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APOLLO LUNAR MODULE REACTION CONTROL SUBSYSTEM TEST

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Propulsion and Power Division
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INTRODUCTION

The Lunar Module Reaction Control Subsystem (LM RCS) performs the following functions:

a. Provides small thrust impulses to stabilize the Lunar Module.

b. Provides necessary thrust impulses to control the vehicle attitude and translation movements during hover, rendezvous, and docking maneuvers.

c. Provides necessary thrust impulses to accomplish the Lunar Module — Command Service Module separation maneuver.

d. Provides necessary thrust impulses to accomplish accelerations for ullage and settling for the ascent and descent propellant storage tanks as required.

The complete LM RCS consists of two similar and independent systems, identified as system A and system B. Each system consists of a pressurized helium storage and distribution system, hypergolic propellant storage and distribution system, and eight rocket engines. The LM RCS test was conducted with both systems A and B.

The primary objectives of this test program were to define the general operational characteristics of the LM RCS under simulated altitude conditions and to obtain performance data on individual subsystem components. Specific areas of investigation were:

a. Determination of the hydraulic transients resulting from various operational modes and the effects of these transients on engine performance.

b. Evaluation of various RCS priming techniques.

c. Evaluation of the LM RCS compatibility with the Caution and Warning Subsystem (CWS).

d. Determination of propellant consumption as a function of pulse width and/or pulse mode.

e. Determination of the oxidizer to fuel mixture ratios for the mission duty cycles.

f. Evaluation of the capability of the subsystem to successfully perform simulated mission duty cycles.

g. Evaluation of subsystem performance during contingency and failure modes.

h. Evaluation of the rocket engine cluster heater system and thermal insulation blanket.

i. Determination of the magnitude and effects of regulator overshoot.

j. Evaluation of the thrust chamber assembly (TCA) failure detection pressure switches.

k. Evaluation of the propellant quantity measuring system.

The LM RCS test was conducted by the Propulsion Test Section, Thermochemical Test Branch, Propulsion and Power Division, in response to a request from the Auxiliary Propulsion and Pyrotechnics Branch (ref. 1).

TEST ARTICLE DESCRIPTION

The test article was a complete LM RCS with all qualified components except the combustion chamber pressure switches. Most of the subsystem components and all propellant lines were previously used in tests on the HR-3 design verification test (DVT) subsystem at the Marquardt Corporation's (TMC) Magic Mountain Test Facility. The results of these Marquardt tests are documented in reference 2.

The HR-3 DVT subsystem was disassembled and shipped to MSC after completion of testing at Magic Mountain. The shipment included the entire LM RCS and the test frame (ref. 3) in a disassembled condition. The system A tankage module was shipped via Grumman Aircraft Engineering Corporation (GAEC) where post-test functional tests were conducted.

After receipt at MSC, the individual components were acceptance tested to verify conformity with the operational requirements of the applicable GAEC specifications. Acceptance tests also included proof tests and cleanliness checks of the propellant tanks. Engine repairs were performed as required. The propellant manifold, propellant injection pressure, and engine chamber pressure transducers were calibrated at MSC. Acceptance test results are recorded in references 4, 5, and 6.

After acceptance testing, the components and tubing were individually cleaned to the level N requirements specified in reference 7 and moved to the class 100 cleanroom at building 36, NASA/MSC, where subsystem assembly was performed. After assembly, the propellant distribution system was flushed with freon TF and verified clean to the requirements specified in reference 8. Figure 1 is a photograph of the complete test article assembly in the cleanroom.

On September 27, 1967, the assembled subsystem was transported to the subsystems chamber (SSC) in building 353 of the Thermochemical Test Area. The LM RCS was installed in the subsystems chamber and verified dry in accordance with the requirements outlined in reference 9. Support and servicing equipment were then installed as shown schematically in figure 2. Figure 3 illustrates the complete LM RCS installation relative to the Lunar Module structure and includes the engine numbering code which will be used in this document.

During the process of subsystem assembly, the HR-3 DVT configuration was modified and updated as required to meet specific test objectives and to incorporate the latest changes to flight subsystems. Deviations from the original HR-3 DVT configuration as tested at Marquardt included the following:

a. Propellant quantity measuring devices (PQMD) were installed in each helium tank.

b. The mechanical fittings at the helium inlets to the propellant tanks were disconnected and capped to facilitate checkout operations (fig. 4).

c. The propellant tank mounting brackets were modified and the tanks were mounted on load cells (fig. 5) for propellant quantity measurements.

d. Propellant inlet pressure transducers (16) and drain lines (16) were installed in the y-block fittings (fig. 6). The eight flight-type propellant inlet pressure transducers in system A were replaced with Kistler model 601A pressure transducers.

e. Propellant temperature transducers (16) were installed in the fittings originally occupied by the propellant injection pressure transducers (fig. 6).

f. The system A, quad IV, fuel cluster isolation valve LSC 310-403-204, S/N 0048, was replaced with a new valve, LSC 310-403-206, S/N 214.

g. The fuel interconnect valves LSC 310-403-204, S/N 0044; and LSC 310-403-204, S/N 0055 were replaced with valves LSC 310-403-103, S/N 0026; and LSC 310-403-204, S/N 0051.

h. Propellant manifold pressure transducers P-13, P-14, P-15, and P-16 were replaced with Kistler model 601A pressure transducers.

i. One flight-type thruster heater, LSC 310-601-11, was installed on each system A engine, and one flight-type thruster heater, LSC 310-601-12, was installed on each system B engine (fig. 7).

j. A propellant filter (Marquardt P/N 229494) was installed in each engine injector valve.

k. The engine injector head assemblies were modified as shown in figure 8 to accomodate both a pressure switch and a pressure transducer.

l. The L-605 nozzle extensions were removed from all but the downfiring engines (fig. 7).

m. The eight system B engine chamber pressure transducers were replaced with Taber model 185 pressure transducers (fig. 7).

n. A pressure switch, LSC 310-651-3, was installed in each of 15 engine injector heads. Engine IV D/2 was equipped with a backup pressure switch manufactured by Electro-Optical Systems.

o. A partial cluster insulation blanket and shield assembly, LSK 280-11127-1, was installed on the cluster III downfiring engine (fig. 9).

p. Flight-type arc suppression circuitry was installed on each engine (fig. 10).

A complete test article schematic is included in figure 2, and all components and instrumentation are identified in appendix C, Equipment List. Figures 11 and 12 are photographs of sections of the LM RCS after installation in the subsystems chamber.

TEST PROGRAM

Phase I — Pretest Operations

The objectives of this phase of the program were to assemble, check out, and load the LM RCS. Assembly of the subsystem included acceptance testing of individual components, cleanroom buildup, and cleanliness verification. Checkout was then performed to verify the operational capability of the subsystem and all auxiliary test equipment immediately prior to subsystem testing. Propellant and helium loading operations were performed to prepare the subsystem for hot-firing and to evaluate the LM1 and LM3 manifold priming techniques.

Phase II — Baseline Performance Duty Cycles

Phase II of the test program was designed to bleed-in each engine and to observe nominal performance characteristics for the subsystem components during subsystem operation at altitude. The bleed-in firings were also used as a final validation of the data acquisition system operation. The baseline duty cycles performed are included in appendix A, Engine Firing Record and Run Chronology.

Phase III — Mission Duty Cycles

The objective of this portion of the program was to run simulated LM1 and lunar mission duty cycles utilizing both Primary Guidance Navigation and Control System (PGNCS) and Abort Guidance System (AGS) firing modes. The propellant distribution system operated in the normal mode during the mission duty cycles; that is, crossfeed and interconnect valves were closed. Representative portions of the following simulated missions were performed:

a. LM1 — Mission phase 7 — separation

b. LM1 — Mission phase 9 — first Descent Propulsion System (DPS) burn

c. LM1 — Mission phase 11 — second DPS burn, fire-in-the-hole (FITH), and first Ascent Propulsion System (APS) burn

d. LM1 — Mission phase 13 — second APS burn

e. Lunar Mission — abort from hover

f. Lunar Mission — coelliptic sequence initiation

g. Lunar Mission — coelliptic delta height

h. Lunar Mission — transfer point initiation

i. Lunar Mission — midcourse corrections

Simulations a through d (above) utilized the PGNCS mode and e through i utilized the AGS mode. Individual engine firing summaries are included in appendix A.

Phase IV — Special Duty Cycles

This portion of the program included various special duty cycles designed to accomplish specific test objectives and evaluate subsystem performance when subjected to worst case duty cycles. Areas of special interest in this phase included:

a. Hydraulic transient effects (normal and crossfeed modes)

b. Pressure switch evaluation

c. Propellant consumption and oxidizer-fuel (O/F) mixture ratio duty cycles

d. Mission duty cycle performance in crossfeed mode

e. Failure modes

f. Pulse widths of less than minimum impulse

g. Baseline performance with manual (direct) coils

h. Manual coil maneuvers

i. High-low voltage effects

j. Effects of short pulses on injector temperature

k. Cluster insulation evaluation

A summary of the duty cycles performed in this phase is included in appendix A.

Phase V — Post-test Checkout and Decontamination

The objectives of this portion of the program were to determine component performance after completion of the test program described above and to decontaminate the LM RCS for storage. As the result of facility scheduling problems, only very limited post-test component checks were performed. A partial subsystem decontamination was performed immediately after the completion of the test program; however, a complete decontamination was not performed until 4-1/2 months later.

TEST PROCEDURE

Phase I — Pretest Operations

Component acceptance tests.- Since the HR-3 DVT components had been previously used in the Magic Mountain testing, it was considered necessary to conduct partial acceptance tests on the components before initiating test article buildup. Acceptance tests were conducted on the tankage module components, propellant filters, and propellant latch valves as described in reference 4. Static calibration checks were performed on the propellant manifold, propellant injection, and engine chamber pressure transducers to verify specification compliance. Engine acceptance tests were conducted as delineated in references 5 and 6.

Cleanroom buildup and cleanliness verification.- After completion of the components acceptance tests, all components and tubing were individually cleaned to the level N requirements specified in reference 7. The hardware was then moved into the class 100 cleanroom, building 36, NASA/MSC, where buildup and cleanliness verification were performed. Cleanliness verification of the assembled LM RCS was accomplished by flushing freon TF through the propellant manifolds and obtaining and analyzing samples for particulate matter until two successive samples from each outlet met the requirements specified in reference 8. Samples were then taken and analyzed for nonvolatile residue according to reference 8.

Buildup and cleanliness verification were accomplished in two steps. Samples were extracted from the propellant manifolds at the cluster isolation valve outlets before the filters and cluster tubing were installed. Samples were then extracted at the engine inlet fittings (Dynatubes) after the filters and cluster tubing were installed. In both of the above cases the flush fluid was admitted through the service couplings with the main shutoff valves closed. The helium pressurization systems were not verified clean since they were sealed and kept intact after testing at TMC.

Prior to transfer of the assembled LM RCS to the test chamber the crossover section between the tankage modules was removed and the tube ends were sealed. Installation of the LM RCS in the subsystem chamber and dryness verification procedures are delineated in reference 9.

Subsystem checkout.- Subsystem checkout was initiated November 13, 1967, with the LM RCS test article and support equipment configured as shown in figure 2. Subsystem checkout was accomplished in accordance with references 10 and 11. Within the limitations of the available support equipment, the checkout procedures conformed to GAEC Operational Checkout Procedures OCP-GF-31008, OCP-GF-31022, and OCP-GF-31031 (refs. 12, 13, and 14). During helium component checkouts, the helium panels were isolated from the propellant tanks by mechanical fittings as shown in figure 4.

Proof test of the high pressure helium systems (upstream of the regulators) and leak checks of the entire helium pressurization systems were simultaneously performed on the system A and system B tankage modules. The helium tanks and all plumbing upstream of the regulators were pressurized to 3600 psig and maintained at that pressure for 5 minutes for proof testing. Pressurization of the helium tanks resulted in pressurization of the low pressure helium systems (below the regulators) to lockup pressure since the helium initiation squib valves had been previously activated. The low pressure helium systems were not subjected to proof pressure at this time since they had been pressurized to 300 psig during acceptance testing as described in reference 4.

Following proof pressure testing, the helium tank pressures were reduced to 1500 psig for leak checking. Leak checks were performed on all brazed joints, disconnect couplings, mechanical fittings, et cetera, in the helium system with Leak Tec solution.

Regulator checkouts were conducted on the primary and secondary stages of the system A and system B regulator assemblies. Flowrates were maintained by a regulated helium source at the helium fill couplings (D-1 and D-34) and a metering hand valve at the low pressure helium couplings (D-9 and D-42). Flowrates were measured with an orifice type flowmeter (Foxboro) installed in line with the metering hand valve. Regulator stages were deactivated as required by pressurizing the reference ports with 50 psig GHe.

Overall check valve assembly cracking and reseating differential pressures were measured by admitting GHe at the high pressure helium couplings (D-2 and D-35) and observing flow through a volumetric leak detector (VLD) attached to the helium vent couplings (D-16, D-17, D-49, and D-50). Pressures were measured with a 0-50 psia gage attached to the low pressure helium couplings. Overall check valve assembly reverse leakages were determined by admitting GHe at the helium vent couplings and monitoring for leakage at the low pressure helium couplings with a VLD.

Relief valve checkouts were accomplished in the following manner. The relief valve inlets were pressurized to 180 psig GHe and burst disc leakages measured for 30 minutes with a VLD attached at the relief valve couplings (D-14, D-15, D-48 and D-47). Relieving and reseating pressures and relief valve leakages were determined by monitoring a VLD attached to the relief valve vent ports while simultaneously pressurizing the relief valve inlets and couplings. Bleed valve closing and opening pressures were determined during the above pressurization cycles by monitoring the VLD attached to the vent ports.

The helium supply lines were connected to the propellant tanks at the Gamah fittings before initiating the propellant system component checkouts (fig. 4).

Propellant tank bladder leakages were determined by attaching a VLD to the appropriate helium vent coupling and maintaining an internal pressure of 10 ± 1 psig·GHe through the propellant bleed couplings (D-18, D-19, D-51, and D-52).

Reverse leakage checks were performed on the main shutoff valves by pressurizing the propellant manifold to 180 psig GHe and measuring leakage rates with a VLD at the bleed couplings. Proof pressure tests were performed on the propellant manifolds by pressurizing them to 270 ± 5 psig GHe with the main shutoff valves closed. The pressure was then decreased to 180 psig and leak checks performed on all brazed joints and mechanical fittings with Leak Tek solution.

Cluster isolation valve leak tests were performed by pressurizing the propellant manifolds to 200 psig GHe and measuring leakage rates with a VLD attached to the appropriate y-block drain line. Crossfeed and ascent interconnect valve leakages were also measured at 200 psig.

The injector valves were cycled utilizing both the automatic and direct (manual) coils at nominal operating voltage (23-24 V dc) and 25 psig GHe inlet pressures. Valve voltage traces were obtained through the Data Acquisition System (DAS) in order to verify engine wiring and valve response times.

Pressure switch checkouts were performed by slowly evacuating and pressurizing the engine combustion chambers through a throat plug. The pressures at which the switches opened and closed were measured by simultaneously monitoring the oscillograph recorder and a test gage installed in the vacuum line.

Thruster heater checkouts were conducted by applying voltage to the heaters and monitoring the injector head and cluster temperatures through the DAS until heater cycling occurred.

Engine gas flow checkout was conducted in accordance with reference 11. Basically, the engine gas flow test was used to determine the relative flow capacities of each RCS engine. Regulated GN_2 was admitted to the system A fuel service coupling through the orifice flow control panel as shown in figure 2. The crossfeed valves were opened and a gage (G-3) was attached to the fuel service coupling in system B to measure manifold pressure. The engine IV D/2 fuel valve was opened and the pressure regulated until G-3 had stabilized to 40.00 ± 0.05 psia and G-1, G-2, and G-3 were recorded. The engine IV S/4 fuel valve was then opened and the engine IV D/2 fuel valve closed. Readings were again taken after stabilization. This process was repeated until values had been recorded for all system A fuel valves. A similar procedure was utilized for the remaining fuel and oxidizer valves.

After completion of the engine gas flow checkout, forward leakage checks were performed on all engine injector valves with 100 psig GN_2.

System loading.- The propellant and helium tanks were loaded in accordance with reference 15.

Two priming methods were evaluated for propellant manifold loading. The system A propellant manifolds were primed by the LM3 method and the system B manifolds by the LM1 method. Both techniques involved evacuating the propellant lines downstream of the main shutoff valves and performing the priming operation with the helium system pressurized with 50 psia GHe. The helium systems were vented upstream of the check valves to simulate a system with squib valves intact. In the LM1 method the manifolds were primed to the engine valves in one step by opening the main shutoff valves (MSOV's) with the isolation valves (TPIV's) open, whereas in the LM3 method, the manifolds were primed in a two step operation by first opening the MSOV's with the TPIV's closed and then opening the TPIV's to complete the priming to the engine valves.

After propellant manifold loading was accomplished, the helium tanks were loaded according to the standard flight loading envelope to the following conditions:

System A, 3130 psia at 80° F

System B, 3140 psia at 84° F

This step pressurized the low pressure system to regulator lockup since the squib valves had been previously activated.

NOTE

Phases II, III, and IV were the hot-firing portion of the test program (ref. 16). The following general procedures were utilized for all runs during these phases unless otherwise specified:

a. All engine firings were controlled by a programmed firing tape

b. Injector valve voltage was maintained at 23-24 V dc

c. Analog and digital recorders were sequenced to start 10 seconds prior to run initiation and stop 5 seconds after run termination

d. The Electro-Instrument (EI) printer and Esterline Angus (EA) recorders ran continuously except during prolonged periods of inactivity

e. All firings were performed at pressure-altitudes in excess of 97 000 feet and at ambient temperature

f. Subsystem valve positions (except engine valves) were manually controlled

g. Red-line parameters were monitored by digital cathode ray tube (CRT) display and strip chart recorders

h. Real time oscillograph records were produced during each run for "quick-look" evaluation of system performance

i. Pertinent operational parameters were manually recorded before and after each run to provide the test conductor a real time view of subsystem operation

j. The normal propellant distribution system configuration was utilized (crossfeed and interconnect valves closed)

k. Hydraulic and temperature stabilization was allowed between runs

l. Engine firings were observed on four closed circuit television monitors (one monitor and camera per cluster); two of the cameras were recorded on video tape

Phase II — Baseline Performance Duty Cycles

Bleed-in firings.- One bleed-in firing of 1-second duration was performed on each of the LM RCS engines in order to verify engine and system operation and to remove any gas bubbles which may have been trapped in the propellant lines during the priming procedures. These firings were also used to evaluate the priming techniques.

Baseline single engines.- Baseline single engine firings were performed on all 16 thrusters as recorded in appendix A (runs II-A-2-17 through II-A-2-192).

Phase III — Mission Duty Cycles

Simulated mission duty cycles were performed for the periods of major activity in the LM1 mission and the lunar abort from hover mission. Excerpts from the LM1 and lunar mission duty cycles performed are shown in figures 13 through 20. These trilevel traces, which were obtained from the engine firing program tapes, indicate the electrical on times for each engine for duty cycles representative of the various mission phases.

The LM1 duty cycles and the lunar mission duty cycles were obtained from mission simulations described in references 17 and 18, respectively. Specific run numbers and run times are recorded in table I. These simulations were based on a nominal LM1 mission and a lunar abort from hover case with no engine or component failures. Grumman Aircraft Engineering Corporation data tapes from the above mentioned simulations were used to generate the program tapes required to control engine firings. Long ullage runs were omitted due to facility limitations.

The LM1 simulation utilized the PGNCS, and the lunar abort from hover simulation utilized the AGS. Additional information concerning the simulations may be found in references 17 and 18.

Phase IV — Special Duty Cycles

Hydraulic transient effects (normal and crossfeed modes).- Special duty cycles designed to produce dynamic interactions in the LM RCS which should represent worst case hydraulic conditions were performed as recorded in appendix A (runs IV-B-1-1 through IV-B-10-10 and IV-C-2-1 through IV-C-10-9). These duty cycles were based on maneuvers which might be performed in the PGNCS mode and included two, four, six, and eight engine operation. Identical duty cycles were performed in both the normal and crossfeed configurations for comparison purposes.

Pressure switch evaluation.- Special duty cycles designed to evaluate pressure switch performance for minimum impulse firings, short off times, and simulated oxidizer cold flows were performed as shown in appendix A (runs IV-D-1-1 through IV-D-5-6). Identical duty cycles were performed on three engines equipped with flight-type pressure switches and on the engine equipped with a special backup switch (engine IV D/2). The engine IV D/2 pressure switch was designed to switch at 23 psia instead of the normal 3-10.5 psia. Injector valve voltages of 20-21, 23-24, and 27-28 V dc were utilized to evaluate the effects of valve voltage on switch performance characteristics. Pressure switch performance was also determined from several other phases of the test program in addition to these special duty cycles.

Propellant consumption and O/F ratio duty cycles.- Special duty cycles designed to define the relationship between propellant consumption and oxidizer to fuel mixture ratio and pulse duration were executed on one engine in each system as shown in appendix A (runs IV-E-1 through IV-E-13). Injector valve voltage was maintained at 23-24 V dc and propellant quantities were determined from the propellant tank load cells.

Mission duty cycle performance in crossfeed mode.- The LM1 mission phase 11 (second DPS burn — FITH — first APS burn) simulated duty cycle was repeated in the crossfeed mode utilizing the system A propellant supply (run IV-F-1A in appendix A).

