SATURN S-IVB-507 STAGE ACCEPTANCE FIRING REPORT

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

MCDONNELL DOUGLAS CORPORATION

SATURN S-IVB-507 STAGE ACCEPTANCE FIRING REPORT

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PREPARED FOR:
NATIONAL AERONAUTICS AND
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UNDER NASA CONTRACT NAS7-101

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ABSTRACT

This report presents an evaluation of the Saturn S-IVB-507 stage acceptance firing that was conducted at the Sacramento Test Center on 16 October 1968. Included in this report are stage and ground support equipment deviations associated with the acceptance firing configuration.

The acceptance firing test program was conducted under National Aeronautics and Space Administration Contract NAS7-101, and established the acceptance criteria for buyoff of the stage.

DESCRIPTORS

Saturn S-IVB-507 Stage

Saturn S-IVB-507 Stage Test Evaluation

J-2 Engine

Complex Beta

Countdown Operations

Saturn S-IVB-507 Stage Acceptance Firing

Saturn S-IVB-507 Stage Test Configuration

Sacramento Test Center

Sequence of Events

O_2-H_2 Burner

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PREFACE

This report documents the evaluation of the Saturn S-IVB-507 stage acceptance firing as performed by MDAC-WD personnel at the Sacramento Test Center.

The report was prepared under National Aeronautics and Space Administration Contract NAS7-101 and is issued in accordance with line item 129 of the MSFC Data Requirements List 021, dated 15 September 1966.

This report evaluates stage test objectives, instrumentation, and configuration deviations of the stage, test facility, and ground support equipment.

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INTRODUCTION

1.1 General

This report was prepared at the McDonnell Douglas Astronautics Company - Western Division (MDAC-WD) Huntington Beach (HB), by the Saturn S-IVB Test Planning and Evaluation (TP&E) Committee for the National Aeronautics and Space Administration under Contract NAS7-101.

Activities connected with the Saturn S-IVB-507 stage included a pre-firing checkout and the acceptance firing. Checkout started at the subsystem level and progressed to completion with the integrated systems test and the simulated acceptance firing. The information contained in the following sections documents and evaluates all events and test results of the acceptance firing which was completed on 16 October 1968. The tests were performed at Complex Beta, test stand I, Sacramento Test Center (STC).

1.2 Background

The S-IVB-507 stage was assembled at MDAC-WD/HB. A checkout was performed in the vertical checkout laboratory (VCL) prior to shipping the stage to STC. The stage was delivered to STC on 7 August 1968 and installed on test stand I on 9 August 1968. The stage was ready for acceptance firing on 14 October 1968.

The APS modules were shipped to Santa Monica checkout laboratory for production acceptance tests. The modules were then shipped to STC for stage interface checks. No confidence firings of these modules were scheduled.

Table 1-1 lists the milestones of the Saturn S-IVB-507 stage events and dates of completion.

1.3 Objectives

All test objectives outlined in Douglas Drawing No. 1B71775C, Test Plan Acceptance Firing, S-IVB/SV-STC, dated 25 September 1968 were successfully completed.

Stage acceptance objectives which provided maximum system performance evaluation were as follows:

a. Countdown control and operational capability verification

b. J-2 engine system performance verification

c. Oxidizer system performance verification

d. Fuel system performance verification

e. Pneumatic control system performance verification

f. Propellant utilization system performance verification

g. Stage data acquisition system performance verification

h. Stage electrical control and power system performance verification

i. Hydraulic system performance and J-2 engine gimbal control performance verification

j. Structural integrity verification

k. Auxiliary propulsion system stage interface compatibility verification

l. Ambient repressurization system performance verification

m. O_2-H_2 burner performance verification.

TABLE 1-1
MILESTONES, SATURN S-IVB-507 STAGE

Event	Completion Date
Tank assembly	8 May 1967
Proof test leak and dye	26 June 1967
Insulation and bonding	15 August 1967
Stage checkout and join J-2 engine	2 Nov. 1967
Systems checkout	19 Feb. 1968
Ship to STC	7 Aug. 1968
Stage installed on test stand	9 Aug. 1968
Ready for acceptance firing	14 Oct. 1968
Acceptance firing	16 Oct. 1968
Abbreviated postfire checkout on stand	29 Oct. 1968
Ready for storage	30 Oct. 1968

2. SUMMARY

The S-IVB-507 stage was acceptance fired on 16 October 1968 at Complex Beta, test stand I, Sacramento Test Center. The countdown was designated as CD 614113. The mainstage firing duration was 436.079 sec; engine cutoff was initiated through the PU processor when LOX was depleted below the 1 percent level.

2.1 Countdown Operations

Countdown 614113 was initiated on 15 October and proceeded to a successful acceptance firing on 16 October 1968. The acceptance firing was preceded by a simulated orbital coast, a cold helium leak check, two O_2-H_2 burner firings, and an ambient repressurization test.

2.2 J-2 Engine System

The S-IVB-507 stage utilized an uprated (230,000 lbf thrust) J-2 engine (S/N J2119). All systems operated satisfactorily and the performance predictions were well within the allowable deviations. All hardware functioned normally.

2.3 Oxidizer System

The oxidizer system functioned adequately supplying LOX to the engine pump inlet within the specified limits. The net positive suction pressure (NPSP) available at the LOX pump inlet exceeded the engine manufacturer's minimum requirement at all times.

2.4 Fuel System

The fuel system performed as designed and supplied LH2 to the engine within the limits defined in the engine specification. The LH2 tank pressurization system adequately controlled LH2 tank ullage pressure throughout the firing and during the repressurization periods.

2.5 Pneumatic Control and Purge System

The pneumatic control and purge system performed adequately during the acceptance firing. All components functioned normally.

2.6 Oxygen-Hydrogen Burner System

The high chamber pressure O_2-H_2 burner was started twice prior to J-2 engine firing -- the first time to repressurize the LH2 and LOX tanks and the second time, to demonstrate burner restart capability for ullaging purposes. The LH2 repressurization control orifice inlet pressure (D0231) shifted downward 13.5 psia, 56 sec into the burner repressurization operation and produced a 2.4 percent downward shift in LH2 repressurization flowrate. This shift was not accompanied by detrimental effects and repressurization was accomplished normally. The cause of the downward shift is still under investigation.

2.7 Propellant Utilization System

The PU system performed satisfactorily and accomplished all the design objectives.

2.8 Data Acquisition System

The data acquisition system performed satisfactorily throughout the O_2-H_2 burner and mainstage firing. Two hundred and twenty-two measurements were active of which one failed resulting in a measurement efficiency of 99.5 percent.

2.9 Electrical Power and Control Systems

The electrical power and control systems performed satisfactorily throughout the acceptance firing. All firing objectives were satisfied and all system variables operated within design limits.

2.10 Hydraulic System

The hydraulic system operated properly supplying pressurized fluid to the servo-actuators. All specified test objectives were achieved and all system variables operated within design limits.

2.11 Flight Control System

The dynamic response of the hydraulic servo-thrust vector control system was measured while the J-2 engine was gimbaled during the acceptance firing. The performance of the pitch and yaw hydraulic servo control systems was satisfactory.

2.12 Structural Systems

Structural integrity of the stage was maintained for the vibration, temperature, and thrust load conditions of the acceptance firing with the exception of cracking and peeling of Korotherm ablative coating on certain areas of the forward skirt. The damaged coating is to be repaired under direction of Materials & Methods/Research and Engineering.

2.13 Thermoconditioning and Purge System

The thermoconditioning and purge system functioned properly supplying purge and environmental conditioning to the stage within design limits.

2.14 Effectiveness Engineering

All malfunctions of Flight Critical Items were investigated and documented as follows:

Total number of malfunctions	3
Number of items reworked in place and accepted by engineering	1
Number of items requiring final disposition	1
Number of items to be reworked postfiring	1

3. TEST CONFIGURATION

This section describes the stage and ground support equipment (GSE) deviations and modifications from the flight configuration affecting the acceptance firing. Additional details of specific system modifications are discussed in appropriate sections of this report. Details of the S-IVB-507 stage configurations are presented in drawing No. 1B66684, S-IVB/V Stage End-Item Test Plan.

Figure 3-1 is a schematic of the S-IVB-507 stage propulsion system and shows the telemetry instrumentation transducer locations from which the test data were obtained. The functional components are listed in table 3-1. Hardwire measurements are noted in the appropriate subsystem schematics included in this report. The propulsion system orifice characteristics and pressure switch settings are presented in tables 3-2 and 3-3. J-2 engine S/N J-2119 was installed.

The propulsion GSE (figure 3-2) consisted of pneumatic consoles "A" and "B," two propellant fill and replenishing control sleds, a vacuum system console, and a gas heat exchanger.

3.1 Configuration Deviations

Configuration deviations required for the acceptance firing are discussed in drawing 1B71775C, Test Plan, Acceptance Firing, S-IVB/SV-STC. Significant configuration changes to the stage and GSE for the acceptance firing are discussed in the following paragraphs.

3.1.1 Propulsion System

a. Stage propellant vent and bleed systems were connected to the facility vent system. The nozzles were removed from the LH2 tank continuous vent system and the LOX and LH2 nonpropulsive vent systems.

b. The stage portions of the propellant and pneumatic quick-disconnects were replaced with hardlines.

c. A converging water-cooled diffuser was installed in the engine thrust chamber exit to reduce the possibility of sideloads induced by jet stream separation.

d. A GN2 ejector system was used to provide low pressure environment at the O_2-H_2 burner nozzle exit.

e. A heated GN2 purge was used for the LOX dome to prevent injector icing during the simulated orbital coast.

3.1.2 Propellant Utilization System

The propellant loading fast-fill sensors installed on the instrumentation probes were used in the indicating mode only.

3.1.3 Electrical Power System

a. Model DSV-4B-170 battery simulators were used to supply stage internal power.

b. Model DSV-4B-727 primary battery simulators were used in place of primary flight batteries.

3.1.4 Electrical Control System

a. The instrument unit and S-IVB/V stage electrical interfaces were simulated by GSE.

b. Two Model DSV-4B-188B APS simulators were used to provide APS module electrical loads to the stage control signals.

c. The electrical umbilicals remained connected throughout the acceptance firing.

3.1.5 Data Acquisition System

a. The MSFC Basic Static Firing Measurement Program hardwire transducers were installed.

b. All instrumentation parameters without transducers, and those disconnected for hardwire usage, were left as open channels.

3.1.6 Forward Skirt Environmental Control System

Coolant for the forward skirt thermoconditioning system was supplied by Model DSV-4B-359 Servicer.

3.1.7 Secure Range Safety Command System

a. The Engine Cutoff Command output from Range Safety Systems 1 and 2 was disconnected and stowed.

b. Pulse sensors were attached to the output of the exploding bridgewire (EBW) firing units.

3.1.8 Structural Systems

a. The main and auxiliary tunnel covers were not installed.

b. The stage was mounted on the Model DSV-4B-540 Dummy Interstage.

3.1.9 GSE and Facilities

a. Resistance wire fire detection system was installed for monitoring critical areas of the stage, GSE, and facilities.

b. GH2 leak detection system was installed for monitoring critical areas of the stage, GSE, and facilities.

c. Blast detectors were installed in the test area for monitoring ranges of 0 to 25 psi overpressure.

d. Model 742 static firing hazardous gas shield, thrust cone water spray Firex, cryogenic spill pan, forward skirt support ring, and vent port covers were installed.

e. Model 601 flame resistant protective firing cover was installed to enclose the forward skirt area.

f. An auxiliary propellant tank pressurization system was installed using a GSE ambient helium source.

g. Model DSV-4B-618 Engine Unlatch Restrainer Links were installed to restrain the J-2 engine during start transient sideloads.

h. Two O_2 content analyzer sense lines were installed in the thrust structure.

TABLE 3-1 (Sheet 1 of 6)
S-IVB-507 STAGE HARDWARE LIST

FIND NO.*	PART NO.	S/N	NAME
1	7851861-1	55	Disconnect, LH2 tank prepressurization
2	10414087	N/A	Valve, hand, LOX vent and relief valve purge
3	1B65673-1	21	Valve, check, LH2 tank prepressurization line
4	1A57350-507	0204	Module, control helium fill
-	1B66868-501	34	Sphere, control helium, 4.5 cu ft
6	1A58345-519	N/A	Module, pneumatic power control
7	7851823-503	1088	Disconnect, ambient helium fill
9	1A48857-1	49	Plenum, control helium, 100 cu in.
10	1A48848-511	N/A	Disconnect, LH2 ground vent
11	10414087	N/A	Valve, hand, LH2 chilldown valve, vent and relief valve, continuous vent, nonpropulsive vent, and fill valves purge
--	1B67598-501	--	Valve, check (eight installed)
15	1B66692-501-004	97	Module, actuation control, continuous vent bypass
18	1B67193-511	059	Module, continuous vent
22	1B66692-501-004	100	Module, actuation control, LH2 fill and drain
24	1B66932-501	N/A	Disconnect, LH2 fill and drain
25	1A48240-505-007	0113	Valve, LH2 fill and drain
26	1B41065-1	N/A	Disconnect, common bulkhead vacuum system
27	1B66932-501	047	Disconnect, LOX fill and drain

*Indicates location in figures 3-1 and 3-2

N/A - Not available

TABLE 3-1 (Sheet 2 of 6)
S-IVB-507 STAGE HARDWARE LIST

FIND NO.*	PART NO.	S/N	NAME
30	1A48240-505-007	0128	Valve, LOX fill and drain
31	1B66692-501-004	108	Module, actuation control LOX fill and drain valve
32	1B57781-507	010	Module, cold helium dump
33	1B40824-507	124	Valve, check, cold helium fill (bottle)
34	1B42290-507	0047	Module, LOX tank pressurization control
35	7851844-501	13	Disconnect, cold helium fill and LOX tank prepressurization
36	1B40384-507	120	Valve, check, cold helium fill (system)
37	1B58006-7	53	Plenum, LOX tank pressurization, 250 cu in.
41	1A49958-517	N/A	Disconnect, ground checkout, cold helium, ambient helium, and engine purge
42	1A49958-517	N/A	Disconnect, mainstage OK pressure switch checkout
42A	1A49958-519	N/A	Disconnect, thrust chamber jacket purge and chilldown
43	1B66230-505	1018	Module, control, LH2 tank pressurization
51	1A49988-509	0005	Valve, directional, LH2 tank vent
54	1B74535-1	0005	Valve, latching relief, LH2 tank, crack 34 psia max, reseat 31 psia min
55	1A48257-525	0056	Valve, LH2 tank vent and relief, crack 34 psia max, reseat 31 psia min

*Indicates location in figures 3-1 and 3-2

N/A - Not available

TABLE 3-1 (Sheet 3 of 6)
S-IVB-507 STAGE HARDWARE LIST

FIND NO.*	PART NO.	S/N	NAME
56	1A48858-1	1180	Sphere, cold helium, 3.5 cu ft (nine installed)
		1216	
		1168	
		1218	
		1194	
		1191	
		1185	
		1187	
		1173	
57	1B58100-503	N/A	Probe, LH2 tank instrumentation
57A	1A48430-503	N/A	Probe, LOX mass sensor
58	1B65813-1	N/A	Diffuser, LH2 tank pressurization
59	1A48431-501	N/A	Probe, LH2 mass sensor
59A	1A69275	N/A	Probe, LOX instrumentation
60	1A49421-507-010	190	Pump, LH2 chilldown
64	1A49423-509	---	Valve, relief, LOX chilldown pump purge, crack and reseat 65 to 85 psia (part of pump assembly)
66	1A49423-509	1868	Module, pump, LOX chilldown
67	1A49964-501	275	Valve, check, LOX chilldown return line
68	1A49965-529-013B-012	502	Valve, LOX chilldown shutoff
69	1A89104-507	N/A	Flowmeter, LOX chilldown

*Indicates location in figures 3-1 and 3-2

N/A - Not available

TABLE 3-1 (Sheet 4 of 6)
S-IVB-507 STAGE HARDWARE LIST

FIND NO.*	PART NO.	S/N	NAME
70	1B53920-503	063	Valve, check, LOX chilldown pump discharge
71	1B52985-501	N/A	Filter, LOX chilldown pump purge
72	1A49968-509-010	146	Prevalve, LOX
74	1B53920-501	041	Valve, check, GH2 tapoff pressurization line
75	1B69550-1	026	Module, LH2 repressurization control
77	1A49990-505	018	Sphere, LH2 repressurization, 4.5 cu ft
		N/A	
		015	
		26	
		33	
		32	
78	1B66692-501-004	99	Module, actuation control, directional vent
79	1B66692-501-004	102	Module, actuation control, LH2 tank vent and relief valve
80	1B66692-501-004	103	Module, actuation control, O_2-H_2 burner LOX supply valve
83	1B66639-515	054	Actuator assembly, valve, O_2-H_2 burner LOX shutdown
84	1B59008-501	N/A	Filter, O_2-H_2 burner LOX supply
87	1B67723-1	N/A	Injector, No. 2, O_2-H_2 burner
88	1B67723-1	N/A	Injector, No. 1, O_2-H_2 burner

*Indicates location in figures 3-1 and 3-2

N/A - Not available

TABLE 3-1 (Sheet 5 of 6)
S-IVB-507 STAGE HARDWARE LIST

FIND NO.*	PART NO.	S/N	NAME
89	1B62600-509	014	Burner assembly, O_2-H_2
92	1B59010-509Z	121	Valve, O_2-H_2 burner LH_2 propellant
93	1B66692-501-004	110	Module, actuation control, O_2-H_2 burner LH2 supply and LOX shutdown valves
94	1B59008-501	N/A	Filter, O_2-H_2 burner LH2 supply
97	1B67598-503	69	Valve, check, O_2-H_2 burner LH2 tank pressurization coil inlet
100	1B40824-507	123	Valve, check, O_2-H_2 burner LOX tank pressurization coil inlet
101	1B69030-1	0010	Valve, relief, LOX tank, crack 45.5 psia max, reseat 41 psia min
102	1B43659-501	N/A	Filter, O_2-H_2 burner LOX tank pressurization coil inlet
104	1A48312-505-008-007	47	Valve, vent and relief, LOX tank, crack 44 psia max, reseat 41 psia min
105	1B62778-503	014	Module, plenum and valve, O_2-H_2 burner LH2 tank pressurization coil inlet, 250 cu in.
106	1B62778-503	024	Module, plenum and valve, O_2-H_2 burner LOX tank pressurization coil inlet, 250 cu in.
107	1B66692-501-004	109	Module, actuation control, LOX tank vent and relief valve
110	1A49968-507-010	136	Prevalve, LH2
111	1B52985-501	N/A	Filter, LH2 chilldown pump discharge
112	1B53920-503	062	Valve, check, LH2 chilldown pump discharge

*Indicates location in figures 3-1 and 3-2

N/A - Not available

TABLE 3-1 (Sheet 6 of 6)
S-IVB-507 STAGE HARDWARE LIST

FIND NO.*	PART NO.	S/N	NAME
113	1A89104-509	31609	Flowmeter, LH2 chilldown pump discharge
114	1A49965-523-012	0106	Valve, shutoff, LH2 chilldown line
115	1B66692-501-004	107	Module, actuation control, chilldown valves and prevalves
116	1A49964-501	291	Valve, check, LH2 chilldown return
117	1B69550-1	027	Module, control, LOX tank repressurization
118	1A49990-505	31	Sphere, LOX tank repressurization, 4.5 cu ft
		35	
120	1A58347-513	7	Module, engine purge control
122	1A49958-521	N/A	Disconnect, engine start sphere vent and relief valve drain
123	1A49958-515	N/A	Disconnect, engine control helium sphere fill
124	1A49958-523	N/A	Disconnect, engine start sphere fill
125	1A49958-517	N/A	Disconnect, LH2 turbine seal drain

*Indicates location in figures 3-1 and 3-2

N/A - Not available

TABLE 3-2 (Sheet 1 of 4)
S-IVB-507 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

FIND NO.*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (in.^{2})
	Stage			
15C	Continuous vent bypass valve actuation control module inlet	0.017 in. dia	--	N/A
16	Continuous vent bypass valve bellows purge	300 scim with 3,200 psid	--	Sintered
17	Continuous vent bypass valve switch cavity purge	15 scim with 3,200 psid	--	Sintered
19	Continuous vent No. 1	1.090 in. dia	--	
20	Continuous vent No. 2	1.090 in. dia	--	
21	Continuous vent purge	1 scfm with 3,200 psid	--	Sintered
23	LH2 fill and drain valve purge	15 scim with 3,200 psid	--	Sintered
29	LOX fill and drain valve purge	15 scim with 3,200 psid	--	Sintered
35A	LH2 chilldown valve purge	66 scfm with 1,600 psid	--	Sintered
39	LOX tank pressurization module, heat exchanger primary	0.2188 in. dia	0.87	0.03283
40	LOX tank pressurization module, heat exchanger bypass	0.1820 in. dia	0.87	0.02311
43	LH2 tank pressurization--step mode (All three orifices used for acceptance firing only)	--	--	0.1335**

*Indicates location in figures 3-1 and 3-2.

**Discharge coefficient and effective area are calculated for overcontrol and step orifices in combination with the undercontrol orifice.

TABLE 3-2 (Sheet 2 of 4)
S-IVB-507 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

FIND NO.*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (in.^{2})
44	LH2 tank pressurization module (Overcontrol-second burn)	0.2058 in. dia	**	0.1040***
45	LH2 tank pressurization module normal (Under-control)	0.3283 in. dia	**	0.0735
46	LH2 tank pressurization module control (Over-control-first burn)	0.2056 in. dia	**	0.1030***
47	LH2 tank repressurization module outlet	0.3130 in. dia	0.82	0.0645
47A	O_2-H_2 burner LH2 supply valve purge	15 scim with 3,200 psid	--	Sintered
48	LH2 tank nonpropulsive vent purge	1 scfm with 3,200 psid	--	Sintered
49	LH2 tank nonpropulsive vent No. 1	2.180 in. dia	--	
50	LH2 tank nonpropulsive vent No. 2	2.180 in. dia	--	
61	LOX chilldown pump purge	37 scim with 475 psid	--	Sintered
73A	LOX sensing line purge	1 scfm with 3,200 psid	--	Sintered
85	O_2-H_2 burner GH2 balance, injector No. 1	0.445 in. dia	--	0.1395
86	O_2-H_2 burner GH2 balance, injector No. 2	0.445 in. dia	--	0.1372
90	O_2-H_2 burner LH2 tank pressurization coil outlet	0.221 in. dia	--	0.0340

*Indicates location in figures 3-1 and 3-2.

**Not recorded during calibration

***Discharge coefficient and effective area are calculated for overcontrol and step orifices in combination with the undercontrol orifice.

TABLE 3-2 (Sheet 3 of 4)
S-IVB-507 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

FIND NO.*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (in.^{2})
91	LOX tank vent and relief valve purge	65 scfm with 3,200 psid	--	Sintered
95	O_2-H_2 burner LH2 tank pressurization coil helium inlet balance	0.120 in. dia	0.88	0.00993
96	O_2-H_2 burner LOX tank pressurization coil outlet	0.089 in. dia	0.895	0.00566
119	LOX tank ambient repressurization module outlet	0.1109 in. dia	--	0.00890
120	Engine purge control module	6 scfm	--	0.00028
	<u>Console A</u>			
--	All console A stage bleeds	Variable	--	--
A9515	Pressure actuated valve and main-stage pressure switch supply	1.2 scfm	--	Sintered
A9526	J-box inerting supply	0.013 in. dia	--	--
A9533	LH2 system checkout supply	1.2 scfm	--	Sintered
A9534	LOX system checkout supply	2.0 scfm	--	Sintered
A9535	LH2 tank and umbilical purge supply	0.260 in. dia	0.88	0.0468
A9536	Pressure switch checkout-Low pressure	1.2 scfm	--	Sintered
A9537	Pressure switch checkout-High pressure	0.044 in. dia	0.91	0.00139

*Indicates location in figures 3-1 and 3-2.

TABLE 3-2 (Sheet 4 of 4)
S-IVB-507 STAGE AND GSE ACCEPTANCE FIRING ORIFICES

FIND NO.*	DESCRIPTION	ORIFICE SIZE OR NOMINAL FLOWRATE	COEFFICIENT OF DISCHARGE	EFFECTIVE AREA (in.^{2})
A9538	LH2 tank repressurization supply	Union	--	--
A9539	Console GN2 inerting supply	0.013 in. dia	--	--
	Console B			
--	All console B stage bleeds	Variable	--	--
--	LOX tank repressurization supply	0.114 in. dia	0.88	0.00898
--	Turbine start sphere supply	Union	--	--
--	LOX tank prepressurization supply	0.096 in. dia	0.94	0.00680
A9348	Console GN2 inerting supply	Variable	--	--
A9525	Engine control helium sphere supply	0.125 in. dia	0.83	0.0102
A9527	LH2 tank prepressurization supply	0.161 in. dia	0.83	0.0169
A9528	Thrust chamber jacket purge and chilldown supply	0.072 in. dia	0.91	0.00370
A9529	LOX tank and umbilical purge supply	0.302 in. dia	0.89	0.0635
A9540	J-box inerting supply	0.013 in. dia	--	--
A9552	Turbine start sphere supply vent	0.081 in. dia	0.83	0.00479
OR396	LOX tank auxiliary pressure	0.2517 in. dia	0.94	0.0465
OR395	LH2 tank auxiliary pressure	0.385 in. dia	0.91	0.1060

*Indicates location in figures 3-1 and 3-2.

TABLE 3-3 (Sheet 1 of 2)
S-IVB-507 STAGE PRESSURE SWITCH DATA

FIND NO.	NAME	PART NO. AND SERIAL NO.	SPECIFICATIONS (psia)			PREFIRING (psia)		
			PICKUP	DROPOUT	DEADBAND	PICKUP*	DROPOUT*	DEADBAND*
	LH2 TANK							
52	First Burn and Flight Control	1B52624-511 S/N 21	31.5 max	27.8 min	0.5 min	30.38	28.24	2.14
53	Second Burn, Ground Fill, and Prepressurization	1B52624-511 S/N 24	31.5 max	27.8 min	0.5 min	30.65	28.43	2.22
	LOX TANK							
73	LOX Flight Control and Ground Fill	1B52624-515 S/N 55	41.0 max	37.5 min	0.5 min	40.29	38.29	2.00
	LOX PRESSURIZATION SYSTEM							
38	Cold Helium Regulator Backup	1B52624-519 S/N 34	467.5 ± 23.5	362.5 ±33.5	---	475.30	374.11	---
	PNEUMATIC POWER SYSTEM							
6A	Control Helium Regulator Backup	1B52624-517 S/N 022	600 ± 21	490 ± 31	---	603.95	499.68	---
121	Engine Pump Purge	1B52623-515 S/N 26	136 max	99 min	3.0 min	121.40	110.57	10.83

*The values listed are the average of three actuations

TABLE 3-3 (Sheet 2 of 2)
S-IVB-507 STAGE PRESSURE SWITCH DATA

FIND NO.	NAME	PART NO. AND SERIAL NO.	SPECIFICATIONS (psia)			PREFIRING (psia)		
			PICKUP	DROPOUT	DEADBAND	PICKUP*	DROPOUT*	DEADBAND*
	J-2 ENGINE SYSTEM							
**	Mainstage OK No. 1	308390 S/N 25559A	515 ± 36	Pickup minus 75 +56, -31	---	513.86	432.89	80.97
**	Mainstage OK No. 2	308390 S/N 25580A	515 ± 36	Pickup minus 75 +56, -31	---	521.76	468.36	53.39
	O_2-H_2 BURNER							
103	LOX Tank Repressurization	1B52624-519 S/N 20	465 +20 -15	350 +40 -15	---	467.85	375.13	---
90	LH2 Tank Repressurization	1B52624-519 S/N 36	465 +20 -15	350 +40 -15	---	474.78	370.76	---

*The values listed are the average of three actuations
**Part of module

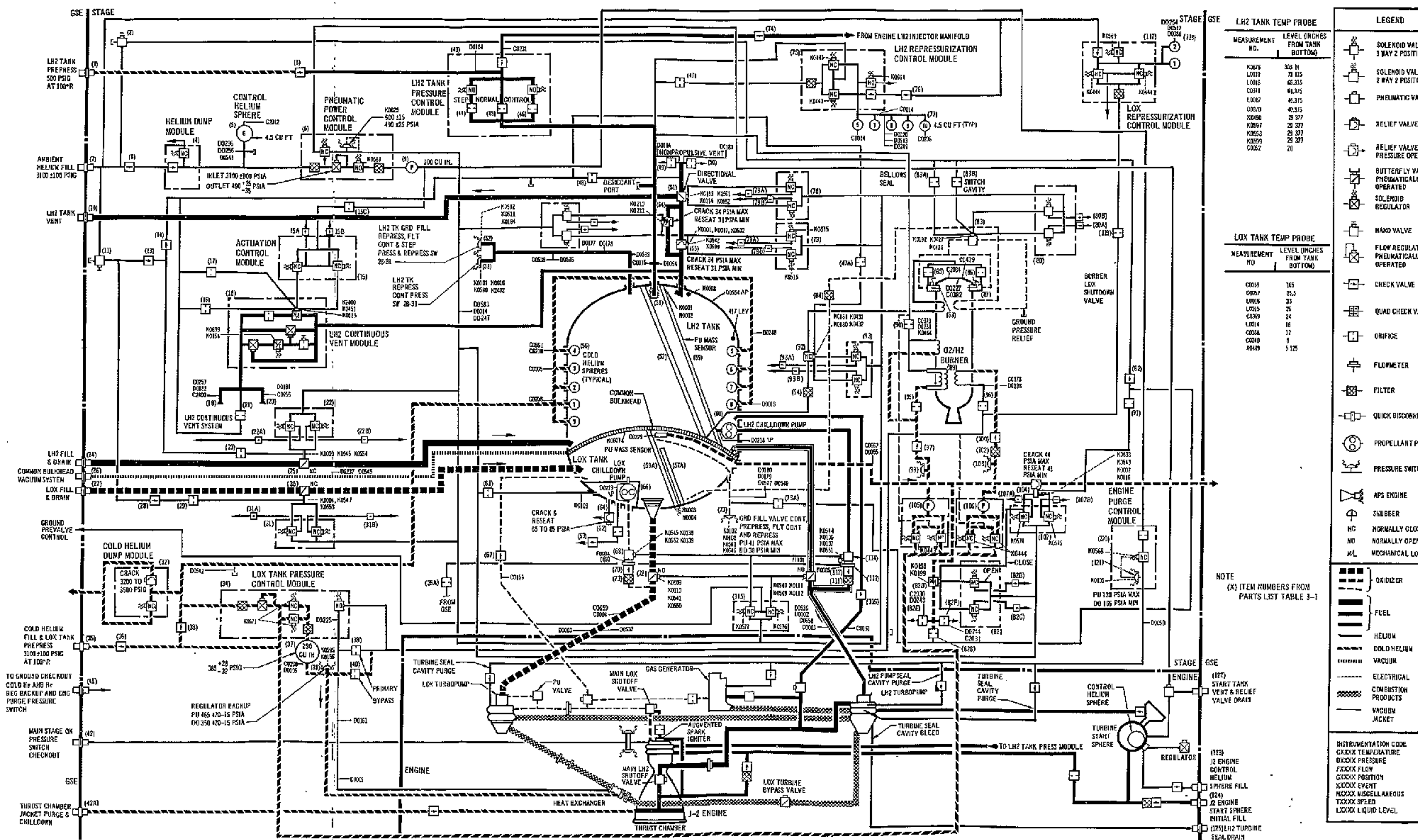


Figure 3-1. Propulsion System and Instrumentation

FOLDOUT FRAME 1

FOLDOUT FRAME 2

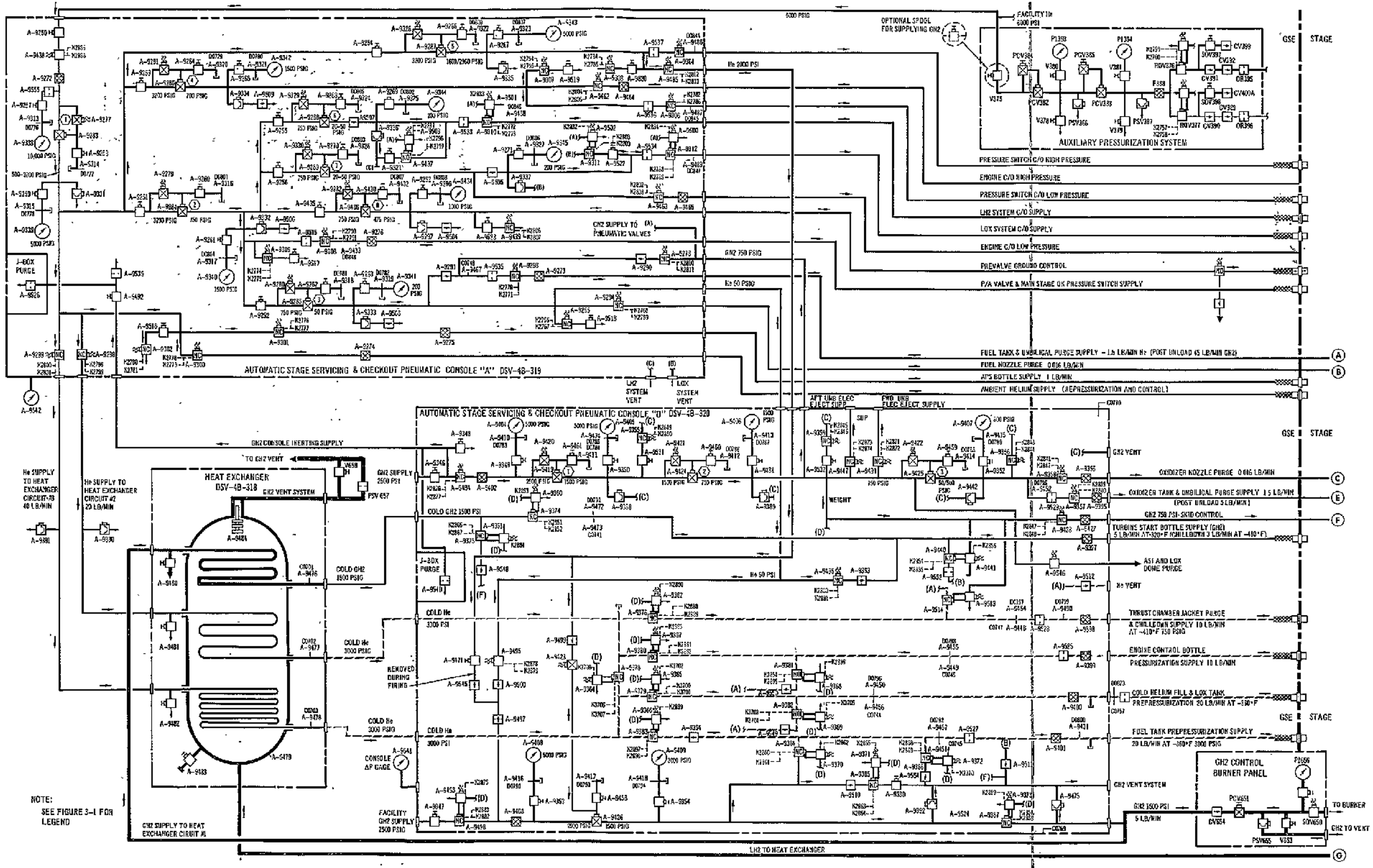


Figure 3–2. Facility Propellant and Pneumatic Loading Systems (Sheet 1 of 2)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

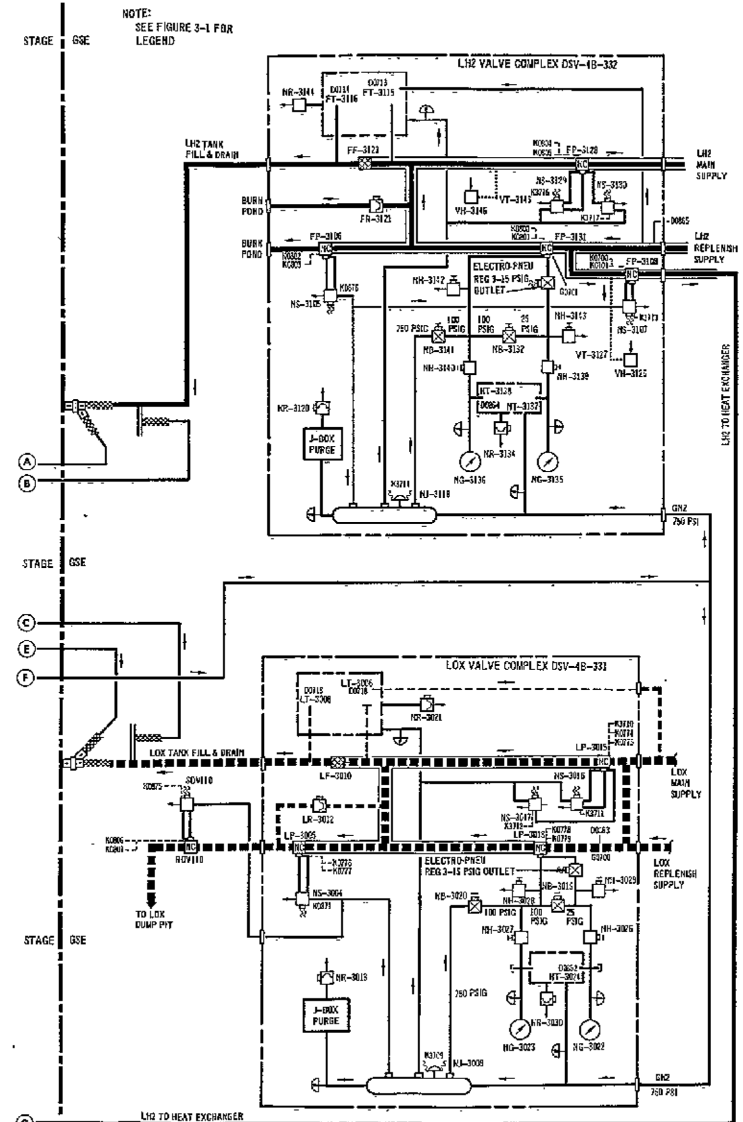


Figure 3-2. Facility Propellant and Pneumatic Loading Systems (Sheet 2 of 2)

4. COUNTDOWN OPERATIONS

The S-IVB-507 stage was the seventh of the basic S-IVB/V series to be successfully acceptance fired and the second with an O_2-H_2 burner restart sequence. The acceptance firing was preceded by two O_2-H_2 burner firings and an ambient repressurization test. Details of the countdown and checkout (precountdown) activities are presented in the following paragraphs.

4.1 Countdown 614113

The acceptance firing (countdown 614113) was a full duration J-2 engine firing initiated on 15 October and terminated on 16 October 1968. The countdown proceeded normally and the only problem encountered was the failure of measurement D0016, cold helium sphere pressure. However, correct system pressures were verified by backup measurement D0248.

Except for the deviations necessitated by a single J-2 engine burn, the performance of a second O_2-H_2 burner firing, and the ambient repressurization test, the countdown conformed to the sequence intended for use at Kennedy Space Center. Significant events during these operations are presented in tables 4-1, 4-2, and 4-3. The propulsion operations were performed in the following sequence:

a. Propellants were loaded to the 68 percent level.

b. LOX and LH2 tanks were pressurized to the relief settings.

c. The continuous vent valve was functionally tested.

d. Two O_2-H_2 burner firings were performed.

e. The ambient repressurization system was functionally tested.

f. The LOX and LH2 tanks were reloaded to the 100 percent level.

g. The terminal countdown and J-2 engine firing were performed.

The tank vent and relief tests were accomplished during the propellant loading test and were not repeated during the acceptance firing countdown. The vent and relief valves vented at the following pressures:

Valve	Pressure (psia)		
LOX	42.9	42.8	42.8
LH2	32.0	32.0	32.0

The first firing of the restartable O_2-H_2 burner was initiated at 1246 PDT and proceeded normally through burner shutdown. The burner firings were of 455 and 134 sec in duration, as planned.

4.1.1 Cryogenic Loading

Setups for LOX loading began on 16 October, and both tanks were loaded to the 68 percent level by 1024 PDT. The on-stand inspection was accomplished, and the fuel sled main fill valve packing gland was retorqued to eliminate a previously noted leak.

After the burner and ambient repressurization tests were accomplished, the tanks were reloaded to the 100.5 percent levels.

4.1.2 Terminal Countdown

The terminal countdown was initiated at 1538:55 PDT (T -20:30 min). The count proceeded smoothly through J-2 engine cutoff which was initiated by the PU processor due to LOX depletion at T +947 sec. Mainstage operation was 433 sec.

4.2 Checkout

After the S-IVB-507 stage was assembled at MDAC-WD/HB, it was subjected to a complete stage checkout including an all systems test. It was then modified and shipped to STC. It arrived at STC on 7 August and was installed in the Beta Complex test stand I on 9 August. The modification program continued concurrently with stage checkout. All modifications were completed before the integrated systems test, which was satisfactorily completed on 27 September.

A practice countdown was conducted on 3 and 4 October for software verification and countdown crew training. The "Ready for Acceptance Firing" milestone was met on 14 October, 4 days after satisfactory completion of the simulated static firing test. The handling and checkout procedures that were used for the prefiring and postfiring checkouts are described in report DAC 56622, Narrative End Item Report - Saturn S-IVB-507, dated April 1968.

4.3 Countdown Problems

One problem occurred during countdown. During the test stand inspection, a leak that had been noted in the LH2 shutoff valve in the facility storage area was eliminated by retorquing the bonnet packing gland.

4.4 Atmospheric Conditions

The following atmospheric conditions were noted during the countdown:

Time (PDT)	1037	1735
Wind Speed (knots)	8	CALM
Wind Direction (deg)	135	--
Barometric Pressure (in. Hg)	30.07	30.03
Ambient Temperature (deg F)	54	73
Dew Point (deg F)	47	49

TABLE 4-1 (Sheet 1 of 2)
O_2-H_2 BURNER SEQUENCE OF EVENTS

TIME (sec)	MEAS	EVENT
-10.492	K0532	LH2 tank vent valve closed
-0.007	K0431	O_2-H_2 LH2 propellant valve open
0		Start first burn operation ignition sequence (12:55:43 PDT)
0.724	K0427	O_2-H_2 LOX propellant valve open
0.882	K0699	LH2 tank vent relief overboard valve closed
0.973	K2400	LH2 tank vent orifice bypass valve closed
2.896	K0452	LH2 tank vent orifice and relief reset
4.064	K0437	O_2-H_2 burner system relay reset
6.758	K0438	O_2-H_2 voting circuit enabled
6.874	K0443	LH2 tank repressurization valve energized
7.087	K0444	LOX tank repressurization valve energized
7.467	K0429	APS 70 lbf ullage engine relay reset
157.443	K0444	LOX tank repressurization valve closed
158.199	K0443	LH2 tank repressurization valve closed
158.200	K0616	LH2 tank overpressurization pressure switch energized
178.318	K0513	Hydraulic auxiliary pump on energized
178.319	K0445	Hydraulic pump coast relay reset
207.730	K0519	LOX chilldown pump/inverter energized
212.789	K0512	LH2 chilldown pump/inverter energized
217.963	K0576	LH2 and LOX prevalve closed - energized
408.685	K0524	LH2 tank flight pressure valve energized
408.685	K0523	LH2 tank step pressurization valve energized
455.463	K0432	LH2 propellant valve closed
455.591	K0441	LH2 and LOX repressurization system reset
455.593	K0438	O_2-H_2 voting circuit disabled
455.789	K0452	LH2 tank vent orifice and relief reset off
456.205	K0440	LH2 and LOX repressurization mode - ambient
459.969	K0428	O_2-H_2 LOX propellant valve closed
462.992	K0437	O_2-H_2 burner system relay reset
518.750	K0545	LOX chilldown shutoff valve open

TABLE 4-1 (Sheet 2 of 2)
O_2-H_2 BURNER SEQUENCE OF EVENTS

TIME (sec)	MEAS	EVENT
520.474	K0540	LH2 prevalve open
520.622	K0541	LOX prevalve open
528.108	K0641	LH2 chilldown pump relay reset
528.328	K0644	LOX chilldown pump relay reset
529.663	K0621	Hydraulic auxiliary pump flight relay reset
688.017*	K0532	LH2 tank vent valve closed
691.000	---	Start second burner operation ignition sequence
700.045	K0431	LH2 propellant valve open
700.765	K0427	LOX propellant valve open
706.727	K0438	O_2-H_2 voting circuit enabled
830.629	K0432	LH2 propellant valve closed
835.121	K0428	LOX propellant valve closed

*Start of second burner operation sequence

TABLE 4-2
AMBIENT REPRESSURIZATION SEQUENCE

TIME (sec)	MEAS	EVENT
-101.238	K0543	LOX tank vent valve closed
0	K0444	LOX tank repressurization valve open (Start of ambient repressurization--13:11:15 PDT)
4.545	K0699	LH2 tank vent relief overboard valve closed
4.623	K2400	LH2 tank vent orifice bypass closed
20.470	K0443	LH2 tank repressurization valve open
49.373	K0523	LH2 tank step pressurization valve open
49.373	K0616	LH2 tank over-pressure pressure switch energized
49.375	K0443	LH2 tank repressurization valve closed
75.262	K0444	LOX tank repressurization valve closed
75.262	K0563	LOX tank over-pressure pressure switch energized
108.534	K0523	LH2 tank step pressurization valve closed
234.492	K0516	LH2 tank vent valve open
279.003	K2424	LOX tank vent and NPV latch reset
281.204	K0466	LOX tank NPV valve open

TABLE 4-3 (Sheet 1 of 4)
ACCEPTANCE FIRING SEQUENCE

TIME (sec)	MEAS	EVENT
-874.223	K2881	Engine start tank purge supply closed
-870.238	K2853	Start engine start tank fill
-407.876	K2888	Start engine thrust chamber chilldown
-326.594	K2852	End engine start tank fill
-326.478	K2855	Engine start tank vent open
-298.961	K2892	Start engine control bottle fill
-298.618	K0512	LH2 chilldown pump on
-288.607	K0519	LOX chilldown pump on
-283.577	K0576	LOX and LH2 prevalve closed command
-283.462	K0540	LH2 prevalve open position drop-out
-283.447	K0541	LOX prevalve open position drop-out
-283.240	K0549	LH2 prevalve closed position pick-up
-283.096	K0550	LOX prevalve closed position pick-up
-208.837	K2424	LOX NPV latched
-165.453	K0533	LOX vent valve closed
-163.880	K0571	Start LOX tank prepressurization
-150.830	K0571	End LOX tank prepressurization
-143.763	K0571	Start LOX tank prepressurization
-142.727	K0571	End LOX tank prepressurization
-113.320	K0571	Start LOX tank prepressurization
-112.338	K0571	End LOX tank prepressurization
-95.685	K0532	LH2 tank vent valve closed
-94.125	K2897	Start LH2 tank prepressurization
-62.297	K2897	End LH2 tank prepressurization
-8.168	K3705	Cold helium supply vent opened
-8.111	K2870	LH2 tank prepressurization supply vent open
0		Simulated Liftoff (15:59:25.000 PST)
11.779	K5815	LOX tank boiloff vent valve open
37.622	K5814	LOX tank boiloff vent valve closed
162.243	K0563	LOX tank minimum pressure indicated
162.251	K0571	Cold helium shutoff valves opened
163.485	K0563	LOX tank maximum pressure indicated

TABLE 4-3 (Sheet 2 of 4)
ACCEPTANCE FIRING SEQUENCE

TIME (sec)	MEAS	EVENT
163.491	K0571	Cold helium shutoff valves closed
467.533	K0563	LOX tank minimum pressure indicated
467.542	K0571	Cold helium shutoff valves opened
468.824	K0563	LOX tank maximum pressure indicated
468.831	K0571	Cold helium shutoff valves closed
488.922	K2889	Engine thrust chamber chilldown terminated
507.704	K0576	LH2 and LOX prevalve open command
508.623	K0549	LH2 prevalve closed position drop-out
508.724	K0550	LOX prevalve closed position drop-out
509.404	K0571	Open cold helium shutoff valves
510.199	K0540	LH2 prevalve open pick-up
510.362	K0541	LOX prevalve open pick-up
511.063	K0519	LOX chilldown pump off
511.152	K0512	LH2 chilldown pump off
511.229	K0533	LOX tank vent valve opened
511.755	K0556	Engine Start Command
511.757	K0531	Engine control helium valve opened
511.795	K0627	LOX ASI valve opened
511.810	K0557	LH2 bleed valve closed
511.813	K0632	Main LH2 valve start to open
511.826	K0558	LOX bleed valve closed
511.861	K0458	Main LH2 valve opened
512.883	K0536	Start tank discharge valve open command
513.017	K0695	Start tank discharge valve starts to open
513.099	K0460	Start tank discharge valve open
513.335	K0536	Start tank discharge valve close command
513.434	K0631	GG valve starts to open
513.474	K0460	Start tank valve starts to close
513.552	K0457	GG valve open
513.689	K0695	Start tank valve closed
513.990	K0633	MOV starts to open
514.699	K0524	LH2 tank flight pressure valve close command

TABLE 4-3 (Sheet 3 of 4)
ACCEPTANCE FIRING SEQUENCE

TIME (sec)	MEAS	EVENT
514.904	K0533	LOX tank vent valve closed
515.484 } 515.567 }	K0533	LOX vent valve relieving
515.583	K0459	MOV open
515.588 } 515.593 }	K0533	LOX vent valve relieving
515.840	K0532	LH2 tank vent valve and latching vent valve relieving
545.529	K2431	
532.876	K2432	J-2 heat exchanger bypass valve open disabled
540.656	K0563	J-2 heat exchanger bypass valve opened
552.431	K0563	Heat exchanger bypass valve closed
560.233	K0563	Heat exchanger bypass valve opened
571.058	K0563	Heat exchanger bypass valve closed
582.955	K0563	Heat exchanger bypass valve opened
593.911	K0563	Heat exchanger bypass valve closed
611.362	K0563	Heat exchanger bypass valve opened
623.608	K0563	Heat exchanger bypass valve closed
649.948	K0563	Heat exchanger bypass valve opened
663.945	K0563	Heat exchanger bypass valve closed
699.791	K0563	Heat exchanger bypass valve opened
716.193	K0563	Heat exchanger bypass valve closed
711.895	K0524	LH2 tank flight pressurization valve opened
711.895	K0523	LH2 tank step pressurization valve opened
711.994	K0523	LH2 tank step pressurization valve closed
711.995	K0524	LH2 tank flight pressurization valve closed
921.865	K0524	LH2 tank flight pressurization valve opened
921.865	K0523	LH2 tank step pressurization valve opened
921.945	K0577	LH2 and LOX chilldown shutoff valve closed command
922.091	K0545	LOX chilldown shutoff valve open drop-out
922.107	K0544	LH2 chilldown shutoff valve open drop-out

TABLE 4-3 (Sheet 4 of 4)
ACCEPTANCE FIRING SEQUENCE

TIME (sec)	MEAS	EVENT
922.133	K0552	LOX chilldown shutoff valve closed pick-up
922.172	K0551	LH2 chilldown shutoff valve closed pick-up
926.626	K2431	LH2 tank latching vent valve open position drop-out
926.707 } 930.454 }	K0532	LH2 vent valve relieving
930.455	K0532	LH2 tank vent valve open position drop-out
947.835	K4796	Engine Cutoff Command

5. SEQUENCE OF EVENTS

The S-IVB-507 acceptance firing sequence of events is presented in table 5-1. The two time bases used in this table are as follows:

First O_2-H_2 Burner Ignition Sequence	1255:43.000 hr PDT
Simulated Liftoff for J-2 Engine Firing	1559:25.000 hr PDT

The data sources were the Digital Events Recorder (DER/CAT 57) and the PCM/FM System (CAT 42). Accuracies of the listed events are as follows:

Data Source	Accuracies
Digital Events Recorder (DER/CAT 57)	+0, -1 ms
PCM/FM	
Discrete Bi-Level (CAT 42)	
Direct Inserted	+0, -9 ms
Submultiplexed	+0, -84 ms

TABLE 5-1 (Sheet 1 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Launch Automatic Sequence Start (J-2 Eng Firing Phase)					
S-IVB Engine Cutoff	12	K3890	-477.740		
Aux Hyd Pump Flt Mode On	28	K3890	-476.593		
Aux Hyd Pump Flt Rel Reset - Off		K0621	-476.589		
Aux Hyd Pump Coast Mod Off	31	K3890	-476.501		
Aux Hyd Pump Power On		K0513	-476.496		
Aux Hyd Pump Coast Relay Reset - On		K0445	-476.496		
Eng St Tk Dump Close		K3885	-329.987		
LH2 Chilldown Pump On	58	K3890	-298.627		
LH2 C/D Pump Rel Reset - Off		K0641	-298.620		
LH2 C/D Pump Inverter On		K0512	-298.618		
LOX Chilldown Pump On	22	K3890	-288.617		
LOX C/D Pump Rel Reset - Off		K0644	-288.609		
LOX C/D Pump Inverter On		K0519	-288.607		
LOX & LH2 Prevalve Close Command - On		K0576	-283.577		
LH2 Prevalve Open Indication - Off		K0540	-283.462	K0111	-283.399

TABLE 5-1 (Sheet 2 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
LOX Prevalve Open Indication - Off		K0541	-283.447	K0109	-283.399
LH2 Prevalve Closed Indication - On		K0549	-283.240	K0112	-283.149
LOX Prevalve Closed Indication - On		K0550	-283.099	K0110	-283.066
Heat Exchanger Bypass Valve Control Disable (Preflight Command Only)	51	K3890	-208.989		
Heat Exchanger Bypass Disable		K2432	-208.979		
LOX Tk NPV Vlv Latch Open Off	45	K3890	-208.847		
LOX Tk Vent & NPV Latch Rst On		K2424	-208.837		
LOX Tank Vent Valve Open Command - Off		K0575	-165.936		
LOX Tank Vent Valve Closed Indication - On		K0533	-165.453	K0002	-165.406
Cold He Shutoff Valve Open Command		K3802	-163.888		
Cold He Shutoff Valve Open Indication		K0571	-163.880		
LOX Tk Overpress P/S Ener		K0563	-150.834	K0102	-150.824
He Cold Sol Vlv Opn De-Ener		K0571	-150.830		
LOX Tk Overpress P/S De-Ener		K0563	-143.771	K0102	-143.741
He Cold Sol Vlv Opn Ener		K0571	-143.763		

TABLE 5-1 (Sheet 3 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
He Cold Sol Vlv Opn De-Ener		K0571	-142.727		
LH2 Tank Vent Valve Close Command - On		K0516	-96.278		
LH2 Tank Vent Valve Closed Indication - On		K0532	-95.685	K0001	-95.669
LOX Tank Fill & Drain Bst Close - On		K3845	-85.342		
LOX Tank Fill & Drain Open - Off		K0547	-84.837		
LOX Tank Fill & Drain Closed Indication - On		K0553	-84.403	K0004	-84.336
LOX Tank Fill & Drain Bst Close - Off		K3845	-83.294		
LH2 Tank Fill & Drain Bst Close - On		K3831	-83.264		
LH2 Tank Fill & Drain Open - Off		K0546	-82.864		
LH2 Tank Fill & Drain Closed Indication - On		K0554	-82.519	K0003	-82.503
LH2 Tank Fill & Drain Bst Close - Off		K3831	-81.199		
Aft Bus 1 Transfer Internal Indication		K0622	-49.290		
Aft Bus 2 Transfer Internal Indication		K0623	-49.030		

TABLE 5-1 (Sheet 4 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Fwd Bus Transfer Internal		K0639	-48.780		
LH2 Tank Vent Dir Gnd Position Off		K0561	-25.219	K0113	-25.165
LH2 Tank Vent Dir Flight Position On		K0562	-25.128	K0114	-25.082
R/S 1 PD Cmd Inhibit Off Indication		K0662	-8.077		
R/S 2 PD Cmd Inhibit Off Indication		K0661	-8.041		
Simulated Liftoff (T_0)*			000.000		
T/M Calibration On	62	K3890	116.660		
T/M Calibration Off	63	K3890	117.773		
Eng Pump Prg Cont Valve Enable On	24	K3890	330.858		
Eng Pump Prg Sol Valve Energized		K0566	330.870		
Eng Cutoff Arm - Observer		K5811	334.096		
Eng Pump Prg Cont Valve Enable Off	25	K3890	450.928		
Eng Pump Prg Sol Valve De-energized		K0566	450.943		
T/M Calibration On	62	K3890	452.229		
T/M Calibration Off	63	K3890	453.346		
Charge Ullage Ignition On	54	K3890	507.565		

*T_0 = 1559:25.000

TABLE 5-1 (Sheet 5 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Ullage Rkt Pilot Relays Rst Off		K0673	507.572		
LH2 & LOX Prevalve Open Command - On		K0576	507.704		
LH2 Prevalve Closed Indication - Off		K0549	508.623	K0112	508.636
LOX Prevalve Closed Indication - Off		K0550	508.721	K0110	508.803
LOX Tk Flt Press Sys On	103	K3890	509.391		
LH2 Prevalve Open Indication - On		K0540	510.199	K0111	510.218
LOX Prevalve Open Indication - On		K0541	510.362	K0109	510.385
LOX Chilldown Pump Off	23	K3890	511.057		
LOX C/D Pump Inverter Off Indication		K0519	511.063		
LOX C/D Pump Rel Reset Indication		K0644	511.066		
LH2 C/D Pump Off	59	K3890	511.146		
LH2 C/D Pump Inverter Off Indication		K0512	511.152		
LH2 C/D Pump Rel Reset Indication		K0641	511.154		
S-IVB Engine Cutoff Off	13	K3890	511.305		
Engine Cutoff Ind - Sw Sel Reset		K0418	*Not Available	K0140	511.360
Engine Cutoff Indicator - De-energized		K0522	511.315		

*DER malfunction

TABLE 5-1 (Sheet 6 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Aft Separate Simu 1 On		K4790	511.361		
Aft Separate Simu 2 ON		K5714	511.386		
Fire Ullage Ign On	56	K3890	511.449		
Ullage Rkt Ign PS 1 Indication				K0176	511.485
Ullage Rkt Ign PS 2 Indication				K0177	511.480
S-IVB Engine Start On	9	K3890	511.751		
Engine Start Command Rel Rst		K0634	511.754		
Engine Start Command On		K0556	511.755	K0021	511.758
Eng Ign Ph Cont Sol Ener		K0535	511.756	K0006	511.758
Eng Spark T/C Sys On		K0454	511.756	K0010	511.758
Eng Spark GG Sys On		K0455	511.756	K0011	511.758
Eng Cont He Sol Valve Ener		K0531	511.757	K0007	511.758
Eng Ready Sign Off		K0530	511.760	K0012	511.810
Eng ASI LOX Valve Open		K0627	511.795		
Eng LH2 Bld Valve Cls - On		K0557	511.810		
Eng Main LH2 Vlv Cls - Off		K0632	511.813		
Eng LOX Bld Vlv Cls - On		K0558	511.826		
Eng Main LH2 Vlv Open - On		K0458	511.861	K0118	511.893

TABLE 5-1 (Sheet 7 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Eng Ign Detected		K0537	511.898	K0008	511.900
Aft Separate Simu 1 Off		K4790	512.100		
Aft Separate Simu 2 Off		K5714	512.108		
Fuel Inj Temp OK Bypass	11	K3890	512.874		
Fuel Inj Temp OK Bypass Reset		K0446	512.880		
Engine Start Tk Disch Sol Ener		K0536	512.883	K0096	512.883
S-IVB Engine Start Off	27	K3890	513.082		
Engine Start Command Rel Rst		K0634	513.086		
Engine Start Command Off		K0556	513.088	K0021	512.117
Eng St Tk Disch Vlv Cls - On		K0460	513.099	K0122	513.143
Eng St Tk Disch Sol Ener - Off		K0536	513.335	K0096	513.314
Eng M/S Cont Sol Ener - On		K0538	513.335	K0005	513.333
Eng GG Vlv Cls - Off		K0631	513.434		
Eng St Tk Disch Vlv Opn - Off		K0460	513.474	K0122	513.477
Eng GG Vlv Opn - On		K0457	513.552	K0117	513.560
Eng LOX Turb Byp Vlv Open - Off		K0461	513.573	K0124	513.652
Eng St Tk Disch Vlv Cls - On		K0695	513.689		

