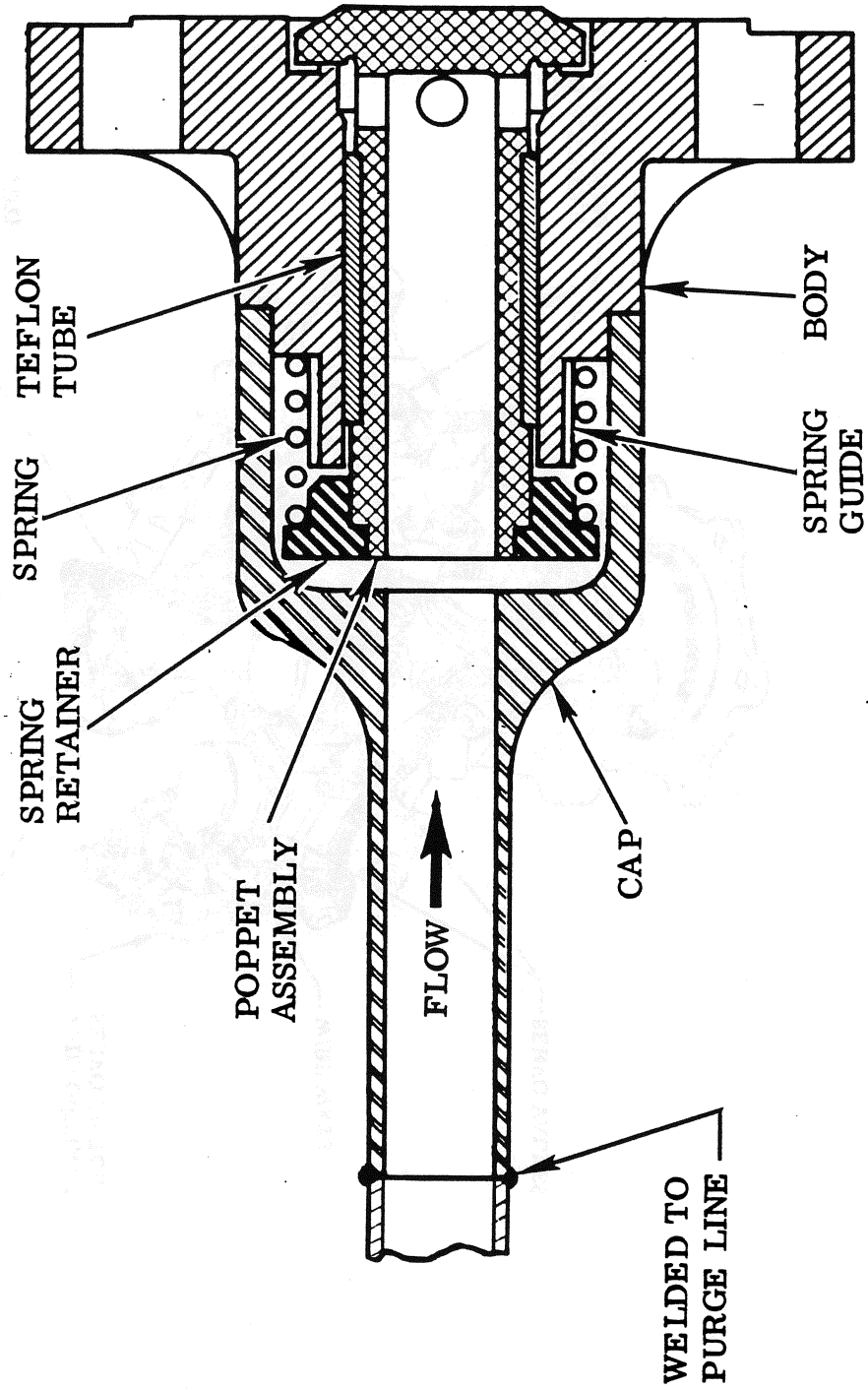


Figure 2-46. Purge Check Valve

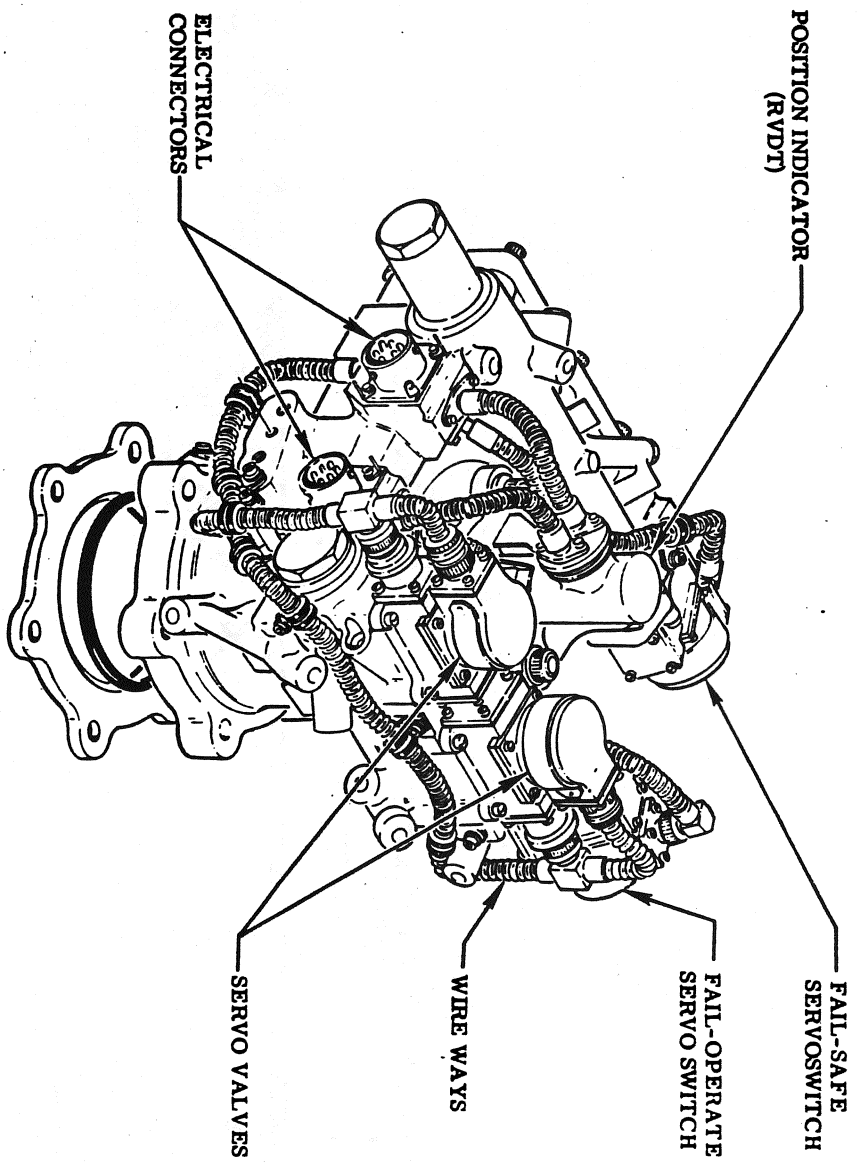


Figure 2-47. Propellant Valve Hydraulic Actuator

hydraulic fluid pressure to rotary motion of the actuator shaft as a function of electrical input command.

2.2.3.10.10.1 Two servovalves, which are integral parts of each servoactuator, convert the electrical command signal from the engine controller to hydraulic flow to position the valve actuator. The dual servovalves provide redundancy that permits a single servovalve failure with no change in actuator performance. A fail-operate servoswitch used to automatically select the redundant servovalve upon failure of a single servovalve. A fail-safe servoswitch is used to hydraulically lock up the servoactuator upon failure of both servovalves.

2.2.3.10.10.2 A dual, redundant, Rotary Variable Differential Transformer (RVDT) is connected to the actuator shaft and returns two electrical signals of position to the controller.

2.2.3.10.10.3 All actuators are capable of utilizing an emergency shutdown system to pneumatically close the propellant valves. Pneumatic sequence valves in the oxidizer and fuel preburner actuators provide for a proper closing sequence of the propellant valves during an emergency shutdown condition. A pneumatic sequence valve in the chamber coolant valve actuator is used to terminate the engine postshutdown purges.

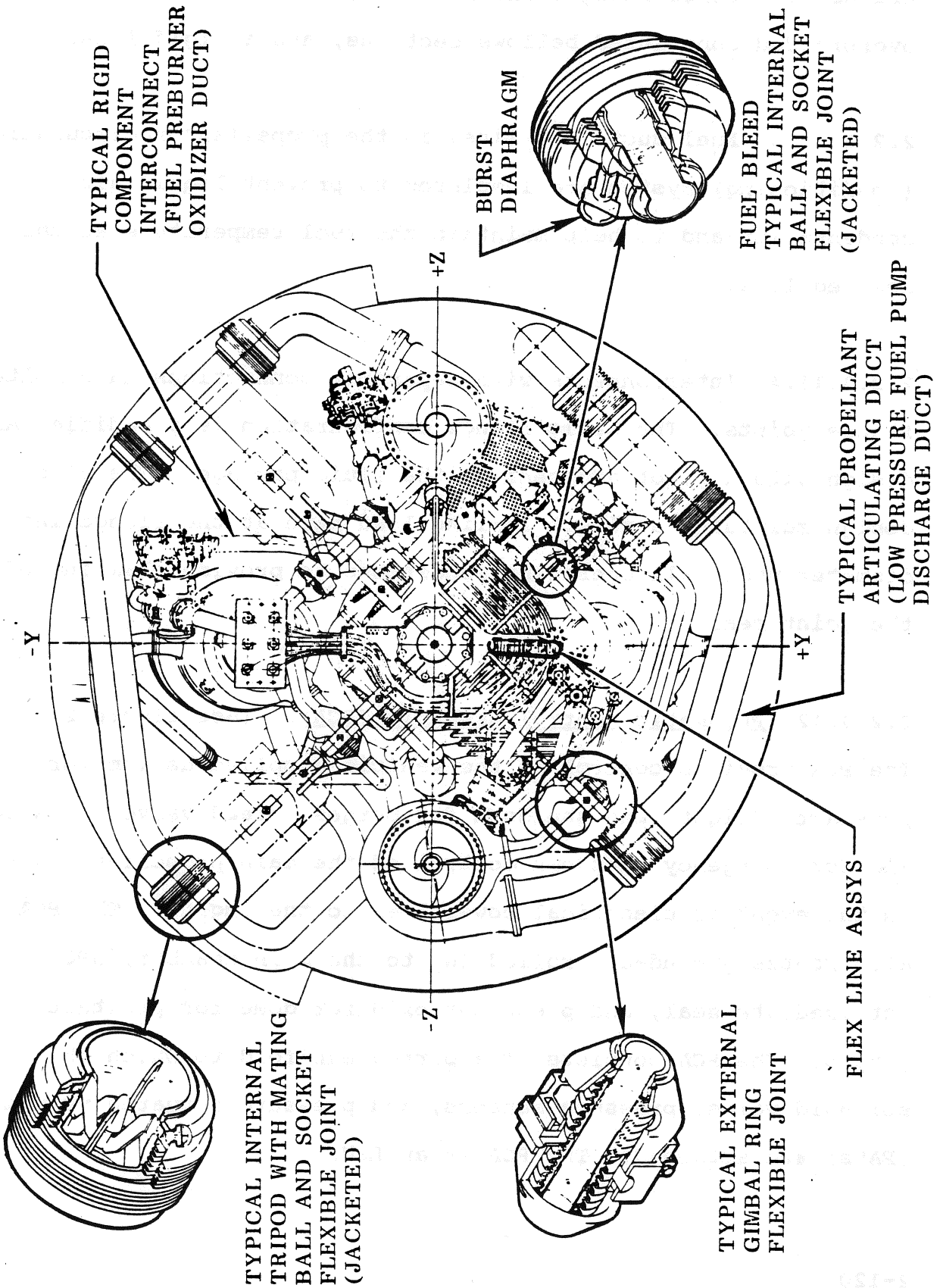
Operating Parameters

Supply pressure, psig	700 to 3100
Return pressure, psig	200 nom, 250 max
Flowrates, gpm:	
Steady state	2.5 min
Transient	12

2.2.3.11 Interconnects. (See figure 2-48.) Engine interconnects are divided into three categories: main propellant articulating ducts, fluid interface lines, and component interconnects.

2.2.3.11.1 Main propellant articulating ducts interconnect the low-pressure turbopumps, which do not gimbal, to components of the engine that gimbal. The ducts wraparound, having both rigid and flexible sections. The flexible sections consist of a convoluted bellows, a bellows sleeve, and a tension restraint. Three types of tension restraints are used. One restraint has external yokes and a gimbal ring with shear pins, another has internal tripods with a mating ball and socket, and the third has an internal ball and socket.

2.2.3.11.2 Fluid interface lines are the vehicle-to-engine interface lines for recirculation of propellants, propellant tank pressurants, hydraulics, and pneumatics. Three types of lines



TYPICAL RIGID
COMPONENT
INTERCONNECT
(FUEL PREBURNER
OXIDIZER DUCT)

BURST
DIAPHRAGM

FUEL BLEED
TYPICAL INTERNAL
BALL AND SOCKET
FLEXIBLE JOINT
(JACKETED)

-Y

+Z

TYPICAL PROPELLANT
ARTICULATING DUCT
(LOW PRESSURE FUEL PUMP
DISCHARGE DUCT)

+Y

FLEX LINE ASSYS

-Z

TYPICAL INTERNAL
TRIPOD WITH MATING
BALL AND SOCKET
FLEXIBLE JOINT
(JACKETED)

TYPICAL EXTERNAL
GIMBAL RING
FLEXIBLE JOINT

Figure 2-48. Interconnects

are used: articulating flexible ducts, flexible lines with overbraided convoluted bellows sections, and a rigid line.

2.2.3.11.3 Fuel ducts and lines in the propellant recirculation (conditioning) system are insulated to prevent liquid air condensation and to help maintain the fuel temperature at the desired level.

2.2.3.11.4 Interconnects with separable connections have bolted flange joints. The basic flange configuration is a modified ASME design with a pilot adjacent to the fluid passage. The pilot design maintains a direct in-line load path at the flange inside diameter under all operating conditions to provide clamping of the joint seal.

2.2.3.12 Pneumatic Control Assembly (PCA). (See figure 2-49.)

The PCA provides control of the vehicle-supplied helium for prestart, flight, and shutdown for purges, bleed valve operation, and for emergency shutdown control of the main propellant valves in the event of electrical power loss to the engine. The PCA also routes ground-controlled GN₂ to the main chamber, HPOT intermediate seal, and preburner oxidizer dome for prestart purges. The PCA consists of a ported manifold to which the solenoid valve, pressure sensors, and pressure-actuated valves (PAVs) are attached. The PCA is an LRU.

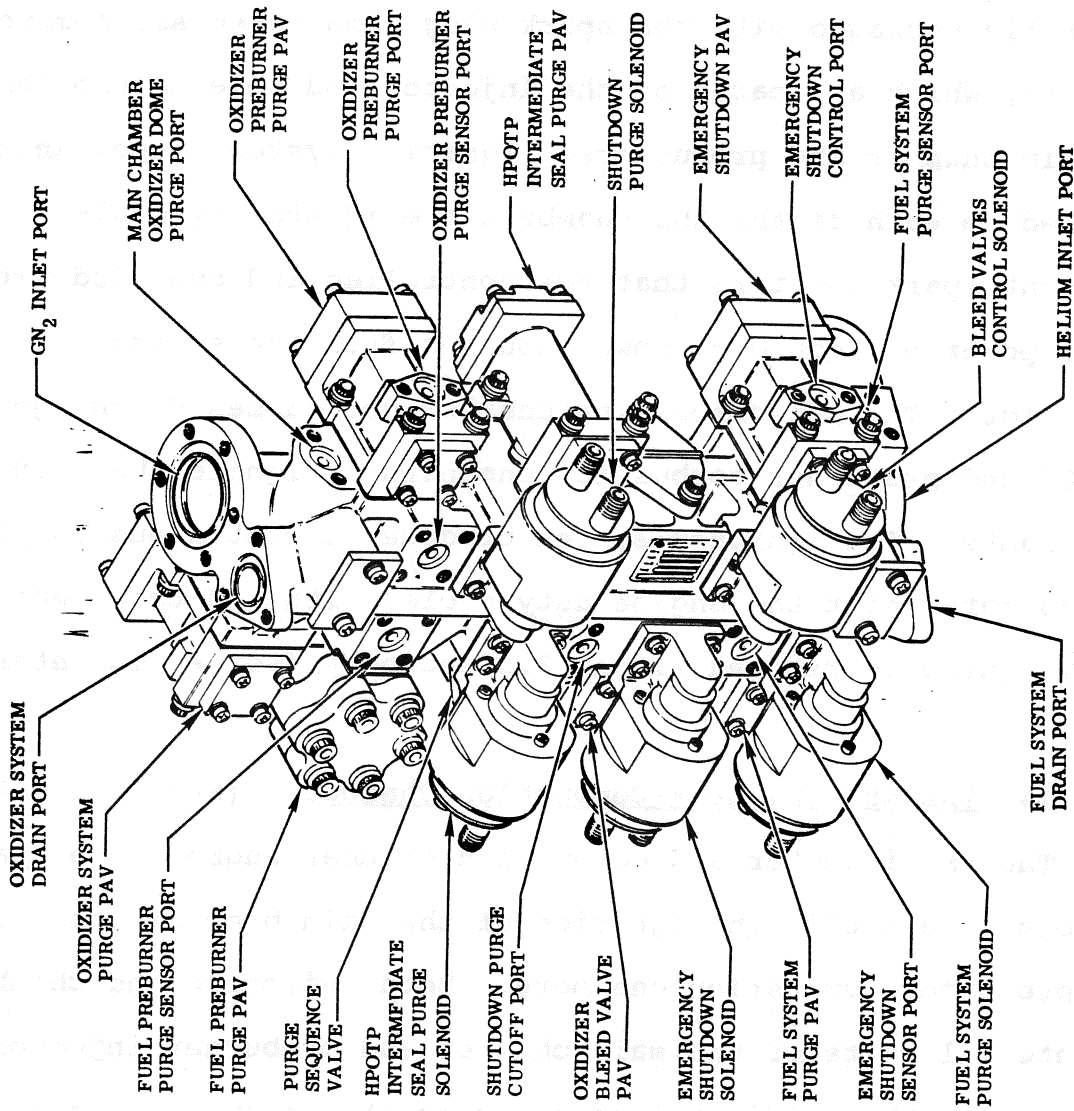


Figure 2-49. Pneumatic Control Assy-Flight Configuration

2.2.3.13 Ignition System. (See figure 2-50.) The ignition system is an ASI-type that initiates combustion of main propellants in the main combustion chamber and in the fuel preburner and oxidizer preburner. The system consists of six spark igniters, which have the spark exciter electronic circuitry integrally packaged with the spark plug, and three ASI combustion chambers, which are parts of the injector and dome assemblies of the main chamber and preburners. Ignition system propellants supplied to each of the ASI chambers are ignited by dual-redundant spark igniters that are controlled and supplied with 28V dc power by redundant power sources from the engine controller. The ASI combustion chamber hot gasses discharge into the MCC and preburner combustion chambers to ignite the main propellants. The ignition system produces a continuous supply of hot gas throughout the engine duty cycle, although the electrical energy source is removed within 3.5 seconds after engine start.

2.2.3.14 The ASI Injector/Combustion Chamber. (See figure 2-51.) The ASI injector and combustion chamber augment the spark igniters in establishing ignition of the main propellants for the main preburner combustion chambers. Both injectors and chambers are integral parts of the main chamber and preburner injector assemblies. The oxidizer injector consists of two orifices, 180° apart, that direct the ASI oxidizer into the centerline of the ASI chamber at the plane of the spark igniter electrodes.

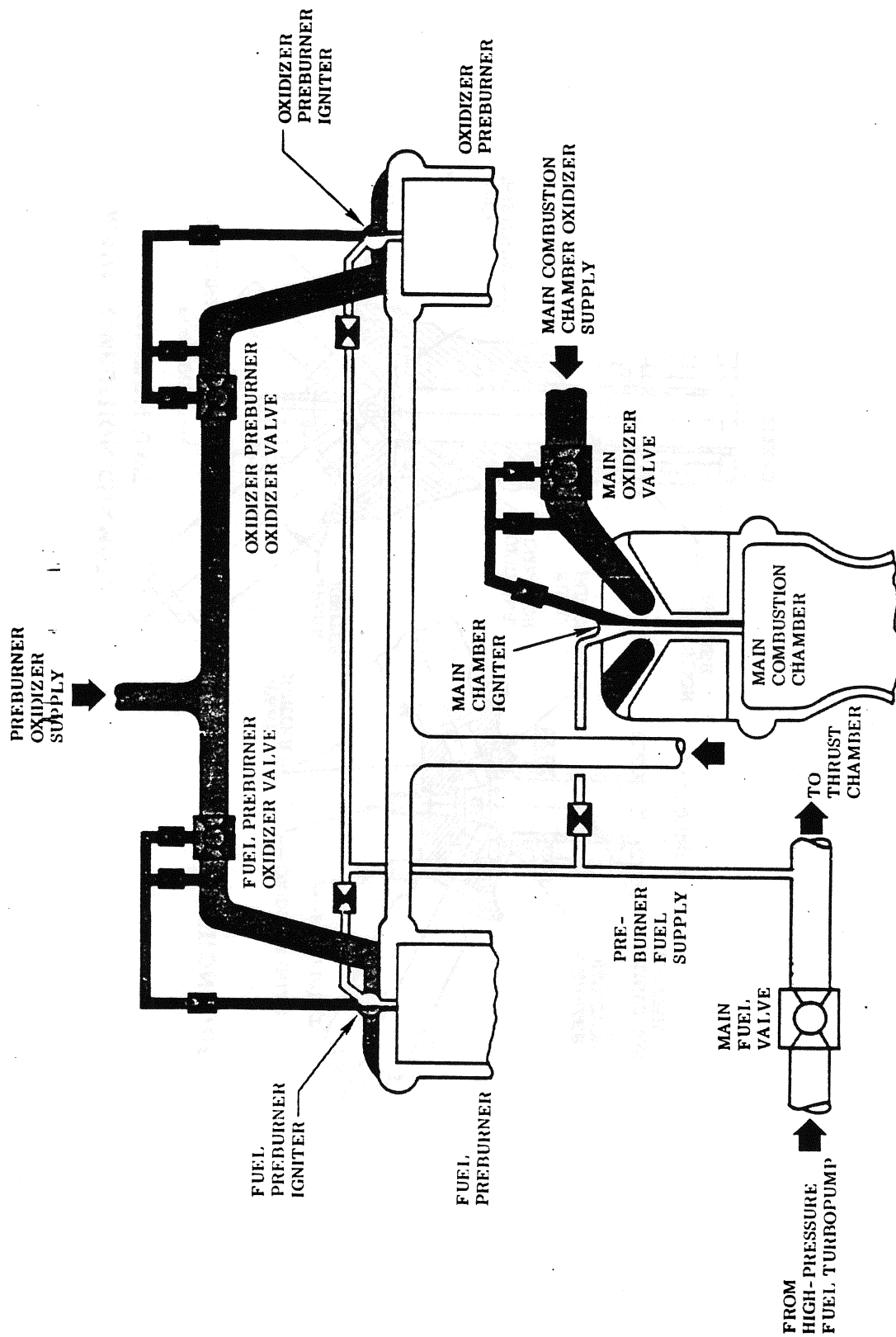


Figure 2-50. Ignition System Schematic

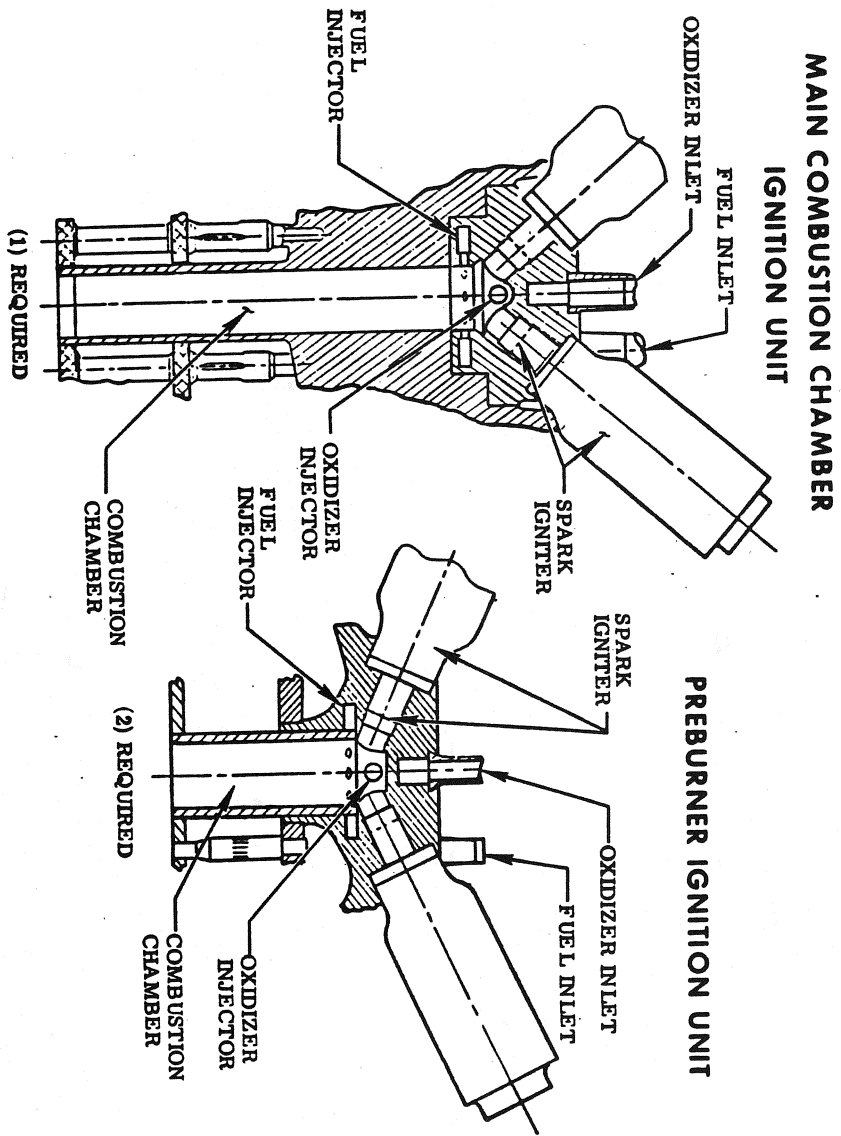


Figure 2-51. ASI Injector/Combustion Chamber

2.2.3.14.1 Eight orifices comprise the fuel injector, directing the ASI fuel tangentially into the ASI combustion chamber at a plane approximately 0.5 inches downstream of the oxidizer orifices. This injection flow pattern creates an oxidizer-rich condition in the vicinity of the spark igniter electrodes prior to ignition. After ignition, the flow pattern develops is not a relatively low mixture ratio environment around the spark igniter electrodes and an oxidizer-rich core along the combustion chamber length surrounded by a fuel-rich zone that protects the ASI combustion chamber walls.