Failure modes.- Duty cycles designed to simulate the following failure modes were performed (appendix A, runs IV-G-2-2 through IV-G-6-6):

a. Cluster isolation valve pair closure as the result of an engine "on" failure.

b. Inadvertent fuel cluster isolation valve closure.

Isolation valve actuations were performed manually from the control console.

Pulse widths of less than minimum impulse.- These duty cycles consisted of two pulses of less than design minimum impulse followed by a 20-msec pulse. Off times between the pulses were 2.5 seconds in order to simulate AGS commands. Pulse widths of 4, 6, 7, 8. 9, and 10 msec were performed on engines IV S/4 and II F/11 as shown in appendix A (runs IV-H-1-1 through IV-H-2-12).

Baseline performance with manual coils.- Baseline single engine firings were performed on engines IV S/4 and I U/13 utilizing the manual coils as recorded in appendix A (runs IV-I-16 through 20 and 61 through 65).

Manual coil maneuver.- Manual coil duty cycles designed to simulate + roll, + pitch, and + yaw maneuvers in both two- and four-jet logic were performed as shown in appendix A (runs IV-J-1 through 11).

High-low voltage effects.- The lunar mission transfer point initiation duty cycle was repeated with the injector valve voltage set at 27-28 and 20-21 V dc (runs IV-K-1 and IV-K-2 in appendix A).

Effects of short pulses on injector temperature.- Duty cycles as described in runs IV-L-1-1 through 6 and IV-L-2-1 through 6 in appendix A were performed on the engine with flight-type cluster insulation (engine III D/6, fig. 9) and an uninsulated engine (engine I D/14). The pulse duration for the firings was maintained at 17 msec (PGNCS normal minimum impulse duration) and off times were varied in an attempt to establish the duty cycle which produced the maximum injector head cooling rate.

Cluster insulation evaluation.- A 20-second steady state firing was performed on an uninsulated downfiring engine (engine I D/14) to establish baseline information. The firing was followed by a 10-pulse series of 17 msec on and 183 msec off when the maximum injector head soakback temperature was reached. The same duty cycles were then performed on a downfiring engine (engine III D/6) on which flight-type cluster insulation had been installed (fig. 9). Run descriptions are included in appendix A (runs IV-M-1-1 and IV-M-2-2).

Phase V — Post-test Checkout and Decontamination

At the completion of Phase IV, the LM RCS propellant tanks and propellant manifolds were drained of propellants and purged with ambient temperature GHe. The propellant manifolds were than vacuum dried by opening SV-106 and SV-308 (fig. 2) and allowing the SSC steam system to evacuate the manifolds to 2.5 mm Hg. The LM RCS was then pressurized to the following pressures with GHe for temporary in-place storage:

System A helium, 25 psia

System B helium, 25 psia

System A and B fuel feed systems, 38 psia

System A and B oxidizer feed systems, 38 psia

The post-test component checkouts were deleted from the program because of facility scheduling problems; however, the LM RCS remained in the SSC for LM1 post-flight support.

RESULTS AND DISCUSSION

Phase I — Pretest Operations

Component acceptance tests.- Results of the partial tankage module component acceptance tests are included in reference 4. The limited acceptance tests performed indicated that all the major components in the tankage modules were operating within specification and the modules were considered acceptable for the LM RCS subsystem test. Cleanliness verification tests revealed that all propellant tanks except the system B oxidizer tank complied with the required cleanliness specification (ref. 8) as received. The system B oxidizer tank was only slightly out of specification and was, therefore, utilized without further cleaning.

Results of the propellant inline filter acceptance tests, which consisted of a differential pressure test and a visual inspection, were all within specification.

The propellant latch valve acceptance tests revealed that many valves did not operate within specification on receipt from TMC. Acceptance test data are recorded in reference 4 and table II. Further discussion of the latch valve deficiencies is included later in this section.

Inspection of the HR-3 DVT propellant feed system tubing revealed a reddish-brown deposit or residue on the brazed joints in the oxidizer tubing. This residue could not be removed by a detergent solution; however, a passivation solution consisting of a diluted nitric acid did remove the residue.

Analysis of a residue buildup similar to this, which occurred on the PA-1 LM RCS test article at the White Sands Test Facility (WSTF), is included in the report on TTA Test No. 2T999, "Lunar Module Reaction Control System Plumbing (PA-1)". The report (ref. 19) concluded that the deposits consisted largely of iron, with a small amount of nickel, which seems to indicate corrosion in the area of the oxidizer brazed joints.

Calibration checks on the propellant manifold, propellant injection, and engine chamber pressure transducers indicated that all the transducers were linear; however, some of the slopes from a plot of pressure versus voltage output had shifted slightly out of specification. This shift was especially prevalent on the engine chamber pressure transducers. The transducers were considered acceptable for use on this test since they were linear and repeatable and, therefore, compatible with the DAS.

Thruster acceptance tests revealed that fuel injector valve S/N 140, from engine assembly S/N 1013, leaked in excess of specification limits; consequently, a new valve seat assembly was installed. In general, the engines were dirty, with an overall poor appearance on arrival at MSC.

After partial disassembly, cleaning, and checkout, they were acceptable for test operation. All 16 engines were retrofitted with engine inlet filters and new orifices just prior to installation on the LM RCS. Subsequent to retrofit, water calibrations were performed on eight of the engines to determine the effects of the addition of the filters and new orifices. In general, the addition of engine inlet filters reduced the water flowrates through both the fuel and oxidizer valves; however, all the water flowrates measured after the filters were installed remained within the allowable limits of $^{+2}_{-4}$ percent of the preburn flowrates recorded in the engine log books. The overall O/F ratios were probably reduced since the addition of filters reduced the oxidizer valve water flowrates more than the fuel valve water flowrates. The face of injector head S/N 1003 was severely pitted around the main doublets as shown in figure 21. The injector head was replaced with injector head S/N 0007. Complete engine acceptance test results are included in references 5 and 6.

During checkout operations, several leaks were discovered in the stem area of the propellant ground half couplings. The couplings had been refurbished during the HR-3 DVT testing at TMC. All 16 couplings were returned to the manufacturer for refurbishment and complete checkout prior to test initiation.

Cleanroom assembly and cleanliness verification.- The entire propellant distribution system downstream of the main shutoff valves was verified clean to the requirements specified in table II of reference 8. During the process of cleanliness verification, it was necessary to maintain a high freon flowrate in order to obtain a valid sample. Samples obtained at a low flowrate (less than 1 gpm) appeared much cleaner than samples obtained at a flowrate of 3-5 gpm. Consequently, all particulate samples were obtained while the effluent was flowing into the sample bottle at a rate of 3-5 gpm. In general, achieving acceptable cleanliness levels was a difficult operation.

System dryness was verified to the following levels:

Component	Concentration (ppm)
A-50	<100
N_2O_4	<100
freon	< 25
IPA	< 25
H_2O	< 25

System checkout.- Proof tests of the high pressure helium systems were successful. No leakage was observed during leak checks of the brazed joints, disconnect couplings, mechanical fittings, et cetera, in the helium pressurization systems.

The results of the regulator checkouts are included in table III. The system A primary regulator exhibited low outlet pressure at the high flowrate, and the system A secondary regulator exhibited low outlet pressure at both the high and low flowrates. These values were only slightly out of specification and were within the accuracy of the instrumentation. In addition, the propellant tank ullages were not simulated in the flow tests. The system B primary regulator outlet pressure oscillated between 178.4 and 179.3 psig at a frequency of approximately one Hz when subjected to the high flowrate. However, these values were within the specification limits. The above flow pressure conditions were not considered detrimental to successful completion of the test program.

The results of the check valve cracking and reseating checks are shown below. All values were within specification limits except for the second check of the system A fuel check valve. All check valve reverse leakages were within specification limits.

Measurement identification	Spec. limits	CV 110 sys. A, oxid.	CV 109 sys. A, fuel	CV 210 sys. B, oxid.	CV 209 sys. B, fuel
Overall cracking pressure, psid					
Check no. 1	3 ± 1	3.96	2.16	3.89	3.19
Check no. 2	3 ± 1	3.81	1.61	3.74	3.14
Overall reseating pressure, psid					
Check no. 1	None	2.81	0.56	2.09	1.38
Check no. 2	None	2.81	0.16	2.39	1.59
Reverse leakage at 0.6 ± 0.1 psid, scc/30 min	2.5	0	0	0	0
Reverse leakage at 180 $^{+5}_{-0}$ psid, scc/15 min	1.25	0	0	0	0

Relief valve checkout results are summarized in table IV. The system A oxidizer relief valve produced anomalous results in three areas. The bleed valve did not completely seat until a pressure of 170 psig was reached. In addition, the second relief pressure check and the first and second reseat pressure checks produced slightly out of specification readings; however, three subsequent checks were made with acceptable and repeatable values. Also, after reseat was reached on the relief valve assembly, leakage continued at about 7 scc/min until the pressure was decreased to approximately 203-206 psig. No explanation is offered for the anomalous performance other than the previous testing at Magic Mountain and the extended storage period. The anomalous conditions were not considered detrimental to successful completion of the test program. The burst disc in the system A fuel relief valve was inadvertently ruptured during leak and functional testing.

Results of the propellant bladder leakage checks were as follows:

Tank	Specification limits	Measured leakage, scc/15 min[a]
System A oxidizer	143 scc/15 min	
Check no. 1		92
Check no. 2		100
System A fuel	120 scc/15 min	
Check no. 1		110
Check no. 2		105
System B oxidizer	143 scc/15 min	
Check no. 1		80
Check no. 2		82
System B fuel	120 scc/15 min	
Check no. 1		80
Check no. 2		80

[a] Two consecutive samples must be within 10 scc of each other to insure stabilization.

As can be seen from the above results, all bladder leakage rates were within specification limits; however, the system A fuel bladder leakage test was repeated six times before two acceptable rates within ± 10 scc of each other were obtained. This seems to indicate that gas was trapped between the bladder and the tank shell at the beginning of the test.

The main shutoff valve leakage rates were all within specification as shown in table II. During the propellant manifold leak check, several small leaks were detected in mechanical fittings. These were repaired by retorquing or seal replacement. The results of all propellant latch valve leakage checks are recorded in table II. Table II also includes leakage rates on the valves as they were received from TMC following the HR3-DVT test and latch currents after cycling at 24 V dc.

The following observations were made during propellant latch valve checkouts:

a. Position indicator switch failures occurred on latch valves no. 222 and no. 219.

b. The position indicator switch produced an open indication at all times when voltage was applied to the valve. A closed indication was produced only when the valve was closed and no voltage was applied. This characteristic was common to all valves.

c. Fifty percent of the valves leaked at rates in excess of the specification limit. Variations in leakage rates between consecutive leak checks were as large as several thousand scc/15 min if cycling had occurred in the interim.

d. The valves were received at MSC with an average of only 32 days propellant exposure and an average of 45 actuations; therefore, the number of valves which did not meet leakage specifications in acceptance testing seemed high.

e. Two valves (no. 130 and no. 226) which exhibited extremely high leakage rates during acceptance testing were corrected to acceptable limits by cleaning, but this approach was unsuccessful on the seven other cluster isolation valves with high leakage rates.

f. Initial leak checks of valves no. 120 and no. 122 on the test stand indicated that they were out of specification. This was corrected by removing tube loads which were inadvertently induced during system assembly. This corrective process was also applied to valve no. 220 with no significant change in leakage rate. It is possible that some of the cluster isolation valves which leaked at a higher rate after subsystem assembly than before were influenced by excessive tube loading. The cluster isolation valve mounting brackets were modified during valve installation in an attempt to prevent tube loading.

g. All but three of the valves checked had latch currents which were above the recently established acceptable level of 0.85 amps. Latch current is defined as the minimum current required to actuate the valve from the open to closed position or vice versa.

h. Valve LSC 310-403-204, S/N 0048 was returned to the manufacturer for failure investigation after gold particles were observed in the valve effluent.

During the injector valve checkouts, it was discovered that the flight-type arc suppression circuitry as shown in figure 10 increased the indicated valve response times and suppressed the transient associated with voltage removal. Automatic coil signature traces were obtained by recording the induced voltage across the direct coils. Figure 22 contains sample automatic coil traces from engine II D/10 comparing voltage traces with and without the arc suppression network installed. These traces indicate that the arc suppression network had no appreciable effect on the valve opening times; however, the network did increase the fuel and oxidizer valve closing times by about 1.5 and 2.0 msec, respectively. Consequently, the effective engine on time should be increased accordingly for a given electrical on time.

The results of the pressure switch checkouts are shown in table V. Pressure switch S-156 did not operate, and switch S-154 did not open within specification limits. Switching pressures varied slightly as a function of the pressurization rate. Switch S-151 was a special backup switch developed by the Instrumentation and Electronics Systems Division of MSC and was designed to switch at a higher pressure than the flight-type switches.

During heater checkout, the heaters would not heat the engines above approximately 90 – 100° F at atmospheric pressure because of convective cooling; therefore, the checkout was completed at altitude. At altitude (130 000 feet) all heaters operated according to specification. It should be noted that the clusters were not insulated with flight-type blanket and shield assemblies and only one heater per engine was used instead of the two normally used in flight. Figure 23 illustrates the warmup period for a sample heater from each cluster. The clusters were insulated from the cluster mounts by phenolic strips in order to prevent excessive heat conduction into the heavy aluminum cluster mounts. During the heater checkout, one phenolic strip was missing from cluster III; therefore, the heaters on cluster III did not warm up as rapidly as the other clusters. This is shown by the slower temperature increase of engine III F/7 in figure 23. This situation was corrected before the start of hot-firing by installing the missing insulation. The warmup depicted in figure 23 was performed at altitude after the heaters had been on for 1-1/2 hours at sea level resulting in an initial temperature of 90 – 100° F. Direct extrapolation of the curves in figure 23 to ambient temperature indicates a total warmup time of approximately 2 hours for the test configuration.

Results of the engine gas flow checkout are shown in table VI and figures 24, 25, 26, and 27 which illustrate the relationship between flow pressures and the pretest water flowrates.

The system B water flowrates were obtained from TMC data before engine filter installation, and the system A water flowrates were obtained from MSC data generated after engine filters were installed. This arrangement was necessary since only the system A engines were water calibrated after filter installation. The above mentioned figures indicate a distinct inverse relationship between gas flow pressure and water flowrate. The engine IV U/1 fuel valve seat was replaced at MSC because of excessive leakage; therefore, MSC water flowrate was used for engine IV U/1 on figure 25. None of the engines appeared to have significant flow obstructions, but the engine II F/11 oxidizer flow was marginal based on the acceptance band used for flight vehicles.

All engine injector valves exhibited zero leakage with 100 psig GN_2 inlet pressure.

System loading.- The following table is a summary of the propellant quantities loaded and a comparison with nominal mission values:

	Fuel A	Fuel B	Oxid A	Oxid B
Propellant quantities loaded, lbs	101.7	104.2	204.1	204.2
Nominal mission quantities, lbs	103.5	103.5	203.7	203.7

Comparative propellant manifold pressure histories for the two priming techniques are shown in figures 28 and 29. These figures clearly indicate that no pressure levels occurred in either method which would damage the propellant lines or components. In addition, the first firings from each system produced chamber pressure and hydraulic characteristics indicative of normal ignition with the absence of gas bubbles.

Phase II — Baseline Performance Duty Cycles

Bleed-in firings.- The bleed-in firings produced no evidence of gas bubbles and indicated nominal performance on all engines with the exception of engine III U/5. The engine III U/5 chamber pressure indicated reduced performance (90 psia steady state). This anomaly was attributed to a problem in the DAS and not the engine (see Appendix E).

Baseline single engines.- Sample baseline engine performance and hydraulic conditions are included in appendix B for engines IV D/2, IV S/4, II F/11, and I U/13 (runs II-A-2-28 through II-A-2-158). Figures 30, 31, and 32 illustrate the variation in engine inlet hydraulic conditions for single 50 msec pulses at various engine locations. Engines located at comparable positions in system A and system B were plotted on the same figure to permit direct comparison. As expected, the major characteristics of the inlet pressure fluctuations for these engines were similar. The following general observations can be made from figures 30, 31, and 32:

a. The oxidizer natural frequency was approximately 21 Hz.

b. The fuel natural frequency was approximately 28 Hz.

c. The fuel recovery time (time required after valve opening to regain initial pressure) for the engines located farthest from the tankage modules (engines IV D/2, I D/14, II U/9, and III S/8) was an average of 19 msec. The fuel recovery time for the engines located nearest the tankage module (engines I U/13 and IV U/1) was an average of 8 msec.

d. The oxidizer recovery time for the engines located farthest from the tankage modules was an average of 25 msec. The oxidizer recovery time for the engines located nearest the tankage module was an average of 11 msec.

e. In several cases, harmonic frequencies appeared to be superimposed on the natural frequency.

f. Minimum pressures following valve opening ranged from 97 to 127 psia for fuel and from 95 to 116 psia for oxidizer.

g. Maximum pressures following valve closing ranged from 244 to 264 psia for fuel and from 250 to 276 psia for oxidizer.

Figures 33, 34, and 35 include sample oscillograms illustrating engine and feed system characteristics for baseline pulses of 17, 50, and 100 msec on engine IV D/2.

Pressure waves of varying amplitudes were transmitted across the crossfeed valves from the propellant system in which the engine was firing to the other propellant system. This phenomenon can be readily observed from the data recorded for system B manifold pressure in appendix B. Special tests (runs SP-2 and SP-3 in appendix A) were performed to determine if this tranfer resulted from the crossfeed valve poppet lifting partially off its seat and transferring fluid into the other system. On one system, the main shutoff valves were closed and then an engine was pulsed to reduce the manifold pressures. On the other system, an engine was then pulsed in an attempt to transfer propellant to the low pressure system. The oxidizer manifolds were "soft" (little reaction to valve motion), and the fuel manifolds were "hard" (significant reaction to valve motion) during the special tests. No increase in pressure was detectable in the low pressure system for either propellant. This test was repeated, reversing the systems, with a similar lack of detectable propellant transfer. The wave transfer mechanism, therefore, seemed to be through bellows flexures in the crossfeed valves.

Table VII is a summary of system performance characteristics during the baseline firings. Chamber pressure rise times for the engines nearest the tankage module (engines II F/11 and I U/13) were significantly shorter than for the more distant engines (engines IV D/2 and IV S/4). The chamber pressure rise times (time to 75 percent of steady state Pc minus ignition delay) were 10.2, 9.7, 8.6, 8.4 msec for engines IV D/2, IV S/4, II F/11, and I U/13, respectively. The propellant feed system transients were of greater magnitude on the more distant engines. Minimum and maximum fuel inlet pressures for these single engine firings were 86 and 310 psia. Minimum and maximum oxidizer inlet pressures were 71 and 324 psia. In general, the manifold pressure extremes were about 10 to 60 psia less than the inlet pressure extremes, and the oxidizer transients were more severe than the fuel transients.

Figures 36, 37, 38, and 39 illustrate baseline engine performance (integrated chamber pressure) as a function of pulse width. The normal linear relationship was observed for all engines. Variations from engine to engine were small with engine II F/11 exhibiting the highest performance for the four sample engines. Baseline data used for analysis purposes included runs II-A-2-23 through 37, II-A-2-55 through 59, II-A-2-132 through 136, and II-A-2-154 through 158.

Phase III — Mission Duty Cycles

The LM RCS successfully completed the simulated LM1 and lunar abort from hover mission duty cycles. The mission duty cycles provided an excellent system test since both the AGS and PGNCS modes were simulated. The LM1 mission phase 13 run was aborted after 7 minutes 50 seconds because of overheating of the altitude test chamber.

General observations from the LM1 mission duty cycle indicated that the prevalent minimum impulse firing duration was 17 msec with a minimum firing duration of 15 msec. This is assumed to be representative of the PGNCS operation. PGNCS operation was consistent with the design pulse frequency limit of 5 pulses/second (fig. 13).

The abort from hover duty cycles were often extremely active. Because of facility constraints on free air temperature and vacuum pressure, only limited portions of the various mission phases could be fired; however, the portions were selected to be representative of the periods of major activity. The upfiring engines were deactivated in the midcourse correction simulation because the test cell pressure exceeded the 10 mm Hg red-line for upfiring operation. The lunar mission coelliptic sequence initiation duty cycle included periods in which each of the four down-firing engines was pulsed at a 30 to 45 percent duty cycle (fig. 17). Figures 19 and 20 include periods of extreme activity on all 16 engines. Cases were observed in which as many as eight engines were firing simultaneously (fig. 16).

Many engine commands of less than minimum impulse (13 msec) were observed during the lunar mission duty cycles. A maximum of 19 consecutive engine commands of less than 13 msec duration were observed on engine II U/9 during the coelliptic delta height simulation (run III-B-3-1). The duration of these 19 pulses ranged from 1 to 4 msec. In most cases the short pulses occurred as isolated pulses on a particular engine; however, in some cases they occurred on a vertical engine immediately before startup or immediately subsequent to shutdown of the opposing vertical engine. While the short pulses did not damage the RCS engines, they could have caused the LM Caution and Warning System to indicate a failed thruster since only seven consecutive engine commands of less than 80 msec with no corresponding indication of ignition are required to signal a failure. Because the AGS design limited the off times between short pulses to a minimum of 1 to 2 seconds, engine damage due to fuel cold flows (which sometimes were the result of short pulses) was prevented. This off time was probably sufficient to allow the propellants in the chamber to vaporize between pulses; however, the short firings associated with a firing on the opposing thruster as mentioned above were not subject to a minimum off time. Apparent nominal pulses were sometimes interrupted by short off times on the order of 0 to 10 msec duration. Sample engine commands illustrating the above anomalies are included in figures 16 through 20.