TABLE 5-1 (Sheet 8 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57) MEAS NO.	DIGITAL EVENT RECORDER (CAT 57) TIME (sec)	PCM/FM SEQUENCE (CAT 42) MEAS NO.	PCM/FM SEQUENCE (CAT 42) TIME (sec)
Eng LOX Turb Byp Vlv Closed - On		K0463	513.782	K0125	513.818
Eng Main LOX Vlv Cls - Off		K0633	513.990		
First Burn Relay On	68	K3890	514.691		
First Burn Press Cont Vlv Sol Ener		K0524	514.699		
First Burn Step Press Cont Vlv Ener		K0523	514.699		
Eng M/S OK Press Sw-1		K0610	514.795	K0014	514.877
Eng M/S OK P/S-2 Pressurized		K0573	514.796	K0159	514.835
Eng M/S OK P/S-2 Pressurized				K0157	514.835
Eng M/S OK Press Sw Pick-up (No)		K0685	514.797		
Eng M/S OK Press Sw Pick-up (No)		K0412	514.797		
Eng M/S OK P/S-1 Pressurized		K0572	514.800	K0158	514.835
Eng Main LOX Vlv Open		K0459	515.583	K0120	515.643
Eng Spark GG Sys - Off		K0454	516.629	K0010	516.633
Eng Spark T/C Sys - Off		K0455	516.630	K0011	516.633
PU Activate On	5	K3890	517.882		
PU Activated		K0507	517.887		

TABLE 5-1 (Sheet 9 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Chg Ullage Jett On	55	K3890	519.343		
Fire Ullage Jett On	57	K3890	521.856		
EBW Fire 1 PS				K0149	521.910
EBW Fire 2 PS				K0150	521.910
Fucl Inj Temp OK Bypass Reset	16	K3890	523.068		
Engine LH2 Inj Temp Byp Rst		K0446	523.077		
Ullage Chg Reset	88	K3890	525.498		
Ullage Firing Reset	73	K3890	525.498		
UR Pilot Relays Rst		K0673	525.555		
Ht Exch Valve Control Enable	50	K3890	532.820		
R/S Tone 2 EBW Arm & ECO		K5758	536.256		
R/S 2 Arm & ECO Cmd Rcvd		K0659	*Not Available		
R/S 1 Arm & ECO Cmd Rcvd		K0660	*Not Available		
R/S 1 EBW Arm & ECO On		K0693	536.369		
R/S 2 EBW Arm & ECO On		K0692	536.426		
R/S Tone 2 EBW Arm & ECO Off		K5758	536.482		
R/S 2 PD EBW FU Pwr On		K0561	536.539		
R/S 1 PD EBW FU Pwr On		K0650	536.539		

*DER malfunction

TABLE 5-1 (Sheet 10 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
R/S 1 Arm & ECO Cmd Rcvd Off		K0660	*Not Available		
R/S 2 Arm & ECO Cmd Rcvd Off		K0659	*Not Available		
R/S Tone 1 PD Cmd ON		K5757	539.521		
R/S 2 PD Cmd Rcvd On		K2405	539.638	K0142	539.651
R/S 1 PD Cm Rcvd On		K2404	539.638	K0141	539.651
R/S 2 PD Cmd Rcvd Off		K2405	539.667		
R/S 1 PD Cmd Rcvd Off		K2404	539.669		
R/S Tone 1 PD Cmd Off		K5757	539.779		
R/S Tone 6 Sys Off Cmd - On		K5759	542.851		
R/S 2 Sys Off Cmd Rcvd - On		K0679	542.964		
R/S 1 Sys Off Cmd Rcvd - On		K0681	542.964		
R/S 2 Sys Off Cmd Rcvd - Off		K0679	542.965		
R/S 2 PD EBW FU Pwr Off		K0651	542.965		
R/S 2 Rcvr Pwr Off		K0678	542.965		
R/S 1 Sys Off Cmd Rcvd Off		K0681	542.965		
R/S 1 PD EBW FU Pwr Off		K0650	542.965		
R/S 1 Rcvr Pwr Off		K0680	542.965		
R/S Tone 6 Sys Off Cmd - Off		K5759	543.099		

*DER malfunction

TABLE 5-1 (Sheet 11 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Aux Hyd Pmp Flt Mode Off	29	K3890	656.801		
Aux Hyd Pmp Flt Rel Rst - Off		K0621	656.806		
Aux Hyd Pmp On Ener - Off		K0513	657.044		
Aux Hyd Pmp Flt Mode On	28	K3890	706.671		
Aux Hyd Pmp Flt Rel Reset - Off		K0621	706.675		
Aux Hyd Pmp Power On		K0513	706.768		
First Burn Relay Off	69	K3890	711.887		
Fuel Tank Step Press Cont Vlv Sol De-ener		K0523	711.895		
Fuel Tank Press Cont Vlv Sol De-ener		K0524	711.895		
Second Burn Relay On	32	K3890	711.987		
LH2 Tk Step Pres Vlv Ener		K0523	711.994		
Fuel Tk Press Cont Vlv Sol Ener		K0524	711.995		
Second Burn Relay Off	33	K3890	921.858		
Fuel Tk Press Cont Vlv Sol De-ener		K0524	921.865		
LH2 Tk Step Pres Vlv Ener		K0523	921.865		
LH2 & LOX C/D Shutoff Close Ener - On		K0577	921.945		
LOX S/D Shutoff Valve Open - Off		K0545	922.091	K0138	922.169

TABLE 5-1 (Sheet 12 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
LH2 C/D Shutoff Valve Open - Off		K0544	922.107	K0137	922.160
LOX C/D Shutoff Valve Closed - On		K0552	922.133	K0139	922.169
LH2 C/D Shutoff Valve Closed - On		J0551	922.172	K0136	922.243
Point Level Sensor Arming	97	K3890	939.400		
Eng Pump Purge Cont Vlv Enable On	24	K3890	939.499		
Eng Pump Prg Sol Vlv Ener - On		K0566	939.512	K0105	941.526
Eng Cutoff Lock-in Ind - On		K0539	947.837	K0013	947.866
Eng Ign Ph Cont Sol Ener - Off		K0535	947.837	K0006	947.840
Eng Cutoff Ind - Veh Ener - On		K0522	947.839		
Eng M/S Cont Sol Ener - Off		K0538	947.840	K0005	947.840
Eng Cutoff Ind - Non Prog - On		K0419	947.841		
O_2-H_2 Burner Sys Rel Rst		K0437	947.845		
Eng GG Vlv Open - Off		K0457	947.870	K0117	947.950
Eng Main LOX Vlv Open - Off		K0459	947.931	K0120	947.950

TABLE 5-1 (Sheet 13 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Eng GG Vlv Cls - On		K0631	947.932		
Eng Main LH2 Vlv Open - Off		K0458	947.974	K0118	948.033
Eng M/S OK P/S-2 Depressurized		K0573	948.024	K0159	948.058
Eng M/S OK P/S-1 Depressurized		K0572	948.028	K0158	948.058
Eng M/S OK Press Sw No. 1 - Off		K0610	948.030	K0014	948.100
Eng Thrust OK 2		K0412	948.031		
Eng Thrust OK 1		K0685	948.031		
Eng Main LOX Vlv Cls - On		K0633	948.034		
Eng Pmp Prg Cont Vlv Enable On	24	K3890	948.053		
Eng LOX Turb Byp Vlv Cls - Off		K0463	948.138	K0125	948.208
Fwd Bus Transfer External Indication		K0639	948.163		
Eng Main LH2 Vlv Cls - On		K0632	948.180		
Aft Bus 1 Transfer External Indication		K0622	948.321		
Aft Bus 2 Transfer External Indication		K0623	948.475		
Eng LOX Turb Byp Vlv Opn		K0461	948.565	K0124	948.625
Eng Cont He Sol Vlv Ener - Off		K0531	948.829	K0007	948.831

TABLE 5-1 (Sheet 14 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Eng Cutoff Lock-in Ind - Off		K0539	948.831	K0013	948.866
Eng Ready Sign On		K0530	948.835	K0012	948.866
LH2 & LOX Prevalve Closed Command - On		K0576	949.123		
LH2 Prevlv Open Indication - Off		K0540	949.237	K0111	949.275
LOX Prevlv Open Indication - Off		K0541	949.255	K0109	949.275
LH2 Prevlv Cls - On		K0549	949.457	K0112	949.525
LOX Prevalve Close - On		K0550	949.601	K0110	949.608
S-IVB Engine Start Off	27	K3890	949.768		
He Cold Sov Cls - On		K3802	949.834		
He Cold Sov Opn - Ener - Off		K0571	949.841		
S-IVB Engine Cutoff	12	K3890	949.884		
Engine Cutoff Ind - Sw Sel		K0418	949.888		
LOX Tk Press Shutoff Vlvs Cls On	79	K3890	949.999		
First Burn Relay Off	69	K3890	950.093		
Second Burn Relay Off	33	K3890	950.224		
LOX Tank Flight Press System Off	104	K3890	950.327		

TABLE 5-1 (Sheet 15 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
LOX Chilldown Pmp Off	23	K3890	950.479		
LH2 Chilldown Pmp Off	59	K3890	950.568		
Point Level Sensor Disarming	98	K3890	951.914		
Fuel Inj Temp OK Bypass Reset	16	K3890	953.158		
Ullage Chg Reset	88	K3890	953.564		
Ullage Firing Reset	73	K3890	953.654		
T/M Calibration Off	63	K3890	953.769		
Heat Exchanger Valve Control Enab	50	K3890	954.242		
Eng Cont Btl Dmp Opn - On		K3817	954.353		
Eng Cutoff Arm - Observer - Off		K5811	954.421		
Eng Cutoff Cmd - Observer - Off		K2741	954.421		
PU Fuel Boiloff Bias On	34	K3890	954.563		
PU Boiloff Bias On		K0417	954.567		
PU Boiloff Bias Off	35	K3890	969.677		
PU Activate Off	6	K3890	969.771		
PU System Off		K0507	969.774		
Aux Hyd Pump Coast Mode On	30	K3890	969,886		
Aux Hyd Pmp Cst Rel Rst		K0445	969.890		
Aux Hyd Pmp Flt Mode Off	29	K3890	969.998		

TABLE 5-1 (Sheet 16 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Aux Hyd Pmp Flt Rel Rst		K0621	970.002		
Aux Hyd Pmp on Ener No.		K0513	970.248		
PU Valve Hardover Position On	17	K3890	1738.918		
PU Valve Hardover Position Off	18	K3890	1741.031		
Eng Cutoff Cmd - C/T Pwr		K4796	1741.189		
Eng Cutoff Cmd - GSE Pwr		K4797	1741.216		
S-IVB Eng Cutoff Off	13	K3890	1779.220	K0140	1779.282
Eng Cutoff Ind - Sw Sel - Off		K0418	1779.225		
Eng Cutoff Ind - Veh Ener - Off		K0522	1779.230	K0013	1836.479
LH2 & LOX Prevalve Open Command On		K0576	1779.341		
LH2 & LOX C/D Sov Clsd Ener - Off		K0577	1779.365		
LH2 Prevlv Cls - Off		K0549	1780.231	K0112	1780.307
LOX Prevlv Cls - Off		K0550	1780.307	K0110	1780.390
LH2 C/D Sov Cls - Off		K0551	1780.528	K0136	1780.607
LOX C/D Sov Cls - Off		K0552	1780.716	K0139	1780.699
LH2 C/D Sov Opn - On		K0544	1781.193	K0137	1781.274
LOX C/D Sov Opn - On		K0545	1781.460	K0138	1781.366

TABLE 5-1 (Sheet 17 of 17)
SEQUENCE OF EVENTS (J-2 ENGINE)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
LH2 Prevlv Opn Indication - On		K0540	1781.842	K0111	1781.890
LOX Prevlv Opn Indication - On		K0541	1781.892	K0109	1781.974
LOX Tk Press Shutoff Vlvs Cls Off	80	K3890	1786.590		
LH2 Tk Vnt Dir Flt Pos - Off		K0562	1786.936	K0114	1786.474
LH2 Tk Vnt Dir Gnd Pos - On		K0561	1787.006	K0113	1787.057
T/M Prelaunch C/O Grp On Command		K0406	1817.006		
T/M Prelnch C/O Grp On Indication		K0408	1817.050		
T/M Prelnch C/O Grp On Comm - Off		K0406	1817.190		
T/M Calibration Off	63	K3890	1823.863		
RACS Cal (Beginning)		K4851	1823.946		
RACS Cal (End)		K0403	1849.315		
T/M Calibration On	62	K3890	1909.629		
T/M Calibrarion Off	63	K3890	1910.742		
RACS Calibration (Beginning)		K4851	1910.825		
RACS Calibration (End)		K0403	1936.182		
PCM RF Assy Pwr Off	65	K3890	1992.686		

TABLE 5-2 (Sheet 1 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
O_2-H_2 Burner Start (T_A)*					
T/M Calibration On	62	K3890	-599.041		
T/M Calibration Off	63	K3890	-597.923		
RACS Cal (End)		K4802	-573.078		
T/M Prelnch C/O Grp Off Command		K0403	-572.783		
T/M Prelnch C/O Grp On Ind - Off		K0408	-572.449		
T/M Prelnch C/O Grp Off Command - Reset		K0403	-563.885		
Aft Bus 1 Transfer Internal Indication		K0622	-563.845		
Aft Bus 2 Transfer Internal Indication		K0623	-563.579		
Fwd Bus Transfer Internal Indication		K0639	-563.324		
Ambient Repress Mode Sel Off and Cryo On	37	K3890	-509.292		
Burner Fuel Prop Vlv Clsd Off	61	K3890	-509.109		
Burner Automatic Cutoff Sys Arm	85	K3890	-508.607		
Ambient Repress Mod Sel Off and Cryo On	37	K3890	-499.159	K0195	-499.140
S-IVB Ullage Eng No. 1 Off	43	K3890	-498.985		

*T_A = 1255:43.00 PDT

TABLE 5-2 (Sheet 2 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
S-IVB Ullage Eng No. 2 Off	102	K3890	-498.930		
Burner Automatic Cutoff Sys Disarm	86	K3890	-498.894		
Burner Fuel Prop Vlv Clsd Off	61	K3890	-498.666		
Burner LOX Shutdown CIs Off	75	K3890	-498.576		
LOX Tk NPV Valve Latch Open On	44	K3890	-485.330		
S-IVB Ullage Eng No. 1 On	42	K3890	-40.047		
S-IVB Ullage Eng Rel Rst		K0429	-40.039		
S-IVB Ullage Eng No. 2 On	101	K3890	-39.953		
Burner Fuel Prop Vlv Open On	26	K3890	-0.089		
Burner System Rel Rst - Off		K0437	-0.083		
Burner LH2 Prop Vlv Cls - Off		K0432	-0.037	K0180	-0.005
Burner LH2 Prop Vlv Opn - On		K0431	-0.007	K0181	-0.005
Burner Exciters On	70	K3890	0.225		
Burner LOX Shutdown Valve Open On	89	K3890	0.647		
Burner LOX Shutdown Vlv Cls - Off		K0428	0.717		

TABLE 5-2 (Sheet 3 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Burner LOX Shutdown Vlv Opn - On		K0427	0.724		
LH2 Tank Continuous Vent Valve Closed On	84	K3890	0.854		
LH2 Tank Continuous Vent Valve Relays Reset - Off		K0452	0.860		
LH2 Tank Continuous Vent Relief Overrd Vlv Clsd - On		K0699	0.882	K0154	0.904
LH2 Tank Continuous Vent Orf Byp Vlv Open - Off		K0451	0.969		
LH2 Tank Continuous Vent Orf Byp Vlv Closed - On		K2400	0.973	K0155	1.003
Burner Fuel Prop Vlv Open - Off	72	K3890	1.461		
Burner LOX Shutdown Valve Open Off	90	K3890	2.179		
LH2 Tank Continuous Vent Valve Close Off	87	K3890	2.887		
LH2 Tank Continuous Vent Valve Relays Reset - On		K0452	2.896		
Burner Exciters Off	71	K3890	4.056		
Burner Sys Rel Rst - On		K0437	4.064		
Burner Automatic Cutoff Sys Arm	85	K3890	6.574		
LH2 & LOX Repress Sys Rst - Off		K0441	6.757		

TABLE 5-2 (Sheet 4 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Burner Automatic Cutoff Sys Enable On		K0438	6.758		
LH2 Tk Repress Control Valve Open On	39	K3890	6.865		
LH2 Repress Valve Ener - On		K0443	6.874		
LOX Tk Repress Cont Valve Open On	3	K3890	7.074		
LOX Tk Repress Valve Ener On		K0444	7.087		
S-IVB Ullage Eng No. 1 Off	43	K3890	7.368		
S-IVB Ullage Eng No. 2 Off	102	K3890	7.459		
S-IVB Ull Eng Rel Rst - Off		K0429	7.467		
LH2 Tk Repress Vlv Ener - Off		K0443	157.238		
LOX Tk Repress Cont Vlv Open Off	4	K3890	157.430		
LOX Tk Repress Vlv Ener - Off		K0444	157.443		
Aux Hyd Pump Flt Mode - On	28	K3890	178.225		
Aux Hyd Pump Flt Rel Rst		K0621	178.228		
Aux Hyd Pump Coast Mode Off	31	K3890	178.315		

TABLE 5-2 (Sheet 5 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Aux Hyd Pump On - Ener		K0513	178.318		
Aux Hyd Pump Cst Rel Rst		K0445	178.319		
LOX Tk Repress Cont Vlv Opn Off	4	K3890	207.563		
LOX Chilldown Pump On	22	K3890	207.720		
LOX Chilldown Pump Rel Rst - Off		K0644	207.728		
LOX Chilldown Pump Inv On		K0519	207.730		
LH2 Chilldown Pump On	58	K3890	212.780		
LH2 Chilldown Pump Rel Rst - Off		K0641	212.787		
LH2 Chilldown Pump Inv On		K0512	212.789		
LH2 & LOX Prevlv Close Command - On		K0576	217.963		
LH2 Prevlv Open Indication - Off		K0540	218.078	K0111	218.082
LOX Prevlv Open Indication - Off		K0541	218.095	K0109	218.165
LH2 Prevlv Closed Indication - On		K0549	218.320	K0112	218.415
LOX Prevlv Closed Indication - On		K0550	218.454	K0110	218.499
Second Burn Relay On	32	K3890	408.678		
LH2 Tk Flt Press Vlv Ener		K0524	408.685		
LH2 Tk Step Presvlv Ener		K0523	408.685		

TABLE 5-2 (Sheet 6 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
PU Vlv Hardover Position On	17	K3890	408.766		
S-IVB Ull Eng No. 1 On	42	K3890	454.876		
S-IVB Ull Eng Rel Rst		K0429	454.883		
S-IVB Ull Eng No. 2 On	101	K3890	454.966		
LOX Tk Repress Cont Valve Open Off	4	K3890	455.103		
LH2 Tk Repress Cont Valve Open Off	81	K3890	455.240		
Burner Fuel Prop Vlv Clsd On	60	K3890	455.383		
Burner Sys Rel Rst - On		K0437	455.390		
Burner Automatic Cutoff Sys Disarm	86	K3890	455.587		
LH2 + LOX Repress Sys Rst		K0441	455.591		
Burner Automatic Cutoff Sys Enab		K0438	455.593		
LH2 Tk Cont Vent Vlv Close On	84	K3890	455.782		
LH2 Tk Cont Vent Vlv Rel Rst		K0452	455.789		
Amb Repress Mode Sel On and Cryo Off	36	K3890	456.201		
LH2 + LOX Repress Sys Rst		K0441	456.204		

TABLE 5-2 (Sheet 7 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
LH2 + LOX Repress Mode Amb		K0440	456.205		
LH2 Tk Cont Vent Vlv Close Off	87	K3890	457.799		
LH2 Tk Vent Orf + Rlf Rst		K0452	457.808		
Burner Fuel Prop Vlv Clsd Off	61	K3890	458.399		
Burner Sys Rel Rst - On		K0437	458.409		
Burner LOX Shutdown Vlv Close On	74	K3890	459.904		
LH2 Tk Cont Vent Vlv Close Off	87	K3890	460.044		
Burner LOX Shutdown Vlv Close Off	75	K3890	462.983		
Burner Sys Rel Rst		K0437	462.999		
LH2 + LOX Prevlv Close Ener		K0576	518.024		
Chilldown Vlv Open On		K0545	518.570		
LH2 Prevalve Clsd On		K0549	518.934		
LOX Prevalve Clsd On		K0550	518.986		
LH2 Prevalves Open On		K0540	520.474	K0111	520.563
LOX Prevalves Open - On		K0541	520.622	K0109	520.646
LH2 Chilldown Pump Off	59	K3890	528.098		
LH2 C/D Pmp Inv Off - Indication		K0512	528.106		

TABLE 5-2 (Sheet 8 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
LH2 C/D Pmp Relay Rst Indication		K0641	528.108		
LOX Chilldown Pump Off	23	K3890	528.318		
LOX C/D Pmp Inv Off Indication		K0519	528.325		
LOX C/D Pmp Relay Rst Indication		K0644	528.328		
Aux Hyd Pump Coast Mode On	30	K3890	529.568		
Aux Hyd Pump Coast Rel Rst On		K0445	529.571		
Aux Hyd Pmp Flt Mode Off	29	K3890	529.658		
Aux Hyd Pump Flt Rel Rst - Off		K0621	529.663		
S-IVB Ull Eng No. 1 Off	43	K3890	529.813		
S-IVB Ull Eng No. 2 Off	102	K3890	529.900		
S-IVB Ull Eng Rel Rst		K0429	529.909		
PU Vlv Hardover Position Off	18	K3890	530.012		
LH2 Tk Cont Vent Orf Shutoff Vlv Opn On	111	K3890	644.875		
LH2 Tk Cont Vent Vlv Rel Rst		K0452	644.881		
LH2 Tk Cont Vent Rlf Ovrrd Shutoff Vlv Open On	107	K3890	644.964		

TABLE 5-2 (Sheet 9 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
LH2 Cont Vent Orf Byp Vlv Opn Indication		K0451	644.985		
LH2 Tk Cont Vent Rlf Ovrrd Vlv Clsd On		K0699	644.985		
LH2 Cont Vent Orf Byp Vlv Opn Indication		K0451	644.993		
LH2 Cont Vent Orf Byp Vlv Opn Indication		K0451	644.994		
LH2 Tk Cont Vent Orf Shutoff Vlv Open Off	112	K3890	647.078		
LH2 Tk Cont Vent Rlf Ovrrd Shutoff Vlv Open Off	108	K3890	647.167		
LH2 Tk Cont Vent Vlv Rel Rst		K0452	647.177		
Burner LH2 Prop Vlv Opn On	26	K3890	699.963		
Burner Sys Rel Rst		K0437	699.970		
Burner LH2 Prop Vlv Cls Off		K0432	700.016		
Burner LH2 Prop Vlv Opn On		K0431	700.045		
Burner Exc On	70	K3890	700.268		
Burner LOX Shutdown Opn On	89	K3890	700.688		
Burner LOX Shutdown Vlv Cls Off		K0428	700.758		

TABLE 5-2 (Sheet 10 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
Burner LOX Shutdown Vlv Opn On		K0427	700.765		
Burner LH2 Prop Vlv Opn Off	72	K3890	701.496		
Burner LOX Shutdown Vlv Open Off	90	K3890	702.217		
Burner Exc Off	71	K3890	704.131		
Burner Sys Rel Rst		K0437	704.139		
Burner Automatic Cutoff Sys Arm	85	K3890	706.722		
Burner Automatic Cutoff Sys Disable		K0438	706.727		
Burner LH2 Prop Vlv Close On	60	K3890	830.548		
Burner Sys Rel Rst		K0437	830.555		
Burner Automatic Cutoff Sys Disarm	86	K3890	830.750		
Burner Automatic Cutoff Sys Disable		K0438	830.756		
Burner LH2 Prop Vlv Cls Off	61	K3890	833.549		
Burner Sys Rel Rst		K0437	833.558		
Burner LOX Shutdown Vlv Cls On	74	K3890	835.059		
Burner LOX Shutdown Vlv Cls Off	75	K3890	838.008		
Burner Sys Rel Rst		K0437	838.017		

TABLE 5-2 (Sheet 11 of 11)
SEQUENCE OF EVENTS (O_2-H_2 BURNER)

EVENT/RESULT OF COMMAND	SWITCH SELECTOR CHANNEL	DIGITAL EVENT RECORDER (CAT 57)		PCM/FM SEQUENCE (CAT 42)	
		MEAS NO.	TIME (sec)	MEAS NO.	TIME (sec)
LOX Tk Repress Cont Vlv Open On	3	K3890	946.493		
LOX Tk Repress Vlv Ener		K0444	946.507		
LH2 Tk Cont Vent Vlv Close On	84	K3890	951.025		
LH2 Tk Vent Orf + Rlf Rst		K0452	951.032		
LH2 Tk Vent Rlf Ovrd Cls		K0699	951.052		
LH2 Tk Vent Orf Byp Opn		K0451	951.127		
LH2 Tk Cont Vent Vlv Close Off	87	K3890	953.146		
LH2 Tk Vent Orf + Rlf Rst		K0452	953.155		
LH2 Tk Repress Cont Vlv Opn On	39	K3890	966.969		
LH2 Tk Repress Vlv Ener		K0443	966.977		
LH2 Tk Step Pres Vlv Ener		K0523	995.880		
LH2 Tk Repress Vlv Ener		K0443	995.982		

6. ENGINE SYSTEM

The S-IVB stage acceptance firing was performed with an uprated (230,000 lbf thrust) Rocketdyne engine S/N 2119 (figure 6-1) mounted on the stage. The engine was manufactured in the configuration baseline designed for J-2 engine S/N 2088 and subs and is described in the Rocketdyne configuration report (R-5788). The manufacturer conducted the Engine Acceptance Test Program on 22 and 23, June, 1967. The necessary performance demonstration was achieved in three test firings with an accumulated duration of 346.1 sec. As a result of these tests the engine performance tag values were established as follows:

Thrust (F)	231,700 lbf
Engine Mixture Ratio (EMR)	5.548
Specific Impulse (Isp)	424.9

The tag values were established with a LOX flowmeter constant of 5.6278 cpg and an LH2 flowmeter constant of 1.8289 cpg. The gas generator feed system contained orifices with diameters of 0.266 in. for LOX and 0.481 in. for LH2. The engine was equipped with a 1-sec start tank discharge valve timer in the engine control. None of the other modifications produced any significant performance effects.

6.1 Engine Chilldown and Conditioning

6.1.1 Turbopump Chilldown

Chilldown of the engine LOX and LH2 turbopumps was adequate to provide the conditions required for proper engine start. An analysis of the chilldown operation is presented in paragraphs 7.4 and 8.3. The LOX pump discharge was 21.2 deg subcooled compared to the recommended minimum of 3 deg.

6.1.2 Thrust Chamber Chilldown

The thrust chamber skin temperature (figure 6-2) was 221 deg R at Engine Start Command, well within the engine start requirements of 235 $\pm$ 75. A comparison of three acceptance firings is presented in table 6-1. The LH2 pump demonstrated satisfactory start transient buildup characteristics, as shown in figure 6-3.

6.1.3 Engine Start Sphere Chilldown and Loading

Chilldown and loading of the GH2 start sphere (figure 6-4) met requirements for engine start (figure 6-5). The maximum warmup rate was 4.0 deg R/min for 1.75 min after sphere pressurization and averaged 1.87 deg R/min from sphere pressurization to Engine Start Command. Significant data from three S-IVB stages are compared in table 6-2.

6.1.4 Start Tank Refill Performance

Figure 6-6 shows the refill performance of the J-2 start tank during the S-IVB-507 stage acceptance firing. Immediately prior to start tank discharge, the start tank conditions (1,307 psia and 276 deg R) were within the safe start envelope. When the start tank discharge valve (STDV) opened, the GH2 discharged through the turbines, as shown in figure 6-6. The discharge was completed and the refill initiated when the temperature and pressure were 184 deg R and 136 psia, respectively, at ESC +1.82 sec. Except for the initial period when the injector was at its lowest temperature (immediately after fuel lead), the refill was practically an exact reversal of the discharge. The tank was topped with lower temperature hydrogen from the LH2 pump discharge starting at ESC +5.95 sec. The topping was terminated when the pressure differential across the topping check valve was lower than the minimum required for flow. At this time (ESC +91.3 sec) the tank pressure and temperature were 1,246 psia and 219.4 deg R, respectively. Environmental heating caused the start tank pressure and temperature to increase to the required level for start.

Figure 6-7 shows the restart capability of the engine based on a Rocketdyne-determined criterion. The start tank pressure at STDV +60 sec (ESC +61.230 sec) was 1,224.75 psia as compared to a minimum allowable of 950 psia. At ESC +43.375 sec, the start tank condition was within the safe start envelope; at Engine Cutoff Command, the pressure and temperature were 1,328.8 psia and 233.2 deg R. The pressure did not reach the relief valve setting (1,455 psia) during the firing.

6.1.5 Engine Control Sphere Chilldown and Loading

The engine control sphere conditioning was adequate (figure 6-4), and all objectives were satisfactorily accomplished. The engine start requirement (2,800 to 3,450 psia) was met. Significant engine control sphere performance data from three S-IVB stages are compared in table 6-3.

6.2 J-2 Engine Performance Analysis Methods and Instrumentation

Engine performance for the acceptance firing was calculated by use of computer programs G105-1 and G307. The average of the results of the two programs, which is considered to be the best current estimate of engine performance, was calculated by computer program PA49. Computer program PA53, utilizing revised techniques and the latest Rocketdyne correlations, was used to compute start and cutoff transient performance.* A description of the operation and a comparison of the results of each program is presented in table 6-4. Data inputs to the computer programs, with the applicable biases, are shown in table 6-5.

6.3 J-2 Engine Performance

The engine performance was satisfactory. Plots of selected data showing engine characteristics are presented in figures 6-8 through 6-13. The engine propellant inlet conditions are discussed in sections 7 and 8. The engine performance level at ESC +60 sec as determined by computer program G307 (Past-641 deck) was as follows:

Parameter	DAC Acceptance	Rocketdyne Acceptance	Difference	3δ Run to Run
Thrust (lbf)	231,841	231,700	+141	±2,216
Mixture Ratio	5.514	5.548	-.034	±0.03
Specific Impulse (sec)	425.8	424.9	+0.9	±2.46

These values are comparable, within the run-to-run deviations, to the J-2 engine acceptance results. The composite values for steady-state performance are shown in table 6-6.

*Program UT23 was also used to analyze and study engine component performance.

Flow integral mass analysis indicated that 187,396 lbm of LOX and 36,426 lbm of LH2 were consumed between engine start command and engine cutoff command. The overall stage average performance from the 90 percent performance level (ESC +3.625 sec) to engine cutoff (ESC +436.079 sec) is presented in table 6-6. The variation of specific impulse with mixture ratio is shown in figure 6-13.

Total impulse generated from engine start command to engine cutoff command was 96.54 x 10^6 lbf-sec. Extrapolation of the propellant residual as indicated by the point level sensors (1,790 lbm of LOX, 1,122 lbm of LH2) indicates that a LOX depletion cutoff would have occurred at ECC +4.33 sec. In that time an additional 917,856 lbf-sec impulse would have been generated, making the total stage potential impulse from engine start command to depletion cutoff 97.46 x 10^6 lbf-sec, as compared to the predicted value of 97.79 x 10^6 lbf-sec. The 0.34 percent deviation is within the prediction accuracy of approximately 1 percent. The 13.024 sec difference between the actual (ESC +436.079 sec) and predicted (ESC +449.103 sec) depletion times is also within the prediction accuracy (paragraph 6.5.6).

6.3.1 Start Transient

The J-2 engine start transient was satisfactory. A summary of engine performance is presented in the following table:

PARAMETER	ACCEPTANCE FIRING	LOG BOOK
Time to 90 percent performance level (sec)	ESC +3.625	ESC +3.500
Time of start tank discharge command (sec)	ESC +1.125	ESC +1.000
Thrust at 90 percent performance level (lbf)	183,426	189.232
Total Impulse (lbf sec)	170,582	166,892*

*Based on stabilized thrust at null PU and standard altitude conditions.

Thrust buildup to the 90 percent performance level (STDV +2.50 sec) was within the maximum and minimum thrust bands as shown in figure 6-14. The acceptance firing total impulse was in agreement with the value given in the log book.

6.3.2 Steady-State Performance

The J-2 engine performed satisfactorily during the steady-state portion of engine burn. A performance shift occurred during hardover operation (between ESC +119 sec and 126 sec). The effect of this shift was observed in the majority of engine instrumentation although no corresponding deviations in PU valve position were noted. The shift, probably caused by a GG bootstrap system resistance shift, resulted in a 0.7 percent thrust variation at the rate of -669 lbf/sec. The allowable is ±500 lbf/sec.

Average performance values for the acceptance firing steady-state operation are presented in figure 6-15 and compared with predicted performance values in table 6-6. During closed PU valve operation, the deviation was less than 0.3 percent. Overall performance deviations were a result of the difference in predicted and actual cutback time (refer to section 11) and the difference in predicted and actual engine response after cutback (paragraph 6.5.6).

Engine thrust variations during the acceptance firing are presented in table 6-6. They are compared to the predicted acceptance firing thrust history and to Contract End Item (CEI) thrust variation limits for flight. These limits do not apply to acceptance firing performance and are presented for reference only. The thrust variations will be modified by flight effects on stage operation. Thrust variations during three phases of engine operation are presented in figure 6-16 and discussed in the following paragraphs:

a. The thrust variations during hardover, or maximum, engine mixture ratio operation (EMR = 5.5) were within the CEI limits for normal engine operation.* Normal operating thrust variations during this period of engine burn are caused by stabilization of the engine and by stage perturbations, including the effects of variations in propellant supply environmental conditions.

*Engine performance shifts are excluded from CEI specifications.

b. Thrust variations during the transient period from PU valve cutback +75 sec to ESC -70 sec were within the CEI limits for normal engine operation. The thrust variations during this period were caused by stabilization of the engine after cutback and can be directly linked to movements of the PU valve. Data derived from the acceptance firing will aid in the flight calibration of the PU system in order to more accurately predict the thrust variation during this cutback transient.

c. Thrust variations during the final 70 sec of engine operation were within the CEI limits for normal engine operation. These thrust variations were mainly due to movements of the PU valve. These movements will be modified somewhat by flight effects on stage performance and by improved flight calibration of the PU system.

6.3.3 Cutoff Transient

The time lapse between engine cutoff, as received at the J-2 engine, and thrust decrease to 11,500 lbf was within the maximum allowable time of 800 ms for the acceptance firing as shown in the following table:

PARAMETER	ACCEPTANCE FIRING	LOG BOOK
Time of thrust decrease to 11,500 lbf (ms)	492	343
Measured total impulse (lbf-sec)	39,086*	---
Total impulse corrected to null (-2.0 deg) PU valve position (lbf-sec)	36,981	30,827
Total impulse corrected to 0 deg F oxidizer valve skin temperature (lbf-sec)	**	32,012

*PU valve at +3.93 deg.

**Valve skin temperature data not available.

The thrust decay time for the acceptance firing was greater than the log book value, and the cutoff total impulse corroborated this larger value. For this firing, the total impulse was corrected to null PU valve position so that a direct comparison could be made to the log book value. At engine cutoff, the PU valve was 3.93 deg above the null position requiring a small correction. It was not possible to correct to 0 deg F LOX valve skin temperature since that measurement was not available. Figure 6-17 presents the data for the thrust chamber pressure cutoff transient, accumulated cutoff impulse, and cutoff thrust to the 11,500 lbf level.

6.4 Engine Sequencing

The engine sequencing was satisfactory throughout the acceptance firing and compatible with the engine logic and the acceptance firing test plan. However, as in past acceptance firings, the sequence times differ in many respects from the values quoted in the log book.

Most of the disagreements between measured and log book values are insignificant and may be ascribed to sampling rate errors or to the effects of the liquids that are present during the acceptance firing but absent during log book testing. It should also be noted, that because of the low sampling rate (12 sps) all sequence of events data are only accurate to ±80 ms.

Figure 6-18 presents the engine start sequence for the acceptance firing; table 6-8 presents the time of significant events during the firing and compares them with the nominal values.

During the start sequence, dropout of the Engine Start Command signal, which is externally supplied to the engine, was later than nominal. The gas generator valve opening time was longer than nominal, but was in general agreement with the opening times of previous engines tested and caused no ill effects during engine start.

During the cutoff sequence, the main oxidizer valve and main fuel valve closing times were both longer than nominal.

6.5 Component Operation

6.5.1 Main LOX Valve

The main LOX valve opened satisfactorily during the acceptance firing. The main LOX valve opening time data were as follows:

Item	Specification	STC Pretest Checkout	Acceptance Firing
First stage travel (ms)	50 ±25	52	66
First plateau (ms)	510 ±70	640	528
Second stage travel (ms)	1,825 ±75	1,877	1,830
Total time (ms)	2,385 ±170	2,569	2,424

The valve opening times were within specifications for the acceptance firing. The first plateau time was less than it was during pretest checkout when the specification limit was exceeded (ambient conditions). The valve closing time was 168 ms which was approximately 32 ms longer than the maximum specified; however, this did not contribute to any significant reduction in cutoff transient performance.

6.5.2 PU Valve

At engine start command, the PU valve was at -1.94 deg (null) which was within the -2 ±2 deg limit. PU valve response was satisfactory (see section 11). PU activation occurred at ESC +6.0 sec. The PU valve went to the high EMR position where it remained until PU cutback at ESC +184.7 sec as shown in figure 6-13. The engine mixture ratio (EMR) was properly controlled to the required reference of 5.0/1.0 following cutback; however the actual valve position was approximately 4 deg higher than predicted as shown in figure 6-12. The more positive valve position produced high total engine flowrates and thrust at the correct EMR resulting in a 13 second earlier than predicted cutoff time. The deviation is due to generalized PU valve response effects used for performance predictions on S-V stages 505 through 511 whose valves have been reworked following engine acceptance test at Rocketdyne per ECP #J-2-601 (MD-283).

Results from the stage acceptance firing will be used in generating actual flight performance predictions.

6.5.3 LH2 Pump

Pump performance was normal throughout the firing. The stall margin as indicated by the characteristic head versus flow curve (figure 6-3) was normal. The pump also performed satisfactorily during mainstage and responded characteristically to PU system cutback. Mainstage pressure, speed, and flow data are presented in figures 6-8 through 6-15.

6.5.4 LOX Pump

LOX pump performance was satisfactory. LOX pump speed, discharge pressure, and temperature responded to PU system cutback, perturbations, and engine inlet conditions. The pressure and temperature rise across the pump were satisfactory. Performance profiles indicative of the pump operation are shown in figure 6-9 .

6.5.5 Turbines

Performance of both LH2 and LOX turbines was satisfactory. Temperatures and pressures for both turbines responded as expected to PU system cutback and perturbations. Pressure and temperature drops across the turbines were nominal. Performance profiles are presented in figure 6-9 .

6.5.6 Gas Generator

The gas generator (GG) performance was adequate. The GG chamber pressure and LH2 turbine inlet temperature indicated nominal values before and after EMR cutback. The performance shift discussed in paragraph 6.3.2 was also apparent in most GG measurements, including GG chamber pressure and fuel and oxidizer injector pressures probably caused by changes in the LOX bootstrap line resistance. Plots of GG performance are shown in figure 6-19.

6.5.7 Engine-Driven Hydraulic Pump

The engine-driven hydraulic pump performed satisfactorily during the acceptance firing. The required horsepower 60 sec after engine start was 4.93.

6.5.8 Engine Vibration

There were five vibration measurements monitored on the engine during the firing (figures 6-20 and 6-21). Three were located on the combustion chamber dome, one at the LOX turbopump, and one at the LH2 turbopump. The vibration amplitudes at these locations were comparable to those measured on past acceptance firings.

TABLE 6-1

THRUST CHAMBER CHILLDOWN DATA

Parameter	S-IVB-507	S-IVB-506N	S-IVB-505N	S-IVB-504N
Thrust chamber chilldown initiated (sec from simulated liftoff)	-407.942	-408.537	-405.356	-405.619
Thrust chamber chilldown terminated (sec from simulated liftoff	488.808	488.474	488.288	519.96
Thrust chamber temperature				
Required at Engine Start Command (deg R)	235 ±75	235 ±75	260 ±50	260 ±50
At Engine Start Command (deg R)	221	237	247	225
At end of chilldown (deg R)	213	228	244	217

TABLE 6-2

ENGINE START SPHERE PERFORMANCE DATA

Parameter	Temperature (°R)			Pressure (psia)			Mass (lbm)		
	S-IVB-507	S-IVB-506N	S-IVB-505N	S-IVB-507	S-IVB-506N	S-IVB-505N	S-IVB-507	S-IVB-506N	S-IVB-505N
Engine start requirement	See start region figure 6-5			See start region figure 6-5					
Engine Start Command							3.50	3.42	3.40
After start sphere blowdown	188	194	196	185	132	138	0.77	0.54	0.56
Engine cutoff	233	247	256	1329	1325	1321	4.22	3.97	3.82
Total GH2 usage during start	---	---	---	---	---	---	2.73	2.88	2.84

TABLE 6-3

ENGINE CONTROL SPHERE PERFORMANCE DATA

Parameter	S-IVB-507	S-IVB-506N	S-IVB-505N	S-IVB-504N
Temperature				
Required at Engine Start Command (deg R)	277 ±30	287 ±20	291 ±20	291 ±20
At Engine Start Command (deg R)	290	298	297	295
At Engine Cutoff Command (deg R)	246	252	262	254
Pressure				
Required at Engine Start Command (psia)	2,800 to 3,450	2,800 to 3,450	2,975 ±475	2,975 ±475
At Engine Start Command (psia)	2,974	2,933*	3,082	3,081
At Engine Cutoff Command (psia)	1,922	1,987*	2,161	2,094
Mass				
At Engine Start Command (lbm)	1.88	1.81	1.89	1.90
After Engine Cutoff Command (lbm)	1.46	1.43	1.54	1.53
Total helium usage (lbm)	0.42	0.38	0.35	0.37

*Pressures are lower than usual because of low GSE regulator setting.

TABLE 6-4
COMPARISON OF COMPUTER PROGRAM RESULTS

PROGRAM	INPUT	METHOD	RESULTS
G105 Mode 3	LOX and LH2 flowmeters, pump discharge pressures and temperatures, chamber pressures, chamber thrust area	Flowrates are computed from flowmeter data and propellant densities. The C_F is determined from equation $C_F = f\ (P_c,\ MR)$ and thrust is calculated from equation $F = C_F\ A_t\ P_c$.	F = 234,487 lbf $\dot{W}_T$ = 548.4 lbm/sec I_{sp} = 427.6 sec MR = 5.52
PA53	Thrust chamber pressure, chamber throat area	The C_F is computed from equation $C_F = f\ (P_c)$ and thrust is computed from equation $F = C_F\ A_t\ P_c$. The impulse is determined from integrated thrust.	Refer to paragraph 6.3.3.
PA63	Pump inlet and outlet conditions, PU valve position, chamber pressure, turbine inlet and outlet conditions, flowmeter speed	Math models of rocket engine components are linked together by program which iterates among the component models until an operating point is reached where the power required by the pumps "balances" the power available from the turbines.	F = 233,863 lbf $\dot{W}_T$ = 549.3 lbm/sec I_{sp} = 425.8 sec MR = 5.543

TABLE 6-5 (Sheet 1 of 2)
DATA INPUTS TO COMPUTER PROGRAMS

PARAMETER	PROGRAM	SELECTION	REASON	BIAS	REASON
Chamber Press	G-105 PA63 PA53	D0524 (H/W)	Very Close Agreement Between (H/W) and (T/M)	-.280	PSIG + 14.72 = PSIA P_c Meas - 15 = P_c act (Rocketdyne Estimation of P_c Purge Effect)
LH_2 Pump Discharge Press	G-105-1	D0008 (T/M)	Closer Agreement with Engine Log Book Data	0	
LH_2 Pump Discharge Temperature	G-105-1	C0134 (T/M)	Close Agreement Between (H/W) and (T/M)	0	
LOX Pump Discharge Pressure	G-105-1	D0009 (T/M)	Close Agreement Between (H/W) and (T/M)	0	
LOX Pump Discharge Temperature	G-105-1	C0133 (T/M)	Least Noisy	0	
LH_2 Flowrate	G-105-1	F0001 (T/M)	Close Agreement Between (H/W) and (T/M)	-104.4 gpm	Agree with actual pip count
LOX Flowrate	G-105-1	F0002 (T/M)	Least Noisy	-33.6 gpm	Agree with actual pip count
LH_2 Pump Inlet Pressure	PA63	D0002 (T/M)	Least Noisy	+1.375 psi	Change Static Press to Total Press
LH_2 Pump Inlet Temperature	PA63	C0003 (T/M)	Very Close Agreement Between (H/W) and (T/M)	0	

TABLE 6-5 (Sheet 2 of 2)
DATA INPUTS TO COMPUTER PROGRAMS

PARAMETER	PROGRAM	SELECTION	REASON	BIAS	REASON
LOX Pump Inlet Pressure	PA63	D0537 (H/W)	Least Noisy	17.345	PSIG + 14.72 = PSIA + 1.375 psi (1.375 psi is to change static pressure to total pressure)
LOX Pump Inlet Temperature	PA63	C0004 (T/M)	Very Close Agreement Between (H/W) and (T/M)	0	
PU Valve Position	PA63	G0010 (T/M)	Very Close Agreement Between (H/W) and (T/M)	0	

TABLE 6-6
ENGINE PERFORMANCE

PARAMETER	CLOSED PU VALVE OPERATION			REFERENCE MIXTURE RATIO OPERATION			OVERALL PERFORMANCE 90% TO ECC		
	ACTUAL	PREDICTED	% DEV	ACTUAL	PREDICTED	% DEV	ACTUAL	PREDICTED	% DEV
Thrust (lbf)	233,356	232,809	-0.2	211,976	206,563	-2.6	222,813	219,316	-1.6
Total Flowrate (lbm/sec)	546.82	548.32	0.3	495.78	483.34	-2.6	521.54	514.91	-1.3
LOX Flowrate (lbm/sec)	462.44	464.48	0.4	413.27	402.44	-2.7	438.01	432.53	-1.3
LH2 Flowrate (lbm/sec)	84.38	83.85	-0.6	82.51	80.90	-2.0	83.53	82.38	-1.4
Engine Mixture Ratio	5.48	5.54	1.1	5.01	4.97	-0.7	5.24	5.25	0.1
Special Impulse	426.75	424.58	-0.5	427.56	427.37	-0.0	427.21	426.03	-0.3

TABLE 6-7
ENGINE THRUST VARIATIONS

PARAMETER \ TIME PERIOD	LIMITS	HARDOVER OPERATION	TRANSIENT FROM PU VALVE (CUTBACK +75 SEC TO ECC -70 SEC)	FINAL 70 SEC OF S-IVB BURN
Variation in mean thrust level (lbf) or thrust band centerline variation at ECC -75 sec (lbf)	Allowable	±4,000	±8,000	+6,000, -5,000
	Actual	+172	-5,282	-5,635
	Predicted	--	--	--
Oscillations about mean thrust level (lbf) or thrust variation band (lbf)	Allowable	±2,500	±7,500	±3,000
	Actual	±1,325	±2,225	±1,613
	Predicted	±516	±1,660	±760
Rate of change of thrust (lbf/sec)	Allowable	±500	±500	+435, -385
	Actual	-355	+138.2	+211.8
	Predicted	+365	+75.6	+104.5
Thrust acceleration (lbf/sec/sec)	Allowable	±125	±500	±500
	Actual	±74	±7.3	±16.5
	Predicted	--	--	--
Thrust band slope (lbf/sec)	Allowable	--	--	+100, -85
	Actual	--	--	+6.73
	Predicted	--	--	-6.57
Variation of thrust band scope about nomiani (lbf/sec)	Allowable	--	--	+35, -50
	Actual	--	--	-13.3
	Predicted	--	--	--

TABLE 6-8 (Sheet 1 of 6)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
K0021 (K0021)	*Engine Start Command P/U			0	511.758 0	
		K0007 (K0531)	Helium Control Solenoid Enrg P/U	Within 10 ms of K0021	0	0
		K0010 (K0454)	Thrust Chamber Spark on P/U	Within 10 ms of K0021	1	1
		K0011 (K0455)	Gas Generator Spark on P/U	Within 10 ms of K0021	1	1
		K0006 (K0535)	Ignition Phase Control Solenoid Enrg P/U	Within 20 ms of K0021	1	1
		K0012 (K0530)	Engine Ready D/O	Within 20 ms of K0006	5	4
		K0126 (K0558)	LOX Bleed Valve Closed P/U	Within 130 ms of K0007	71	71
		K0127 (K0557)	LH2 Bleed Valve Closed P/U	Within 130 ms of K0007	55	55
		K0020 (K0627)	ASI LOX Valve Open P/U	Within 20 ms of K0006	40	39

(KOXXX) Actual number from acceptance firing event recorder.

*Engine ready and stage separation signals (or simulation) are required before this command will be executed. This command also actuates a 640 ±30 ms timer which controls energizing of the start tank discharge solenoid valve (K0096).

P/U - Pickup D/O - Dropout

TABLE 6-8 (Sheet 2 of 6)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
		K0119 (G506)	Main Fuel Valve Closed D/O	60 ±30 ms from K0006	40	39
		K0118 (G506)	Main Fuel Valve Open P/U	80 ±50 ms from K0119 D/O	132	92
K0008 (K0537)	Ignition Detected*			Within 250 ms of K0021 P/U	142	142
K0021 (K0021)	Engine Start** D/O			Approx 200 ms from K0021 P/U	359	359
K0096 (K0536)	Start Tank Disc Control Solenoid Enrg†			1,120 ±20 ms from K0021 P/U††	125	1,125
		K0123 (G508)	Start Tank Disc Valve Closed D/O	100 ±20 ms from K0096	1,272	147
		K0122 (G508)	Start Tank Disc Valve Open P/U	105 ±20 ms from K0123	1,354	82
K0005 (K0538)	Mainstage Control Solenoid Enrg			450 ±30 ms from K0096	1,575	450

*This signal must be received within 1,110 ±60 ms of K0021 P/U or cutoff will be initiated.

**This signal drops out after a time sufficient to lock in the engine electrical.

†An indication of fuel injection temperature of -150 ±40 deg F (or simulation) is required before this command will be executed. This command also actuates a 450 ±30 ms timer which controls the start of mainstage.

††Based on GSE signal sent after engine timer runs out.

P/U - Pickup D/O - Dropout

TABLE 6-8 (Sheet 3 of 6)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
		K0096 (K0536)	Start Tank Disc Control Solenoid Enrg D/O	450 ±30 ms from K0096	1,580	455
		K0121 (G507)	Main LOX Valve Closed D/O	50 ±20 ms from K0005	1,618	43
		K0116 (G509)	Gas Generator Valve Closed D/O	140 ±10 ms from K0005	1,679	104
		K0122 (G508)	Start Tank Disc Valve Open D/O	95 ±20 ms from K0096 D/O	1,696	116
		K0117 (G509)	Gas Generator Valve Open P/U	50 ±30 ms from K0116	1,797	118
		K0124 (G510)	LOX Turbine Bypass Valve Open D/O		1,788	
			LOX Turbine Bypass Valve 80% Closed	400 $^{+150}_{-50}$ ms from K0122	2,122	426
		K0123 (G508)	Start Tank Disc Valve Closed P/U	250 ±40 ms from K0122	1,955	259
		K0125 (G510)	LOX Turbine Bypass Valve Closed P/U*		2,075	
K0158 (K0572)	Mainstage Press Switch #1 Depress D/O				3,045	
K0159	Mainstage Press Switch #2 Depress D/O				3,041	

*Within 5,000 ms of K0005 (normally = 500 ms)

P/U - Pickup   D/O - Dropout

TABLE 6-8 (Sheet 4 of 6)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
K0191 (K0610)	Mainstage OK*				3,040	
		K0120 (G507)	Main LOX Valve Open P/U	2,435 $\pm$145 ms from K0005	4,050	2,475
		K0010 (K0454)	Thrust Chamber Spark On D/O	3,300 $\pm$200 ms from K0005 P/U	4,875	3,300
		K0011 (K0455)	Gas Generator Spark On D/O	3,300 $\pm$200 ms from K0005 P/U	4,875	3,300
K0507 CSS-22	PU Activate Switch P/U				6,132	

*One of these signals must be received within 4,410 $\pm$260 ms from K0021 P/U, or cutoff will be initiated. Signal occurs when LOX injection pressure is 500 $\pm$30 psig.

P/U - Pickup D/O - Dropout

TABLE 6-8 (Sheet 5 of 6)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
K0013 (K0522)	Engine Cutoff PU (New time reference)			0	0	
		K0005 (K0538)	Mainstage Control Solenoid Enrg D/O	Within 10 ms of K0013	3	3
		K0006 (K0535)	Ignition Phase Control Solenoid Enrg D/O	Within 10 ms of K0013	3	3
		K0020 (0627)	ASI LOX Valve Open D/O		22	
		K0120 (G507)	Main Oxidizer Valve Open D/O	50 $\pm$15 ms from K0005	70	67
		K0117 (G509)	Gas Generator Valve Open D/O	75 $^{+25}_{-35}$ ms from K0006	33	30
		K0118 (G506)	Main Fuel Valve Open D/O	90 $\pm$25 ms from K0006	100	97
		K0121 (G507)	Main Oxidizer Closed P/U	120 $\pm$15 ms from K0120	238	168
		K0116 (G509)	Gas Generator Valve Closed P/U	500 ms from K0006	208	205
		K0119 (G506)	Main Fuel Valve Closed P/U	225 $\pm$25 ms from K0118	400	300

P/U - Pickup D/O - Dropout

TABLE 6-8 (Sheet 6 of 6)
ENGINE SEQUENCE

CONTROL EVENTS		CONTINGENT EVENTS		NOMINAL TIME FROM SPECIFIED REFERENCE	ACTUAL TIME (ms)	
MEAS NO.	EVENT AND COMMENT	MEAS NO.	EVENT AND COMMENT		FROM ESC	FROM SPECIFIED REFERENCE
K0158 (K0572)	Mainstage Press Switch A Depress P/U*				191	
K0159 (K0573)	Mainstage Press Switch B Depress P/U			*	187	
K0191 (K0610)	Mainstage OK D/O			*	193	
K0007 (K0531)	Helium Control Solenoid Enrg D/O			1,000 ±110 ms from K0013	994	994
SS-22 K0507	PU Activate Switch D/O			N/A	21,937	
		K0125 (G510)	Oxidizer Turbine Bypass Valve Closed D/O		240	
		K0124 (G510)	Oxidizer Turbine Bypass Valve Open P/U	10,000 ms from K0005	825	822
K0126 (K0558)	LOX Bleed Valve Closed D/O			30,000 ms from K0005	7,778	7,775
K0127 (K0557)	LH2 Bleed Valve Closed D/O			30,000 ms from K0005	6,935	6,932

*Signal drops out when pressure reaches 425 ±25 psig.