2.2.3.15 Spark Igniter. (See figure 2-52.) The spark igniter is a dual-series-gap, high-voltage, inductive-discharge sparking device that ignites the propellants supplied to the ignition system. The spark igniter combines a spark plug and spark exciter electronics in an integral, hermetically sealed unit that transforms a low-level 28V dc input into a 10-kV output at a minimum of 50 sparks per second.

2.2.3.15.1 The dual-surface spark gaps are in series and are formed by the center electrode and intermediate electrode, and by the intermediate electrode and outer electrode (igniter housing). Two igniters are installed in threaded ports of the ASI chambers. A captive Naflex seal, which is retained by an elastomeric seal that ensures positive seal placement during installation, seals the interface of igniter and ASI chamber. The elastomeric seal

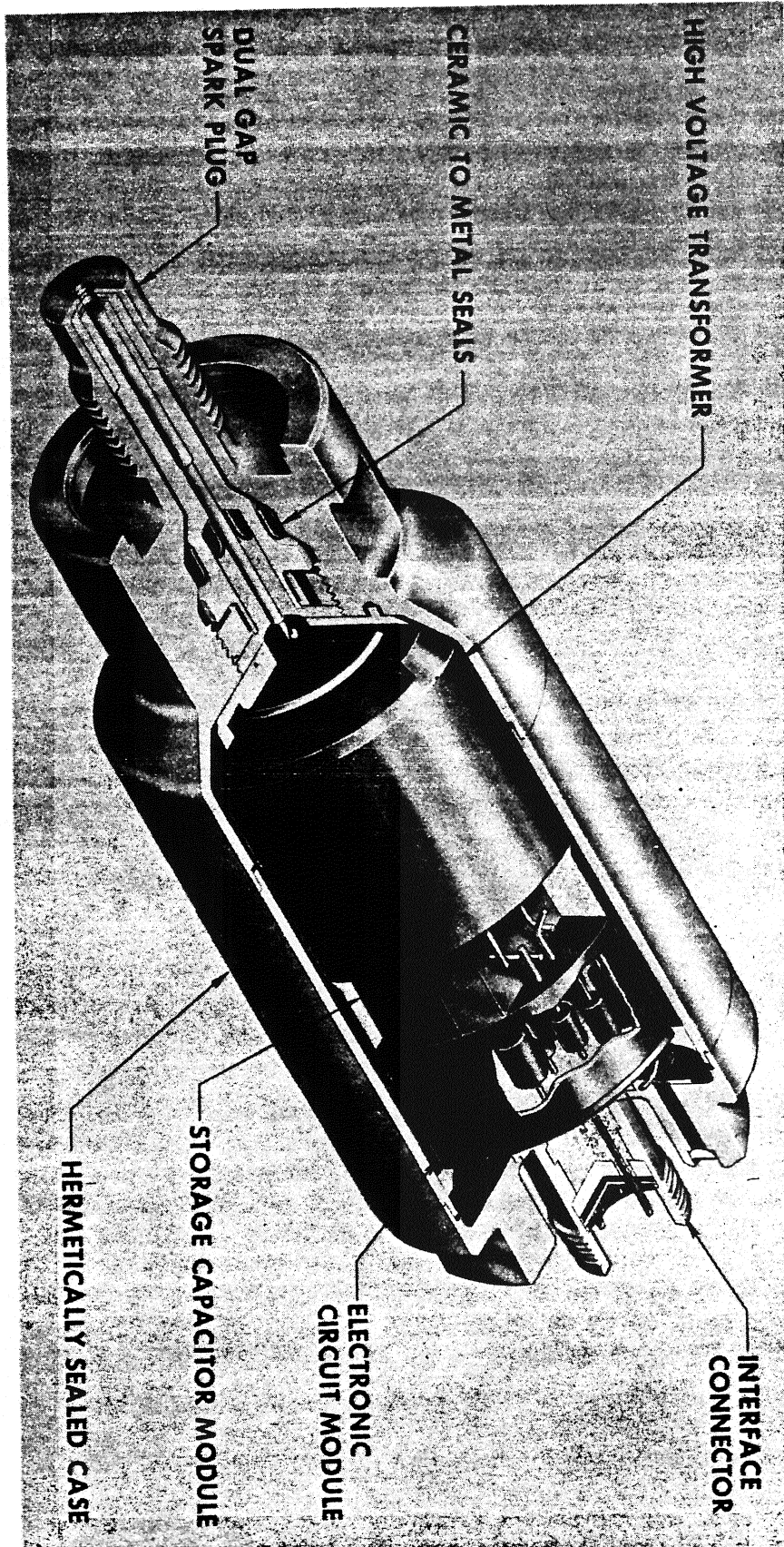


Figure 2-52. Spark Igniter

serves as a secondary seal, and the area between the two seals is ported to a monitoring port to permit the measurement of leakage past the Naflex seal. The unit is an LRU and is approximately 5.75 inches long and 2.0 inches at its maximum diameter.

2.2.3.16 Gimbal Bearing. (See figure 2-53.) The gimbal bearing assembly is a spherical, low-friction, universal joint that has ball and socket bearing surfaces. The bearing assembly provides the mechanical interface with the vehicle for transmitting thrust loads and permits angulation of the actual thrust vector about each of two vector-control axes. The gimbal bearing is attached to the engine main injector thrust cone by 10 bolts through offset bushings that allow lateral positioning of the bearing. The gimbal bearing position is established by optical alignment during engine building to ensure that the actual thrust vector is within 30 minutes of arc to the engine centerline and 0.60 inches of the gimbal center. Cyclic life is obtained by low-friction, antigalling bearing surfaces that operate under high loads. The assembly has an overall dimensional envelop of approximately 11.3 by 14 inches.

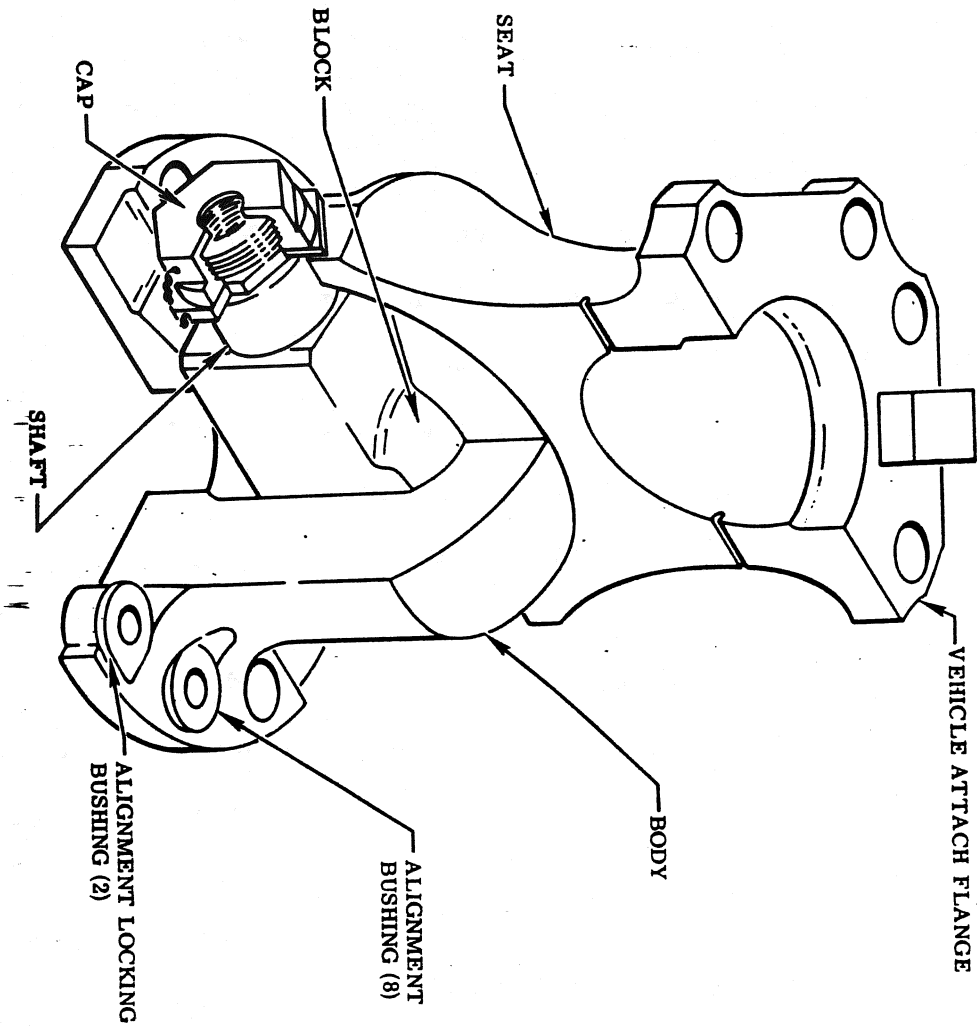


Figure 2-53. Gimbal Bearing Assembly

2.2.4 POWER REQUIREMENTS.

2.2.4.1 Electrical. Electrical power required for SSME processing varies according to the individual system. The paragraphs below differentiate between the separate systems and their own distinct electrical power requirements.

2.2.4.1.1 Main Fuel Valve Heaters. The MFV heaters are powered by 28 Vdc, 10 amps.

2.2.4.1.2 LH₂ Recirculation pumps. These pumps require 28 Vdc, 400 Hz electrical power for operation.

2.2.4.1.3 GN₂ Heater System. The GN₂ heater system requires 28 Vdc, 480 volts, 150 amps, 3 ϕ electrical power.

2.2.4.1.4 GSE Panels. Electrical power used for the various ground support equipment panels utilized during SSME processing is described below.

2.2.4.1.4.1 GN₂ Purge Panels.

End Item Control #	Location	Power Requirement
S72-1107-01	MLP	28 Vdc internal
S70-0679-06	OPF	28 Vdc internal

2.2.4.1.4.2 Low Pressure He Activation Panel.

End Item Control #	Location	Power Requirement
S70-0695-02	OPF	28 Vdc internal

2.2.4.1.4.3 High Pressure He Activation Panel.

End Item Control #	Location	Power Requirement
S70-0695-08	OPF	28 Vdc internal

2.2.4.1.4.4 He Activation Panel - MLP.

End Item Control #	Location	Power Requirement
S72-0685-01	MLP	28 Vdc internal

2.2.4.1.5 Hardwire Safing Functions. Each of the hardwire safing functions listed below uses 28 Vdc electrical power.

- A. MLP/Orbiter Aft Heat Shield Spray.
- B. GN₂ Purge Pressure Measurement.
- C. LH₂ Recirculation Pumps Cutoff.
- D. SSME Timing Module.

2.2.4.2 Pneumatic Power. (See figure 2-54.)

2.2.4.2.1 Valves. All of the following valves are driven by 750 PSIG He, regulated from the Pneumatic Control Assembly (PCA):

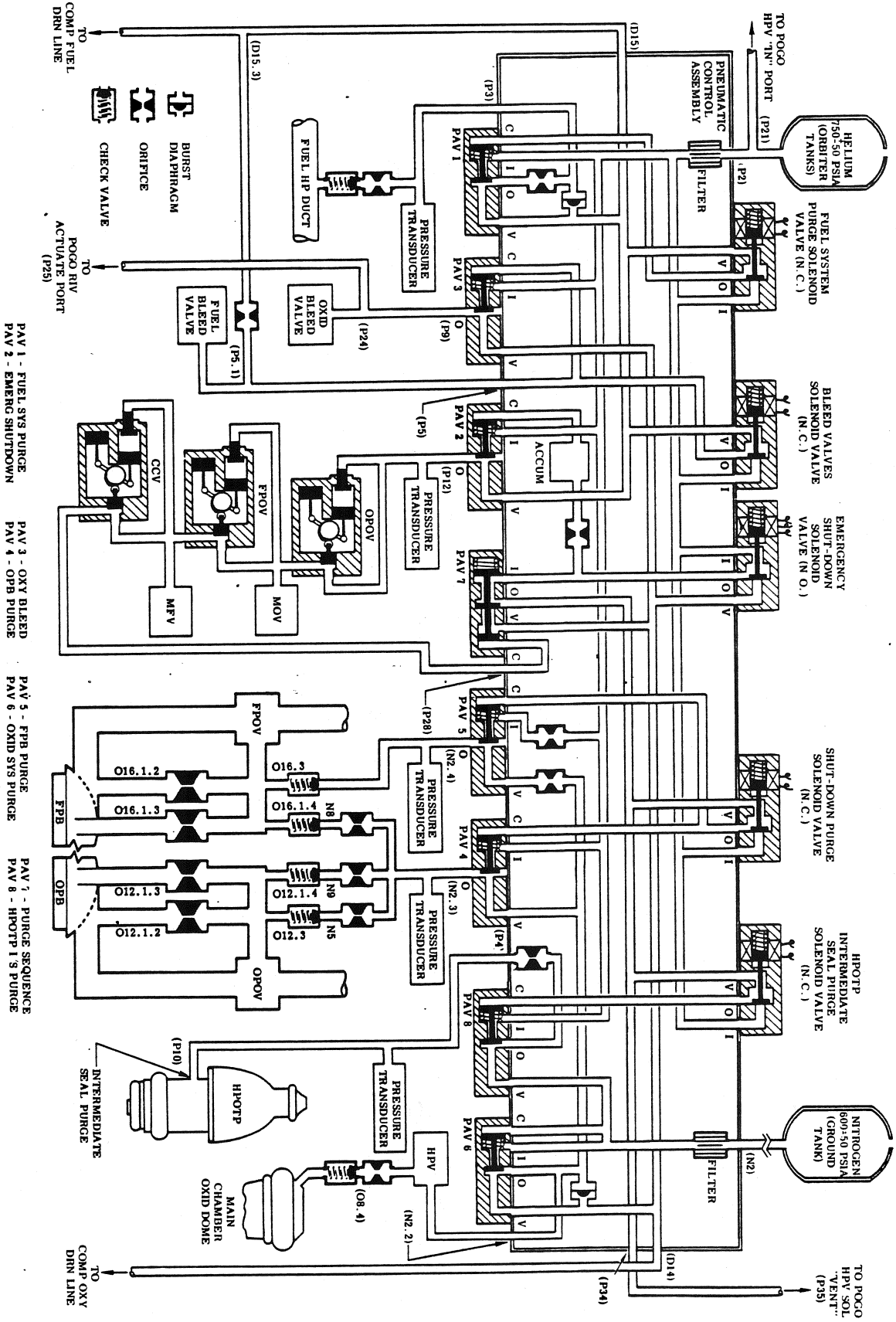
- A. Main Fuel Valve (MFV)
- B. Main Oxidizer Valve (MOV)
- C. Oxidizer Pre-burner Oxidizer Valve (OPOV)
- D. Fuel Pre-burner Oxidizer Valve (FPOV)
- E. Chamber Coolant Valve (CCV)

2.2.4.3 Hydraulic Power. All hydraulic requirements are identified in ICD-13M15000 - SSME Interface Control Document.

2.2.4.3.1 Valves and Actuators. All of the following valves and actuators are driven by 2700 - 3100 psig of MIL-H-83282B hydraulic servicing fluid, regulated from hydraulic isolator valves and accumulators:

- A. Main Fuel Valve (MFV)
- B. Main Oxidizer Valve (MOV)
- C. Oxidizer Pre-burner Oxidizer Valve (OPOV)
- D. Fuel Pre-burner Oxidizer Valve (FPOV)
- E. Chamber Coolant Valve (CCV)
- F. Thrust Vector Control (TVC) Actuators (pitch and yaw)

DEPICTS: NO POWER-NO PRESSURE APPLIED



- PAV 1 - FUEL SYS PURGE
- PAV 2 - EMERG SHUTDOWN
- PAV 3 - OXY BLEED
- PAV 4 - OPB PURGE
- PAV 5 - FPB PURGE
- PAV 6 - OXID SYS PURGE
- PAV 7 - PURGE SEQUENCE
- PAV 8 - HPOTP I'S PURGE

Figure 2-54. SSME Pneumatic Schematic (Sheet 1 of 5)

DEPICTS: GROUND CONTROLLED GN² PURGE

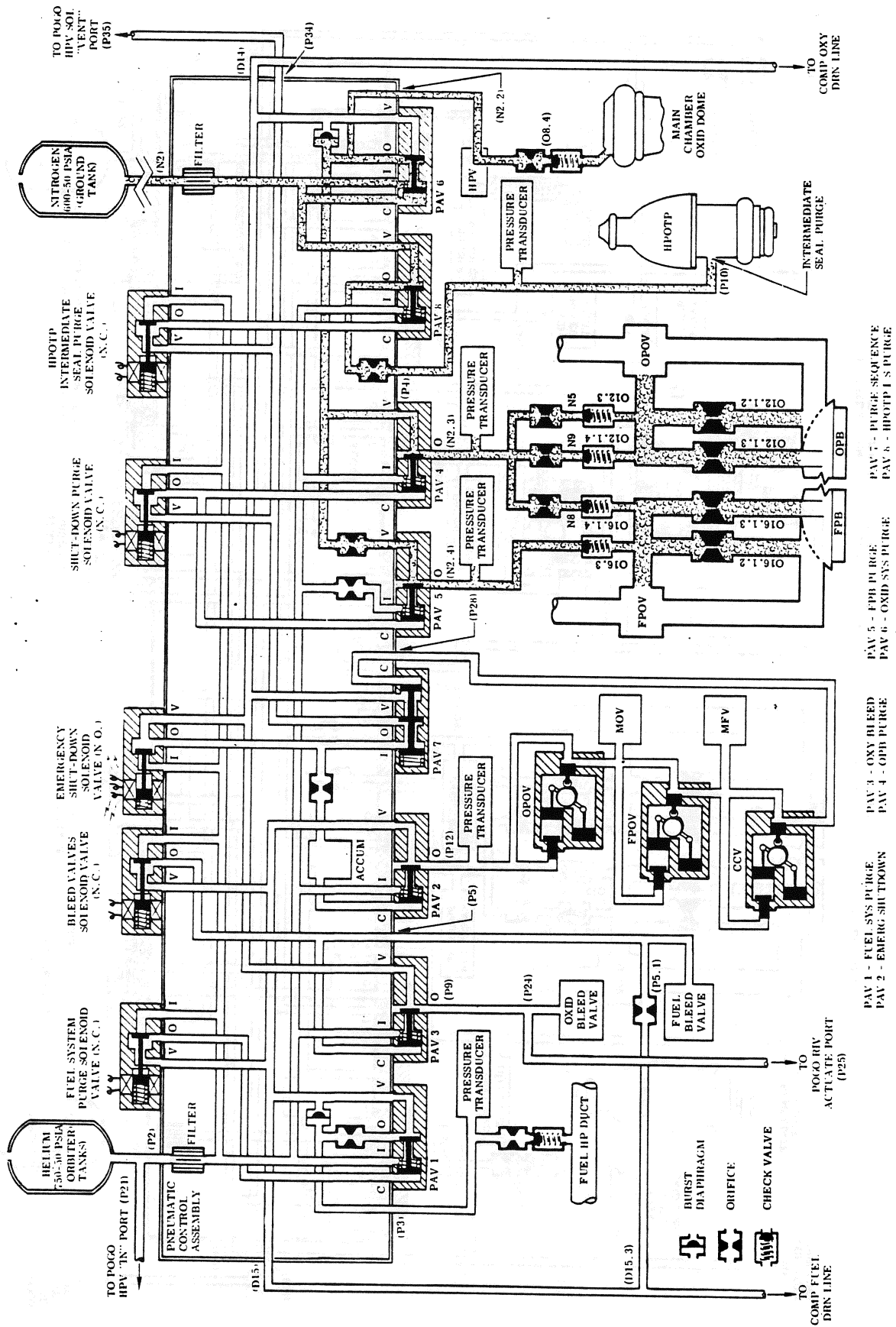
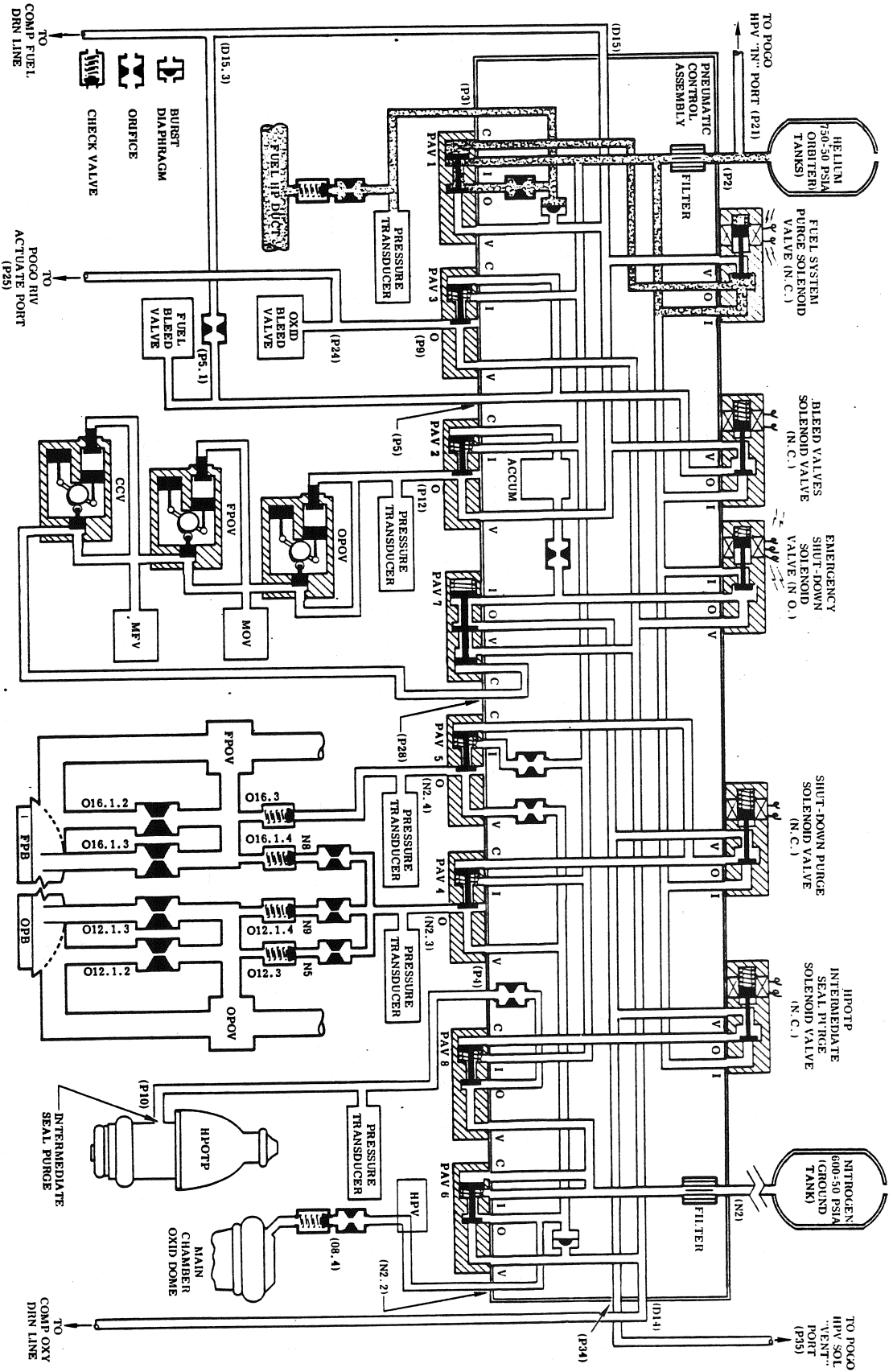


Figure 2-54. SSME Pneumatic Schematic (Sheet 2 of 5)

- PAV 1 - FUEL SYS PURGE
- PAV 2 - EMERG SHUTDOWN
- PAV 3 - OXY BLEED
- PAV 4 - OPB PURGE
- PAV 5 - FPH PURGE
- PAV 6 - OXID SYS PURGE
- PAV 7 - PURGE SEQUENCE
- PAV 8 - HIPOTP PURGE

DEPICTS: FUEL SYSTEM PURGE



- PAV 1 - FUEL SYS PURGE
- PAV 2 - EMERG SHUTDOWN
- PAV 3 - OXY BLEED
- PAV 4 - OXP PURGE
- PAV 5 - FPB PURGE
- PAV 6 - OXID SYS PURGE
- PAV 7 - PURGE SEQUENCE
- PAV 8 - HPOTP I S PURGE

Figure 2-54. SSME Pneumatic Schematic (Sheet 3 of 5)

2.2.5 FLUIDS. Knowledge of fluids and their associated hazards is essential to the System engineer. Though the following paragraphs provide basic information about these substances, the System Engineer is encouraged to research these liquids further as a complete product description would go beyond the scope of this handbook.