Refer to appendix A for a summary of the total pulses and total on time for each engine during the simulated mission duty cycles (runs III-A-1-1 through III-A-4-1 and III-B-1-1 through III-B-5-1). Table I is a record of the simulation run numbers and run times performed in this test program. Sample engine and system performance characteristics are included in appendix B for engines IV D/2, IV S/4, II F/11, and I U/13. Figures 36, 37, 38, and 39 are comparisons of sample mission duty cycle engine performance with baseline performance. From these figures, it can be seen that integrated chamber pressure was generally slightly less for the mission duty cycle firings than for the baseline firings. This is probably the result of the more extreme hydraulic transients and lower feed pressures associated with multiple engine firings. The linear relationships shown in figures 36, 37, and 39 were derived using the least-squares technique. The standard deviations for the relationships shown ranged from 0.105 to 0.395 psia-seconds for the mission duty cycle firings and from 0.0701 to 0.168 psia-seconds for the baseline firings. Deletion of the most extreme data point in figure 39 would probably result in a more realistic relationship.

Table VIII is a summary of engine performance during the simulated mission duty cycle runs. Ignition delays and times required to attain 75 percent of steady state chamber pressure compare favorably with baseline data (table VII).

Table IX is a comparison of the propellant feed system characteristics for the various mission phases. This table is based on sample pulses from the four engines chosen for analysis and recorded in appendix B. Using manifold pressures as the criterion, the mission duty cycle hydraulic transients appeared to be slightly more severe than the baseline transients. It should be noted that the effects of helium saturation have not been considered in this table. This may account for the somewhat smaller extremes experienced during the lunar mission duty cycle simulation which was performed near the end of the test program (appendix A).

Phase IV — Special Duty Cycles

Hydraulic transient effects.- Table X contains a comparison of pertinent engine operating characteristics for the baseline, hydraulic effects in normal mode, and hydraulic effects in crossfeed mode duty cycles. This table, which was tabulated from sample pulses from engines IV D/2, IV D/4, and I U/13, indicates slightly lower performance in the crossfeed mode than in the normal mode. The crossfeed mode average performance was 10.6 percent less than baseline, and the normal mode average performance was 8.2 percent less than baseline. Engine performance in the crossfeed mode was as much as 48 percent less than baseline for 17 msec pulses. The average differences in ignition delay and chamber pressure rise time were insignificant; however, chamber pressure rise times were significantly increased in the runs in which four engines in the same system were simultaneously started. The time required to reach 75 percent of steady state chamber pressure was a maximum of 34.6 msec on the first pulse on engine I U/13 in run IV-B-2-4. Figure 40 illustrates this characteristic for engines IV D/2, IV S/4, III S/8 and I U/13 starting simultaneously in the normal mode. Engines IV D/2 and IV S/4 required 31 and 32.4 msec, respectively, to attain 75 percent of steady state chamber pressure. This characteristic was not repeated when the identical duty cycles were performed in the crossfeed mode using the system A tankage module. Apparently, the additional manifold aided feed pressure recovery for this particular duty cycle. It should be noted that the engines chosen for analysis were all in the system used for propellant supply during the crossfeed mode runs.

Figures 41, 42, and 43 are comparisons of engine performance (using integrated chamber pressure as the performance measurement) during the baseline and hydraulic effects duty cycles. These plots are based on randomly selected sample pulses from three engines chosen to be representative of the system. As can be seen from the curves, integrated chamber pressure was consistently lower during the hydraulic transient effects duty cycles at all pulse widths in both the normal and crossfeed modes. Crossfeed mode performance was consistently lower than normal mode performance.

Figures 40 and 44 through 47 are sample oscillograms which are indicative of engine and system performance characteristics during the normal mode hydraulic transient effects duty cycles. It should be noted that the parameters associated with only two engines of the programmed four or eight engine duty cycles are included in the oscillograms.

Table IX provides a comparison of the propellant feed system characteristics during the hydraulic transients effects duty cycles with other portions of the test program. This table indicates that the extremes experienced during these duty cycles were more severe than those experienced in other portions of the test program; however, the difference between the crossfeed and normal modes appears to be insignificant. This is probably true since only pressures in system A, which was utilized as the propellant supply during the crossfeed mode, were analyzed. More variation would probably be observed if the system B hydraulic characteristics were analyzed.

The hydraulic effects duty cycles were performed successfully by the test article. The hydraulic pressure transients created in the propellant system during the programmed "worst case" duty cycles produced significant effects on engine performance and feed pressure amplitudes; however, no engine or feed system damage was observed.

Pressure switch evaluation.- A summary of pressure switch performance during baseline and special pressure switch evaluation duty cycles is included in table XI. Pressure switch closing time is defined as the time from engine electrical on to switch closure; pressure switch opening time is the time from engine electrical off to switch opening; and pressure at switch opening is the engine chamber pressure at the time of switch opening.

Anomalies and questionable performance observed in pressure switch operation included:

a. Four switch failures occurred during the program.

Switch no.	Engine no.	Failure mode	Run no.	Total firings
S-253	IV U/1	Closed	II-A-2-19	16
S-256	III D/6	Open	IV-L-1-6	625
S-257	II U/9	Closed	II-A-2-112	31
S-156	II D/10	Closed	failed in checkout	

Switch S-156 on engine 10 indicated a "failed on" condition during system checkout but worked intermittently during the test program.

b. Pressure switch opening times ranged from 30 to 74 msec for the flight-type switches summarized in table XI. Consequently, engine electrical off times of less than the above values did not permit the switches to open between pulses.

c. The backup switch (S-151) setting was too high to provide a sufficient signal for proper CWS operation at pulse widths of less than approximately 12 msec (fig. 48).

d. Switch oscillations were often observed during a pulse as the result of chamber pressure fluctuations during buildup or decay periods (fig. 49).

e. Oxidizer cold flows of 100 msec produced firing indications (switch closure) on two out of three pressure switches tested (figs. 50 and 51). Therefore, a fuel injector valve failed closed or an oxidizer injector valve failed open could occur without immediately being detected by the CWS.

Chamber pressures were in the 7.5 to 8.5 psia range. The closing pressure switches had switching pressures slightly below these values, and those not closing, slightly above. A series of 10 oxidizer cold flows at 75 msec on and 125 msec off on two engines only produced switch actuations on the first pulse. This indicated that the oxidizer cold flows cooled the combustor and injector head resulting in lower chamber pressures. It should be noted that although oxidizer could react with the engine post shutdown residue, the chamber pressure does not appear to have been influenced because the indicated chamber pressure increased very gradually and remained stable until valve closure — no abrupt reactions were noted.

f. Seven short pulses of 17 msec subsequent to a simulated fuel cluster isolation valve closure produced ignition indications; consequently, a fuel cluster isolation valve could inadvertently close without being immediately detected (fig. 52).

The pressure switches utilized on this test were not flight qualified switches; however, the operating limits and characteristics were identical to flight switches. Flight qualified switches are equipped with a backup shoulder behind the Belleville washers (disk spring). Three of the four failed switches have been forwarded to GAEC for failure analyses.

Results of the special tests on pulses of less than minimum impulse (appendix A, runs IV-H-1-1 through 6 and IV-H-2-7 through 12) indicated that the switches would actuate at a minimum pulse duration of 7 msec. Of course, this value is a function of the presence of ignition and the switching levels of the individual pressure switches.

Propellant consumption and O/F ratio duty cycles.- Results of these duty cycles showing the relationship between propellant consumption and O/F mixture ratio and pulse duration are included in figures 53 and 54. The two engines selected for this study should approximate the system extremes since engine III D/6 is near the system B tankage module and engine IV D/2 is the most distant engine from the system A tankage module (fig. 3). In addition, the system B manifold pressure was about 3 psi higher than the system A manifold pressure.

Figure 53 indicates that the LM RCS O/F mixture ratio was slightly less than was experienced in engine qualification testing for pulse widths greater than 20 msec. This can be partially attributed to the injector valve voltage which was 27 V dc during qualification testing.

At pulse widths of less than 20 msec, the O/F mixture ratio began to increase with decreasing pulse width to a value of 1.95 at 14 msec. This is a significant departure from the previous single engine test results. The apparent reason for this phenomenon was the presence of an extremely soft oxidizer system and a hard fuel system during the propellant consumption duty cycles. Figures 55, 56, and 57 illustrate this propellant condition for the baseline manual coil runs performed immediately after the propellant consumption duty cycles. The entire O/F ratio curves shown in figure 53 were probably affected. It should be noted that the oxidizer propellant feed system became gradually "softer" as the test program progressed because of apparent helium ingestion.

Figure 54 is a plot of propellant consumed as a function of electrical on time for engines III D/6 and IV D/2. These curves are almost identical to engine qualification data. Engine III D/6, which was closer to the propellant module and fed by a higher propellant pressure, had higher propellant consumption than engine IV D/2.

Mission duty cycle performance in crossfeed mode.- Table XII is a comparison of system performance during a simulated mission duty cycle for normal and crossfeed operation. Identical pulses were randomly selected from each mode to provide the data shown in the table; consequently, all performance parameters should be directly comparable.

As can be seen from the table, the total impulse for the crossfeed mode was slightly higher than for the normal mode. This result is consistent for the four sample engines chosen for analysis. These four engines were all located in the system with the active tankage module. No significant variations between the two modes were noted for the ignition delay and the time required to attain 75 percent of steady state chamber pressure. In summary, it appears that there were no significant variations between the crossfeed and normal mode performance for the simulated mission duty cycle performed. The LM RCS successfully performed the simulated mission duty cycle in the crossfeed mode.

Failure modes.- The simulated engine "on" failures resulting in cluster isolation valve closure were completed with no problems. Figure 58 is an oscillogram illustrating the system conditions during a simulated failure of engine IV D/2. The abrupt decrease in chamber pressure and propellant inlet pressure correspond to cluster isolation valve closure. The manifold pressure fluctuations occurring every 250 msec were caused by engine II F/11 which was firing at a duty cycle of 50 msec on and 200 msec off. The apparent fluctuations in propellant inlet pressure which occur after isolation valve closure were the result of transducer shift and should be disregarded.

Figure 52 is an oscillogram illustrating system conditions during the simulated inadvertent fuel cluster isolation valve closure. The decrease in fuel propellant inlet pressure (P-19) corresponds to fuel cluster isolation valve closure. The duty cycle was designed for fuel cluster isolation valve closure to occur at the end of the 2 second firing in engine IV S/4; however, closure did not occur until after the first pulse of a programmed series of seven 17 msec pulses. Ignition occurred on the six remaining pulses accompanied by a pressure switch indication; consequently, this particular failure mode would not have been detected by the CWS.

An indication of momentary combustion instability occurred during the 2 second firing in engine IV S/4. Since the previous firing on this engine was the simulated engine "on" failure described above, a small gas bubble may have been trapped in the propellant lines while the engine valves were open and the cluster isolation valves closed. From previous history, it is known that gas bubbles can produce combustion instability.

Pulse widths of less than minimum impulse.- Figure 59 is an oscillogram comparing system performance for pulse widths of 4, 6, and 7 msec on engine IV S/4. As can be seen from the figure, the 4 msec pulse width produced no reaction in the fuel or oxidizer manifolds; the 6 msec pulse width produced an indication of fuel valve opening with no ignition, and the 7 msec pulse produced an indication of both fuel and oxidizer valve opening with ignition. The 7 msec pulse also produced an indication of ignition on the engine IV S/4 pressure switch. Unfortunately, the engine IV S/4 injector valve voltage traces were recorded erroneously on these runs, precluding an accurate determination of the injector valve voltage characteristics. Engine II F/11 produced the same results as engine IV S/4; that is, ignition first occurred on a 7 msec pulse.

The engines successfully completed the short pulse width duty cycles without damage or failure. The duty cycles performed in this block were supplemented by the short pulses in the lunar mission duty cycles as previously mentioned. Again it appears that the long minimum off times in the AGS design allowed sufficient time for vaporization of the raw fuel between pulses which caused fuel cold flows, or the fuel accumulation was insufficient to cause problems.

Baseline performance with manual coils.- Sample results of the baseline single engine firings utilizing the manual (or direct) coils are included in appendix B (runs IV-I-16, 17, 18 and IV-I-61, 62, 63). Figures 60 and 61 include a comparison of baseline performance using the automatic and manual coils for engines IV S/4 and I U/13, respectively. These figures indicate that the decrease in performance in the manual mode is almost constant for the pulse widths shown. This is the result of a constant decrease in effective pulse duration caused by the slower manual coil opening response; therefore, the performance for all pulse widths would be decreased by this constant amount.

Figures 55, 56, and 57 are sample oscillograms of 30, 50, and 100 msec pulses, respectively, in the manual mode on engine IV S/4. A comparison of these figures with the automatic coil baseline firings on engine IV D/2 (figs. 33, 34, and 35) clearly illustrate the "softer" hydraulic conditions. The "softer" feed system was probably the result of both helium ingestion in the propellants and large helium ullage in the propellant tanks.

Manual coil maneuvers.- Based on real-time observations, no problems were encountered in these simulated maneuvers. Data from these runs were not reduced.

High-low voltage effects.- Appendix B contains a tabulation of pertinent system operating characteristics for identical pulses randomly selected from the high-low voltage duty cycle (runs IV-K-1 and IV-K-2). Comparable data for the nominal voltage case are included for run III-B-4-1. The following table illustrates the effects of voltage variation on engine performance for two sample engines (IV D/2 and IV S/4) during the simulated transfer point initiation duty cycle.

Run no.	Injector valve voltage, V dc	Description	Ignition delay, msec	Time to 75 percent Pc, msec	Integrated Pc, psia-sec
IV-K-1	27-28	Maximum	10.5	21.3	
		Average	10.1	19.8	5.22 at avg.
		Minimum	9.5	18.6	pulse width of 59 msec
III-B-4-1	23-24	Maximum	11.7	22.4	
		Average	11.2	20.6	5.13 at avg.
		Minimum	10.8	19.2	pulse width of 59 msec
IV-K-2	20-21	Maximum	13.2	24.0	
		Average	11.9	21.9	5.10 at avg.
		Minimum	10.5	19.4	pulse width of 59 msec

NOTE: The above data were obtained from appendix B.

This table indicates about a 1 msec change in ignition delay and time to 75 percent Pc per each 3 to 4 volt change in injector valve voltage. The quality of the valve traces did not permit an accurate measurement of valve opening and closing traces; however, it is assumed that the valve opening times were similarly affected. Average integrated Pc for the average pulse width of 59 msec decreased slightly as the voltage decreased. A more accurate determination of the effects at various pulse widths may be obtained by examination of the data in appendix B. It should be noted that the values in the above table may have been affected by changes in tank ullage and system hydraulics.

Effects of short pulses on injector temperature.- The programmed duty cycles were insufficient for establishing the worst case injector head cooling duty cycle. The fifty 17-msec pulses fired in each run did not provide sufficient time for the minimum temperature to be reached or for indentification of the maximum overall cooling rate. The following limited data were recorded:

Duty cycle (time in sec.)	No. pulses	Initial injector temperature, °F	Final injector temperature, °F	Cooling rate
0.017 on/0.183 off	50	130	130	0° F/10 sec.
0.017 on/0.283 off	50	130	130	0° F/15 sec.
0.017 on/0.383 off	50	130	130	0° F/20 sec.
0.017 on/0.483 off	50	132	127	5° F/25 sec.
0.017 on/0.983 off	50	131	121	10° F/50 sec.
0.017 on/2.500 off	50	131	121	10° F/125 sec.

In order to obtain more conclusive data, the injector head temperature behavior during the propellant consumption duty cycles (runs IV-E-1 through IV-8-13) was plotted. Figure 62 illustrates the injector head temperature as a function of time and duty cycle for a typical uninsulated engine. A minimum of 98° F was obtained with a duty cycle of 0.014 seconds on and 1.000 seconds off. Figure 63 illustrates the injector head temperature as a function of time and duty cycle for the insulated engine. This figure indicates that the 0.014 seconds on/0.500 seconds off duty cycle produced the highest initial cooling rate (curves 1 through 5). In general, a comparison of curves 1 through 5 indicates that the initial cooling rate increases as the off time decreases for the off times tested; however, a comparison of curves 4 and 5 illustrates that the trend would not have continued since 5 appears to be crossing 4. Curve 6 indicates that the 0.014 seconds on/1.000 seconds off duty cycle produced the minimum injector head temperature of 102° F.

It should be noted that the above discussion relates only to the test configuration and may not be representative of flight since only one heater was installed per engine, the cluster blanket and shield assembly was installed on only one engine, and the thermal environment of space was not simulated.

Cluster insulation evaluation.- The results of runs IV-M-1-1 and IV-M-2-2 were surprising. The engine with the thermal shield ran slightly cooler than the exposed engine; maximum chamber temperatures recorded between the chamber ribs, 180 degrees apart, were 1100° and 1240° F on the covered engine, and 1200° and 1325° F on the exposed chamber. Peak flange temperatures during the firings were 155° and 163° F on the covered and exposed engine, respectively, and 290° and 312° F at maximum soakback. The heater thermostat temperature on the shielded engine was 135° F during the firing and 240° F at maximum soakback. The heater thermostat temperature on the exposed engine was erratic because of improper attachment of the thermocouple. The test was repeated with similar results. The instrumentation setup for this test was as shown in figure D3, appendix D. The above data suggest that the extension of the thermal blanket and shield assembly over the combustion chamber had little effect on the engine's thermal characteristics.

Figures 64 and 65 illustrate the effects of engine firings on the partial blanket and shield assembly. Some charring and degradation were observed in the vicinity of the combustion chamber on the H-film, aluminized H-film tape, and SiO-Al thermal control coating. It is probable that minor charring and degradation will occur in actual LM missions; however, design changes effective on LM3 and subsequent vehicles should minimize these effects.

Phase V — Post-test Checkout and Decontamination

During the period following the decontamination as described in the test procedure section of this report, a columbium chamber evaluation test (ref. 20) and a LM1 anomalies investigation test (ref. 21) were performed on the system. All system components, with the exception of some Pc transducers, performed adequately on these tests. Consequently, it may be stated that the system components functioned properly after a 4 1/2 months exposure to an uncontrolled and unknown concentration of propellant. It should be noted that a complete checkout of the components was not performed before or after the referenced tests; therefore, the preceding statement was based only on the fact that system performance was adequate for completion of the tests.

Special Analyses

Propellant consumption.- Table XIII is a summary of the propellant consumption and engine firing distribution for the mission duty cycles performed and for the total test program. This table illustrates that the downfiring engines experienced the most pulses and total on time in MDC operation. The O/F ratios were slightly lower than were experienced in engine qualification testing. This can be partially attributed to the injector valve voltage which was 27 V dc during qualification testing and 23-24 V dc in this test. The mission duty cycle O/F ratios shown in table XIII were slightly lower than the single engine data shown in figure 53 for engine IV D/2, using average pulse widths. The total test program O/F ratio falls about midway between the single engine curves shown in figure 53.

Propellant quantity measurement technique.- Figures 66, 67, and 68 illustrate PQMD operation for the test program. Figure 66 is a comparison of actual PQMD output with theoretical output based on measured helium tank temperatures and pressures. In general, the system A PQMD output was slightly higher than theoretical while the system B PQMD output was almost identical to theoretical. In all cases, the PQMD's operated within the four percent acceptable limit.

Figures 67 and 68 include propellant consumption histories as measured by both the load cell technique (fig. 5) and the PQMD's. Figure 67 indicates an almost constant bias of 5 to 7 lbs on the system A PQMD with PQMD readings higher than the corresponding load cell readings. This bias developed during the initial firings and was maintained for the remainder of the test program. The maximum difference between the system A PQMD and the system A load cells was about 12 lbs which was less than four percent of the total available propellants in system A. Figure 68 indicates close agreement between the system B PQMD and the system B load cell readings. The system B PQMD indicated higher than the load cells in the early portions of the test program but crossed over and became lower in the latter portions. The maximum difference observed was again about 12 lbs but most of the differences were less than 5 lbs. It should be noted that the differences discussed above could have resulted from inaccuracies in the load cells and/or the PQMD's. Appendix A may be used to correlate real time with test duty cycles.

Compatibility of CWS monitored operating limits with CWS operation.- The helium tank and regulator output pressures experienced during the test program appeared to be compatible with the CWS limits. A caution light illuminates in flight when the helium tank pressure falls below 1696 psia. The steady state regulator outlet pressures recorded during the test program were all well within the CWS limits of 164.4 to 204.3 psia.

Since no attempt was made to simulate the thermal environment of an actual mission, the cluster temperature limits could not be realistically evaluated; however, under the test conditions, the temperature limits of 119° to 190° F were compatible with CWS operation.

Several possible areas of incompatibility between the RCS and CWS were observed in the TCA failure detection system. These areas included the following:

a. Four pressure switch failures occurred during the program.

b. Short engine off times did not permit the pressure switches to open between pulses.

c. Pressure switch oscillations were often observed during a pulse as the result of chamber pressure fluctuations during buildup and decay periods.

d. Oxidizer cold flows (fuel injector valve inhibited) sometimes produced pressure switch signals; therefore, a fuel injector valve failed closed or an oxidizer injector valve failed open could occur without immediate detection.

e. Seven short pulses of 17 msec subsequent to a simulated fuel cluster isolation valve closure produced ignition indications on the pressure switches; consequently, a fuel cluster isolation valve could inadvertently close without being immediately detected.

f. Many engine commands of less than minimum impulse (13 msec) occurred during the simulated lunar mission duty cycles. This condition could result in an erroneous TCA failure indication since only seven consecutive engine commands of less than 80 msec with no corresponding indication of ignition are required to signal a failure. As previously noted, pulses of less than 7 msec will not normally produce ignition.