P/U - Pickup D/O - Dropout

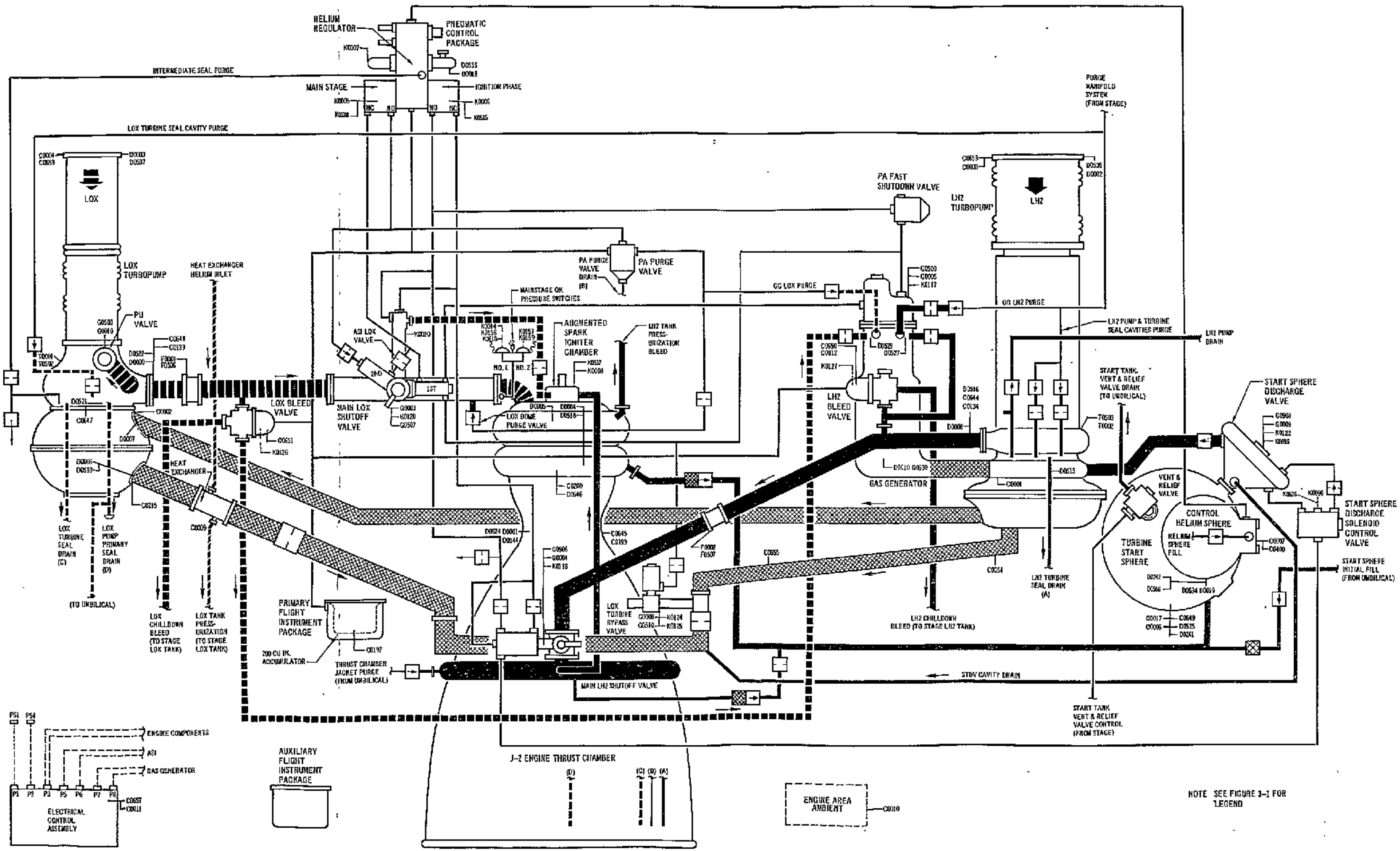


Figure 6-1. J-2 Engine System and Instrumentation

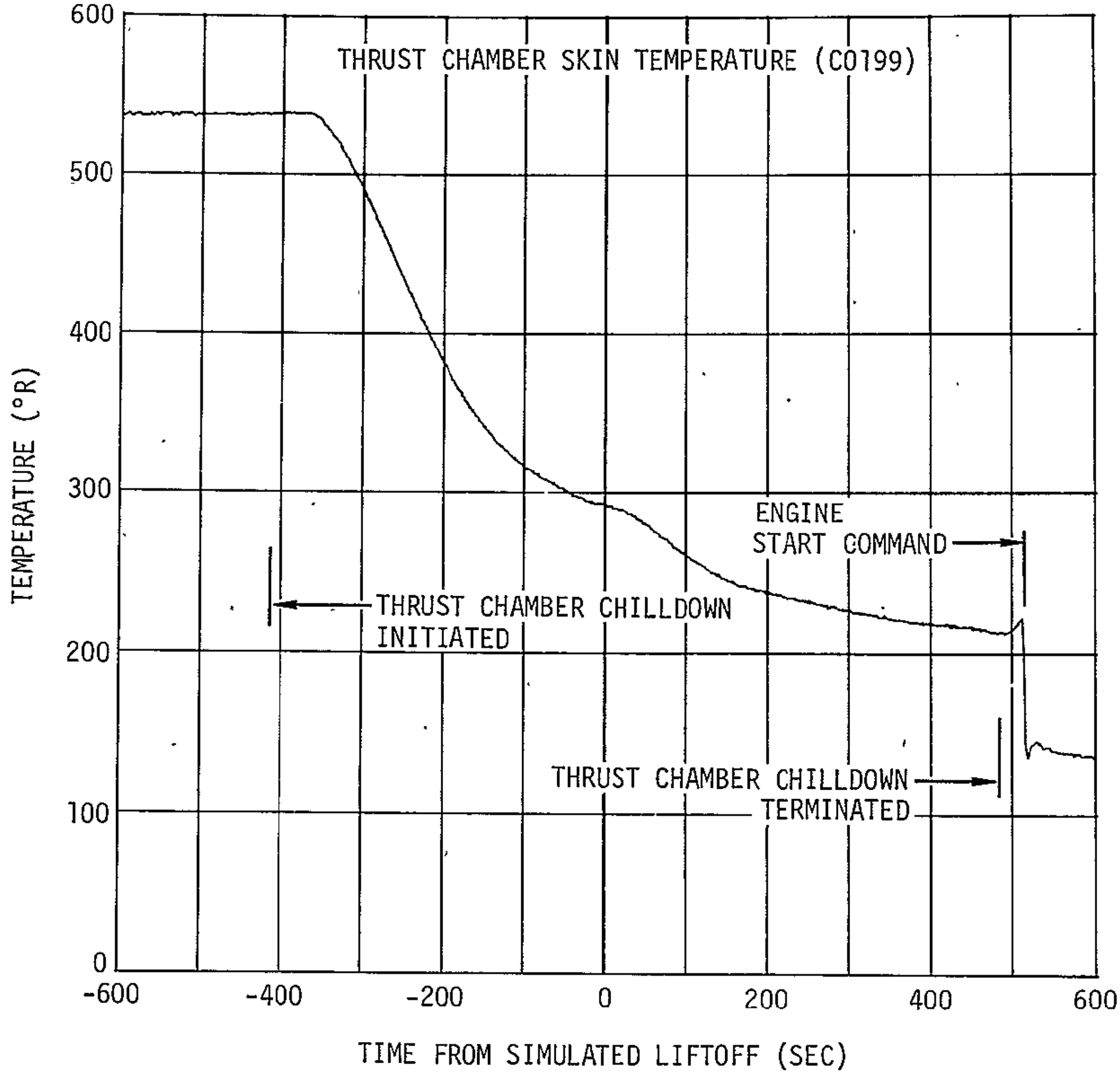


Figure 6-2. Thrust Chamber Chilldown

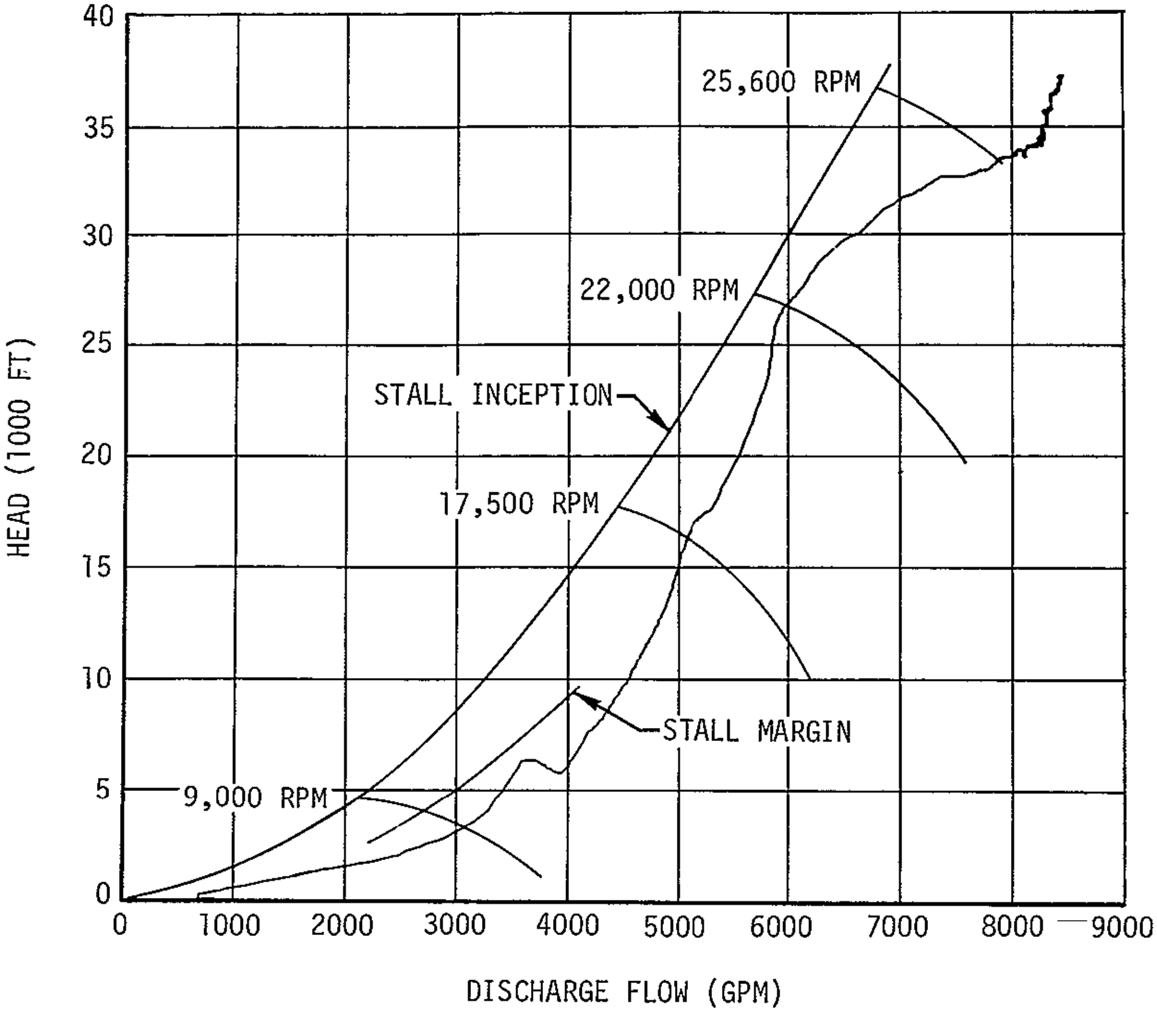


Figure 6-3. LH2 Pump Performance During Engine Start

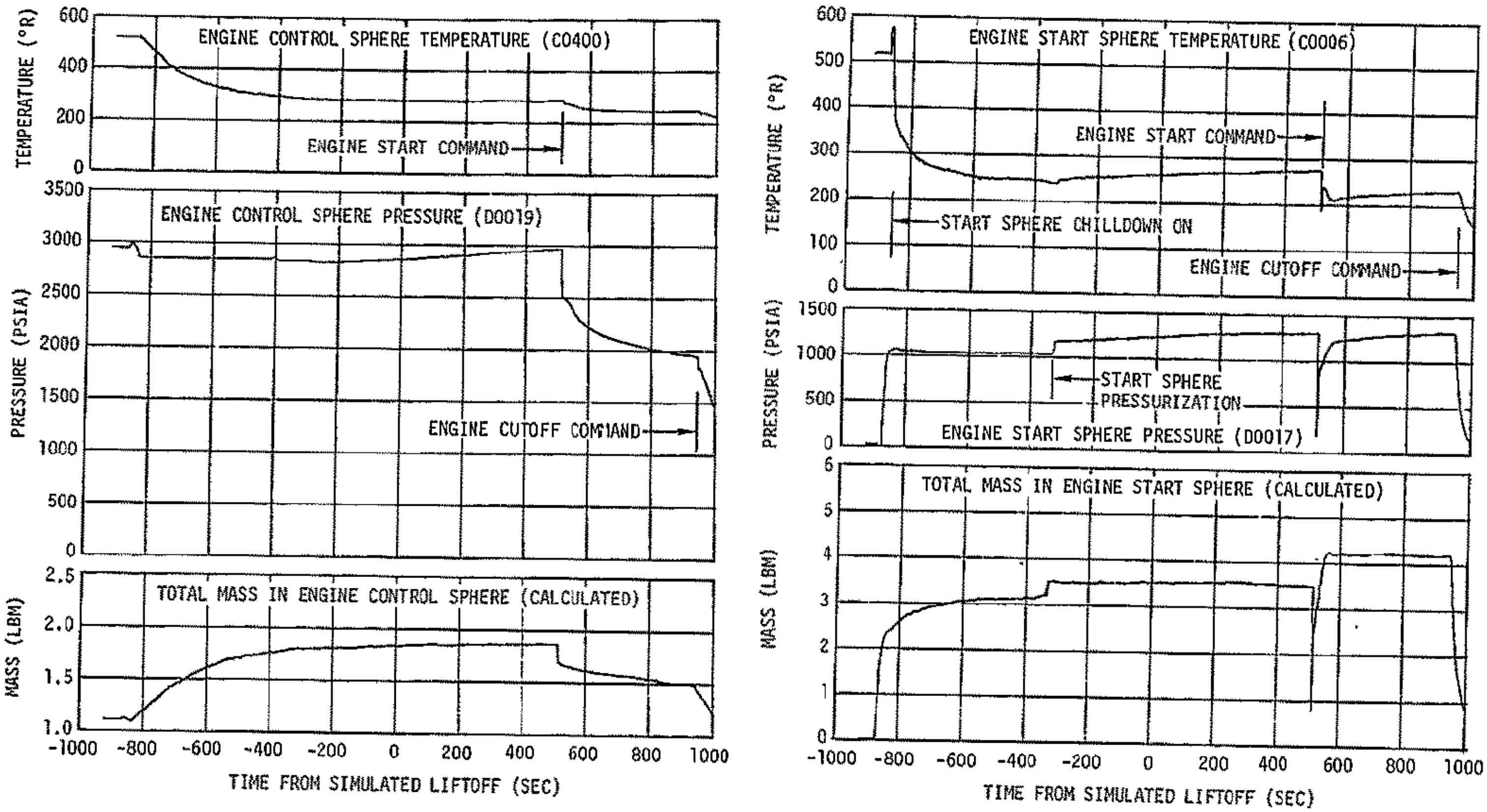


Figure 6-4. Engine Start and Control Sphere Performance

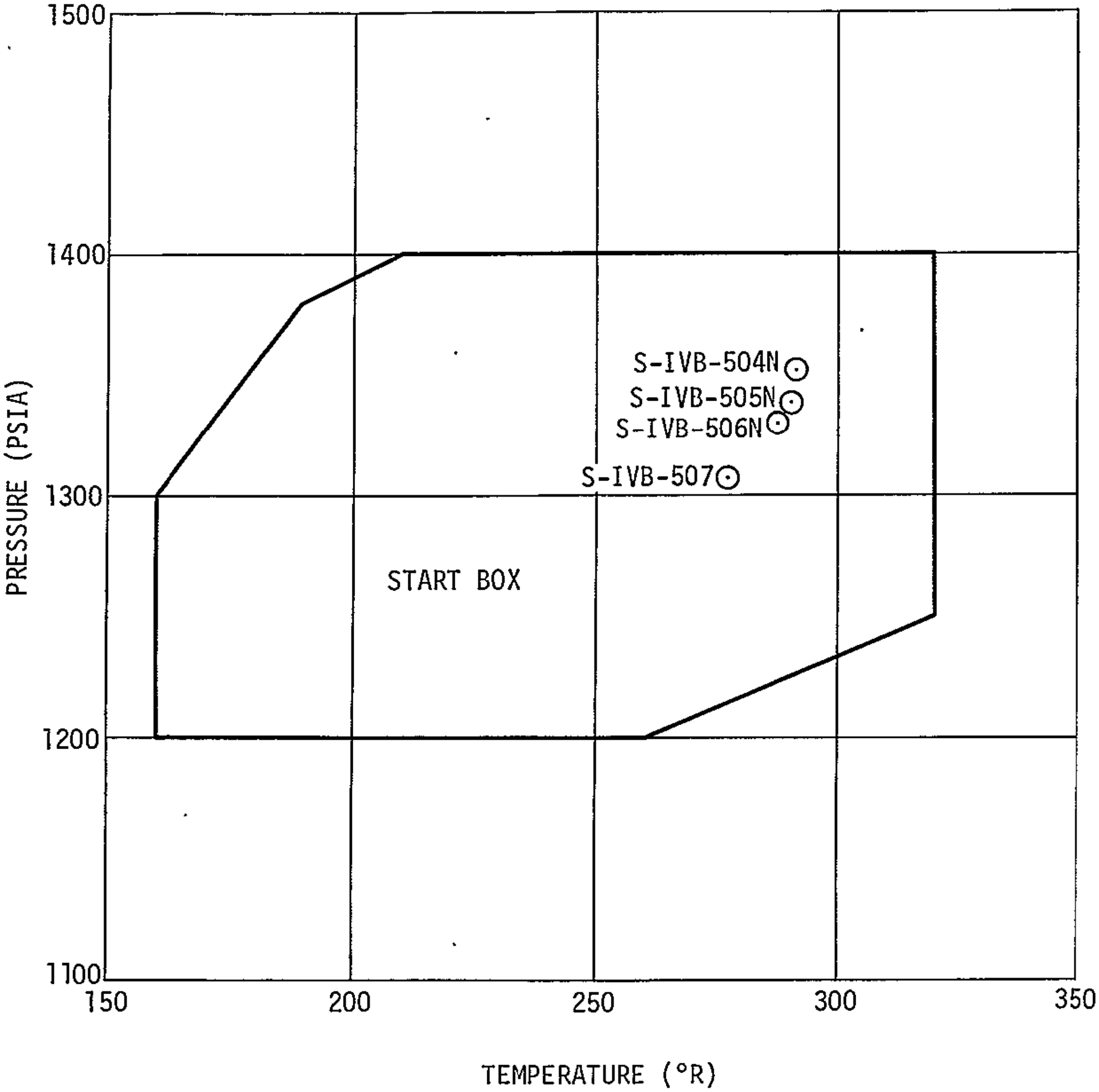


Figure 6-5. Engine Start Sphere Performance

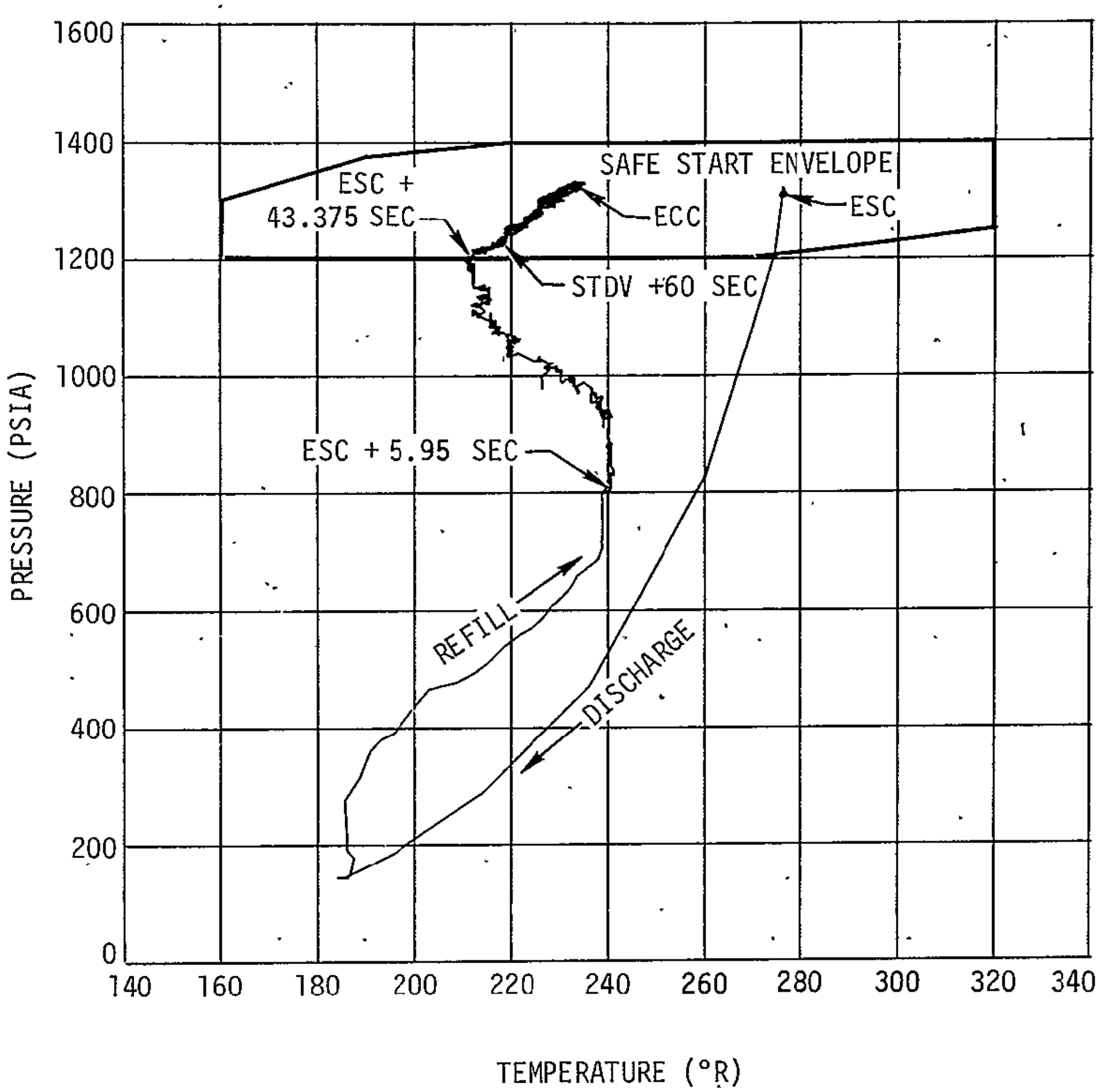
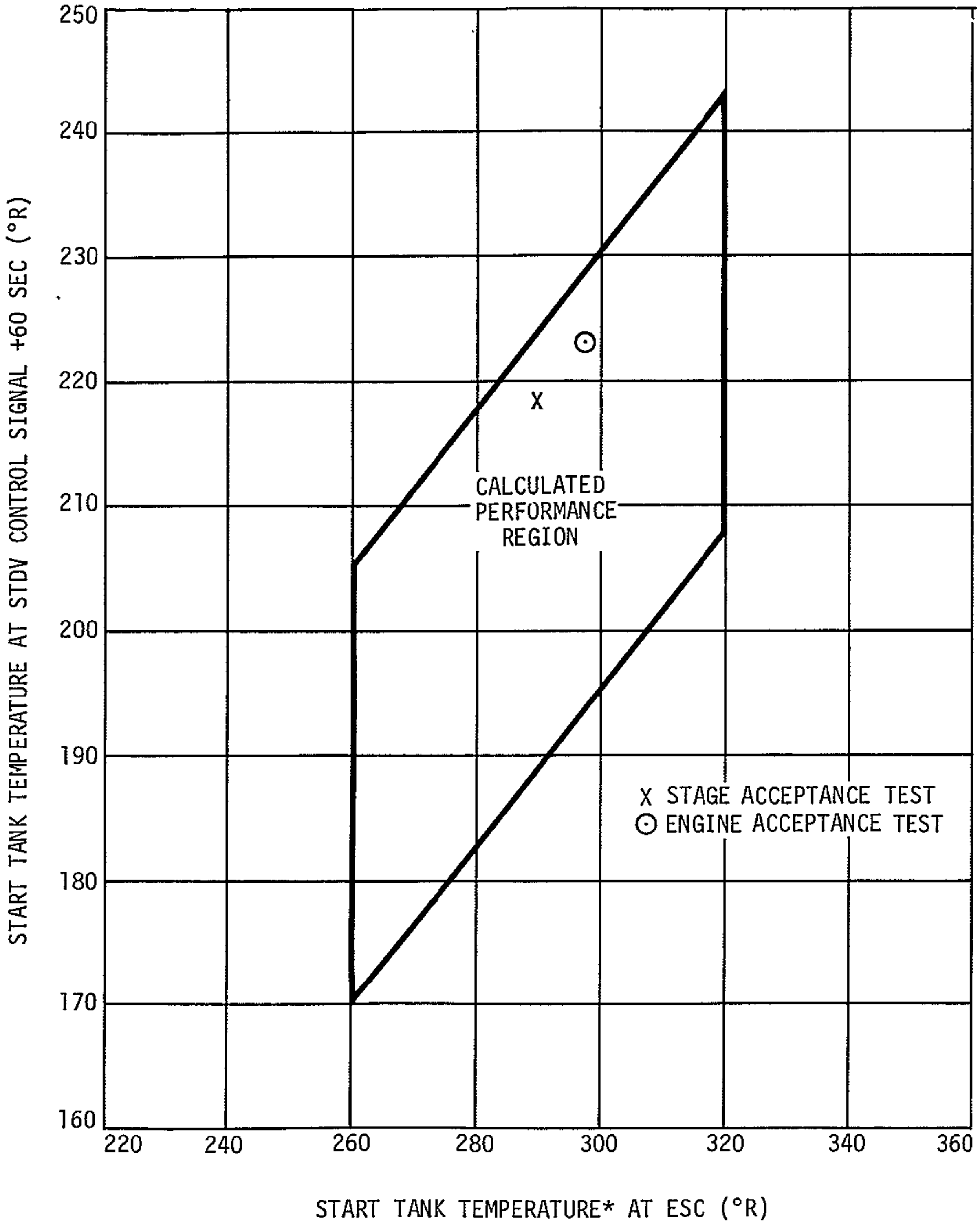


Figure 6-6. Start Tank Refill Performance



*CORRECTED TO ZERO DIFFERENTIAL WITH RESPECT TO HELIUM TANK TEMPERATURE

Figure 6-7. S-IVB-507 Restart Capability

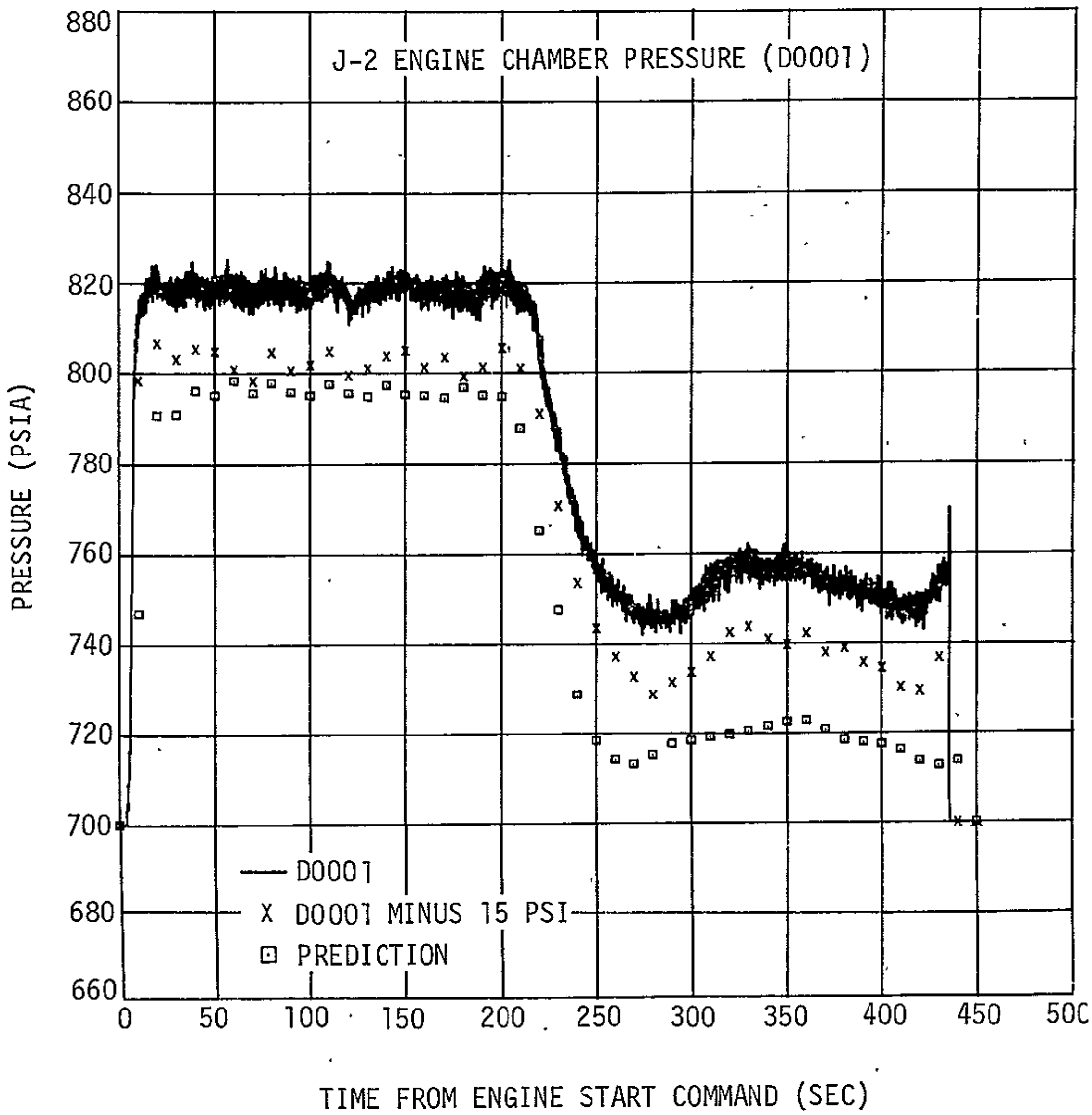


Figure 6-8. J-2 Engine Chamber Pressure

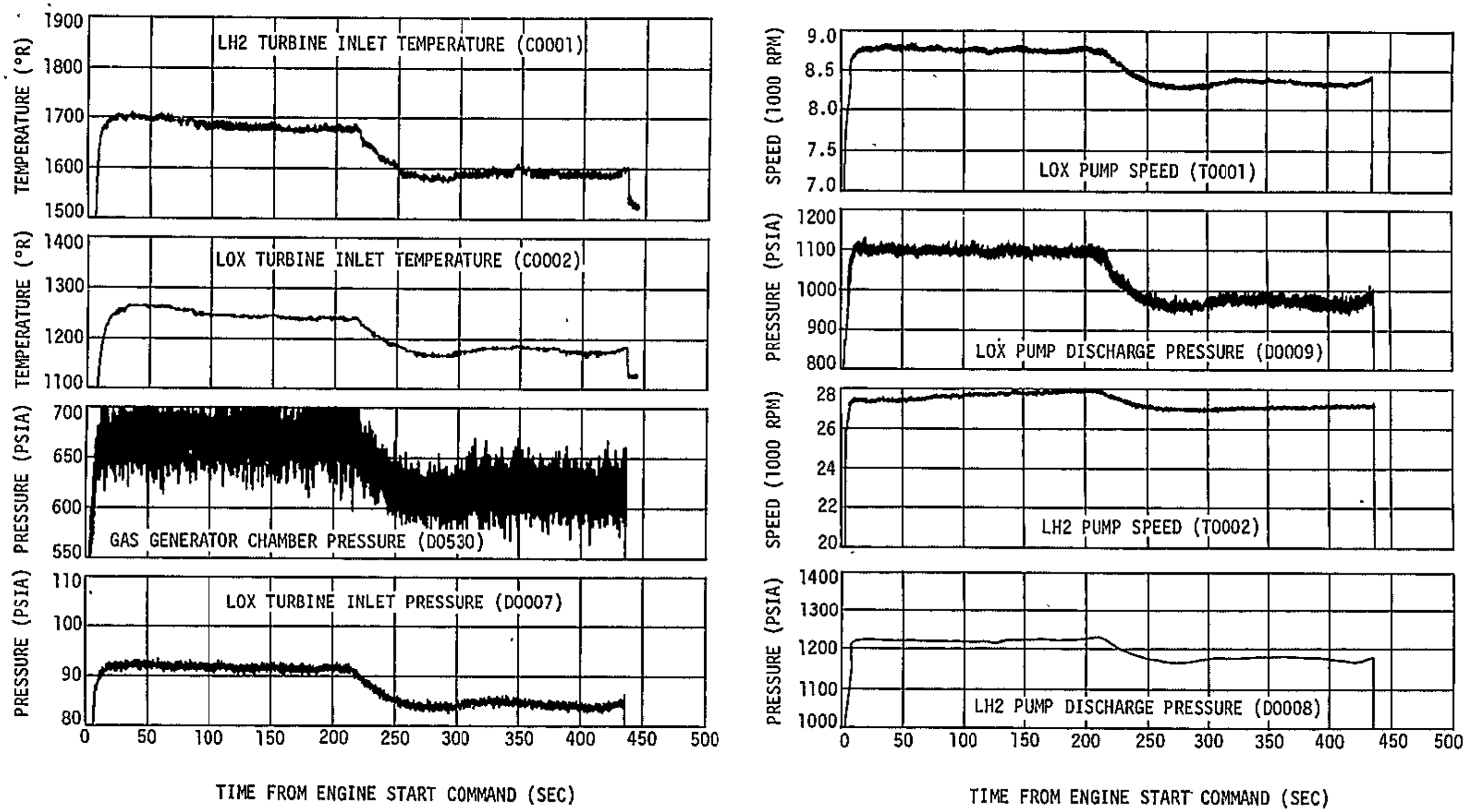


Figure 6-9. Turbopump Operating Characteristics

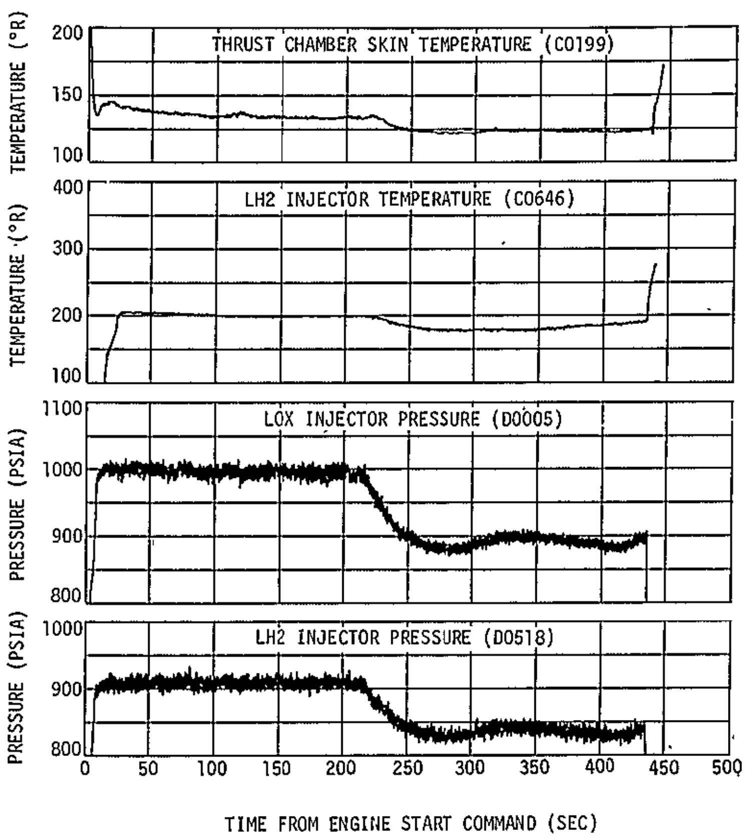


Figure 6-10. J-2 Engine Injector Supply Conditions

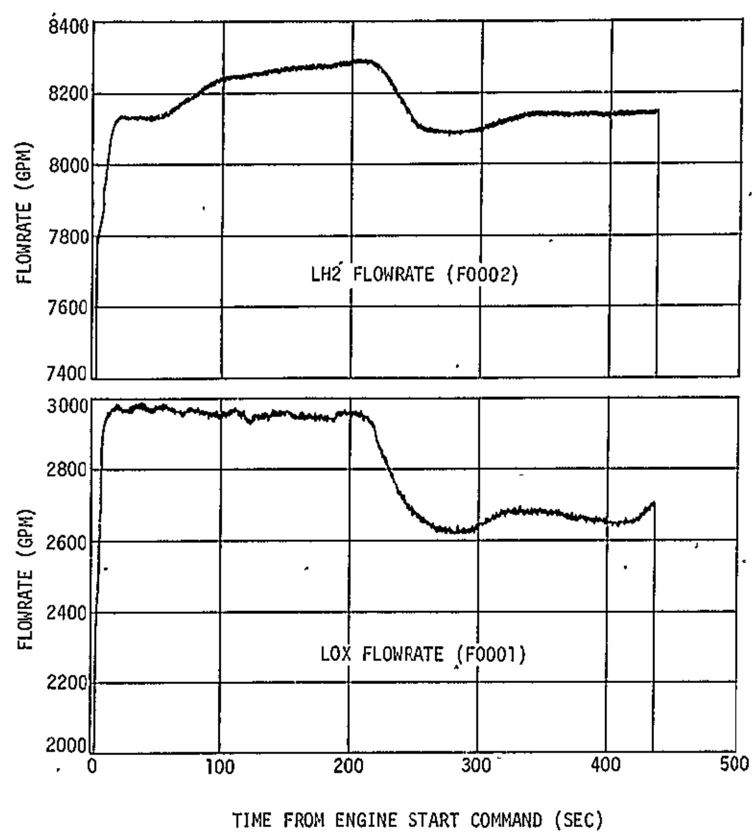


Figure 6-11. LOX and LH2 Flowrate

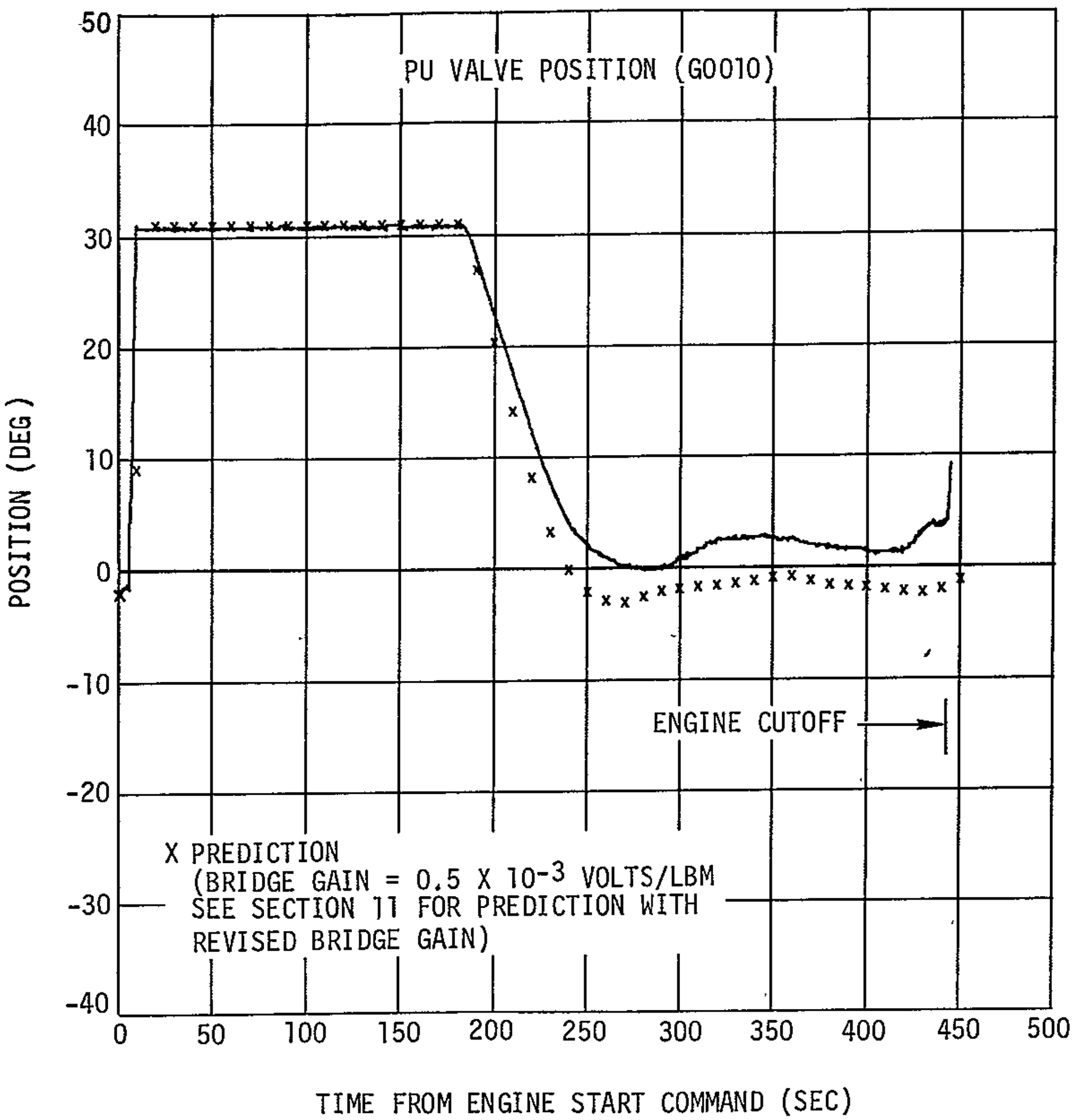


Figure 6-12. PU Valve Position

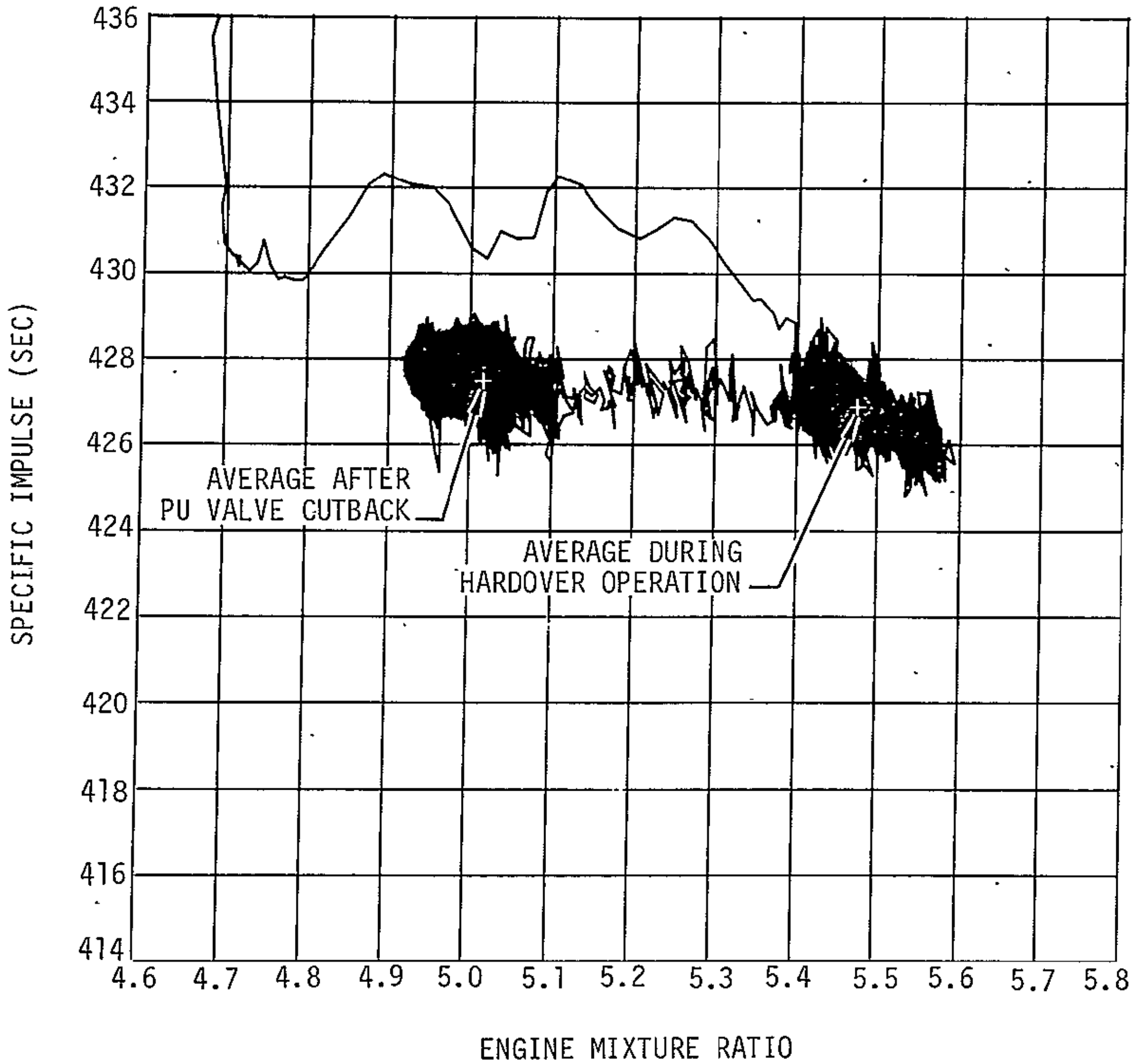


Figure 6-13. Engine Mixture Ratio vs Specific Impulse

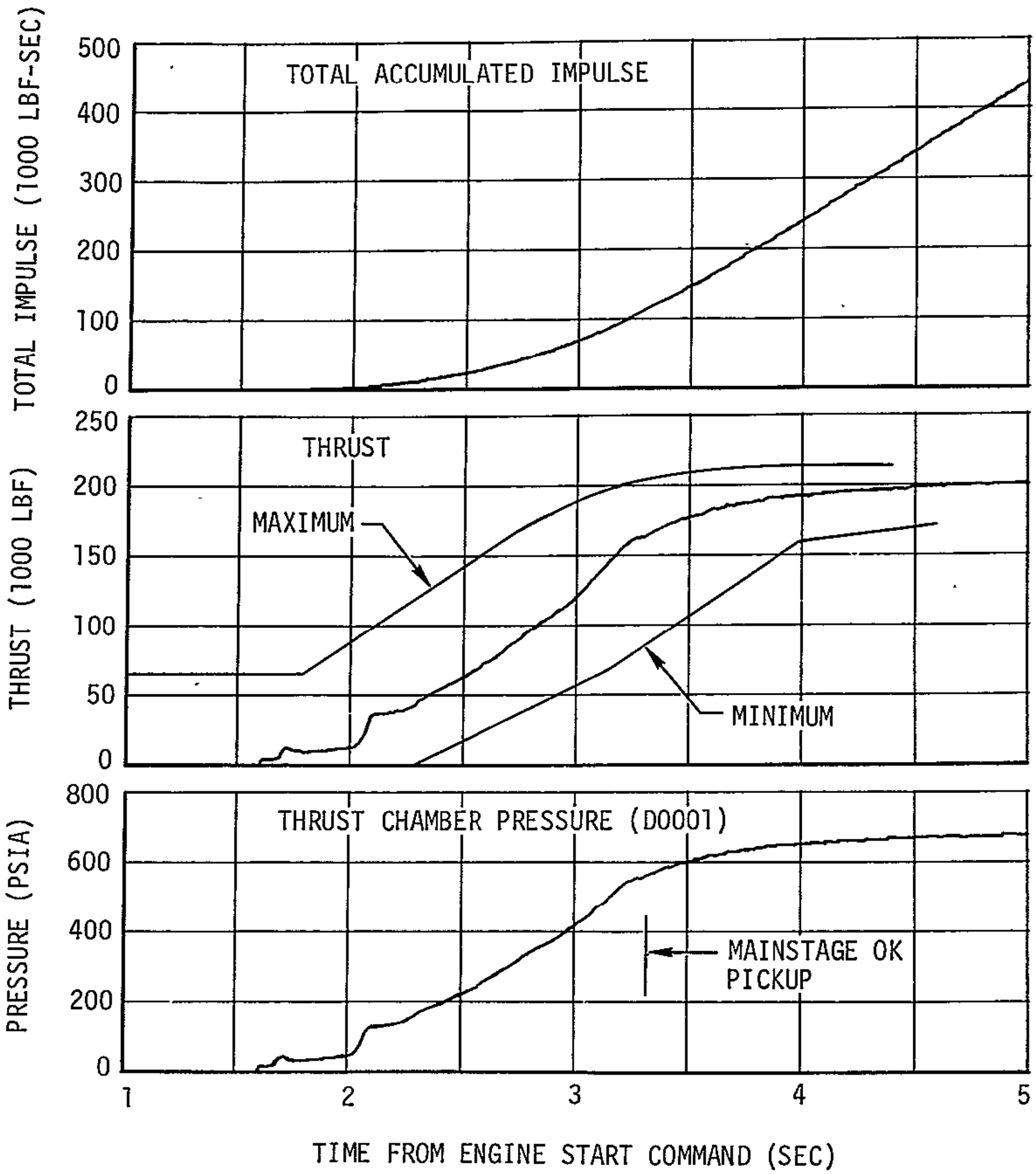


Figure 6-14. Engine Start Transient Characteristics

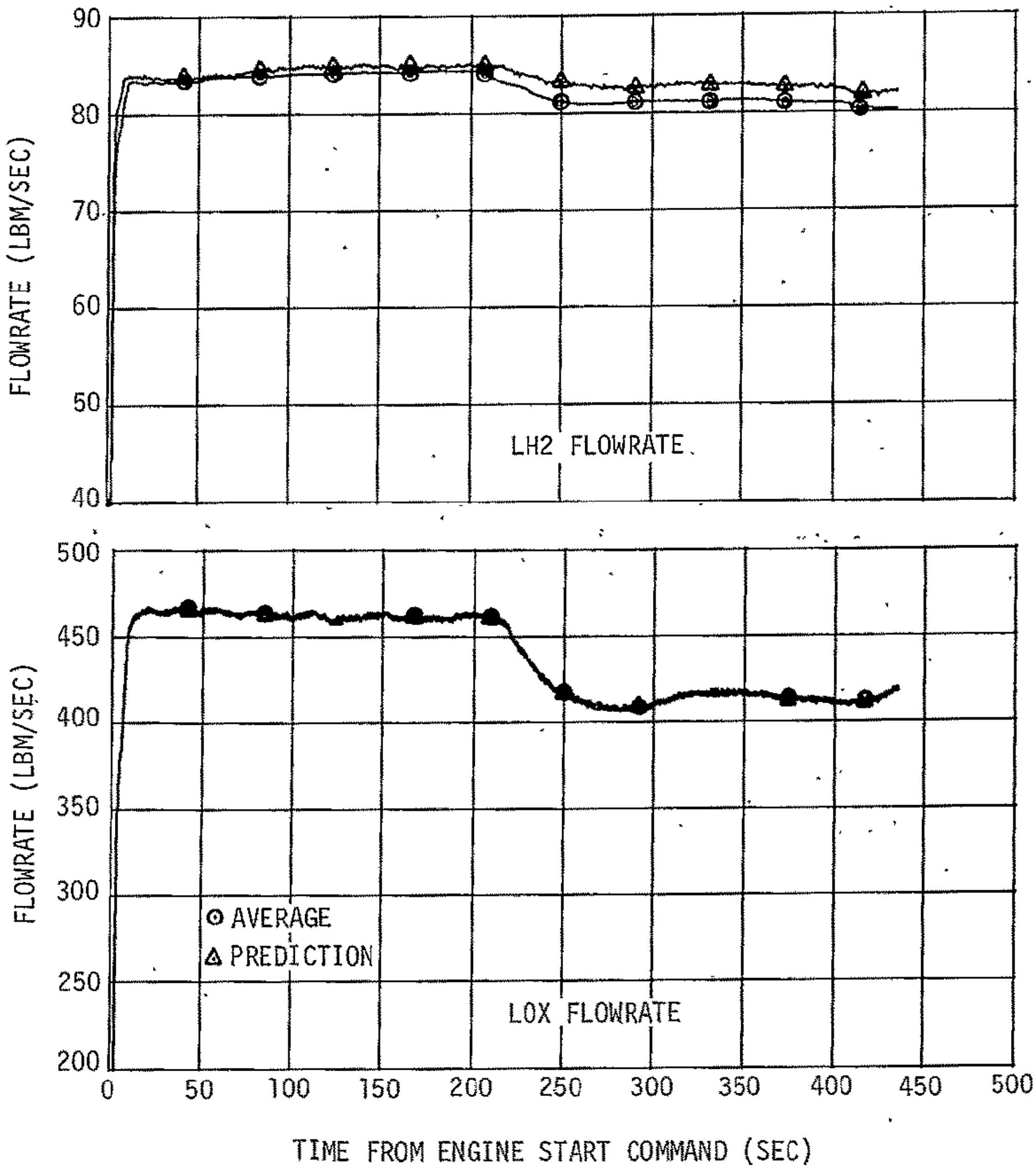


Figure 6-15. Engine Steady State Performance (Sheet 1 of 3)

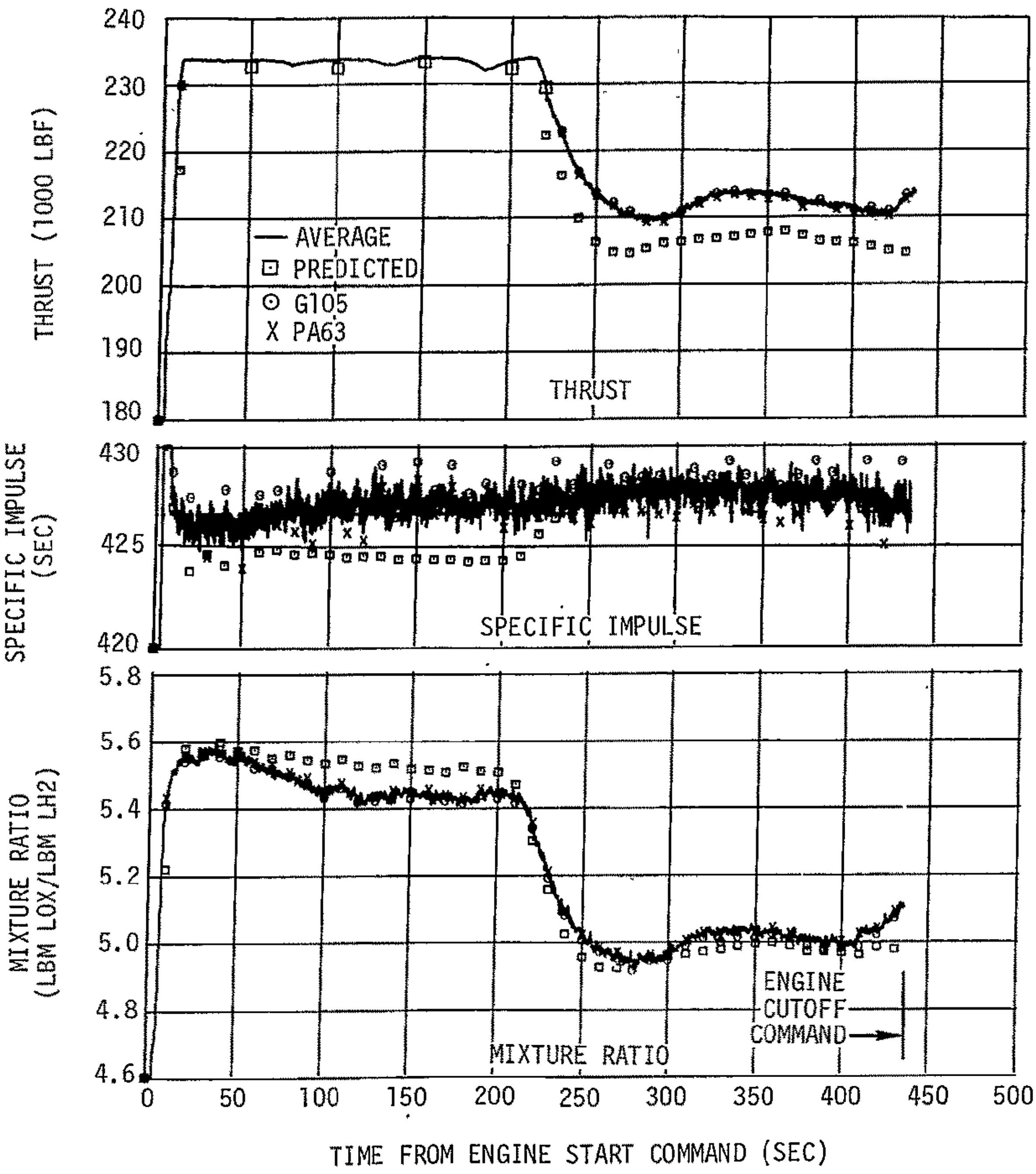


Figure 6-15. Engine Steady State Performance (Sheet 2 of 3)

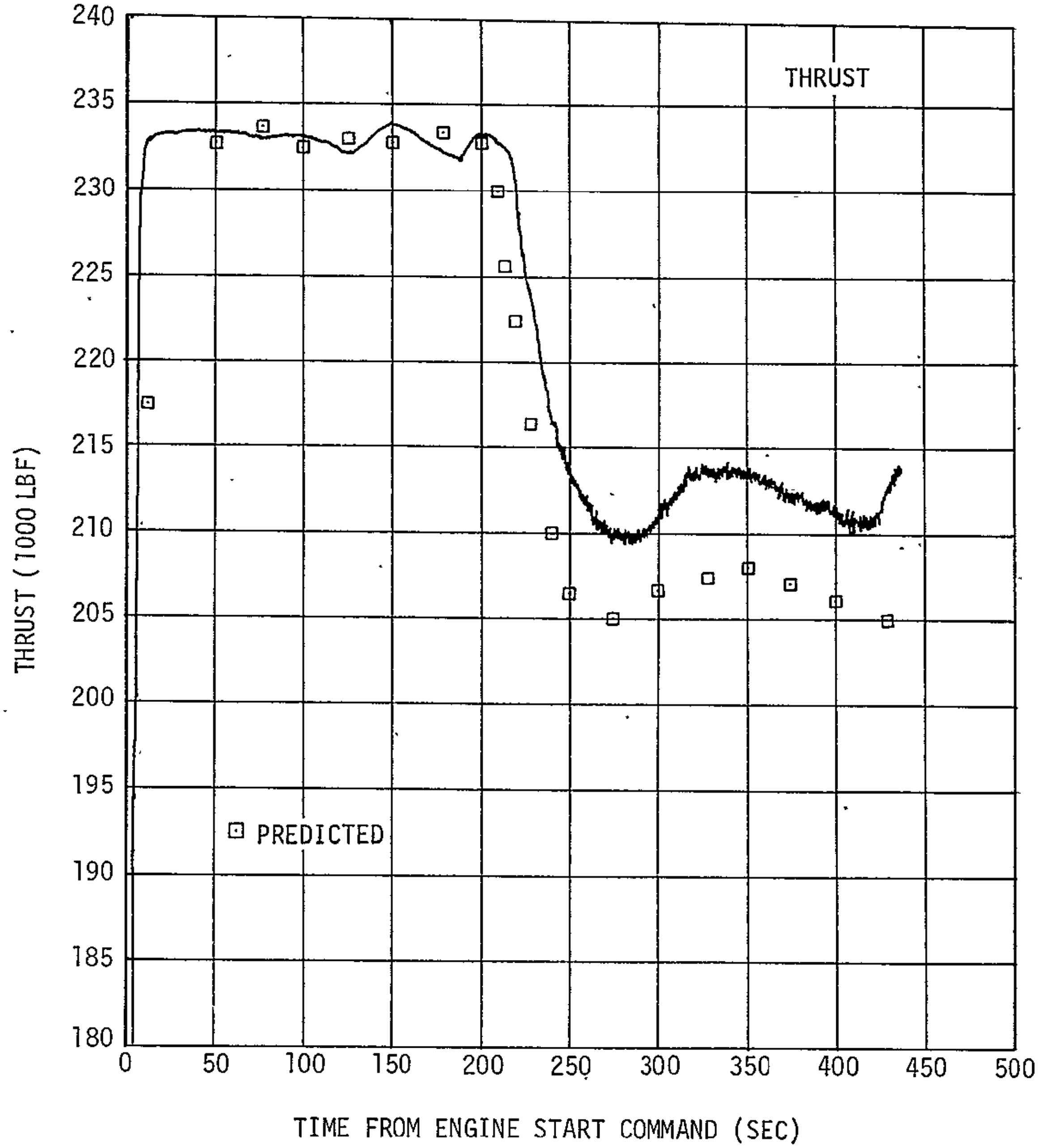


Figure 6-15. Engine Steady State Performance (Sheet 3 of 3)

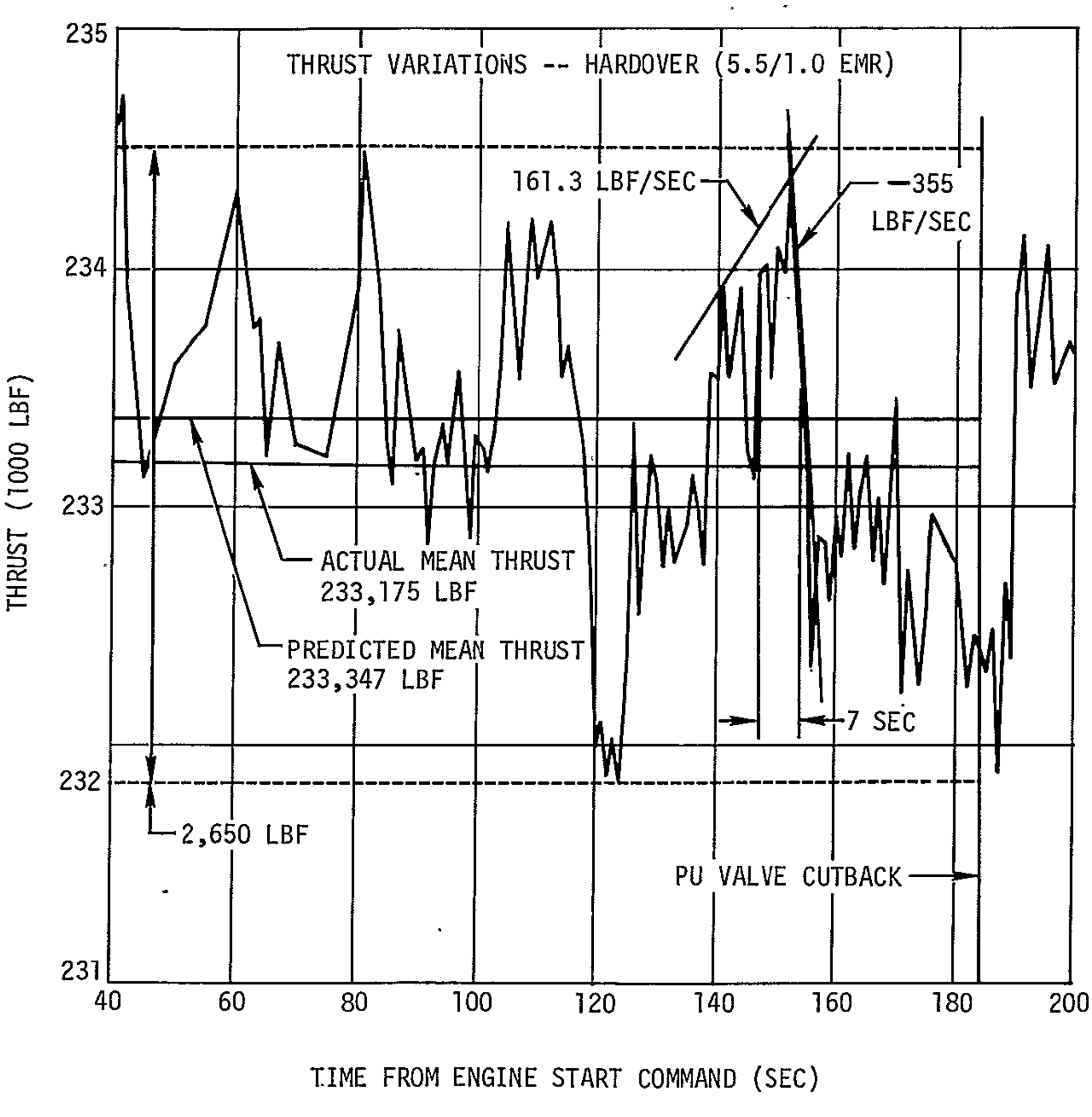


Figure 6-16. Thrust Variation (Sheet 1 of 3)