2.2.5.1 LO₂. High purity liquid oxygen is an odorless, light blue, transparent liquid. Due to its low boiling point, it is usually boiling vigorously. As a result, the exterior of uninsulated containers is normally frosted.

2.2.5.1.1 Chemical Properties. In either gaseous or liquid form, oxygen is a strong oxidizer which vigorously supports combustion. Liquid oxygen can be mixed with liquid nitrogen and methane. Light hydrocarbons are usually soluble in liquid oxygen. For example, acetylene is soluble to approximately 4 ppm. Most common solvents are solid at liquid oxygen temperatures. Liquid oxygen is chemically stable and will not decompose; nor is it shock sensitive. At ordinary temperatures in properly designed containers, its 24 hour evaporation rate may be as low as 1.4 percent in a 450 gallon container or 0.4 percent in a 1,350 gallon container.

2.2.5.1.2 Physical Properties. The physical properties of LO₂ are presented in Table 2-1.

2.2.5.1.3 Toxicity. Inhalation of very cold oxygen gas may irritate the upper respiratory tract. Liquid oxygen spilled on the skin will result in a burn-like injury.

2.2.5.1.4 Fire. Though liquid oxygen does not burn, it does vigorously support combustion.

2.2.5.1.5 Types. Fuel and liquid oxygen detonate upon ignition. If liquid oxygen is introduced after a fire has started, flare combustion results, accompanied by repeated explosions.

2.2.5.1.6 Control. Procedures for extinguishing fires involving liquid oxygen vary with the circumstances of the fire. Fires resulting from small spills on combustible materials should be extinguished with water. Any oxygen flow to the fire should first be stopped.

2.2.5.1.6.1 When LO_2 flows into large quantities of fuel, the oxygen flow should be stopped and the remaining fire extinguished with Class B firefighting agents. When fuel flows into large quantities of oxygen, the fuel flow should be stopped. Water should be used to dilute water-soluble fuels and to reduce the intensity of the fire. This method cannot be used with fuels which do not mix with water. Appropriate extinguishing agents should be used to put out fuel fires after the oxygen has evaporated.

2.2.5.1.6.2 If fuel and LO₂ mix but are not burning, all ignition and shock sources should be removed and the area evacuated until the oxygen evaporates.

2.2.5.1.7 Explosion. When mixed with liquid oxygen, combustible materials, especially rocket fuels, represent an explosive hazard. These mixtures can be exploded by static electricity, mechanical shock, electrical spark, and similar energy sources. Mixtures of frozen fuel and liquified oxygen are particularly explosive.

2.2.5.1.8 Personnel Protection. The principal hazards concerning the handling of liquid oxygen are inhalation of cold vapor and exposure of skin to the cryogenic liquid.

2.2.5.1.9 Hands and Feet. Personnel should wear gloves. The gloves should fit loosely for easy removal in case liquid oxygen enters them. High-top leather footwear should be worn. Pant legs shall be worn outside and over the shoe tops.

2.2.5.1.10 Head, Face, and Body. Handlers of liquid oxygen should wear acid-protective goggles or a face shield, such as a nitrometer mask or hood, that protects against splashes from all directions. Flame retardant coveralls should be worn.

2.2.5.1.11 Respiratory System. Respiratory protection is not required.

2.2.5.1.12 First Aid. The immediate effects of freezing by liquid oxygen can be minimized by soaking the affected area in tepid water. Extensive burns require prompt medical attention.

2.2.5.1.13 Storage and Transfer. All operations involving the handling of liquid oxygen should be performed by two or more persons. Potentially hazardous activities should be supervised by personnel who are thoroughly familiar with the properties and hazards of liquid oxygen, its handling procedures, operation of proper equipment, use and care of protective equipment, safety measures, and first aid.

2.2.5.1.13.1 Tanks, piping, and equipment must be clean and free of grease or oil. Storage, transfer, and test areas should be kept free of trash and combustibles. Deluge-type personnel showers should be conveniently located for immediate use in an emergency.

2.2.5.1.14 Storage. Containers and cylinders of liquid oxygen must be adequately vented. Vents should be checked periodically to ensure that they are not plugged with ice. Containers and cylinders must be stored in well-ventilated areas. Uninsulated containers should be stored in an open-sided structure with a

she-type roof. Pressure rupture of system equipment can be avoided by periodically checking to ensure that refrigeration and vacuum insulation is maintained.

2.2.5.1.15 Handling. Liquid oxygen should be transferred slowly to avoid splashing and excessive pressures, and to minimize thermal stresses in the receiving vessel from the cold oxygen. A funnel should be used to pour liquid oxygen into small containers. The top of the funnel should be partly covered to reduce splashing.

2.2.5.1.15.1 If it is not safe to tilt the container, a discharge tube should be used. The tube should be inserted well into the liquid, and the packing material or tube stopper should seal the neck of the container. If normal evaporation does not produce adequate pressure for sustained withdrawal, the container may be pressurized with CO_2 or He. Minimum pressure should be applied.

Table 2-1. Physical Properties of LO₂.

PROPERTY	VALUE
Boiling Point	-297.4 °F
Freezing Point	-361 °F
Density at -297.4 °F Liquid (lb/gal)	9.527 -181.1
Vapor Pressure	
-181.8 °F	716
-200 °F	480
-240 °F	155
-280 °F	29
-297.4 °F	0
Viscosity at -297.4 °F (centipoise)	0.19

2.2.5.2 Nitrogen (N₂). N₂ can be a colorless gas, colorless liquid, or cubic crystals at low temperatures. Physical Properties of N₂ are listed in table 2-2.

Table 2-2. Physical Properties of N₂.

PROPERTY	VALUE
Boiling Point	-195.8 °F
Density at -195.8 °F, liquid (lb/ft ³)	0.808
Density at 32 °F, gas (g/l)	1.2506

2.2.5.3 LH₂. High purity LH₂ is a transparent, colorless, odorless liquid. When observable, LH₂ is usually boiling vigorously due to its low boiling point. When exposed to the atmosphere, LH₂ creates a voluminous vapor cloud.

2.2.5.3.1 LH₂ is noncorrosive. LH₂ forms combustible mixtures with oxidizers. GH₂ is combustible with air over a wide range of mixtures. LH₂ and GH₂ ignite spontaneously with either liquid or gaseous fluorine and chlorine trifluoride.

2.2.5.3.2 LH₂ is chemically stable. Because of its low boiling point, LH₂ is physically stable only when stored under suitable conditions. When stored in the LH₂ storage tank, the allowable 24 hour evaporation rate is 0.075% or less.

2.2.5.3.3 All known substances are essentially insoluble in LH₂. He is slightly soluble (about 1 percent in pressurized liquid storage tanks).

2.2.5.3.4 Physical Properties. See table 2-3 for the physical properties of LH₂.

Table 2-3. Physical Properties of LH₂

PROPERTY	VALUE
Boiling Point	- 423.2° F
Freezing Point	- 435° F
Density at -423° F	
Liquid (lb/gal)	0.59
Vapor (lb/ft ₃)	0.083 (1.02 times heavier than air at -423° F)
Density at 32° F, gas (lb/ft ₃)	0.005 (14.5 times lighter than air at 32° F)
Emissivity of Flame	0.085
Autoignition Temperature	1075° F
Flammability Limits in Air, by Volume (GH ₂)	4.0% to 74.2%
Flammability Limits in Oxygen, by Volume (GH ₂)	4.6% to 93.9%
Viscosity at -423° F	140 micropoises
Critical Temperature	-400° F
Critical Pressure	188 psia
Vapor Pressure	
-433° F	-12.8 psig
-423° F	0 psig
-420° F	9.0 psig
-402° F	147.3 psig

2.2.5.4 Helium (He). As an inert gas, He is colorless, odorless, and tasteless. As a liquid, He cannot be solidified by lowering the temperature (He is the only liquid with this property). He remains liquid down to absolute zero at ordinary pressures, but it can readily be solidified by increasing the pressure. Physical properties of He are listed in table 2-4.

Table 2-4. Physical Properties of He.

PROPERTY	VALUE
Boiling Point	-452 °F
Density at -452 °F, liquid (lb/ft ³)	7.62
Density at 32 °F, gas (g/l)	0.1785

2.2.6 CONTROLS AND INDICATORS.

2.2.6.1 Main Engine Status and Shutdown. (See figure 2-55 and tables 2-5 and 2-6.) The main engine status lights are located on panel F7, the shutdown switches on panel C3 on the Flight Station lower console.

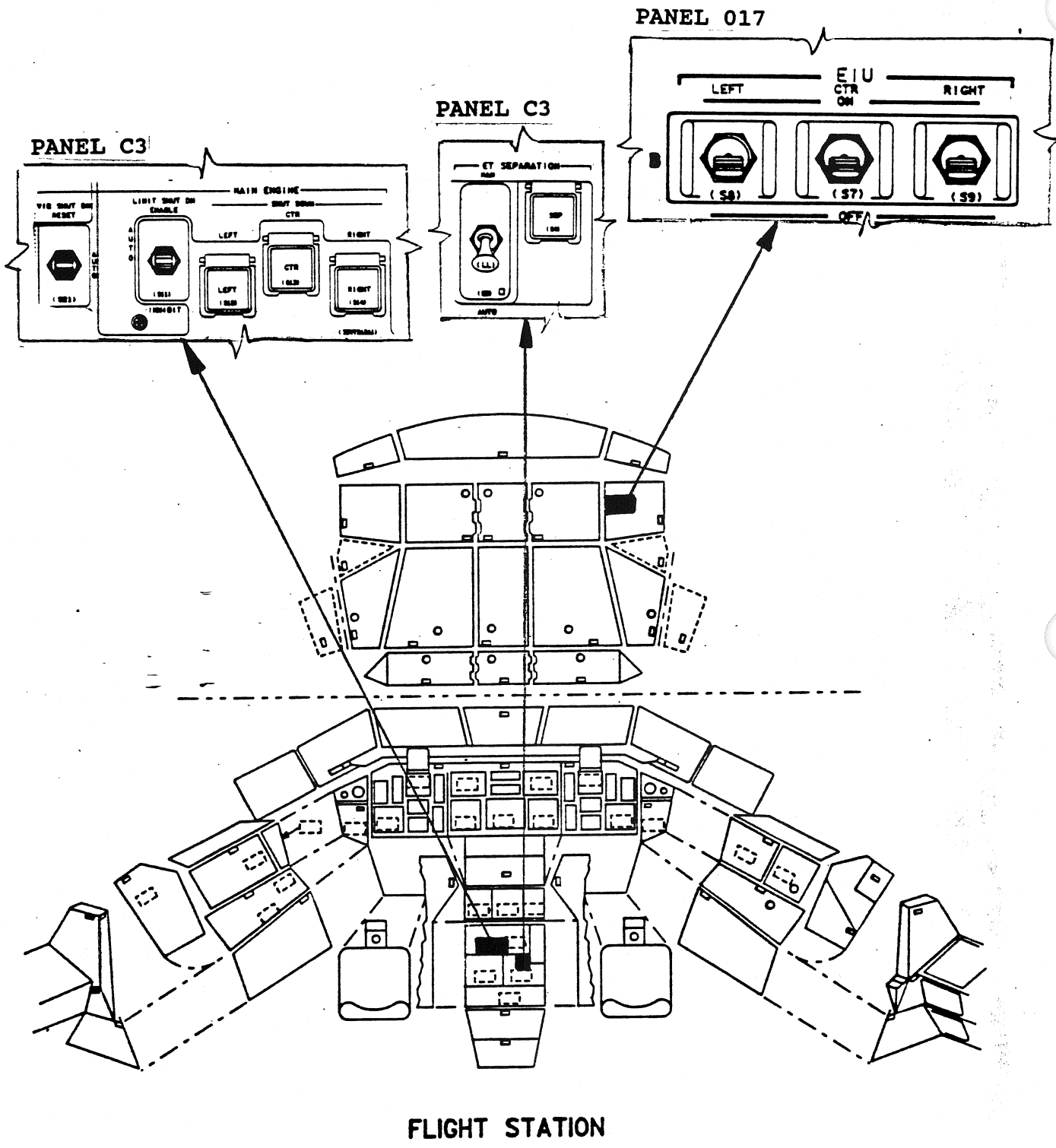


Figure 2-55. SSME Controls and Indicators

Table 2-5. Main Engine Status (Panel F7).

Nomenclature/ position	Function	Remarks
<p>MAIN ENGINE STATUS LEFT lt</p> <p>red</p> <p>off</p> <p>amber</p>	<p>Any engine shutting down will cause the corresponding red status light to be illuminated.</p> <p>When the previously defined parameters are within limits, during prelaunch, when the corresponding engine is in mainstage phase, or after ET structural separation.</p> <p>Indicates any of the following conditions:</p> <ol style="list-style-type: none"> 1. Loss of data from both pairs of sensors for fuel flow rate. 2. Electronic hold. 3. Hydraulic lockup. 4. Loss of 2 or more channels from the SSMEC: 5. Loss of both data channels to the SSMEC. 	<p>Upper half of each indicator is red, lower half is amber. Determined on an individual basis.</p>
<p>MAIN ENGINE STATUS CTR lt</p>	<p>Same as ENGINE STATUS LEFT lt except center engine.</p>	
<p>MAIN ENGINE STATUS RIGHT lt</p>	<p>Same as ENGINE STATUS LEFT lt except right engine.</p>	

Table 2-6. Main Engine Shut Down.

Nomenclature/ position	Function	Remarks
<p>MAIN ENGINE LIMIT SHUT DN sw</p> <p> ENABLE</p> <p> AUTO</p> <p> INHIBIT</p>	<p>Allows any SSME which violates operating limits to be shut down automatically by its own SSMEC.</p> <p>Allows only the first SSME which violates operating limits to be shut down automatically. SSMECs for the two remaining SSMEs cannot shut down their respective SSMEs because of an operating limit violation.</p> <p>Prevents any SSME shutdown automatically as a result of an operating limit violation.</p>	
<p>MAIN ENGINE SHUT DOWN LEFT pb</p>	<p>When depressed during engine burn, causes an immediate shutdown of the corresponding main engine.</p>	<p>Pushbuttons have spring-loaded covers (guards).</p>
<p>MAIN ENGINE SHUT DOWN CTR pb</p>	<p>Same as SHUT DOWN LEFT pb except center engine.</p>	
<p>MAIN ENGINE SHUT DOWN RIGHT pb</p>	<p>Same as SHUT DOWN LEFT pb except right engine.</p>	
<p>MAIN ENGINE VIB SHUT DN sw</p> <p> RESET</p>	<p>Provides signals to the GPCs which enable a second auto shutdown of a main engine due to excess vibration.</p>	<p>Normally in AUTO.</p> <p>Reset function is operational only after an engine has previously shut down. Reset allows for a second shutdown, but not a third</p>

Table 2-6. Main Engine Shut Down (Continued).

Nomenclature/ position	Function	Remarks
AUTO	Provides signals to the GPCs which enable an auto shutdown of an engine (if three are running) due to excess	The auto function allows one engine to shut down, if three of four accelerometers on the high-pressure O ₂ pump sense accelerations >10g. If two engines simultaneously exceed the 10g limit, the shut down sequence is inhibited.
INHIBIT	Provides signals to the GPCs which inhibit any engine from an automatic shutdown due to excess vibration.	

2.2.7 SAFETY REQUIREMENTS.

2.2.7.1 Thrust Chamber Entry. Thrust chamber entry can be very hazardous due to the possibility of toxic levels of GN₂ and He within the chamber. This possibility exists at any time as the thrust chamber is a confined area. Safety Engineering will perform a test for toxic levels of these gases prior to Service Engineer entry.

2.2.8 SOFTWARE.

2.2.8.1 General. (See figure 2-56.) SSME system software is described in detail in KLO-82-0015, Software Specification Document. The paragraphs below briefly describe the basic function of the programs pertinent to SSME processing.

2.2.8.1.1 VAE25 SSME Vehicle Data Table (VDT)/Control (see figure 2-57.) VAE25 allows the operator to select SSME data to display using VAE45, VAE46, and VAE47 for SSMEs 1, 2, and 3 respectively. It processes operator interrupts to display SSME analog data and performs a program to display data in response to an interrupt. If an interrupt occurs during performance of a lower level program, VAE25 must be able to process the interrupt when the lower level program terminates.

2.2.8.1.1.1 VAE45 SSME 1 VDT Monitor. (Refer to figure 2-57.) Called by VAE25, VAE45 monitors SSME 1 measurements and displays them to the operator on skeleton VDE25. Once initialized, VAE45 updates the data display until the operator selects termination or requests display of an alternate data set. The schematic represents one SSME with all components labeled. Cursor interrupt blocks for control of the displayed data are located in the lower left of the skeleton, the termination block in the lower right.

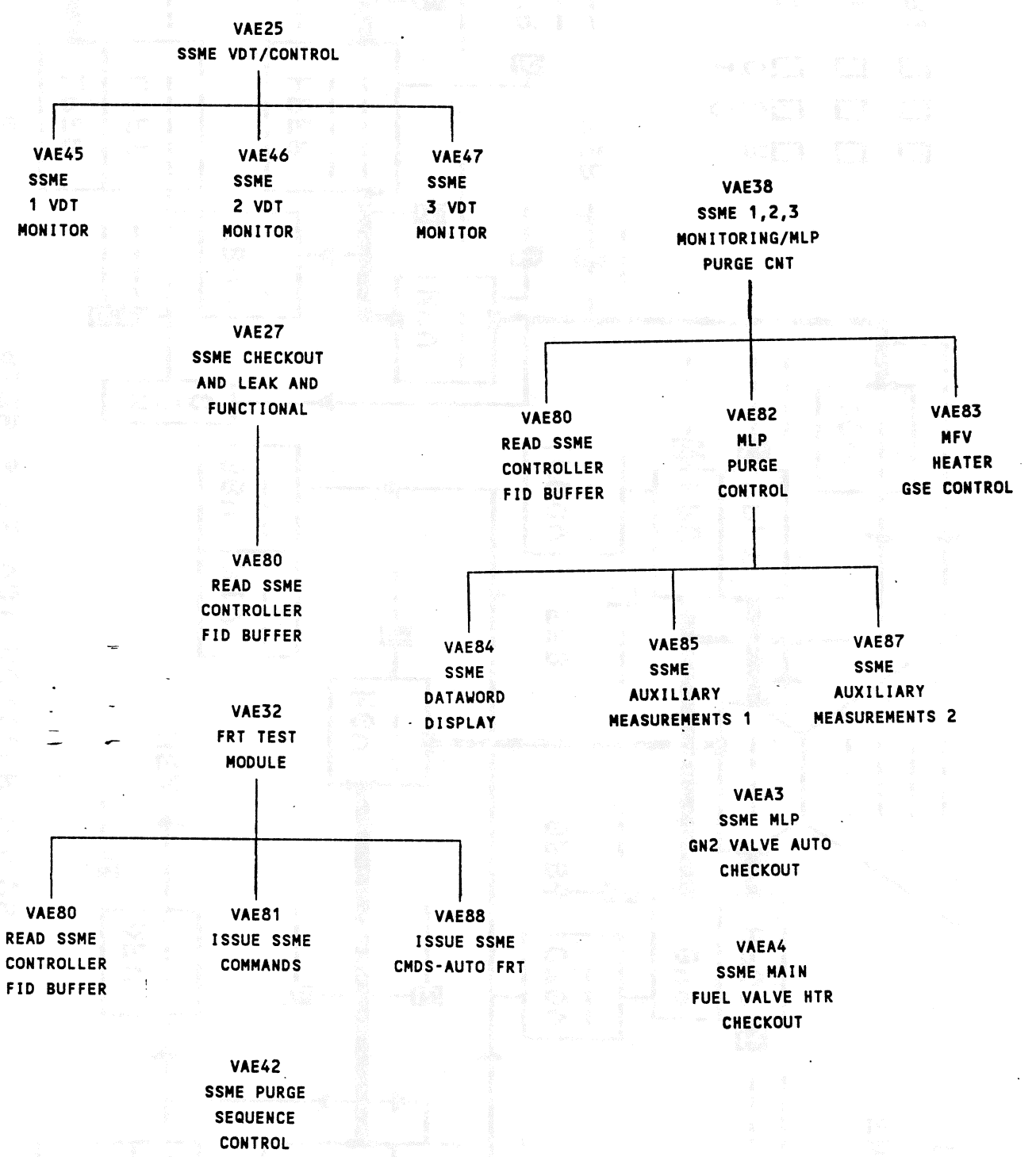


Figure 2-56. SSME Software

272: 06/42 5827RB2 P-08 OCT-88 53/58 HD IN PROGRESS P123456
 SM SA 0123 0123 0123 0123 1AB 2AB 3AB 4AB 5AB 6AB VAE25
 VAE25SKEL VDE05 VAE25 SSME VDT MONITOR VDE25
 26/23 AINT101 VAE25 HAS BEEN INITIATED IN TOB T2 AT B300

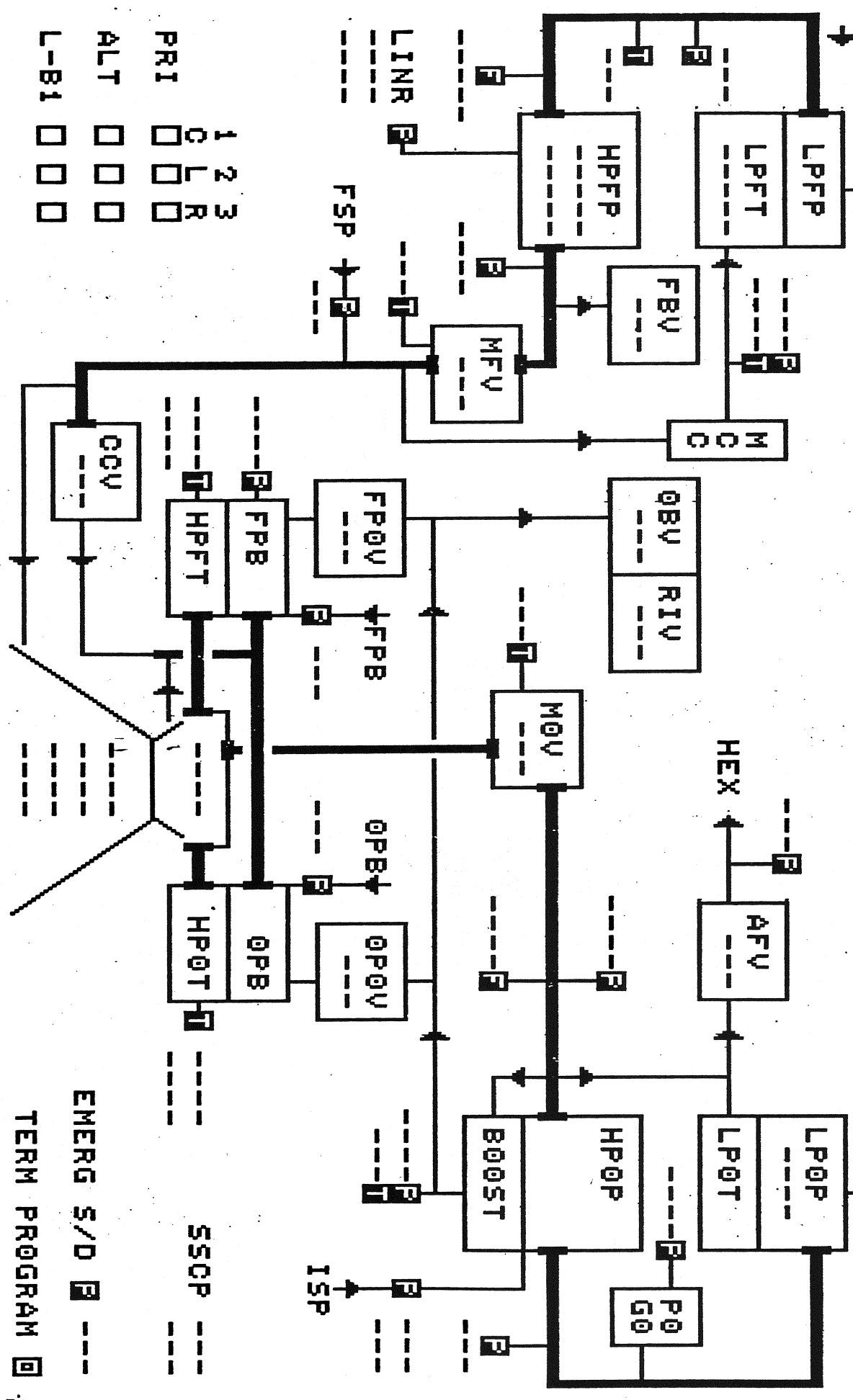


Figure 2-57. VAE25-SSME VDT/Control

Note:

A request for termination of VAE45 will also cause VAE25 to terminate.