Heater system evaluation.- Heater system performance appeared to be satisfactory with the exception of the short pulse cooling effects mentioned earlier in the results and discussion section of this report. The cooling problem could not be properly evaluated with the test setup which utilized only one heater per engine, incomplete thermal insulation, and no simulation of space thermal environment.

In general, injector head temperatures were maintained at 126° to 132° F with the thermostat cycling off for about 2 minutes every 6 or so minutes, depending on ambient conditions. Cluster temperatures were generally 3° to 5° F warmer than the injector heads. Valve temperatures, measured near the seat, were in the 110° to 120° F range, with the fuel valve normally a few degrees warmer than the oxidizer valve. Combustion chamber temperatures were about 127° F.

The manual lead on one heater (engine II F/11) was accidentally grounded to the test stand during pretest operations. Consequently, the thermostat was bypassed, resulting in a continuously on situation. The heater remained on for the entire test program and maintained the engine II F/11 injector head between 145° and 155° F.

Figure 69 is a representative temperature profile for cluster III during the lunar mission duty cycle transfer point initiation simulation.

CONCLUSIONS

Phase 1 — Pretest Operations

1. A reddish-brown deposit, which was analyzed in earlier testing (ref. 19) to consist primarily of iron, was discovered in the LM RCS oxidizer tubing in the vicinity of the brazed joints during pretest cleaning. The tubing had been previously exposed to design verification testing at TMC.

2. In general, the HR-3 DVT subsystem components performed within specification limits after testing at Marquardt and several months storage at MSC. Exceptions were as follows:

    a. The propellant ground half couplings (GAEC specification number LSC 310-401) were subject to leakage in the stem area.

    b. The system A oxidizer relief valve produced anomalous results in three areas during system checkout; however, the anomalous conditions were not severe enough to require replacement for test operations.

    c. Numerous anomalies were observed during propellant latch valve (GAEC specification number LSC 310-403) checkouts. These included two position indicator switch failures, excessive leakage on 50 percent of the valves, and nonrepeatability of leakage rates.

3. Flight-type arc suppression circuitry delayed the fuel and oxidizer valve closing times by about 1.5 and 2.0 msec, respectively.

4. Both the LM1 and LM3 priming techniques were found to be acceptable.

Phase II — Baseline Performance Duty Cycles

1. Pressure waves of varying amplitudes were transmitted across closed crossfeed valves from the propellant system in which an engine was firing to the other propellant system. These waves were not accompanied by any detectable propellant transfer.

2. Baseline engine performance was comparable to single engine qualification data.

Phase III — Mission Duty Cycles

1. The LM RCS test article successfully completed portions of simulated LM1 and lunar abort from hover mission duty cycles which had been generated in the GAEC FCI laboratory.

2. The simulated mission duty cycles were found to contain numerous engine commands of less than minimum impulse (13 msec) and short off times on the order of 0 to 10 msec.

3. Engine performance during the mission duty cycles firings was slightly less than baseline performance.

Phase IV — Special Duty Cycles

1. The LM RCS test article successfully completed the programmed "worst case" duty cycles. Hydraulic pressure transients created in the propellant system during these duty cycles produced significant effects on engine performance and feed pressure amplitudes; however, no engine or feed system damage was observed. Engine performance was reduced during "worst case" hydraulic duty cycles with the crossfeed mode experiencing a greater reduction than the normal mode.

2. Four of the 15 pressure switches (LSC 310-651-3) utilized in this test experienced failure. One switch failed with the contacts open and the other three failed with the contacts closed. The pressure switches did not include various design modifications which have been added to the flight switches.

3. The fuel and oxidizer hydraulic transients became progressively smaller in amplitude and frequency as the test program progressed. The oxidizer was affected to a greater extent than the fuel.

4. The O/F ratio and the propellant consumption for engines operating in the LM RCS were comparable to single engine qualification data for pulse widths of greater than 20 msec. The relatively "soft" (little reaction to valve motion) condition of the oxidizer manifold at the time of the O/F ratio testing apparently caused the O/F ratio to increase with decreasing pulse width at pulse widths of less than approximately 20 msec.

5. The LM RCS test article successfully completed a simulated mission duty cycle in the crossfeed mode with no significant reduction in engine performance.

6. The LM RCS test article successfully completed the following simulated failure modes:

    a. Cluster isolation valve closure to isolate a failed "on" engine

    b. Inadvertent fuel cluster isolation valve closure

7. LM RCS engines produced ignition at electrical pulse widths as low as 7 msec with 23-24 V dc injector valve voltage.

8. The LM RCS test article successfully completed the manual or direct coil baseline firings and simulated maneuvers. Manual coil performance was less than automatic coil performance by a constant amount which was independent of the pulse duration.

9. Engine performance increased as injector valve voltage was increased.

10. For the test article configuration and test environment, certain duty cycles cooled the engine injector heads from 130° to about 100° F.

11. For the conditions tested, the extension of the thermal blanket and shield assembly over the combustion chamber had little effect on the engine thermal characteristics.

Phase V — Post-test Checkout and Decontamination

1. The system performance was adequate for completion of subsequent testing (see refs. 20 and 21) after a 4-1/2 month exposure to an unknown and uncontrolled concentration of propellants.

Special Analyses

1. The oxidizer to fuel mixture ratios during mission duty cycle operation were slightly less than comparable single engine system data; however, the total test program oxidizer to fuel mixture ratio was identical to single engine system data. Average pulse widths were used for the mission duty cycles and total test program in order to obtain these comparisons.

2. The system A and system B PQMD's operated within a four percent acceptance band throughout the test program. Load cells were utilized as the reference for calculating PQMD errors.

3. All the RCS operating limits which will be monitored by the CWS in LM flight appeared to be compatible with RCS operation except in the thrust chamber assembly failure detection system. Possible incompatibilities are listed in the results and discussion section of this report.

4. Heater system performance appeared to be satisfactory with the exception of the cooling effects mentioned in conclusion 10 above.

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ABBREVIATIONS

amps	amperes
AGS	Abort Guidance System
APS	Ascent Propulsion System
avg	average
chan	channel
CRT	cathode ray tube
XFV	crossfeed valve
CV	check valve
CWS	Caution and Warning Subsystem
DAS	Data Acquisition System
dia	diameter
DPS	Descent Propulsion System
D	down engine
DVT	design verification test
EA	Esterline Angus
EI	Electro-Instruments
eng	engine
fig.	figure
fm	frequency modulation
FCI	Flight Controls Integration (GAEC, Bethpage, N.Y.)
FITH	fire-in-the-hole
F	forward engine, fahrenheit
galvo	galvanometer
GAEC	Grumman Aircraft Engineering Corporation

G	gage
gpm	gallons per minute
hr	hours
inj	injector
ICV	ascent interconnect valve
IPA	isopropyl alcohol
TPIV	thruster pin isolation valve
lbs	pounds
LM	Lunar Module
max	maximum
min	minute, minimum
mm	millimeter
msec	millisecond
MSOV	main shutoff valve
misc	miscellaneous
no.	number
O/F	oxidizer/fuel
oxid	oxidizer
PGNCS	Primary Guidance Navigation and Control System
P/N	part number
pph	pounds per hour
ppm	pounds per minute
PQMD	propellant quantity measuring device
press	pressure
psia	pounds per square inch absolute
psid	pounds per square inch differential

psig	pounds per square inch gage
ref	reference
RCS	Reaction Control Subsystem
RV	relief valve
S/C	strip chart
scc	standard cubic centimeter
sec	second
SEL	System Engineering Laboratory
S/N	serial number
S.S.	steady state
SSC	subsystems chamber
sym	symbol
S	side engine
temp	temperature
TCA	thrust chamber assembly
TMC	The Marquardt Corporation
TP	test procedure
TTA	Thermochemical Test Area
U	up engine
V dc	volts direct current
VLD	volumetric leak detector
WSTF	White Sands Test Facility

SYMBOLS

A_T	area of throat
A-50	Aerozine-50
C_F	coefficient of thrust
F	farenheit
GHe	gaseous helium
GN_2	gaseous nitrogen
Hg	mercury
H_2O	water
Hz	Hertz
I_T	total impulse
N_2O_4	nitrogen tetroxide
Pc	chamber pressure
$\leq$	less than or equal to
$\geq$	greater than or equal to
$>$	greater than
$<$	less than
$\approx$	nearly equal to

TABLE I.- MISSION DUTY CYCLES RUN TIMES

[See references 17 and 18 for a description of the mission simulations.]

Run description	Simulation start time			Simulation stop time			Test run start time			Test run stop time		
	hrs.	min.	sec.	hrs.	min.	sec.	hrs.	min.	sec.	hrs.	min.	sec.
LM1 — Mission phase 7 (separation) GAEC run no. 266	20	49	3.66	20	57	04	20	54	38	20	56	51
LM1 — Mission phase 9 (first DPS burn) GAEC run no. 103	4	55	16	5	3	6	4	55	30	5	2	0
LM1 — Mission phase 11 (second DPS burn-FITH — first APS burn) GAEC run no. 103	8	33	7	8	49	56	8	33	50	8	49	50
LM1 — Mission phase 13 (second APS burn) GAEC run no. 115	6	8	42	6	19	43	6	9	10	6	16	59.5
Lunar Mission Simulation (abort from hover) GAEC run no. 514 A	0	10	1	0	19	0	0	10	1	0	11	3.5
Lunar Mission Simulation (coelliptic sequence initiation) GAEC run no. 514 B	0	44	50	0	50	20	0	44	55	0	48	9.1

TABLE I.- MISSION DUTY CYCLES RUN TIMES — Concluded

[See reference 17 and 18 for a description of the mission simulations.]

Run description	Simulation start time			Simulation stop time			Test run start time			Test run stop time		
	hrs.	min.	sec.	hrs.	min.	sec.	hrs.	min.	sec.	hrs.	min.	sec.
Lunar Mission Simulation (coelliptic delta height) GAEC run no. 514 C	1	36	52	1	41	35	1	36	52	1	39	57.7
Lunar Mission Simulation (transfer point initiation) GAEC run no. 514 D	1	52	52	2	10	32	1	56	43	2	5	11
Lunar Mission Simulation (midcourse corrections) GAEC run no. 514 E	2	16	14	2	24	48	2	19	39	2	23	57

NOTE: Times based on simulation time reference. Long ullage burns removed because of facility limitations.

TABLE II.- PROPELLANT LATCH VALVE CHECKOUT DATA

[Leakage specification limits: 45 scc/15 min at 200 psid]

Valve no.	Valve S/N	Valve location	Acceptance test leakage rate, scc/15 min		Leak rate in test stand, scc/15 min		Latch current, amps	
			Forward	Reverse	Forward	Reverse	Open	Closed
117	0059	A MSOV-Fuel				0		
119	0026	A ICV-Fuel				0		
121	0054	XFV-Fuel				0	1.10	1.30
123	214	A-VI TPIV-Fuel	New valve (not checked)		0			
125	0038	A-III ICV-Fuel	3 213		5 250		1.25	1.22
127	0061	A-II ICV-Fuel	0	0	4 125		.82	1.18
129	0028	A-I ICV-Fuel	75	28	615		1.30	1.30
217	0064	B-ICV-Fuel				0		
219	0051	B-ICV-Fuel				60		
221	0062	B-IV TPIV-Fuel	2 043		90 000		1.00	1.22
223	0041	B-III TPIV-Fuel	10 000		3 270		1.12	1.68
225	0049	B-II TPIV-Fuel	276		7 500		1.10	1.42
227	0039	B-I TPIV-Fuel	11 250		30 000		.68	1.22
118	0032	A-MSOV-Oxid				0	.90	1.45
120	0021	A-ICV-Oxid	0			22	1.30	1.40
122	0057	XFV-Oxid			0		1.30	1.25
124	0030	A-IV TPIV-Oxid	0	0	0		1.00	1.40
126	0069	A-III TPIV-Oxid	Less than 1	0	25		1.41	1.20
128	0033	A-II TPIV-Oxid	26	0	2 130		1.20	1.36
130	0062	A-I TPIV-Oxid	5 040		120		1.30	1.55
218	0043	B-MSOV-Oxid				0		
220	0058	B-ICV-Oxid	0			10 340	1.10	1.42
222	0032	B-IV TPIV-Oxid	46	0	15		.90	1.45
224	0065	B-III TPIV-Oxid	(a)		7 875		1.42	1.62
226	0036	B-II TPIV-Oxid	3 465		0		.70	1.28
228	0063	B-I TPIV-Oxid	3 465		130		1.25	1.50

[a] Too large to measure

TABLE III.- REGULATOR CHECKOUT DATA[a]

Measurement	Specification limits	No. 108 System A regulator	No. 208 System B regulator
Primary lockup pressure before flow	—	180 psig	181 psig
Primary flow pressure at 0.20 lb/min	178 to 184 psig	176.5 psig	Oscillated between 178.4 – 179.3 psig
Primary flow pressure at 0.038 lb/min	178 to 184 psig	178.6 psig	179.6 psig
Primary lockup after flow	≤188 psig	179.5 psig	181.5 psig
Primary leakage rate	≤1.5 psig/15 min	-0.3 psig/15 min[b]	0.2 psig/15 min
Secondary flow pressure at 0.20 lb/min	182 to 188 psig	181.2 psig	182.0 psig
Secondary flow pressure at 0.038 lb/min	182 to 188 psig	181.3 psig	182.3 psig
Secondary lockup after flow	≤192 psig	183 psig	185 psig
Secondary leakage rate	≤1.35 psig/15 min	1.4 psig/15 min Repeated: 0.3 psig/15 min	-0.3 psig/15 min[b]

[a] Regulator inlet pressures maintained at 1500 ± 50 psig throughout test.

[b] Negative pressure change was probably the result of temperature stabilization.

TABLE IV.- RELIEF VALVE CHECKOUT DATA

Measurement Identification	Specification limit	No. 111 System A fuel side RV	No. 112 System A oxid side RV	No. 211 System B fuel side RV	No. 212 System B oxid side RV
Burst disc leakage at 180 psig inlet, scc/30 min	0 scc/30 min	0	0	0	0
Pressure at bleed valve closure, psig	<150 psig	30	[a]40	31	37
Pressure at bleed valve opening, psig	>20 psig	26	26	26	24
RV relieving pressure, psig					
Check No. 1	224-240 psig	228	229	232.5	232
Check No. 2		228	220	228	229
Check No. 3			231	229	229
Check No. 4			229		
Check No. 5			229		
RV reseating pressure, psig					
Check No. 1	≥212 psig	216	205	219	223
Check No. 2		216	210	219	223
Check No. 3			216	219	223
Check No. 4			219		
Check No. 5			[b]223		

[a] Leaked at about 6 scc/min until 170 psig was reached.

[b] Leakage rate at reseat pressure was 7 scc/min and leakage ceased when pressure decreased to approximately 203-206 psig.

TABLE IV.- RELIEF VALVE CHECKOUT DATA — Concluded

Measurement idenification	Specification limit	No. 111 System A fuel side RV	No. 112 System A oxid side RV	No. 211 System B fuel side RV	No. 212 System B oxid side RV
RV leakage rate at 200 psid scc/15 min	5 scc/15 min	0	0	0	0

TABLE V.- PRESSURE SWITCH CHECKOUT DATA[a]

Switch no.	Switch location	Opening pressure, psia	Closing pressure, psia
[b]S151	Engine #2	21.15	21.65
S152	Engine #4	3.85	5.90
S153	Engine #5	4.90	7.45
S154	Engine #8	2.45	6.05
S155	Engine #11	4.05	7.75
S156	Engine #10	Switch failed closed	
S157	Engine #13	4.30	8.05
S158	Engine #15	4.55	7.55
S253	Engine #1	4.60	9.60
S254	Engine #3	4.90	8.75
S255	Engine #7	4.25	7.30
S256	Engine #6	4.55	9.25
S257	Engine #9	4.75	7.35
S258	Engine #12	4.25	8.25
S259	Engine #14	3.27	7.35
S260	Engine #16	3.25	8.25

[a] Specification limits: The pressure switch must open before 3.0 psia is reached while decreasing pressure and must close before 10.5 psia is reached while increasing pressure.

[b] Backup switch manufactured by Electro-Optical Systems.

TABLE VI.- ENGINE GAS FLOW DATA

Propellant system	Engine no.	G-1, regulated pressure, psig	G-2, system inlet pressure, psia	G-3, manifold pressure, psia
System A Fuel	15	190	43.16	39.99
	13	190	43.57	40.45
	10	190	43.09	39.88
	11	190	43.52	40.39
	8	190	42.95	39.75
	5	190	43.25	40.07
	4	190	43.02	39.77
	2	190	43.65	40.53
System B Fuel	16	191	43.53	40.23
	14	191	43.32	40.00
	12	191	43.58	40.28
	9	191	43.48	40.15
	6	191	43.63	40.32
	7	191	43.44	40.10
	3	191	43.28	39.95
	1	191	42.75	39.35
System A Oxidizer	15	172	45.98	40.04
	13	172	46.79	40.96
	10	172	46.25	40.32
	11	172	47.55	41.87
	8	172	46.19	40.24
	5	172	46.07	40.09
	4	172	45.95	39.95
	2	172	46.74	40.88

TABLE VI.- ENGINE GAS FLOW DATA - Concluded

Propellant system	Engine no.	G-1, regulated pressure, psig	G-2, system inlet pressure, psia	G-3, manifold pressure, psia
System B Oxidizer	16	171	45.97	40.00
	14	171	46.42	40.52
	12	171	45.76	39.67
	9	171	46.03	40.05
	6	171	46.07	40.09
	7	171	45.61	39.53
	3	171	46.29	40.35
	1	171	46.42	40.50

TABLE VII.- BASELINE SYSTEM PERFORMANCE[a]

Performance criteria		14 msec pulse width, average	17 msec pulse width, average	50 msec pulse width, average	100 msec pulse width, average	150 msec pulse width, average	Overall baseline, all pulse widths		
							Min.	Avg.	Max.
Ignition delay, msec	Eng. 2	11.5	11.1	11.7	12.2	11.0	10.6	11.5	13.0
	Eng. 4	10.8	11.2	10.5	10.6	10.5	9.0	10.8	12.1
	Eng. 11	11.3	11.3	11.2	11.2	10.7	10.1	11.1	12.2
	Eng. 13	11.8	12.2	12.1	11.6	12.4	10.6	12.0	12.8
Time to 75% of S.S. chamber pressure, msec	Eng. 2	20.7	22.2	20.6	22.9	21.4	20.4	21.7	24.2
	Eng. 4	19.8	21.0	20.4	21.1	20.7	18.9	20.5	22.4
	Eng. 11	19.1	19.4	19.9	20.4	20.2	18.2	19.7	20.8
	Eng. 13		20.6		20.3	20.2	19.8	20.4	21.1
Integrated chamber pressure, psia/sec	Eng. 2	0.90	1.10	4.43	9.46	14.24			
	Eng. 4	1.03	1.41	4.71	9.64	14.77			
	Eng. 11	0.94	1.23	4.56	9.59	14.89			
	Eng. 13	0.84	1.18	4.47	9.61	14.41			
Minimum fuel inlet pressure at valve opening, psia	Eng. 2	96	98	92	110	95	92	98	110
	Eng. 4	90	93	94	94	117	86	95	137
	Eng. 11	110	118				103	127	155
	Eng. 13	140	122	94	123	118	92	118	143
Minimum oxidizer inlet pressure at valve opening, psia	Eng. 2	92	90	90	114	90	84	94	119
	Eng. 4	84	88	90	72	76	71	83	93
	Eng. 11								
	Eng. 13		130		117	116	111	122	137
Maximum fuel inlet pressure at valve closure, psia	Eng. 2	271	300	265	253	262	251	272	302
	Eng. 4	273	305	265	255	257	253	275	310
	Eng. 11	252	263	233			233	249	266
	Eng. 13	237	266	274	267	254	230	260	276
Maximum oxidizer inlet pressure at valve closure, psia	Eng. 2	298	306	271	255	286	254	285	312
	Eng. 4	299	315	262	268	273	260	285	324
	Eng. 11								
	Eng. 13		252		271	265	246	261	274
Minimum fuel manifold pressure for pulse, psia	Eng. 2	148	147	148	146	145	143	147	150
	Eng. 4	141	142	148	146	144	139	144	149
	Eng. 11	135	136	136	139	139	134	137	139
	Eng. 13	154	154	158	155	155	153	155	166
Minimum oxidizer manifold pressure for pulse, psia	Eng. 2	121	120	126	124	124	113	123	133
	Eng. 4	115	108	127	119	118	102	117	131
	Eng. 11	143	142	145	141	130	121	141	150
	Eng. 13		151		123	152	122	143	154
Maximum fuel manifold pressure for pulse, psia	Eng. 2	242	243	221	209	209	207	226	246
	Eng. 4	236	239	217	210	207	204	224	241
	Eng. 11	218	225	204	187	187	186	207	227
	Eng. 13	207	219	205	205	205	203	209	219
Maximum oxidizer manifold pressure for pulse, psia	Eng. 2	254	272	218	223	231	216	241	275
	Eng. 4	249	262	217	210	210	207	233	266
	Eng. 11	241	253	208	195	201	192	223	261
	Eng. 13		211		194	193	191	201	213

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[a] Data obtained from appendix B, runs II-A-2-33 through 37, II-A-2-55 through 59, II-A-2-132 through 136, and II-A-2-154 through 158. Test conditions shown in appendices A and B.