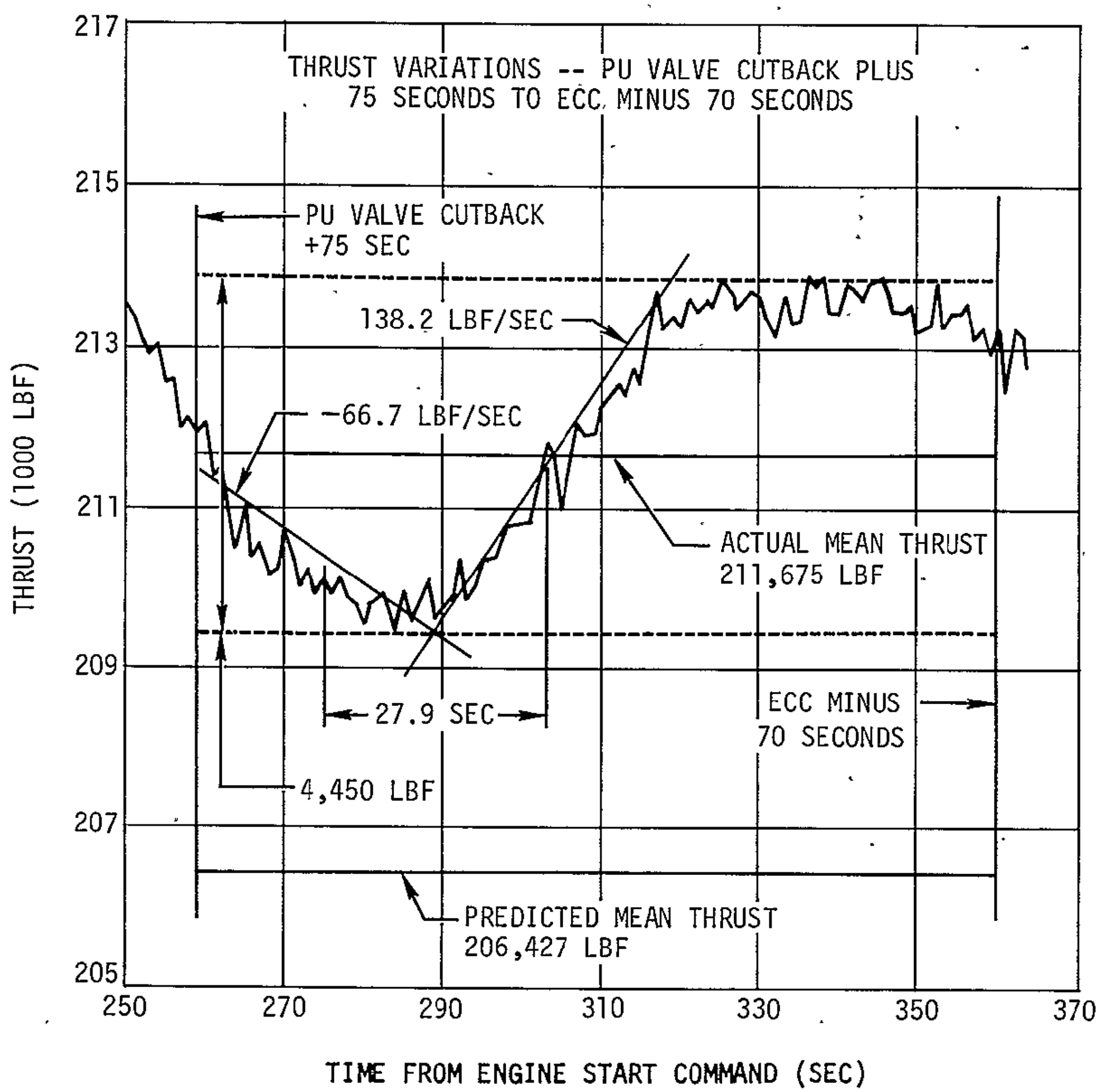


Figure 6-16. Thrust Variation (Sheet 2 of 3)

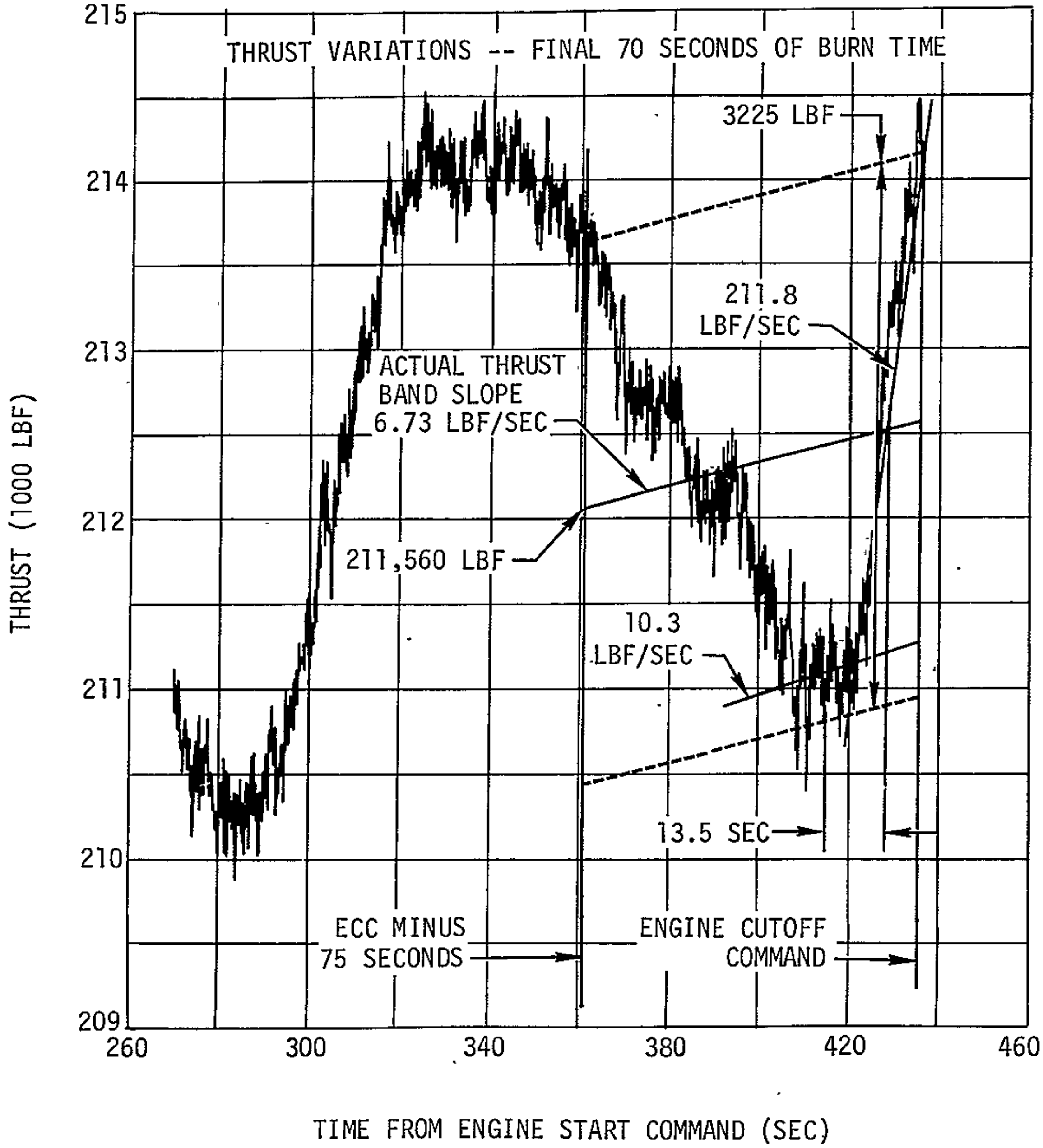


Figure 6-16. Thrust Variation (Sheet 3 of 3)

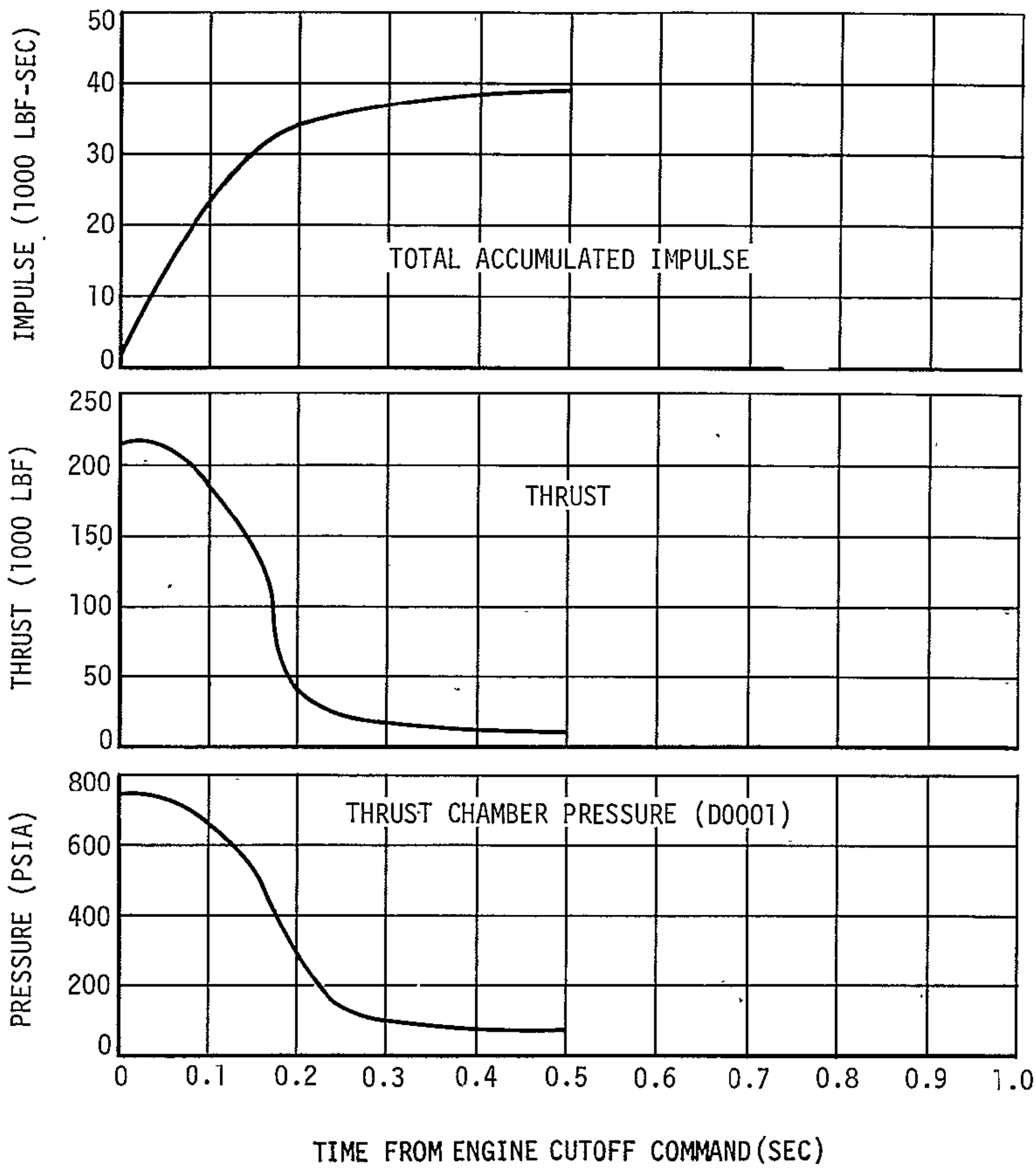


FIGURE 6-17 ENGINE CUTOFF TRANSIENT CHARACTERISTICS

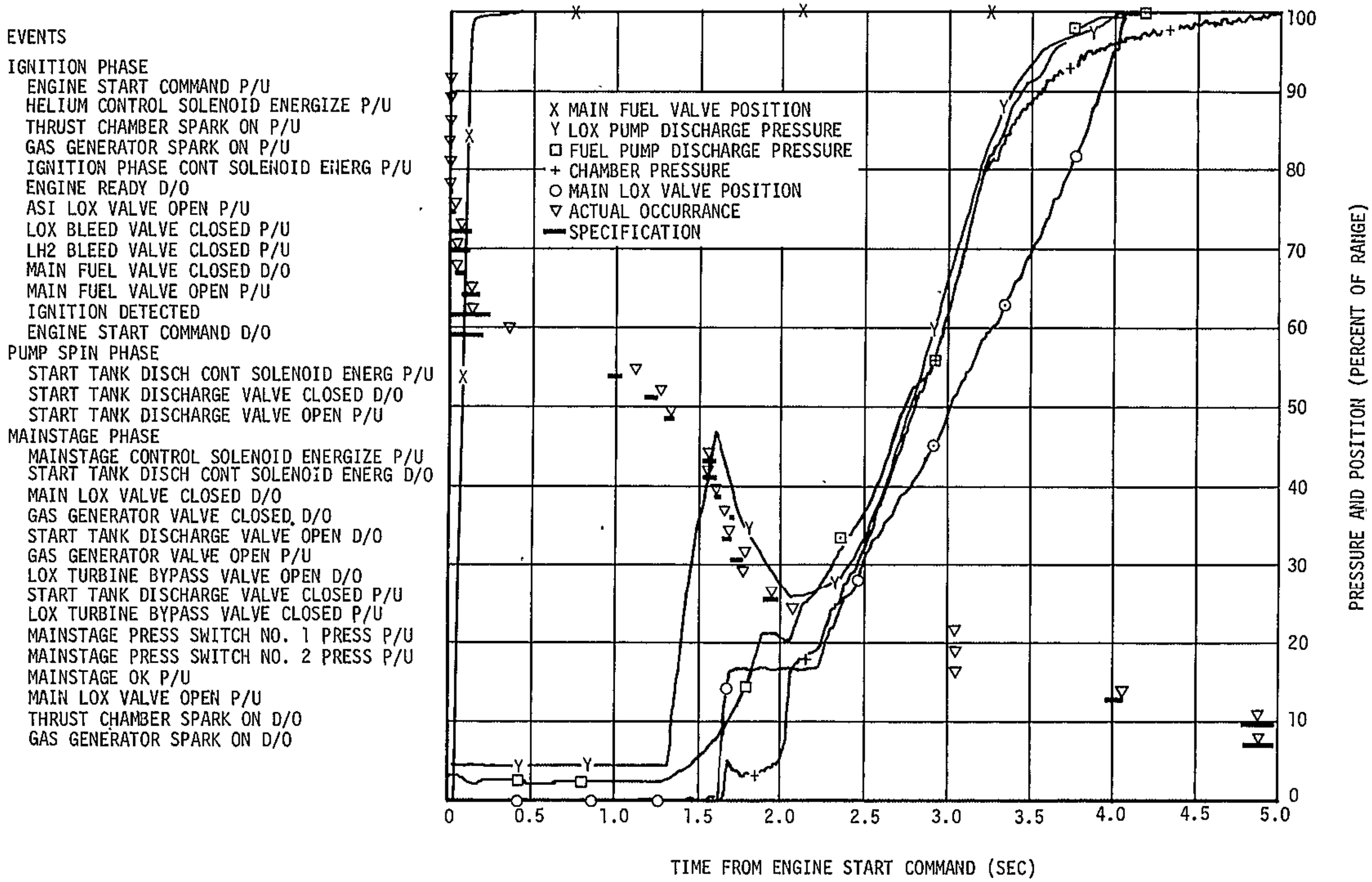


Figure 6-18. Engine Start Sequence

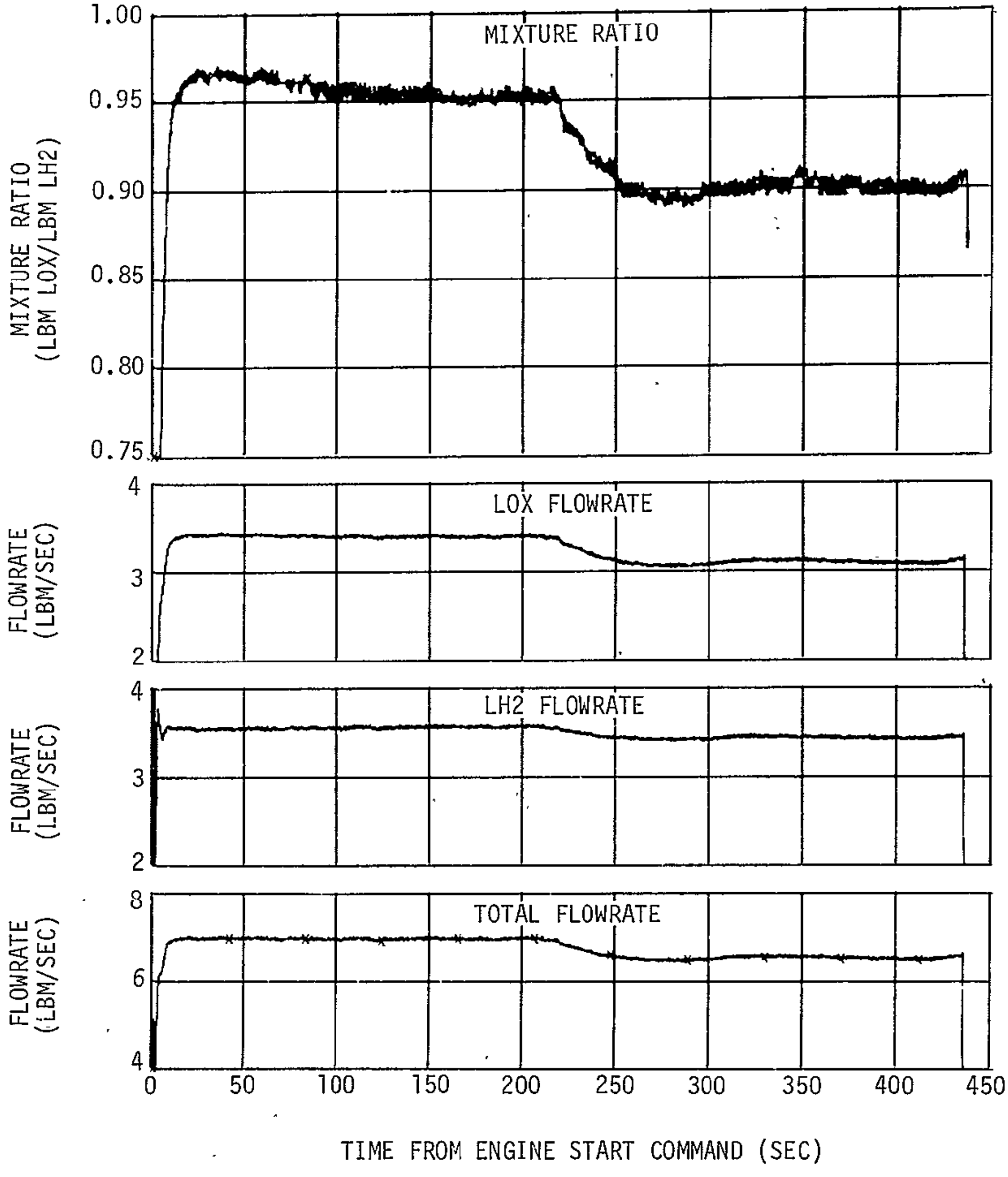


Figure 6-19. Gas Generator Performance

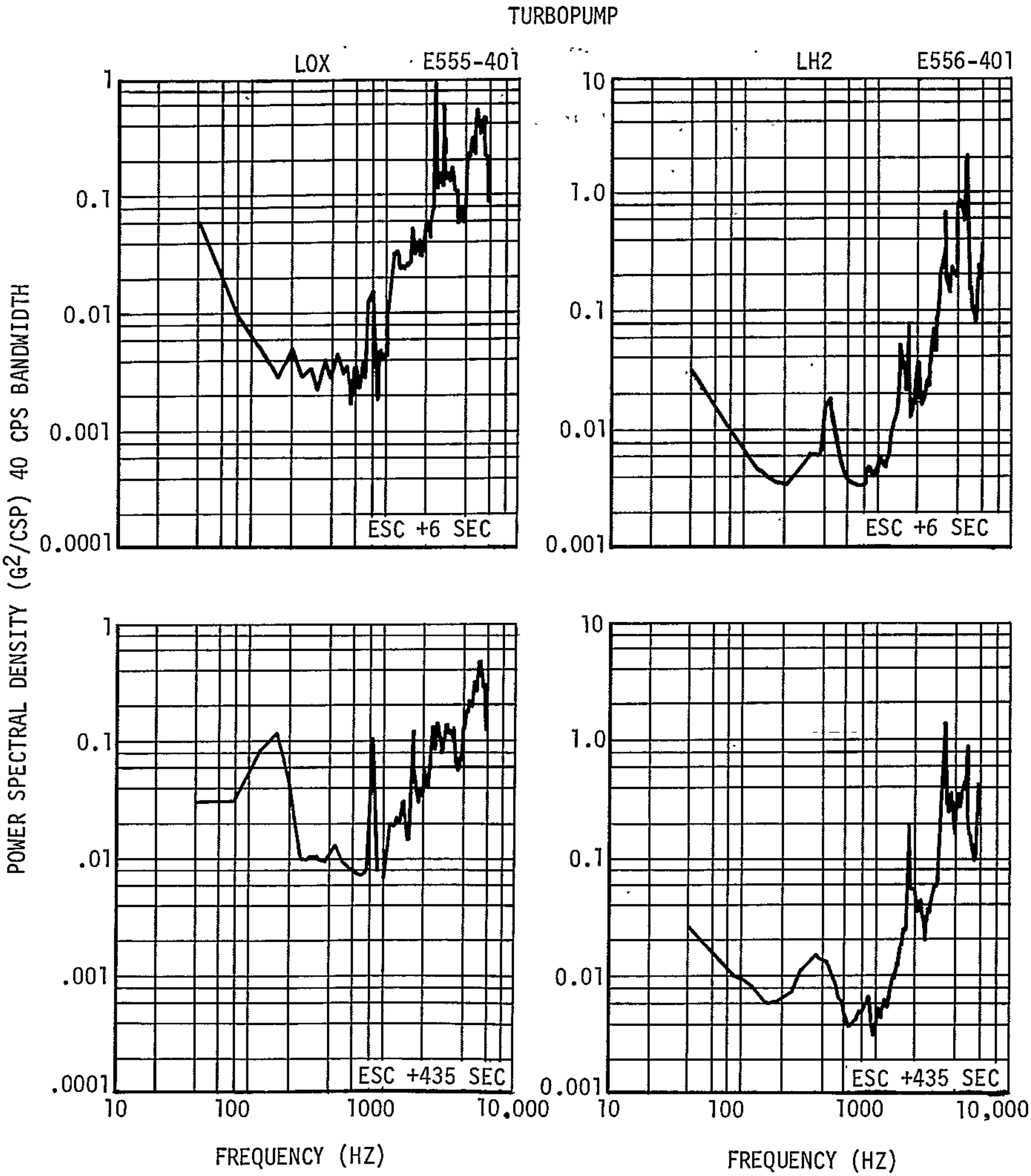


Figure 6-20. Engine Vibration Levels – Turbopumps

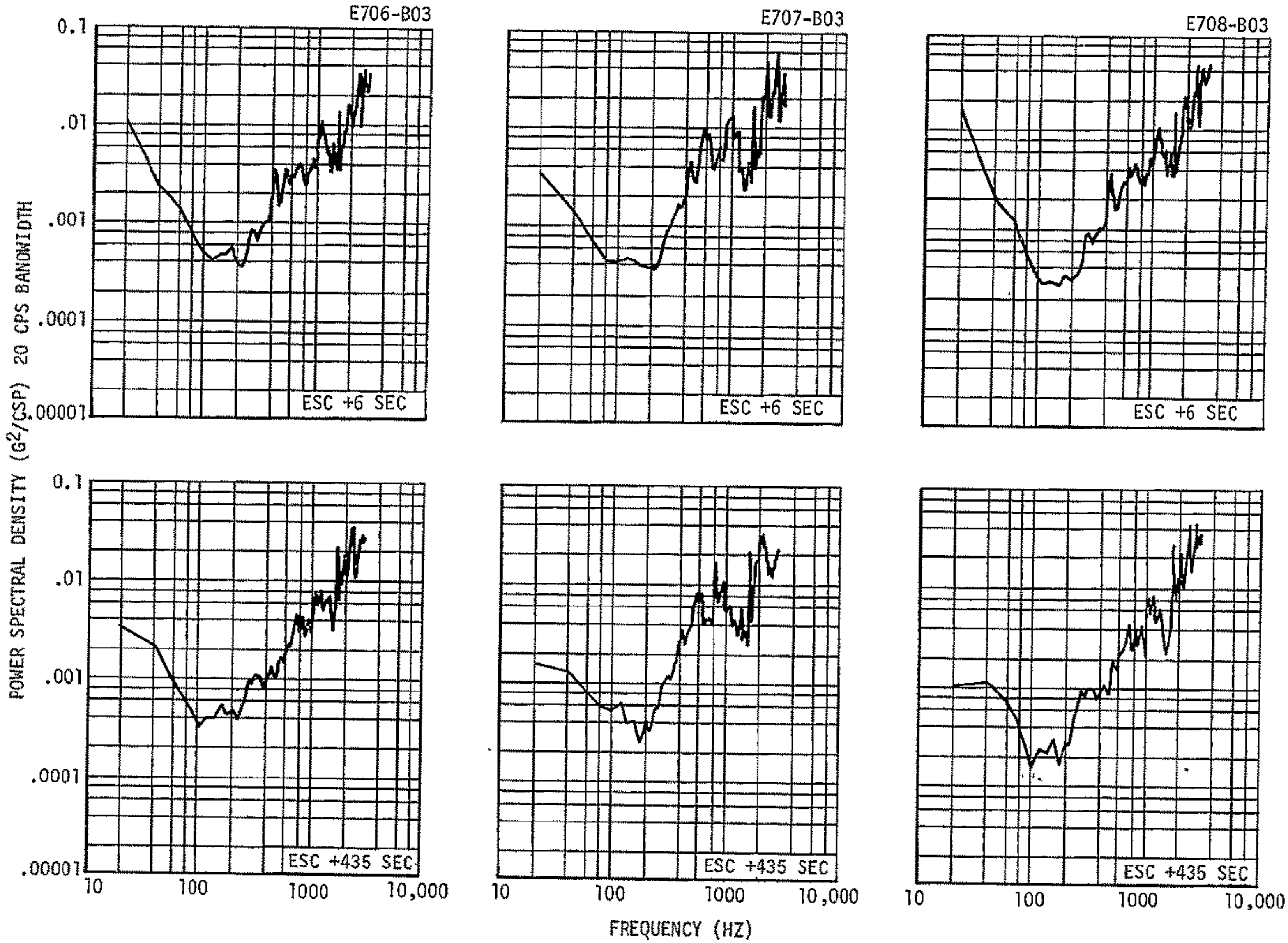


Figure 6-21. J-2 Engine Vibration Levels - Thrust Chamber Dome

7. OXIDIZER SYSTEM

The oxidizer system functioned adequately, supplying LOX to the engine pump inlet within the specified limits. The net positive suction pressure (NPSP) available at the LOX pump inlet exceeded the engine manufacturer's minimum requirement at all times.

7.1 Pressurization Control

The LOX tank pressurization system (figure 7-1) satisfactorily maintained pressure in the LOX tank throughout the acceptance firing, and all portions of the system performed within the design requirements.

7.1.1 Prepressurization

LOX tank prepressurization and the pressure makeup cycles before simulated liftoff were accomplished from ground support equipment (GSE) cold helium supply (figure 7-2). The LOX tank pressure increased from 41.0 psia to 42.0 psia due to an ullage volume decrease (caused by the common bulkhead depression and stage geometric changes that occur during LH2 tank prepressurization) and to the helium purges of the vent valve and the LOX tank ullage pressure sensing line.

The LOX tank boiloff valve was opened following simulated liftoff to allow the ullage pressure to decay to 39.0 psia. In the course of simulated boost, the ullage pressure twice decayed to 38.4 psia, thus initiating two cold helium sphere supplied makeup cycles which increased the ullage pressure to the upper level of 41.0 psia. The pressure decay following the boiloff valve opening was caused by cooling ullage gas which resulted from heat transfer with the colder common bulkhead.

Significant LOX tank prepressurization data are compared with that from two previous acceptance firings in table 7-1.

7.1.2 Pressurization

The LOX tank pressurization system performance was satisfactory during engine operation (figure 7-3) and compared reasonably well with that from previous stages. The ullage pressure was 42.6 psia at Engine Start Command. Secondary flow was required seven times to maintain the ullage pressure within the range of 38.2 to 40.3 psia during the firing.

The modified LOX tank pressurization sequence, which was utilized for the first time during the S-IVB-506N acceptance firing, was also used for the S-IVB-507 acceptance firing. The cold helium shutoff valves were opened at ESC -2.4 sec, increasing the ullage pressure from 40.0 to 42.8 psia by Engine Start Command. During this 2.4-sec period, 0.60 lbm of helium were added to the LOX tank ullage. The heat exchanger control valve was programmed to the open position during cold helium lead and during the first 21 sec of engine burn. The resulting higher initial flowrate completely eliminated the usual LOX tank ullage pressure dip.

The S-IVB-507 stage LOX tank pressurization system data are compared with that from the S-IVB-505N and 506N acceptance firings in table 7-2.

7.1.3 Repressurization with O_2-H_2 Burner

LOX tank repressurization was performed during a test utilizing the O_2-H_2 burner and pressurant helium from the cold helium spheres. The tank was filled to a nominal second start level and prepressurized to 33.7 psia to simulate the burner inlet conditions expected during burner start and subsequent repressurization. The tank conditions are shown in figure 7-4; significant data are compared to that from previous firings in table 7-3. Data are also presented in section 10.

Burner start was followed by a 7.087-sec lag before the initiation of LOX tank repressurization in order to provide higher burner chamber pressure (and improved combustion stability) during the start transient. The tank was pressurized from 33.7 to 36.5 psia during 151 sec of repressurization for an average tank pressure rise rate of 1.11 psi/min, which is very close to the theoretical prediction of 1.15 psi/min.

7.1.4 Ambient Repressurization

After burner repressurization, the ambient repressurization test was performed. The LOX tank was loaded to approximately 68 percent to simulate the load expected during orbital restart. The test data are presented in figure 7-5.

The S-IVB-507 ambient repressurization system performance for the acceptance firing is compared with the performances for the S-IVB-506N and 505N acceptance firings in table 7-3. The ullage volume was smaller during the S-IVB-507 firing than during the S-IVB-506N; consequently a shorter repressurization period and less repressurant helium were required to pressurize the LOX tank. Since the helium flowrate decays with time, the average helium flowrate and, therefore, the average ullage pressure rise rate were higher than usual during this shorter repressurization period.

7.2 Cold Helium Supply

The cold helium spheres were the source of the pressurant for both propellant tanks during O_2-H_2 burner operation and for the LOX tank during J-2 engine operation.

The system performance during the O_2-H_2 burner firing is discussed in paragraph 10.4.

During J-2 engine operation, demands on the cold helium system were normal and adequately met. The sphere pressure (2,993 psia) at Engine Start Command was well within the start requirement of 2,600 $\pm$600 psia. Due to the failure of the primary cold helium pressure measurement (D0016) after O_2-H_2 burner operation, the backup pressure measurement (D0248) was used for system evaluation. The system performance is shown in figure 7-6. System conditions, at significant times, are compared to three previous acceptance firings in table 7-4.

7.3 J-2 Heat Exchanger

The J-2 heat exchanger functioned satisfactorily (figure 7-7). The heat exchanger pressures, temperatures, helium flowrates and heat input rate were consistent with past performance. The LOX vent inlet temperature and pressure, and the theoretical mixture temperature were comparable to previous test data. Table 7-5 compares significant S-IVB-507 acceptance firing data with that from two previous acceptance firings.

7.4 LOX Pump Chilldown

The LOX pump chilldown system performance was adequate. At Engine Start Command, the NPSP at the LOX pump inlet was above the minimum 11.9 psi required at that time. The results of the chilldown performance calculations are presented in figures 7-8 and 7-9; significant chilldown system data are compared with S-IVB-505N and 506N data in table 7-6.

The chilldown pump was started at T -289 sec in order to simulate conditions during the flight countdown. The chilldown shutoff valve was left open until ECC -26 sec.

For the calculation of heat input to the LOX chilldown system, the normal reference temperature for section 1 (tank to engine pump inlet) is the chilldown pump discharge temperature (C0163). This assumes no heat input from the tank to the chilldown pump outlet. Since C0163 was not installed on S-IVB-507, the LOX bulk temperature (C0040) was used as a basis for constructing the chilldown pump discharge temperature.

7.5 Engine LOX Supply

The LOX supply system (figure 7-10) delivered the necessary quantity of LOX to the engine pump inlet throughout the engine firing and maintained the pressure and temperature conditions within a range that provided a LOX pump NPSP above the minimum requirements. The data and the calculated performance are presented in figure 7-11 and are compared with that from two previous acceptance firings in table 7-7.

During engine operation, the LOX pump inlet pressure and temperature were near the predicted values. Both were plotted in the engine LOX pump operating region and showed that the LOX pump inlet conditions were satisfactory throughout engine operation (figure 7-12).

In figure 7-13, the LOX pump inlet temperature is plotted against the mass remaining in the tank during engine operation and compared to the S-IVB-505N and 506N acceptance firing data. The data used for comparison have been biased to the LOX pump inlet temperature observed at Engine Start Command of the S-IVB-507 acceptance firing to correct for instrumentation error, differences in heating during pressurization, and other test-to-test variations.

TABLE 7-1
LOX TANK PREPRESSURIZATION DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Prepressurization duration (sec)	13.1	10.5	16.8
Number of makeup cycles before T_0	2	1	2
Number of makeup cycles after T_0	2	2	0
Prepressurization helium			
Average flowrate (lbm/sec)	0.31	0.44	0.25
Mass added to LOX tank during prepressurization (lbm)	4.11	4.58	4.25
Mass added to LOX tank during makeup cycles before T_0 (lbm)	2.0	1.61	1.32
Mass added to LOX tank during makeup cycles after T_0 (lbm)	1.16	0.59	0
Ullage pressure			
At prepressurization initiation (psia)	15.1	14.9	15.3
At prepressurization termination (psia)	41.0	41.0	41.2
At Engine Start Command (psia)	42.6	43.1	39.1
Events (sec from T_0)			
Prepressurization initiation	-163.88	-164.38	-159.01
Prepressurization termination	-150.83	-153.91	-142.17
Engine Start Command	511.758	511.378	511.789

TABLE 7-2
LOX TANK PRESSURIZATION DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Number of secondary flow intervals	7	8	6
Pressure control band			
Minimum (psia)	38.2	38.6	38.4
Maximum (psia)	40.3	40.5	40.1
Ullage pressure			
At start of pressurization (psia)	40.0	39.4	37.5
At Engine Start Command (psia)	42.6	43.1	37.5
Minimum during start transient (psia)	38.3	38.5	35.6
At Engine Cutoff Command (psia)	39.1	39.6	39.2
Total pressurant flowrate			
Overcontrol (lbm/sec)	0.35 to 0.42	0.32 to 0.43	0.38 to 0.43
Predicted (lbm/sec)	0.35 to 0.44	0.37 to 0.45	0.39 to 0.43
Undercontrol (lbm/sec)	0.24 to 0.31	0.24 to 0.32	0.28 to 0.32
Predicted (lbm/sec)	0.24 to 0.31	0.28 to 0.34	0.29 to 0.33

TABLE 7-3
LOX TANK REPRESSURIZATION DATA

PARAMETER	S-IVB-507		S-IVB-506N		S-IVB-505N	
	AMBIENT	BURNER	AMBIENT	BURNER	AMBIENT	BURNER
Repressurization duration (sec)	75	115**	118	201	205	181
Number of makeup cycles	0	0	0	0	0	0
Repressurization helium						
Usage (lbm)	9.7	4.4*	11.5	5.5*	14.7	5.2*
Average flowrate (lbm/sec)	0.129	0.0291	0.0974	0.025	0.0717	0.027
Orifice effective area ($in.^2$)	0.00890	0.00566	0.00858	0.00565	0.00875	0.00563
Ullage pressure						
At repressurization initiation (psia)	31.7	33.7	31.5	34.7	25.9	34.4
At repressurization termination (psia)	40.4	36.5	40.3	38.6	36.6	38.0
Rise rate (psi/min)	6.96	1.11	4.47	1.16	3.14	1.19

*These values include the flow through the pilot bleed port on the burner helium shutoff valves. See paragraph 10.5 for further information.

**Does not include 7.087-sec lag in repressurization initiation following burner start command.

TABLE 7-4
COLD HELIUM SUPPLY DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Pressure			
Simulated liftoff (psia)	2,993	2,806	3,070
Engine Start Command (psia)	2,838	2,664*	2,425***
Engine Cutoff Command (psia)	1,050	1,021	815
Average Temperature			
Simulated liftoff (deg R)	41.2	41.6	40.3
Engine Start Command (deg R)	41.0	40.8*	36.8**
Engine Cutoff Command (deg R)	44.0	43.8	44.9
Helium Mass			
Engine Start Command (lbm)	368	360*	337
Engine Cutoff Command (lbm)	216	211	168
Helium Consumption			
Calculated from sphere conditions (lbm)	152	149**	169
Calculated from flowrate integration (lbm)	141	145**	148

*At ESC -2.4 sec, when LOX tank pressurization was initiated

**Includes 2.4 sec of flow prior to Engine Start Command

***Low because of cold helium leak

TABLE 7-5
J-2 HEAT EXCHANGER DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Flowrate through heat exchanger			
During overcontrol (lbm/sec)	0.20	0.20	0.20
During undercontrol (lbm/sec)	0.090	0.085	0.080
Heat exchanger outlet temperature			
At end of 50-sec transient (deg R)	930	960	960
During overcontrol (deg R)	950	980	975
During undercontrol (deg R)	970	1,000	995
At Engine Cutoff Command (deg R)	950	962	941
Heat exchanger outlet pressure			
During overcontrol (psia)	340	350	330
During undercontrol (psia)	395	400	375
Average LOX vent inlet pressure			
During overcontrol (psia)	63	62	70
During undercontrol (psia)	49	48	50

TABLE 7-6
LOX CHILLDOWN SYSTEM PERFORMANCE DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
NPSP			
At Engine Start Command (psi)	33.8	34.6	30.3
Minimum required at start (psi)	11.9	11.6	16.5
At opening of prevalve (psi)	40.0	39.7	38.7
Pump inlet conditions			
Pressure at engine start (psia)	51.1	51.3	47.0
Temperature at engine start (deg R)	165.1	164.5	164.7
Average flow coefficient ($sec^2/in.^2ft^3$)	17.2	16.9	15.7
Heat absorption rate (btu/hr)			
Section 1 (tank to pump inlet)	10,500	3,200	3,500
Section 2 (pump inlet to bleed valve)	6,500	14,500	16,000
Section 3 (bleed valve to tank)	5,000	1,800	1,500
Total	22,000	19,500	21,000
Chilldown flowrate			
Unpressurized (gpm)	39.5	39.4	40.8
Pressurized (gpm)	41.2	42.5	43.0
Chilldown system pressure differential			
Unpressurized (gpm)	9.5	9.8	9.0
Pressurized (gpm)	10.4	10.7	10.9
Events (sec from T_0)			
Chilldown initiated	-288.6	-289.4	-298.2
Prepressurization	-163.9	-164.4	-159.0
Prevalve open command	507.7	507.4	507.5
Prevalve closed signal dropout	508.7	508.6	508.8
Prevalve open signal pickup	510.4	510.2	510.9
Delay between prevalve open command and pickup of open signal	2.50	2.78	3.45
Engine Start Command	511.7	511.4	511.8
Chilldown shutoff valve closed	922.1	921.9	862.2

TABLE 7-7
LOX PUMP INLET CONDITION DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Pump inlet conditions			
Static pressure at engine start (psia)	51.1	51.3	46.8
Temperature at engine start (deg R)	165.1	164.5	164.8
Temperature at engine cutoff (deg R)	166.8	166.3	166.4
NPSP requirements at pump interface			
Minimum at engine start (psi)	11.9	11.6	16.3
At high EMR (psi)	20.0	19.8	20.8
After EMR cutback (psi)	14.0	14.7	15.6
NPSP available at pump interface			
At engine start (psi)	33.8	34.6	30.0
Maximum during firing (psi)	33.8	34.6	34.4
Time of maximum (sec from ESC)	0	0	5
Minimum during firing (psi)	19.0	22.4	22.1
Time of minimum (sec from ESC)	436	448	450
At Engine Cutoff Command (psi)	19.0	22.4	22.1
LOX feed duct			
At high EMR			
Pressure drop (psi)	1.4	2.0	2.5
Flowrate (lbm/sec)	465	460	463
After EMR cutback			
Pressure drop (psi)	0.9	1.2	1.5
Flowrate (lbm/sec)	422	400	397