2.2.8.1.1.2 VAE46 SSME 2 VDT Monitor. (Refer to figure 2-57.)

Called by VAE25, VAE46 monitors SSME 2 measurements and displays them to the operator on skeleton VDE25. Once initialized, VAE46 updates the data display until the operator selects termination or requests display of an alternate data set. The schematic represents one SSME with all components labeled. Cursor interrupt blocks for control of the displayed data are located in the lower left of the skeleton, the termination block in the lower right.

Note:

A request for termination of VAE46 will also cause VAE25 to terminate.

2.2.8.1.1.3 VAE47 SSME 3 VDT Monitor. (Refer to figure 2-57.)

Called by VAE25, VAE47 monitors SSME 3 measurements and displays them to the operator on skeleton VDE25. Once initialized, VAE47 updates the data display until the operator selects termination or requests display of an alternate data set. The schematic represents one SSME with all components labeled. Cursor interrupt blocks for control of the displayed data are located in the lower left of the skeleton, the termination block in the lower right.

Note:

A request for termination of VAE47 will also cause VAE25 to terminate.

2.2.8.1.2 VAE27 SSME Checkout and Leak and Functional (see figure 2-58.) VAE27 allows the operator to perform SSME checkout tests, cycle SSME pneumatic and hydraulic valves, and issue selected commands to the SSME controllers. Once initialized, VAE27 remains in a monitor loop, updating the displayed data until an interrupt occurs. After the sequence performed in response to the interrupt is complete, VAE27 returns to the monitor loop unless the interrupt was for program termination. Throughout performance of the program, the number of cycles each SSME valve is put through is recorded, then output upon operator request prior to program termination. VAE27 allows the operator to select the option to perform VAE80 to read the SSME Failure Identification (FID) buffer.

2.2.8.1.2.1 VAE80 Read SSME Controller FID Buffer. (See figure 2-59.) VAE80 allows the operator to read part of the SSME memory that is used to contain failure data via display. Once initialized, VAE80 remains in a loop cycling an update symbol until an interrupt. Upon completion of the sequence in response to the interrupt, the program returns to cycling the symbol. The operator is notified which SSME controller channel the data being

22/36 CPR01097 RESU SUCCESSFUL - PROC VAE27 (T2) EXECUTION RESUMED
 VAE27 SSME CHECKOUT/MONITOR - WDE04

PHASE	MODE	STAT	CONFIG	I FLAG	FIDC	FID#	DLM#	HEA	HEB	HYDP
E1	STANDBY	ENG OK	FLT OPS	0	0	000	000	12	748	3000
E2	STANDBY	ENG OK	FLT OPS	0	0	000	000	12	776	3000
E3	STANDBY	ENG OK	FLT OPS	0	0	000	000	12	12	3000

PNEUMATIC CONTROL RSYS 12 12 12 12 0I 129 GPC 42 12

TEST FLAG	FUEL SYS	HPOTP ISP	P/B PURGE	POGO HPV	BLEED VLV	TEST FLAG	EMERG S/D	CTRS
E1 PSIA	15	113	125 375	15	FBV 0 100	00	752	00
E2 PSIA	15	114	126 375	15	FBV 0 100	00	776	00
E3 PSIA	15	111	126 373	15	FBV 0 100	00	15	00

HYDRAULIC CONTROL TEST FLAG	MFV	MOV	FPOV	OPOV	CCV	TEST FLAG	C/O STBY	DE-ACT VLV	RESUME	AUTO SEQ	STEP	FEP STAT	E1	E2	E3	CLR CURSORS	TERM	PGRM
E1	0	0	0	0	0	00	00	00	00	00	00	00	00	00	00	00	00	00
E2	0	0	0	0	0	00	00	00	00	00	00	00	00	00	00	00	00	00
E3	0	0	0	0	0	00	00	00	00	00	00	00	00	00	00	00	00	00

Figure 2-58. VAE27-SSME Checkout and Leak and Functional

READ SSME CONTROLLER FID BUFFER

<input type="checkbox"/> CHAN A	}	SSME 1 FID	COUNT <	>	1
<input type="checkbox"/> CHAN B			BUFFER	>	2
<input type="checkbox"/> CHAN A	}	SSME 2 FID	COUNT <	>	3
<input type="checkbox"/> CHAN B			BUFFER	>	4
<input type="checkbox"/> CHAN A	}	SSME 3 FID	COUNT <	>	5
<input type="checkbox"/> CHAN B			BUFFER	>	6
<input type="checkbox"/> CHAN A	}	SSME 3 FID	COUNT <	>	7
<input type="checkbox"/> CHAN B			BUFFER	>	8
<input type="checkbox"/> TERM PGM					9
					10
					11
					12
					13

SSME
 2
 10
 11
 12
 13

SSME
 3
 10
 11
 12
 13

Figure 2-59. VAE80-Read SSME Controller FID Buffer

displayed is from. If program termination is selected, the operator is notified and the program terminates.

2.2.8.1.3 VAE32 Flight Readiness Test (FRT) Module (see figure 2-60.) VAE32 allows the operator to perform an FRT with a selected SSME by issuing commands to the engine in an automated sequence or by sending each command to the engine one at a time via cursor interrupts. VAE32 uses VAE81 and VAE88 to send commands to the SSMEs during the automation FRT and VAE80 which reads the SSME FID buffer. VAE32 monitors SSME status until an interrupt occurs. After performance of the sequence in response to the interrupt, the program will return to the monitor loop unless the interrupt was for program termination.

2.2.8.1.3.1 VAE88 Issue SSME CMDS - Auto FRT. VAE88 is used to issue SSME commands in support of the automated FRT in program VAE32. The program uses the SSME command acceptance pseudo - setting it OFF before issuing the command and verifying it turns ON after command issuance. The higher level program is notified if the pseudo has not turned ON. VAE88 then terminates.

2.2.8.1.3.2 VAE81 Issue SSME Commands. VAE81 is used to issue a command to a selected SSME, or to all three SSMEs, in support of a non-automatic FRT generated with VAE32. Once initialized, VAE81 issues the command or commands to

272 21/37 SE27RB2 408 ROT 2858 59 HOLD IN PROGRESS P103456

VAE32

21/15 C&D 23 A

NO SUPPORT FOR THIS REQUEST ON THIS PAGE, KEY 30

CONTROLLED STATUS

PURGES E-1 E-2 E-3

EFRT	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PSN1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
XFRT	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PSN2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
RSME	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PSN3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
LCEN	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	PSN4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
LCIN	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	STEN	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SCAF	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	STRT	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SCBF	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	65%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SOOL	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AUTO	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	109%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
CMD ACCEPT	1	2	3	SDEN	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				SHTD	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				PSHT	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				ODMP	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				TSE0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				CTRS	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

PHASE	---	---	---
MODE	---	---	---
TCMD	---	---	---
DM98	---	---	---
DM99	---	---	---
FID	---	---	---
IFLG	---	---	---
STAT	---	---	---
TRM	---	---	---
RSYS	12	12	12
MODID	---	---	---
FRTST	---	---	---
LCTL	---	---	---

MCC/HYD PRESSURE	0	0	0
MCC	0	0	0
HYD	0	0	0
EMER	0	0	0
FUEL	0	0	0
ISP	0	0	0
FPPB	0	0	0
OPB	0	0	0
HPV	0	0	0
BLEED/POGO/HEX			
FBV	0	0	0
OBV	0	0	0
RIV	0	0	0
AFV	0	0	0
MAIN PROP VALVES			
MFV	0	0	0
MOV	0	0	0
FPO	0	0	0
OP0	0	0	0
CCV	0	0	0
FUELS			
E-1	0	0	0
E-2	0	0	0
E-3	0	0	0
OXID			
E-1	0	0	0
E-2	0	0	0
E-3	0	0	0

Figure 2-60. VAE32-FRT Test Module

turning OFF the command acceptance pseudos and issuing the command(s).

2.2.8.1.4 VAE42 SSME Purge Sequence Control - OPF (see figure 2-61). VAE42 provides the capability to the operator to monitor and control components on the GN₂ heated purge panel in the OPF. After initialization, the display data is monitored and any changes in the data cause the display to be updated. When an interrupt occurs, a sequence is performed in response. Upon completion of the sequence, VAE42 returns to the monitor loop, unless the interrupt was for program termination. A monitoring mode option is provided which allows the operator to provide overtemp protection for the GN₂ heater if the panel outlet temperature exceeds 160° F. Skeleton VDE42 displays a schematic of the GN₂ panel. Heater temperature and overtemperature indicators are displayed in the lower left section of VDE42. GN₂ panel transducer calibration command and program termination cursor blocks are located in the lower middle left of VDE42.

2.2.8.1.5 VAE38 SSME 1, 2, 3 Monitoring/MLP Purge Control (see figure 2-62). VAE38 is used to control SSME purging operations during launch countdown. It can also be used to control SSME GSE, the heated GN₂ purge panel and MFV heaters, and to issue commands to the SSME. VAE38 performs VAE80 to read the SSME FID buffer, VAE82 and VAE83 to control and monitor SSME GSE, and VAE84, VAE85, and VAE87 to display additional MPS/SSME data.

27/09 5827RB2 1-08 00T-3 358/58 HD IN PROGRESS
 SM SA 0123 0123 E123 1AB 2AB 3AB 4AB 5AB 6AB VAE42 P.23456
 27/03 AINT101 VAE42 HAS BEEN INITIATED IN TCB T2 AT B300
 VAE42 SSME OPF GND CONTROL MONITOR VAE42

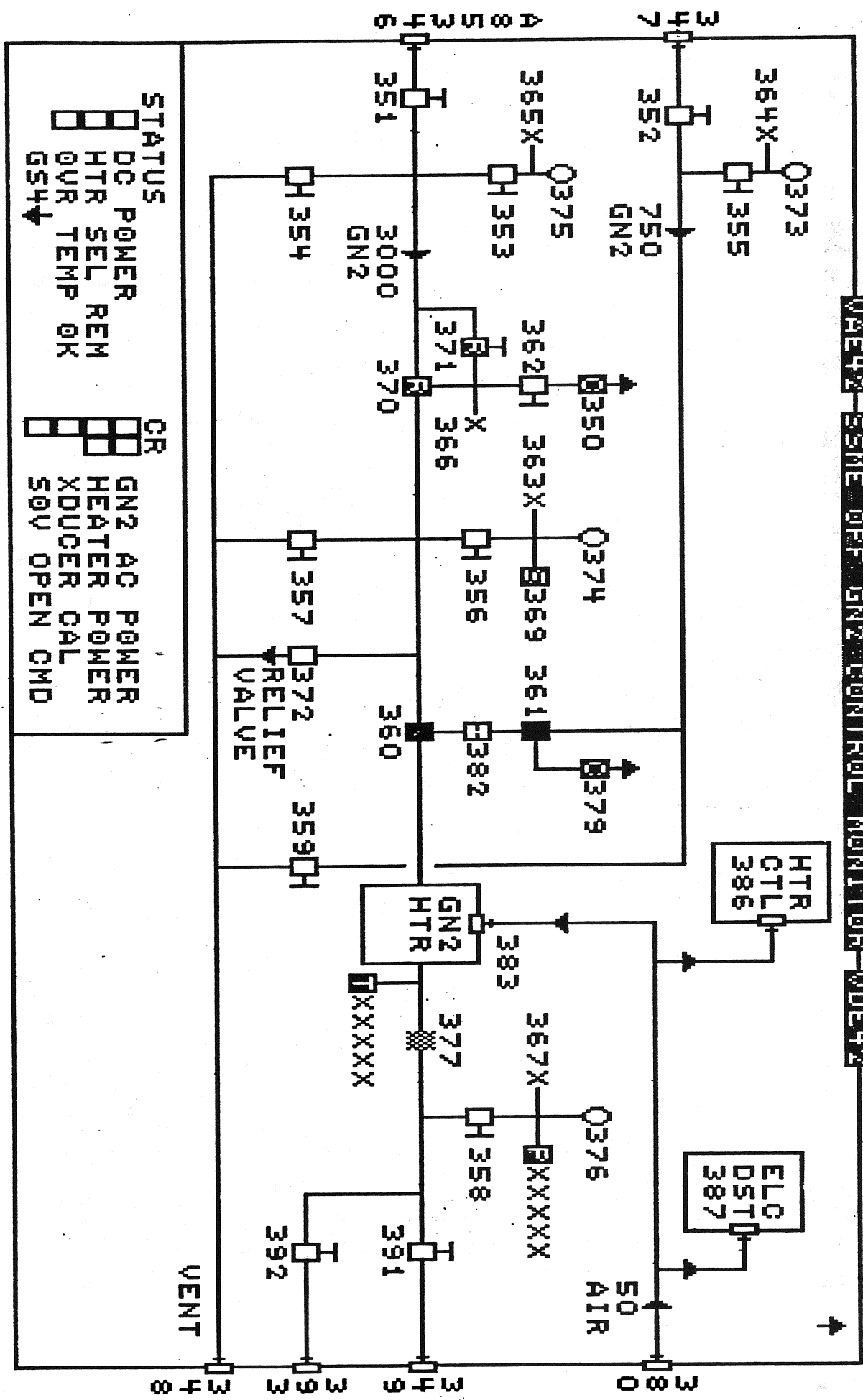


Figure 2-61. VAE42-SSME Purge Sequence Control -OPF

272 26/03 SB27RB2 4-02 NOT -353/53 HC IN PROGRESS PI 3456
 SM SR 0123 D123 E123 1AB 2AB 3AB 4AB 5AB 6AB VAE38 /VAE87
 VAE38SKEL VDE05

24/28 AINT101 VAE38 HAS BEEN INITIATED IN TCB T2 AT B300
 PSN1 1 2 3 4 VALVE POSITIONS-%
 PSN2 1 2 3 4 FBV 0 0 0 0 P 0
 PSN3 1 2 3 4 OBV 0 0 0 0 T -0
 PSN4 1 2 3 4 RIV 100 100 100 100 MFV HTR -AMP
 TRW AFV 0 0 0 0 ENG1 0.0 0.0
 DOME T 500 500 500 500 2 0.0 0.0
 HPFT T 540 540 540 540 3 0.0 0.0
 HPOT T 540 540 540 540 DATA WORDS
 AFV1 T 73 73 73 73 HYD MONITOR
 AFV2 T 73 73 73 73 MPS MONITOR
 OPOV 1 73 73 73 60KB MODE
 OPOV 2 71 71 71 71 ENG 1 2 3
 MFV 1 80 80 80 80
 MFV 2 78 78 78 78

LEAK DETECTION
 FSP 15 15 15 15A
 ISP 113 114 111A
 SSCP 15 15 15A
 ENGINE PURGES
 ENGINE READY
 LPFP P 15.0 15.0 15.0A
 LPFP T 54.0 54.0 54.0R
 LPOP P 14.0 14.0 14.0A
 PBP T 210.0 210.0 210.0R
 EMER P 752.0 776.0 14.2A
 OPBP P 374.8 374.6 373.3A
 FPBP P 125.2 125.6 125.7A
 MOVA T 588.4 588.4 588.3R
 MFVA T 588.8 588.8 588.9R

Figure 2-62. VAE38-SSME 1,2,3 Monitoring/MLP Purge Control

SM SA 0123 0123 0123 0123 1AB 2AB 3AB 4AB 5AB 6AB VAE38

VAE38SKEL VDEF05
 24/28 AINT101 VAE38 HAS BEEN INITIATED IN TCB T2 AT B300

PSN1 PHASE S/P S/P S/P
 MODE PSN1 PSN1 PSN1
 STATUS OK OK OK

PSN2 DM98 PSN1
 DM99 PSN1 PSN1
 TRM 232 239 245

PSN3 LEAK DETECTION
 DOME T 500 500 500R
 HPFT T 540 540 540R
 HPOT T 540 540 540R
 AFU1 T 73 73 73F
 AFU2 T 73 73 73F
 OP0V 1 73 73 73F
 OP0V 2 71 71 71F
 MFV 1 80 80 80F
 MFV 2 78 78 78F

PSN4 VALVE POSITIONS-%
 FBV 0 0 0
 OBV 0 0 0
 RIV 100 100 100
 AFV 0 0 0

STEN MFV 0 0 0
 TSEQ MOV 0 0 0
 CTRS OP0V 0 0 0
 RSME CCV 0 0 0
 LCEN HYD 3000 3000 3000

↑ E1 E2 E3
 IFL 0 0 0
 FID 0 0 0

000 000 000
 000 000 000
 VDT A A A
 FEP OK OK OK
 CMD
 RSC 12 12 12
 01 129/ACTIU
 128KB
 FMT 42 12

ENGINE PURGES
 FSP 15 15 15A
 ISP 113 114 111A
 SSCP 15 15 15A

ENGINE READY
 LPFP P 14.0 14.0 15.0A
 LPFP T 54.0 54.0 54.0R
 LP0P P 14.0 14.0 14.0A
 PBP T 210.0 210.0 210.0R
 EMER P 752.0 776.0 14.7A
 OPBP P 374.8 374.6 373.3A
 FPBP P 125.2 125.6 125.7A
 MOV A T 388.4 388.4 388.3R
 MFV A T 588.9 588.8 588.8R

HYDRAULIC PRESSURE
 CIRC PUMP 13 13 16 01
 SYS SUPP 8 8 16 GP
 SYS SUPP 8 8 16 GP
 ENGINE 3000 3000 3000 GP
 ENGINE 2985 2985 2985 EI
 RTN-RSVR 14 15 16 01

HYDRAULIC TEMPERATURE
 IN-SSME 73 75 75 01
 OUT-SSME 75 75 76 01
 THRUST VECTOR CONTROL
 ISO VALVE CLS CLS CLS 01
 PITCH -0.06 0.06 -0.06 01
 YAW 0.05 0.05 0.05 01

Figure 2-62. VAE38-SSME 1,2,3 Monitoring/MLP Purge Control

272 +25/37 SB27RB2 4-08 BOT - 2358/58 HC IN PROGRESS P123456
 SM SA 0123 D123 E123 1AB 2AB 3AB 4AB 5AB 6AB VAE38
 VAE38SKEL VDE05

24/28 AINT101 VAE38 HAS BEEN INITIATED IN TCB T2 AT B300
 PSN1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100
 PHASE S/P S/P VALVE POSITIONS-%
 MODE PSN1 PSN1 PSN1 E1 E2 E3
 STATUS PSN1 OK OK OK P FBV 0 0 0
 DW98 PSN1 PSN1 PSN1 Q OBV 0 0 0
 DW99 PSN1 PSN1 PSN1 R RIV 100 100 100
 TRW 1297 653 5 AFV 0 0 0
 LEAK DETECTION MFV 0 0 0
 DOME T 500 500 500R MOV 0 0 0
 HPFT T 540 540 540R FPOV 0 0 0
 HPOT T 540 540 540R OPOV 0 0 0
 AFV1 T 73 73 73F CCV 0 0 0
 AFV2 T 73 73 73F HYD 3000 3000 3000
 OPOV 1 71 71 71F
 OPOV 2 80 80 80F
 MFV 1 78 78 78F
 MFV 2 15 15 15A
 FSP 113 114 111A
 ISP 15 15 15A
 SSCP ENGINE PURGES ENGINE READY
 LPFP P 14.0 14.0 15.0A
 LPFP T 54.0 54.0 54.0R
 LPFP P 14.0 14.0 14.0A
 LPBP T 210.0 210.0 210.0R
 EMER P 752.0 776.0 14.7A
 OPBP P 374.8 374.6 373.3A
 FPBP P 125.2 125.6 125.7A
 MOVA T 588.4 588.4 588.8R
 MFVA T 588.9 588.9 588.9R

GN2 PRI SEC
 P 0 0 0
 T -0 -0 -0
 MFV HTR -AMP
 ENG1 0.0 0.0 0.0
 2 0.0 0.0 0.0
 3 0.0 0.0 0.0
 DATA WORDS
 HYD MONITOR
 MPS MONITOR
 -60KB MODE
 ENG 1 2 3

-E1- -E2- -E3-
 15 15 15
 1 1 1
 15 15 15
 14 14 14
 15 15 15
 15 15 15
 14 14 14
 15 15 15
 15 15 15
 15 15 15
 540 540 540
 1 1 1
 1 1 1
 0 0 0

ME-DATA
 MCC-AVG
 FUEL-GPM
 OXID-GPM
 HPFP-PR
 HPOP-PR
 FPB-PC
 LINER-P
 PBP-PR
 HEX-PR
 FUEL-INJ
 COOLANT-T
 COOLANT-T
 LPFP-RPM
 LPFP-RPM
 HPFP-RPM

Figure 2-62. VAE38-SSME 1,2,3 Monitoring/MLP Purge Control

272: 5/12 SB27RB2 4-03 BOT -88-58/58 HC IN PROGRESS P103456
 SM SA 0123 D123 E123 1AB 2AB 3AB 4AB 5AB 6AB VAE38
 VAE38SKEL VDE05

24/28 AINT101 VAE38 HAS BEEN INITIATED IN TCB T2 AT B300
 PSN1 1 2 3 4 VALVE POSITIONS-%
 PSN2 1 2 3 4 FBV 0 0 0 0
 PSN3 1 2 3 4 OBV 0 0 0 0
 PSN4 1 2 3 4 RIV 100 100 100 100
 STEN 1 2 3 4 AFV 0 0 0 0
 TSEQ 1 2 3 4 MFV 0 0 0 0
 CTRS 1 2 3 4 MOV 0 0 0 0
 RSME 1 2 3 4 FPOV 0 0 0 0
 LCGEN 1 2 3 4 OPOV 0 0 0 0
 IFL 0 0 0 CCV 0 0 0 0
 FID 0 0 0 HYD 3000 3000 3000 3000

MODE S/P PSN1 PSN1 PSN1 PSN1
 STATUS OK OK OK OK
 DW98 PSN1 PSN1 PSN1 PSN1
 DW99 PSN1 PSN1 PSN1 PSN1
 TRW 831 139 801 801

LEAK DETECTION
 DOME T 500 500 500R
 HPFT T 540 540 540R
 HPOT T 540 540 540R
 AFV1 T 73 73 73F
 AFV2 T 73 73 73F
 OPOV 1 71 71 71F
 OPOV 2 80 80 80F
 MFV 1 78 78 78F
 MFV 2 15 15 15A
 FSP 113 114 111A
 ISP 15 15 15A
 SSCP 15 15 15A