TABLE VIII.- ENGINE PERFORMANCE DURING SIMULATED MISSION DUTY CYCLES[a]

Test title		Engine IV D/2			Engine IV S/4			Engine II F/11			Engine I U/13			Combination of engines 2, 4, 11, and 13		
		[b]1	[c]2	[d]3	1	2	3	1	2	3	1	2	3	1	2	3
LM1 mission duty cycle	Maximum	11.8	24.6	18.7	11.7	21.1	-11.3	10.7	20.0	-12.9	10.9	20.5	-22.0	11.8	24.6	-22.0
	Average	10.8	21.3	- 1.4	10.7	19.7	- 6.9	10.4	18.7	- 3.8	10.7	20.2	- 8.7	11.1	20.1	- 4.3
	Minimum	10.0	19.2	-	10.3	18.5	-	10.0	17.6	-	10.6	19.9	-	10.0	17.6	-
Lunar abort from hover mission duty cycle	Maximum	11.8	23.9	- 6.8	11.8	26.1	-37.9	12.3	21.2	-12.6	12.0	20.7	-13.9	12.3	26.1	-37.9
	Average	11.0	21.0	- 2.1	10.9	20.2	-14.7	11.5	18.8	- 4.8	11.5	20.0	- 0.5	10.7	20.3	- 3.9
	Minimum	10.3	19.4	-	9.7	15.6	-	10.3	14.9	-	11.2	18.4	-	9.7	14.9	-

[a] This table is based on data recorded in appendix B for sample pulses from the mission duty cycle runs.

Pulse widths analyzed were less than 150 msec duration.

[b] Column 1 is ignition delay (msec).

[c] Column 2 is time to reach 75 percent of steady state chamber pressure (msec).

[d] Column 3 is deviation of MDC integrated Pc from baseline integrated Pc (percentage).

TABLE IX.- SUMMARY OF LM RCS PROPELLANT FEED SYSTEM HYDRAULIC CHARACTERISTICS[a]

Test title		Min. fuel inlet pressure at valve opening, psia	Min. oxid. inlet pressure at valve opening, psia	Max. fuel inlet pressure at valve closing, psia	Max. oxid. inlet pressure at valve closing, psia	Min. fuel manifold pressure, system A, psia	Min. oxid. manifold pressure, system A, psia	Max. fuel manifold pressure, system A, psia	Max. oxid. manifold pressure, system A, psia
Baseline duty cycles	Maximum	155	137	310	324	166	154	246	275
	Average	108	96	265	280	146	129	216	228
	Minimum	86	71	230	246	134	102	186	191
LM1 mission simulation	Maximum					145	140	314	329
	Average					136	120	238	253
	Minimum					118	86	205	221
Lunar abort from hover mission simulation	Maximum					151	145	246	277
	Average					139	117	224	240
	Minimum					122	94	209	206
Normal mode hydraulic transient effects duty cycles	Maximum	137	144	462	418	145	136	335	328
	Average	70	86	331	301	113	109	258	269
	Minimum	2	16	241	227	68	62	216	208
Crossfeed mode hydraulic transient effects duty cycles	Maximum	123	150	445	379	142	108	314	328
	Average	50	69	320	289	115	103	246	305
	Minimum	0	6	230	202	82	98	205	276
Manual coil baseline duty cycles	Maximum	124	158	302	265				
	Average	113	145	255	227				
	Minimum	105	128	230	206				

[a] Data extracted from appendix B

TABLE X.- ENGINE PERFORMANCE FOR HYDRAULIC TRANSIENT DUTY CYCLES

Test title		Position of cross-feed valves	Engine IV D/2			Engine IV D/4			Engine I U/13			Total of engines 2, 4, & 13		
			Ignition delay, msec	Time to 75% of S.S. P_c, msec	Percent deviation from baseline integrated P_c	Ignition delay, msec	Time to 75% of S.S. P_c, msec	Percent deviation from baseline integrated P_c	Ignition delay, msec	Time to 75% of S.S. P_c, msec	Percent deviation from baseline integrated P_c	Ignition delay, msec	Time to 75% of S.S. P_c, msec	Percent deviation from baseline integrated P_c
Hydraulic transient effects	Max.	Closed	16.3	33.6	-36.0	14.0	33.6	-47.0	14.0	34.6	-16.0	16.3	34.6	-47.0
	Avg.		12.2	22.6	-5.5	11.5	23.0	-14.4	11.9	21.6	-4.9	11.9	22.4	-8.2
	Min.		8.7	14.0		7.7	18.3		8.9	18.8		7.7	18.8	
Hydraulic transient effects	Max.	Open	13.8	26.8	-35.0	14.2	25.0	-48.0	13.0	23.5	-18.0	14.2	26.8	-48.0
	Avg.		12.2	22.4	-8.8	11.9	21.3	-16.8	11.6	20.7	-6.5	11.9	21.5	-10.6
	Min.		10.8	18.9		10.3	19.0		9.8	17.9		9.8	17.9	
Baseline single engines	Max.	Closed	13.0	24.2		12.1	22.4		12.8	21.1		13.0	24.2	
	Avg.		11.5	21.7		10.8	20.5		12.0	20.4		11.4	21.0	
	Min.		10.6	20.4		9.0	18.9		10.6	19.3		9.0	18.9	

NOTE: These data are based on data recorded in appendix B for sample pulses from engines 2, 4, and 13 for runs IV-B-2-1 through IV-B-10-9 and IV-C-2-1 through IV-C-10-9. Pulse widths were from 17 to 150 msec and identical pulses and duty cycles were used for the normal and crossfeed mode hydraulic transient duty cycles. Baseline single engine performance data are from figures 36, 37, and 39.

TABLE XI.- PRESSURE SWITCH PERFORMANCE[a]

Test title		Pressure switch closing time, msec				Pressure switch opening time, msec				Pressure at switch opening, psia			
		Eng. 2	Eng. 4	Eng. 11	Eng.13	Eng. 2	Eng. 4	Eng.11	Eng.13	Eng. 2	Eng. 4	Eng.11	Eng. 13
Baseline	Max.	16.6	11.5	12.0	12.9	20.7	74.2	61.9	62.5	39.7	5.2	5.7	5.4
	Avg.	14.3	10.5	10.7	11.8	17.1	51.1	45.7	49.0	20.0	4.1	4.6	4.6
	Min.	10.6	9.0	9.2	10.1	11.8	40.0	29.7	36.0	12.5	2.4	0	3.6
LM simulated duty cycle	Max.	16.3	12.0	10.9	11.3	20.2	67.6	38.0	56.7	23.8	7.1	5.7	4.7
	Avg.	15.7	11.1	10.5	10.9	17.3	47.9	35.8	49.8	17.2	5.2	5.3	4.5
	Min.	15.1	10.3	10.0	10.6	13.5	38.2	32.7	40.6	14.9	3.8	4.8	3.8
Lunar abort from hover simulated mission duty cycle	Max.	15.9	12.3	12.5	12.5	20.8	51.2	42.3	54.9	26.3	7.0	6.6	6.1
	Avg.	15.3	11.4	11.7	11.9	18.3	43.2	36.6	47.2	18.3	5.3	5.8	4.9
	Min.	14.4	10.0	10.9	11.1	16.4	30.0	34.2	39.2	15.4	4.7	4.5	3.8
Hydraulic transient effects (normal mode)	Max.	19.3	13.0	13.3	14.9	20.5	62.5	54.9	60.0	33.9	6.2	5.7	6.0
	Avg.	15.6	11.4	12.1	12.0	17.7	48.6	45.1	45.3	18.7	4.9	4.8	4.9
	Min.	11.2	9.7	9.9	9.2	12.5	31.3	33.4	34.6	13.3	3.3	4.0	3.3
Hydraulic transient effects (crossfeed mode)	Max.	18.9	16.0		18.2	20.0	61.3		57.7	29.1	6.6		6.1
	Avg.	15.7	11.9		12.0	17.5	47.4		44.9	18.7	4.7		4.8
	Min.	11.9	10.3		9.2	12.8	35.9		32.8	13.7	3.8		3.3
Baseline manual coils	Max.		27.7		26.9		63.8		62.1		4.8		6.4
	Avg.		26.0		26.6		53.6		49.8		4.1		4.4
	Min.		25.3		26.3		46.1		39.9		2.7		2.9

[a] Data extracted from appendix B. The engine 2 pressure switch was a special backup switch with a higher pressure actuation level.

TABLE XII.- CROSSFEED EFFECTS ON MDC PERFORMANCE

[Data based on sample pulses from LM1 mission II simulated duty cycles]

Run no.		Engine no. and location														
		Engine IV D/2			Engine IV S/4			Engine II F/11			Engine I U/13			Summary		
		Ignition delay, msec	Time to 75% P_c, msec	Inte-grated P_c, (psia-sec)	Ignition delay, msec	Time to 75% P_c, msec	Inte-grated P_c, psia-sec	Ignition delay, msec	Time to 75% P_c, msec	Inte-grated P_c, psia-sec	Ignition delay, msec	Time to 75% P_c, msec	Inte-grated P_c, psia-sec	Ignition delay, msec	Time to 75% P_c, msec	Inte-grated P_c, psia-sec
Run III-A-3-1 (Normal mode)	Max.	11.0	24.6		10.3	18.6		10.4	20.0		10.6	20.5		11.0	24.6	
	Avg.	10.6	21.7	[a]2.56	10.3	18.6	[b]1.08	10.2	19.4	[c]3.35	10.6	20.4	[d]5.99	10.4	20.2	[e]3.17
	Min.	10.0	19.2		10.3	18.5		10.0	18.8		10.6	20.2		10.0	18.5	
Run IV-F-1A (Crossfeed mode)	Max.	11.0	22.5		11.3	19.2		11.1	20.1		11.2	20.6		11.3	22.7	
	Avg.	10.9	21.5	[a]2.64	11.1	18.7	[b]1.20	10.7	19.2	[c]3.75	11.0	20.6	[d]6.17	10.9	20.0	[e]3.35
	Min.	10.6	19.7		10.9	18.2		10.3	18.2		10.8	20.5		10.3	18.2	

[a] Average integrated P_c for average pulse duration of 32 msec.

[b] Average integrated P_c for average pulse duration of 16 msec.

[c] Average integrated P_c for average pulse duration of 43 msec.

[d] Average integrated P_c for average pulse duration of 77 msec.

[e] Average integrated P_c for average pulse duration of 42 msec.

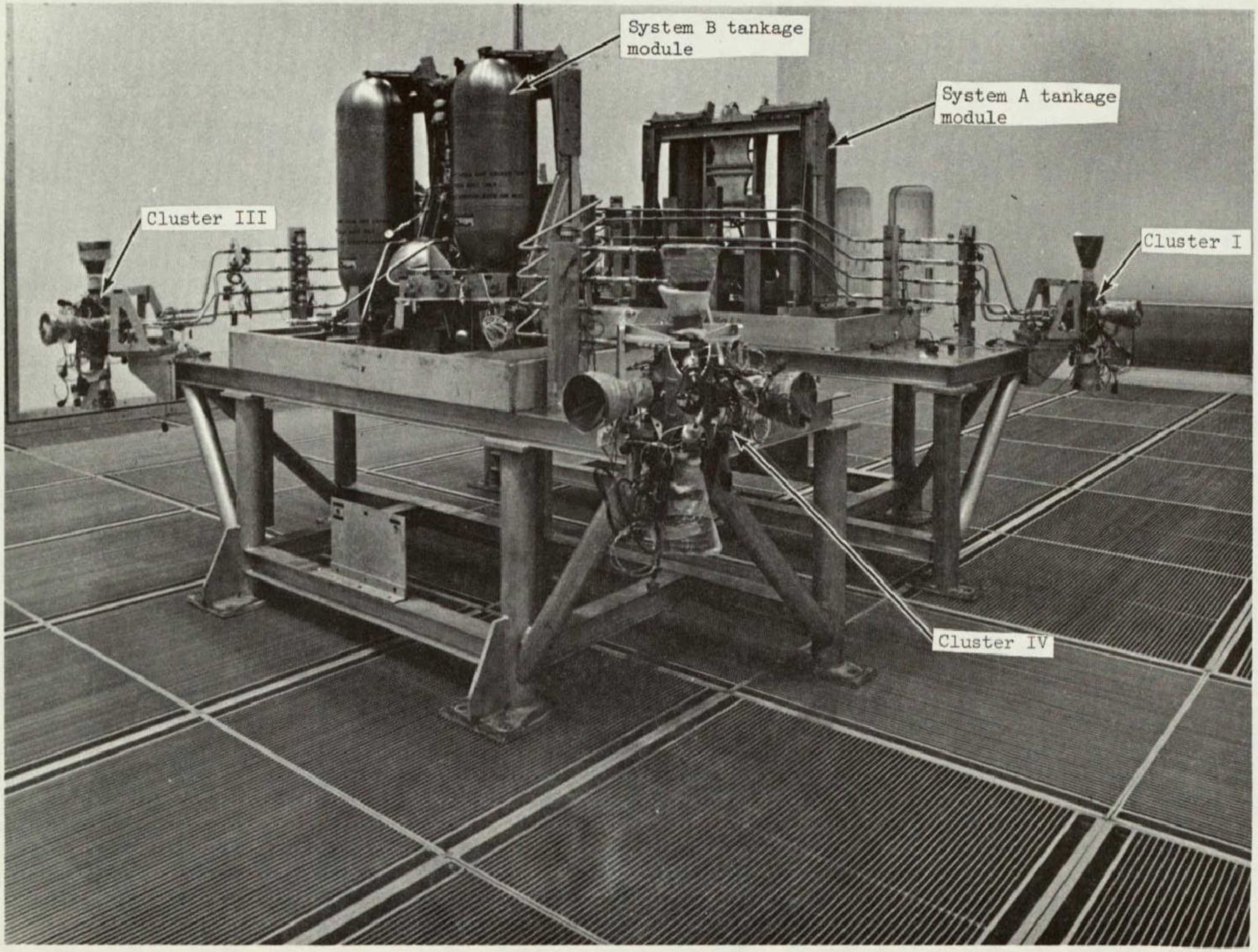


Figure 1.- Complete LM RCS assembly in building 36 cleanroom.

TABLE XIII.- PROPELLANT CONSUMPTION AND ENGINE FIRING SUMMARY FOR MISSION DUTY CYCLES AND TOTAL TEST PROGRAM

Measurement	Engine number																System A	System B	Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
							LM 1 mission duty cycle												
Total on time, sec	19.432	25.067	1.013	2.397	15.684	27.982	0.724	3.211	18.149	32.603	2.038	4.629	6.041	61.343	0.611	3.409	87.652	136.681	224.333
Total pulses	197	187	34	30	119	289	28	35	172	175	33	29	34	273	25	35	638	1 057	1 695
Avg. pulse width, sec	.099	.134	.030	.080	.132	.096	.025	.092	.106	.186	.062	.160	.178	.225	.024	.097	.137	.129	.132
Fuel consumption, lb																	9.9	16.9	26.8
Oxid consumption, lb																	18.6	30.4	49.0
Total propellant, lb																	28.5	47.3	75.8
Overall O/F																	1.88	1.80	1.83
Fuel flowrate, lb/sec																	.113	.124	.119
Oxid flowrate, lb/sec																	.212	.222	.218
Total flowrate, lb/sec																	.325	.346	.337
																	Average voltage = 23-24 V dc		
							Lunar mission abort from hover mission duty cycle												
Total on time, sec	3.904	19.990	5.643	5.422	2.039	54.431	5.765	5.412	4.112	46.060	5.190	5.514	6.135	28.150	5.240	5.557	95.488	113.081	208.569
Total pulses	55	230	129	127	54	416	119	119	91	501	111	113	85	235	116	112	1 343	1 270	2 613
Avg. pulse width, sec	.071	.087	.044	.043	.038	.131	.048	.045	.045	.092	.047	.049	.072	.120	.045	.050	.071	.089	.080
Fuel consumption, lb																	11.90	14.90	26.80
Oxid consumption, lb																	20.90	26.90	47.80
Total propellant, lb																	32.80	41.80	74.60
Overall O/F																	1.76	1.81	1.78
Fuel flowrate, lb/sec																	.125	.132	.128
Oxid flowrate, lb/sec																	.219	.238	.229
Total flowrate, lb/sec																	.344	.370	.358
																	Average voltage = 23-24 V dc		
							Total propellant consumption and firing summary for test program												
Total on time, sec	47.761	273.707	14.756	46.731	45.763	355.061	22.747	33.056	51.070	108.413	22.204	30.254	46.931	172.437	18.185	18.921	664.867[a]	643.130[a]	1 307.997
Total pulses	518	6065	329	908	370	6345	437	653	593	1030	612	516	629	1202	397	308	11 343[a]	9 569[a]	20 912
Avg. pulse width, sec	.092	.045	.045	.051	.124	.056	.052	.051	.086	.105	.036	.059	.075	.143	.046	.061	.059	.067	.063
Fuel consumption, lb																	85	85	170
Oxid consumption, lb																	154	164	318
Total propellant, lb																	239	249	488
Overall O/F																	1.81	1.93	1.87
Fuel flowrate, lb/sec																	0.128	0.132	.130
Oxid flowrate, lb/sec																	0.232	0.255	.243
Total flowrate, lb/sec																	.360	0.387	.373
																	Average voltage = 23-24 V dc		

[a] These totals are based on the total on time and total pulses from each tankage module including crossfeed mode operation; therefore, the totals are not summations of the individual engine firing summaries.

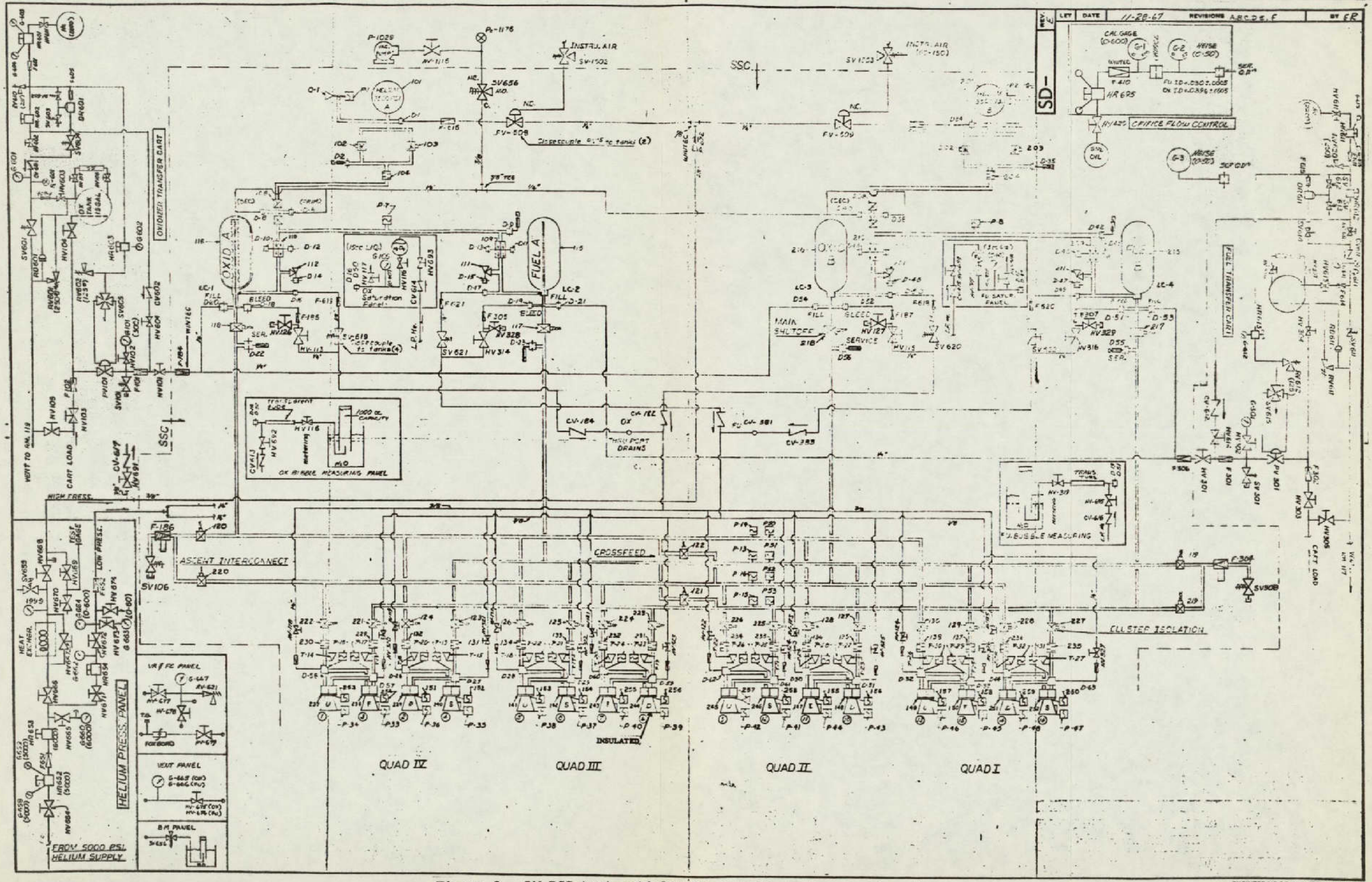


Figure 2.- LM RCS test article and support equipment schematic.