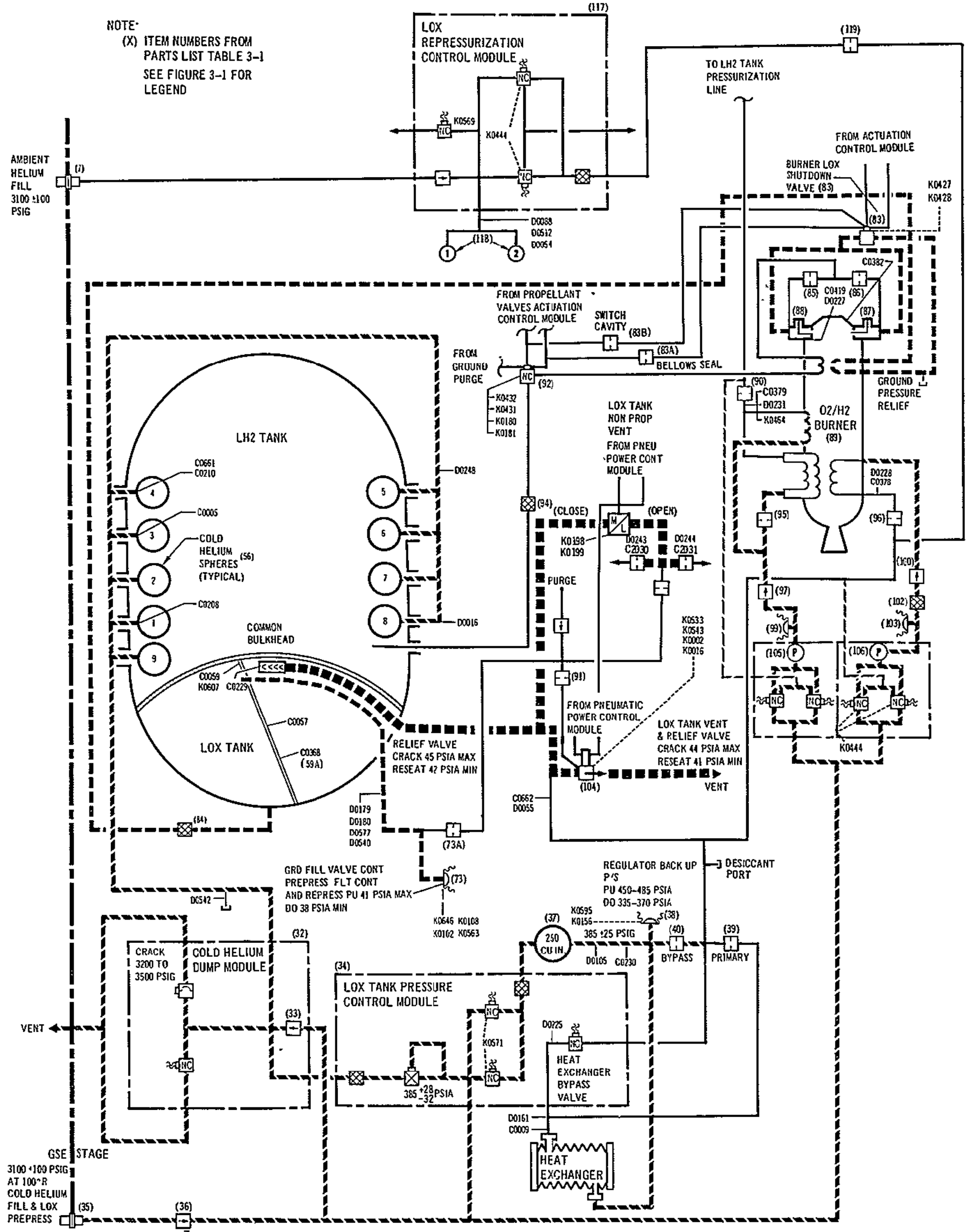


Figure 7–1. LOX Tank Pressurization System

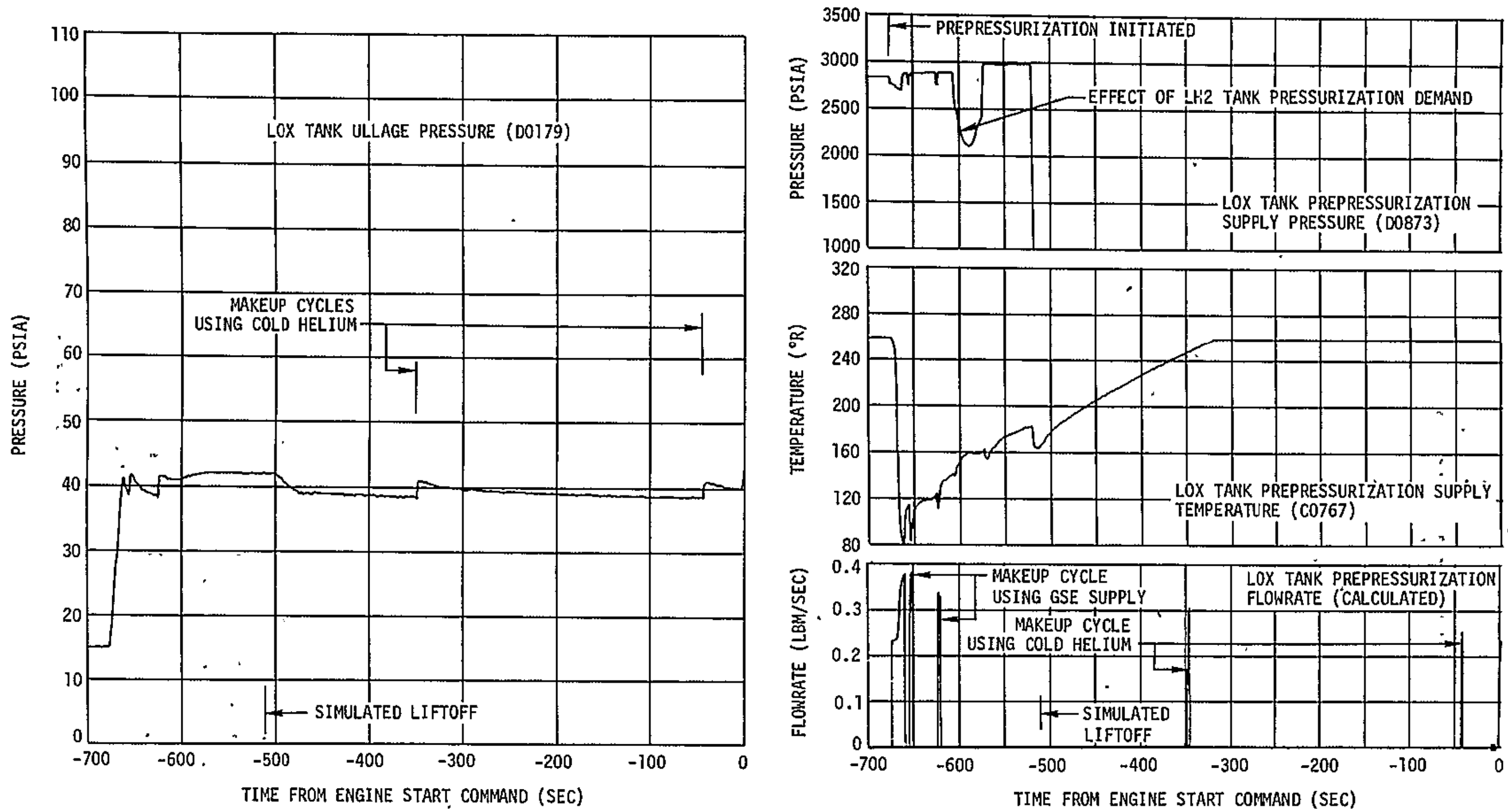


Figure 7-2. LOX Tank Prepressurization System Performance

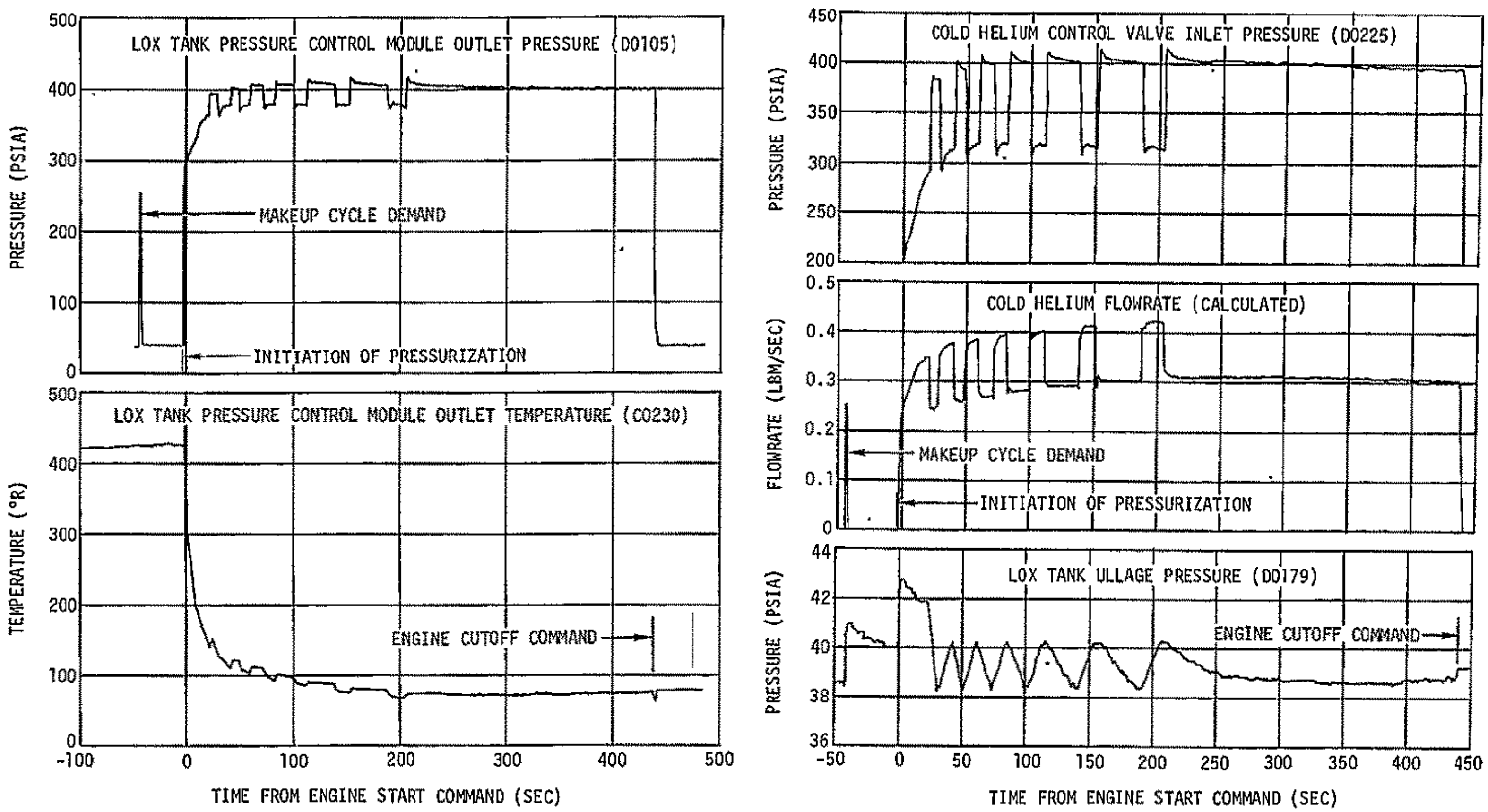


Figure 7-3. LOX Tank Pressurization System Performance

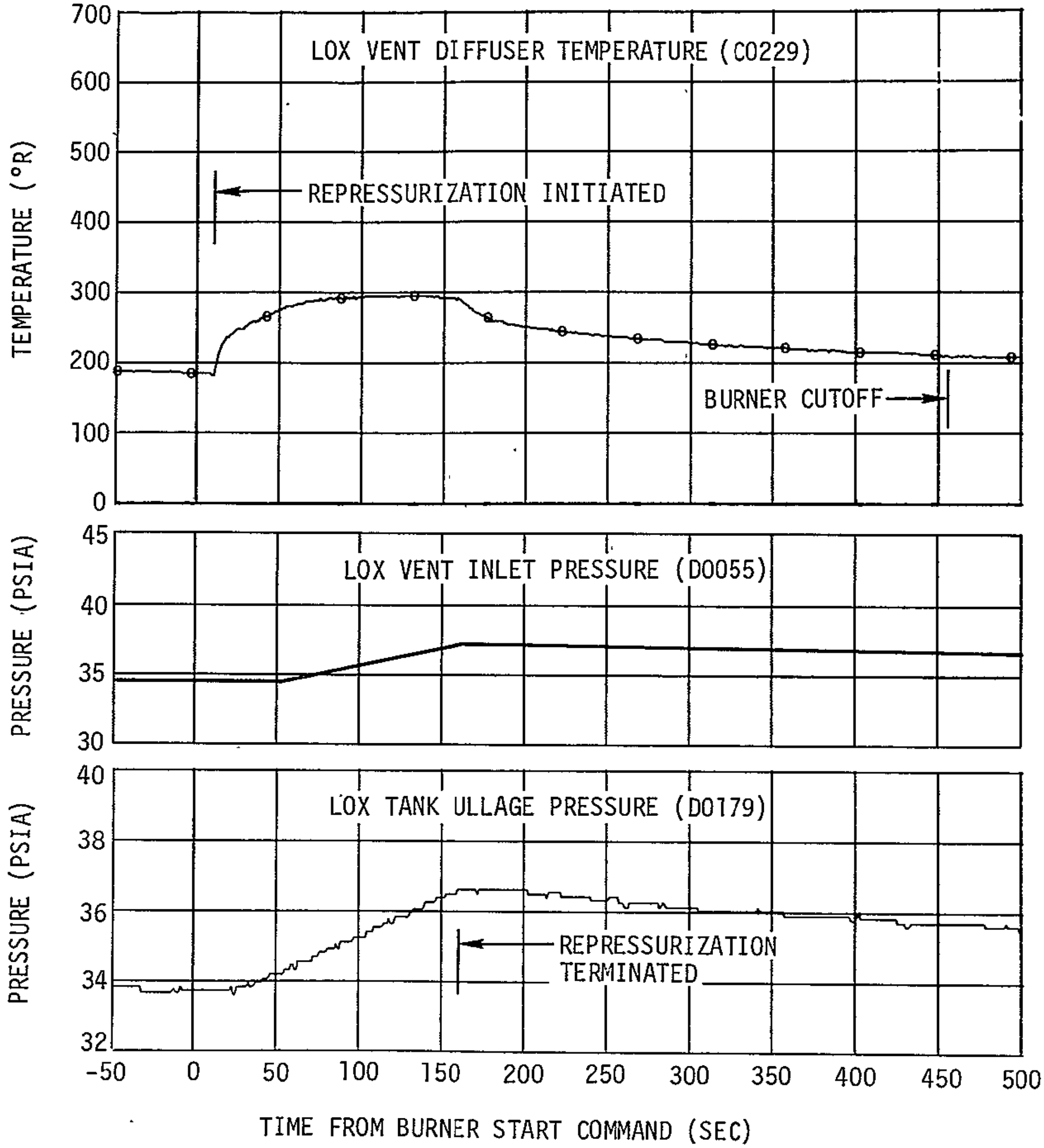


Figure 7-4. LOX Tank O2-H2 Burner Repressurization

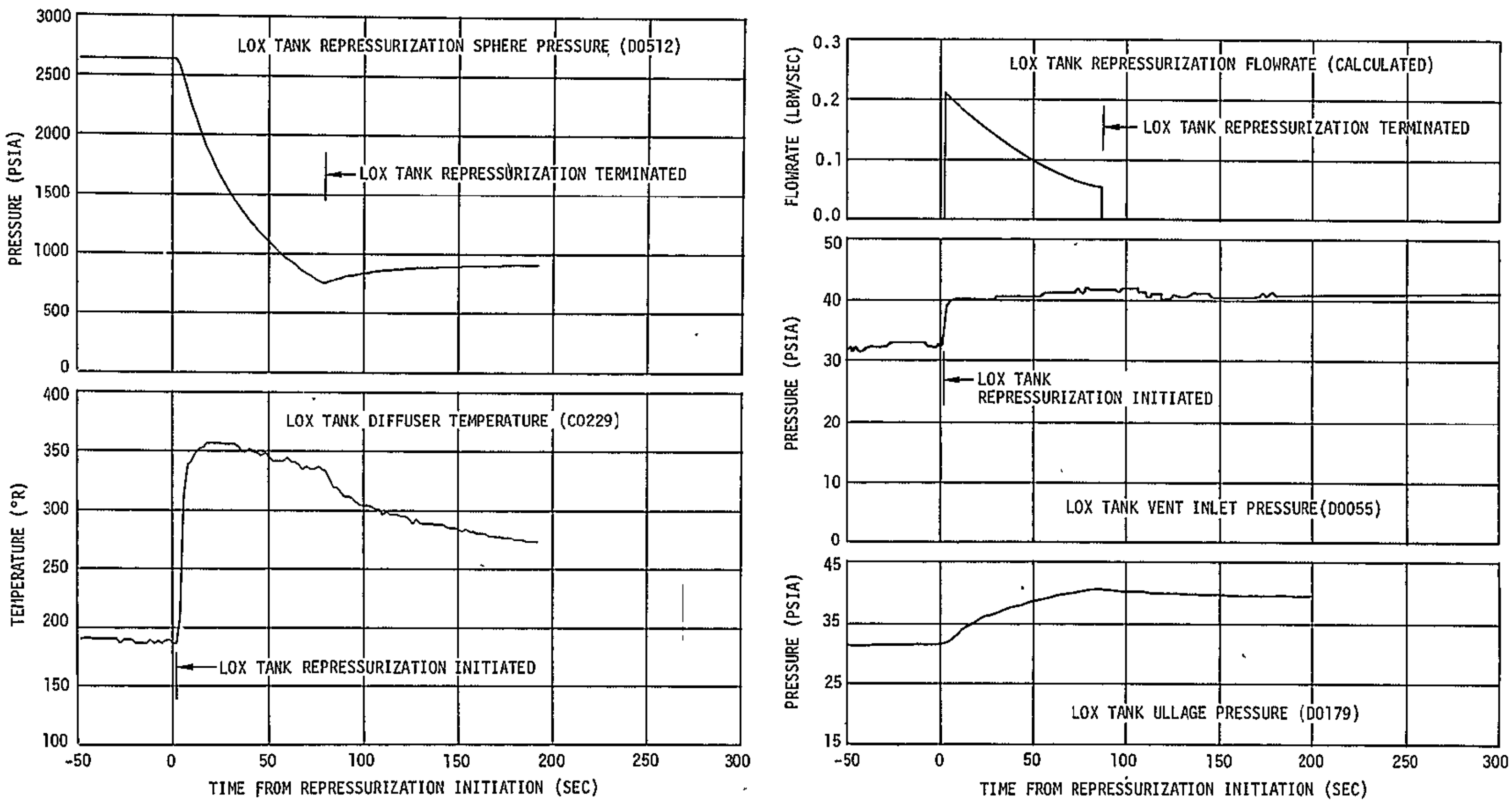


Figure 7-5. LOX Tank Ambient Helium Repressurization

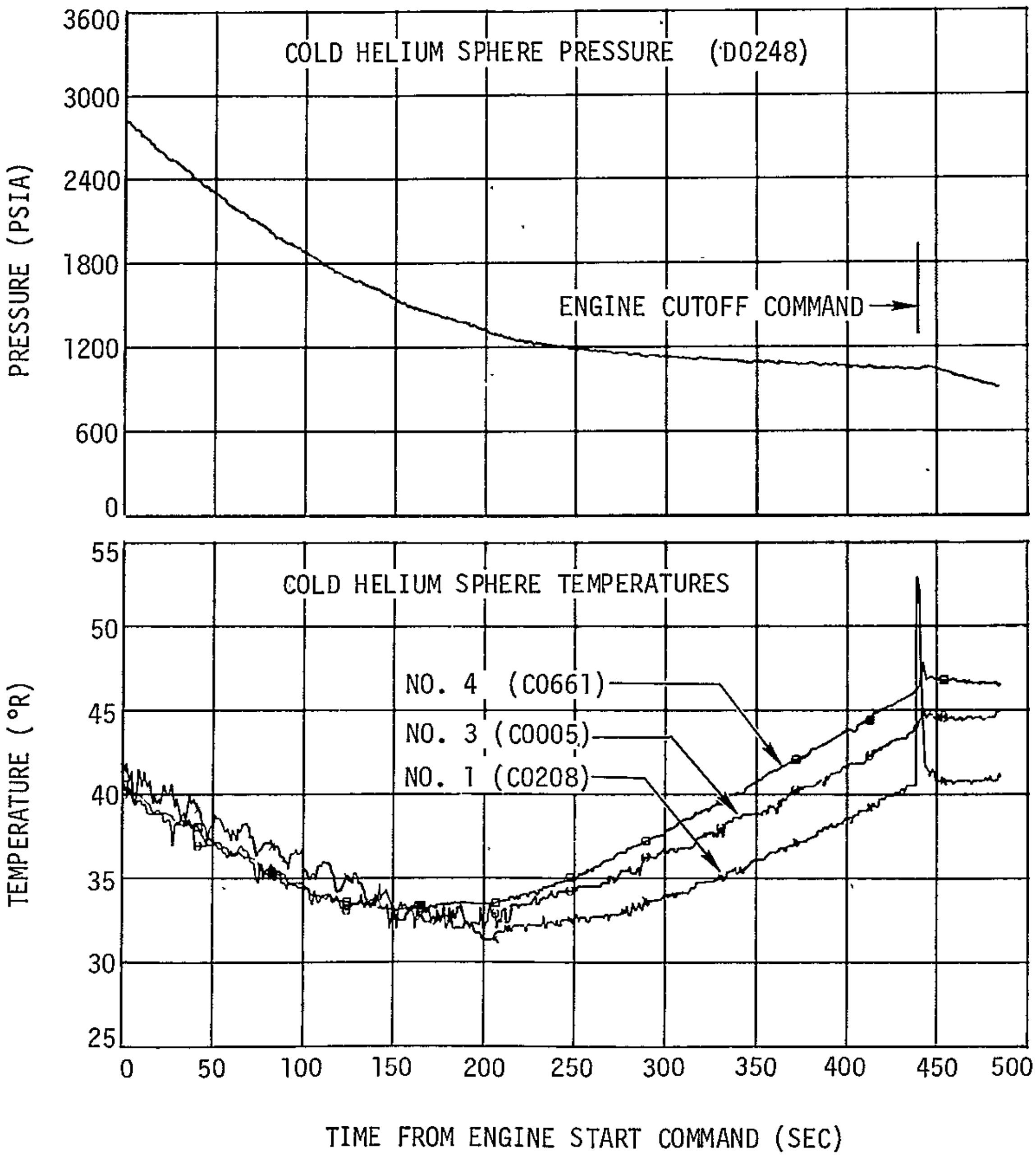


Figure 7-6. Cold Helium Supply

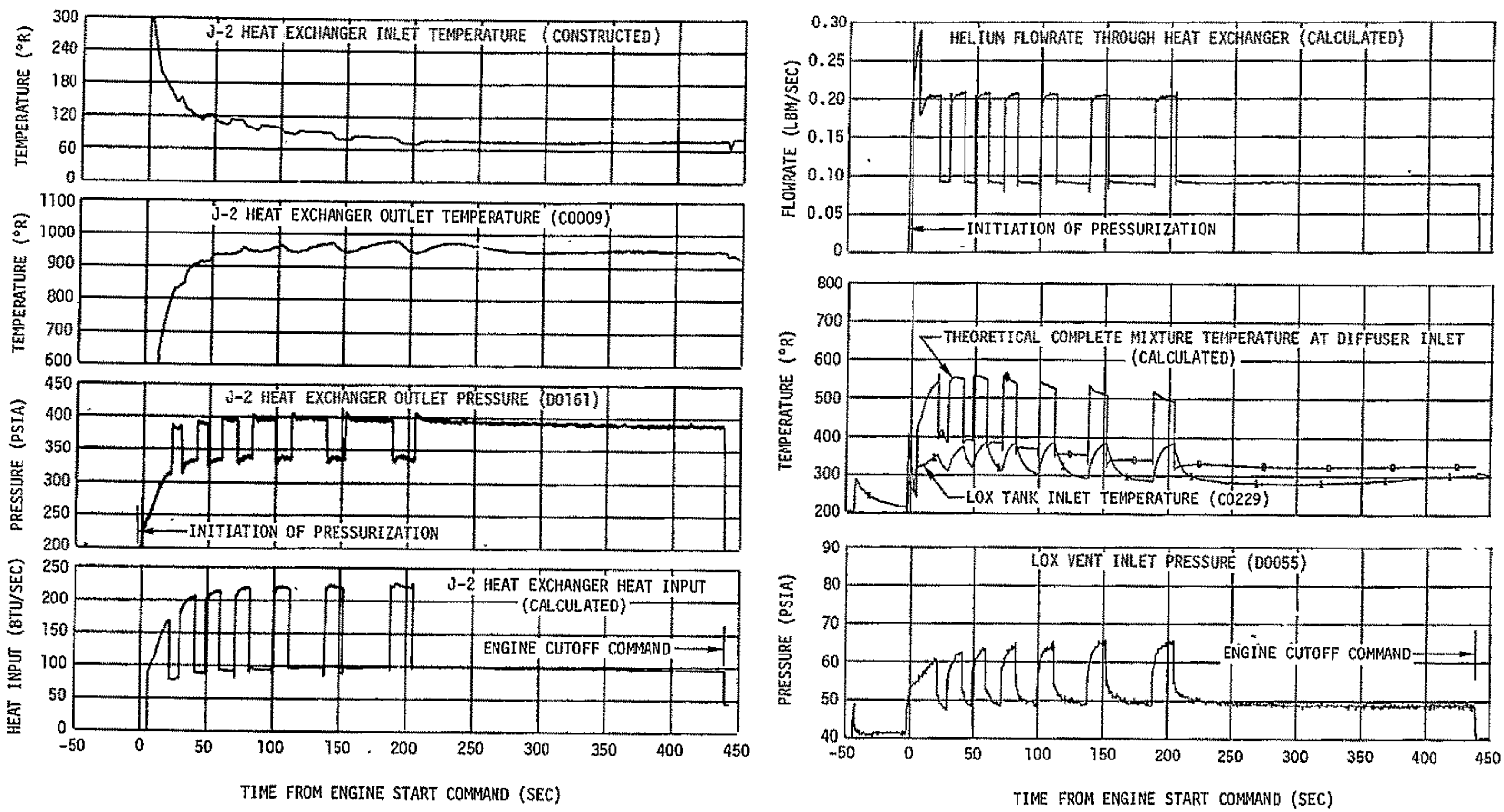


Figure 7-7. J-2 Heat Exchanger Performance

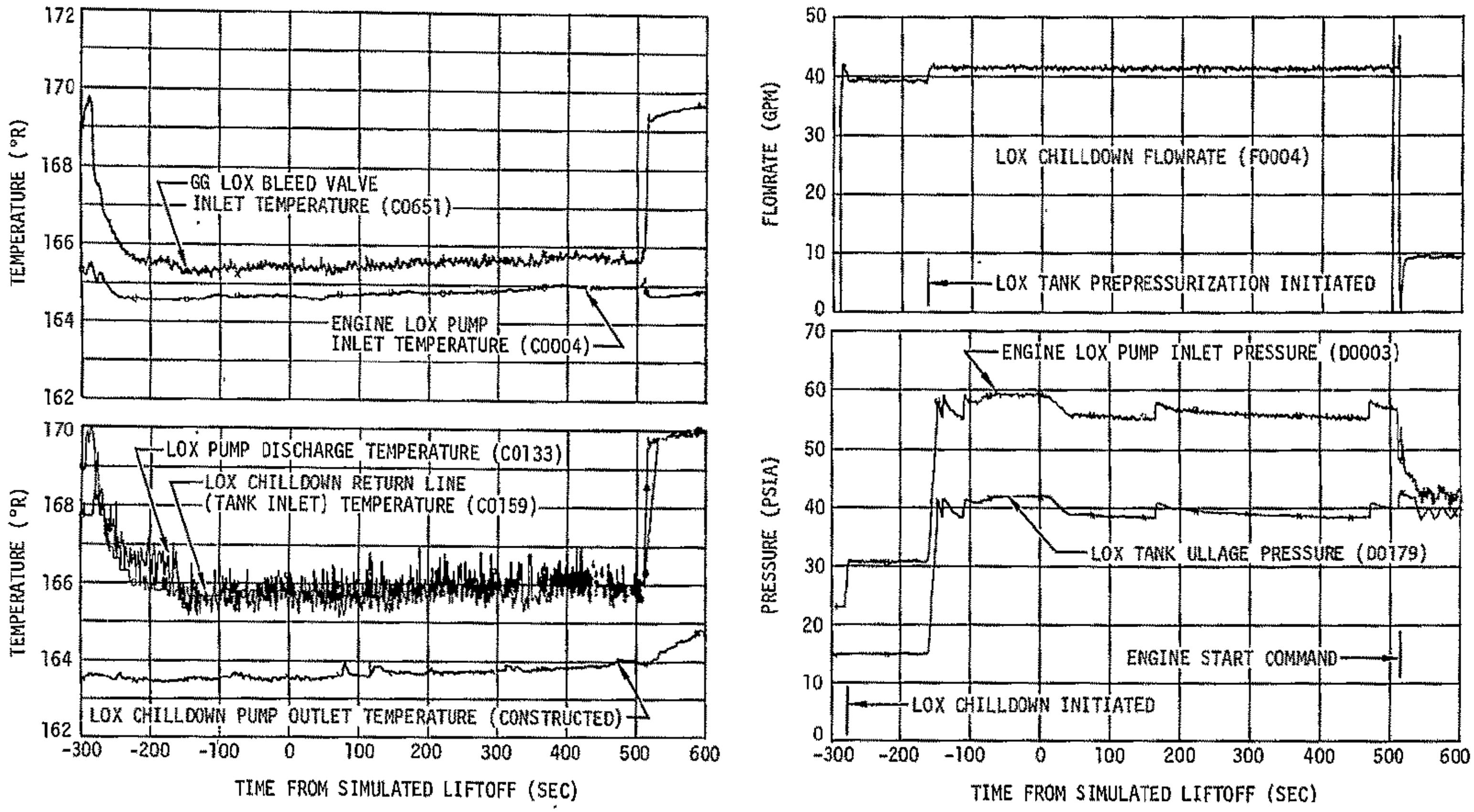


Figure 7-8. LOX Pump Chilldown System Operation

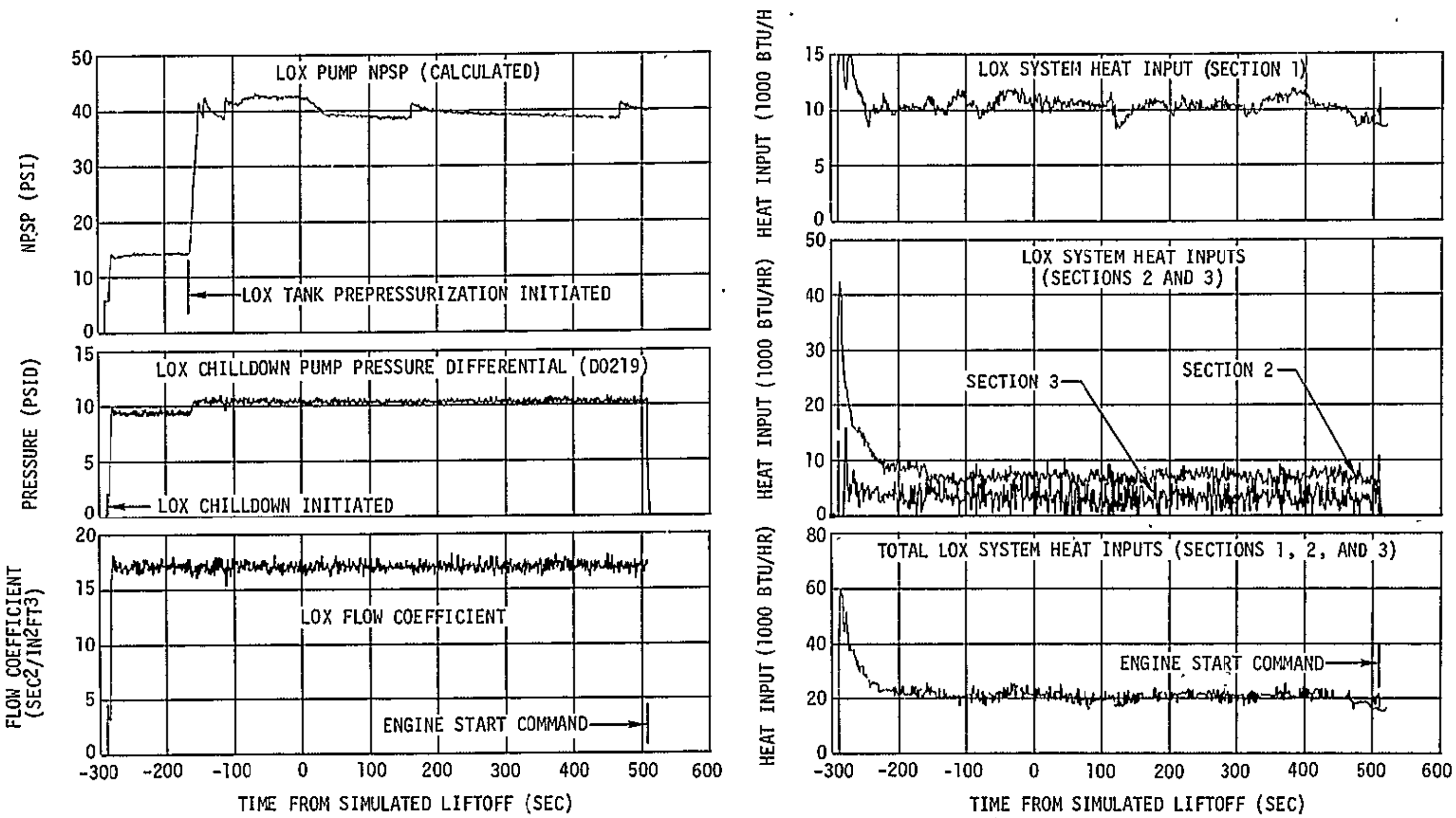


Figure 7-9. LOX Pump Chilldown System Performance

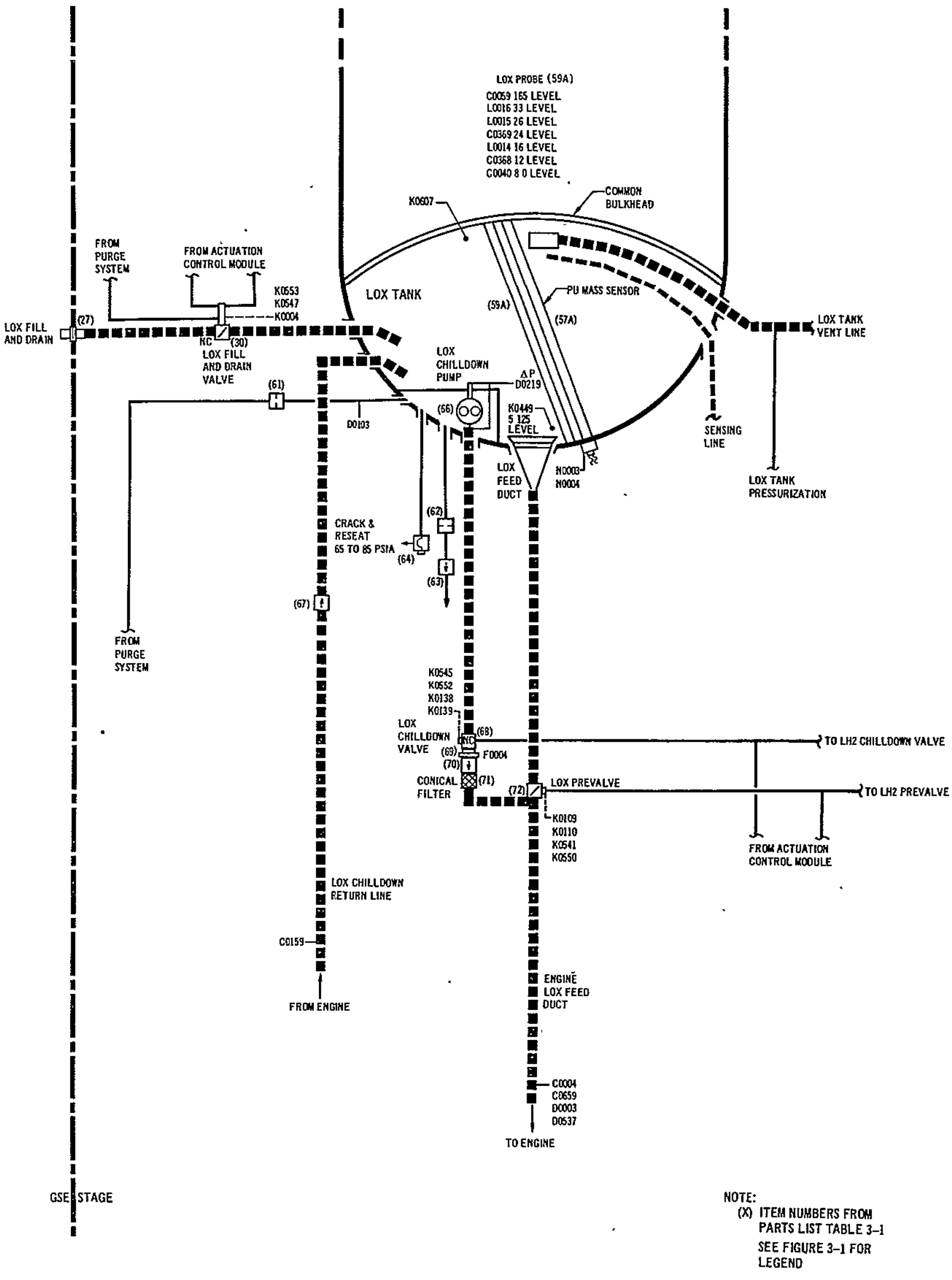


Figure 7-10. LOX Supply System

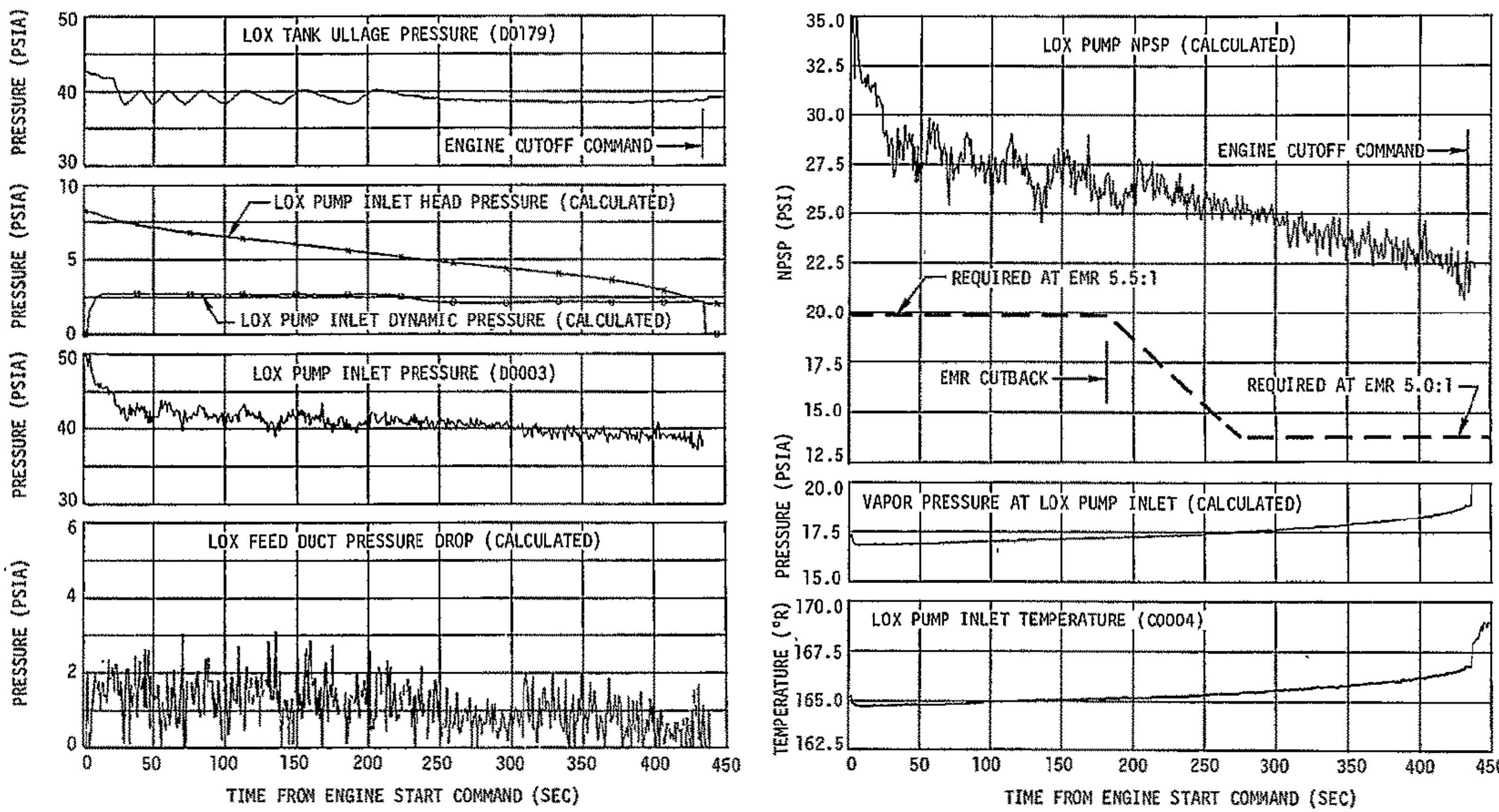


Figure 7-11. LOX Pump Inlet Conditions

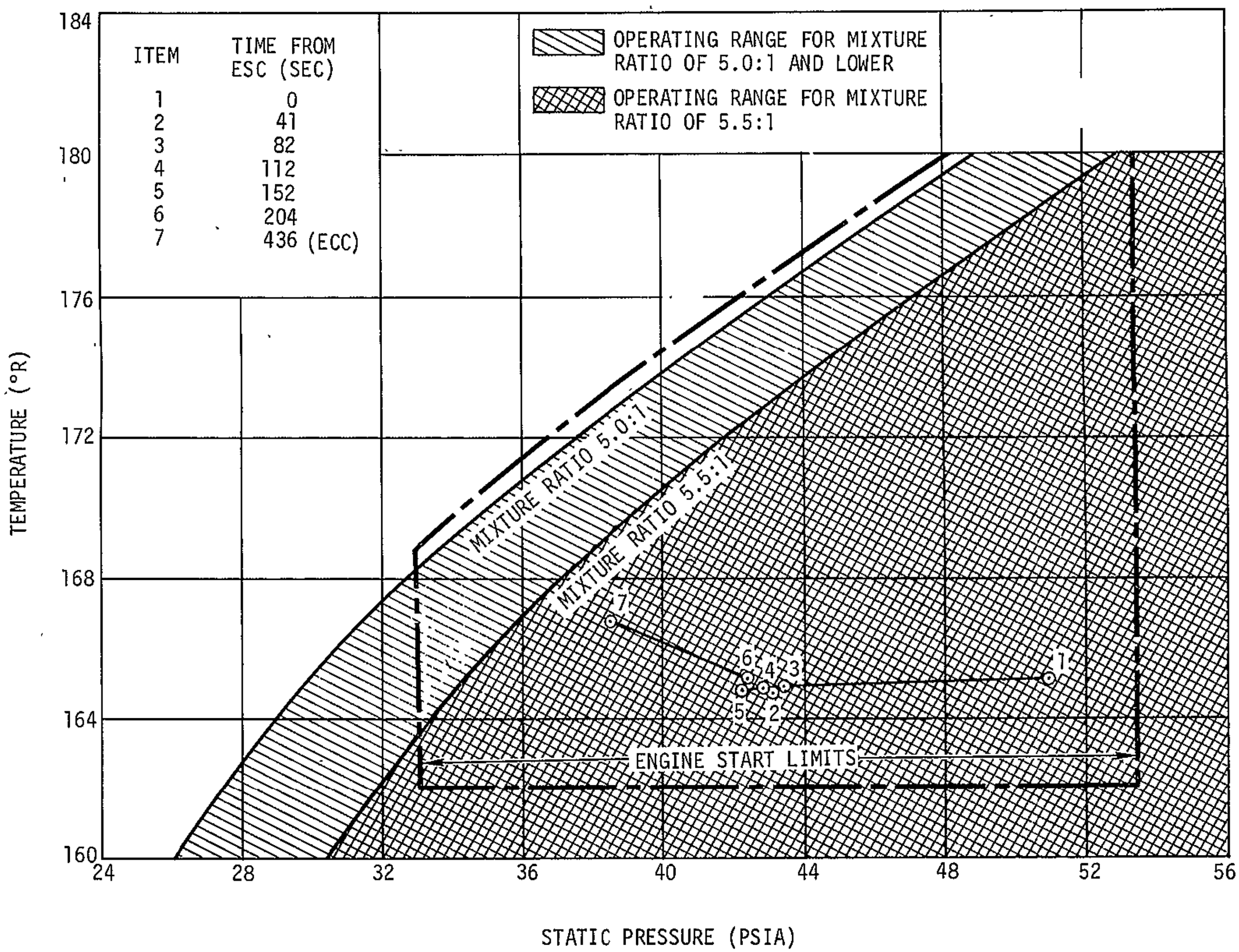


Figure 7-12. LOX Pump Inlet Conditions During Firing

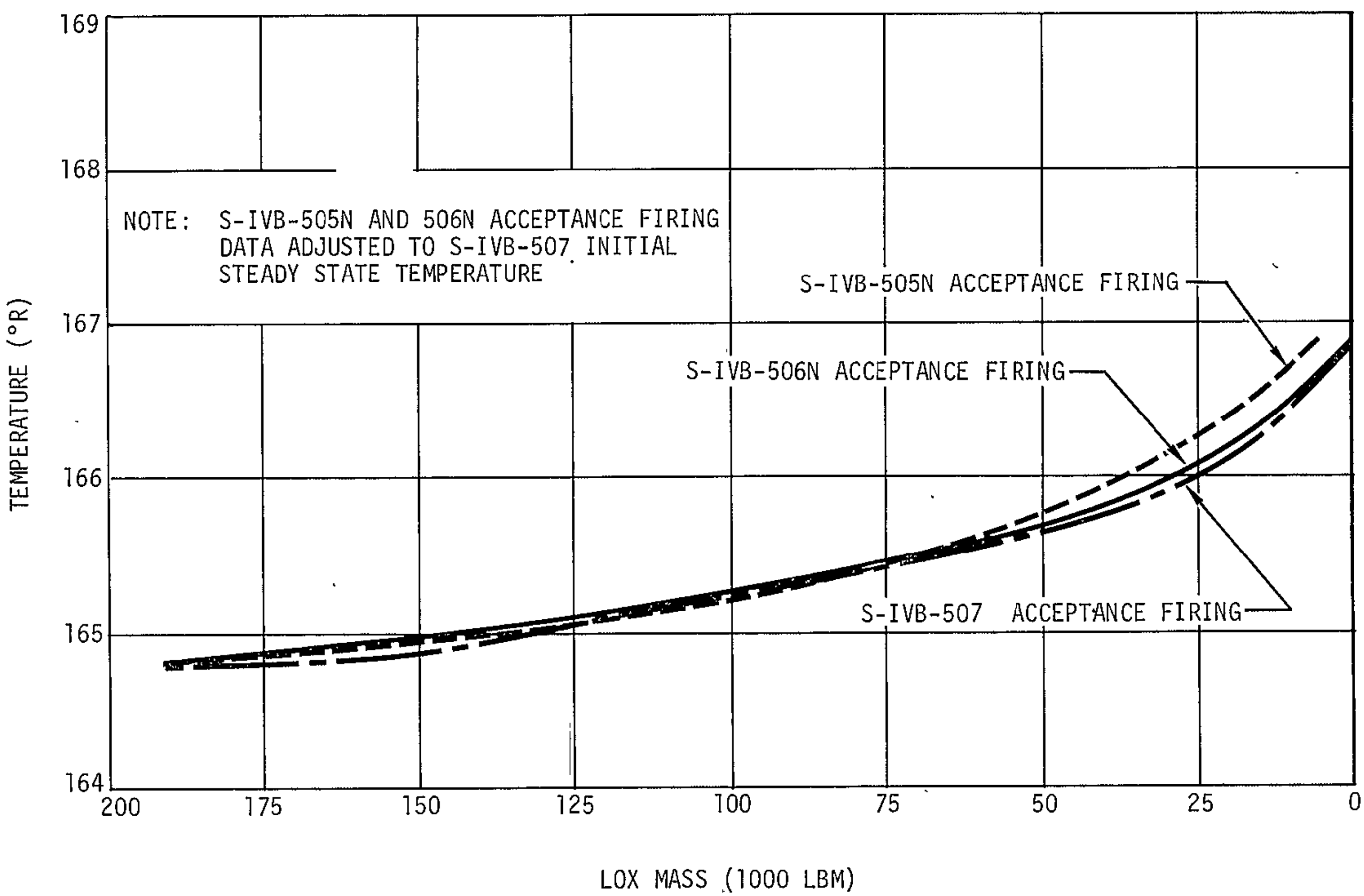


Figure 7-13. Effect of LOX Mass Level on LOX Pump Inlet Temperature

8. FUEL SYSTEM

The fuel system performed as designed and supplied LH2 to the engine within the limits defined in the engine specification.

8.1 Pressurization Control

The LH2 tank pressurization system (figure 8-1) adequately controlled LH2 tank ullage pressure throughout the firing and during repressurization periods. As part of an effort to avoid overstressing the LH2 tank structure, the LH2 tank operating pressure levels have been reduced on this firing as on S-IVB-506N. The pressurization system operating range during the second burn phase was reduced to 28 - 31 psia from the previous 31 - 34 psia. The vent and relief valve relief band was also lowered from 34 - 37 psia to 31 - 34 psia.

8.1.1 Prepressurization

The LH2 tank was satisfactorily prepressurized with helium from ground support equipment (GSE) console B. Figure 8-2 presents the prepressurization data; table 8-1 compares the S-IVB-507 data with S-IVB-506N and 505N data. The rate of prepressurization was substantially faster on S-IVB-507 than 506N because the supply pressure (measurement D0792) was significantly higher (figure 8-2). Prepressurization was terminated by actuation of the control pressure switch at T_0 -62 sec. After prepressurization, the ullage pressure increased because of ambient heating until it reached the relief setting of 31.7 psia at T_0 +20.0 sec.

8.1.2 Pressurization

During engine operation, the LH2 tank pressurization was satisfactorily accomplished by GH2 bleed from the J-2 engine (figures 6-1 and 8-1). The data are presented in figure 8-3 and compared with data from two previous acceptance firings in table 8-2.

As a result of the reduced LH2 tank operating pressure levels, the LH2 tank ullage pressure operated to a lower pressure schedule than during the previous acceptance firings, as shown in table 8-2. In order to exercise all system components in both burn modes, control was transferred from the first burn pressurization mode to the second burn pressurization mode at ESC +200 sec. Since the pressure switch range is the same for both modes (28 to 31 psia), no change in system performance resulted. During both burn phases, the system operated in the under-control mode. To preclude the possibility of loss of NPSP near the end of the firing because of bulk heating, step pressurization ~~pressure~~ was initiated at ESC +410 sec.

Throughout most of the burn, the tank ullage pressure was above the 31 psia pressure switch pick-up level and was maintained at the vent and relief valve relief setting. At EMR cutback, the ullage pressure decreased 0.2 psi and remained at this new level until step pressurization, when the pressure increase caused venting until after Engine Cutoff Command. The relative stability of the ullage pressure prior to PU cutback suggests the tank was relieving. The vent and relief valve microswitch talkback indicated tank relieving occurred ~~did occur~~ during two periods: from Engine Start Command to ESC +20 sec and from ECC -18 sec to engine cutoff. Analysis of the tank data (figure 8-3) indicated that the tank was relieving until ECC, as shown by the collapse factor. As on the 506N acceptance firing, the high level of ullage pressure resulted from an increase in the primary orifice size in the GH2 pressurization module causing an increased pressurant flow.

The collapse factor shown in figure 8-3 is higher than normal and would indicate excessive pressurant flow or low pressurization efficiency. However, with the vent and relief valve relieving continuously during the first burn phase, the system would not be closed and a high collapse factor would result.

8.1.3 Repressurization with O_2-H_2 Burner

The O_2-H_2 burner was utilized for LH2 tank repressurization. For the test, the tank was filled to a nominal second start level. Burner start command was followed by a 6.87-sec lag before the initiation of repressurization in order to provide higher burner chamber pressure (and improved combustion stability) during the start transient. The LH2 tank conditions are shown in figure 8-4; significant data are compared to previous acceptance firing data in table 8-3.

The LH2 tank ullage pressure rise rate was 29 percent higher than the theoretical rate of 3.18 psi/min that was based on a constant-Q burner, a constant helium flowrate, and an assumed constant burner helium inlet temperature of 40 deg R (the same reference conditions used for the S-IVB-504N, 505N, and 506N acceptance firing evaluations). During the S-IVB-507 O_2-H_2 burner operation, the actual total energy in the helium at the burner outlet to the LH2 tank was 35 percent higher than the theoretical total energy calculated by assuming the temperature of the helium at the burner inlet to be 40 deg R. The 35 percent increase was due to the ambient heating that occurred between the cold helium spheres and the O_2-H_2 burner inlet.

Under ideal conditions any heating above the reference should be reflected by a corresponding percentage increase in the pressurization rate above the theoretical. The actual and theoretical values do not agree because the boundary conditions vary slightly and because LH2-boiloff does not actually terminate when pressurization is initiated.

8.1.4 Ambient Helium Repressurization

Although the S-IVB-507 stage is equipped with an O_2-H_2 burner, the ambient helium repressurization system was retained as a redundant system and was tested prior to the acceptance firing.

The LH2 tank was satisfactorily repressurized from the five ambient helium spheres. Repressurization time was considerably less for S-IVB-506N and 507 than for 505N. This was due to a higher initial ullage pressure and a lower required final pressure, as noted in paragraph 8.1. Data and performance levels are presented in figure 8-5 and compared to S-IVB-506N and 505N data in table 8-3.

8.2 LH2 Tank Vent and Relief Operations

The LH2 tank ullage pressure was maintained at an acceptable level throughout the acceptance firing.

8.2.1 LH2 Tank Vent and Relief Valve Performance

Performance of the LH2 tank vent and relief valve and the latching valve was satisfactory. The LH2 tank ullage pressure profile indicates that one or both of the valves relieved from shortly after simulated liftoff to EMR cutback. However, the valve microswitch talkbacks indicated the valves were feathering between T_0 +456 and T_0 +552 sec only. Shortly after LH2 tank step pressurization both valves relieved and valve talkback indicated that the valves remained partially open until after engine cutoff.

8.2.2 Vent Operations During Simulated Coast

The continuous vent system (CVS) was operated for approximately 24 min prior to O_2-H_2 burner repressurization. Both the CVS nozzles and the nonpropulsive vent (NPV) orifices were removed and a manifold system conducted the vented GH2 to the facility burn pond. At the LH2 tank ullage pressures maintained during the period, the flow of GH2 through the manifold (to atmospheric back pressure) was unchoked; however, choked flow at the vent exits will occur during actual orbital coast conditions. The CVS and NPV pressure data reflected venting (figure 8-6). Due to the common manifold system, both systems would indicate venting if either one vented.

Continuous venting was initiated by opening the relief override valve and allowing the continuous vent regulator (CVR) to open. After CVS initiation the ullage pressure dropped from 32.0 to 27.7 psia in 43 sec, yielding a pressure decay rate of 5.9 psi/min. This is consistent with the decay rates of 4.5 and 4.9 psi/min noted during the S-IVB-505N and 506N acceptance firings, respectively. At 43 sec after CVS initiation, the CVR was closed. The CVS bypass orifice was opened at CVS initiation plus 50.9 sec, and the CVR was reopened at CVS initiation plus 69 sec.

The ullage pressure then decreased and stabilized at 21.2 psia, indicating that the CVR was functioning properly. At first CVS initiation plus 336 sec, the LH2 NPV valve was opened for 5.6 sec in order to drop the ullage pressure below the regulating band of the continuous vent regulator and thus allow the main poppet of the regulator to reseat. The tank was then allowed to self-pressurize. At 20.9 psia the CVR cracked; regulation at 20.9 psia continued for 631 sec.

During the period prior to burner operation, the LH2 NPV valve was cycled in order to maintain the ullage pressure within the burner start limits.

8.3 LH2 Pump Chilldown

The LH2 pump chilldown system performed adequately. At Engine Start Command the net positive suction pressure (NPSP) at the LH2 pump inlet was above the 4.5 psi required. The chilldown system data are presented in figures 8-7 and 8-8. The S-IVB-507 acceptance firing data are compared in table 8-4 with data from two previous acceptance firings.

The chilldown system operation was initiated at T_0 -298.6 sec. System performance levels were in good agreement with those of previous acceptance firings. During unpressurized chilldown, the liquid in the system was subcooled to a point between the engine pump inlet and the chilldown system return line; the system became entirely subcooled during prepressurization. The chilldown shutoff valve was left open until shortly before engine cutoff (ECC -26 sec).

For the calculation of heat input to section 1 of the LH2 chilldown system (tank to pump inlet), the reference temperature is the chilldown pump discharge temperature (C0157). Since this measurement was not installed on S-IVB-504N and subsequent stages, the LH2 bulk temperature (C0052) plus a 1.0-deg R bias was substituted. The bias was established from previous acceptance firing data.

8.4 Engine LH2 Supply

The LH2 supply system (figure 8-9) delivered the necessary quantity of LH2 to the engine pump inlet during engine firing and maintained the pressure and temperature conditions within a range that provided an LH2 pump NPSP above the minimum requirements. The data and the calculated performance are presented in figure 8-10. Table 8-5 compares the S-IVB-507 stage readout data and calculated performance data with that from previous acceptance firings.

During engine operation, the LH2 pump inlet temperature and pressure were very near the predicted values. The LH2 pump inlet temperature and pressure at selected times during engine operation were plotted in the engine LH2 pump operating region (figure 8-11) and showed that the engine inlet conditions were met satisfactorily throughout engine operation.

Figure 8-12 is a plot of the pump inlet temperature as a function of the propellant mass remaining in the LH2 tank and includes S-IVB-505N and S-IVB-506N data comparisons. The data compared have been biased to the LH2 pump inlet temperature observed at S-IVB-507 Engine Start Command to correct for instrument error, different heating during pressurization, and other test-to-test variations.

TABLE 8-1
LH2 TANK PREPRESSURIZATION DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Prepressurization duration (sec)	31.8	50.5	51.8
Helium mass added (lbm)	25.7	20.2	30.5
Ullage pressure			
At prepressurization initiation (psia)	15.2	15.4	15.1
At prepressurization termination (psia)	30.3	30.2	33.7
At simulated liftoff (psia)	31.5	31.0	34.3
At Engine Start Command (psia)	31.7	32.0	35.8
Rate of increase after prepressurization (psi/min)	1.2	0.9	1.0
Events (sec from T_0)			
Prepressurization initiation	-94.1	-94.7	-93.5
Prepressurization termination	-62.3	-44.2	-41.7
Engine Start Command	511.7	511.4	511.8

TABLE 8-2
LH2 TANK PRESSURIZATION DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Pressure switch setting			
First burn			
Lower (psia)	28.2	28.3	28.0
Upper (psia)	30.3	30.7	30.7
Second burn			
Lower (psia)	28.4	28.3	31.1
Upper (psia)	30.6	30.5	33.6
Ullage pressure			
At Engine Start Command (psia)	31.7	32.0	35.8
At step pressurization (psia)	31.7	31.9	33.0
At Engine Cutoff Command (psia)	32.1	32.7	35.8
GH2 pressurant flowrate			
Overcontrol--high EMR (lbm/sec)	--	--	--
Overcontrol--low EMR (lbm/sec)	--	--	0.70
Undercontrol--high EMR (lbm/sec)	0.63	0.63	0.51
Undercontrol--low EMR (lbm/sec)	0.61	0.60	--
Step	1.09	1.03	0.90
Total GH2 added (lbm)	281	290	294
Events (sec from T_0)			
Vent and relief valve open	921.9	927.5	927.3
Engine Cutoff Command	947.8	959.5	963.3

TABLE 8-3
LH2 TANK REPRESSURIZATION DATA

PARAMETER	S-IVB-507		S-IVB-506N		S-IVB-505N	
	AMBIENT	BURNER	AMBIENT	BURNER	AMBIENT	BURNER
Repressurization duration (sec)	28.9	151*	40	147*	157	181**
Ullage volume (ft^3)	4,519	4,559	4,720	4,880	4,820	4,750
Ullage pressure						
At repressurization initiation (psia)	21.4	20.0	21.0	19.6	17.2	20.2
At repressurization termination (psia)	30.3	30.3	30.0	30.2	33.4	33.5
Rise rate (psi/min)	18.4	4.10	13.5	4.30	6.18	4.41
Repressurization helium usage (lbm)	24.6	18.1	26.1	16.5	39.0	22.6

*Does not include the 6.84-sec lag in repressurization initiation following burner start command.

**Does not include the 11-sec lag in repressurization initiation following burner start command.

TABLE 8-4 (Sheet 1 of 2)
LH2 RECIRCULATION CHILLDOWN DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
NPSP			
At Engine Start Command (psi)	13.3	8.8	14.8
Minimum required at start (psi)	4.5	4.5	6.3
Maximum during chilldown (psi)	21.0	19.2	23.4
Average flow coefficient ($sec^2/in.^2\ ft^3$)	18.1	18.1	18.2
Fuel quality in sections* 2 and 3 (lb gas/lb mixture)			
Maximum--unpressurized chilldown	0.014	0.027	0.034
At prepressurization initiation	0.011	0.023	0.020
Fuel pump inlet conditions			
Static pressure at start (psia)	33.5	33.6	36.8
Temperature at start (deg R)	38.5	39.9	38.9
Amount of subcooling at start (deg R)	3.6	2.3	3.6
Heat absorption rate			
Unpressurized chilldown			
Section* 1 (Btu/hr)	10,000	20,000	18,200
Sections* 2 and 3 (Btu/hr)	18,000	17,500	16,900
Total (Btu/hr)	28,000	37,500	35,100
Pressurized chilldown			
Section* 1 (Btu/hr)	9,000	18,000	16,200
Section *2 (Btu/hr)	12,000	8,500	13,900
Section* 3 (Btu/hr)	18,000	18,000	13,600
Total (Btu/hr)	39,000	44,500	43,700

*Section 1 is tank to pump inlet; section 2 is pump inlet to bleed valve; section 3 is bleed valve to tank

TABLE 8-4 (Sheet 2 of 2)
LH2 RECIRCULATION CHILLDOWN DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Chilldown flowrate			
Unpressurized (gpm)	120	108	108
Pressurized (gpm)	140	137	138
Chilldown pump pressure differential			
Unpressurized (psi)	8.7	9.4	8.8
Pressurized (psi)	7.8	7.75	7.6
Events (sec from T_0)			
Chilldown initiated	-298.6	-299.4	-295.1
Prevalve closed	-283.2	-283.9	-291.4
Prepressurization	-94.1	-94.7	-93.5
Prevalve opened	510.2	509.7	508.4
Chilldown pump off	511.2	510.7	510.8
Engine Start Command	511.7	511.4	511.8
Chilldown shutoff valve closed	922.2	921.8	862.2

TABLE 8-5
LH2 PUMP INLET CONDITION DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Pump inlet conditions			
Static pressure at engine start (psia)	33.5	33.6	36.8
Static pressure at engine cutoff (psia)	31.7	31.1	34.5
Temperature at engine start (deg R)	38.5	39.9	38.9
Temperature at engine cutoff (deg R)	39.0	39.6	39.5
NPSP requirements at pump interface			
Minimum at engine start (psi)	4.5	4.5	6.0
At high EMR (psi)	5.3	5.3	6.5
After EMR cutback (psi)	4.9	4.9	5.8
NPSP available at pump interface			
At engine start (psi)	13.3	8.8	14.8
Maximum (psi)	15.9	15.1	21.5
Minimum (psi)	11.0	9.5	10.3
At engine cutoff (psi)	11.0	10.0	12.2
LH2 suction duct			
At high EMR			
Pressure drop (psi)	0.3	0.5	0.9
Flowrate (lbm/sec)	85	83	81
After EMR cutback			
Pressure drop (psi)	0.5	0.4	0.8
Flowrate (lbm/sec)	84	80	77