ENGINE PURGES
 ENGINE READY
 LPFP P 15.0 15.0 15.0A
 LPFP T 54.0 54.0 54.0R
 LPOP P 14.0 14.0 14.0A
 LPOP T 210.0 210.0 210.0R
 EMER P 752.0 776.0 14.2A
 OPBP P 374.8 374.6 373.3A
 FPBP P 125.2 125.6 125.7A
 MOVA T 588.4 588.4 588.3R
 MFVA T 568.9 568.9 568.9R

DATA MONITOR
 MPS MONITOR
 -60KB MODE
 ENG 1 2 3
 ENG 1 2 3

MAIN FUEL VALVE HEATER CONTROL

1 MFV HTR
 CMD ON OFF ON OFF
 PWR RDY RDY

2 MFV HTR
 CMD ON OFF ON OFF
 PWR RDY RDY

3 MFV HTR
 CMD ON OFF ON OFF
 PWR RDY RDY

ALL HTR PRI A A SEC A A
 ALL HTR OFF A A

Figure 2-62. VAE38-SSME 1,2,3 Monitoring/MLP Purge Control

272: 15/00 SB27RB2 4:03 001-322 033/53 HD IN PROGRESS P.43456
 SM SA 0123 0123 E123 1AB 2AB 3AB 4AB 5AB 6AB VAE38 /VAE82
 VAE38SKEL VDE05

24/28 AINT101 VAE38 HAS BEEN INITIATED IN TCB T2 AT B300
 PSN1 1 2 3 4 PHASE S/P S/P S/P VALVE POSITIONS-% G2 PRI SEC
 PSN2 1 2 3 4 STATUS PSN1 PSN1 PSN1 T 0 -0 -0
 PSN3 1 2 3 4 MODE PSN1 PSN1 PSN1 FBV 0 0 0
 PSN4 1 2 3 4 TRM PSN1 PSN1 PSN1 RBV 0 0 0
 TRM 538 1200 551 AFV 0 0 0

LEAK DETECTION
 DOME T 500 500 500R
 HPFT T 540 540 540R
 HPOT T 540 540 540R
 AFV1 T 73 73 73F
 AFV2 T 73 73 73F
 OP0V 1 71 71 71F
 OP0V 2 71 71 71F
 MFV 1 80 80 80F
 MFV 2 78 78 78F

ENGINE PURGES
 FSP 15 15 15A
 ISP 113 114 111A
 SSCP 15 15 15A
 ENGINE READY
 LPFP P 15.0 15.0 15.0A
 LPFP T 54.0 54.0 54.0R
 LP0P P 14.0 14.0 14.0A
 LP0P T 14.0 14.0 14.0R
 PBP T 210.0 210.0 210.0R
 PBP T 210.0 210.0 210.0R
 EMER P 752.0 776.0 776.0R
 EMER P 752.0 776.0 776.0R
 OPBP P 374.8 374.6 373.3A
 OPBP P 374.8 374.6 373.3A
 FPBP P 125.2 125.6 125.7A
 FPBP P 125.2 125.6 125.7A
 MOVA T 588.4 588.4 588.8R
 MOVA T 588.4 588.4 588.8R
 MFVA T 588.8 588.8 588.8R
 MFVA T 588.8 588.8 588.8R

GN2-MLP
 REG OUT
 CONT TRICKLE
 PURGE
 VENT
 CALL RM

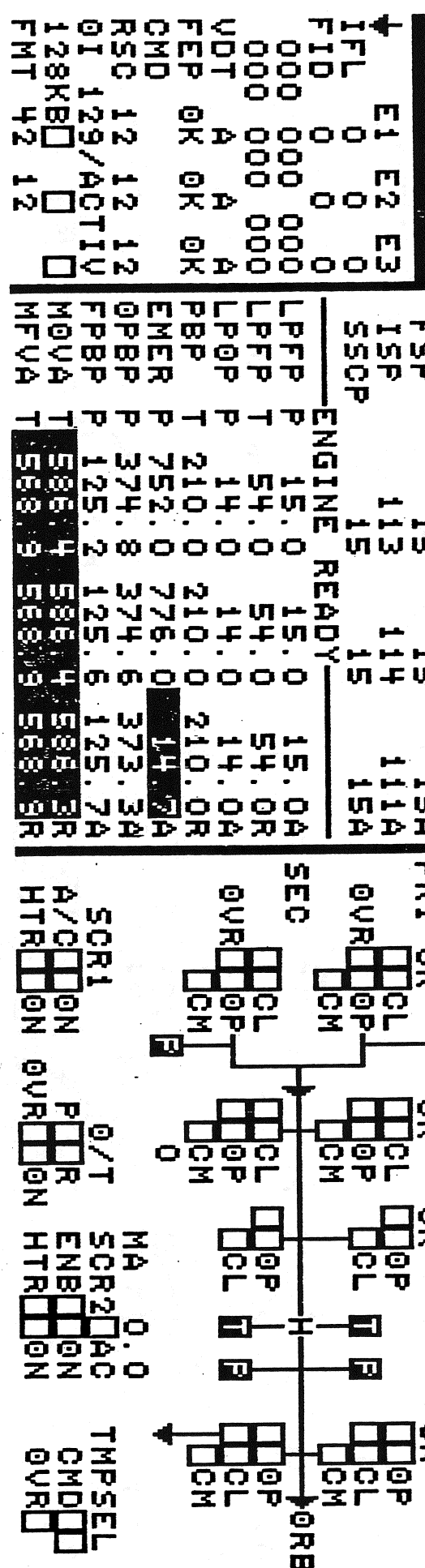


Figure 2-62. VAE38-SSME 1,2,3 Monitoring/MLP Purge Control

2.2.8.1.5.1 VAE83 MFV Heater GSE Control. VAE83 processes operator input to VAE38 to display data for or issue a command to the MFV heaters. VAE83 issues a command or performs a power up or power down sequence, then displays MFV heater status and terminates.

2.2.8.1.5.2 VAE82 MLP Purge Control. Called by VAE38, VAE82 allows the operator to control components on the MLP GN₂ purge control panel for the SSMEs. The operator can issue commands to components on the panel, calibrate the transducers, and control the SCR #2 drive current set point in steps of one milliamp. VAE82 displays component status to the operator upon completion of the requested action on a program-generated skeleton displayed on the lower right quadrant of skeleton VAE03.

2.2.8.1.5.2.1 VAE84 SSME Dataword Display. Used to display auxiliary SSME data words, VAE84 displays one of two groups of data. The group displayed depends on the value of a passed parameter. After initialization, VAE84 displays a skeleton compatible with the selected data group and then displays the data, after which it terminates.

2.2.8.1.5.2.2 VAE85 SSME Auxiliary Measurements 1. After initialization, VAE85 displays SSME hydraulic system data to the operator in the lower right quadrant of skeleton VDE38 and then terminates. Column headings on VDE38 designate one column for

each SSME. An additional column on the left describes the data being displayed and gives the units. VAE85 is performed by VAE38.

2.2.8.1.5.2.3 VAE87 SSME Auxiliary Measurements 2. Performed by VAE38, VAE87 allows the operator to display MPS/SSME interface data in the lower right quadrant of skeleton VDE38 and then terminates. An additional column on the left describes the data being displayed and gives units for the analog data.

2.2.8.1.6 VAEA3 SSME MLP GN₂ Valve Automatic Checkout. VAEA3 performs an automatic checkout of SSME MLP GN₂ valves. Each valve is cycled using both primary and redundant commands. Responses are verified for each command configuration. Having no interfaces, VAEA3 performs the sequence through to completion, then terminates.

2.2.8.1.7 VAEA4 SSME MFV Heater Functional Checkout (see figure 2-63). VAEA4 performs an automatic functional checkout of the three MFV heaters. Each heater is powered up, verified, and powered down using primary and redundant commands. Command responses are also verified for each command configuration. If an error occurs during the sequence, the operator can either terminate or continue the program. Upon completion of the sequence, VAEA4 terminates. VAEA4 has no interfaces.

272 28/49 SB27RB2 4-03 BOT - 358/58 HD IN PROGRESS P123456
 SM SH 0123 D123 E123 1AB 2AB 3AB 4AB 5AB 6AB VAEA4
 VAEA4SKEL VDE05
 28/25 CPR01097 RESU SUCCESSFUL - PROC VAEA4 (T2) EXECUTION RESUMED
 VAEA4-SSME MAIN FUEL VALVE HEATER CHECKOUT-VDE01

SYSTEM		CHECKOUT MODE	↑
MFV HEATER 1	PRI	HIM STATUS CHECK	
MFV HEATER 1	SEC	POWER AVAILABLE CHECK	
MFV HEATER 2	PRI	POWER UP INITIATED	
MFV HEATER 2	SEC	DRIVE CURRENT VERIFY	
MFV HEATER 3	PRI	POWER DOWN INITIATED	
MFV HEATER 3	SEC	TERMINATE/SAFING	
DRIVE CURRENT / SUPPLY VOLTAGE		SYSTEM FAILURES	
ENG 1	PRIMARY		SEE PAGE-A FOR LISTING OF
ENG 2	SECONDARY		SYSTEM FAILURE MESSAGES
ENG 3			

Figure 2-63. VAEA4-SSME MFV Heater Checkout

2.2.9 GSE REQUIREMENTS.

2.2.9.1 General. SSMEs are assembled in a vertical attitude using the Interface Panel and Strut Set, H70-0911. After assembly completion, the engine is rotated to the horizontal position using the Engine Rotating Sling, H70-0903, and placed on an Engine handler, H70-0901.

2.2.9.2 OPF/OMRF Operations. The following paragraphs discuss GSE applications in OPF/OMRF operations.

2.2.9.2.1 Routine Maintenance. Protective covers are installed over critical SSME components prior to any activity in the orbiter aft section or around the exposed external thrust chamber nozzle tubes. Critical areas include flexible duct bellows, sensors, FAMOS components, spark igniter, propellant feed lines, etc. These protective covers are currently packaging-type hardware and are not formal GSE. The feasibility of making them GSE is under evaluation.

2.2.9.2.1.1 Engine systems drying is conducted as soon as possible. Purge adapters and the thrust chamber (TC) throat plug from the Scheduled Engine Leak Test Set, C70-0914, are installed on openings in the SSME hot-gas system and in the TC throat. Facility-supplied heated gaseous nitrogen is connected to the adapters. Prior to installing the TC throat plug in the nozzle,

the TC Protective Pad, S70-0903, is installed in the nozzle to protect the nozzle tubes. This pad is continually in use in the OPF/OMRF to support inspections, leak checks, preparation for rollout, etc. During the drying operation, a launch-site-supplied moisture measuring device is used to sample the effluent gaseous nitrogen to determine when the system has attained the required dryness.

2.2.9.2.1.2 Internal leak checks of the critical components are conducted after each flight. Various test plates, adapters, and plugs from the Installed Engine Test Set, C70-0914, are installed on the engine to provide an interface for facility pressurization sources or to collect leakages past component seals and provide an interface for flowmeters to measure the leakage. Propellant systems are pressurized through the vehicle propellant ducts. The hot-gas system is pressurized through the thrust chamber throat plug.

2.2.9.2.1.3 A launch-site-supplied mass spectrometer leak detector (MSLD) is required to leak check the heat exchanger. The coils of the heat-exchanger are evacuated by the MSLD and a helium environment is applied to the exterior of the coils. Following the leak test the ultrasometer, part of the Special Tool Set, S70-0905, is used to reassemble the LOX tank pressurization system.

2.2.9.2.1.4 Internal inspections and turbopump torque tests are done concurrently. Turbopump rotating equipment from the Internal Inspection Set, C70-0907, is used to determine pump breakaway and running torques while the first stage blades of the high pressure turbopumps are inspected with borescopes from the C70-0907 set. Other critical areas of the engine, e.g., preburner and main combustion chambers, are inspected using a variety of flexible and rigid borescopes from the C70-0907 set.

2.2.9.2.1.5 After all maintenance is completed, a helium signature leak check is conducted on the fuel, oxidizer, and hot-gas systems to verify that leakages into the orbiter aft section do not exceed a safe level. During this check the systems of the three SSMEs are pressurized, and leakage into the orbiter aft section is monitored by a launch-site-supplied halogen gas detector. If excessive leakage is detected, the Multiple Gas Analyzer, C70-0917 is used to isolate the source of the leak.

2.2.9.2.2 Periodic Maintenance. Certain less-critical components for the SSME are leak and functionally checked less frequently at some predetermined interval (see table 2-7). For example, oxidizer tank pressurization (GOX) and helium system joints are leak tested after ten engine starts. The engine-to-orbit interface seals have features that trap the leakage and route it to a leakage monitor port where it is measured with the Atmospheric Flowtester, C70-0903. The C70-0903 flowtester is

also used to measure leakage at insulated fuel system joints. At these joints, a hypodermic-type needle (part of the C70-0903 set) is inserted through the porous insulation, the leakage is then measured at the needle at the needle outlet with the C70-0903 flowtester. All other joints on the engine are leak tested with leak-detection solution.

2.2.9.2.2.1 Task numbers C-1 through C-3 in Table 2-7 require the removal/replacement of life/cycle limited parts. These tasks require use of the launch-site supplied SSME LRU Installation Set, H70-0528, for component replacement and the Self-Propelled Lift Truck, H70-0764, for engine replacement. SSME GSE requirements are described as follows.

2.2.9.2.2.2 Removal of the HPFTP/HPOTP requires the use of the applicable sling of the Component Handler Sling Set, H70-0905. While the pumps are removed from the powerhead, detailed inspections of the preburner areas are conducted. Items of the injector repair/maintenance tool set (part of S70-0908, Maintenance/Repair Set) are used to conduct LOX post concentricity checks. Also while the HPOTP is removed, a detailed inspection of heat exchanger coils is made to check coil-to-bracket clearances, damage, etc. Tools have been provided to enhance this inspection.

Table 2-7. OPF/OMRF Maintenance Requirements vs. GSE

TASK No.	SCHEDULED REQUIREMENTS-ROUTINE	GSE ITEM #											
			T-3	T-4	T-5	T-6	T-9	T12	I-1	M-1	P-1		
A-1	AUTO/ELEC CHECKOUTS					X							
A-2	HEAT EXCH LEAK TEST				X		X				X		
A-3	TC NOZ LK TST, COLD W						X					X	
A-4	MCC-TO-NOZ LEAK TST						X					X	
A-5	AFV SEAT LEAK TEST		X		X		X						
A-6	OXIDIZER PROP VALVES BALL SEAL LEAK TEST		X					X				X	
A-7	MFV BALL SEAL & FUEL PUMP LIFT-OFF SEALS LEAK TEST		X					X				X	
A-8	He SIGNATURE LK TEST		HALOGEN LEAK DETECTOR REQ'D					X	X				X
A-9	VIO JOINTS LEAK TEST		X					X				X	
A-10	EXTERNAL INSPECTIONS			SURFACE INDICATOR FOR MCC THROAT REQ'D								X	
A-11	INTERNAL INSPECTIONS									X		X	
A-12	TURBOPUMP TORQUE TST									X			
A-13	PROT COVER & CLOSURE INSTL/REMOVAL											X	
A-14	ENGINE SYS DRYING							X				X	
A-15	TURB SENSOR IR TEST			STANDARD SHOP EQUIPMENT									
A-16	HPOT PRIM LOX SEAL LEAK TEST			X				X					
A-17	GCV CK VLV LEAK TEST		X										
A-18	LP FUEL DUCT OVALITY CHECK												

Table 2-7. OPF/OMRF Maintenance Requirements vs. GSE (Cont.)

TASK No.	SCHEDULED REQUIREMENTS- AS NOTED	GSE ITEM #	T-3	T-5	T-6	T-8	T-9	T14	I-1	M-1	M-2
B-1	F VLVS, PMPs SHFT/PIS SEALS CK VLV LK TST (EVERY 10 STARTS)		X				X				
B-2	BLD VLVS SEAT LK TST (EVERY 10 STARTS)		X				X				
B-3	OX VLVS SHFT SEALS & PURGE CK VLVS LK TST (EVERY 10 STARTS)		X				X				
B-4	POGO VLVS LK & F TST (EVERY 10 STARTS)		X	X			X				
B-5	PCA LEAK TEST (EVERY 10 STARTS)		X								
B-6	He/GOX SYS EX LK TST (EVERY 10 STARTS)		X				X				
B-7	INT INSP-HPOTP INLET (EVERY 10 STARTS)								X		
B-8	TC NOZ LK TEST, HOT W (EVERY 10 STARTS)						X				
B-9	AFV FUNCTIONAL TEST (EVERY 10 STARTS)			X			X				
B-10	HT EXCH INSPECTION (EVERY 10 STARTS)										EDDY CURRENT TESTER REQ'D
C-1	HPFTP/FPB INSP W/PMP REM (EVERY 3RD START)						X		X	X	X
C-2	HPOTP/OPB INSP W/PMP REM (EVERY 3500 SECS)			X			X		X	X	X
C-3	ENG REPL- ULTIMATELY EVERY 55 STARTS OR 7.5 HRS OF OPERATION		X	X	X	X*	X	X*	X		X
C-4	HT EXCH LK/PRF TST- POST HPOTP INSTL			X			X			X	

Table 2-7. OPF/OMRF Maintenance Requirements vs. GSE (Cont.)

TASK No.	SCHEDULED REQUIREMENTS- AS NOTED	GSE ITEM #	M-3	P-1	H-1	H-2	H-3	H-5	H-6		
B-1	F VLVS, PMPS SHFT/PIS SEALS CK VLV LK TST (EVERY 10 STARTS)			X							
B-3	OX VLVS SHFT SEALS & PURGE CK VLVS LK TST (EVERY 10 STARTS)			X							
B-6	He/GOX SYS EX LK TST (EVERY 10 STARTS)			X							
B-8	TC NOZ LK TEST, HOT W (EVERY 10 STARTS)			X							
C-1	HPFTP/FPB INSP W/PMP REM (EVERY 3RD START)			X			X				
C-2	HPOTP/OPB INSP W/PMP REM (EVERY 3500 SECS)			X			X	EDDY CURRENT TESTER REQ'D			
C-3	ENG REPL- ULTIMATELY EVERY 55 STARTS OR 7.5 HRS OF OPERATION		X	X	X	X		X	X		

Table 2-7. OPF/OMRF Maintenance Requirements vs. GSE (Cont.)

TASK No.	UNSCHEDULED REQUIREMENTS	GSE ITEM #	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T10	T12
D-1	ENGINE REPLACEMENT		X		X	X		X*	X		X
D-2	FAILED LRU REPL, INCLUDING JOINT SLS		X	X	X	X	X		X		
D-3	ISOLATION LK TESTS		X		X				X	X	X
D-4	AUTO FAULT ISOLATION					X					
D-5	EXTERNAL LEAK TESTS		X						X		

TASK No.	UNSCHEDULED REQUIREMENTS	GSE ITEM #	T14	L-1	M-1	M-2	M-3	P-1	H-1	H-2	H-3
D-1	ENGINE REPLACEMENT		X*	X		X	X	X	X	X	
D-2	FAILED LRU REPL, INCLUDING JOINT SLS			X	X	X	X				X
D-3	ISOLATION LK TESTS				X			X			
D-5	EXTERNAL LEAK TESTS		X					X			

TASK No.	UNSCHEDULED REQUIREMENTS	GSE ITEM #	H-5	H-6
D-1	ENGINE REPLACEMENT		X	X

* = To conduct critical lift on H-5.

Table 2-7. OPF/OMRF Maintenance Requirements vs. GSE (Cont.)

GSE ITEM NUMBER LEGEND

<u>GSE</u> <u>ITEM</u> <u>NO.</u>	<u>NOMENCLATURE</u>
H-1	ENGINE HANDLER
H-2	ENGINE HANDLER SLING
H-3	COMPONENT HANDLER SLING SET
H-4	VERTICAL ENGINE INSTALLER SET
H-5	ENGINE ROTATING SLING
H-6	INTERFACE PANEL AND STRUT SET
I-1	INTERNAL INSPECTION SET
M-1	SPECIAL TOOL SET
M-2	MAINTENANCE/REPAIR SET
M-3	LPTP INTERFACE SEAL TOOL
P-1	THRUST CHAMBER PROTECTIVE PAD
P-2	ENVIRONMENTAL PROTECTION SET
P-3	FERRY FLIGHT SET
P-4	NOZZLE BUMPER SET
T-3	ATMOSPHERIC FLOW TESTER
T-4	LARGE VOLUME FLOW TESTER
T-5	HIGH PRESSURE FLOW TESTER
T-6	DCU MEMORY LOADER
T-7	ELECTRICAL CHECKOUT AND MAINTENANCE SET
T-8	PROOF TEST WEIGHTS
T-9	SCHEDULED ENGINE LEAK TEST SET
T-10	UNSCHEDULED ENGINE LEAK TEST SET
T-11	ENGINE INTERFACE TEST PLATE SET
T-12	MULTIPLE GAS ANALYZER
T-13	COMMAND AND DATA SIMULATOR
T-14	ENGINE SIMULATING WEIGHT SET

2.2.9.2.2.3 During reinstallation of the turbopumps, the ultrasonic extensometer, part of the Special Tool Set, S70-0905, is used to preload (stretch) studs and bolts at the large pump interface flanges.

2.2.9.2.2.4 After installation of the pump is complete, pump torque checks are required. Pump rotating adapters, part of the Internal Inspection Set, C70-0907, are used to adapt the pump shafts to a standard shop-supplied torque wrench.

2.2.9.2.2.5 The requirements for use of the Engine Rotating Sling, H70-0903, for engine replacement assumes the replacement engine is stored vertically in the engine shop. If this is the case, the replacement engine is rotated to the horizontal position by the rotating sling and placed on the Engine Handler, H70-0901. The removed engine will be prepared for shipment on an engine handler and loaded on an air-ride truck with the Engine Handler Sling, H70-0902. The turbopump rotating adapters in the Internal Inspection Set, C70-0907, are used to torque check the turbopumps following engine installation.

2.2.9.2.3 Unscheduled Maintenance. The major items of unscheduled maintenance are identified in Table 2-7, Task No. D-1 through D-5. Some of the internal leak tests conducted on the SSME are combined leakage tests, i.e., the leakages of several components are gathered at a common point and measured. If the

leakage exceeds the maximum allowed for that system, leak tests must be conducted to isolate the discrepant component. To do this, test plates from the Unscheduled Engine Leak Test Set, C70-0915, are installed into the system at separable joints to restrict leakage flows from the upstream components. After completion of the tests, the plates are removed, and the system joints are remated using the ultrasonic extensometer from the Special Tool Set, S70-0905. Also, after completion of engine installation, the automatic checkout modules (5) are loaded into the controller memory through the orbiter and an automatic checkout of the engine is conducted. Should discrepancies be detected during checkout, the DCU Memory Loader, C70-0910, is used for fault isolation.

2.2.9.2.4 Preparation for Rollout From the OPF/OMRF. This is the final maintenance activity for the SSMEs in the OPF/OMRF. The protective covers are removed from the components forward of the orbiter heat shields after all activity in the aft section has been completed. A desiccated throat closure is installed in the main chamber of each SSME and a flexible closure is installed across the nozzle exits. At VAFB, protective covers will be installed over the TC nozzles to provide protection during the long trip to the launch complex. The SSMEs are then ready for OPF/OMRF rollout.

2.2.9.3 Vehicle Assembly Operations in the VAB.

2.2.9.3.1 Scheduled Maintenance. When the orbiter is rolled out of the OPF/OMRF, the SSMEs are ready for Shuttle Assembly operations. After solid rocket boosters and orbiter are mated to the external tank, the SSME MFV heater operation is verified. The power and current monitoring requirements are supplied by a ground source, there is no SSME GSE required.

2.2.9.3.2 Unscheduled Maintenance. Any maintenance that can be done in the OPF/OMRF on a scheduled or unscheduled basis can be done in the VAB. The SSME GSE can support vertical as well as horizontal maintenance. Should the need arise to remove an engine in the vertical attitude, the Vertical Engine Installation Set, H70-0774-1 would be used. The engine would be lowered out of the vehicle with the vertical installer, removed from the vertical installer with the Engine Rotating Sling, H70-0903 and placed on the Engine Handler, H70-0901 for transport to the engine shop. Line Replaceable units (LRUs) that weigh some more than 50 pounds will require that Component Handler Sling Set, h70-0905 for removal. The sling set can interface with the vertical installer component adapter or the SO.ISSD-produced SSME LRU Installation Set, H70-0528 used in the vertical mode.

2.2.9.4 Launch Pad Operations.

2.2.9.4.1 Scheduled Maintenance. The primary SSME maintenance activity at the launch pad is automatic checkout prior to loading LO₂ and LH₂. The sensor and pneumatic component checkout modules (software) are loaded into the controller memory via the orbiter, and automatic checkout is connected. Following checkout, flight software is reloaded into the controller memory and the memory is verified. The SSMEs are ready for launch countdown.