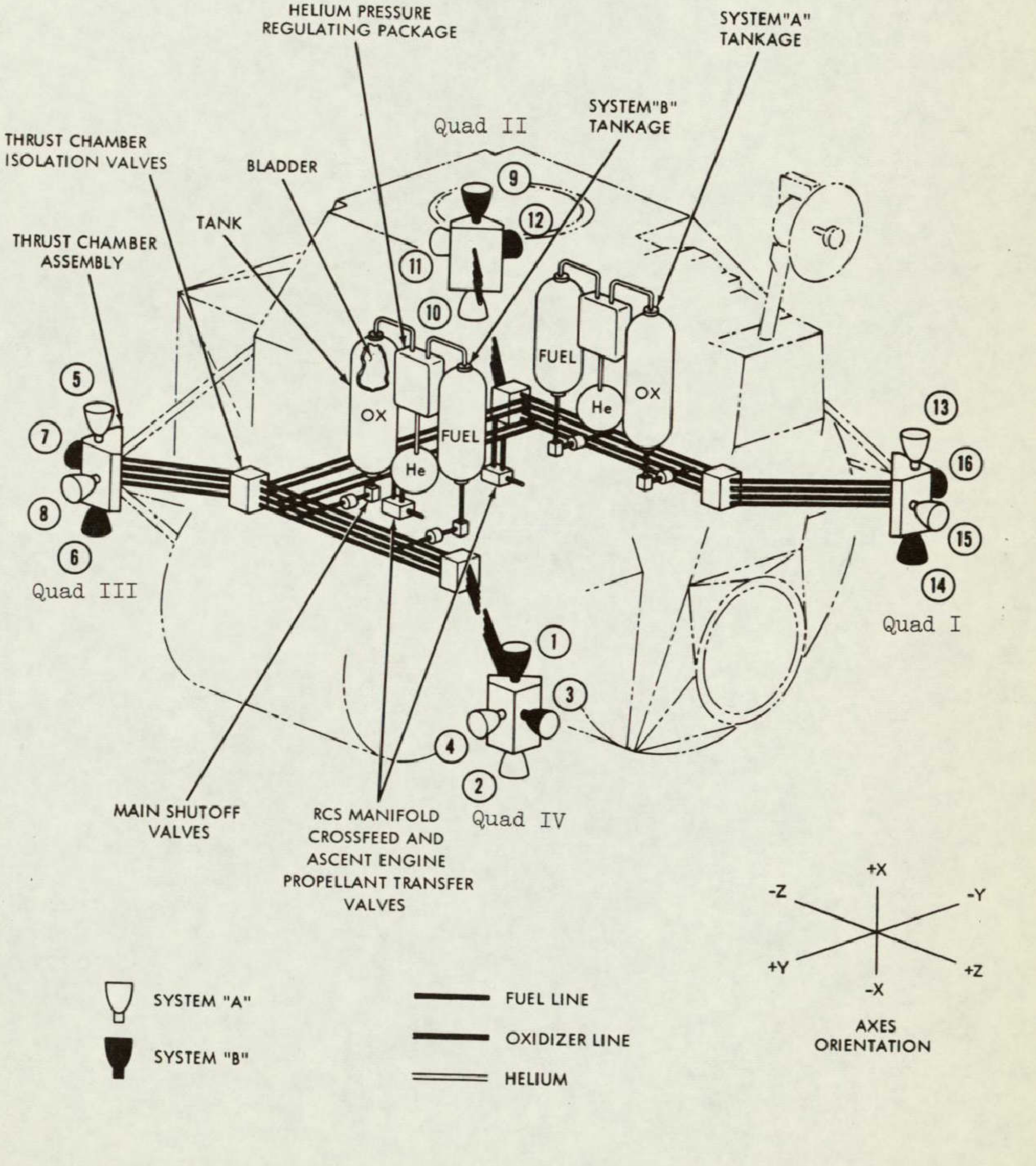
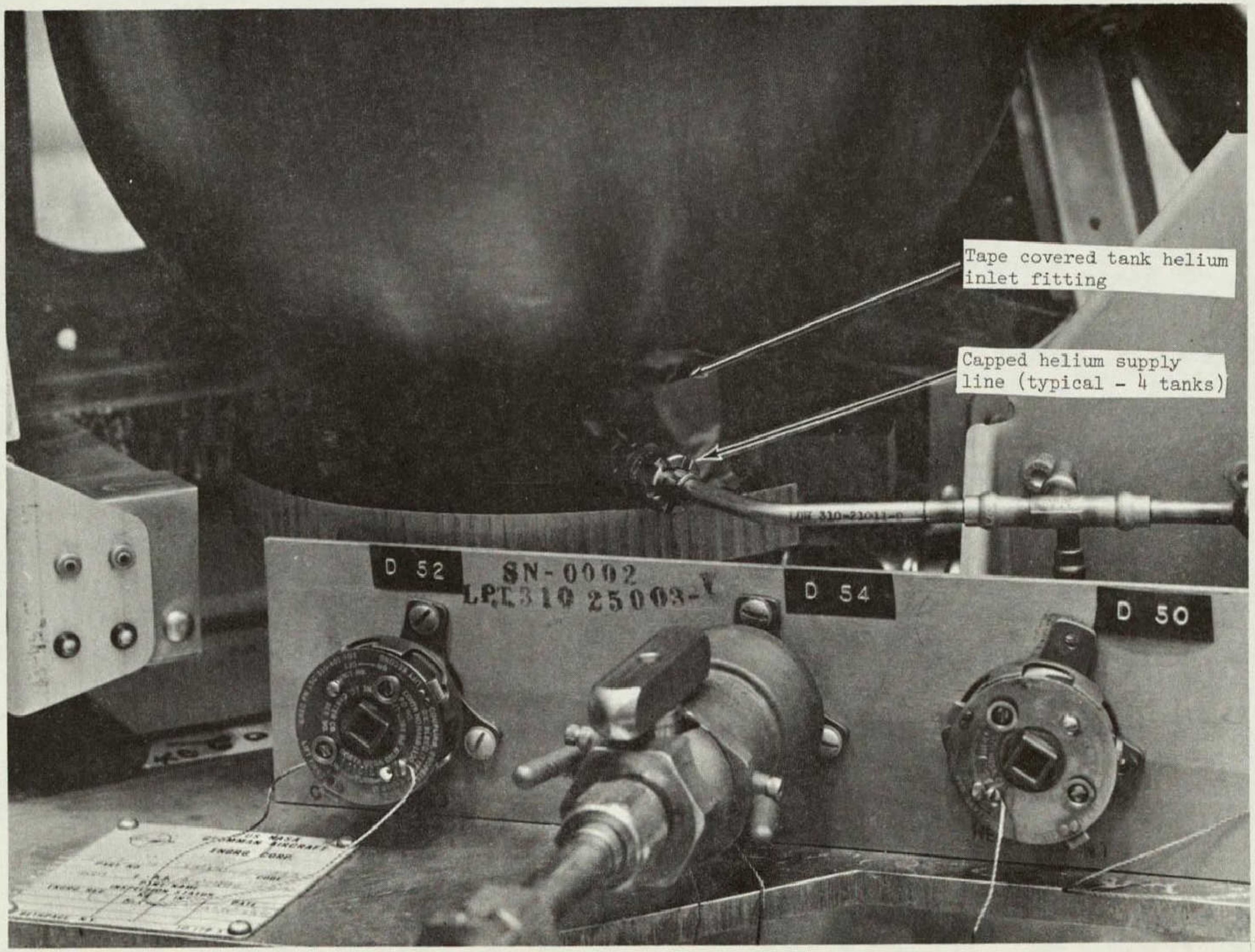


Figure 3.- LM RCS installation.



Tape covered tank helium inlet fitting

Capped helium supply line (typical - 4 tanks)

Figure 4.- Helium isolation configuration utilized during pretest operations.

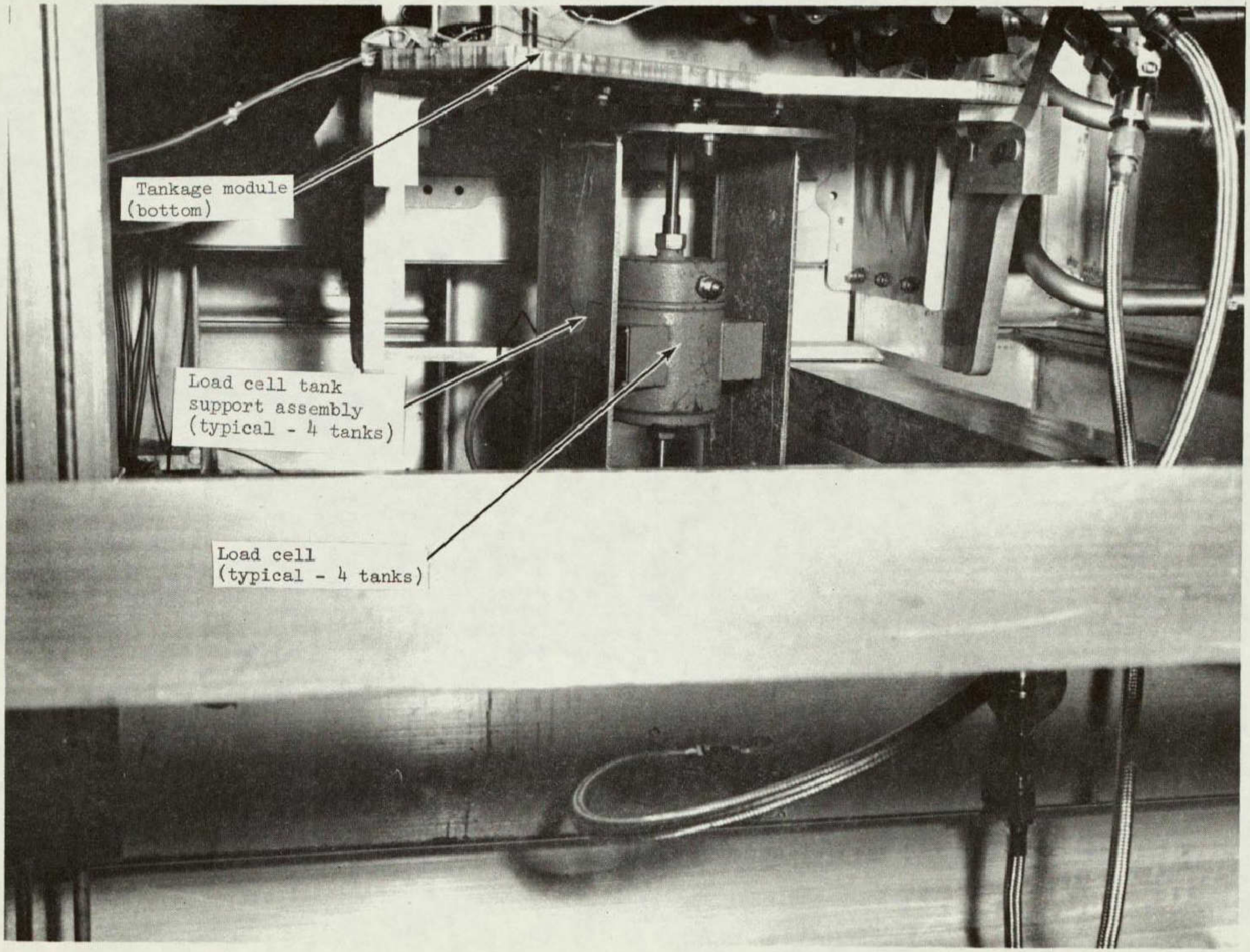


Figure 5.- Load cell installation.

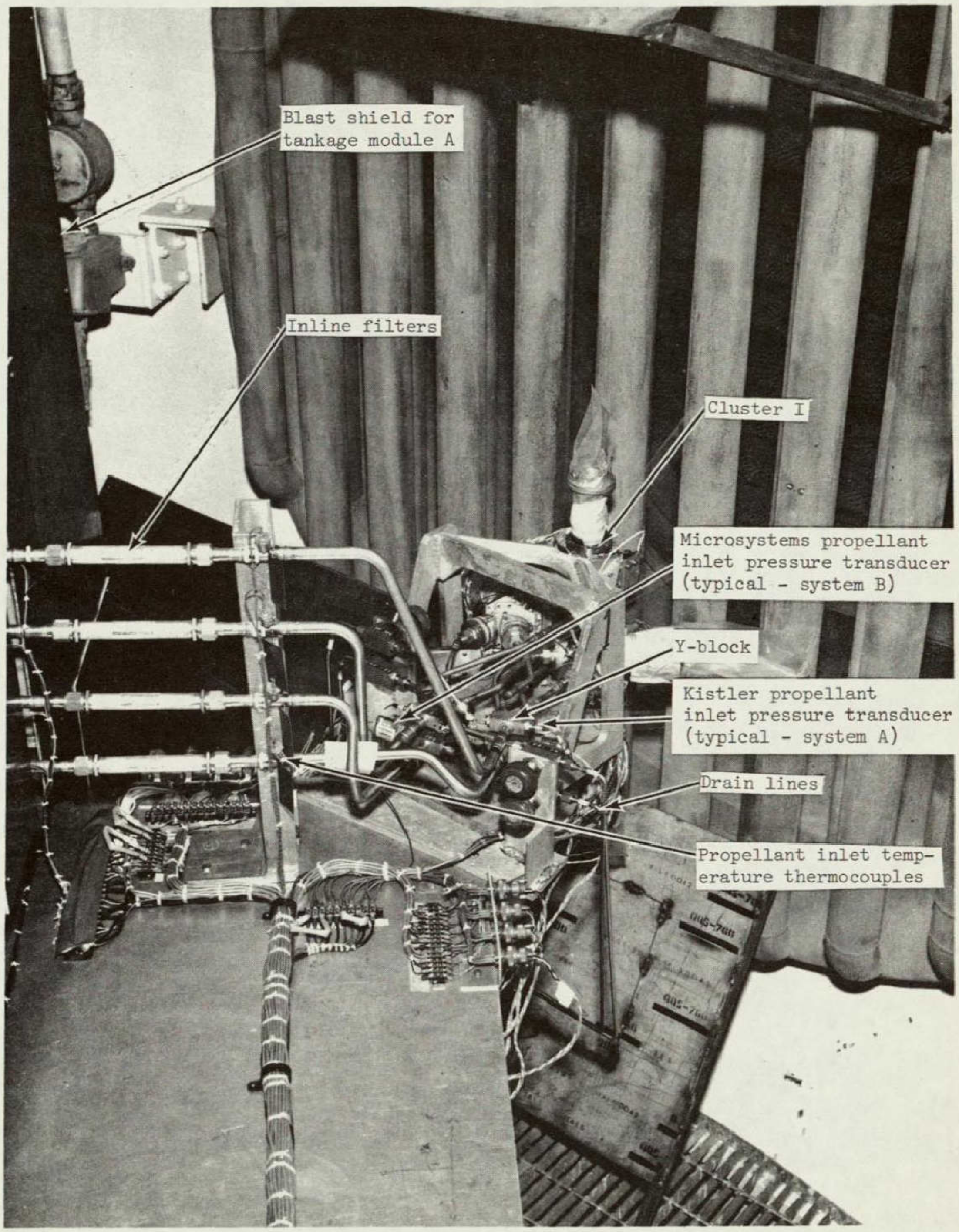


Figure 6.- Typical cluster assembly.

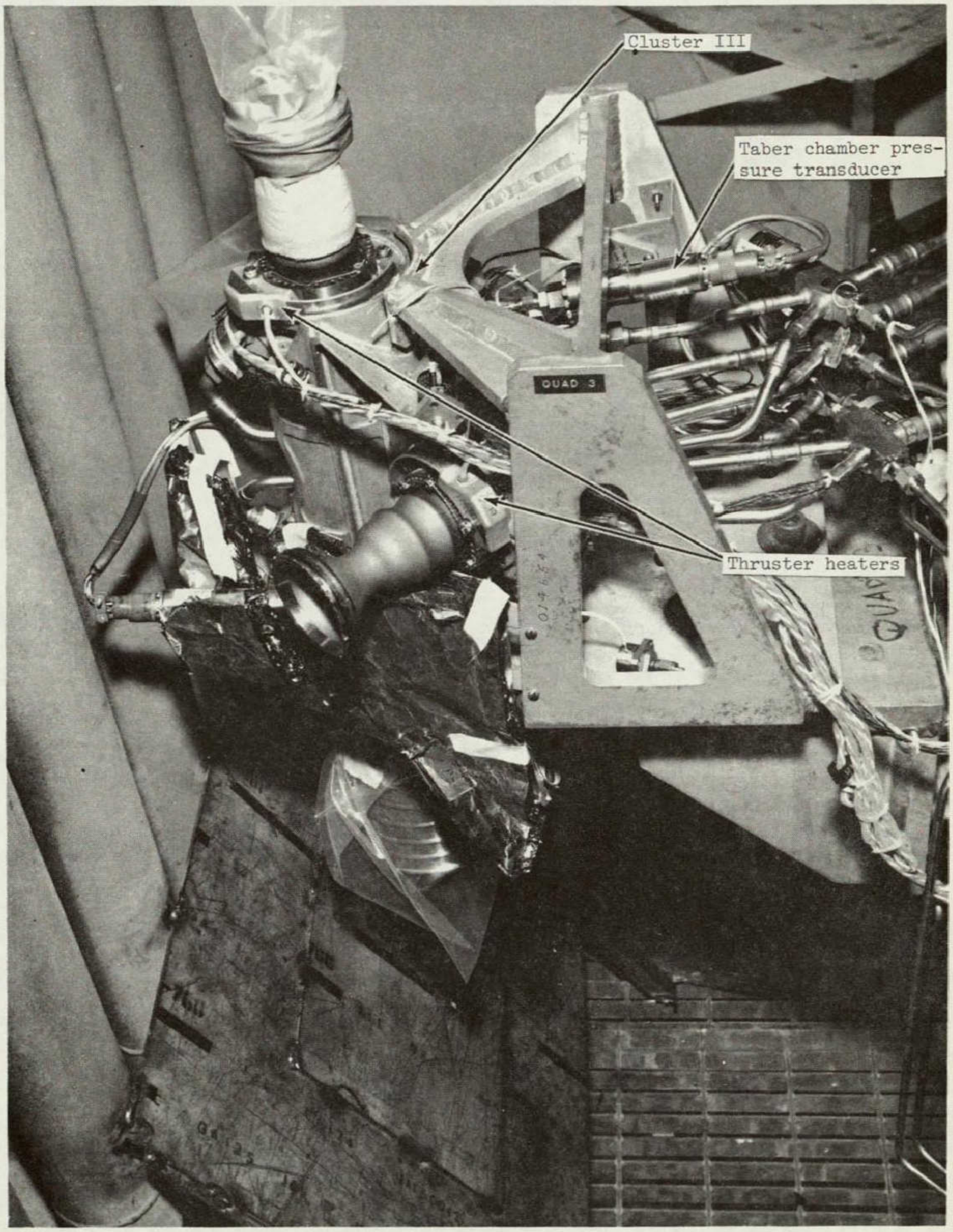
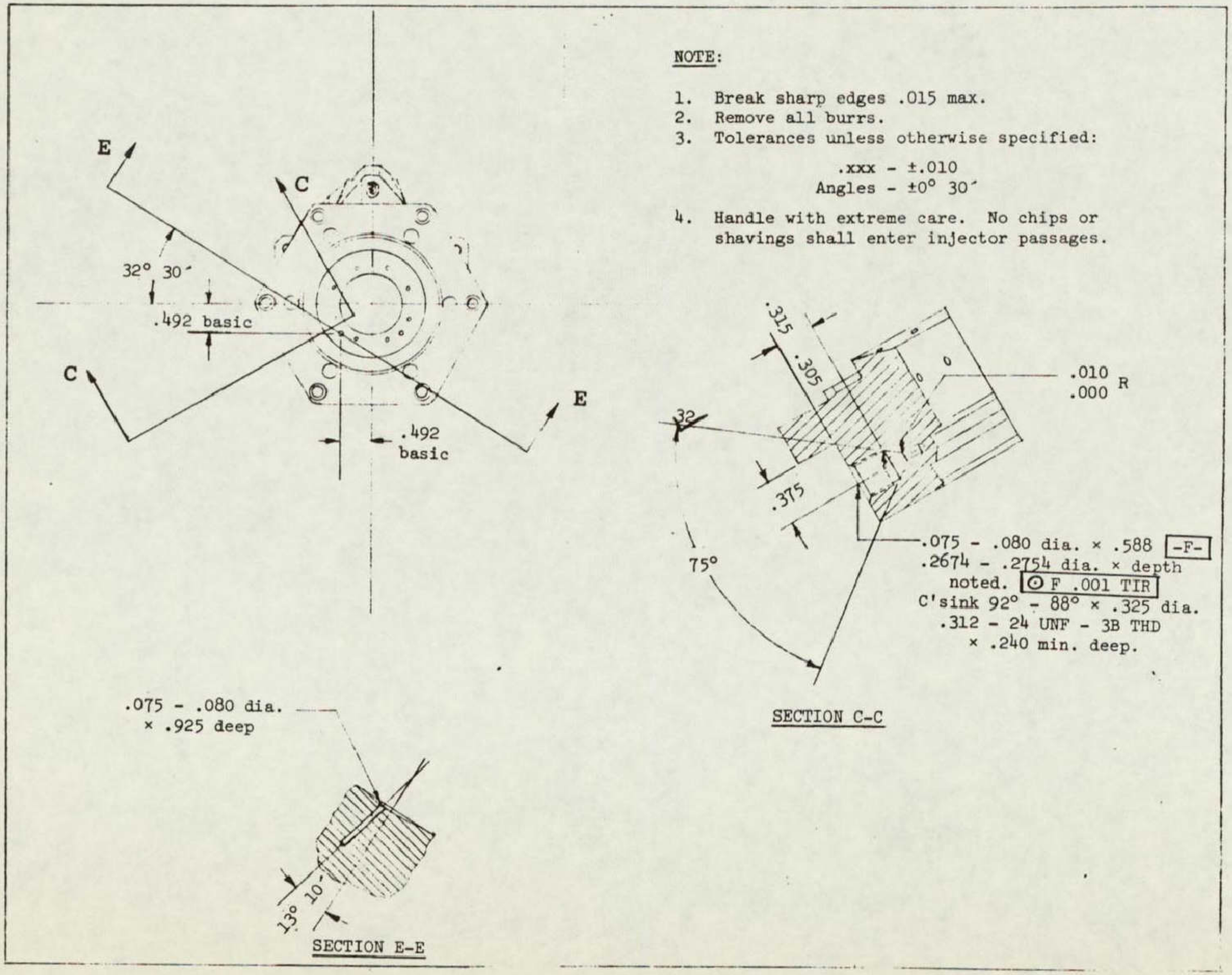


Figure 7.- Typical heater installation.