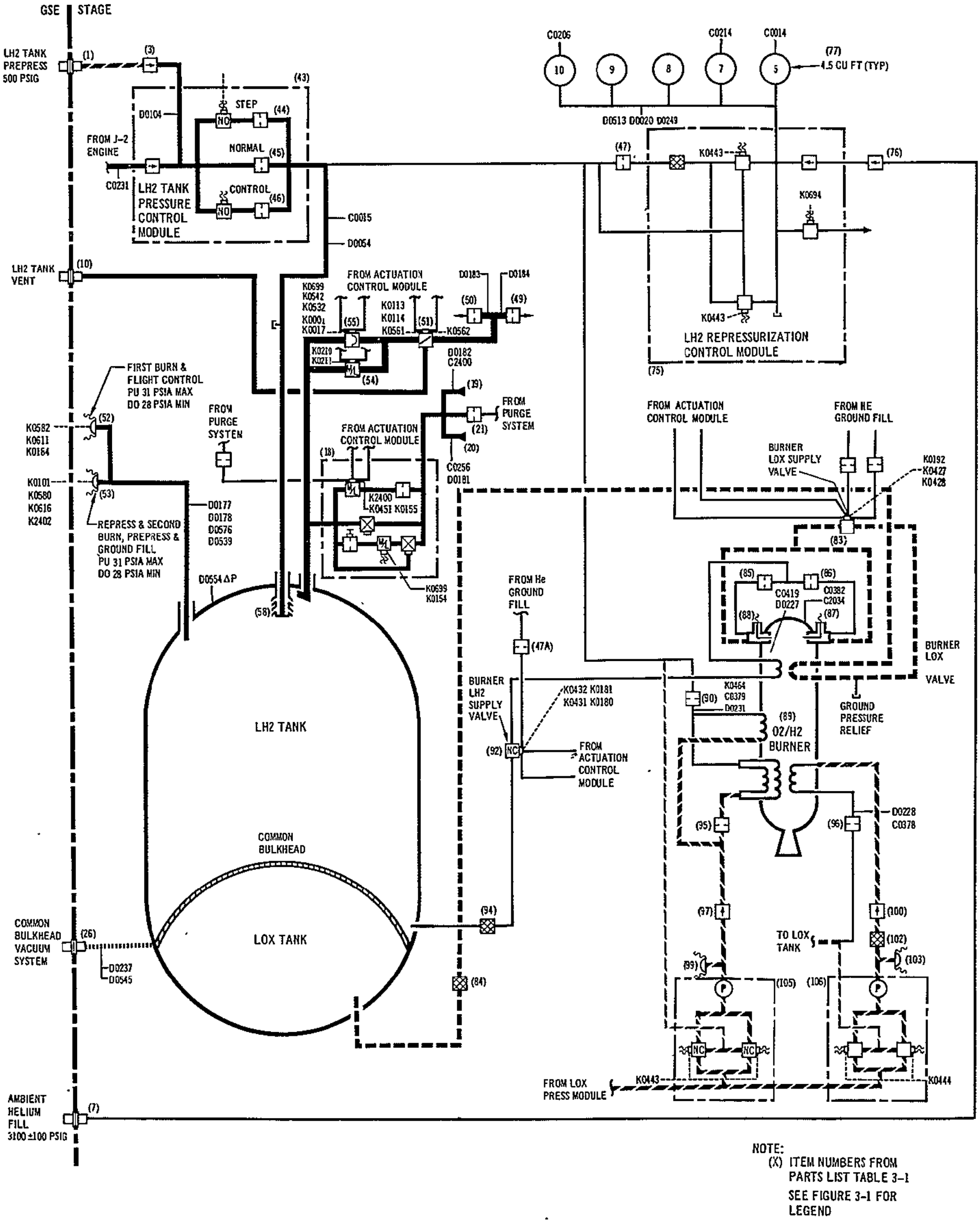


Figure 8–1. LH2 Tank Pressurization System

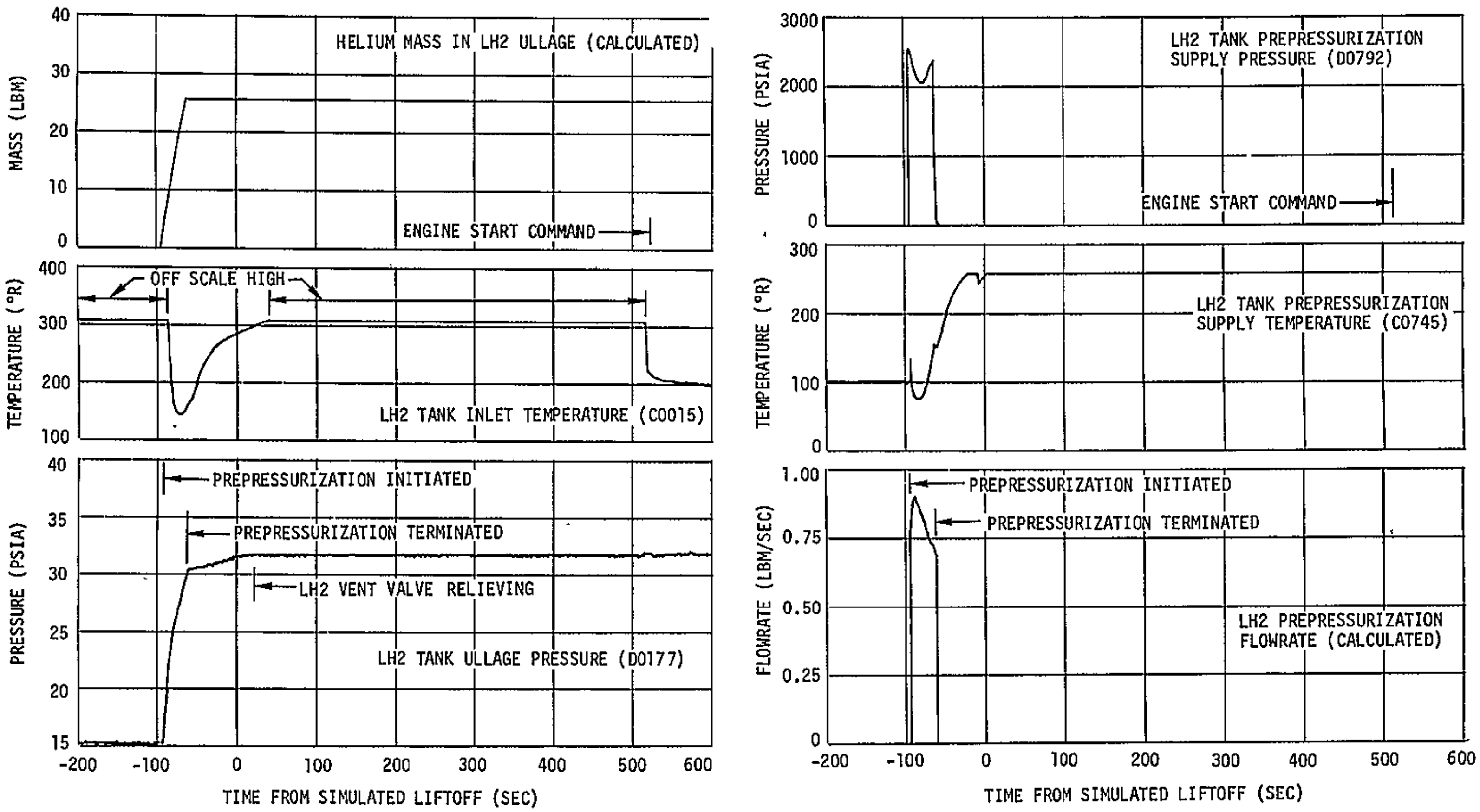


Figure 8-2. LH2 Tank Prepressurization System Performance

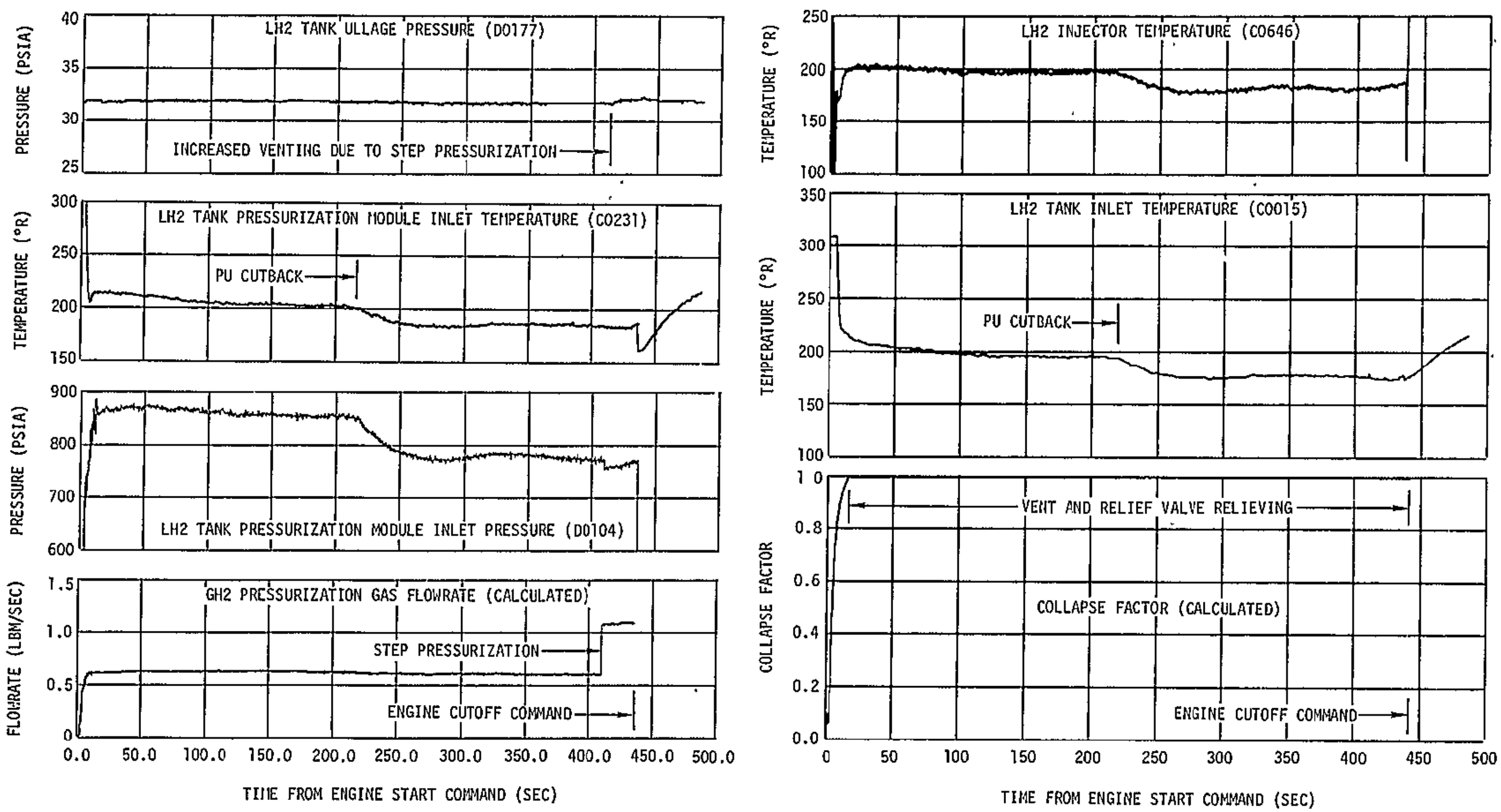


Figure 8-3. LH2 Tank Pressurization System Performance

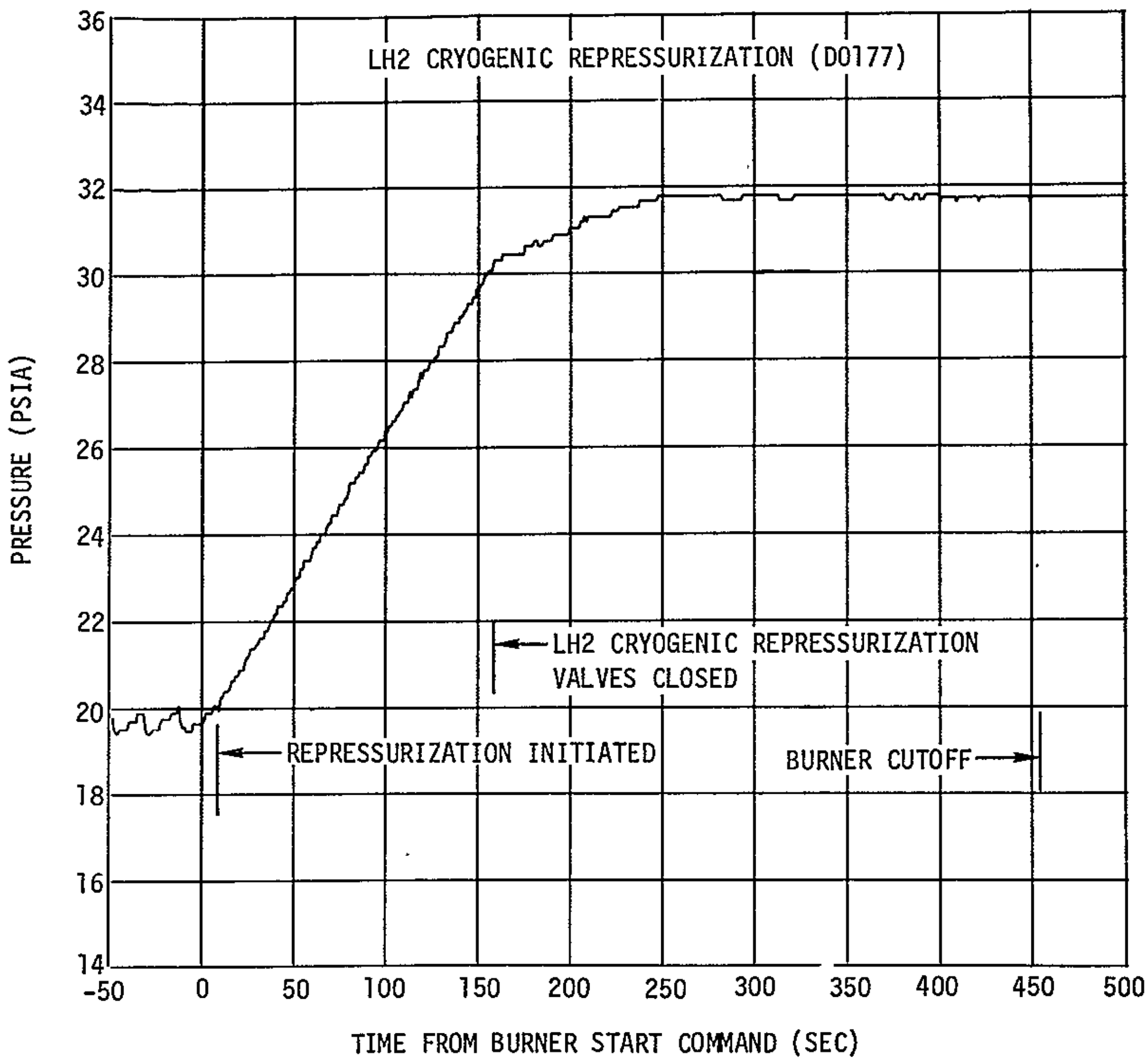


Figure 8-4. LH2 Tank Pressures During O2-H2 Burner Repressurization

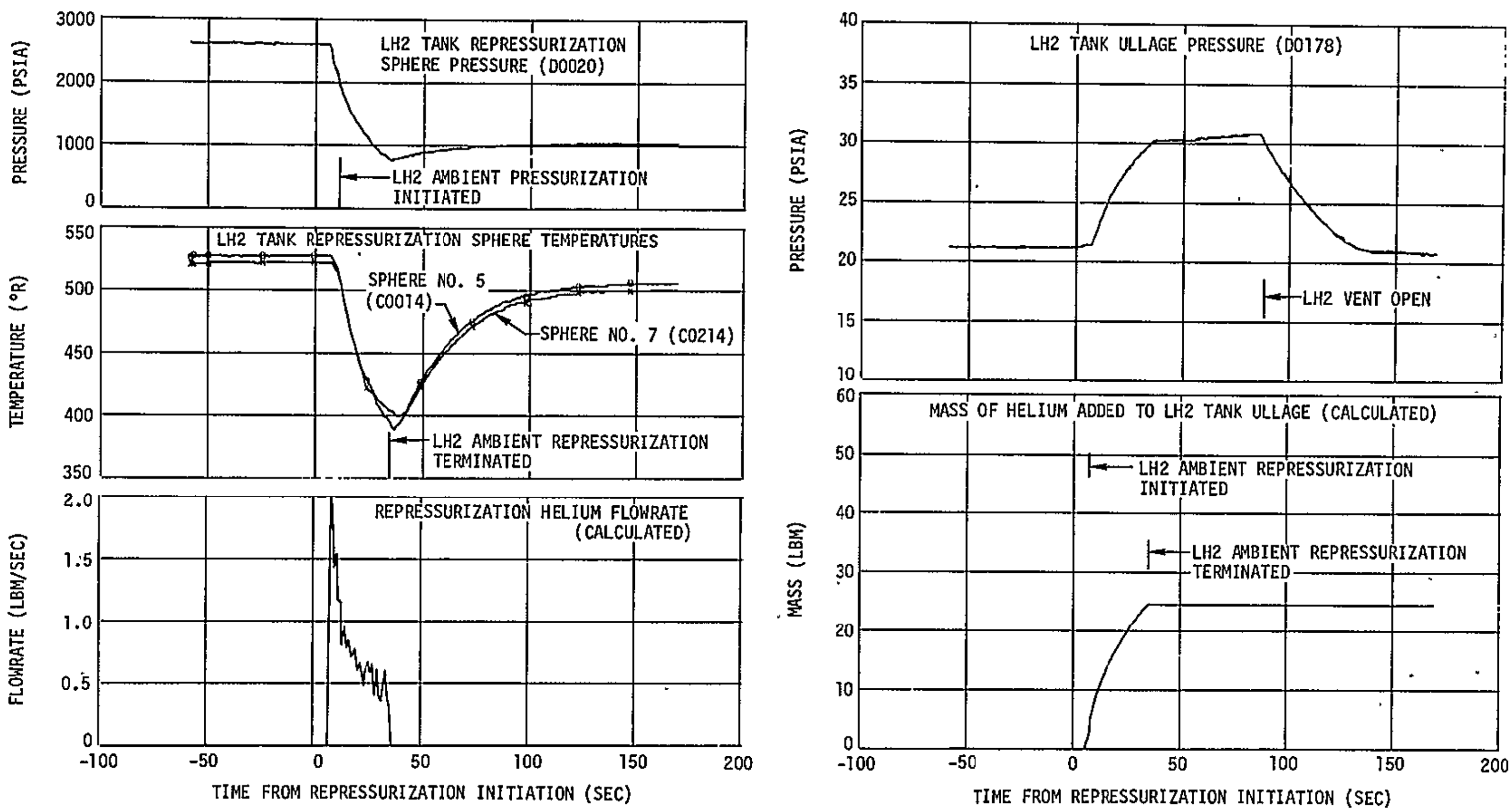


Figure 8-5. LH2 Tank Ambient Helium Repressurization System Performance

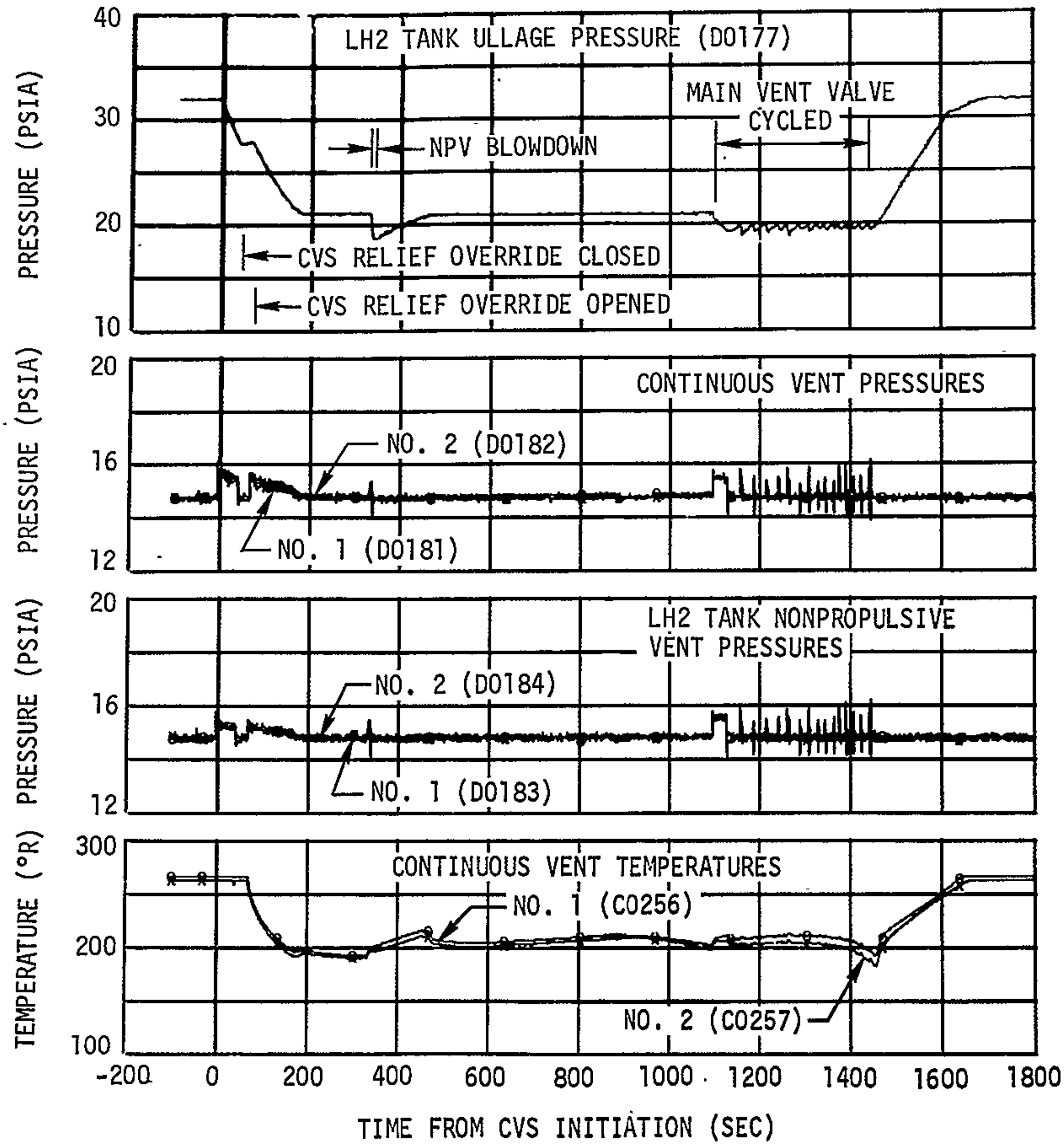


Figure 8-6. LH2 Tank Venting System Operation

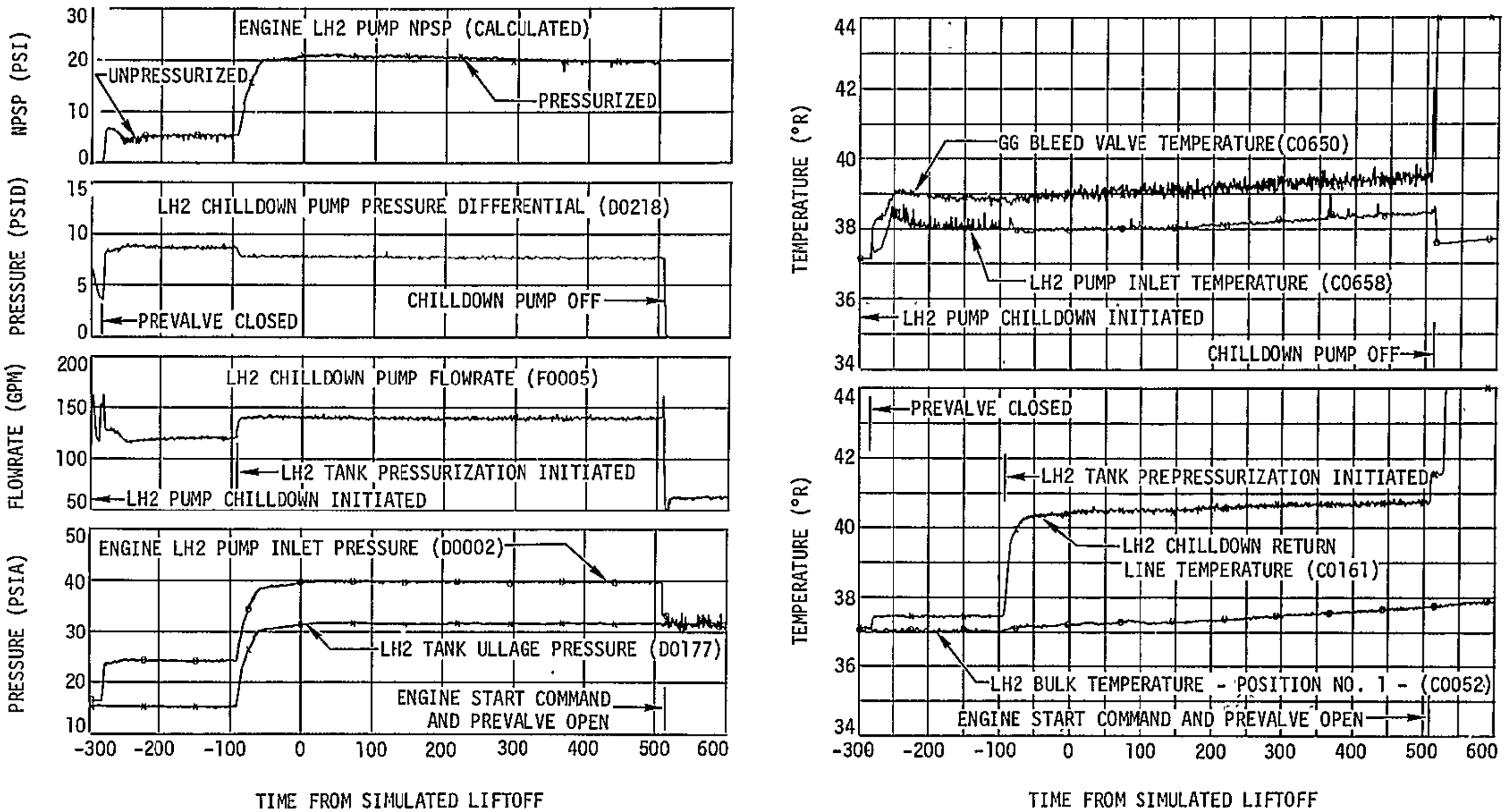


Figure 8-7. LH2 Pump Chilldown

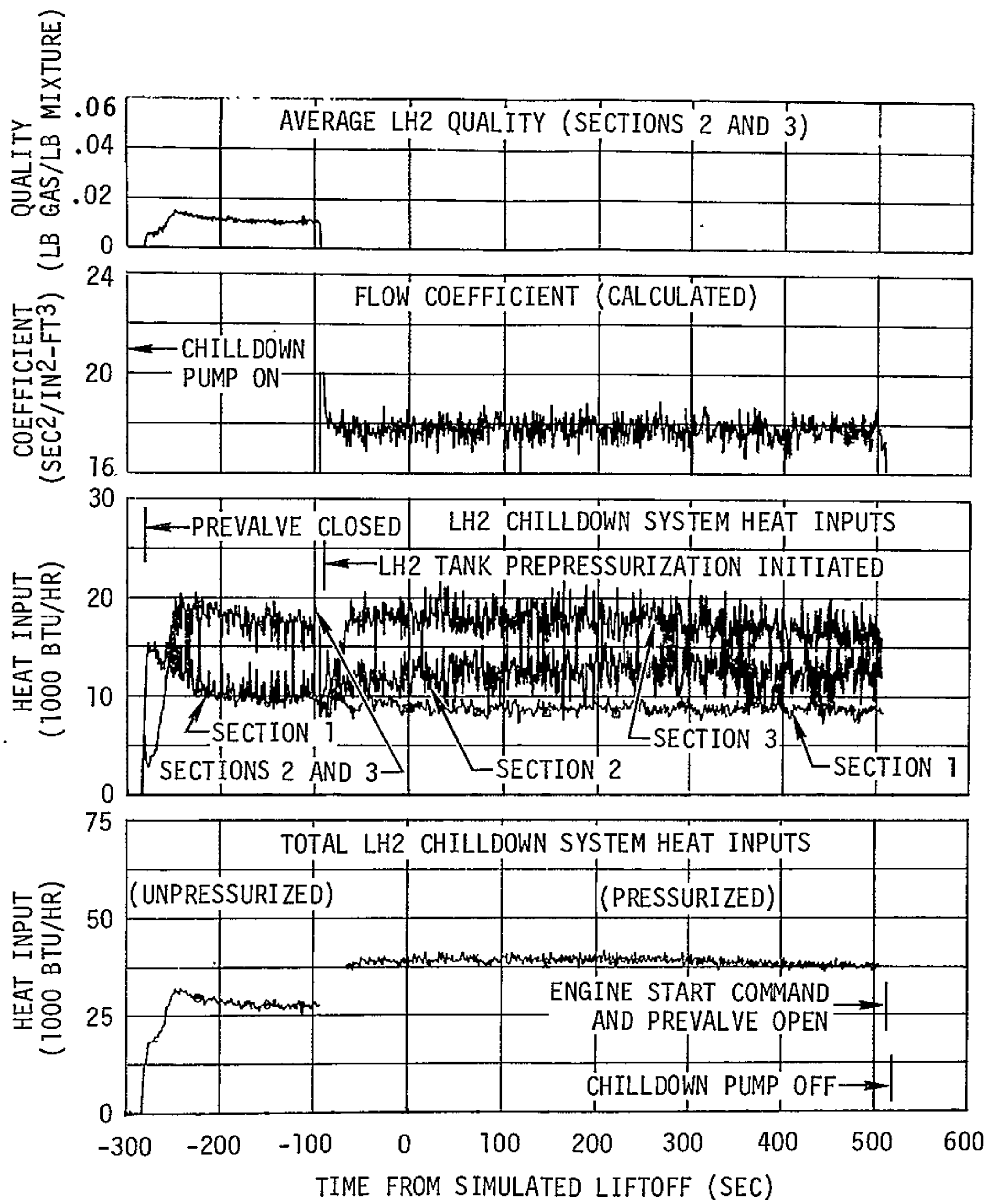
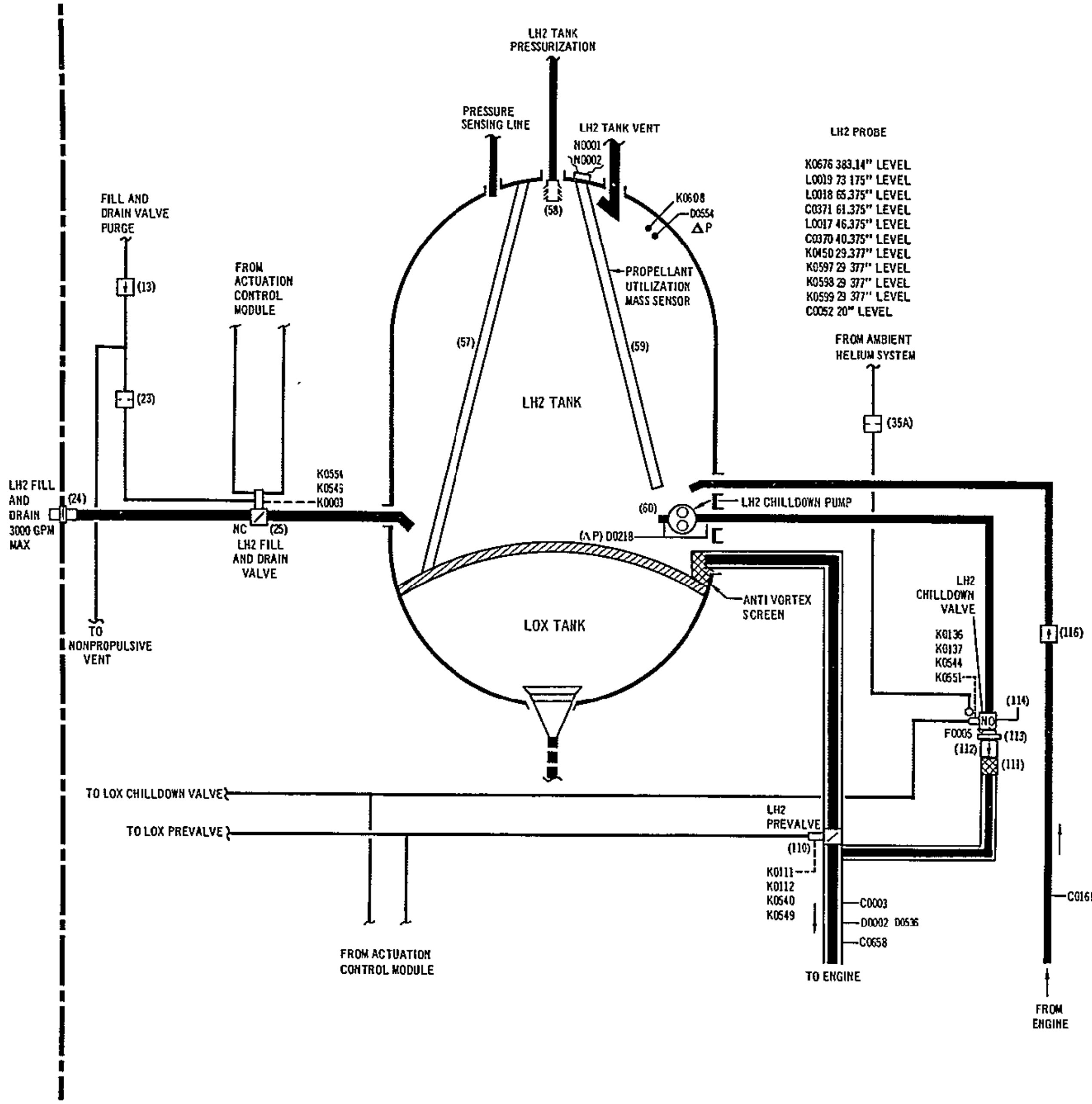


Figure 8-8. LH2 Pump Chilldown Characteristics



NOTE.
(X) ITEM NUMBERS FROM PARTS LIST TABLE 3-1
SEE FIGURE 3-1 FOR LEGEND

Figure 8-9. LH2 Supply System

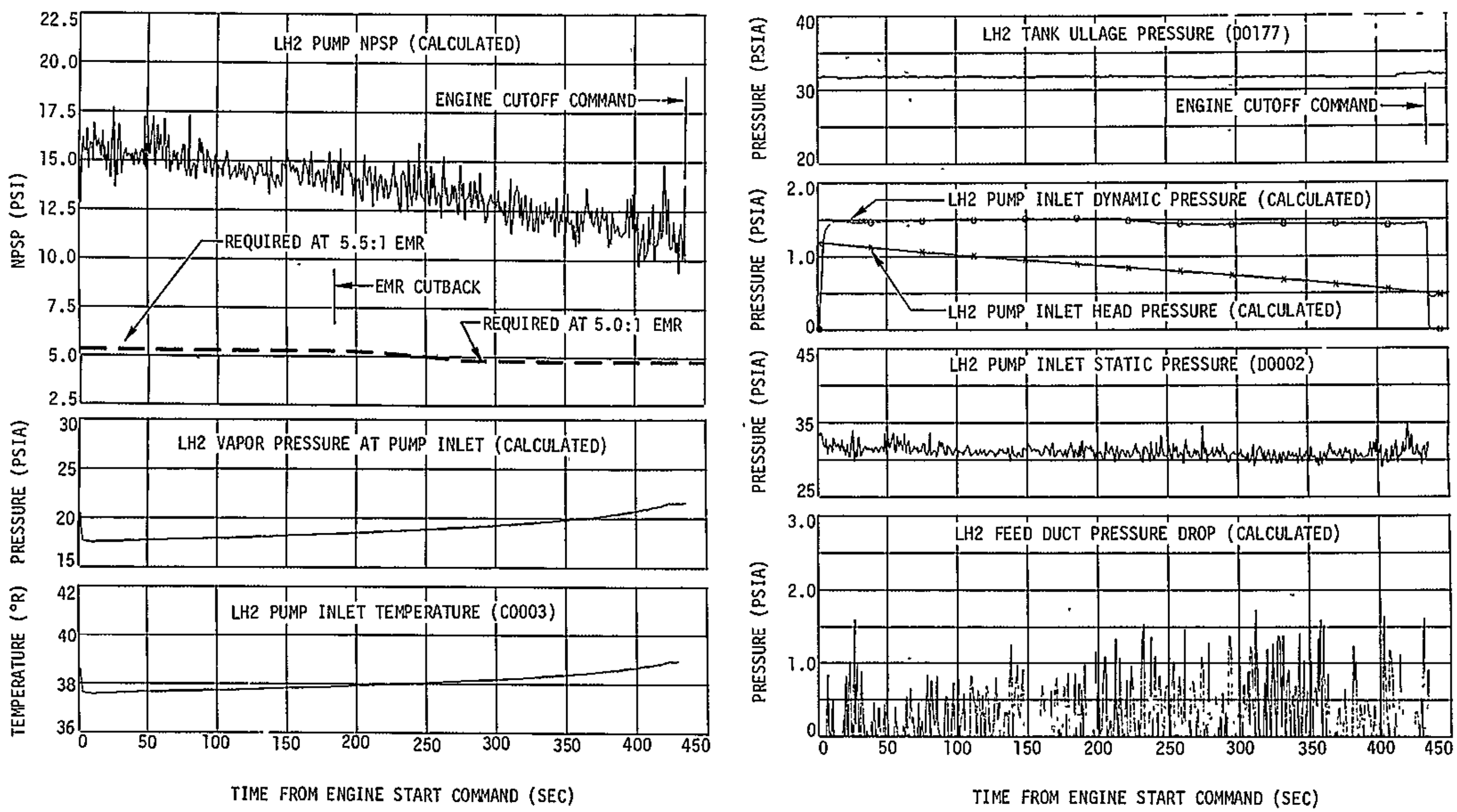


Figure 8-10. LH2 Pump Inlet Conditions

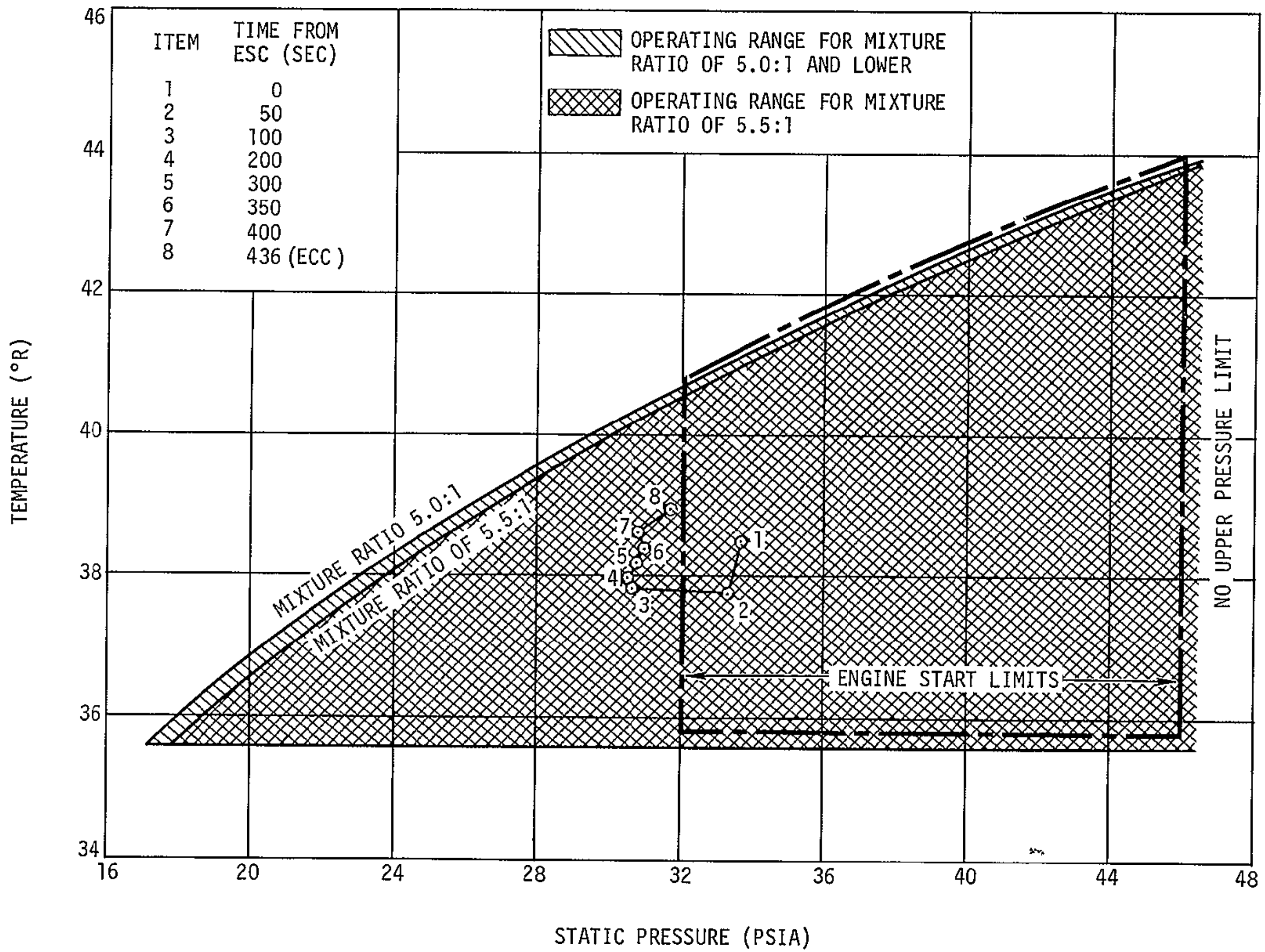


Figure 8-11. LH2 Pump Inlet Conditions During Firing

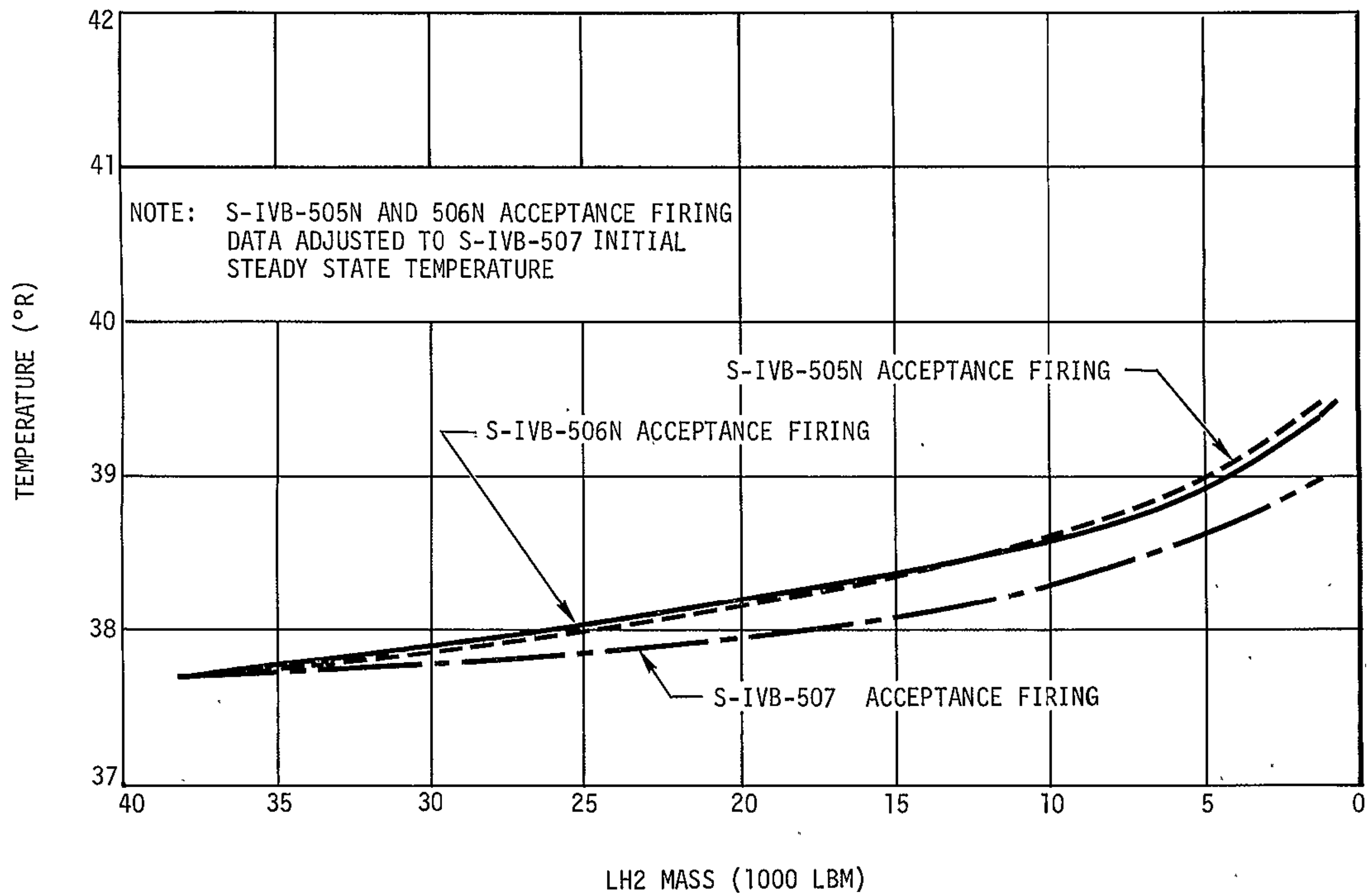


Figure 8-12. Effect of LH2 Tank Mass Level on LH2 Pump Inlet Temperature

9. PNEUMATIC CONTROL AND PURGE SYSTEM

The pneumatic control and purge system (figure 9-1) performed adequately during the acceptance firing. All components functioned properly. The test results are summarized and compared with previous acceptance firing data in table 9-1.

9.1 Ambient Helium Supply

In order to simulate actual flight conditions the stage was isolated from the ground support equipment (GSE). The helium supply valve was closed 513 sec prior to simulated coast and remained closed during the continuous venting period and both the burner and ambient helium repressurization operations. The valve was also closed at T_0 -7 sec and remained closed through J-2 engine operation.

9.2 Pneumatic Control

All engine and stage pneumatic control valves responded properly throughout the terminal countdown, simulated coast, O_2-H_2 burner operation, ambient repressurization, and J-2 engine operation.

During a period of simulated coast the pressure decay of the control helium sphere was higher than normal. This was due to the high bleed rate that accompanies the opening of the latch in the LH2 latching vent and relief valve and the opening of the LOX vent boost close and latch release. The latch in the LH2 latching vent and relief valve was left open during all of the O_2-H_2 burner operation.

The normal system pressure drops that result from regulator operation during J-2 engine and O_2-H_2 burner operation are shown in figures 9-2 and 9-3, respectively.

9.3 Ambient Helium Purges

During the acceptance firing all stage purge functions that utilize stage pneumatics were satisfactorily accomplished. The pneumatic system was isolated from the GSE during the periods of simulated coast and engine firing, discontinuing those purges which were facility supplied. Table 3-2 lists the flowrates of the various purge orifices.

TABLE 9-1 (Sheet 1 of 2)
PNEUMATIC CONTROL AND PURGE SYSTEM DATA

PARAMETER	S-IVB-507		S-IVB-506N		S-IVB-505N	
	ENGINE OPERATION	BURNER OPERATION	ENGINE OPERATION	BURNER OPERATION	ENGINE OPERATION	BURNER OPERATION
Sphere volume (cu ft)	4.5	4.5	4.5	4.5	4.5	4.5
Sphere pressure						
At simulated liftoff (psia)	2,966	---	2,817	---	2,945	---
At Engine Start Command (psia)	2,855	2,175 1,941*	2,709	2,159 1,965*	2,844	2,728
At Engine Cutoff Command (psia)	2,852	2,024 1,903*	2,713	2,099 1,950*	2,842	2,725
Sphere temperature						
At simulated liftoff (deg R)	540	---	549	---	537	---
At Engine Start Command (deg R)	534	526 523*	541	537 536*	540	536
At Engine Cutoff Command (deg R)	533	523 522*	541	537 536*	541	537
Helium mass usage rate						
Pre-burn engine pump purge (lbm/min)	0.070	---	0.080	---	0.076	---
Post-burn engine pump purge (lbm/min)	0.146	---	0.125	---	0.100	---
Simulated coast with no engine pump purge (lbm/min)	0.010	---	0.0033	---	0.0037	---

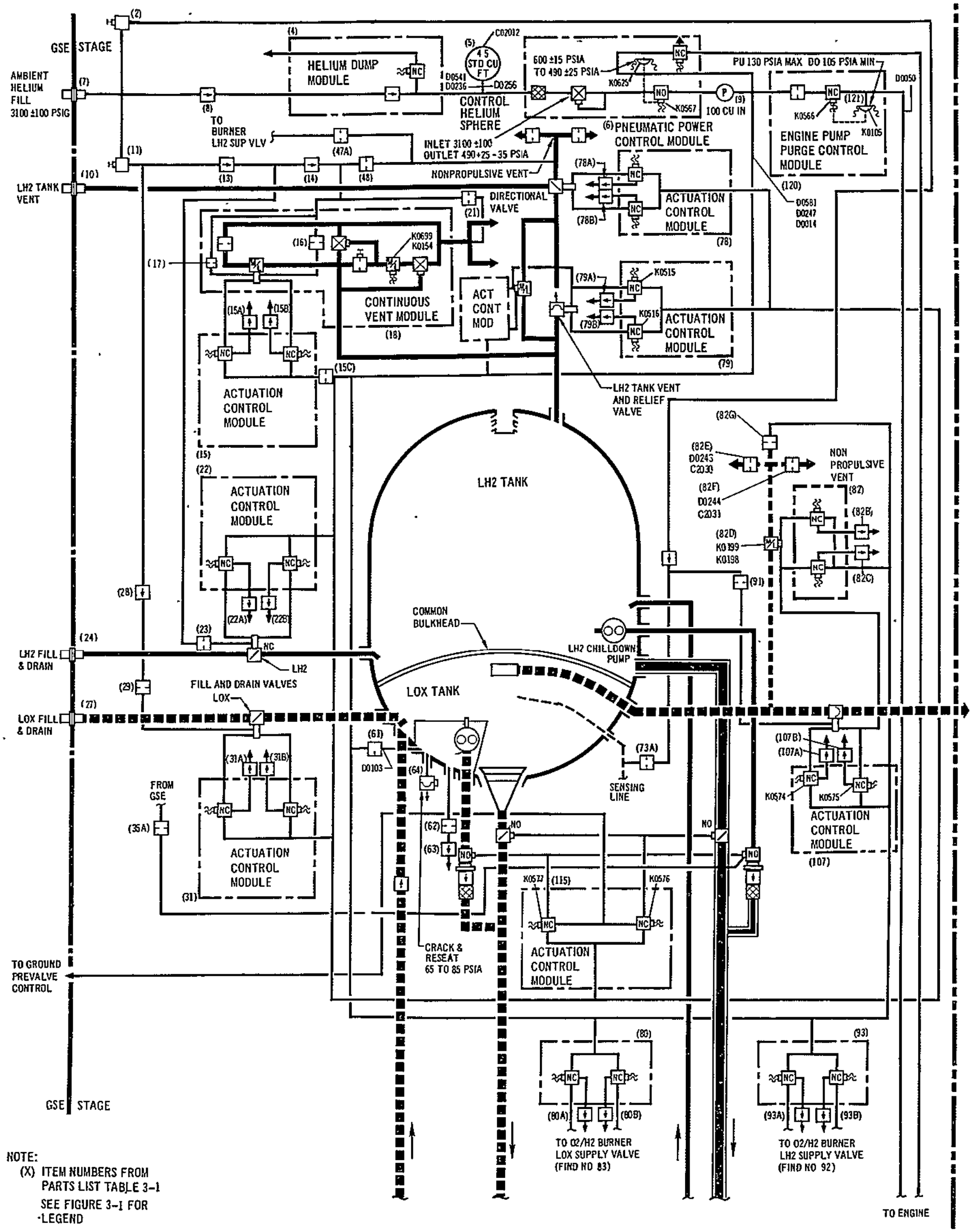
*Value obtained from second burner operation.

TABLE 9-1 (Sheet 2 of 2)
PNEUMATIC CONTROL AND PURGE SYSTEM DATA

PARAMETER	S-IVB-507		S-IVB-506N		S-IVB-505N	
	ENGINE OPERATION	BURNER OPERATION	ENGINE OPERATION	BURNER OPERATION	ENGINE OPERATION	BURNER OPERATION
Burn duration (sec)	436	455 130**	448.1	456 130**	451.5	190
Helium mass						
At simulated liftoff (lbm)	8.39	---	7.89	---	8.39	---
At Engine Start Command (lbm)	8.19	6.46 5.85**	7.71	6.29 5.78**	8.12	7.78
At Engine Cutoff Command (lbm)	8.19	6.07 5.74**	7.71	6.13 5.74**	8.10	7.76
Usage during engine or burner operation (lbm)	0.00	0.39 0.11**	0.00	0.16 0.04**	0.02	0.02
Usage during 10-min post-burn engine pump purge* (lbm)	1.46	---	1.25	---	1.00	---
Maintained regulator outlet pressure band						
Low (psia)	534	540 540**	513	510 510**	520	520
High (psia)	565	543 542**	556	543 540**	550	540
System minimum during start and cut-off transient (psia)	426	---	423	---	434	---
Average LOX chilldown motor container purge pressure (psia)	61	60	57	57 56**	72	63

*Estimated on basis of purge flowrate.

**Value obtained from second burner operation.



NOTE:
(X) ITEM NUMBERS FROM PARTS LIST TABLE 3-1
SEE FIGURE 3-1 FOR LEGEND

Figure 9–1. Pneumatic Control and Purge System

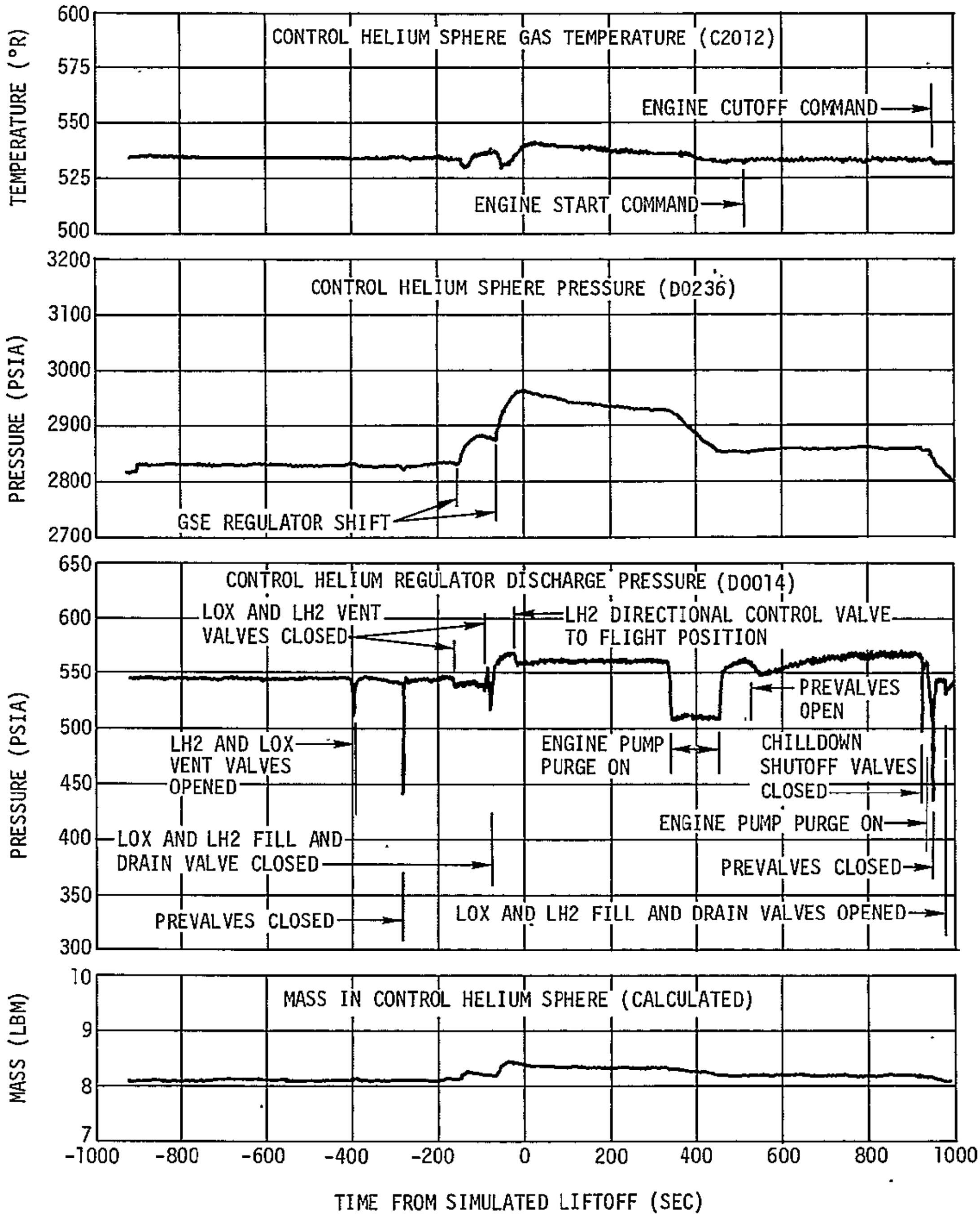


Figure 9-2. Pneumatic Control and Purge System Performance

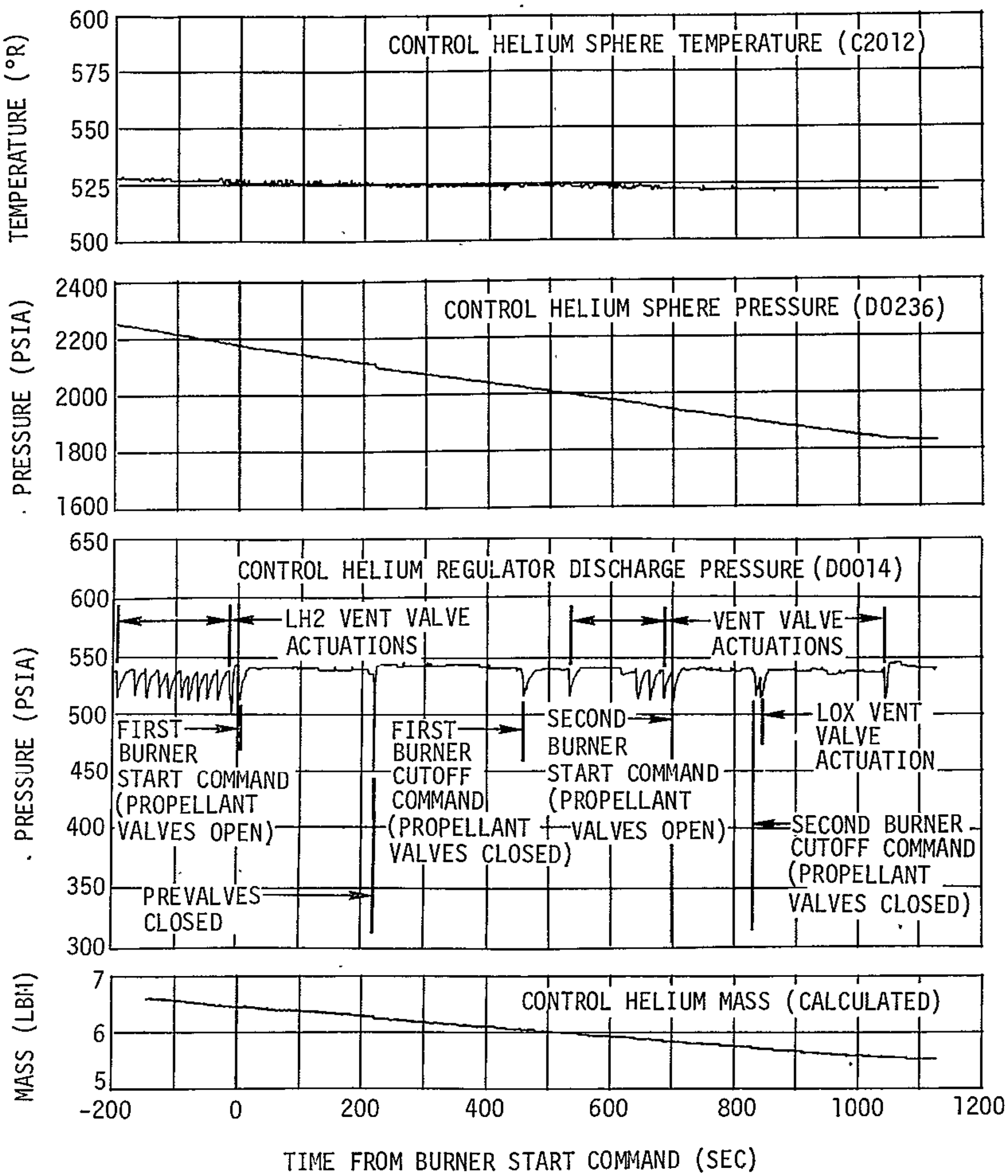


Figure 9-3. Pneumatic Control System Conditions During O2-H2 Burner Operation

10. OXYGEN-HYDROGEN BURNER SYSTEM

The O_2-H_2 burner (figure 10-1) was acceptance tested prior to the S-IVB-507 acceptance firing. It was of the same design (high chamber pressure) that was tested on S-IVB-504N, 505N, and 506N.

The S-IVB-507 burner acceptance test differed from previous acceptance tests in two ways. The S-IVB-503N, 504N, and 505N burner operations were terminated by pickup of the LH2 flight control pressure switch, whereas the S-IVB-506N and 507 burner operations were not. In addition, the burner was operated twice during the S-IVB-506N and 507 acceptance tests - the first time to repressurize the LH2 and LOX tanks, and the second to show the burner restart capability for ullaging purposes.

10.1 O_2-H_2 Burner Performance

10.1.1 First Burner Operation

The burner performed satisfactorily during the first operation which lasted 455 sec. The LH2 tank was repressurized 158 sec after burner start, and the LOX tank repressurization was terminated at the same time. Performance data are presented in figures 10-2 to 10-5, all of which compare the LH2 tank and LOX tank burner repressurization performance during S-IVB-506N and 507 acceptance firings.

During the first burner operation one irregularity did occur. A drop in pressurant flowrate to the LH2 tank occurred 56 sec after burner start. The magnitude of this drop was 2.4 percent of the flow at that time. This drop in flowrate had no detrimental effect on the performance of the burner. The irregularity is presently under investigation.

10.1.2 Second Burner Operation

The burner functioned normally during the restart operation. During this second period of operation, which was 130.6 sec in duration, the fuel supply pressure increased from 20.6 to 21.9 psia, and the LOX supply pressure decreased from 39.9 to 39.4 psia as shown in figure 10-6.

The maximum combustion chamber temperature and thrust were 1,980 deg R and 15.8 lbf, respectively, during operation (figure 10-6). The comparatively steady supply pressures, which resulted from the absence of repressurization during second burner operation, caused the stable burner operation following the start transient.

10.2 LH2 Tank Repressurization

The LH2 tank pressurant started flowing 6.87 sec after burner start command. The LH2 tank ullage was then pressurized from 20.00 to 30.20 psia in 151 sec, for an average rate of 4.05 psi/min. The actual burner LH_2 supply pressure range was from 20.87 psia to 31.07 psia due to a 0.87 psi head.

The 4.05 psi/min repressurization rate was 0.92 psi/min higher than the theoretical rate based on an adiabatic repressurization process. The higher than theoretical pressurization rate was the result of the relatively warm temperatures of the cold helium spheres. Approximately 22.5 lbm of helium were required for LH2 tank repressurization.

The average total LH2 tank repressurization heat flux (the heating of the LH2 tank pressurant gas from the 40 deg R reference base to the burner LH2 repressurization outlet temperature) was 243,000 Btu/hr. Ambient heating (the heating of the LH2 tank pressurant gas from the 40 deg R reference base to the burner inlet temperature) contributed approximately 64,000 Btu/hr to the total LH2 tank repressurization heat flux. The ambient heating was greater for S-IVB-506N and 507 (compared to previous acceptance tests) due to the higher initial temperatures of the cold helium spheres. The cold helium sphere temperatures are discussed further in paragraph 10.4.

The LH2 tank repressurization burner heat input rate (the total minus the ambient heating rate), helium flowrate, and repressurization coil outlet temperature are shown in figure 10-3 and further discussed in paragraph 8.1.3. A comparison of O_2-H_2 burner performance during three acceptance firings is presented in table 10-1.

10.3 LOX Tank Repressurization

The LOX tank pressurant started flowing 7.087 sec after burner start command. The LOX tank ullage was then repressurized from 33.7 to 36.5 psia in 151 sec, for an average rate of 1.11 psi/min, which is very close to the theoretical prediction of 1.15 psi/min. To compensate for the 4.64 psia head due to the LOX load during ground testing, the ullage pressure was kept low enough to provide a burner LOX supply pressure range of 38.3 to 41.1 psia.

The total average LOX tank repressurization heat flux (the heating of the LOX tank pressurant gas from the 40 deg R reference base to the burner LOX repressurization outlet temperature) was 48,200 Btu/hr. Ambient heating (the heating of the LOX tank pressurant gas from the 40 deg R reference base to the burner inlet temperature) contributed approximately 11,500 Btu/hr to the total LOX tank repressurization heat flux. As a result of the cold helium sphere temperatures, the ambient heating and LOX repressurization heat flux were comparable to those seen on the S-IVB-506N acceptance test. Approximately 3.8 lbm of helium were required for LOX tank repressurization.

The LOX tank repressurization burner heat input rate (the total minus the ambient heating rate), helium flowrate, and repressurization coil outlet temperature are shown in figure 10-4 and are further discussed in paragraph 7.1.3. The S-IVB-507 acceptance firing LOX tank repressurization performance is compared with S-IVB-506N and 505N acceptance firing performance in table 10-1.

10.4 Cold Helium Supply

The cold helium spheres provided an adequate amount of helium for cryogenic repressurization. The sphere pressure showed an unusual decay prior to first burner start command. This was due to a rise in the LH2 level which partially wetted the No. 4 and No. 5 spheres. The rise in LH2 level was caused by liquid expansion due to heating along with a reduction in pressure, and by volume increase due to formation of bubbles in the liquid. The temperature and pressure profiles after burner start command were as expected and are shown in figure 10-5. The system performance is compared with previous acceptance firings in table 10-1.

10.5 Pilot Bleed Flowrate

The burner helium shutoff valves utilize a pilot bleed system which diverts approximately 0.004 lbm/sec of the total cold helium flow passing through each module and dumps it downstream of the burner exit orifices. Prior to the S-IVB-506N acceptance firing report, the small amount of helium flow through the pilot bleed ports had been neglected; however, in order to add greater accuracy to helium usage evaluations, this pilot bleed flow is included in this report (table 10-1) and will also be included in all future acceptance firing reports.

TABLE 10-1 (Sheet 1 of 2)
O_2-H_2 BURNER PERFORMANCE DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
Duration of burner operation (sec)			
First burn	455.5	456	192
Second burn	130.6	130.6	None
Lag in pressurant flow after burner start (sec)	6.87	6.84	11
Cold helium supply			
Initial pressure (psia)	1,763	1,819	1,509
Initial average temperature (deg R)	64.0	60.3*	57.8
Initial mass (lbm)	224	252	214
Consumption during burner operation (lbm)	22.5	22.9	26.6**
Burner propellant supply during repressurization period			
LH2 supply pressure range (psia)	20.9-31.1	20.5-31.1	21.1-34.4
LOX supply pressure range (psia)	38.3-41.1	39.3-43.2	38.9-42.5
LH2 tank pressurization			
Ullage volume (cu ft)	4,619	4,880	4,750
Initial pressure (psia)	20.0	19.6	20.2
Final pressure (psia)	30.2	30.2	33.5
Average pressurization rate (psi/min)	4.05	4.30	4.41
Total average heat flux rate***	243,000	234,000	223,000
Ambient heating rate*** of pressurant gas (Btu/hr)	64,000	66,536	40,000
Pressurant helium through burner (lbm)	18.1	16.5	22.6
Pressurant helium through valve pilot bleed (lbm)	0.61	0.9	1.06
Total helium required (lbm)	18.71	17.4	23.66

*Weighted average
**Bleed flowrates not included
***Measured from 40 deg R reference base

TABLE 10-1 (Sheet 2 of 2)
O_2-H_2 BURNER PERFORMANCE DATA

PARAMETER	S-IVB-507	S-IVB-506N	S-IVB-505N
LOX tank pressurization			
Ullage volume (cu ft)	969	999	1,056
Initial pressure (psia)	33.7	34.7	34.4
Final pressure (psia)	36.5	38.6	38.0
Average pressurization rate (psi/min)	1.11	1.16	1.19
Total average heat flux rate* from burner (Btu/hr)	48,200	48,880	46,400
Ambient heating rate* of pressurant gas (Btu/hr)	11,500	10,980	7,900
Pressurant helium through burner (lbm)	3.2	4.3	4.0
Pressurant helium through valve pilot bleed (lbm)	0.61	1.2	1.1
Total helium required (lbm)	3.81	5.5	5.1