2.2.9.4.2 Unscheduled Maintenance. SSME unscheduled maintenance at the launch pad is the same as that described for the VAB. However, the possibility of LRU replacement is slightly greater since the controller is powered up and some checkouts are conducted that will detect discrepant components, if any. If discrepancies occur during checkout and/or memory dump, and the self-test feature of the controller cannot identify the discrepancy, the DCU Memory Loader, C70-0910 can be used for fault isolation. Additionally, prelaunch-leak detector sensors are mounted on or near the main fuel valve and oxidizer preburner oxidizer valve. These sensors will detect a leaking propellant valve ball seal during propellant tanking. If unexplained discrepancies are detected during these operations, LRU replacement would be mandatory.

2.2.9.5 Shuttle Launch. After launch countdown has been completed and propellants have been loaded, the launch count is automatically managed/monitored by the Ground Launch Sequencer (GLS) starting at T-9 minutes. If, after propellant loading, the launch is postponed, the following SSME unscheduled maintenance must be conducted.

A. Launch Scrub (Postponement Prior to SSME Start). The oxidizer system gaseous nitrogen purge must be applied during propellant detanking and for 12 hours after propellants have been removed. This is a ground controlled purge and does not require support from the SSME. If personnel entry into the vehicle aft section is required, protective covers must be installed on critical SSME components. These actions essentially secure the SSME after a launch scrub. To recycle to a launch countdown condition, the prelaunch scheduled maintenance activities previously described must be accomplished.

B. Launch Abort (Postponement After SSME Start). If the launch is aborted between the time the SSMEs are started and the solid rocket boosters (SRBs) are ignited, the engines will have experienced dynamic loads and thermal shock. Much more detailed maintenance is required for the launch abort than was required for the launch scrub. Generally, the routine maintenance described for the OPF/OMRF operations will apply. These

requirements can be adjusted depending on the nature of the abort.

2.2.9.6 Landing Strip Operations.

2.2.9.6.1 Primary Landing Sites. The only SSME maintenance required after the orbiter rolls to a stop on the landing strip of a primary site is to install the Environmental Protection Cover Set, S70-0902 if conditions warrant. Rain, dust, or debris-laden wind will require protection set installation.

2.2.9.6.1.1 The engines will have been gimbaled to their extreme downward position (rain-drain) at the time of orbiter rollout to minimize engine contamination if any of those conditions exist. Access to install the closures is provided by a vehicle with a lift platform. The closures are installed in the thrust chamber throat and on the exits of all drain lines except the HPOTP primary LOX seal drain line. The HPOTP drain system is protected from the environment by the oxidizer system trickle purge that was initiated by the orbiter for re-entry. This purge is supplied by the on-board helium bottles and is estimated to last for 4 hours after landing.

2.2.9.6.2 Secondary/Contingency Landing Sites. During the early flights of the Shuttle, the orbiter landed at Dryden Flight Research Center (DFRC). During future Shuttle flights, DFRC

will be used on an as-required basis only. There are five other secondary/ contingency landing sites besides DFRC; two in the Pacific, one in Spain, one in New Mexico, and one in Senegal. Because of the prevailing dust conditions at DFRC, installation of the Environmental Protection Cover Set, S70-0902. is a scheduled requirement for every landing. The nozzle bumper set is used on an unscheduled basis for the reasons discussed in paragraph 2.2.9.6.1.1.

2.2.9.7 Preparations for Ferry Flight.

2.2.9.7.1 Scheduled Maintenance. After orbiter crew egress and other safing operations are completed on the secondary/contingency landing site strip, the vehicle is towed to the Mate/Demate Facility. Here the SSMEs are serviced and prepared for ferry flight. Servicing consists of drying the HPFTP turbine bearing as soon as possible because moisture in the bearing area degrades bearing life with time. To dry the bearing, an adapter from the Ferry Flight Set, C70-0909, is installed on a fitting on the engine heat shield attach ring. Heated facility gaseous nitrogen is connected to the fitting and gaseous nitrogen is routed to the turbine bearing for a minimum specified time. The remainder of the engine system drying is deferred to the launch site.

2.2.9.7.1.1 The Ferry Flight Set, C70-0909, is installed to contain pressure in the engine systems during ferry flight. Plugs are installed in the thrust chamber throat and all drain line exits. Vehicle propellant feed systems are pressurized.

2.2.9.7.1.2 The vehicle oxidizer system pressure bleeds by the HPOTP and subsequently pressurizes the SSME hot-gas system. Leak tests are conducted on the ferry flight kit plugs and the thrust chamber nozzle to verify the leak-free integrity of the system for ferry flight. Any thrust chamber nozzle or main combustion chamber liner damage that permits leakage is repaired. If possible, temporary repairs are made until arrival at the launch site.

2.2.9.7.1.3 Considerable personnel activity takes place in the vehicle aft section during engine gimbal lock installation. To preclude damage to the engine, protective covers are installed on critical components in the area of activity.

2.2.9.7.1.4 If the orbiter lands at one of the landing sites in the Pacific, the SSMEs must be removed from the orbiter for ferry flight. This presents a logistics problem in that three engine handlers and interface panel and strut sets, plus one engine handler sling must be transported to the landing site. This is in addition to transporting the large engine removal GSE.

2.2.10 TEST AND CHECKOUT OMIS.

2.2.10.1 General. The following OMIS contain SSME prime responsibility test and/or checkout procedures. For a complete list of SSME/MPS OMIS, refer to section 3 of this handbook.

Table 2-8. SSME Test and Checkout OMIS.

OMI	NOMENCLATURE
V1001	SSME ELECTRICAL INTERFACE VERIFICATION
V1011.01	SSME ENG. DRY (LEAK + FUNC.)
V1011.02	SSME (LEAK AND FUNC.) INT. & EXT. INSP.
V1011.03	SSME PUMP TORQUE CHECKS (LEAK + FUNC.) CKS
V1011.04	SSME HEAT EXCHANGER LEAK CHECKS AND FUNC.
V1011.05	SSME HGM/LOX/LH2 LEAK + FUNC. CKS
V1011.06	SSME POST INST LEAK & FUNC PNEU, CONTROLLER CK OUT
V1011.07	SSME 10 START LEAK & FUNCTIONAL TESTS
V1105	SSME TO ORB ALIGN VERIF
V1170	ENG HARNESS ELECT C/O
V1204	SSME ELECT INTERFACE VERIF (CONTING)
V2003	HEATED GN2 PURGE PNL SYS VALID - OPF
V2004	HEATED GN2 PURGE CONSOLE VALID - MLP
V2068	SELF PROP LIFT TRUCK & ENG INST (OPF)
V2237	MPS GN2 PURGE PNL EM CHECKS
V2308	VALID OF SSME PURGE PNL
V2339	SSME DRAG ON GN2 PNL VALID - OPF

Table 2-8. SSME Test and Checkout OMIs (continued).

OMI	NOMENCLATURE
V2340	SSME DRAG ON PURGE PNL VALID - MLP
V3553	SSME LRU RAIL ASSMB INST & REMVL
V5005	SSME INSTALLATION (HORIZ)
V5043	SSME HEAT SHIELD INST + REMOVAL (VOL 1,2,3)
V5057	TVC/SSME GSE INST/REMOV
V5058	SSME REMOVAL (HORIZ)
V5062	SSME INST (VERT)
V5063	SSME REMOVAL (VERT)
V5087	SSME/GSE HANDLING OPS
V5E01	SSME RMVL/ INST - MFV
V5E02	SSME LRU COMP RMVL/INST - HPOTP
V5E03	MAIN ENG CONTROLLER RMVL/INST + VASCOS
V5E04	POGO SUPPRESSION SYSTEM
V5E05	PNEUMATIC CONTROL ASSEMBLY
V5E06	SSME LRU COMP RMVL/INST - HPFTP
V5E17	SSME LRU COMP RMVL/INST - OPOV
V5E18	SSME LRU COMP RMVL/INST - OPOV
V5E19	SSME LRU COMP RMVL/INST - CCV
V5E22	SSME LOW PRESS MAIN OXD VLV COMP RMVL/INST
V5E23	SSME LOW PRESS OXID T-PUMP COMP RMV
V5E24	SSME LOW PRESS FUEL T-PUMP COMP RMVL/INST
V5E25	SSME LRU COMP RMVL/INST - LPF D/D
V5E26	SSME LRU COMP RMVL/INST - TVC ACT

Table 2-8. SSME Test and Checkout OMIs (continued).

OMI	NOMENCLATURE
V5E28	SSME NOZZLE RMVL/INST
V5E29	SSME GIMBAL BOLT RMVL/INST
V6033	SSME RECEIVING INSP
V6A44	LOCK SET MPS ACT
V6A46	MPS ENG ALIGN VERIF SET
V6A47	MPS SEV ACT PRELOAD DEV
V6855	FLOW METER SET LARGE VOL
V6A58	FIXTURE MPS ENG HORIZ INST'
V6A59	AFT HEAT SHIELD SLING
V6A60	SUPPORT SET - MPS ACTUATORS
V6A62	LIFT TRUCK - SELF PROPELLED
V6A63	LIFT TRUCK - SELF PROPELLED
V6A64	SLING - SSME HEAT SHIELD HAND'L
V6A65	SSME HANDLING FIXTURE
V6A67	SLING, SSME COMP HAND'L
V6A70	GN2 PURGE PANEL - OPF
V6A73	COVERS, SSME & ENCLOSURES PROTECT
V6A76	TOOL SET, SSME SPECIAL
V6A79	GN2 PURGE PANEL - MLP
V6E83	SSME LRU HOIST
V6E84	SSME THERMO PROTECTION MAINTENANCE SET
V6E85	SSME PURGE PANEL -SLS
V6F34	SSME DRAG ON PURGE PANEL - MLP

Table 2-8. SSME Test and Checkout OMIs (continued).

OMI	NOMENCLATURE
V6F35	SSME DRAG ON PURGE PANEL - OPF
V6F82	ENG MOUNTED HEAT SHIELD HANDLING SET
V6G04	ENG OUT SAFETY NET/PURGE CVR SET
V6G18	ENG INSTLR SET SSME (VERT)
V6G21	ROTATING SLING - SSME MAINT
V6G22	TURBOPUMP DOLLY - SSME MAINT
V6G23	ELECT C/O / MAINT SET SSME
V6G24	FERRY FLIGHT SET-SSME MAINT
V6G25	SSME LPFTP INTERFACE SET
V6G26	SSME INTERFACE STRUT SET
V6G38	SSME THROAT ACCESS PLATFORM
V6G26	PNL SET, INTERFACE STRUT, ENG HANDLER
V7017	PNEU ATM FLOW METER TESTER CALIB
V7018	HIGH PRESS PNEU FLOW METER TESTER CALIB
V7077	LARGE VOL FLOW METER TESTER CALIB
V7110	GN2 ENG PURGE PNL ASSY CALIB - OPF
V7112	GN2 ENG PURGE PNL ASSY CALIB - MLP
V7147	PNEU PRESS UNIT CALIB C70 - 0743 REG PNL
V7193	CAL OF SSME PURGE PNL
V7214	SSME DRAG ON PURGE PNL ASSY CALIB - OPF
V7215	SSME DRAG ON PURGE PNL ASSY CALIB - MLP
V7240	CALIB OF AMB GHe BOTTLE FILL CONTROL PNL
V7247	AMBIENT He BOTTLE FILL PNL CALIB

Table 2-8. SSME Test and Checkout OMIs (continued).

OMI	NOMENCLATURE
V9001	ORB PWR UP/PWR DN SSME OPTIONS
V9018	SSME/MPS PREPS & SECURING FOR LOAD

3.0 REFERENCE MATERIAL.

3.1 GENERAL.

3.1.1 SSME MANUALS.

3.1.1.1 Table 3-1 lists manuals that the SSME System Engineer should be familiar with.

Table 3-1. SSME Manuals.

MANUAL NUMBER

NOMENCLATURE

80K00060 - MPS Math Model Overview (VME90)

KLO-82-0015 - Software Specification Document

KLO-82-0076 - ESA User's Guide

KSC-LPS-OP-033-1 - LPS CCMS System Operation

LSOC-000272-1750 - Process Engineering Reference Manual (PERM)

ME-110(A)RIR - (Course No.) SSME Orientation (Part A - Engine)

RSS-8559-1-1-1 - SSME Description and Operation (Input Data)

RSS-8559-2-1 - SSME Illustrated Parts Breakdown

SE-S-0073 - Space Shuttle Fluid Procurement and Use Control

SSME Systems Joint Data

3.1.2 SSME SHOP MANUALS.

3.1.2.1 Table 3-2 lists SSME shop manuals useful to the System Engineer.

Table 3-2. SSME Shop Manuals.

MANUAL NUMBER	NOMENCLATURE
RSS-8503-9	- SSME GSE (GSE List and Description)
RSS-8545-20	- SSME Integrated Hazard Analysis Volumes I/IV
RSS-8559-1-1	- Shuttle Input
RSS-8559-1-1-7	- SSME Insp. Criteria for Launch and Landing Sites
RSS-8559-1-3	- SSME GSE
RSS-8559-4	- Configuration Identification and Status and LOAPS

3.1.3 SSME FIRING ROOM INFORMATION.

3.1.3.1 Software. The software programs listed in table 3-3 are maintained in the Firing Room to support SSME launch operations. As some requirements may change, this list may not be exhaustive.

Table 3-3. Firing Room Software.

PROGRAM	NOMENCLATURE
GCH01	PREQ CL for PV11
GCL18	PREQ CL for PV9
GOAL	Ground Operations Aerospace Language - latest revision
VAEA1	FCV Checkout with Ground SIM Panel
VAEA3	SSME MLP GN2 Valve Automatic Checkout
VAEA4	SSME MFV Heater Functional Checkout
VAE18	GH3 System Display and Control
VAE19	LO2 System Display and Control
VAE20	LH2 System Display and Control
VAE24	Pneumatic Console Power Up/Down (OPF)
VAE25	SSME Vehicle Data Table (VDT)/Control
VAE27	SSME Checkout and Leak and Functional
VAE32	Flight Readiness Test (FRT) Module
VAE33	MPS LO2 Copper Path Checkout
VAE35	Pneumatic Console Power Up/Down (MLP)
VAE38	SSME 1,2,3 Monitoring MLP/Purge Control

Table 3-3. Firing Room Software (Continued).

PROGRAM	NOMENCLATURE
VAE39	MPS LH2 VLV CMD Redundancy C/O
VAE42	SSME Purge Sequence Control
VAE43	Orbiter Press Flow Control Valves Verification
VAE44	LH2 Recirc Pump Dry Spin Test
VAE45	SSME 1 VDT Monitor
VAE46	SSME 2 VDT Monitor
VAE47	SSME 3 VDT Monitor
VAE50	MPS LO2 Outboard Fill and Drain Valve Close
VAE59	MPS LO2 Valve Auto Cycle
VAE80	Read SSME Controller FID Buffer
VAE88	Issue SSME CMDS - Auto FRT
VAE91	MPS LO2 System EMON Setup
VAE92	MPS LH2 System EMON Setup
VAE93	MLP He VLV CMD and Bus Redundancy
VAE96	GHe GSE Systems Displays
VAE97	ET Point Sensor Checkout
VAEA6	GOAL Language Processor Source Input Listing
VCE01	React CL for LO2 Manifold Pressure
VFE01	MPS LO2 17" Feed Disconnect Valve - PD1 - Latch Protect
VFE02	MPS LH2 17" Feed Disconnect Valve - PD1 - Latch Protect

3.1.3.2 Engineering Drawings. Engineering drawings which are maintained in the Firing Room to support SSME launch operations are listed in table 3-4.

Table 3-4. Engineering Drawings.

DRAWING NUMBER	NOMENCLATURE
79K05460	LC39B LOX Sys Design Disc Tower Mod (Not released)
79K06005	LOA MPS LH2 System EMCD
79K06006	LOA MPS LO2 System EMCD
79K06017	LOA/VAA SSME Ground Support Sys SMS/EMCD
79K06034	VAA MPS LH2 System SMS/EMCD High Bay 1 & 3
79K06041	OMA Facility GHe SYS SMS/EMCD HB-1 & HB-2
79K06054	OMA SSME GND SPT SYS SMS EMCD
79K06063	LOA MPS LH2 System SMS
79K06064	LOA MPS LO2 System SMS
79K06382	MPS LO2 LOA VAA AES
79K09217	Sys Elect Advanced Schem SSME Sys LOA/VA MLP-1
79K09317	CID SSME Ground Support Sys LOA/VAA/OMA
79K09663	SSME Ground Support Sys OMA
79K14204	Line Dgrm TSM T-0 Umb/Release Sys
79K15932	Purge Pnl Assy SSME Drag on MLP
79K21555	Sys Elect Adv Schem SSME Sys LOA/VAA
VS70-415007	Main Propulsion System - Schematic

3.1.3.3 Miscellaneous publications. Table 3-5 lists miscellaneous publications maintained in the Firing Room to support SSME launch operations.

Table 3-5. Miscellaneous Firing Room Publications.

PUB. NUMBER	NOMENCLATURE
	Launch Commit Criteria (LCC)
	MPS Data Bank Statistics
	MPS Reference OMIs C3 - G6105, G61504, T1205, T1402 (Book)
	MPS Reference OMIs C4 - G6205, G6250, T1204, T1401, T1001, T1201
	OMRSD V41 Operations and Maint Requirements & Specification Doc
S0007	Launch Countdown
S1003	MPS LO2 Load/Drain
S1004	MPS LH2 Load/Drain
S5009	Final Ordnance Instl/Connection, and Aft Closeout (LPS)
S9904	OPF/OMRF Emergency Procedures Document (EPD)
S9908	Launch Pads (LC39 A&B) Emergency Procedures Document (EPD)
S9909	VAB Emergency Procedures Document (EPD)
SAE02	LO2 Propellant Monitor
SAE12	LH2 Propellant Monitor
SAE15	MPS LH2 Recirculation Control
SAE16	MPS LH2 Recirculation Terminate
	SSME Data Bank Statistics
V1171	MPS/SME Press & He Activation OPS
V9002.03	VEH HYD CIRC PUMP PWR UP/DWN-RESERVOIR QTY ADJ & SAMPLE

Table 3-5. Miscellaneous Firing Room Publications (Cont).

PUB. NUMBER

NOMENCLATURE

V9002.06 SSME Pwr Up/Down

V9018 SSME/MPS Preps & Securing for Load

3.1.4 SSME GSE.

3.1.4.1 SSME GSE List. Table 3-6 lists SSME GSE items and related drawings.

Table 3-6. SSME GSE List.

MODEL NUMBER	NOMENCLATURE	DRAWING
A34-0329-301	GO2 Press Reg	N36-854140
A70-0501-00	Lock Set-MPS Act	GW70-500501
A70-0625-01	Int, Prut. Set-Aft-Fus	GW70-005600
A70-0640-01	Cap and Plug Set AF1 Fus	GW70-005800
A70-0640-03	Cap and Plug Set Aft Fus (MPS Test)	GW70-005800
A70-0640-05	Cap and Plug Set Aft Fus (MPS Ferry)	GW70-005800
A70-0640-06	Cap and Plug Set Aft Fus (MPS Ferry)	GW70-005800
A70-0640-08	Cap and Plug Set Aft Fus (MPS Ferry)	GW70-005800
A70-0645-00	MPS Eng. Align. Verif. Set (Includes Pet Tool)	GW70-001000
A70-0733-00	MPS Servo Act Pre-Load Dev	GW70-500733
A70-0983-00	TVC Act Lock Set	GW70-500983

Table 3-6. SSME GSE List (Continued).

MODEL NUMBER	NOMENCLATURE	DRAWING
A70-1004-00	Vacuum Readout Meter	
A70-1056-00	Engine Out Safety Net/ Purge Cover Set	GW70-501056
A70-1265-00	SSME Vert C/O PLT	79K17943
A70-1289-00	Vert Access Stand	79K21669
A70-1290-00	Vert Pallet	79K21669
A78-5202-00	Tool, Lapping, ORB/ET	GW78-505202
A83-0002-00	Centaur Fluidline Support Set	GW83-500002
A83-0003-00	Centaur Mission Kit Cap and Plug Set	GW83-600003
C70-0307-00	3 Engine Simulator	88R0010900
C70-0743-07	Reg Panel	GW70-400743
C70-0903-00	Atmos Pneu Flow Tester	RG000014
C70-0904-00	Hi Press Flow Mtr	RG000015
C70-0907-00	Eng Int Insp set	RG000020
C70-0908-00	Large Vol Flow Mtr	RG003046-141
C70-0909-00	Ferry Flt Set	RG000023
C70-0910-00	DCU Loader	RES1198
C70-0912-00	Elect C/O Set	RG000018
C70-0914-00	Eng Leak Test Set	RG000013
C70-0915-00	Eng Leak Test Set	RG000012
C70-0916-00	Interface Test Pnl	RG000400

Table 3-6. SSME GSE List (Continued).

MODEL NUMBER	NOMENCLATURE	DRAWING
C70-0917-00	Gas Analyzer	RG000480
E70-0012-00	DCU Loader Cable	L070-000045
E70-0015-00	Conn Saver-MEC	L070-000096
E70-0032-00	HTR I/F BO Box	L070-000192
F72-0002-03	Port Gas Samp Pnl	L070-000017
H70-0528-00	Eng LRU Instl Set	GW70-430528
H70-0568-00	Eng Horiz Instl Fix	GW70-430568
H70-0629-00	Act Support Set	GW70-540629
H70-0764-00	Lift Truck	GW70-680674
H70-0774-00	Vert Eng Instl	RG-000327
H70-0852-00	Sling-SSME Heat Shield Handling	GW70-430852
H70-0855-00	Handling & Assy Set Aft Heat Shield Dome	GW70-540855
H70-0856-0	HE Tank Sling Set	GW70-430856
H70-0890-00	Eng Mover Jackset	GW70-540890
H70-0901-00	SSME Handling Fixture	RG000021
H70-0902-00	Sling Set Eng Hdlr	RG000003
H70-0903-00	Sling SSME Rotation	RG000004
H70-0905-00	Sling, SSME Component Handling	RG000009
H70-0911-00	Interface Pnl Set	RG000350

Table 3-6. SSME GSE List (Continued).

MODEL NUMBER	NOMENCLATURE	DRAWING
H70-1208-00	Hoist, SSME LROs	79K12132
H70-1352-00	Heat Shield Handling Fixture	80K50451
H70-1358-00	SSME Heat Shield and LRU Handling Crane	79K-19117
H72-1287-00	Dome Heatshield Removal Access Platform	79K16117
M70-0028-00	Eng Mounted Heat Shield Hndl Set	L070-000151
M70-0029-00	SSME Alignment Calculator Set	L070-000157
M70-0040-00	Turbo Pump Dolly	
S70-0679-06	MPS Heated GN2 Purge Panel	79K06966
S70-0679-07	SSME Drag UN GN2 Purge Panel	79K15931
S70-0679-08	HDLR Steer Bar	
S70-0679-11	Nozzle O2 Support	
S70-0695-02	GHE/GN2 0-1 Panel	79K08355
S70-0695-08	GHE/GH2 02 Panel	79K06356
S70-0902-00	WK PLTFM Shelves	
S70-0903-00	Stiff Arm Crows	
S70-0905-00	LRU Rail Supports	
S70-0908-00	LPG Storage Box	

Table 3-6. SSME GSE List (Continued).

MODEL NUMBER	NOMENCLATURE	DRAWING
S70-0909-00	T/C Covers	
S70-0911-00	HT'D GN2 Panel	79K06966
S70-0958-00	Filter/QU Assy Mps Pres Mon	GN70-420958
S70-1247-00	SSME Purge Panel (SLS)	79K12447
S70-1289-01	Ambient Bottle Fill System	
S72-0685-01	PRI HE, RED'c. & HE Bottle Fill - MLP	79K05639
S72-1107-01	GN2 Purge Panel MLP	79K05640
S72-1107-11	SSME drag On GN2 Purge Panel	79K15932
S72-1107-13	Protective Covers	RG000008
S83-0002-00	Centaur QD/Filter Set	
SA01-908	T/C Pads	RG000010
SA01-979	Special Tool Set	RG000017
SA02-034	Maint/Repair Set	RG000024
SA04-011	LPFTP I/F Seal Instl	RG000199
SA06-015	Eng SIM WGT Assy	RG003010
SA09-017	Purge Pnl (SLS)	79K12447
SA14-011	Purge Pnl - MLP	79K05640
SA17-006	Drag On Purge	79K15932
SA20-007	MPS QD LK CK PNL	79K25329
Z70-0001-00	Sling General Purpose	

Table 3-6. SSME GSE List (Continued).