NOTE:

1. Break sharp edges .015 max.
2. Remove all burrs.
3. Tolerances unless otherwise specified:

   .xxx - ±.010
   Angles - ±0° 30′

4. Handle with extreme care. No chips or shavings shall enter injector passages.

.075 - .080 dia. × .588 -F-
.2674 - .2754 dia. × depth noted. ⊙ F .001 TIR
C'sink 92° - 88° × .325 dia.
.312 - 24 UNF - 3B THD × .240 min. deep.

.075 - .080 dia. × .925 deep

Figure 8.- LM RCS engine injector head modifications.

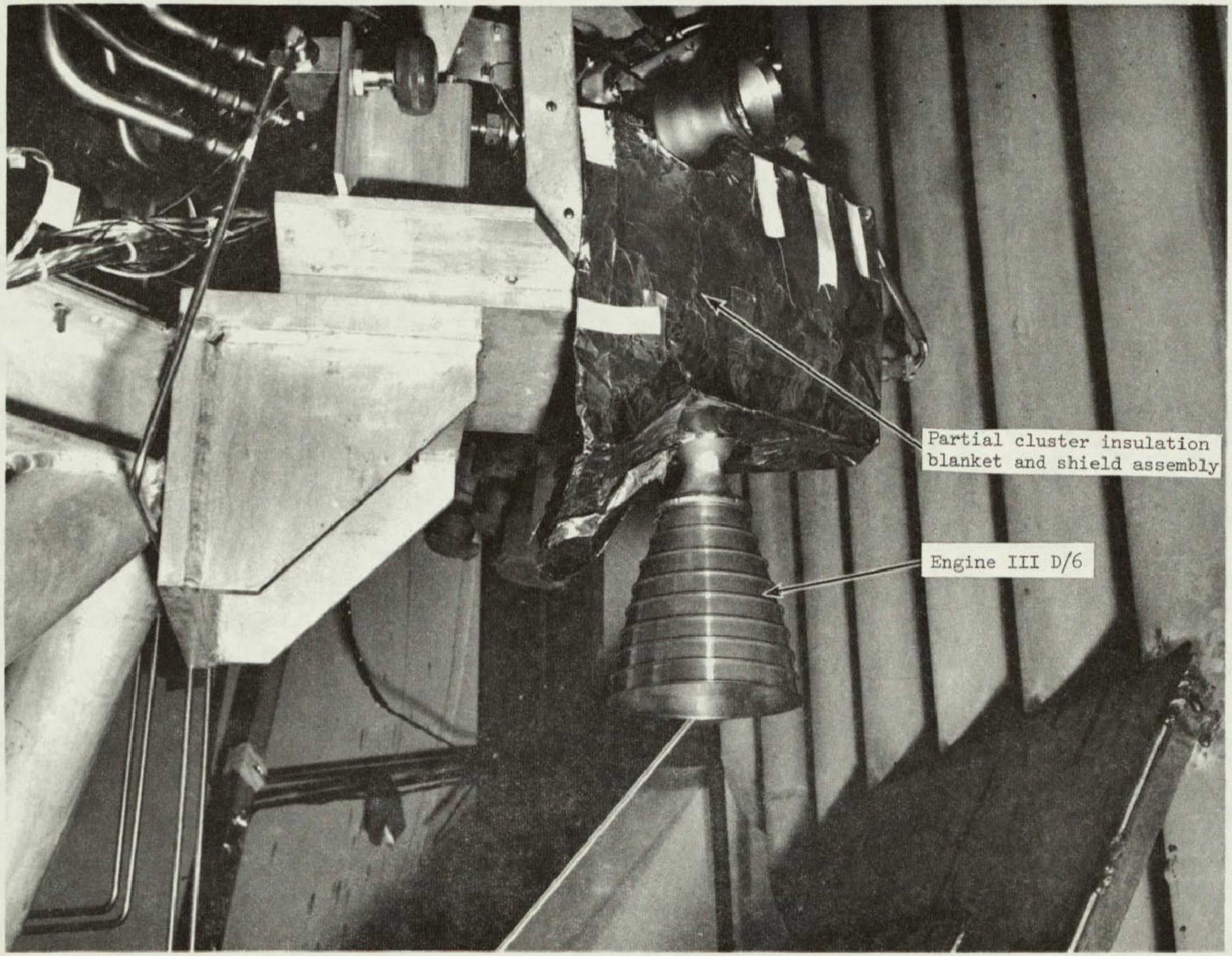


Figure 9.- Cluster installation showing thermal blanket and shield assembly.

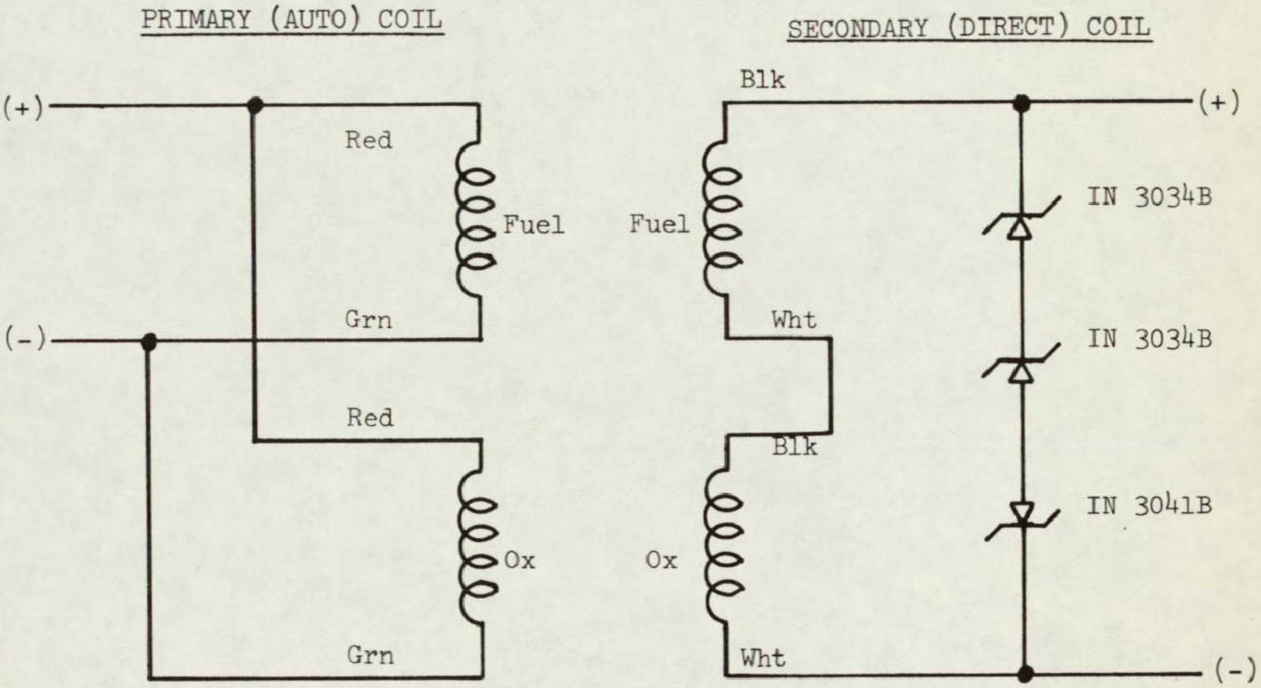


Figure 10.- Series aiding and arc suppression network for LM RCS engines.

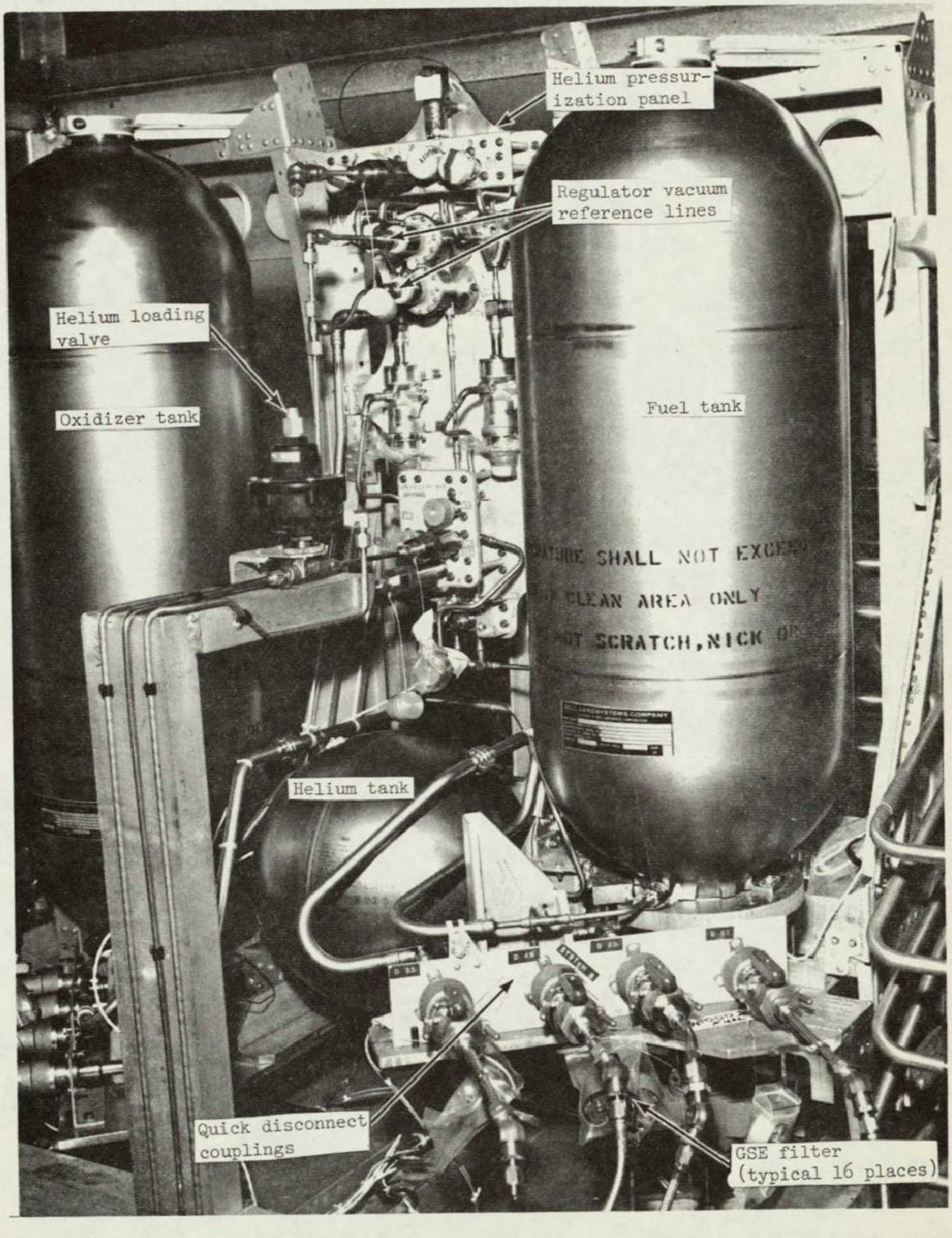


Figure 11.- Test setup - system B tankage module.

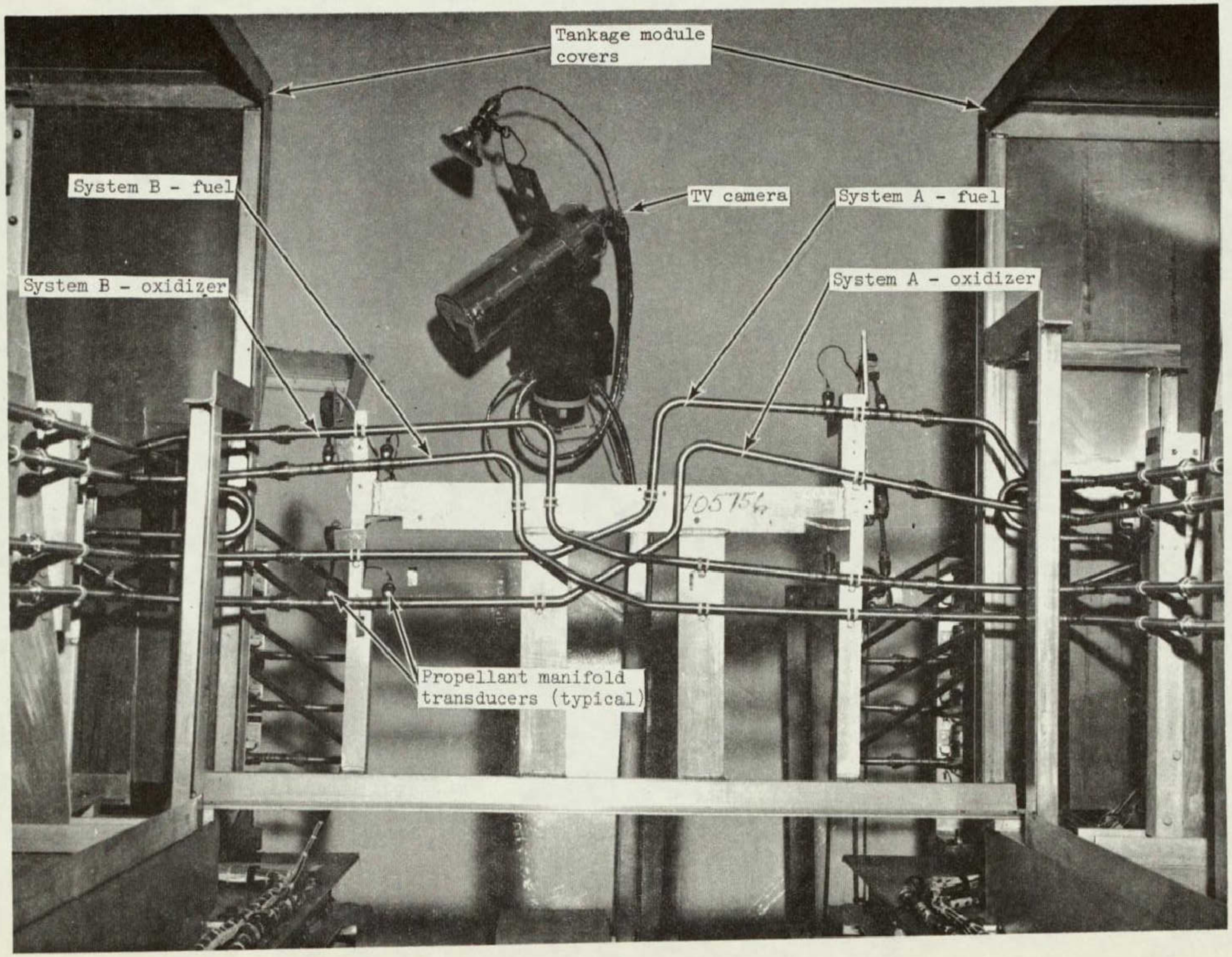


Figure 12.- Crossover assembly.

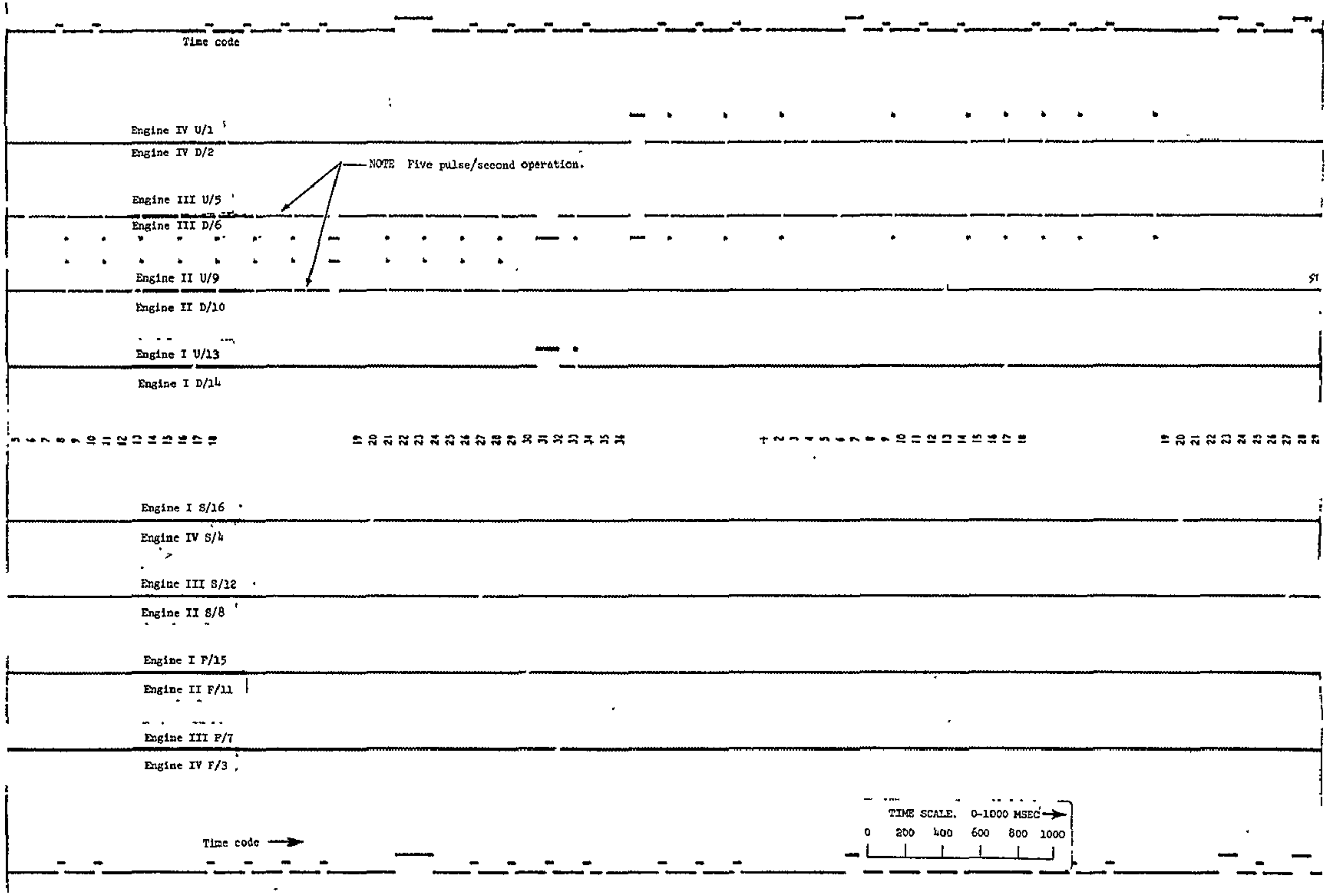


Figure 13.- Excerpt from LM1 mission phase 9 (first DPS burn) duty cycle.