*Measured from 40 deg R reference base

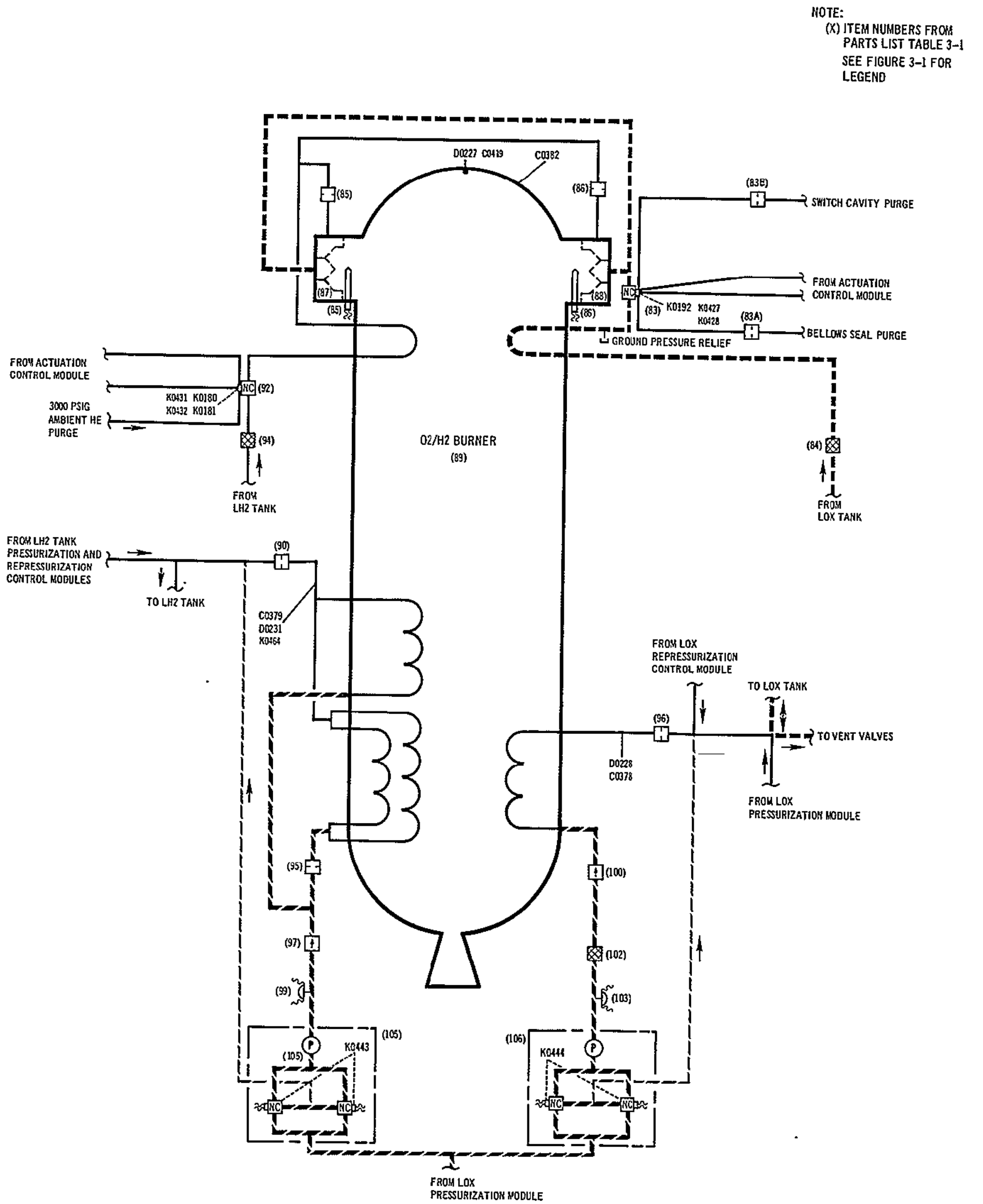


Figure 10-1. O2/H2 Burner Configuration and Instrumentation

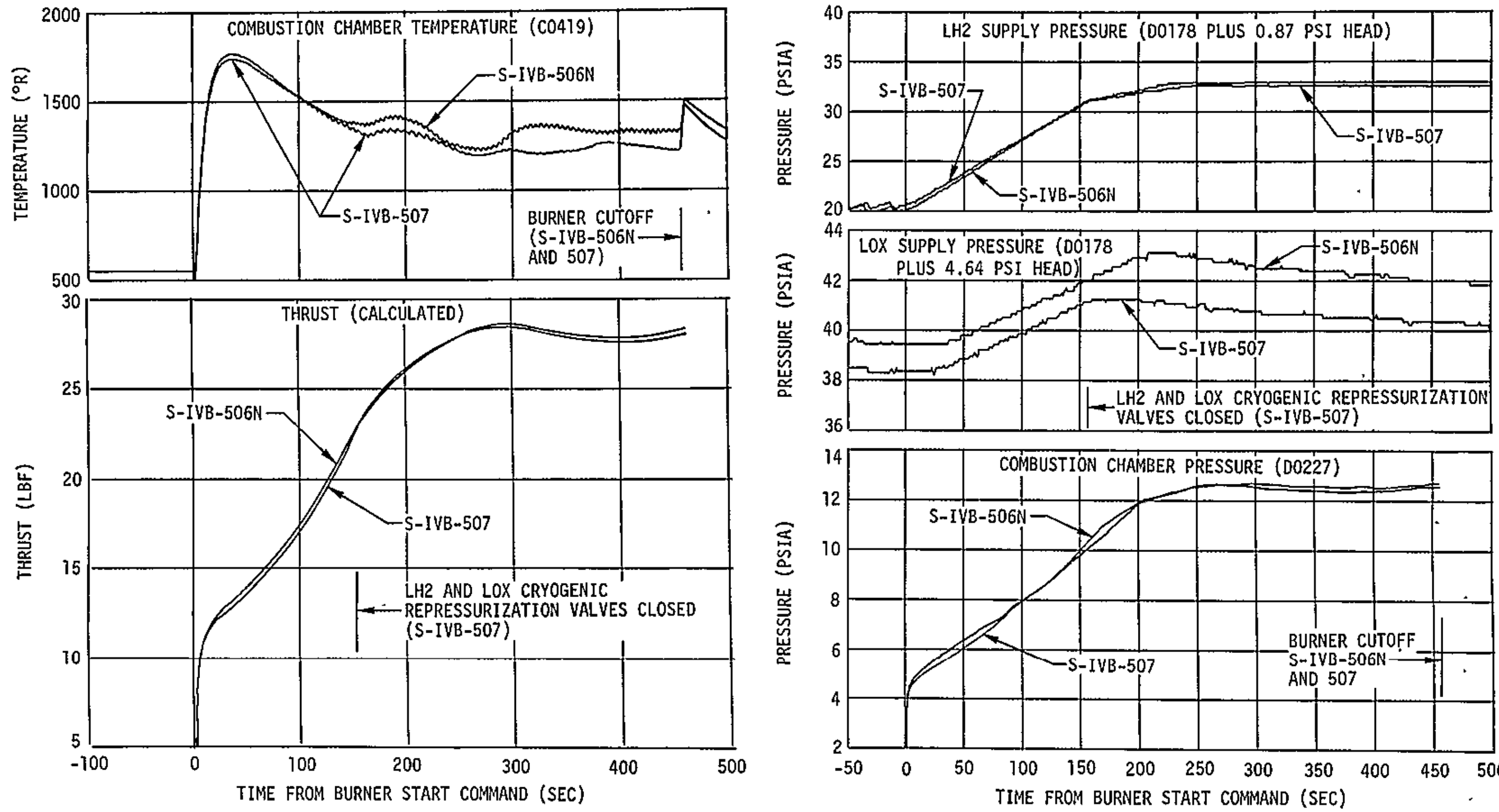


Figure 10-2. First Burner Operation

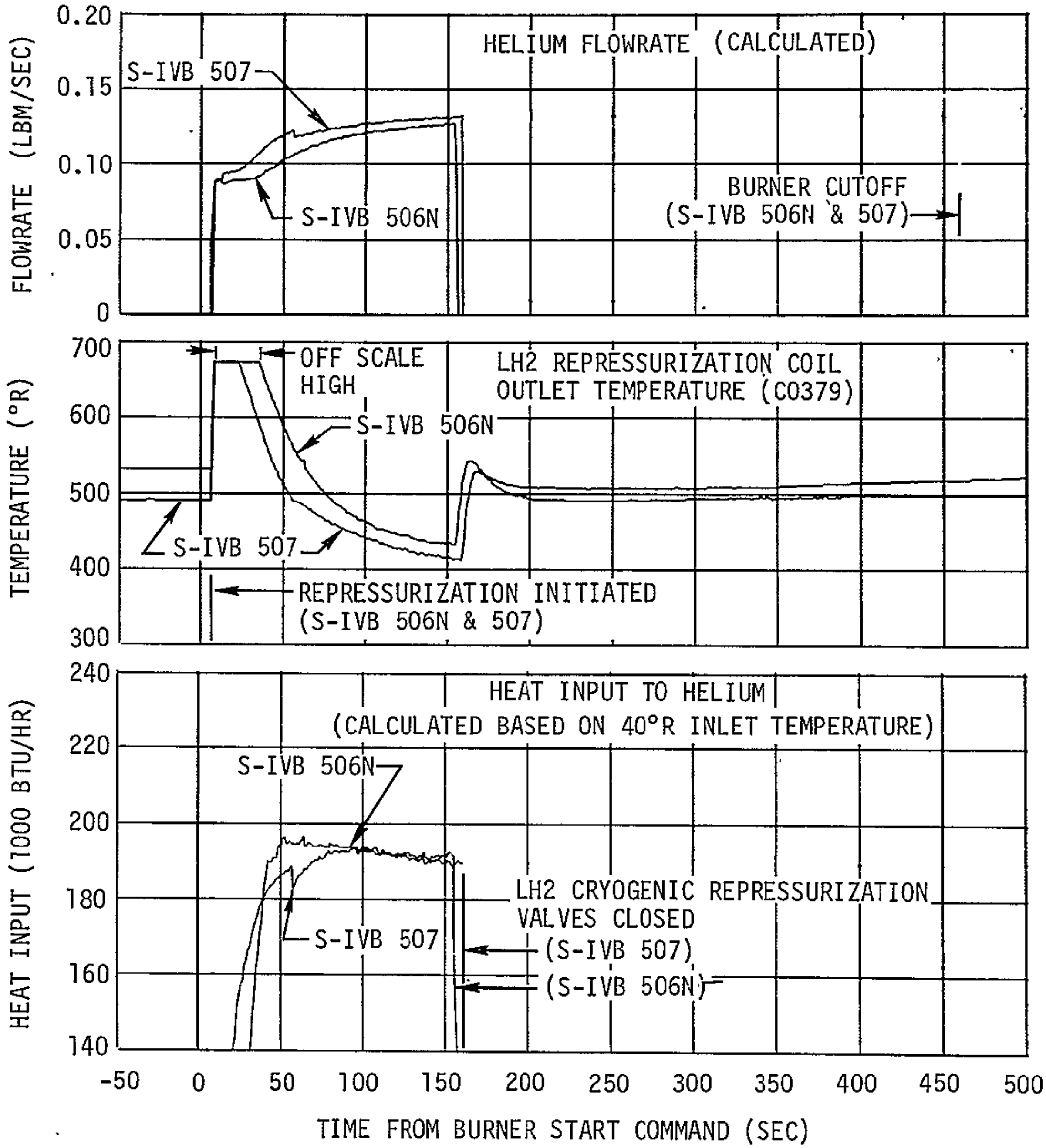


FIGURE 10-3. LH2 TANK REPRESSURIZATION

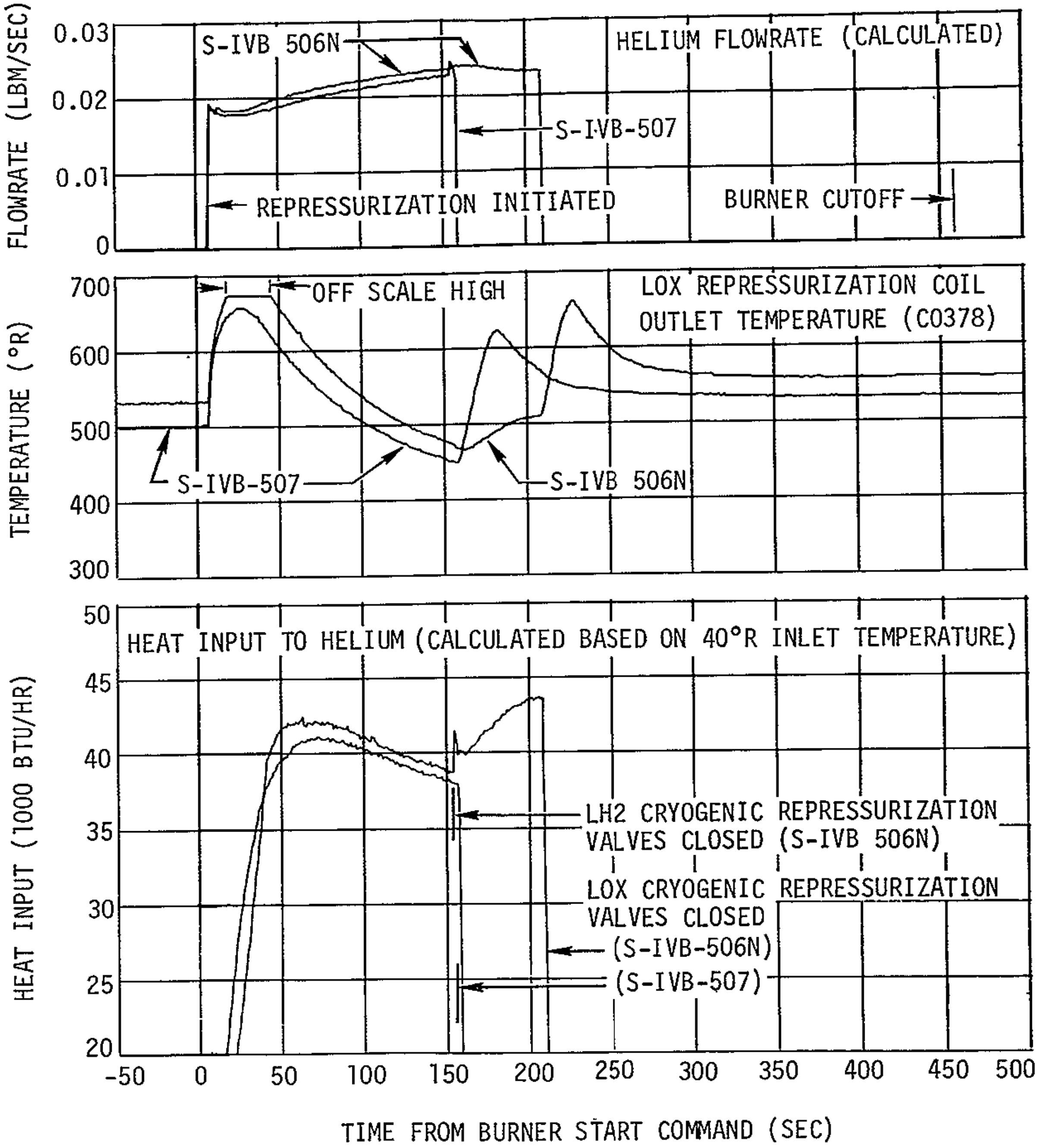


Figure 10-4. LOX Tank Repressurization

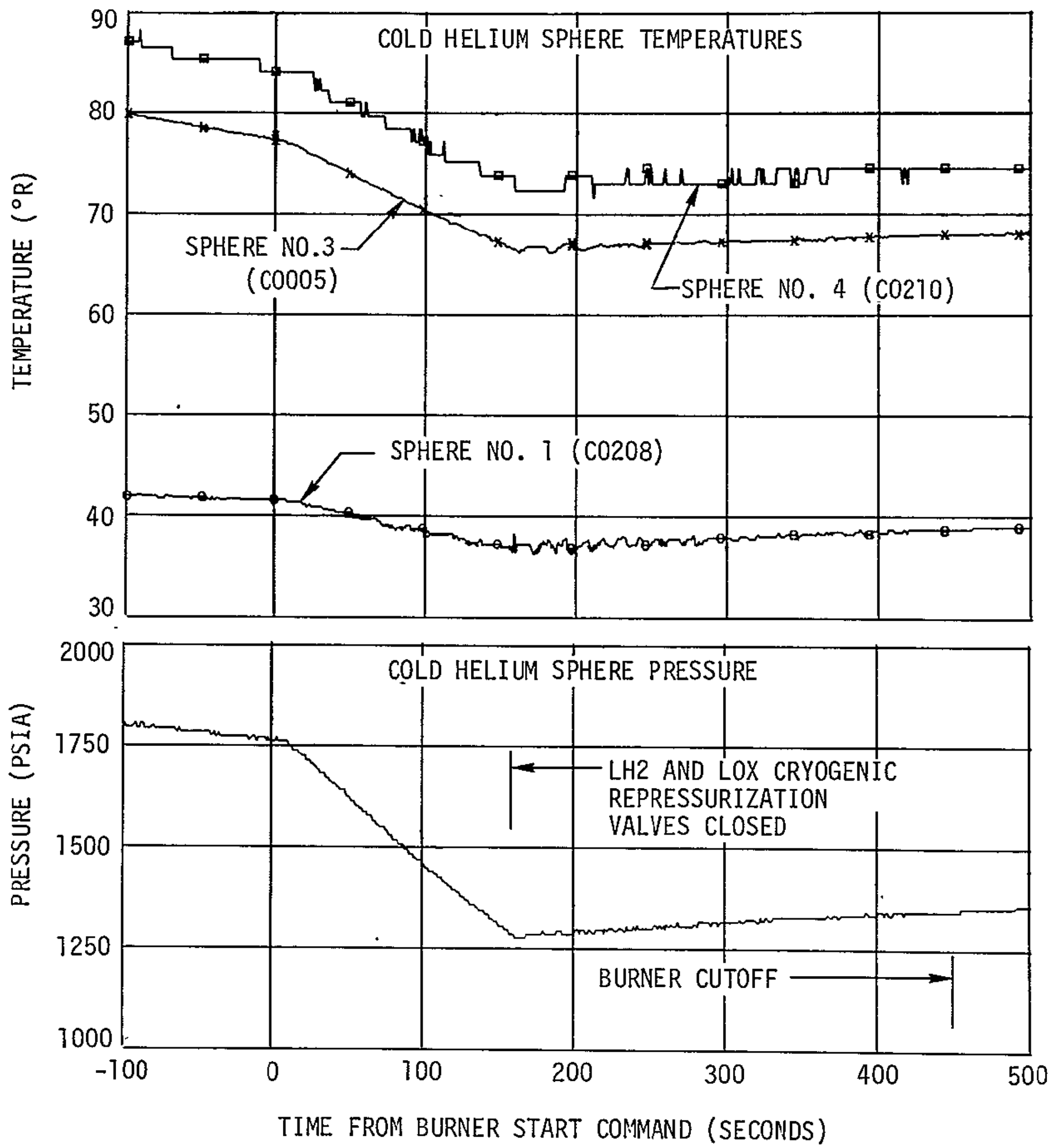


Figure 10-5. Cold Helium Sphere Conditions During O2-H2 Burner Operation

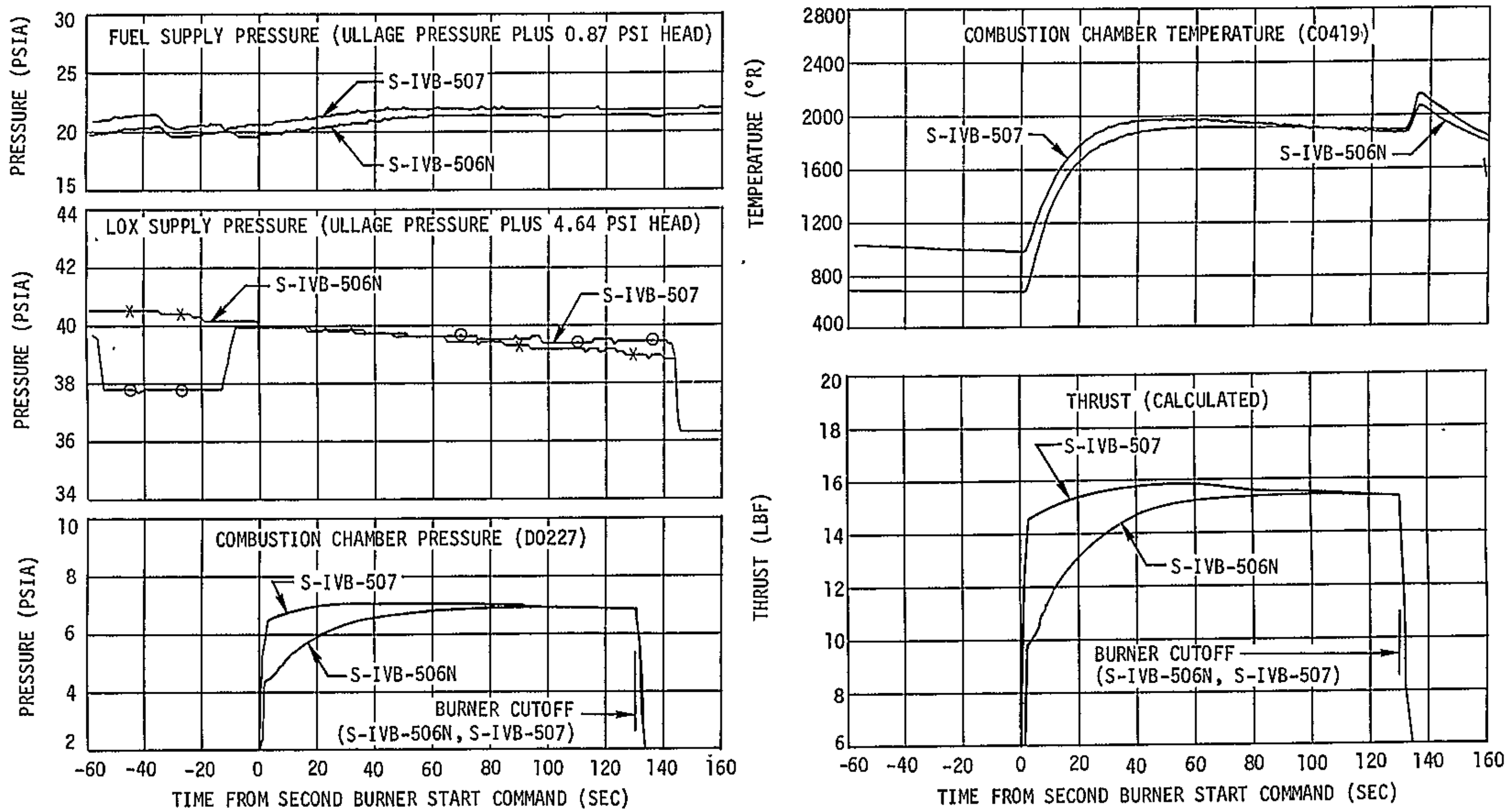


Figure 10-6. Second Burner Operation

11. PROPELLANT UTILIZATION SYSTEM

The propellant utilization (PU) system performed satisfactorily during the acceptance firing. Propellant loading was successfully accomplished based upon a desired common propellant load of 193,273 lbm LOX and 38,000 lbm LH2. The LOX and LH2 masses obtained by the flow integral method were 191,440 lbm and 37,583 lbm, respectively. The PU indicated LOX and LH2 masses were 0.31 percent and 0.88 percent higher than the flow integral masses. These deviations are within the allowable three percent tolerance of PU indicated and flow integral derived masses.

The PU indicated LOX mass was 0.64 percent lower than the desired LOX loading and the PU indicated LH2 mass was 0.23 percent lower than the desired LH2 load. The LOX and LH2 full load masses, as determined by the volumetric method, were respectively 0.24 percent and 0.90 percent higher than the flow integral method derived mass. Loaded mass as determined by the flow integral method was 0.96 percent and 1.11 percent of desired for LOX and LH2, respectively.

The PU system operated in the closed-loop mode with a reference mixture ratio of 5.0:1 throughout the single-burn full duration firing. PU valve cutback occurred at Engine Start Command (ESC) +183.74 sec. The predicted valve cutback time was ESC +183.9 sec. The steady-state valve position following the cutback transient was approximately 3.25 deg higher than predicted.

Based upon extrapolation from the conditions at cutoff, LOX depletion would have occurred with 114 lbm of usable LH2 onboard as compared to a guaranteed maximum flight residual of 575 lbm.

Engine thrust variations were well within the flight thrust variation limits derived for the Contract End Item (CEI) specification.

11.1 PU System Calibration

The nominal S-IVB-507 pre-acceptance mass sensor calibration data were determined from previous acceptance firing results.

The propellant mass at the upper and lower calibration point was determined from calculated unique tank volume data and predicted propellant densities. The capacitance at the lower end was determined from the vendor's sensor air capacitance and average fast drain data from previous acceptance firings.

The LOX sensor capacitance at the full immersion point was determined from the vendor's air capacitance and mean data accumulated from LOX sensor full immersion tests conducted on S-IVB-207, 208, 209, 503N, and 504N. The LH2 sensor capacitance at the upper calibration point was determined from the S-IVB-209, 504N, 505N, and 506 immersion test results and vendor's air capacitance.

The LOX and LH2 PU calibration data are presented in the following table:

PU MASS SENSOR	MASS (lbm)	CAPACITANCE (pf)	LOCATION
LOX	196,425	414.63	Top of inner element
	1,376	282.41	Bottom of inner element
LH2	44,734	1184.65	Top of inner element
	213	970.86	Bottom of inner element.

11.2 PU Mass History

The flow integral, volumetric, and PU indicated methods were used to evaluate the acceptance firing propellant full load and mass history; however, only the flow integral method will be used to recalibrate the PU system for flight.

The flow integral method consists of determining the mass flowrate of LOX and LH2 and integrating as a function of time to obtain total consumed mass during firing. Flow integral mass values are based on the analysis of engine flowmeter data, thrust chamber pressure, engine influence equations, and engine tag values.

The initial full load mass, using the flow integral method, is determined by adding the propellant residuals at engine cutoff, the fuel pressurant added to the ullage, and propellants lost to boiloff to the total mass consumed.

The PU volumetric masses were derived from raw PU probe output data computed according to volumetric calibration slopes and volumetric nonlinearities. The calibration slopes (lbm/pf) were computed from capacitance propellant mass relationships at the upper and lower probe active element extremities. The propellant mass at these extremities was calculated from unique tank volume determined from tank measurements and propellant density.

The PU indicated method measures propellant mass from the raw PU probe output.

Table 11-1 presents the propellant mass history for salient times during the acceptance firing.

11.2.1 Propellant Loading

Propellant loading was accomplished automatically by the loading computer. Desired, indicated, volumetric, and flow integral full propellant loads at ESC are presented in table 11-1.

The deviation between the desired and flow integral masses were within 0.96 percent and 1.11 percent for LOX and LH2 respectively.

11.2.2 Propellant Residuals

Propellant residuals were computed at Engine Cutoff Command (ECC) using both the PU mass sensors and the residual point level sensors. Three level sensors in each tank (L0017, L0018, and L0019 in the LH2 tank, and L0014, L0015 and L0016 in the LOX tank) were activated during the firing and were used for residual analysis.

Level sensor residuals were computed using the engine consumption data (G105 program) to extrapolate from level sensor activation to engine cutoff. A statistical average residual was computed for the point level sensors for each propellant tank. The final residual masses at engine cutoff are the weighted average residuals of the point level sensor and PU mass sensor residual data.

Table 11-2 contains a tabulation of PU volumetric, level sensor, and weighted average data. The residuals as determined from the weighted average data were 1,790 lbm and 1,122 lbm for LOX and LH2, respectively.

11.2.3 PU Efficiency

The closed-loop PU efficienty is determined by expressing the usable residual propellant at depletion cutoff as a percentage of the total propellant load. A LOX depletion cutoff would have occurred 3.04 sec after the actual Engine Cutoff Command. Total stage propellant consumption rates (determined by engine and stage flowrate evaluations) at ECC were 418.7 lbm/sec for LOX and 81.6 lbm/sec for LH2. Extrapolating these flowrates to the theoretical LOX depletion cutoff results in a usable LH2 residual of 114 lbm and a PU efficiency of 99.95 percent.

11.3 PU System Response

PU system mixture ratio valve cutback occurred at ESC +183.74 sec, which was 0.16 sec earlier than the predicted cutback time of 183.9 sec. The actual valve history settled at a steady-state valve position which was approximately 3.25 deg higher than predicted.

The reconstruction of the actual PU valve history was made using the actual engine environment, tank-to-sensor mismatches derived from the flow integral mass histories, and other known system operating conditions. The tank to sensor mismatch of for the LOX and LH2 mass sensors based on volumetric and flow integral data are presented in figures 11-2 through 11-5.

The following table summarizes the deviations between the actual and predicted PU valve position historied and their sources, based on the flow integral results.

DESCRIPTION	CUTBACK TIME DEVIATION (sec)	VALVE POSITION SHIFT (deg)
Loading	-19.3	0
Calibration	+5.0	+1.2
Tank/Sensor Mismatch	-10.9	0
Revised Tag Values and Deviations in Engine Environment	+11.6	+1.8
TOTAL	-13.6	+3.0

The summation of deviations listed in the table would decrease the predicted cutback time by 13.6 sec and raise the mean value of mixture ratio valve position by 3 deg.

11.3.1 PU Cutback Deviations

11.3.1.1 Loading Computer Deviation

Loading computer deviations are the difference between the PU system indicated loads at ESC and the desired PU system indicated loads at ESC. The loading deviations were -1,232 lbm LOX (0.64 percent) and -88 lbm LH2 (0.23 percent). These deviations are within acceptable loading errors of ±3.0 percent. The combined effect of these loading computer deviations decreased cutback time by 19.3 sec. The mean level of the valve position after cutback was not affected by these loading computer deviations.

11.3.1.2 Flow Integral Mass/Capacitance Calibration Deviation

Calibration deviations are the difference between PU indicated loads and flow integral loads during burn. Calibration deviations at ESC were 0.31 percent LOX and 0.88 percent LH2. Calibration deviations at ECC were -0.04 percent LOX and 0.01 percent LH2. The slope deviations between ESC and ECC were 0.35 percent LOX and 0.87 percent LH2.

The desired reference mixture ratio (RMR) for the S-IVB-507 acceptance firing was 5.0:1.0. The bridge gain ratio (BGR) was also calibrated at 5.0:1. Since PU sensor calibration deviations also affect the BGR, the actual ratio was 5.01:1.0. The calibration deviations increased cutback time by 5.0 sec and shifted the mean value of valve position by +1.2 deg.

11.3.1.3 Tank/Sensor Mismatch

The effect of the differences between the average of previous acceptance firing flow integral tank to sensor mismatch results for the S-IVB-507 prediction and the actual flow integral mismatch decreased cutback by 10.9 sec but had no effect on the mean level of valve position. Figures 11-4 and 11-5 show the predicted and actual flow integral LOX and LH2 nonlinearities normalized to the actual loaded masses with the sensor manufacturing nonlinearities included.

11.3.1.4 Tag Values and Engine Environment Deviations

The difference between predicted and actual tag values, pump inlet conditions, pressurization and boiloff rates for the S-IVB-507 acceptance firing was to increase cutback by 11.6 sec. In addition, the mean level of valve position was shifted by +1.8 deg.

TABLE 11-1
PROPELLANT MASS HISTORY

EVENT	DESIRED MASS (lbm)	PU INDICATED MASS (lbm)	PU VOLUMETRIC MASS (lbm)	FLOW INTEGRAL MASS (lbm)	DEVIATION FROM FLOW INTEGRAL MASS		
					DESIRED	PU INDICATED	VOLUMETRIC
Simulated Liftoff (T_0) and Engine Start Command	LOX 193,273	192,041	191,900	191,440	+1833 (0.96%)	+601 (0.31%)	+460 (0.24%)
	LH2 38,000	37,912	37,922	37,583	+417 (1.11%)	+329 (0.88%)	+339 (0.90%)
	TOTAL 231,273	229,953	229,822	229.023	+2250 (0.98%)	+930 (0.41%)	+799 (0.35%)
PU Valve Cutback (ESC +183.74 sec)	LOX	109,101	108,821	108,344		+757 (0.40%)	+477 (0.25%)
	LH2	22,488	22,513	22,236		+252 (0.67%)	+277 (0.74%)
	TOTAL	131,589	131,334	130,580		+1009 (0.44%)	+754 (0.33%)
Engine Cutoff Command	LOX	1,719	1,679	1,790		-71 (0.04%)	-111 (0.06%)
	LH2	1,125	1,135	1,122		+3 (0.01%)	+13 (0.03%)
	TOTAL	2,844	2,814	2,912		-68 (0.03%)	-98 (0.04%)

TABLE 11-2
PROPELLANT RESIDUAL SUMMARY

	LEVEL SENSOR (ACTIVATION TIME)							
	LOX TANK				LH2 TANK			
	L0016 (T_0 +911.569)	L0015 (T_0 +926.485)	L0014 (T_0 +941.901)	ECC (T_0 +947.917)	L0019 (T_0 +940.402)	L0018 (T_0 +928.318)	L0017 (T_0 +944.817)	ECC (T_0 +947.917)
PU Volumetric	16,724	10,393	4,154	1,679	3,377	2,730	1,405	1,135
Level Sensor Indicated Value	16,703	10,676	4,334	-	3,414	2,770	1,367	-
Level Sensor Extrapolated Residual	1,704	1,805	1,823	1,799*	1,131	1,142	1,106	1,121*
Weighted Average Residual	-	-	-	1,790**	-	-	-	1,122**

*Statistical average of level sensor residuals

**Statistical average of level sensor and PU system residuals

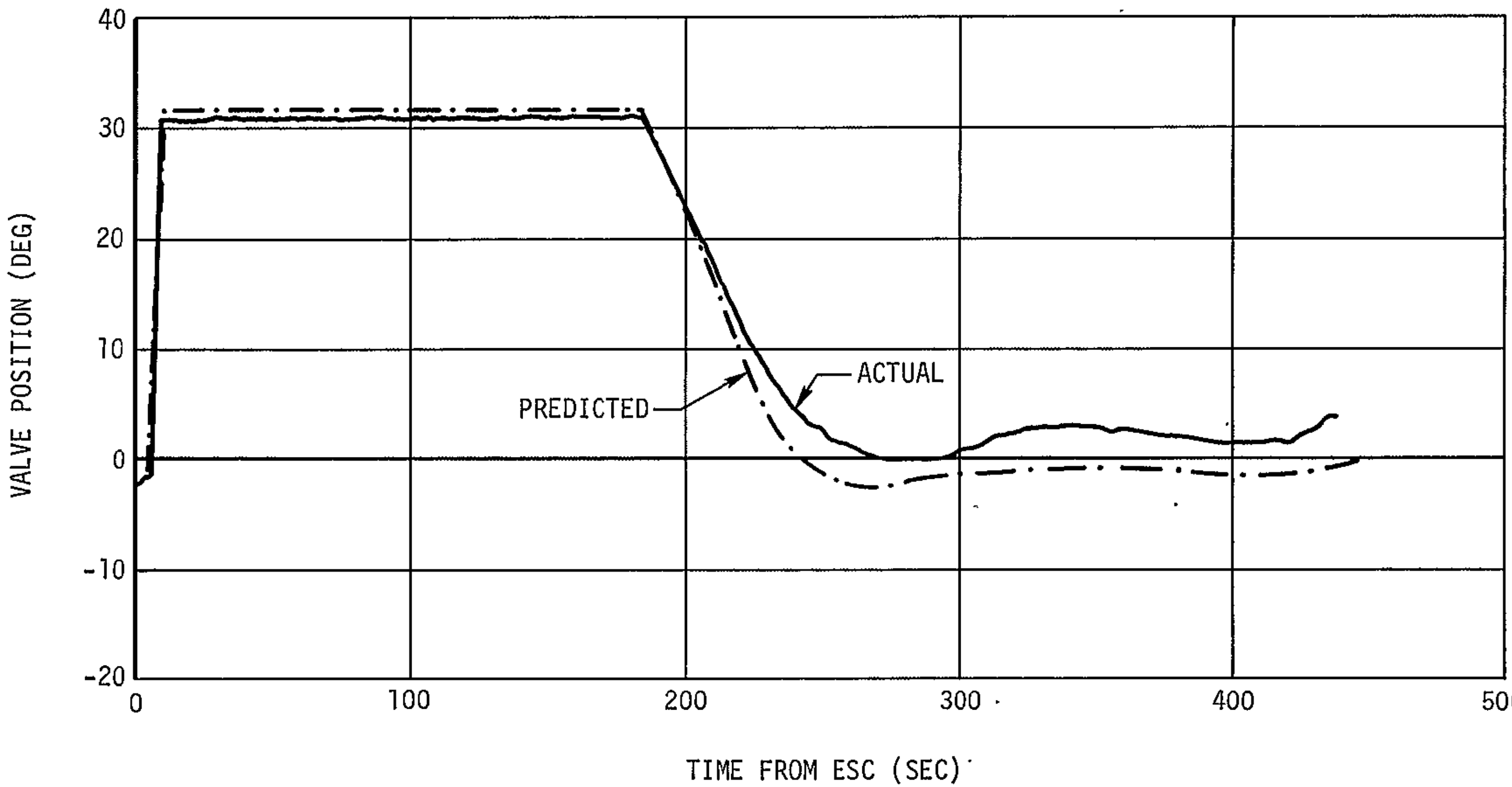


Figure 11-1. PU Valve Response

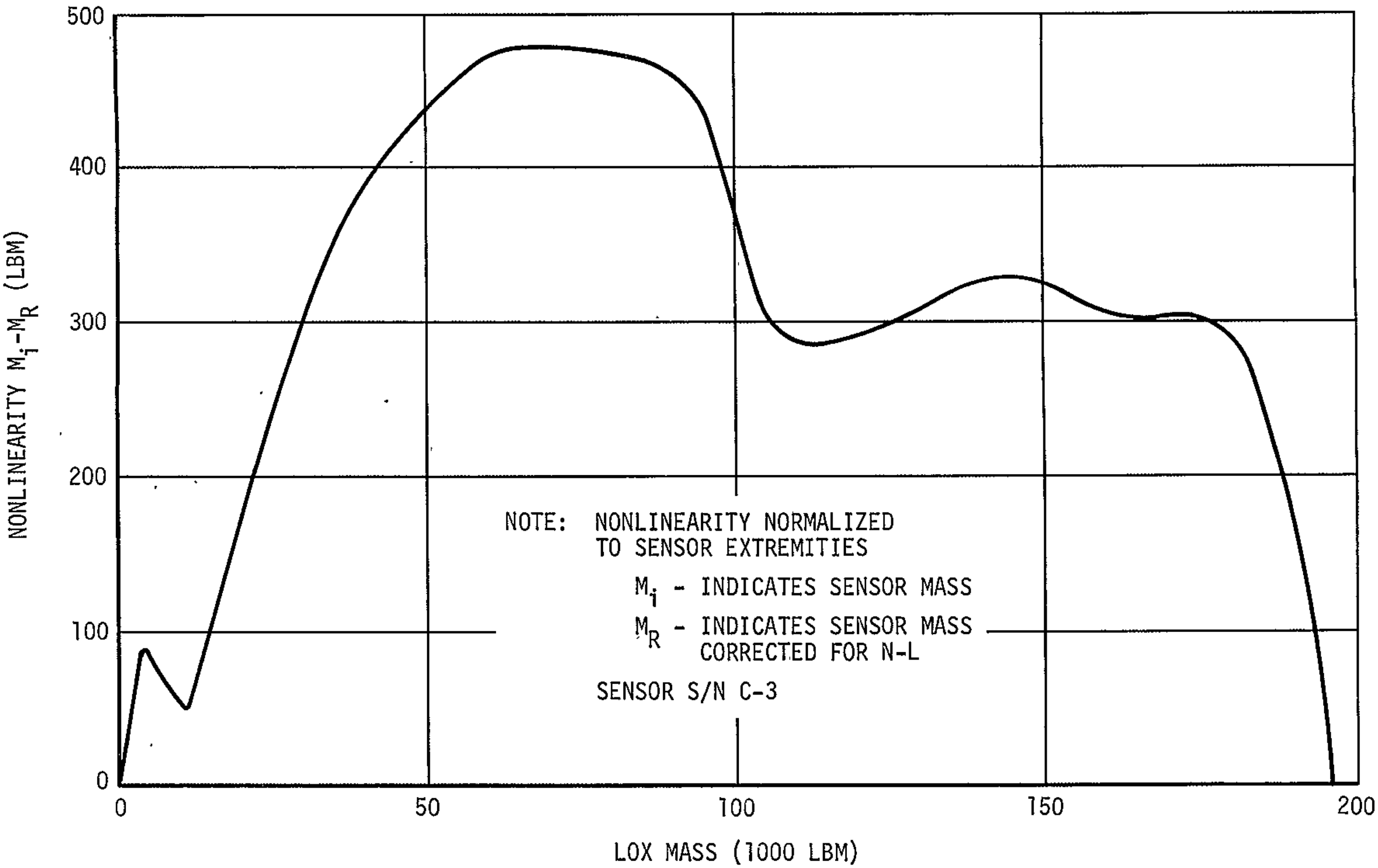


Figure 11-2. LOX Mass Sensor Nonlinearity

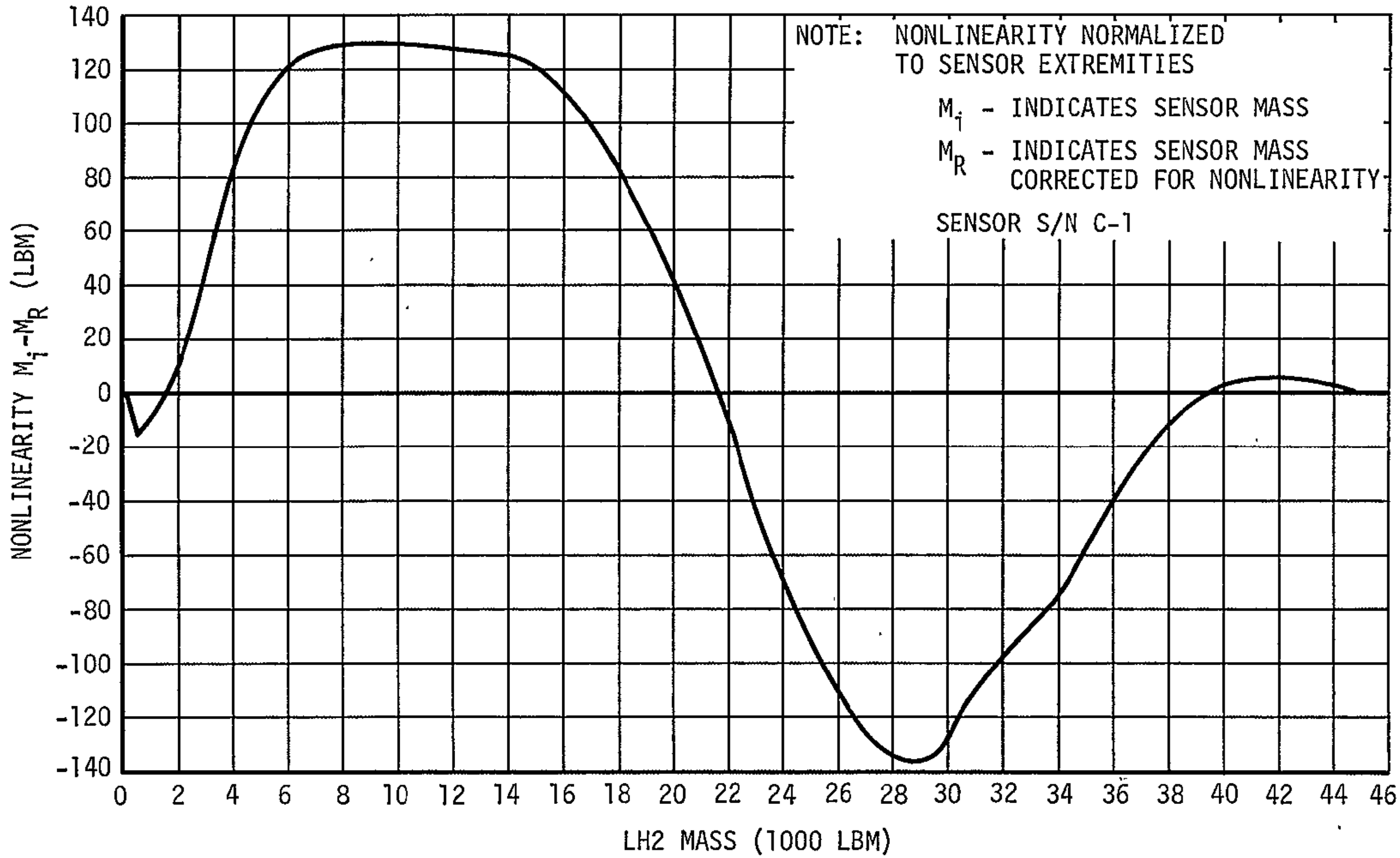


Figure 11-3. LH2 Mass Sensor Nonlinearity

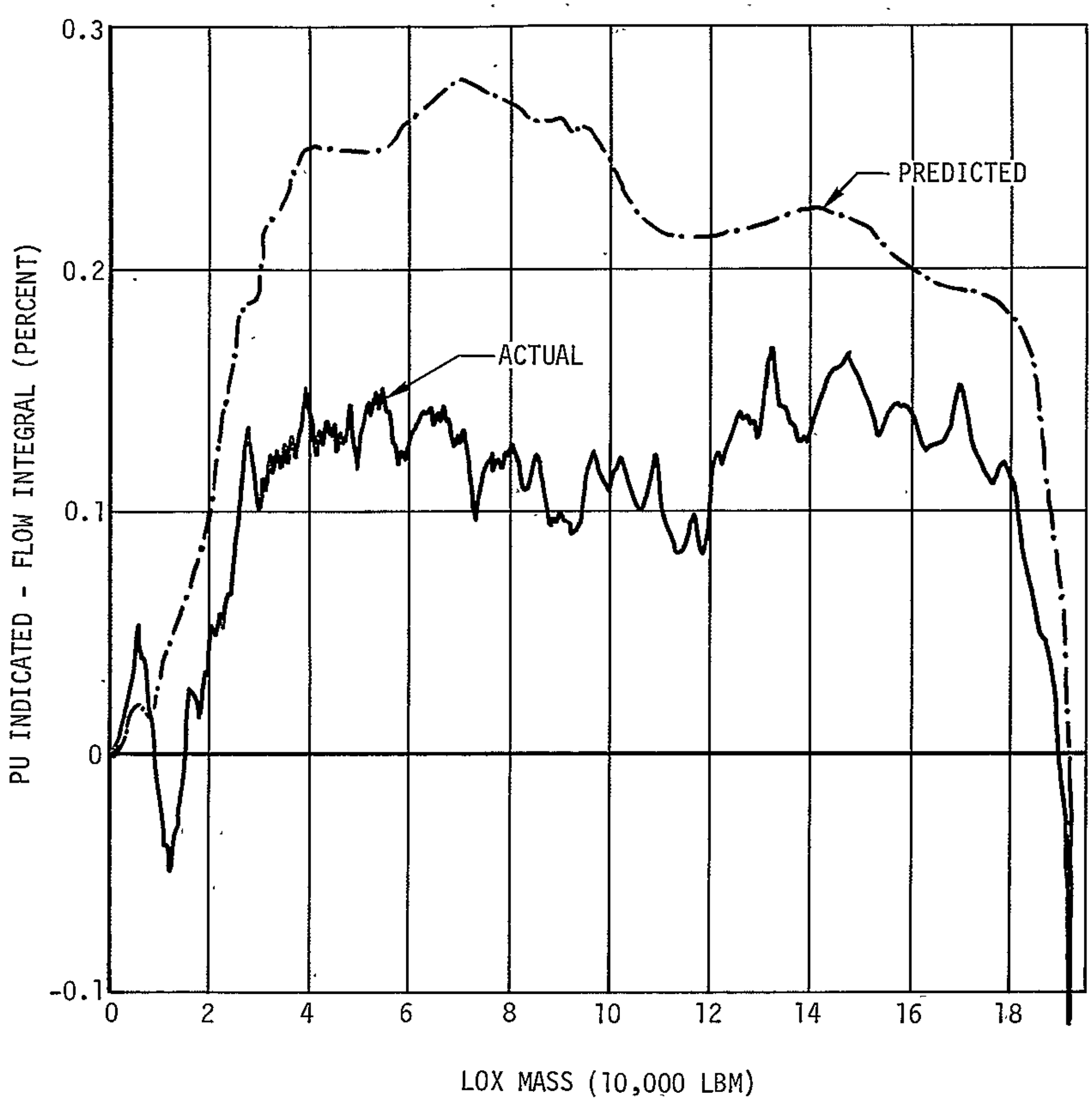


Figure 11-4. LOX Normalized Probe Linearity

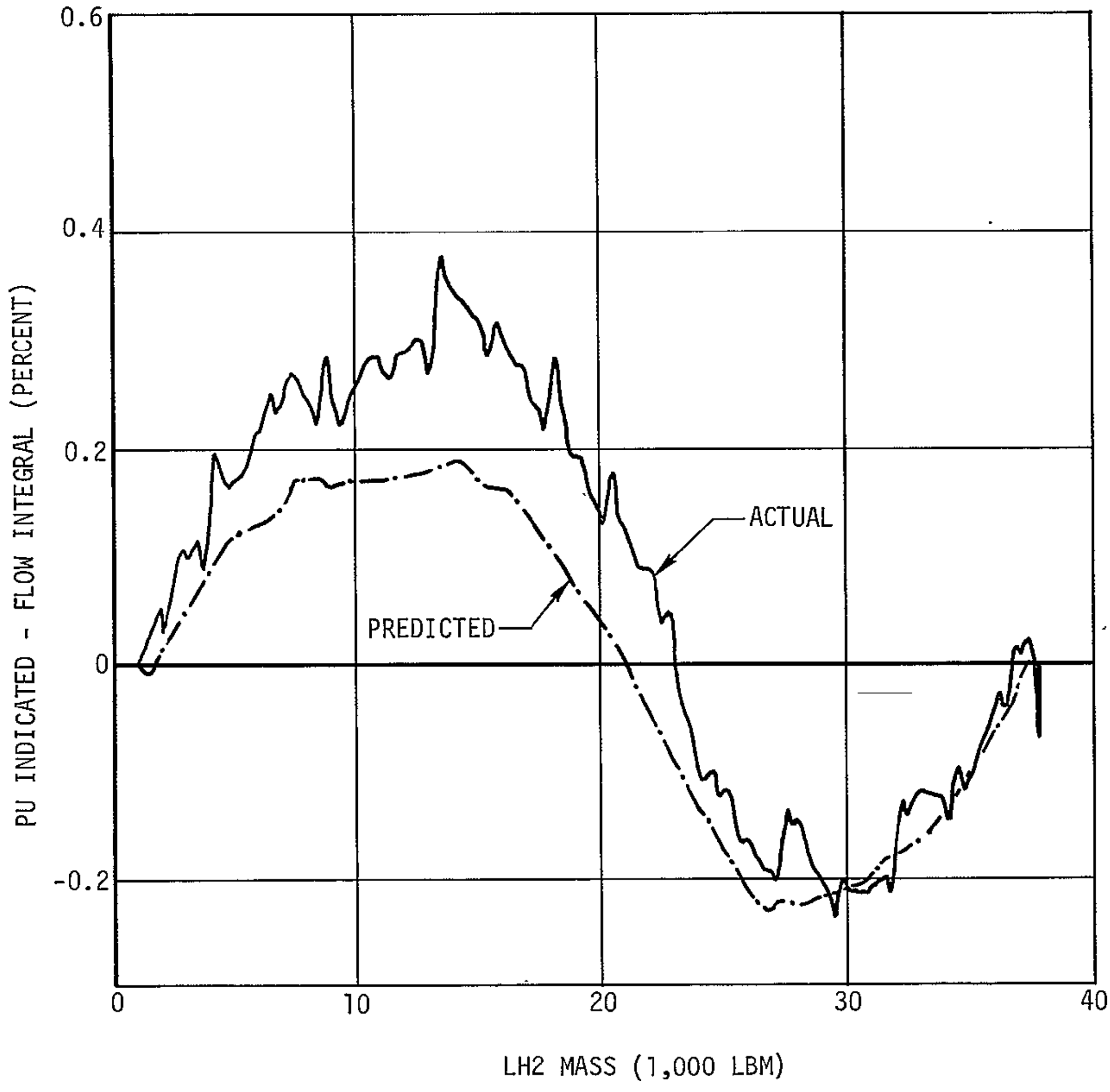


Figure 11-5. LH2 Normalized Probe Linearity

12. DATA ACQUISITION SYSTEM

The data acquisition system demonstrated competency in acquiring stage information, conditioning the data signals, translating these signals into proper telemetry format, and transmitting the telemetry information to a ground station. The measurements which comprise this system are specified in drawing No. 1B43572 Change T, AEO U, and V Instrumentation Program and Components List (IP&CL); although, not all measurements specified in the IP&CL were in operation during this test. The system demonstrated that it was free of radio frequency interference and was electromagnetically compatible with other stage systems.

The performance of the data acquisition system was satisfactory throughout the O_2-H_2 burner and mainstage firing phases of the acceptance firing. The reduced data from all channels were acceptable with the exception of the discrepancies described in tables 12-1 and 12-2.

The following is a summary of the telemetry data measurement system performance during acceptance firing:

Total number of measurements assigned	293
Total number of measurements deleted	71
Total number of active measurements	222
Measurement failures	1
Total acceptable measurements	221
Measurement efficiency	99.5 percent
Measurement discrepancies	7

12.1 Instrumentation System Performance

The instrumentation system performed satisfactorily during all phases of the acceptance firing. One measurement failure was observed and five measurements exhibited data problems. Table 12-1 lists these measurements and table 12-2 elaborates their malfunction characteristics. Table 12-3 lists the measurements that were inactive.

One measurement exhibited invalid data. Measurement D0016 (Press - Cold He Sphere) failed at T + 3,151 sec during the simulated orbital coast period (Phase E - Reference Time T = 1231:28 PST).

Seven measurements indicated data problems. Measurement M0025 (Volt - 5 Volt Excitation Mod. Aft.) exhibited negative dc shifts during childown operation. Measurements M0060 (Volt-PU Valve Control), N0018 (Misc - PCM/FM Transmitter Output Power), N0055 (Misc - T/M RF System Reflected Power Channel 1), and N0061 (Misc - Operational T/M Reflected RF Power Kit) exhibited excessive RFI response. Measurements M0004 (Volt - Static Inverter-Converter 5 Vdc and M0012 (Freq-Static Inverter-Converter) exhibited excessive lever shifts during the PU hardover period.

The measurements listed below were susceptible to the high RF field experienced on the Complex Beta test stand. The RFI condition was exhibited as noise or data shift, or both, when comparing open and closed loop RF data. RFI responses have been observed during previous firings; this problem does not exist when the stage is in the launch vehicle configuration. No action is being contemplated to remedy the problem.

M0060	Volt - PU Valve Contr
N0018	Misc - PCM/FM Xmtr Output Pwr
N0055	Misc - T/M RF Syst Refl Pwr
N0061	Misc - Operational T/M Reflected RF Power Kit

RACS calibrations were evaluated for proper levels at T_0 -2,680 sec (1516.19 hr PDT) of Phase D. All measurements were within the acceptable RACS levels.

Comparison of the T/M and GIS hardwire data was conducted during the STC evaluation. A total of 46 measurements were compared with satisfactory results. Due to the failure of D0016, Press-Cold Helium Sphere, measurement D0248, Press-Cold Helium Sphere (backup) was used instead. The comparison results are shown in table 12-4.

12.2 Telemetry System Performance

The telemetry system performance was good. There was no loss of system synchronization, and good data were received from all channels. DDAS hardwire (600KC) to T/M (open loop RF) comparison did not reveal any stage data discrepancies.

Response of the telemetry system to in-flight multiplexer calibrations were evaluated during phase D at the following times: T_0 + 116 sec and T_0 + 1,822 sec. The chilldown pumps and the auxiliary hydraulic pumps were on at T_0 + 116 sec and off at T_0 + 1,822 sec. All calibration levels during both evaluation periods were within tolerance (±8 bit counts).

12.3 RF System Performance

The RF system performance was satisfactory. During open loop operation the RF power measurements were susceptible to the RF field; therefore, proper assessment of the RF system could not be accomplished. For worst case, using the closed-loop power output and the open-loop reflected power, the VSWR was 1.69:1.

The following table presents the PCM/FM transmitter output power and VSWR data for open and closed-loop operation.

RF SUBSYSTEM DATA		
SYSTEM	OPEN-LOOP VALUE*	CLOSED-LOOP VALUE
PCM/FM Transmitter Output Power (minimum acceptable is 15 W)	27.6	24.3
VSWR (maximum acceptable is 1.8:1)	1.69:1	1.51:1

*RF measurements were susceptible to RFI

The SSB transmitter was installed on the stage, and power to it was turned on, but its operation was not verified during the acceptance firing due to shortages of the SSB translator and signal conditioning components. Since no setup procedures were performed and the measurements for SSB/RF subsystem data were not calibrated, no valid single sideband performance evaluation will be available until the All Systems Test in the VCL (STC).

12.4 Electromagnetic Compatibility

The data acquisition system did not interfere with other stage systems in the areas of electromagnetic compatibility. However, measurements did exhibit data shift and noise caused by the susceptibility to the high RF field experienced on the Complex Beta test stand. Also, measurements indicated noise during the auxiliary hydraulic pump and chilldown inverters operation (see paragraph 12.1).

12.5 Emergency Detection System Measurements

Measurements D0177 (Press - LH_2 Tank Ullage, EDS No. 1), D0178 (Press - LH_2 Tank Ullage, EDS No. 2), D0179 (Press - LOX Tank Ullage EDS No. 1), and D0180 (Press - LOX Tank Ullage, EDS No. 2) all performed satisfactorily.

12.6 Hardwire Data Acquisition System Performance

The ground instrumentation system (GIS) provides a backup and data comparison for certain stage telemetry system parameters in addition to recording measurements from the ground support and facility equipment.

The GIS also provides strip charts for redline and cutoff parameter monitoring. The GIS performance during acceptance firing was satisfactory.

The following table presents the type of recording equipment and the number of channels used.

GROUND RECORDER	CHANNELS ASSIGNED
Beckman 210 Digital Data System	179
Constant Bandwidth FM	63
Wideband FM	7
Strip Charts	36
Total	385

Table 12-5 presents a list of the various types of measurement data recorded and the performance of the system.

12.6.1 Hardwire Measurement Discrepancies

There were seven measurement failures, yielding an overall hardwire measurement efficiency of 99.0 percent. Measurement discrepancies that occurred during the acceptance firing are listed in table 12-6.

TABLE 12-1
INSTRUMENTATION SYSTEM PERFORMANCE SUMMARY

FUNCTION	NUMBER ASSIGNED PER IP&CL	INACTIVE	NET ACTIVE	DISCREPANCIES	FAILURES	PERFORMANCE* (percent)
Acceleration (A)	0	-	-	-	-	-
Acoustic (B)	12	12	0	-	-	-
Temperature (C)	60	17	43	0	0	100.0
Pressure (D)	76	24	52	0	1	98.0
Vibration (E)	3	3	0	-	-	-
Flow (F)	4	0	4	0	0	100.00
Position (G)	8	5	3	0	0	100.00
Events (K)	72	7	65	0	0	100.00
Liquid Level (L)	7	1	6	0	0	100.00
Volt/Current/Freq (M)	38	2	36	4	0	88.8
Miscellaneous (N)	11	0	11	3	0	72.7
Strain (S)	0	-	-	-	-	-
Speed (T)	2	0	2	0	0	100.0
TOTAL	293	71	222	7	1	99.5 percent

*Performance (percent) = $\frac{\text{Net Active - Failures}}{\text{Net Active}} \times 100$

TABLE 12-2 (Sheet 1 of 3)
MEASUREMENT ANOMALIES

MEASUREMENT NO.	PARAMETER	REMARKS
M0025-404	Volt - 5 Volt Excitation Mod Aft	The measurement exhibited 40 mv negative dc shifts during the O_2-H_2 burner and chilldown/J-2 engine operation whenever the chilldown pumps were turned on. The problem was observed to a slight degree on previous stages; however it was considerably pronounced on S-IVB-507. The shift was noted at A3 during VCL testing. Studies conducted indicated a grounding discrepancy where the 5-volt excitation module and the chilldown inverter grounds were connected at the same grounding stud. Since the chilldown inverters draw a heavy load current, the 5-volt excitation module exhibits a ground reference level shift. ECP 2898 was initiated and approved to remedy the problem.
M0060-411 N0018-411 N0055-411 N0061-411	Volt - PU Valve Control Misc - PCM/FM Transmitter Output Power Misc - T/M RF System Reflected Power Channel 1 Misc - Operational T/M Reflected RF Power Kit	M0060-411, N0018-411, N0055-411, and N0061-411 exhibited dc shifts of minus 3%, plus 5%, plus 17%, and plus 13% respectively during open-loop RF data transmission. These dc shifts were due to the lack of environmental RF shielding and a high RF field peculiar to A3-VCL and A45 test stands where considerable structural RF reflections occur. When the S-IVB is mated to other vehicle stages for flight, adequate shielding is provided and the problem does not exist. No action is under consideration to remedy the anomaly. Approximately 4 percent peak-to-peak noise was also noted on measurements N0055-411 and N0061-411 during the engine burn period. The RF power detectors are known to be slightly vibration sensitive,

TABLE 12-2 (Sheet 2 of 3)
MEASUREMENT ANOMALIES

MEASUREMENT NO.	PARAMETER	REMARKS
		and because the measurements operate in the high gain region of the break point amplifier, the amount of noise observed can be expected. A 4 percent noise level represents less than 1 percent of the measurement range of 0 to 109 mv due to the amplifier design, and evaluation of reflected power is not degraded by the magnitude of the noise. No corrective action will be suggested.
M0004-411	Volt - Static Inverter-Converter, 5 VDC	The measurement was out of tolerance from the established acceptable limit in the acceptance firing test plan. The nominal level observed was 5.02 vdc, whereas the test plan limit is 4.9 ±0.1 vdc. While the test plan reflects the contract end item (CEI) specification limits, the handling and checkout calibration document specifies a setup limit of 4.75 vdc to 5.05 vdc. An acceptable tolerance discrepancy exists, but the problem is not considered a measurement difficulty. However, action will be taken to resolve the discrepancy. The measurement also showed a dc shift of approximately 60 mv when the PU hardover command was initiated during the simulated orbit test. The cause of the shift is described in paragraph 13.3.2. ECP 3008 has been initiated to correct the problem. Operation of the PU system was not impaired.

TABLE 12-2 (Sheet 3 of 3)
MEASUREMENT ANOMALIES

MEASUREMENT NO.	PARAMETER	REMARKS
M0012-411	Frequency - Static Inverter-Converter	The measurement showed a frequency shift from 401.7 to 406.4 cps when the PU hardover command was initiated during the simulated orbit test. The frequency shift exceeded the limit of 400 $\pm$6 cps. The reason for the shift is the same as it is for the 5 vdc and is described in paragraph 13.3.2. ECP 3008 is expected to rectify the anomaly.
D0016-425	Press - Cold Helium Spheres	The measurement drifted off-scale high during the simulated orbital coast period (phase E), beginning at T_0 +3,151 sec (T_0 = 1231:28.00) and remained off-scale high throughout the chilldown and J-2 engine operation period (phase D). The measurement did not accept RACS calibration at the end of phase D, but remained off-scale high. The measurement remained off-scale high under ambient conditions for one day after the acceptance firing, but operated correctly at both ambient and calibration levels two days after the test. However, when the measurement was investigated on October 23, 1968, it was off-scale high again under ambient conditions. Wiggling the connector at the sensor end dropped the reading and it varied intermittently between 300 and 1,100 psia. The connector was removed and inspected with no problem. When reconnected, the same intermittency remained. The transducer has been FARR tagged, FARR 500-488-697, removed from the stage, and dispositioned for further testing.