MODEL NUMBER	NOMENCLATURE	DRAWING
Z70-0007-00	Pallet Truck	
Z70-0013-00	Platform Lifting Device	
Z70-0014-00	Fork Lift	
Z70-0018-04	Port Reg Panel	
Z70-0021-00	Fish Pole Hoist	
Z70-0023-00	Varian Leak Detector	

3.1.5 SSME-RELATED OMIs.

3.1.5.1 OMIs related to SSME operations are listed in table 3-7.

Table 3-7. SSME-Related OMIs.

OMI	NOMENCLATURE
A5214	SHUTTLE TRANSFER & MATE TO PAD
A5217	SSV/MLP RETURN TO VAB
V0009	CLOSED + OPEN LOOP ENTRY DYNAMIC STABILITY TEST
*V1001	SSME ELECTRICAL INTERFACE VERIFICATION
V1003	INITIAL ORBITER ACTIVATION
V1010	ORB. HYDRAULIC SYS FILL + BLEED CHECKOUT
*V1011.01	SSME ENG. DRY (LEAK + FUNC.)
*V1011.02	SSME (LEAK AND FUNC.) INT. & EXT. INSP.
*V1011.03	SSME PUMP TORQUE CHECKS (LEAK + FUNC.) CKS
*V1011.04	SSME HEAT EXCHANGER LEAK CHECKS AND FUNC.
*V1011.05	SSME HGM/LOX/LH2 LEAK + FUNC. CKS
*V1011.06	SSME POST INST LEAK & FUNC PNEU, CONTROLLER CK OUT
*V1011.07	SSME 10 START LEAK & FUNCTIONAL TESTS
V1032	ORB CLOSEOUT PRIOR TO ROLLOVER TO VAB
V1034	ORB FLIGHT CONT. FREQ. RESPONSE TEST
*V1038	MPS/SSME POST LANDING OPS (SLS) (CLS)
*V1046	SSME LK. + FUNC. REVERIF. POST FRF (VERT) (CONTINGENCY)

Table 3-7. SSME-Related OMIs (Continued).

OMI	NOMENCLATURE
V1060	FLIGHT CONTROL AEROSURFACE CHECKOUT
V1063	FLT CONTR + TVC C/O + SRB SIM INTERFACE VERIF
V1075	MAIN PROP REVERIF POST FRF
*V1105	SSME TO ORB ALIGN VERIF
V1111	PVD (ECS) SUPP OPS
V1113	ORB ATTITUDE REF
V1149	T-O UMBLICAL INT. LEAK CHECK
V1161	ORB VEH BUS REDUNDANCY TEST
*V1170	ENG HARNESS ELECT C/O
V1171-VOL 1	MPS/SSME PRESS + He ACTIVATION OPS - OPF
V1171-VOL 2	MPS/SSME PRESS + He ACTIVATION OPS - MLP
V1201	MPS/SSME He SIGNATURE TEST - HORIZONTAL
V1202	MPS/SSME He SIGNATURE TEST - VERTICAL
*V1204	SSME ELECT INTERFACE VERIF (CONTING)
V1245	ENGINE LEAK CHECK-ENGINE SHOP
V1246	FERRY FROM KSC
*V2003	HEATED GN2 PURGE PNL SYS VALID - OPF
*V2004	HEATED GN2 PURGE CONSOLE VALID - MLP
V2005	LO2 SYS He /GN2 CONSOLE VALID
V2006	LH2 SYS He/GN2 CONSOLE VALID
V2007	PRI He PRESS RED & He BOTTLE FILL CNSL VALID
V2027	VAC PUMP VALID INSTR

Table 3-7. SSME-Related OMI's (Continued).

OMI	NOMENCLATURE
V2067	INTRNL INSP & FOREIGN OBJ RETRIEVAL EQ VALID
*V2068	SELF PROP LIFT TRUCK & ENG INST (OPF)
V2236	PRI He PRESS RED & He BTL FILL PNL
*V2237	MPS GN2 PURGE PNL EM CHECKS
V2268	SSME DCU MEM LOADER VALID
V2270	ORB ENG SERV PLATFORM (ESP) OPS
*V2308	VALID OF SSME PURGE PNL
V2333	SSME VERT CHANGEOUT PLATFORM OPS
*V2339	SSME DRAG ON GN2 PNL VALID - OPF
*V2340	SSME DRAG ON PURGE PNL VALID - MLP
V2359	LH2/LOX TSM VACUUM JACKETED LINE C/O
V3502	GSE INITIAL CONFIG SETUP - OPF
V3504	GSE INITIAL CONFIG SETUP - PAD
V3508	OPF PLATFORM & DOORS
V3512	ORB PROTECTIVE COVERS & ACCESS PLAT INST & REMOVAL
V3551	He REDUCTION & He BTL FILL PNL ACT & SECURE
*V3553	SSME LRU RAIL ASSMB INST & REMVL
V3569	DCU MEMORY LOADER OPTIONS
V5002	ORB SPOTTING JACKING AND LEVELING
V5003	ORB FERRY KIT REMOVAL + PREP FOR ORB ACCESS
*V5005	SSME INSTALLATION (HORIZ)
*V5043	SSME HEAT SHIELD INST + REMOVAL (VOL 1,2,3)

Table 3-7. SSME-Related OMIs (Continued).

OMI	NOMENCLATURE
*V5057	TVC/SSME GSE INST/REMOV
*V5058	SSME REMOVAL (HORIZ)
*V5062	SSME INST (VERT)
*V5063	SSME REMOVAL (VERT)
V5069	ORB JACK XFER TO/FROM BODY JACK & LNDG GEAR SUPP STAND
V5086	POSITION ENG WITH C7 - 64 (PET TOOL)
*V5087	SSME/GSE HANDLING OPS
*V5E01	SSME RMVL/ INST - MFV
*V5E02	SSME LRU COMP RMVL/INST - HPOTP
*V5E03	MAIN ENG CONTROLLER RMVL/INST + VASCOS
*V5E04	POGO SUPPRESSION SYSTEM
*V5E05	PNEUMATIC CONTROL ASSEMBLY
*V5E06	SSME LRU COMP RMVL/INST - HPFTP
V5E07	PT SENSOR ELECT ICS BOX
V5E08	MPS LH2 RECIRC PUMP PKG RMVL/INST
V5E09	MPS LOX RELIEF VALVE RMVL/INST
V5E10	MPS LH2 MANI RV RMVL/INST
V5E11	MPS LH2 RECIRC ISO VLV RMVL/INST
V5E12	MPS LH2 MANI RSV RMVL/INST
V5E13	MPS LOX MANI RSV RMVL/INST
V5E14	MPS He FILTER REPLACEMENT

Table 3-7. SSME-Related OMIs (Continued).

OMI	NOMENCLATURE
V5E17	SSME LRU COMP RMVL/INST - OPOV
*V5E18	SSME LRU COMP RMVL/INST - OPOV
*V5E19	SSME LRU COMP RMVL/INST - CCV
*V5E22	SSME LOW PRESS MAIN OXD VLV COMP RMVL/INST
*V5E23	SSME LOW PRESS OXID T-PUMP COMP RMV
*V5E24	SSME LOW PRESS FUEL T-PUMP COMP RMVL/INST
*V5E25	SSME LRU COMP RMVL/INST - LPF D/D
*V5E26	SSME LRU COMP RMVL/INST - TVC ACT
*V5E28	SSME NOZZLE RMVL/INST
*V5E29	SSME GIMBAL BOLT RMVL/INST
V5E32	FUEL BLEED VALVE R & R
V5E34	OXIDIZER BLEED VALVE R & R
V5E35	GOX CONTROL VALVE R & R
V5L20	KATS LAB LRU R & R
V6002	POST FLIGHT INSPECTION
V6013	ORB SUPPORT EQ PT MAINTENANCE PLAN
*V6033	SSME RECEIVING INSP
*V6A44	LOCK SET MPS ACT
V6A45	CAP & PLUG SET AFT FUS
*V6A46	MPS ENG ALIGN VERIF SET
*V6A47	MPS SEV ACT PRELOAD DEV
V6848	SSME TVC ACT LOCK SET-LRV

Table 3-7. SSME-Related OMIs (Continued).

OMI	NOMENCLATURE
V6A49	VACUUM READOUT METER
*V6855	FLOW METER SET LARGE VOL
V6A57	MPS SSME LPU INST'L SET
*V6A58	FIXTURE MPS ENG HORIZ INST'
*V6A59	AFT HEAT SHIELD SLING
*V6A60	SUPPORT SET - MPS ACTUATORS
V6A61	HAND'L ADP AFT FUS MPS COMP
*V6A62	LIFT TRUCK - SELF PROPELLED
*V6A63	LIFT TRUCK - SELF PROPELLED
*V6A64	SLING - SSME HEAT SHIELD HAND'L
*V6A65	SSME HANDLING FIXTURE
*V6A67	SLING, SSME COMP HAND'L
V6A69	PUMP ASSM VACUUM & PURGE
*V6A70	GN2 PURGE PANEL - OPF
V6A71	GHe / GN2 0-1 PNL
V6A72	GHe / GN2 0-2 PANEL
*V6A73	COVERS, SSME & ENCLOSURES PROTECT
*V6A76	TOOL SET, SSME SPECIAL
V6A77	FILTER/QD ASSY MPS PRESS MON
V6A78	PRIME RED'C & He BOTTLE FILL - MLP
*V6A79	GN2 PURGE PANEL - MLP
V6B27	PQV/ACOUSTIC EMISSION EQUIP

Table 3-7. SSME-Related OMI's (Continued).

OMI	NOMENCLATURE
V6C03	AFT FUS HORIZ INST SET
V6C07	INST/REPAIR SET TPS
V6C23	VERT AFT FUS EQUIP INST SET
V6C32	PL ATTACH FTG SLING SET
V6C44	ENG SERV PLATFORM
V6C45	ESP TRANSPORTER
V6C46	PREV MAINT ACCESS PLAT OPF BAY 1-2
V6E34	SLING PF 1 & NH3 TANK PALLET
V6E36	SLING SET OMS DELTA V
*V6E83	SSME LRU HOIST
*V6E84	SSME THERMO PROTECTION MAINTENANCE SET
*V6E85	SSME PURGE PANEL -SLS
*V6F34	SSME DRAG ON PURGE PANEL - MLP
*V6F35	SSME DRAG ON PURGE PANEL - OPF
V6F76	He BOTTLE FILL PANEL
V6F81	HANDLING & ASSY SET AFT HEAT SHIELD
*V6F82	ENG MOUNTED HEAT SHIELD HANDLING SET
V6G03	CRYOGENIC SENSOR SIMULATION
*V6G04	ENG OUT SAFETY NET/PURGE CVR SET
V6G11	UNSCHED ENG LEAK TEST SET
V6G12	PM-ENG I/F TEST PLATE SET
V6G13	PM-SCHED ENG LEAK TEST SET

Table 3-7. SSME-Related OMIs (Continued).

OMI	NOMENCLATURE
*V6G18	ENG INSTLR SET SSME (VERT)
*V6G21	ROTATING SLING - SSME MAINT
*V6G22	TURBOPUMP DOLLY - SSME MAINT
*V6G23	ELECT C/O / MAINT SET SSME
*V6G24	FERRY FLIGHT SET-SSME MAINT
*V6G25	SSME LPFTP INTERFACE SET
*V6G26	SSME INTERFACE STRUT SET
*V6G38	SSME THROAT ACCESS PLATFORM
*V6G26	PNL SET, INTERFACE STRUT, ENG HANDLER
*V7017	PNEU ATM FLOW METER TESTER CALIB
*V7018	HIGH PRESS PNEU FLOW METER TESTER CALIB
*V7077	LARGE VOL FLOW METER TESTER CALIB
V7103	GN2/GHe MPS (0-1) REG & CON PNL ASSY
V7104	GN2/GHe MPS (0-2) REG & CON PNL ASSY
*V7110	GN2 ENG PURGE PNL ASSY CALIB - OPF
V7111	PRI He RED & He BOTTLE FILL PNL
*V7112	GN2 ENG PURGE PNL ASSY CALIB - MLP
V7120	PORT VAC PUMP & PURGE UNIT CAL
*V7147	PNEU PRESS UNIT CALIB C70 - 0743 REG PNL
*V7193	CAL OF SSME PURGE PNL
V7200	ENG TO ORB CENTERLINE L/O
*V7214	SSME DRAG ON PURGE PNL ASSY CALIB - OPF

Table 3-7. SSME-Related OMIs (Continued).

OMI	NOMENCLATURE
*V7215	SSME DRAG ON PURGE PNL ASSY CALIB - MLP
*V7240	CALIB OF AMB GHe BOTTLE FILL CONTROL PNL
*V7247	AMBIENT He BOTTLE FILL PNL CALIB
*V9001	ORB PWR UP/PWR DN SSME OPTIONS
V9002.01	OPF VEH HYD PWR UP/DWN
V9002.02	MLP VEH HYD PWR UP/DWN
V9002.03	VEH HYD CIRC PUMP PWR UP/DWN
	-RESERVOIR QTY ADJUST & SAMPLE
V9002.04	GSE HYD PWR UP/DWN
V9002.05	FLT CNTRL & AEROSURF/SSME/OMS ACTUATOR POSITIONING
V9002.06	SSME PWR UP/DWN
V9002.07	HYD PWR UP/DWN WALKDOWN / VEH PREP
V9002.08	VEHICLE SUPPORT TASKS
V9002.09	GSE HYD PWR UP PREPS
V9002.10	S70 - 0952 FLEXHOSE INST/RMVL
V9005	HYD STYD PWR UP/DWN
V9014	SAMP METHODS FOR FLUIDS
*V9018	SSME/MPS PREPS & SECURING FOR LOAD
V9019	ORB MPS VAC JACKETED LINE CKS
V9035	ORB OV-099 DISPLAYS & CONTROLS NOMENCLATURE DOC

3.1.6 MPS/SSME INTEGRATED OMIs.

3.1.6.1 Integrated OMIs. Table 3-8 lists MPS/SSME integrated OMIs.

Table 3-8. MPS/SSME Integrated OMIs.

OMI	NOMENCLATURE
S0001	ORBITER INTEGRATED TEST
S0004	ORBITER TOW & MATE
S0007	LAUNCH COUNTDOWN
S0008	SHUTTLE INTERFACE TEST - VAB
S0009	PAD INTERFACE TEST
S0010	PLUGS OUT OVERALL TEST & CONFIGURATION
S0011	MPS LO2 / LH2 SIMULATED LOADING TEST
S0012	MPS LO2/LH2 AUTO LOAD / DETANK TEST
S0013	CDDT/FRF SIMULATED FIRING TEST
S0014	WET CCDT/FRF
S0015	LAUNCH READINESS VERIFICATION
S0017	LAUNCH COUNTDOWN - DRY
S0018	VERIFICATION TEST AFTER LIGHTNING STRIKE
S0026	SHUTTLE LANDING - POST LANDING CONVOY OPS - EAFB
S0027	SHUTTLE LANDING - POST LANDING CONVOY OPS-NORTHRP
S0028	SHUTTLE LANDING - POST LANDING - KSC
S0029	SHUTTLE LANDING - POST LANDING - CLS
S0030	ORBITER DEMATE FROM E.T.

Table 3-8. MPS/SSME Integrated OMIs (Continued).

OMI	NOMENCLATURE
S0034	SHUTTLE POST LANDING OPS AOA/CLS -WSSH
S0036	SPECIAL TANKING TEST
S0037	INTEGRATED CRYO LOAD & APU RECERTIFICATION
S0038	INTEGRATED PREPS FOR SSV/MLP RETURN TO VAB
S0039	STS LAND BANJUL, GAMBIA
S0042	POST LANDING - KSC
S0044	SIMULATED LAUNCH
S0055	STS LAND MOROCCO
S0056	SIM PROPELLANT LOAD
S0057	POST LANDING
*S1003	MPS LO2 LOAD/DRAIN
*S1004	MPS LH2 LOAD/DRAIN
S1005	TOTAL SYS DEW PT. + LOX PRETANKING CONDITIONING
S1006	LH2 PRETANKING CONDITIONING
S1014	LH2 POST TANKING PURGE
S2005	POST LAUNCH SECURE
S5008	ORB/ET UMBILICAL MATE
S5009	ORD. INSTALL & AFT CLOSEOUT
S6013	SUP. EQUIP. MAINTENANCE PLAN
S9001	SHUTTLE POWER UP
S9002	INTEGRATED DATA REQUIREMENTS

Table 3-8. MPS/SSME Integrated OMIs (Continued).

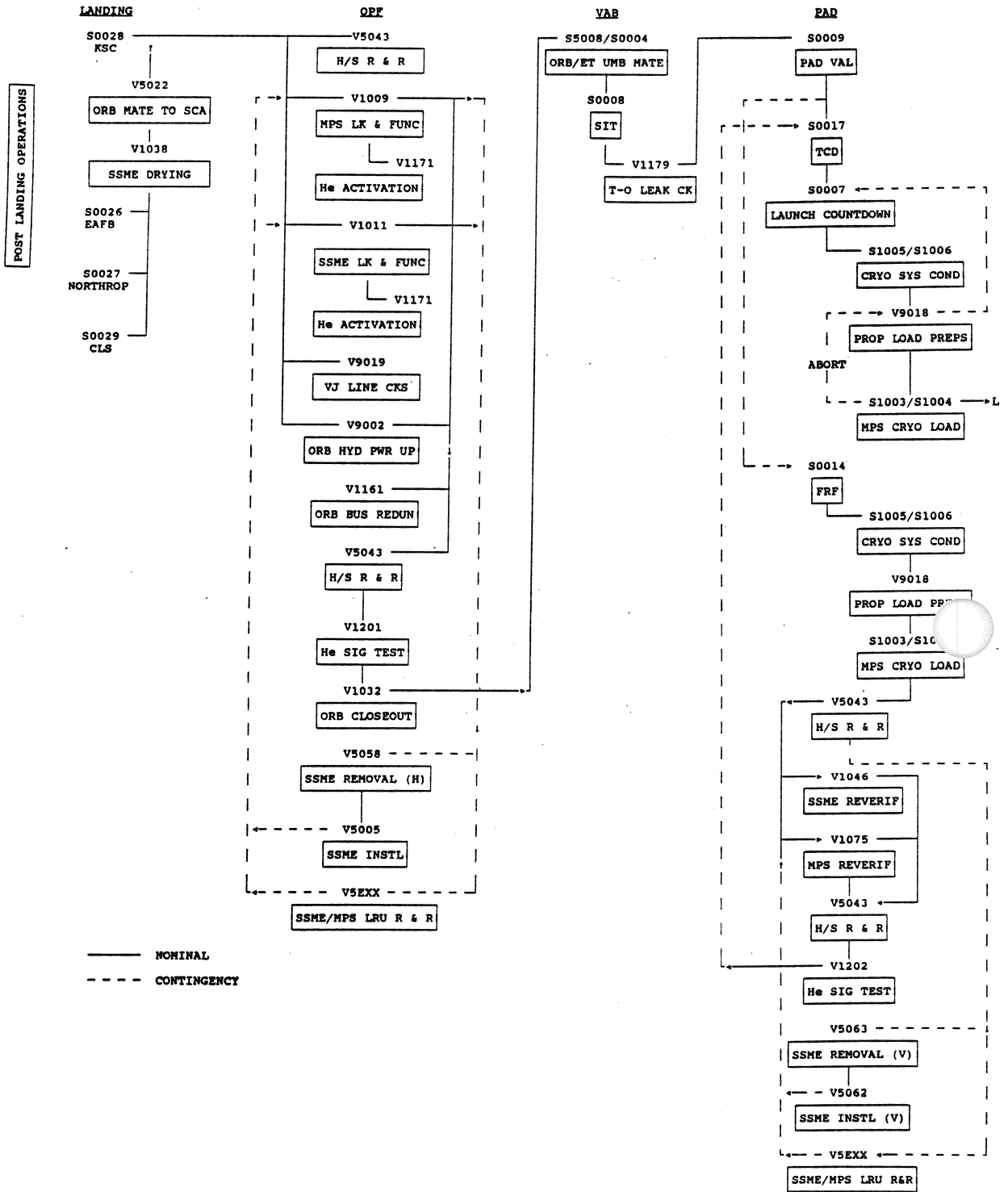
OMI	NOMENCLATURE
S9005	GROUND LAUNCH SEQUENCER DOCUMENT - LAUNCH COUNTDOWN
S9008	PAD EMERGENCY PROCEDURES

* INDICATES PRIME RESPONSIBILITY

3.1.7 MPS/SSME GROUND PROCESSING FLOW.

3.1.7.1 MPS/SSME ground processing flow is depicted in table 3-9.

Table 3-9. MPS/SSME Ground Processing Flow



4.0 GLOSSARY.

4.1 DEFINITION OF TERMS.

4.1.1 The following is a list of terms associated with the Main Propulsion System. For terms having an acronym, the acronym is listed first followed by its definition as it applies to MPS.

ABSOLUTE PRESSURE - A term used in engineering literature to indicate pressure above the absolute zero value corresponding to empty space or the absolute zero of temperature as distinguished from gauge pressure. In vacuum technology, pressure always corresponds to absolute pressure and not to gauge pressure; therefore, the term absolute pressure is not required.

ACCEPTANCE - The act of an authorized agent of the procuring organization by which the procuring organization assents to ownership of existing and identified contract items, or approves specific services rendered as partial or complete performance of the contract.

ACCEPTANCE TESTING - Tests to determine that a part, component, subsystem, or system is capable of meeting performance requirements prescribed in the applicable specification or other documents.

AGOSS - Automated Ground Operations Scheduling System - also known as Autogoss. Computer system used for scheduling.

ATMOSPHERIC PRESSURE - The pressure of the atmosphere at a specified place and time.

- A. The standard atmosphere, or normal atmosphere, is defined (independently of barometric height) as a pressure of 1,013,250 dyne/cm².
- B. The normal atmosphere has also been defined as the pressure exerted by a mercury column 760 mm in height at 0C under standard acceleration gravity of 980.665 cm/sec². Assuming a density of mercury at 0C of 13.59509 g/cm³, this is equal to 1,013,249 dyne/cm².

AWCS - Automated Work Control System. Overall computer system used for paper control.

CA - Corrective Action. Action taken to reduce or prevent recurrence of a nonconformance.

CAAR - Corrective Action Assistance Request. Form used for requesting analysis of recurring problems.

CATEGORY - A specific classification assignment (e.g., 1M-Mission Mandatory) to a configuration change for the purpose of priority identification and management.

CAUSE - The event or series of events responsible for the nonconformance.

CCBD - Configuration Control Board Directive. The disposition document or a computer-generated facsimile that records the approval or disapproval decision of the CCB chairperson on change proposals and is the basis for authorized follow on action by the design, procurement, and implementing organizations.

CHANGE CONTROLLER - A member within each CCB organization that is responsible for the ESR tracking number assignment, ESR record maintenance, and configuration status accounting data entry into CMIS.

CIG - Connector Integrity Group. Making or breaking mechanical or electrical connections requires identification in the CIG Log.

CMIS - Configuration Management Information System. The aggregation of SPC automated systems that support the requirements and functions of configuration management (e.g., Configuration Management Data System, LSOC Configuration Management System).

CONFIGURATION CHANGE - A form, fit, or function change to an end item after the configuration baseline is developed.

CONFIGURATION CONTROLLED END ITEM - A specific SPC end item whose configuration baseline is maintained by the sustaining engineering organization through the formal configuration management change processing system.

CONSTRAINT - A condition which restricts the initiation, continuation, or completion of operations until some action has been taken.

CREW SQUAWK PROBLEMS - A problem of sufficient concern to a crew member/representative such that review of the hardware and/or documentation by the flight crew representative (VITT) is required prior to closure of that document.

CRITICALITY CATEGORIES - The alphanumeric indicator assigned to categorize the predicted consequences of a particular failure during critical operating periods.

<u>Criticality</u>	<u>Definition</u>
1	Loss of life or vehicle.
*2	Loss of mission.
3	All others.

identified by the SPC Certification Board.

CVAS - Configuration Verification Accounting System. Rockwell Computer System used to keep track of orbiter parts. These parts are referenced by an order control number (OCN).

DEGASSING - The deliberate removal of gas from a material, usually by application of heat under high vacuum.

DEV - OMI Deviation. Form used to implement changes in OMIs.

DEVIATION/WAIVER - A specified authorization before the fact to depart from a particular requirement of specifications or related documents is granted by a deviation. Use or acceptance of an article which does not meet specified requirements is authorized after the fact by a waiver.

DISPOSITION - The act of approval or disapproval of a change request by a CCB chairperson or cancellation of the change request by its requester/director.

DR - Discrepancy Report. One of four reports used in the PRACA System. This report returns to flight configuration without Engineering involvement.

DV - Designated Verification. A technician designated to perform

some Quality Inspection functions.