TABLE 12-3 (Sheet 1 of 6)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	PARAMETER	REMARKS
B0028	Acous - Sta 2548	Open, SSB not installed
B0029	Acous - Sta 2574	Open, SSB not installed
B0030	Acous - Sta 2589	Open, SSB not installed
B0031	Acous - Sta 2711	Open, SSB not installed
B0032	Acous - Sta 2733	Open, SSB not installed
B0033	Acous - Sta 2529	Open, SSB not installed
B0034	Acous - Sta 2554	Open, SSB not installed
B0035	Acous - Sta 2589	Open, SSB not installed
B0036	Acous - Sta 2726	Open, SSB not installed
B0037	Acous - Sta 2771	Open, SSB not installed
B0038	Acous - Sta 2784 (Between 98-99 Ext)	Open, SSB not installed
B0039	Acous - Sta 2784 (Between 75-76 Ext)	Open, SSB not installed
C0007	Temp. Engine Control Helium	Open, H/W requirement
C0021	Temp. Attitude Control Fuel Module 2	Simulated, APS not installed
C0022	Temp. Attitude Control Oxid Module 2	Simulated, APS not installed

TABLE 12-3 (Sheet 2 of 6)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	PARAMETER	REMARKS
C0023	Temp. APS Helium Pressure Tank Module 1	Simulated, APS not installed
C0050	Temp. Hydraulic Pump Inlet Oil	Open, H/W requirement
C0102	Temp. Forward Battery No. 1	Simulated, primary battery not used
C0103	Temp. Forward Battery No. 2	Simulated, primary battery not used
C0104	Temp. Aft Battery No. 1	Simulated, primary battery not used
C0105	Temp. Aft Battery No. 2	Simulated, primary battery not used
C0131	Temp. Aft Battery No. 1 Unit 2	Simulated, primary battery not used
C0132	Temp. Attitude Control Oxid Module 1	Simulated, APS not installed
C0136	Temp. Attitude Control Fuel Module 1	Simulated, APS not installed
C0187	Temp. APS Helium Press Tank Module 2	Simulated, APS not installed
C0200	Temp. Fuel Inj.	Open, H/W requirement
C0211	Temp. Fwd Battery No. 1 Unit 2	Simulated, primary battery not used
C0212	Temp. Fwd Battery No. 2 Unit 2	Simulated, primary battery not used
C0382	Temp. O_2-H_2 Burner Chamber Dome	Open, H/W requirement

TABLE 12-3 (Sheet 3 of 6)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	PARAMETER	REMARKS
D0027	Press. Attitude Control Chamber 1-1	Simulated, APS not installed
D0028	Press. Attitude Control Chamber 1-2	Simulated, APS not installed
D0029	Press. Attitude Control Chamber 1-3	Simulated, APS not installed
D0030	Press. Attitude Control Chamber 2-1	Simulated, APS not installed
D0031	Press. Attitude Control Chamber 2-2	Simulated, APS not installed
D0032	Press. Attitude Control Chamber 2-3	Simulated, APS not installed
D0035	Press. Attitude Control Helium Pressure Tank 1	Simulated, APS not installed
D0036	Press. Attitude Control Helium Pressure Tank 2	Simulated, APS not installed
D0037	Press. Helium Reg. Outlet Module 1 (APS)	Simulated, APS not installed
D0038	Press. Helium Reg. Outlet Module 2 (APS)	Simulated, APS not installed
D0041	Press. Hydraulic System	Open, H/W requirement

TABLE 12-3 (Sheet 4 of 6)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	PARAMETER	REMARKS
D0042	Press. Reservoir Oil	Open, H/W requirement
D0070	Press. Fuel Supply Manifold Module 1	Simulated, APS not installed
D0071	Press. Oxid Supply Manifold Module 1	Simulated, APS not installed
D0072	Press. Fuel Supply Manifold Module 2	Simulated, APS not installed
D0073	Press. Oxid Supply Manifold Module 2	Simulated, APS not installed
D0097	Press. Fuel Tank Ullage Vol. Module 1	Simulated, APS not installed
D0098	Press. Oxid Tank Ullage Vol. Module 1	Simulated, APS not installed
D0099	Press. Fuel Tank Ullage Vol. Module 2	Simulated, APS not installed
D0100	Press. Oxid Tank Ullage Vol. Module 2	Simulated, APS not installed
D0220	Press. Ullage Control Chamber 1-4	Simulated, APS not installed
D0221	Press. Ullage Control Chamber 2-4	Simulated, APS not installed

TABLE 12-3 (Sheet 5 of 6)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	PARAMETER	REMARKS
D0250	Press. APS Helium Press Tk 1	Simulated, APS not installed
D0251	Press. APS Helium Press Tk 2	Simulated, APS not installed
E0219	Vib - Aft I/S Edge of 70 Norm	Open, SSB not installed
E0220	Vib - Aft I/S Bey 70-71 Norm	Open, SSB not installed
E0221	Vib - Aft I/S Edge of 71 Norm	Open, SSB not installed
G0003	Position Main LOX Valve	Simulated, H/W requirement
G0004	Position Main Fuel Valve	Simulated, H/W requirement
G0005	Position Gas Generator Valve	Simulated, H/W requirement
G0008	Position LOX Turbine Bypass Valve	Simulated, H/W requirement
G0009	Position GH2 Start Tank Valve	Simulated, H/W requirement
K0020	Event ASI LOX Valve Open	Open, computer requirement
K0126	Event LOX Bleed Valve Closed	Open, computer requirement
K0127	Event LH2 Bleed Valve Closed	Open, computer requirement
K0128	Event Switch Selector Output	Open, computer requirement
K0152	Event Rate Gyro Wheel Speed OK	Simulated, rate gyro not installed

TABLE 12-3 (Sheet 6 of 6)
INACTIVE MEASUREMENTS

MEASUREMENT NO.	PARAMETER	REMARKS
K0182	Event Helium Heater LOX Valve Full - Closed	Open, measurement not required
K0183	Event Helium Heater LOX Valve Full - Open	Open, measurement not required
L0007	Level Reservoir Oil	Simulated, H/W requirement
M0073	Voltage O_2-H_2 Burner Spark Exciter - 2	Open, computer requirement
M0074	Voltage O_2-H_2 Burner Spark Exciter - 1	Simulated, rate gyro not installed

TABLE 12-4 (Sheet 1 of 3)
TELEMETRY TO HARDWIRE DATA COMPARISON (T_0 + 574 SEC)

PARAMETER	UNITS	TELEMETRY		HARDWIRE		
		MEAS NO.	PCM	MEAS NO.	GIS	F/M
Temp - LH2 Pump Inlet	deg R	C0003	37.6	C0658	37.5	37.2
Temp - LOX Pump Inlet	deg R	C0004	164.8	C0659	164.6	164.0
Temp - GH2 Start Bottle	deg R	C0006	218.0	C0649	225.0	--
Temp - Electrical Control Assembly	deg R	C0011	523.0	C0657	522.0	--
Temp - LOX Pump Discharge	deg R	C0133	169.8	C0648	169.7	169.2
Temp - LH2 Pump Discharge	deg R	C0134	51.7	C0644	51.8	51.9
Temp - Thrust Chamber Jacket	deg R	C0199	137.0	C0645	141.0	--
Temp - Cold Helium Sphere No. 4	deg R	C0210	35.0	C0661	36.5	--
Press - Thrust Chamber	psia	D0001	819.0	D0524	811.0	--
Press - LH2 Pump Inlet	psia	D0002	33.4	D0536	33.7	33.0
Press - LOX Pump Inlet	psia	D0003	42.2	D0537	42.7	42.0
Press - Main LH2 Injector	psia	D0004	903.0	D0518	907.0	905.0
Press - LH2 Pump Discharge	psia	D0008	1,246.0	D0516	1,272.0	1,275.0
Press - LOX Pump Discharge	psia	D0009	1,087.0	D0522	1,097.0	1,095.0
Press - Gas Generator Chamber	psia	D0010	684.0	D0530	680.0	685.0
Press - Control He Reg. Discharge	psia	D0014	547.0	D0581	540.0	540.0
Press - Cold Helium Sphere (1)	psia	D0016	2,173.0	D0542	2,111.0	--
Press - GH2 Start Bottle	psia	D0017	1,228.0	D0525	1,223.0	1,225.0
Press - Engine Reg. Outlet	psia	D0018	416.0	D0535	410.0	--
Press - Engine Control He Sphere	psia	D0019	2,267.0	D0534	2,296.0	--
Press - LH2 Repress Sphere	psia	D0020	2,866.0	D0513	2,883.0	--
Press - LOX Turbine Outlet	psia	D0086	34.0	D0533	34.0	--

TABLE 12-4 (Sheet 2 of 3)
TELEMETRY TO HARDWIRE DATA COMPARISON (T_0 + 574 SEC)

PARAMETER	UNITS	TELEMETRY		HARDWIRE		
		MEAS NO.	PCM	MEAS NO.	GIS	F/M
Press - LOX Repress Sphere	psia	D0088	2,919.0	D0512	2,918.0	--
Press - LH2 Tank Ullage	psia	D0177	31.8	D0539	31.5	--
Press - LH2 Tank Ullage	psia	D0178	31.8	D0539	31.5	--
Press - LOX Tank Ullage	psia	D0179	39.9	D0540	40.1	--
Press - LOX Tank Ullage	psia	D0180	39.9	D0540	40.1	--
Press - Ambient Helium Sphere	psia	D0236	2,859.0	D0541	2,860.0	--
Press - Common Bulkhead Internal	psia	D0237	0.1	D0545	0.0	--
Flowrate - LOX	gpm	F0001	2,965.0	F0506	2,972.0	2,942.0
Flowrate - LH2	gpm	F0002	8,145.0	F0507	--	8,239.0
Position - Pitch Actuator	deg	G0001	0.0	G0504	0.0	0.0
Position - Yaw Actuator	deg	G0002	0.1	G0505	0.1	0.1
Position - PU Valve	deg	G0010	30.8	G0503	30.9	31.0
Voltage - Engine Control Bus	vdc	M0006	28.9	M0514	28.8	29.0
Voltage - Engine Ignition Bus	vdc	M0007	29.0	M0007	29.0	29.0
Voltage - Aft Battery 1	vdc	M0014	29.0	M0541	29.0	29.0
Voltage - Aft Battery 2	vdc	M0015	57.3	M0540	57.5	57.5
Voltage - Fwd Battery 1	vdc	M0016	27.8	M0543	28.3	28.0
Voltage - Fwd Battery 2	vdc	M0018	27.6	M0542	27.9	28.0
Current - Fwd Battery 1	amp	M0019	17.0	M0731	17.9	18.0
Current - Fwd Battery 2	amp	M0020	4.7	M0732	4.6	4.6

TABLE 12-4 (Sheet 3 of 3)
TELEMETRY TO HARDWIRE DATA COMPARISON (T_0 + 574 SEC)

PARAMETER	UNITS	TELEMETRY		HARDWIRE		
		MEAS NO.	PCM	MEAS NO.	GIS	F/M
Current - Aft Battery 1	amp	M0021	13.0	M0733	13.0	13.0
Current - Aft Battery 2	amp	M0022	35.0	M0734	35.0	35.0
Speed - LOX Pump	rpm	T0001	8,762.0	T0502	8,805.0	8,796.0
Speed - LH2 Pump	rpm	T0002	27,472.0	T0503	27,338.0	27,360.0

NOTES:

(1) The primary flight measurement D0016 data were qualified as "Invalid Data." The data were obtained from the flight backup measurement D0248.

(2) The hardwire digital data for F0507 were qualified as "Invalid - use raw FM AC Pip data for evaluation."

TABLE 12-5
HARDWIRE DATA ACQUISITION SYSTEM

MEASUREMENT TYPE	RECORDED	FAILED	SUCCESSFUL (percent)
Pressure	96	3	96.9
Temperature	47	2	95.7
Flow	2	1	50.0
Position	10	0	100.0
Voltage-Current	19	0	100.0
Events	651	0	100.0
Speed	2	0	100.0
Level	1	0	100.0
Vibration	5	1	80.0
Miscellaneous	4	0	100.0
TOTAL	837	7	99.0 percent

TABLE 12-6
HARDWIRE MEASUREMENT DISCREPANCIES

MEASUREMENT NO.	PARAMETER	REMARKS
D0525	Press - Start Bottle	Measurement was qualified as invalid after T_0 + 1,100 sec of terminal count.
D0535	Press - Engine Reg. Outlet	Questionable transients on data throughout the countdown.
C0419	Temp - O_2-H_2 Burner Chamber Dome	Measurement data were qualified invalid after 1332 PDT.
D0537	Press - Oxidizer Pump Inlet	The hardware stripchart data from measurement were invalid after postfire calibration.
C0654	Temp - Fuel Turbine Outlet	Measurement data were qualified as invalid after T_0 + 786 sec of terminal count.
F0507	Flow - Engine LH2 AC Output	Measurement digital data were qualified as "Invalid" - use raw FM ac pulse data for evaluation.
E0555	Vib - LOX Turbopump Radial	Measurement data were qualified as invalid from T_0 + 568 to T_0 + 582 sec and questionable during other periods.

13. ELECTRICAL POWER AND CONTROL SYSTEMS

13.1 Electrical Control System

The operational integrity of the electrical control system was verified through the evaluation of the sequence of events records from the digital events recorder (DER) and the PCM flight measurement events data (section 5). The switch selector and sequencer operated properly in sending all control commands to the stage; all commands were received in the stage.

13.1.1 J-2 Engine Control System

All measurements verified that the engine control system responded properly to the engine start and cutoff commands. The sequence of events (section 5) lists the engine firing events and response times.

13.1.2 Secure Range Safety Command System

The secure range safety command system was tested during the engine burn phase to verify the capability of engine cutoff and propellant dispersion. Evaluation of the data showed that the arm and engine cutoff (ECO) and propellant dispersion (P/D) commands were received, and that the EBW firing units (F/U) discharged into their respective pulse sensors. The following measurements were evaluated for system performance:

K0141	R/S 1 EBW Pulse Sensor Indication
K0142	R/S 2 EBW Pulse Sensor Indication
K0650*	R/S 1 P/D EBW F/U Power On
K0651*	R/S 2 P/D EBW F/U Power On
K0659*	R/S 2 Arm and ECO Command Received**
K0660*	R/S 1 Arm and ECO Command Received**
K0678*	R/S 2 Receiver Power On
K0679*	R/S 2 System Off Command Received

*Hardwire Measurement.

**Missing Due to Digital Events Recorder (DER) Saturation.

K0680*	R/S 1 Receiver Power On
K0681*	R/S 1 System Off Command Received
K0692*	R/S 2 EBW Arm and ECO On
K0693*	R/S 1 EBW Arm and ECO On
M0030	R/S 1 EBW Firing Unit (Volts)
M0031	R/S 2 EBW Firing Unit (Volts)
N0057	R/S 1 Low Level Signal Strength
N0062	R/S 2 Low Level Signal Strength
K5757*	R/S Tone 1/Propellant Dispersion Command
K5758*	R/S Tone 2/EBW Arm and ECO Command
K5759*	R/S Tone 6/System Off Command

13.1.3 Control Pressure Switches

A review of the event and pressure measurements associated with the control pressure switches verified that each switch functioned properly during the acceptance firing. Following is a list of the measurements used for each respective pressure switch verification.

a. LOX Tank Ground Fill Valve Control, Prepress, Flight Control, and Repress Pressure Switch

K0102	LOX Prepress and Flight Control Switch - Energized
*K0563	LOX Prepress and Flight Control Switch - Energized
K0108	LOX Prepress Flight Switch - De-energized
D0179	LOX Tank Ullage EDS 1
D0180	LOX Tank Ullage EDS 2
*K0571	Cold He SOV Energized - Indication
*K0444	LOX Tank Repress Valve - Energized

*Hardwire Measurement

b. LOX Tank Repress Regulator Backup Pressure Switch

*K0444	LOX Tank Repress Valve Energized
D0228	LOX/LH2 Burner LOX Press Coil

c. LH2 Tank Repress Regulator Backup Pressure Switch

*K0443	LH2 Tank Repress Valve - Energized
D0231	GOX/LH2 Burner LH2 Press Coil

d. Control (Ambient) Helium Regulator Backup Pressure Switch

D0014	Control Helium Regulator, Discharge

e. LH2 Ground Fill Valve Control, Prepress, Flight Control, and Step-Pressure Switch.

K0184	LH2 Flight Control Pressure Switch - Energized
*K0616	LH2 Tank Prepressurization Pressure Switch - Energized
K0101	LH2 Repress Control Switch - De-Energized
*K0582	LH2 Tank Repress Pressure Switch - On
*K0524	LH2 Tank Flight Pressure Valve - Energized
*K0523	LH2 Tank Step-Pressure Valve - Energized
D0177	LH2 Tank Ullage EDS 1
D0178	LH2 Tank Ullage EDS 2

f. LH2 Tank Repress Pressure Switch

K0101	LH2 Repress Control Switch - De-Energized
*K0582	LH2 Tank Repress Pressure Switch - On
*K0443	LH2 Tank Repress Valve - Energized
D0177	LH2 Tank Ullage EDS 1
D0178	LH2 Tank Ullage EDS 2

*Hardwire Measurement.

g. Engine Pump Purge Control Module Pressure Switch

K0105	Pump Purge Regulator Backup - De-Energized
*K0456	Engine Pump Purge Pressure Switch - De-Energized
*K0566	Engine Pump Purge Solenoid Valve - Energized
D0050	Engine Pump Purge Regulator Pressure

h. LOX Tank Regulator Backup Pressure Switch

K0156	LOX Tank Regulator Backup Pressure Switch - Energized
*K0571	LOX Tank Cold He SOV Energized - Indication
D0105	LOX Tank Pressurization Module He Gas

13.1.4 Vent Valves

The following measurements verified the satisfactory operation of the LOX and LH2 tank vent valves, and the LH2 tank directional valve:

K0001; *K0532	Fuel Tank Vent Valve 1 - Closed
K0017; *K0542	Fuel Tank Vent Valve 1 - Opened
K0002; *K0533	Oxid. Tank Vent Valve 1 - Closed
K0016; *K0543	Oxid. Tank Vent Valve 1 - Opened
K0113	LH2 Tank Directional Vent Valve C - Closed
K0114	LH2 Tank Directional Vent Valve D - Closed

13.1.5 Chilldown Shutoff Valves

The LOX and LH2 chilldown shutoff valves responded properly to commands as verified by the following measurements:

K0136; *K0551	LH2 Chilldown Shutoff Valve - Closed
K0137; *K0544	LH2 Chilldown Shutoff Valve - Opened
K0139; *K0552	LOX Chilldown Shutoff Valve - Closed
K0138; *K0545	LOX Chilldown Shutoff Valve - Opened

*Hardwire Measurement.

13.1.6 Fill and Drain Valves (LH2 and LOX)

A review of the following events showed that the LOX and LH2 fill and drain valves operated according to the GSE commands issued.

K0003; *K0554	LH2 Tank Fill and Drain Valve - Closed
*K0546	LH2 Tank Fill and Drain Valve - Opened
K0003; *K0553	LOX Tank Fill and Drain Valve - Closed
*K0547	LOX Tank Fill and Drain Valve - Opened

13.1.7 Depletion Centers

A review of the following measurements showed that the LOX and LH2 depletion sensors performed satisfactorily, and no anomalies were observed during the test:

*K0601	LOX Depletion Sensor No. 1 - Wet
*K0602	LOX Depletion Sensor No. 2 - Wet
*K0603	LOX Depletion Sensor No. 3 - Wet
*K0449	LOX Depletion Sensor No. 4 - Wet
*K0597	LH2 Depletion Sensor No. 1 - Wet
*K0598	LH2 Depletion Sensor No. 2 - Wet
*K0599	LH2 Depletion Sensor No. 3 - Wet
*K0450	LH2 Depletion Sensor No. 4 - Wet

13.2 Auxiliary Propulsion System (APS) Electrical Control System

The APS simulators, Model DSV-4B-188B, were used during the acceptance firing to verify the APS-stage interface control functions. An evaluation of the performance of the APS engine feed valves in the simulator verified that the stage electrical control system operated within its

*Hardwire Measurement

prescribed limitations during the test. The measurements that were evaluated and the results are listed below:

		Specified Min Value (vdc)	Value (vdc)
K0132	APS Eng. 1-1/1-3 Feed Valves Open	3.2	3.77
K0133	APS Eng. 1-2 Feed Valves Open	3.2	3.86
K0134	APS Eng. 2-1/2-3 Feed Valves Open	3.2	3.68
K0135	APS Eng. 2-2 Feed Valves Open	3.2	3.53

The specified minimum value of 3.2 vdc indicated that all of the feed valves were operating according to commands.

13.3 Electrical Power System

The electrical power system performed satisfactorily throughout the acceptance firing. It supplied power to other stage systems, as required, and the external/internal and motor-driven switches functioned properly.

13.3.1 Battery Simulators

Secondary batteries were used to provide internal electrical power during the acceptance firing. The battery voltage and current levels were measured at the stage battery simulators, Model DSV-4B-727, and these levels remained within their required limits. Figures 13-1 through 13-4 are plots showing the voltage and current levels at the battery simulators during selected phases of the acceptance firing.

13.3.2 PU Static-Inverter Converter

The static inverter converter operated satisfactorily during the acceptance firing. The 115 VAC RMS and 21 vdc voltages, measured by M0001-411 and M0023-411 respectively, were within the acceptable limits specified. However, measurements, M0004-411 (5 vdc) and M0012-411 (400 cps) exhibited positive level shifts during the PU hardover period. The level shifts are expected when the PU hardover command is initiated since the 117 vdc summing potentiometer loads in the PU electronics assembly are removed during this period. Removal of these loads affects the regulation of the oscillator module in the static-inverter converter causing a shift in its unregulated output parameters. The static-inverter output shifts during the period of PU hardover operation are not detrimental to the PU system, and although they are a deviation of design consideration, the PU system operation will not be impaired. ECP 3008 has been generated to remedy the condition on stages 504N and subs.

It was also noted that the 5 vdc exceeded the acceptable limits established in the test plan. While the test plan reflects the contract end item (CEI) specification limits at 4.9 = 0.1 vdc, the handling and checkout calibration document specifies a setup limit of 4.75 to 5.05 vdc.

Obviously, an acceptable tolerance discrepancy exists and action will be taken to remedy the problem. Operation of the PU system was not impaired by the 5 vdc exceeding the CEI and test plan limits.

Voltage and frequency levels during the acceptance firing are shown in the following table:

Measurements and Characteristics	Acceptable Limits	Actual Min Value	Actual Max Value
M0001 Voltage (VRMS)	115.0 ±3.45	115.0	115.0
M0004 Voltage (vdc)	4.9 ±0.1	5.02	5.08
M0023 Voltage (vdc)	21.0 $^{+1.5}_{-1.0}$	21.9	21.9
M0012 Frequency (cps)	400.0 ±6.0	401.7	406.4

13.3.3 Chilldown Inverters

The inverters performed satisfactorily during the firing and the O_2-H_2 burner repressurization test. The phase voltages and frequencies are listed in the following table:

Measurements and Characteristics	Nominal	Acceptable Limits
M0027 Phase A-B, LOX C/D Inv (vac)	56.0	56 ±4
M0040 Phase A-C, LOX C/D Inv (vac)	56.0	56 ±4
M0029 Frequency LOX C/D Inv (cps)	400.8	400 ±10
M0026 Phase A-B, LH2 C/D Inv (vac)	55.8	56 ±4
M0041 Phase A-C, LH2 C/D Inv (vac)	55.8	56 ±4
M0028 Frequency LH2 C/D Inv (cps)	401.5	400 ±10

13.3.4 5-Volt Excitation Modules

The forward 5-volt excitation modules performed as expected during the acceptance firing. The aft 5-volt excitation module showed a dc shift of 40 mv during the operation of the childown inverters. The problem was investigated as a measurement anomaly (M0025-404 5-Volt Excitation Mod, Aft) and is discussed in table 12-2.

The actual performance values are shown in the following table:

Measurements and Characteristics	Acceptable Limits	Actual Min Value	Actual Max Value
M0025 Aft Voltage (vdc)	5.0 ±0.03	4.96	5.00
M0024 Forward 1 Voltage (vdc)	5.0 ±0.03	5.00	5.00
M0068 Forward 2 Voltage (vdc)	5.0 ±0.03	5.00	5.00

13.4 Separation Exploding Bridgewire (Ullage Rocket EBW) System

Since live ordnance is not installed, EBW pulse sensors are used during the acceptance firing to verify the operational integrity of the stage electrical control system in providing the commands necessary to charge, fire, and jettison the ullage rockets. The following measurements furnished the data used to verify this integrity:

K0149	Ullage Rocket Jettison EBW P/S 1 Indication
K0150	Ullage Rocket Jettison EBW P/S 2 Indication
K0176	Ullage Rocket Ignition EBW P/S 1 Indication
K0177	Ullage Rocket Ignition EBW P/S 2 Indication
K0673*	Ullage Rocket Pilot Relays Reset
M0064	Ullage Rocket Ignition, EBW F/U 1 (Volts)
M0064	Ullage Rocket Ignition, EBW F/U 2 (Volts)
M0067	Ullage Rocket Jettison, EBW F/U 1 (Volts)
M0068	Ullage Rocket Jettison, EBW F/U 2 (Volts)

13.5 O_2-H_2 Burner

The operation of the O_2-H_2 burner, with respect to the operational integrity of the electrical control system, was normal and no problems were encountered. The sequence of events (section 5) verifies that burner control commands were sent and received, and that instrumentation response and talkback signals occurred as predicted. The voltage and current profiles of the battery simulators during the burner firings are presented in figures 13-3 and 13-4.

*Hardwire Measurement.

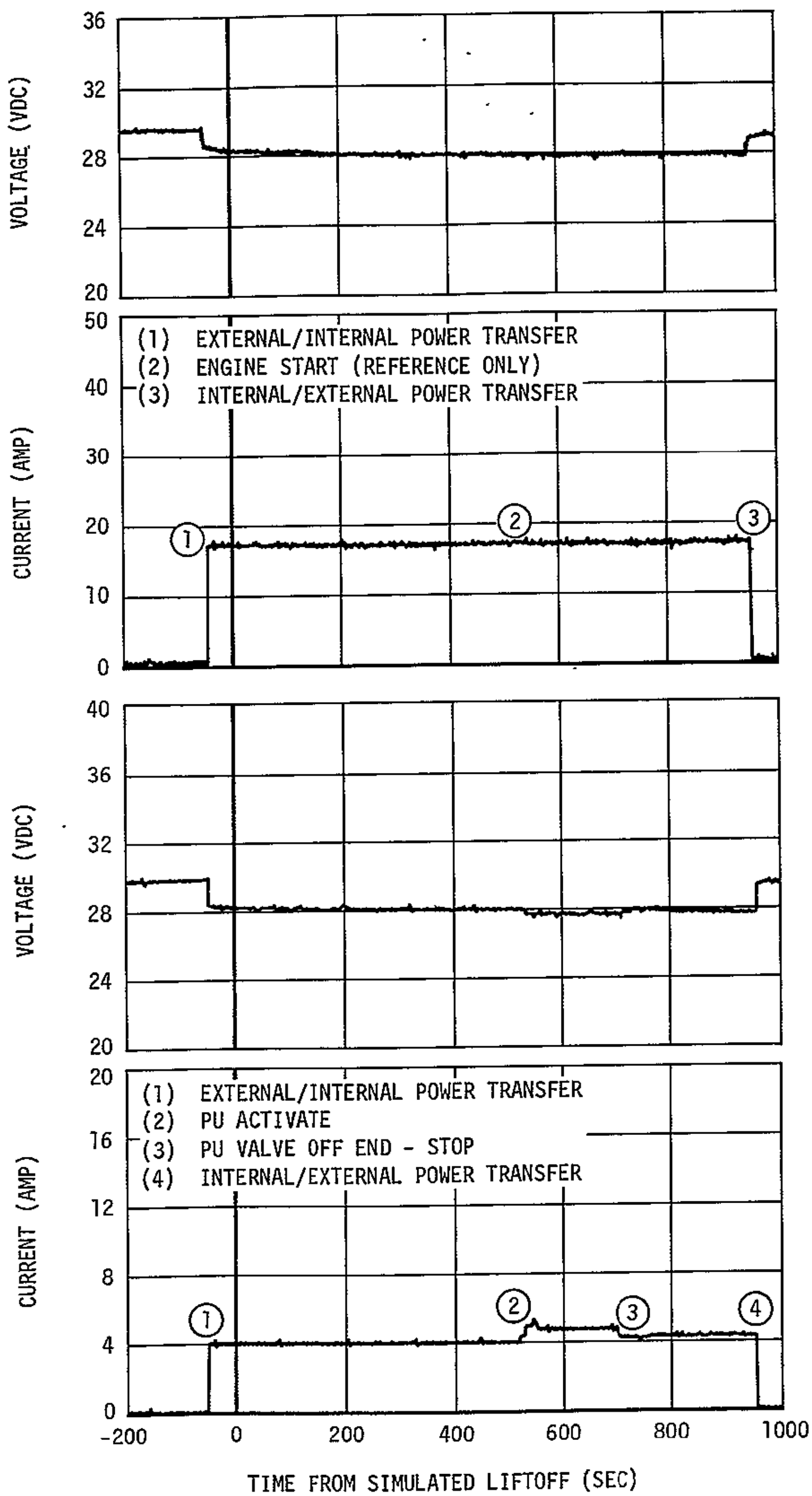


Figure 13-1. Forward Battery Voltage and Current Profiles (Mainstage Firing)

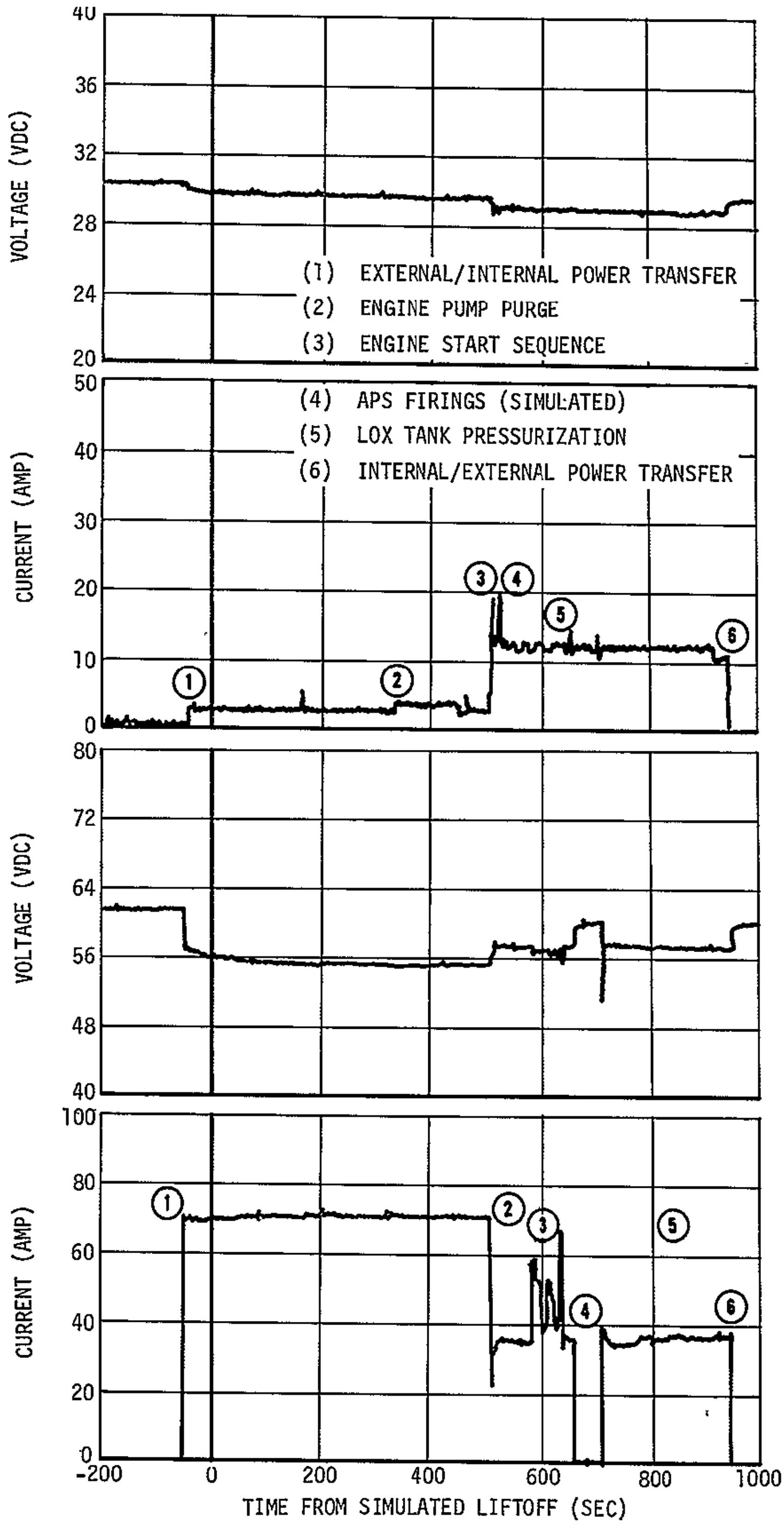


Figure 13-2. Aft Battery Voltage and Current Profiles (Mainstage Firing)

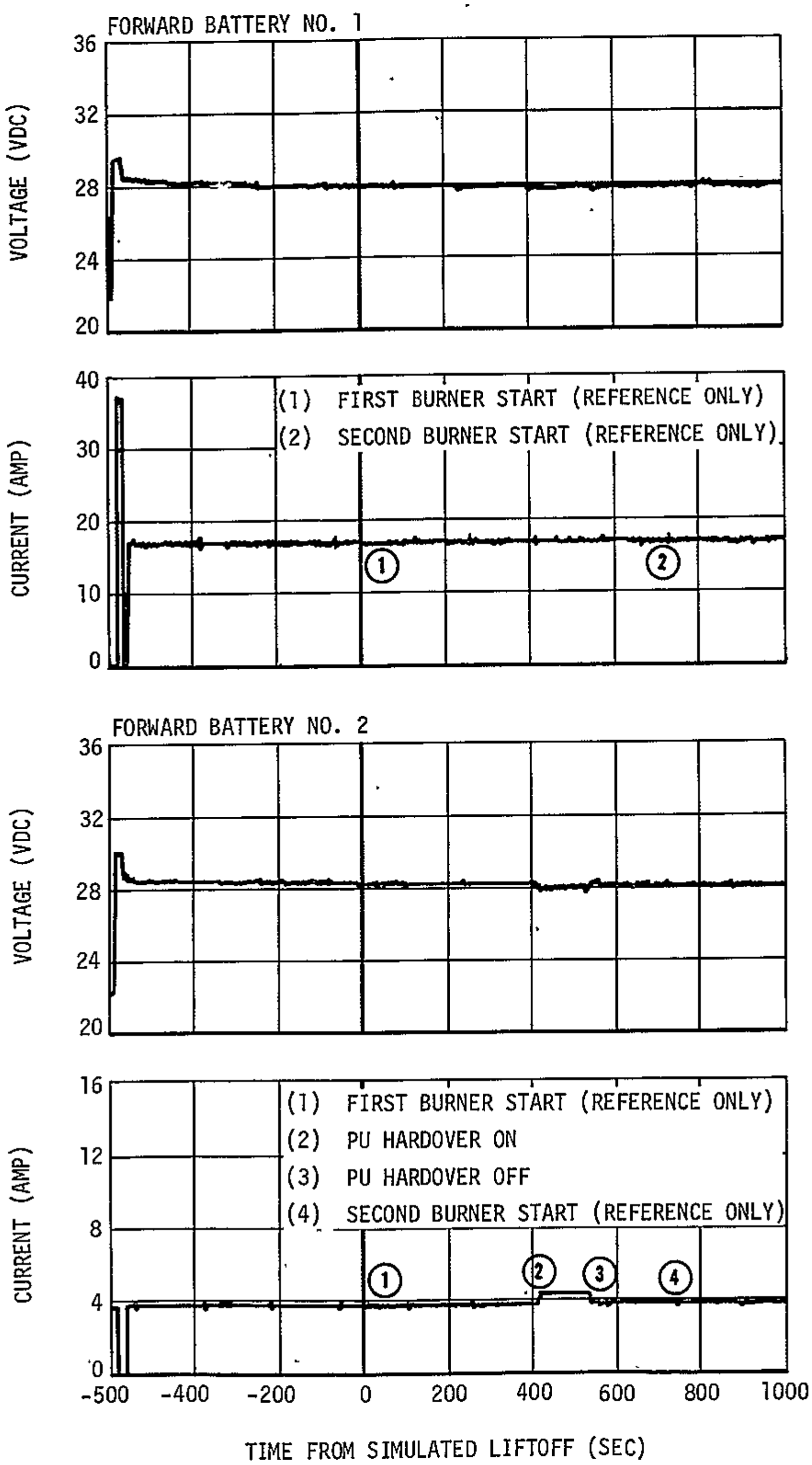


Figure 13-3. Forward Battery Voltage and Current Profiles (O_2-H_2 Burner Firing)

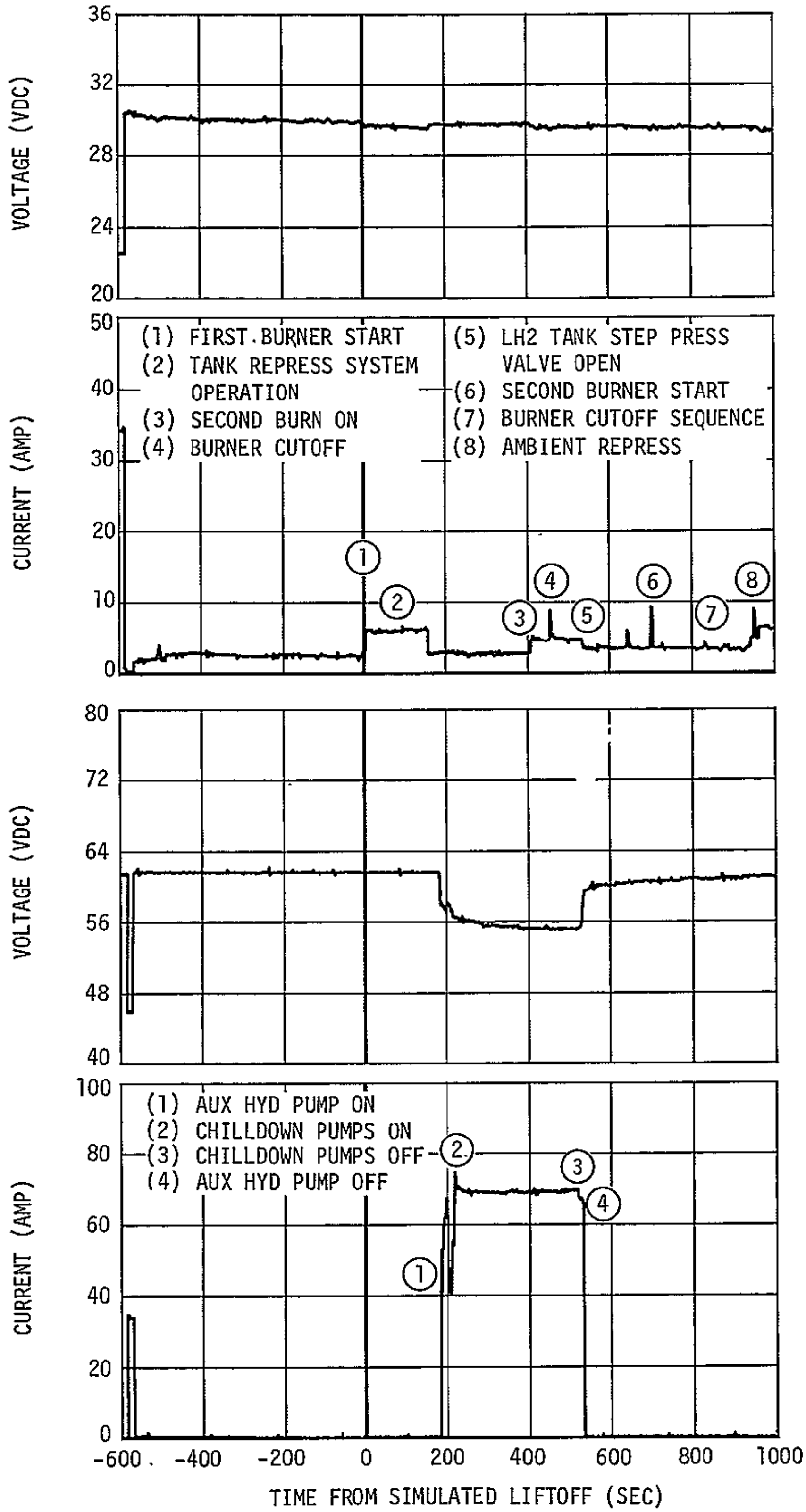


Figure 13-4. Aft Battery Voltage and Current Profiles (O_2-H_2 Burner Firing)

14. HYDRAULIC SYSTEM

14.1 Hydraulic System Operation

The hydraulic system test program was conducted during CD 614113, during which the engine was successfully positioned and gimbaled. System running time for this test from auxiliary pump ON, prior to simulated liftoff, to auxiliary pump OFF following cutoff, was 1,447 sec. The gimbal program was initiated after the engine start side loads subsided and the support links dropped. The auxiliary pump was turned off for 50 sec following the gimbaling program to verify satisfactory engine-driven pump operation.

Significant event times are presented in the following table:

Event	Approximate Time (sec)
Auxiliary Pump ON	T_0 -476
(Simulated Liftoff)	(T_0 +0)
Engine Ignition (Engine-Driven Pump Start)	T_0 +513
Support Links Dropped	T_0 +555
Gimbal Program Start	T_0 +581
Gimbal Program Stop	T_0 +636
Auxiliary Pump OFF	T_0 +657
Auxiliary Pump ON	T_0 +707
Engine Cutoff	T_0 +951
Auxiliary Pump OFF	T_0 +970

14.2 System Pressure at Salient Times

The GN2 accumulator precharge pressure was monitored at 2,242 psia at 48 deg F during prefire checkout. After correcting the gas pressure to 70 deg F temperature, the value was found to be within the 2,350 ±50 psia allowable limits.

Test data indicated that the auxiliary pump discharge pressure increased to 3,640 psia in 19 sec after energizing the pump motor. Acceptable pump pressure was maintained from T_0 -476 sec through T_0 -0. The simulated requirements were met.

During the brief period of auxiliary pump cutoff (50 sec), the engine-driven pump pressure was observed to be 3,680 psia. No noticeable pressure fluctuation was observed during the auxiliary pump cutoff period indicating that the engine-driven pump was operating properly.

The aft battery No. 2 current load (38 amp average) shows that the auxiliary pump shared the hydraulic load throughout the burn period. This also indicates that the two pump compensators were set at nearly the same pressures which maintained a steady-state pressure during burn at 3,670 to 3,690 psia. Although the system pressure upper limit of 3,650 psia was exceeded by this measurement, the actual value was within limits, as verified by a GN2 pressure of 3,621 psia and a reservoir pressure of 172 psia which corresponds to an approximate system pressure of 3,620 psia. System pressure transducer calibration will be checked and corrected as necessary. The significant system pressures are presented in the following table:

Time (sec)	System Pressure (psia)	GN2 Pressure (psia)	Reservoir Pressure (psia)
T_0 -476.5 (aux pump on)	3,640	3,583	170
T_0 +0 (Simulated Liftoff)	3,680	3,600	169
T_0 +520 (After Ignition)	3,690	3,621	172
T_0 +581 to 636 (Gimbal)	3,755 max 3,505 min	3,621 max 3,570 min	184 max 162 min
T_0 +970 (Prior to aux pump off)	3,680	3,521	175

14.3 Reservoir Level at Salient Times

Reservoir level prior to system operation was 88 percent at an oil temperature of 48 deg F. The minimum level during operation was 29 percent which occurred 178 sec after auxiliary pump start.

14.4 Hydraulic Fluid Temperature History

Time	ED Pump Inlet (°F)	Reservoir (°F)	Accumulator GN2 (°F)
T_0 - 476 (Aux pump on)	70	48	52
T_0 +0 (Simulated liftoff)	83	60	60
T_0 +520 (After Ignition)	99	82	60
T_0 +951 (Engine Cutoff)	112	92	60
T_0 +970 (Aux Pump Off)	112	96	60

14.5 Engine Side Loads

Peak loads in the support links during engine start transients are as follows:

Item	Load (lbf)
Pitch Link	+22,000, -9000
Yaw Link	+18,000, -20,000

14.6 Hydraulic Fluid Flowrates

Approximations from reservoir fill and emptying rates are as follows:

Item	Flow (gpm)	Allowable (gpm)
System Internal Leakage	0.607	0.4 to 0.8
Auxiliary Pump Max Flowrate	1.648	1.50 min

14.7 Auxiliary Pump Motor Voltage and Current

Auxiliary pump motor electrical data were monitored only after the stage power source had switched to internal power (battery) and after the chilldown pumps had shutdown. The design requirements are as follows:

Voltage	51-61 vdc
Max Starting Current	300 amp
Max Operating Current	85 amp

The following table shows the values observed during the firing:

Time	Aft Bus No. 2 Voltage Supply (M0540) (V)	Aft Battery No. 2 Current Load (M022) (amp)
T_0 +0	56	71
T_0 +530 (After ignition C/D pumps off)	57.5	36
T_0 +581 to +636 (Gimbal)	57.4 55.5	68 max 38 min
T_0 +707 (Turn aux pump on after brief shutdown)	52 min	128 pk
T_0 +950 (prior to engine C/O)	57.7	38

15. FLIGHT CONTROL SYSTEM

The dynamic response of the hydraulic servo thrust vector control system was measured while the J-2 engine was gimbaling during the acceptance firing. The performance of the pitch and yaw hydraulic servo control system was acceptable.

15.1 Actuator Dynamics

The frequency response test of the pitch and yaw hydraulic servo control system for a ±0.50-deg sinusoidal signal between 0.6 and 9 cps, and for a ±0.25-deg sinusoidal signal between 0.6 and 2 cps verified the acceptability of the actuator responses. The acceptable limits and the gain and phase plots within these limits are presented in figures 15-1 and 15-2.

15.2 Engine Slew Rates

A nominal 2-deg step command was applied to the pitch and yaw actuators from which the engine slew rates were determined. The minimum acceptable engine slew rate is 8 deg/sec, which corresponds to an actuator piston travel rate of 1.66 ips. A nominal slew rate for a 2-deg step without the effects of gimbal friction is 13.6 deg/sec. The measured values were acceptable and are presented in the following table:

Actuator	Condition	Engine Travel (deg)	Engine Slew Rate (deg/sec)
Pitch	Retract	0.0 to +2.0	11.1
	Extend	+2.0 to 0.0	11.0
	Extend	0.0 to -2.0	11.8
	Retract	-2.0 to 0.0	11.1
Yaw	Extend	0.0 to +2.0	11.4
	Retract	+2.0 to 0.0	11.8
	Retract	0.0 to -2.0	11.6
	Extend	-2.0 to 0.0	11.9

The minimum engine slew rate obtained is 11.0 deg/sec. This corresponds to an actuator piston travel of 2.275 ips when using a conversion of 4.83 deg of engine movement per inch of actuator travel. Thus, in all cases, each actuator exceeded the minimum acceptable piston travel rate of 1.66 ips, or corresponding engine travel rate of 8 deg/sec.

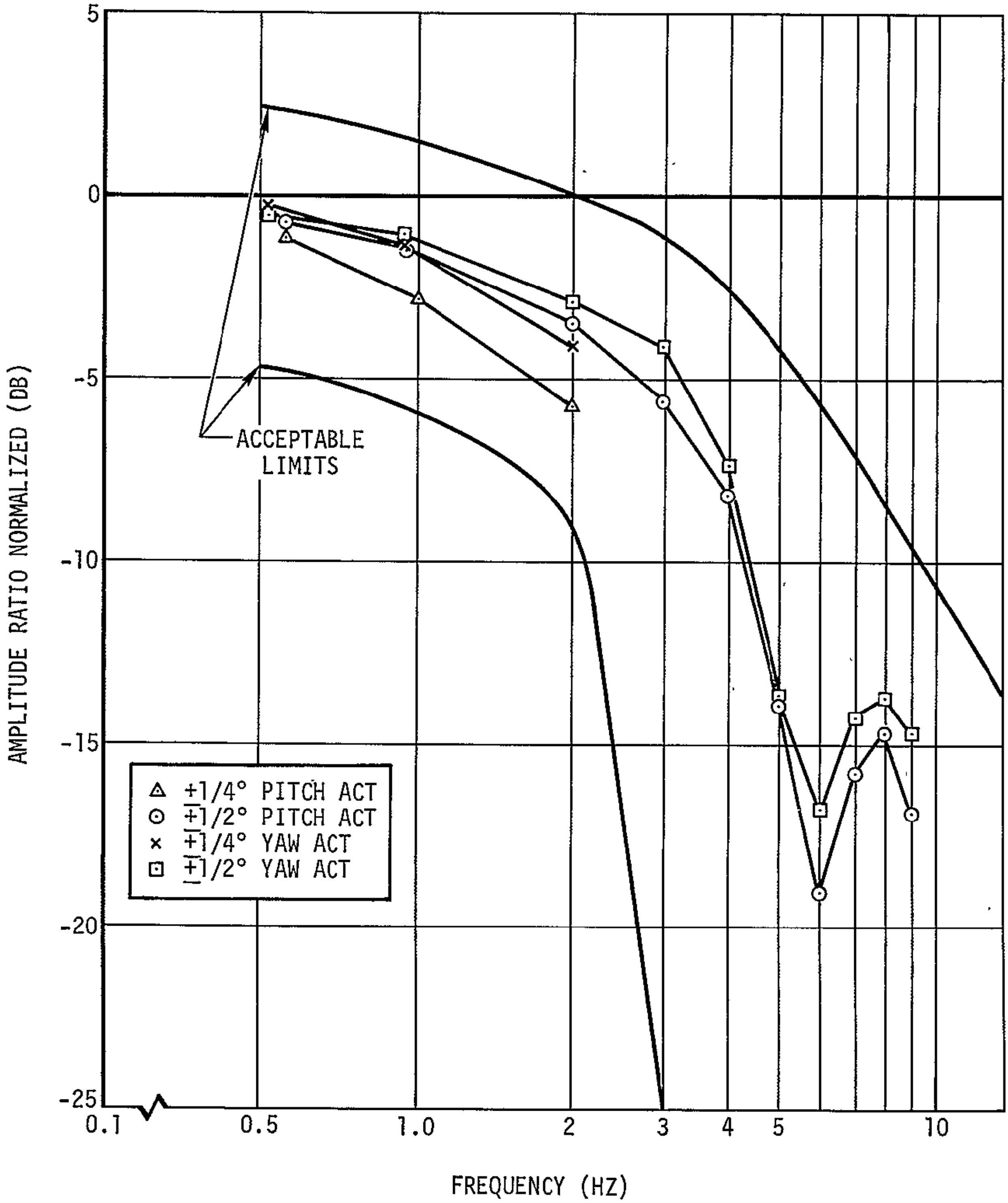


Figure 15-1. Actuator Response (Gain)

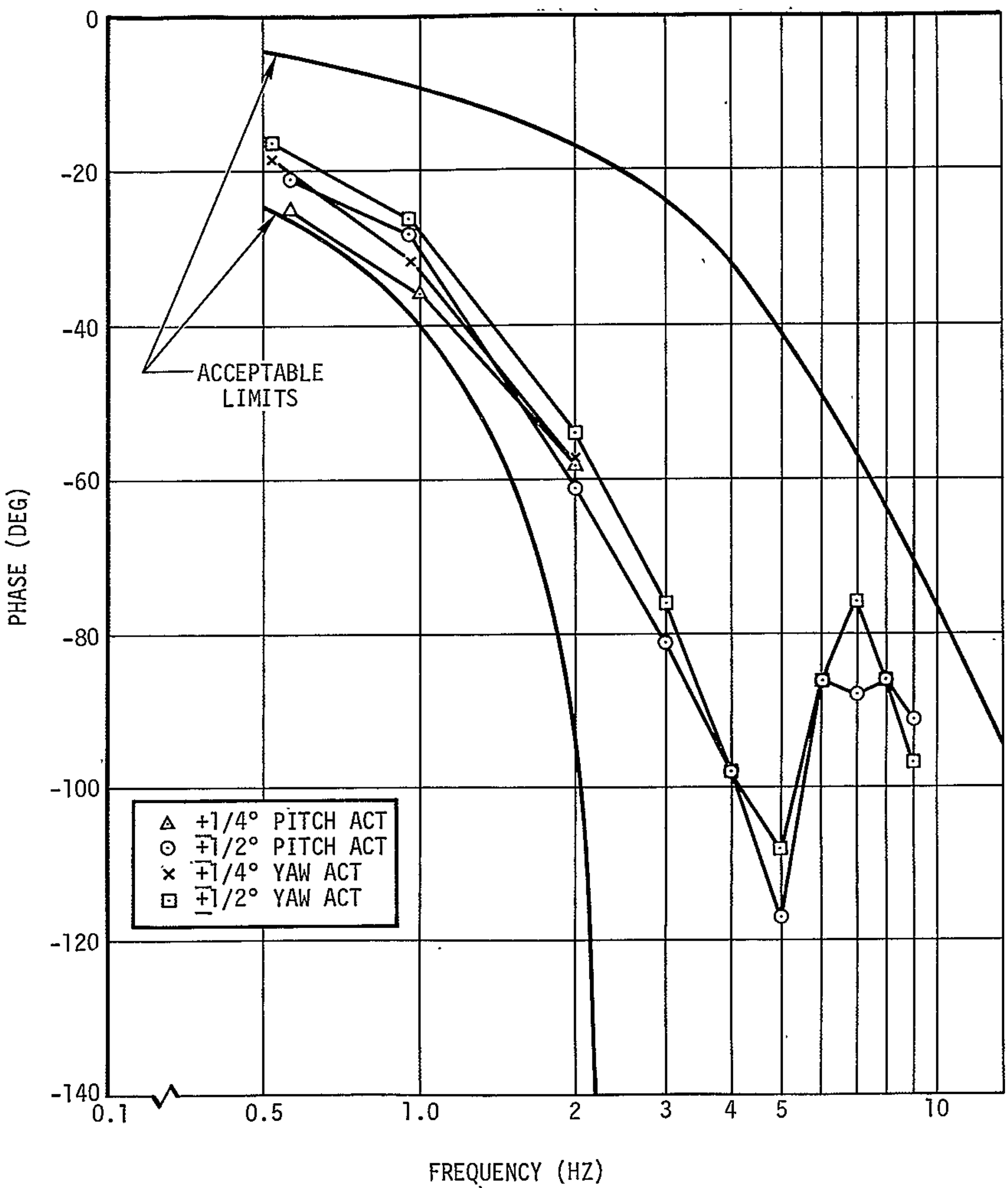


Figure 15-2. Actuator Response (Phase Lag)

16. STRUCTURAL SYSTEMS

Structural integrity of the S-IVB-507 stage was maintained for the vibration, temperature, pressure, and thrust load conditions of the acceptance firing. With the exception of cracking and peeling of Korotherm ablative coating at two local areas on the forward skirt, no structural irregularities were encountered as a result of cryogenic loading, static firing, and O_2-H_2 burner firing. The damaged Korotherm coating is to be repaired under the direction of Materials and Methods/Research and Engineering. The Korotherm damage does not occur under CDDT or launch conditions at FTC due to the more effective thermal conditioning of the forward skirt at the launch facility.

16.1 Common Bulkhead

The results of the gas sample surveys, combined with satisfactory common bulkhead decay checks, indicate the bulkhead is sound and leak tight. During the actual acceptance firing, the bulkhead internal pressure readings were less than 1 psia. Gas sample analyses consistently indicated negligible quantities of hydrogen and helium gases within the common bulkhead. The pressure decay history and gas sample analyses recorded during pre-fire pumpdown, static firing, and post-firing activities are presented in Report DAC-61232, S-IVB-507 Stage Acceptance Firing 15 Day Report, dated November 1968.

16.2 Exterior Structure

A post-firing visual inspection of the S-IVB-507 stage exterior and accessible interior revealed no debonding of supports or brackets. The only evident structural degradation was cracking and peeling of Korotherm ablative coating on skin panel areas adjacent to the auxiliary tunnel of the forward skirt, and a few hairline cracks in the Korotherm coating on the forward skirt aft flange adjacent to the main tunnel. The approximate panel areas affected were 4 by 20 in. between stringers 13 and 14; 4 by 5 in. between stringers 14 and 15; 2 by 3 in. between stringers 16 and 17; and 5 by 6 in. between stringers 17 and 18. This was significantly less damage than occurred previously in the acceptance firing of the S-IVB-506 stage and indicates improved effectiveness of the forward skirt purge system after duct and port modifications to the S-IVB-507 stage. The damaged Korotherm coating is to be repaired in the VCL. To minimize the Korotherm coating problem on the currently uncoated S-IVB-510 stage and subsequent stages, it is planned to apply Korotherm to the affected panels only after the acceptance firings. The problem with the ablative coating at the auxiliary tunnel location has been attributed to liquid nitrogen condensing on the LH2 vent line and dripping on the skirt, as discussed in detail in section 16 of Report SM-47462, Saturn S-IVB-506N Stage Acceptance Firing Report, dated September 1968.

17. THERMOCONDITIONING AND PURGE SYSTEMS

17.1 Aft Skirt Thermoconditioning and Purge System

The aft skirt environmental purge system thermally conditioned the aft skirt area with air and GN2. The air purge was initiated prior to LOX loading, and was switched to GN2 prior to LH2 loading. Following LH2 loading, the air purge was reinitiated for test stand inspection, and then was switched back to GN2 for the relief test, O_2-H_2 burner sequence, and static firing. The purge flowrate was maintained between 3,480 and 3,650 scfm, and the aft skirt environmental temperature was maintained between 547 and 552 deg R.

17.2 Forward Skirt Environmental Control and Thermoconditioning Systems

17.2.1 Forward Skirt Purge

The forward environmental purge system supplied the forward skirt with thermally conditioned GN2. The GN2 purge of the forward skirt was initiated prior to LOX loading and continued throughout the test until the completion of the tank purges. A flowrate of 500 scfm was maintained. The forward skirt GN2 supply temperature (measurement C0768) was maintained between 502 and 523 deg R.

17.2.2 Forward Skirt Thermoconditioning System

The forward skirt thermoconditioning system was supplied with coolant throughout the acceptance firing by the Model DSV-4B-359 Servicer. The coolant supply temperature (measurement C0753) was maintained between 515 and 523 deg R.

18. EFFECTIVENESS ENGINEERING

All functional failures of Flight Critical Items (FCI) and Ground Support Equipment/Special Attention Items were investigated by Effectiveness Engineering. Significant malfunctions of FCI's documented are noted in table 18-1.

TABLE 18-1
FLIGHT CRITICAL COMPONENTS MALFUNCTIONS

P/N AND S/N	PART NAME	TROUBLE DESCRIPTION	CAUSE	ACTION TAKEN
1A48240-505 S/N 0128	Valve, Fill and Drain	During the leak check per procedure 1B70175, numerous scratches were found on the body of the valve near sealing surface. Depth of scratches could not be determined.	To be determined.	The valve was installed on the vehicle using a new conoseal. The valve was re-checked for leakage per procedure 1B70175 and found acceptable to engineering for use.
1A66241-511 S/N X458911	Pump, hydraulic aux motor-driven	During the post-fire check per procedure 1B41006, a leak was found at the gasket where the differential pressure indicator attaches to the pump.	To be determined.	The pump was dispositioned as follows: Replace sealing "O" rings and backup rings; Retorque attach screws; Flush, leak check and sample the system per engineering instructions
103826 S/N J-2119	J-2 Engine	During the test per procedure 1B70175, Para. 4.7.2, Step 5, the following discrepancy of the main fuel valve P/N 409920, S/N 4090663 was noted: The valve had a leakage of 54 scim through the actuator and out of the closing port with 250 psig applied to the opening port. The maximum allowable leakage per R/NAR spec is 10 scim	To be determined during failure analysis.	The part was returned to R/NAR government stores for replacement. A failure analysis is required from the supplier. A complete report is to be furnished to NASA and AFQC. This is a GFP item.

TABLE AP 1-1 (Sheet 1 of 3)
ABBREVIATIONS

Item	Term
ac	Alternating current
Act	Actuator
APS	Auxiliary Propulsion System
ASI	Augmented Spark Igniter
attch	Attach
A_t	Throat area
Aux	Auxiliary
Btu	British thermal unit
Bgr	Bridge gain ratio
c_f	Thrust Coefficient
CDDT	Countdown Demonstration Test
Cfm	Cubic feet per minute
Contr	Control
cpg	Cycles per gallon
cps	Cycles per second
db	Decibel
dc	Direct current
DDAS	Digital Data Acquisition System
deg	Degree
DER	Digital Events Recorder
Disch	Discharge
DNA	Data not available
D/O	Dropout
DPF	Differential Pressure Feedback
EBW	Exploding bridgewire
ECC	Engine Cutoff Command
ECO	Engine Cutoff
EDS	Emergency Detection System
E/I	External/Internal
EMI	Electromagnetic Interference
EMR	Engine Mixture Ratio
ESC	Engine Start Command
F	Fahrenheit
F	Thrust
FCI	Flight Critical Items
Flt	Flight
ft	Feet
FM	Frequency modulation
FTC	Florida Test Center
Fwd	Forward
GG	Gas generator
GH2	Gaseous hydrogen
GIS	Ground Instrumentation System
GN2	Gaseous nitrogen
gpm	Gallons per minute
GSE	Ground support equipment
HB	Huntington Beach
He	Helium
Hg	Mercury
H_2O	Water
hr	Hour
hp	Horsepower
Hyd	Hydraulic
Hz	Hertz
in.	Inch
ips	Inches per second
IP&CL	Instrumentation Program and Components List
I_{sp}	Specific impulse

TABLE AP 1-1 (Sheet 2 of 3)
ABBREVIATIONS

Item	Term
IU	Instrument Unit
K	Kilo - 1,000 or 10^3
Kc	Kilocycle
KSC	Kennedy Space Center
lbf	Pounds force
lbm	Pounds mass
LH2	Liquid hydrogen
Loc	Location
LOX	Liquid oxygen
M&A	Manufacturing and Assembly
MDAC-WD	McDonnell Douglas Astronautics Company - Western Division
MR	Mixture ratio
ms	Millisecond
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
N/A	Not applicable
NPSP	Net positive suction pressure
P_c	Chamber pressure
PCM	Pulse code modulation
PDT	Pacific Daylight Time
pf	Picofarad
Posit	Position
pps	Pulses per second
Press	Pressure
psi	Pounds per square inch
psia	Pounds per square inch, absolute
psid	Pounds per square inch, differential
psig	Pounds per square inch, gauge
PST	Pacific Standard Time
Pt	Point
P/U	Pickup
PU	Propellant Utilization
Pwr	Power
R	Rankine
RACS	Remote Analog Checkout System
RAD	Radial
Refl	Reflected
Reg	Regulator
RF	Radio Frequency
RMR	Reference Mixture Ratio
rpm	Revolutions per minute
RSS	Root sum square
SAI	Special Attention Items
scc	Standard cubic centimeter
sci	Standard cubic inch
scim	Standard cubic inch per minute
scfm	Standard cubic foot per minute
sec	Second
sps	Samples per second
SSB	Single sideband
STC	Sacramento Test Center
sw	Switch
Syst	System
T_0	Simulated liftoff
TAN	Tangential

TABLE AP 1-1 (Sheet 3 of 3)
ABBREVIATIONS

Item	Term	Item	Term
Temp	Temperature		
T/M	Telemetry		
TP&E	Test Planning and Evaluation		
vac	Volts alternating current (100 vac)		
V	Volts		
VCL	Vehicle Checkout Laboratory		
vdc	Volts direct current		
Vib	Vibration		
vswr	Voltage standing wave ratio		
$\dot{W}_T$	Total mass flowrate		

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