EI - Engineering Instruction (KSC 21-122). Form documenting configuration change requiring relatively short downtime, i.e. PROM change, HIM card change, or cable reconfiguration. An EI may provide a S/W patch to permit a test to proceed.

EICN - End Item Control Number. Each piece of equipment (i. e. valve, panel) is assigned a unique identifying number known as the end item number. The EICN is used in the PRACA System for paper and hardware tracking.

EO - Engineering Order. Form used to request changes to drawings, etc.

EPD - Emergency Procedures Document. Each facility has an EPD. The EPD lists emergencies together with actions to be taken in case of that emergency.

ESR - Engineering Support Request. A form used for requesting changes to facilities, system, equipment and specific flight element configuration controlled end items.

FAILURE - The inability of a system, subsystem, component, or part to perform a required function within specified limits, under specified conditions for a specified duration.

FD - Function Designator. Symbolic name for the hardware addresses of the signals and stimuli that interface the GSE and the LPS. These addresses are a composite of the HIM addresses, HIM card slot address, and the HIM card pin. The FDs are stored in the CCMS data bank along with the associated data, e.g., address. As GOAL programs are compiled and configured for execution in the CCMS, the FD names are replaced with the hardware address and sensor characteristics. This approach supports the diverse and ever-changing requirements placed on the CCMS at minimum impact to the application software.

FE - Flight Element, A Space Shuttle System component (e. g., orbiter, ET, or solid rocket booster) that is launched to send the flight crew and payload on a Space Shuttle mission.

FE CCB - Flight Element Change Control Board. An SPC functional body, subordinate to the SPC CCB, whose chairperson is solely responsible for the approval direction for SPC to implement flight element hardware configuration changes within the limits of the authority of the Board.

FE GSE - Flight Element GSE. The specific GSE end items that are the design responsibility of JSC and MSFC flight element development contractors.

FLIGHT EFFECTIVITY - Identification of the NASA assigned STS flight number (e.g., STS-30) for a specific launch/flight.

FRACTURE CRITICAL PART - A part which requires controls such as testing and nondestructive evaluation to ensure an acceptable, calculable service life.

FUNCTIONAL MATH MODEL - A math model that simulates a particular subset of a hardware system, ranging from simple command/measurement initialization as defined by requirements, to complete functional simulation of the system.

GAS - Defined as the state of matter in which the molecules are practically unrestricted by intermolecular forces so that the molecules are free to occupy any space within an enclosure. In vacuum technology, the word has been loosely applied to the noncondensable gas and vapor within a vacuum system.

GAS BALLAST - The venting of the compression chamber of a mechanical pump to the atmosphere to prevent condensation of condensable vapor within the pump. Also called vented exhaust.

GAUGE PRESSURE - A term used in engineering literature to indicate the difference between the absolute pressure and atmospheric pressure as read from a differential manometer having atmospheric pressure on the reference side. This term is seldom used in vacuum technology.

GITS - KSC Ground Interface Technical Subgroup. A functional body composed of government and contractor members, and chaired by the SPC GIWG member, that is responsible for the ground systems technical development and coordination of interfaces defined on all Level II ICDs/IRNs involving KSC.

GIWG - Ground Interface Working Group. A functional body composed of government and contractor members, and chaired by the JSC government member, that ensures Level II ICDs/IRNs are prepared, coordinated, processed, and submitted to the Level II PRCB for disposition.

GROUND SYSTEMS - A generic term to identify the ground support facilities, systems, and equipment of the Space Shuttle operations program.

GS CCB - Ground Systems Configuration Control Board. An SPC functional body, subordinate to the SPC CCB, whose chairperson is solely responsible for the approval or disapproval of proposed configuration-controlled hardware changes to SPC designed facilities/systems/equipment within the limits of the authority of the board. The Board is also responsible for the authorized direction for SPC to implement flight element development contractor designed GSE and KSC Engineering Development Directorate designed facilities/systems/equipment modifications.

GSE - Ground Support Equipment. A specific group of ground systems that are configuration-controlled support equipment and items of the Space Shuttle operations program.

HAZARDOUS OPERATION (Hazardous Tasks) - Any operation involving activities that could result in exposure/injury/loss of life to operating personnel and/or damage to systems/equipment or have an environmental impact.

HDA - Hardware Dispositioning Area. Logistics location through which removed parts must be routed.

HIGH VACUUM - Frequently defined as a pressure less than some upper limit, such as one torr or one millitorr. High vacuum, and similar vacuum terms, should not be defined as a pressure but rather as the condition or state in a gas-filled space at pressures less than some upper limit or within specified limits.

A. High vacuum is defined as the condition in a gas-filled space at pressures less than 10^{-3} torr.

B. The following classification of degrees of high vacuum has been proposed:

Condition	Pressure Range
High Vacuum	10^{-3} to 10^{-6} torr (microtorr range)
Very High Vacuum	10^{-6} to 10^{-9} torr (manotorr range)
Ultra-High Vacuum	10^{-9} torr and below

ICD - Interface Control Document. A set of drawings with a defined limit of scope that records the common design interface features of configuration-controlled end items between two or more design agencies.

ICR - Instruction Change Request. Form used to revise OMIs.

INTERFACE - A region common to two or more elements, systems, projects, or programs characterized by mutual physical, functional, and procedural properties.

IPR - Interim Problem Report. One of four reports in the PRACA System. IPR is used to troubleshoot the problem and find the part causing the problem.

IRN - Interface Revision Notice. A document that contains the exact detail of an approved change to an ICD.

LEAK RATE - In leak detection practice, leak rate is defined as the rate of flow (in pressure-volume units per unit time) through a leak with gas at a specified high pressure (usually atmospheric pressure) on the inlet side and gas at a pressure on the exit side which is low enough to have negligible effect on the rate of flow.

LEO - Lead Engineering Organization. An SPC engineering organization selected by the GS CCB chairman. An individual in the LEO is designated Project Engineer and is responsible for the complete integration and management of each configuration controlled change of end items from assessment through implementation and closure.

LOO - Launch Operations Order. The single authoritative directive to conduct the launch.

LOW VACUUM - Applies to the condition in a gas-filled space at pressures less than 760 torr and greater than some lower limit. It is recommended that this lower limit be chosen as 25 torr corresponding approximately to the vapor pressure of water at 25C and to 1 inch of mercury. Two self-consistent classification schemes which have been proposed for the pressure range from 760 to 10^{-3} torr are as follows:

<u>Condition</u>	<u>Pressure Range</u>
Low Vacuum	760 to 25 torr
Medium Vacuum	25 to 10^{-3} torr
Rough Vacuum	760 to 1 torr (torr range)
Fine Vacuum	1 to 10^{-3} torr (millitorr range)

LRU - Line Replaceable Unit. The part which is removed in the accomplishment of a PR/TPS and must be sent for further dispositioning.

MAJOR NONCONFORMANCE - Any nonconformance that could affect matters such as safety to individuals or facilities, reliability, durability, performance, interchangeability, weight (where weight is a sufficient factor), or basic design intent. Material substitution is defined as a major nonconformance. This definition is limited to, and to be used only, for deviation/waiver processing determinations.

MANOMETER - An instrument for measuring pressure of gases and vapors whether above or below atmospheric pressure.

MATH MODEL - A piece of software written in the SGOS language, capable of providing expected values for measurement FDs and GPC memory addresses GMEM's; and capable of appropriately responding to GSE, LDB, and TCS commands.

McLEOD GAUGE - A liquid level vacuum gauge in which a known volume of the gas, at the pressure to be measured, is compressed by the movement of a liquid column to a much smaller known volume, at which the resulting higher pressure is measured. Particular designs are named after the inventors or by various trade names.

MERL - Material and Equipment Requirements List. Form used to request parts, etc., from Logistics in support of OMIs.

METS - Material, Equipment, Tools, and Support list. Computer-generated list to request parts from Logistics in support of STS Job Cards.

MICR - Material Issuance and Configuration Record. Form used to request parts from Logistics in support of ET/SRB paper.

MIP - Mandatory Inspection Point. A work step requiring verification of a Technician, Quality Inspector, and NASA Quality Inspector.

MISSION EFFECTIVITY - Identification of the NASA assigned mission/manifest number (e.g., 61-A) that corresponds with a specific STS flight number.

MR - Material Review. A one time repair or disposition of articles and materials which cannot or will not be returned to drawing/specification requirements.

MRB - Material Review Board. Group assigned to support Engineering disposition of problems in the case of nonconforming material (not return to drawing.)

MSC - Material Service Center. An activity established adjacent to a facility or work area concentration for the purpose of furnishing supply support services to all organizational and functional activities in the immediate area(s) which require such service. Each MSC provides a single point of contact with the Supply Support System, receives stock, and issues material and supplies required by the area(s) serviced.

OISR - Open Item Status Report. A report in the SPDMS data base in the AGOSS System. Keeps track of all open paper.

OM - Operation Manuals. TOPS which are used for ET/SRB work.

OMI - Operation and Maintenance Instruction. Provides detailed sequence (s)/step-by-step instructions, either included within the procedure or by direct reference to another approved procedure, both of which are accomplished through manual and/or automated means. Procedures derived from the requirements identified in OMRS and operations and maintenance plans and practices to accomplish the processing of flight elements using directly related support equipment and systems. These procedures accomplish organizational level work when initiated. Automated procedures shall be initiated and controlled by manual procedure. Each procedure includes identification of all other procedures necessary to conduct the applicable task, such as: all necessary pretest conditions, safety requirements, and operations that shall be verified or performed prior to initiating and securing operations, a list of tools, equipment, and materials, detailed sequences/step-by-step instructions with appropriate safety warnings and cautions, and when applicable and authorized, nondestructive inspection.

OMP - Operation and Maintenance Plan. Computerized document which compares all contractual obligations (OMRS) to the TOP (WAD) which satisfies it.

OMRSADS - Operation and Maintenance Requirements and Specifications Accomplishment Data Sheet. This is equivalent to Section 1.8 of an OMI. It is used for all real-time paper not containing a Section 1.8 which satisfies an OMRS.

OMRSD - Operations and Maintenance Requirements and Specifications Document. Contains all the contractual obligations SPC has to meet for processing the STS.

OMRS EXCEPTION - Acceptance of nonperformance of a test requirement as defined by OMRS for one flight only. (The requirement has not been performed or is not performed as defined.)

OMRS WAIVER - Granted use or acceptance of a requirement/configuration that does not meet the requirement set forth in OMRS. (The requirement has been attempted but failed to meet the specification.)

PEDS - PED System. Designed to provide detailed instructions on subjects of engineering interest. These instructions include the specifics of how engineering tasks are to be performed at KSC with the objective of ensuring consistency of procedures and the highest quality of engineering.

PIRN - Preliminary Interface Revision Notice. A document that contains the requested detail to change an ICD.

PM OMI - Preventive Maintenance OMI. Standard type OMI that performs periodic inspection and preventive maintenance of GSE.

PMN - Program Model Number. An alphanumeric identifier assigned by the government to Space Shuttle GSE and Ground Support Systems.

PMR - Parts and Materials Request form. Used with a PR to order parts from Logistics.

PP&C - Process Planning and Control. The group of OMD directorate which controls the scheduling of work.

PR - Problem Report. One of four reports of the PRACA System. The PR is used to remove and replace failed parts.

PRACA - Problem Reporting and Corrective Actions System. Used to work and track nonconformances for the SPC. See also DR, IPR, LRU PR, and PR.

PRCBD - Space Shuttle Program Requirements Control Board Directive. The disposition document or a computer-generated facsimile that records the approval or disapproval decision of the Level II PRCB chairperson on change proposals and is the

basis for follow-on actions by the affected space centers/organizations.

PRELIMINARY MATERIAL REVIEW - The action taken by contractor appointed Quality personnel when a nonconformance is found during production but referral to the MRB for disposition is not warranted. Dispositions are limited to rework, return to vendor, scrap, and no defect.

PROJECT EFFECTIVITY - Identification of the STS project (e.g., MLP-3 activation, Centaur deactivation) that is applicable to any Space Shuttle processing activity.

PSP - Processing Support Plan. The document which lists all scheduled work for each flow.

PWO - Project Work Order number. An 8-digit identifier with the capability to identify the site (KSC/VLS) and fiscal year funds involved, mission or type of work, performing/responsible department, and unique tasks. As the job charge number, it is the lowest level of work authorization, budgeting, cost collection, and performance measurement. The PWO number links the responsible or performing department with the WBS to collect labor, material, travel, and other direct costs associated with the specific tasks.

QC Designee - Person/function identified through written documentation from the QC organization as having limited QC authority/ responsibility.

QDC - Quality Document Center. Room in the VAB which houses all closed paper.

QPRD - Quality Planning Requirements Document. Outlines work verification requirements.

RC - Recurrence Control action. Action taken to reduce or prevent the recurrence of a nonconformance.

RCA - Recurrence Control Action. Analysis of recurring problems.

RCN - Requirements Change Notice. Form used when requesting a change to an OMRS.

REMEDIAL ACTION - Action taken to restore a nonconforming item or system to a usable/conforming condition. Remedial action may also be the final action.

REPAIR - To subject nonconforming material to an approved process designed to reduce to an acceptable level, but not completely eliminate, the nonconformance.

RETURN to VENDOR/SUPPLIER/OFFSITE REPAIR FACILITY - A disposition for nonconforming materials/hardware to return to a reliable repair source when local repair is unavailable.

REWORK - To subject nonconforming material to an approved process designed to bring it into complete conformance.

RM&QA - Reliability, Maintainability and Quality Assurance. Data center and central control point from which IPR/PR/DR numbers are issued and IPR/PR/DR information is entered into the PRACA data base/AGOSS where required, and closed WADs are retained. LPS Support Operations Work Control desk issues internal tracking numbers for IPRs.

RRB - Risk Review Board. An SPC functions body that reviews changes with potential technical, schedule, and cost risk whose chairperson makes recommendations to the appropriate CCB chairperson prior to disposition.

SCRAP - Property that has no reasonable prospect of being sold except for the recovery value of its basic material content.

SDS CCB - Shuttle Data Systems Configuration Control Board. An SPC functional body, subordinate to the SPC CCB, whose

chairperson is solely responsible for the approval or disapproval decision of SPC LPS and SPDMS configuration changes within the limits of the authority of the Board.

SPDMS - Shuttle Processing Data Management System. All SPC ADP, information management, telecommunications, and related systems or activities at KSC and VLS, except those directly related to or involved in testing, processing, servicing, or launching space vehicles by SPC.

SPI - Standard Practice Instruction. Documents which outline all procedures for SPC.

SRP - Standard Repair Procedure. An MR disposition that has been preplanned and released as a formal document by the development contractor and approved by PMRB to provide work and verification instructions for the repair of repetitive nonconformances that do not return hardware to drawing configuration. Implementation of a standard repair requires LSS concurrence when specifically required by the SRP limitations. Real-time deviations in the application of a standard repair require full MRB approval.

STATION SET - A defined accumulation of equipment, systems, and facilities at a particular site(s) required to support a particular function(s) (e.g., Station Set 23, launch pad, Station Set 22, MLP, etc.).

SVP - Software Verification Procedure. Working Paper for Software.

SYSTEM LEVEL PROBLEM -

- A. Problems occurring on common hardware items as listed in JSC 07700 Volume VI, Book 2, or Volume VII.
- B. Problems affecting major STS element physical interfaces (e.g., connectors and separation devices).

SYSTEM MATH MODEL - A math model that simulates a hardware system to the extent defined by requirements.

TAIR - Test Assembly Inspection Record. Binders which house all paper. Filed according to the EICN at the WCS.

TAIR BOOK - A collection of WADs and test records maintained and sectionalized in binders or files that provide the systematic recording and accumulation of WADs and special data generated for flight hardware and GSE hardware and software.

TAIR/WORK CONTROL STATION - Areas/locations established within each Space Shuttle site/facility to maintain and control the classified and unclassified WADs required to support flight element and support equipment processing. The work control

station facilitates floor-level planning and supervision of tasks and resources, optimizes hands-on performance and closure of work, and provides management visibility for effective control of schedules and costs.

TDC - Technical Data Center. Room at complex E which handles all vendor drawings, books, etc. Currently operated by subcontract.

TFO - Transfer from Original. The transferring of a stamp number over the phone or headset.

TIR - Temporary Installation/Removal. All flight items are accounted for in the log.

TPS - Test Preparation Sheet (is not used for nonconformances). Provides implementing instructions for accomplishing configuration changes and/or for the fabrication of special test equipment. A TPS also provides real-time instructions for accomplishing one-time nonconfiguration changes. TPS shall conform with formatting instructions in this handbook. After a description of the purpose of the TPS, the first portion of block 12 (description) shall contain paragraphs 1.1 through 1.9 as in an OMI. Paragraphs which do not apply are annotated N/A.

TPS - Thermal Protection System. The insulating material found on the flight hardware.

TPS PRACA - Thermal Protection System Problem Reporting and Corrective Action System. The TPS required completely different form/procedures than those used for other hardware.

UND - User Need Date. A date that reflects when the user of a hardware/software end item needs the baselined/modified end item in a usable state.

UNEXPLAINED CONDITION/ANOMALY - A condition (ghost or phantom) that cannot be repeated or cause cannot be determined.

UNSATISFACTORY CONDITION - Any nonconformance for which engineering resolution is required and/or requires corrective action beyond the specific article under consideration. Included in this definition are conditions which cannot be corrected to the specified configuration using the standard planning operations, or an event which could lead to a failed condition, but does not immediately affect the function of the article such as contamination, corrosion, workmanship requiring engineering disposition, etc, or a suspect condition that may conform to drawing or specification, but represents a potential problem.

WAD - Work Authorization Document. See TOP and OMI. Any document that identifies and authorizes work and provides detailed instructions for the operational checkout, verification, modification, maintenance, repair, servicing, handling, or

transport of flight hardware/software or support equipment.

WCS - Work Control Station. The stations used to control all paper which goes to/form the floor for work. The TAIR books are kept in the station filed by EICN. Also known as TAIR stations.

4.2 ABBREVIATIONS.

4.2.1 COMMON ABBREVIATIONS.

4.2.1.1 The following is a list of standard and non-standard abbreviations used in, but not limited to SSMEs.

ac	alternating current
ALT ACCEL	altitude acceleration
ALT	altitude
BFS	Backup Flight System
bhd	bulkhead
C	centigrade
C	center
c.g.	center of gravity
c/l	centerline
C/O	checkout
C/W	caution/warning
C&W	caution and warning
CB	circuit breaker
CCMS	Checkout, Control and Monitor Subsystem (LPS)
CDB	Common Data Buffer

ABBREVIATIONS (Continued)

CDR	commander
CDS	Central Data System
CIG	Cable Integrity Group
CIG	Communications and Interface Group
CLS	contingency landing site
cmd	command
COMM	communications
CR	Change Request
CRR	Constraints Revision Record
CRT	cathode ray tube
CSS	control stick steering
CTS	call to stations
CVFY	check/verify
D&C	Display and Control
dB	decible
dc	direct current
DEA	deployed electronics assembly
dia	diameter
disc	disconnect
DMA	deployed mechanical assembly
DMS	Data Management System
DOD	Department of Defense
DPS	Data Processing and Software
DPS	Data Processing System
DR	Discrepancy Report

ABBREVIATIONS (Continued)

EAFB	Edwards Air Force Base
ECL	entry closed loop
eng	engine
EO	Engineering Order
EPD	Electrical Power Distribution
EPDC	electrical power distribution and control
EPDCS	Electrical Power Distribution and Control System
EPDS	Electrical Power Distribution System
ESA	Engineering Support Assembly
ESR	Engineering Support Request
ET	external tank
F	Fahrenheit
FCV	Flow Control Valve
FD	function designator
FEP	Front End Processor
FLT	flight
FLT	floating
ft	foot/feet
ft ³	cubic feet
FWD	forward
gal	gallon
GH ₂	gaseous hydrogen
GLS	Ground Launch Sequencer
GMT	Greenwich Mean Time
GN ₂	gaseous nitrogen

ABBREVIATIONS (Continued)

GNC	guidance and navigation computer
GND	ground
GO ₂	gasous oxygen
GOAL	Ground Operations Aerospace Language
GP	general publication
GPC	general purpose computer
GRD	ground
GSE	Ground Support Equipment
GT	greater than
He	helium
HGD	hazardous gas detection
HIM	Hardware Interface Module
HMF	Hypergol Maintenance Facility
HRSI	high-temperature, reusable surface insulation
HYD	hydraulics
Hz	hertz (cycles per second)
I/E	ingress/egress
ib	inboard
IFM	in-flight maintenance
IMU	inertial measurement unit
in.	inch
in ³	cubic inch
inbd	inboard
IND	indicator
INS	Inertial Navigation System

ABBREVIATIONS (Continued)

IPR	Interim Problem Report
ISOL	isolation
jetn.	jettison
JSC	Johnson Space Center
KSC	Kennedy Space Center
L	left
LCC	Launch Commit Criteria
LCC	Launch Control Center
LCT	launch countdown
LED	light-emitting diode
LH ₂	liquid hydrogen
LO ₂	liquid oxygen
LOS	line-of-sight
LPFT	low pressure fuel turbopump
LPOT	low pressure oxidizer turbopump
LPS	Launch Processing System
LRU	Line Replaceable Unit
LSOC	Lockheed Space Operations Company
lt	light
LTD	Lockheed Test Director
LVDT	linear variable differential transducers
manf	manifold
MCC-H	Mission Control Center - Houston
MDM	multiplexer/demultiplexer
ME	main engine

ABBREVIATIONS (Continued)

MECO main engine cut off
MET master events timer
MET Mission Elapsed Time
MET Mission Events Time
MFV main fuel valve
min minutes
MLP Mobile Launch Platform
MPS Main Propulsion System
MRB material review board
MSFC George C. Marshall Space Flight Center
n.mi. nautical miles
NASA National Aeronautics and Space Administration
NC normally closed
NO normally open
nom nominal
NRZ non-return-to-zero
NTD NASA Test Director
O₂ oxygen
ob outboard
od outside diameter
OIR Open Item Review
OIS Operational Intercommunication System
OISR Open Item Status Report
OJT On the Job Training
OMI Operations and Maintenance Instruction

ABBREVIATIONS (Continued)

OMRS	Operations and Maintenance Requirements
OMRSD	Operations and Maintenance Requirements and Specification Document
OMS	Orbital Maneuvering System
OP	open
OPF	Orbiter Processing Facility
OPS	operations
ORB	orbiter
OTC	Orbiter Test Conductor
outbd	outboard
OV	Orbiter Vehicle
p	pressure
P/P	printer plotter
pb	pushbutton
PBI	pushbutton indicator
PCA	pneumatic control assembly
PDU	power drive unit
PE	Project Engineering
PER	Preliminary Evaluation Report
pfk	payload function key
pfp	programmable function panel
PIRN	Preliminary Interface Revision Notice
PLT	pilot
PMS	Propellant Management System
pneu	pneumatic

ABBREVIATIONS (Continued)

POS	position
PR	problem report
PRACA	problem reporting and corrective action
pri	primary
prplt	powerplant
psi	pounds per square inch (static pressure)
psia	pounds per square inch absolute
psid	pounds per square inch differential
QA	Quality Assurance
QC	Quality Control
QE	Quality Engineering
RDB	Remote Data Bus
RPC	Remote Power Controller
RPM	revolutions per minute
RSV	relief shutoff valve
rsys	responsible system
RTLS	return to launch site
RTOMI	Repetitive Task OMI (see OMI)
RTV	room-temperature vulcanized
SCC	Safety Console Coordinator
SCCS	Standard cubic centimeter per second
SCFM	standard cubic feet per minute
SE	support equipment
sec	second
SFOM	Shuttle Flight Operations Manual

ABBREVIATIONS (Continued)

SLF Shuttle Landing Facility
SLS secondary landing site
SOV shutoff valve
SPC Shuttle Processing Contractor
spec specification
SRB solid rocket booster
SRD Support Requirements Documents
SSL System Software Loader
SSME Space Shuttle Main Engine
SSMEC SSME Controller
STM Support Test Manager
sw switch
sys system
TAIR Test Assembly Inspection Record
TBD to be determined
TC Test Conductor
TCP Test Checkout Procedure
TCS Thermal Control System
TCS Test Control Supervisor
TOP technical operating procedure
TPE Test Project Engineering
TPS Test Preparation Sheet
TPS Thermal Protection System
tst test
T_t total temperature

ABBREVIATIONS (Continued)

typ	typical
ull	ullage
UMB	umbilical
VAB	Vehicle Assembly Building
VDT	Vehicle Data Table
vj	vacuum-jacketed
VLS	Vandenburg Launch and Landing Site
vlv	valve
WAD	Work Authorization Document
WPAFB	Wright-Patterson Air Force Base
XOVR	crossover

4.3 SYMBOLS.

%	per cent
<	less than
>	greater than
°	degree
=	equals
φ	phase