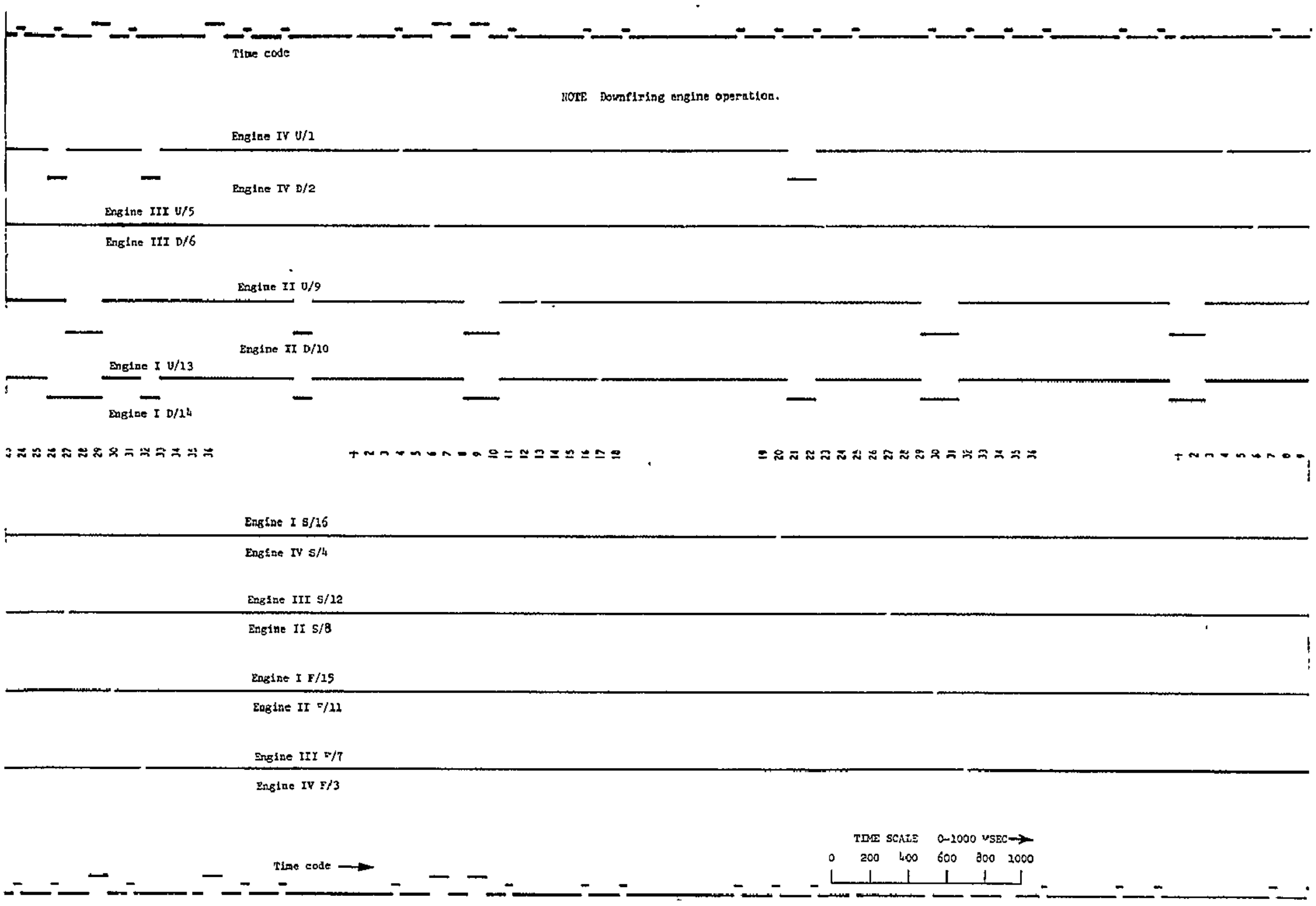


Figure 14.- Excerpt from LM1 mission phase 13 (second APS burn) duty cycle.

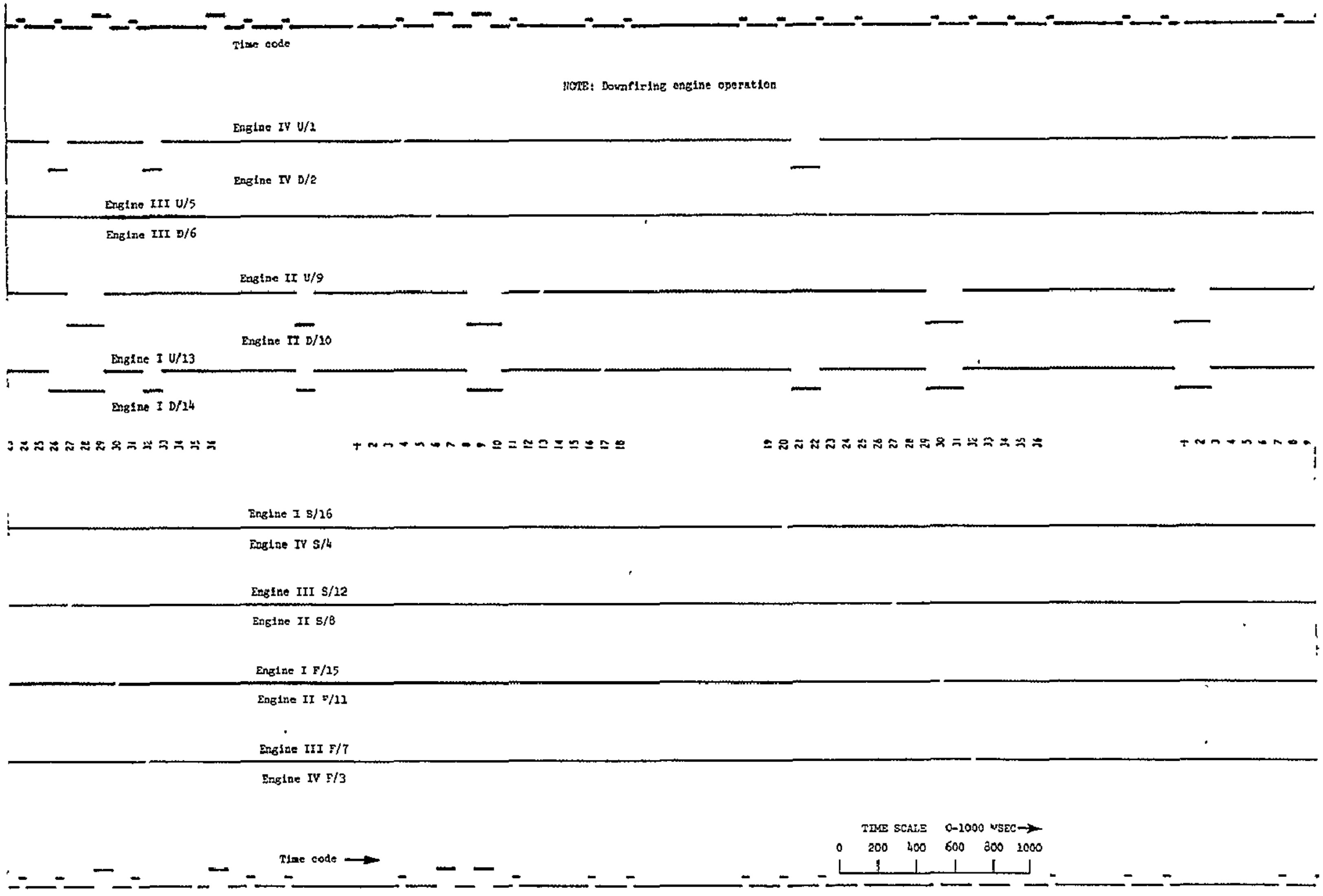


Figure 14.- Excerpt from LM1 mission phase 13 (second APS burn) duty cycle.

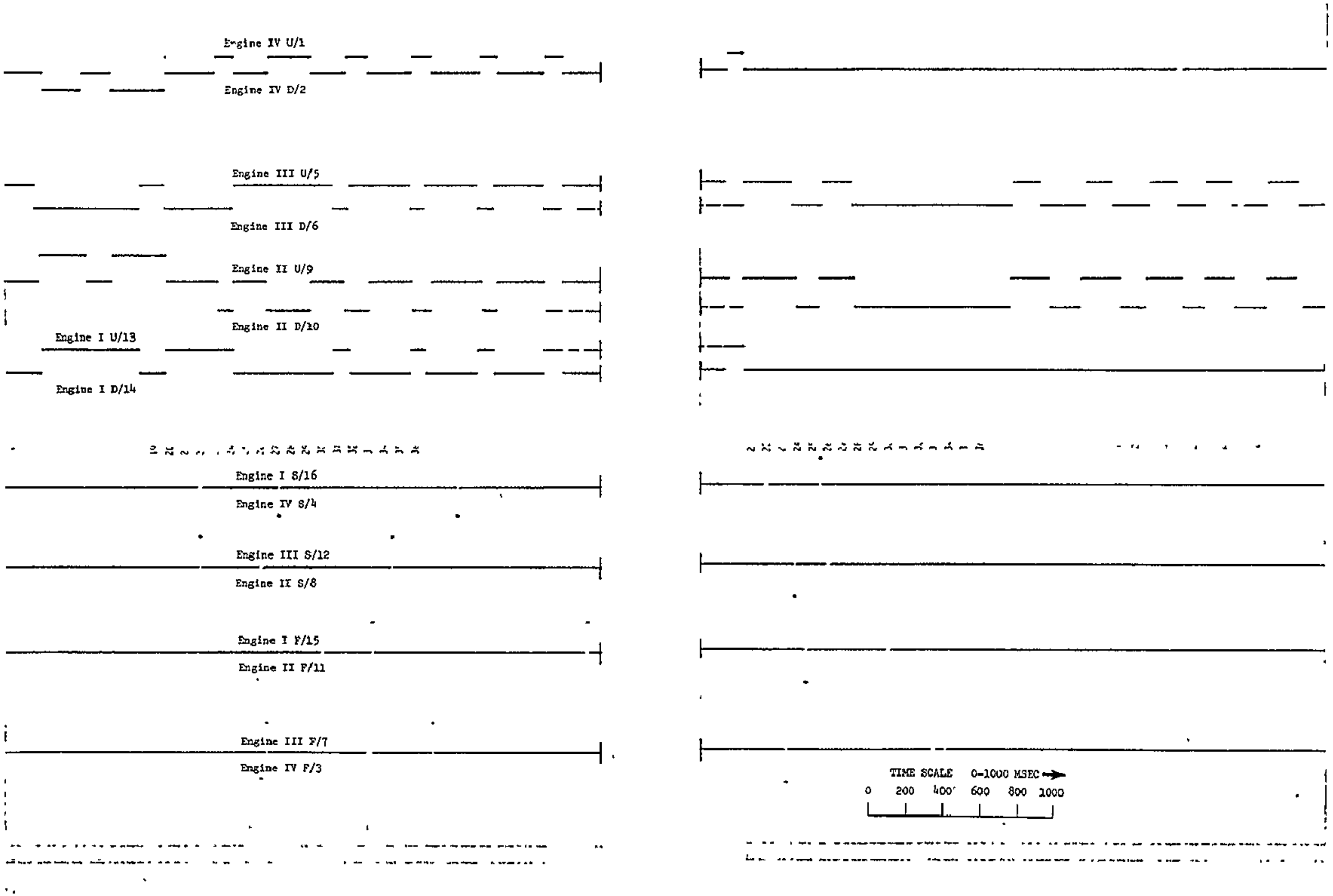


Figure 15.- Excerpt from lunar mission abort from hover duty cycle.

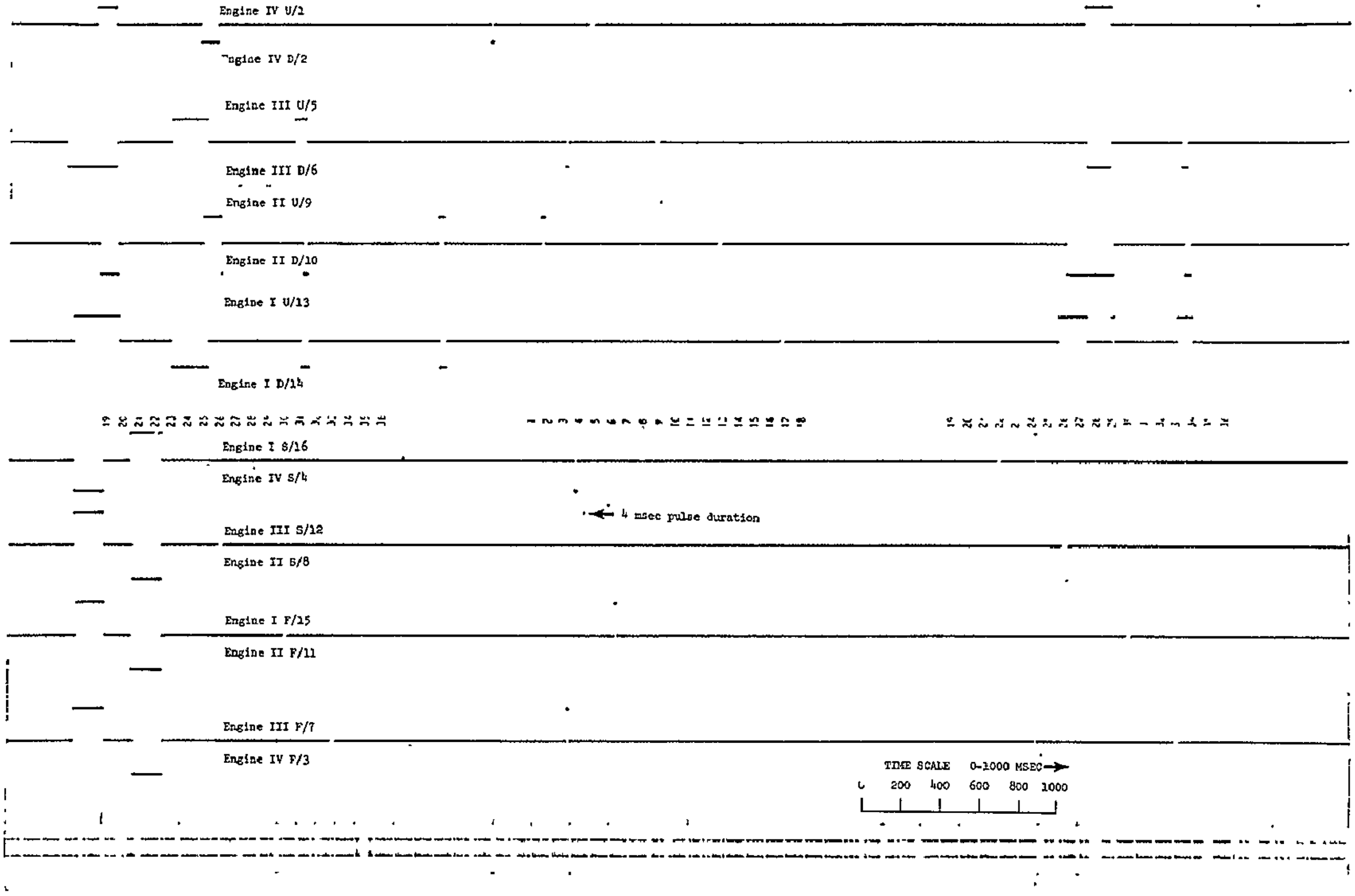


Figure 16.- Excerpt number 1 from lunar mission coelliptic sequence initiation duty cycle.

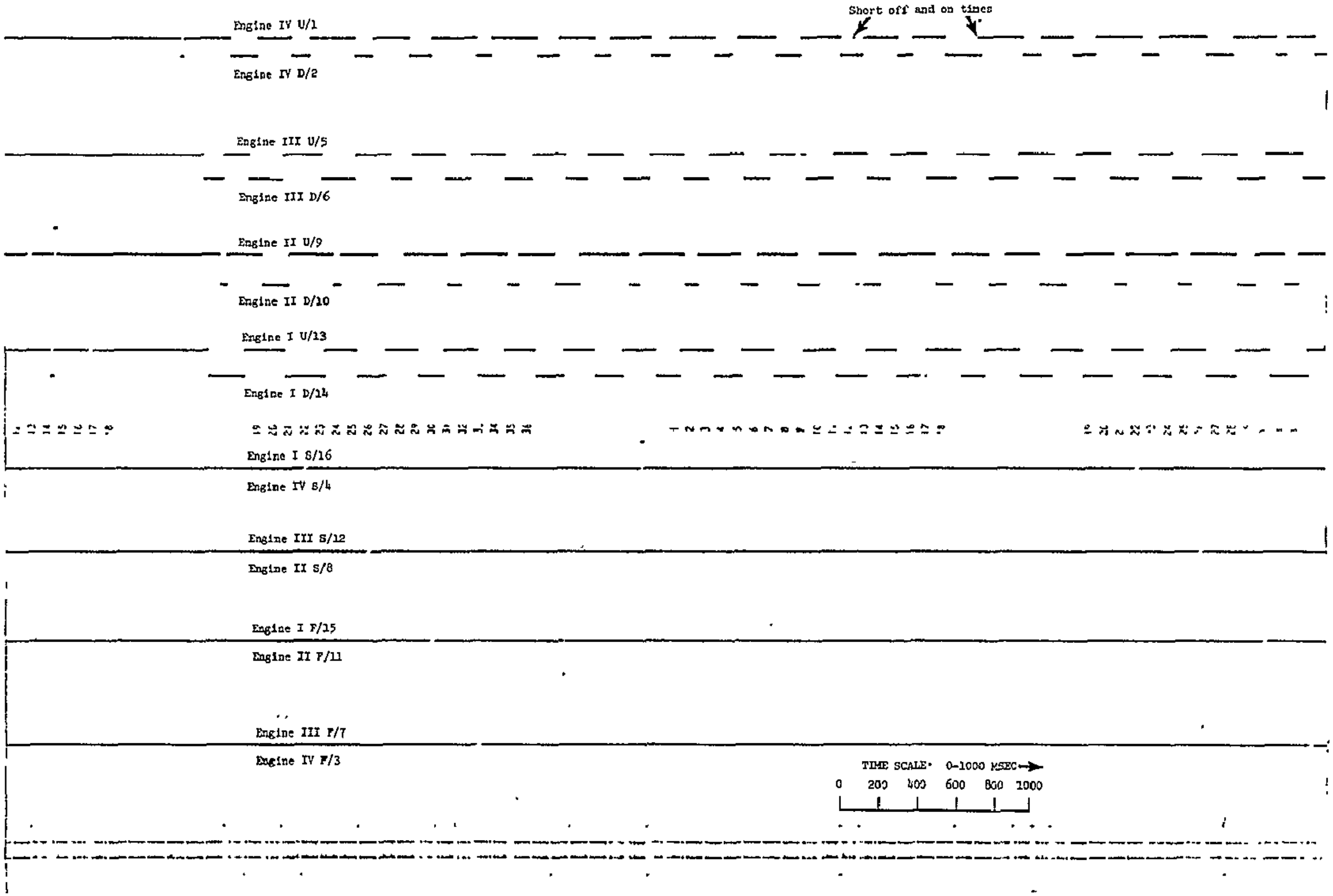


Figure 17.- Excerpt number 2 from lunar mission coelliptic sequence initiation duty cycle.

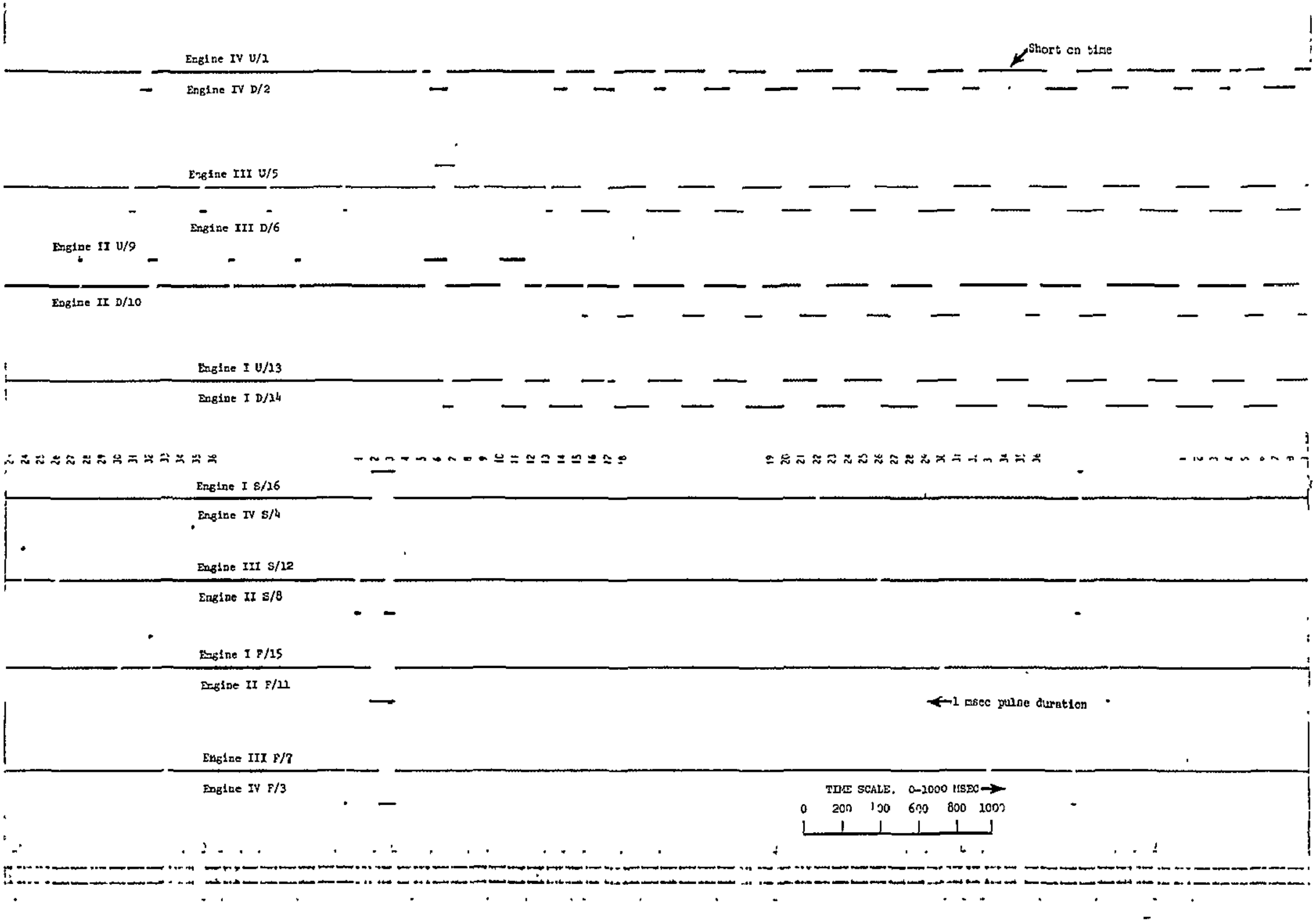


Figure 18.- Excerpt from lunar mission coelliptic delta height duty cycle.

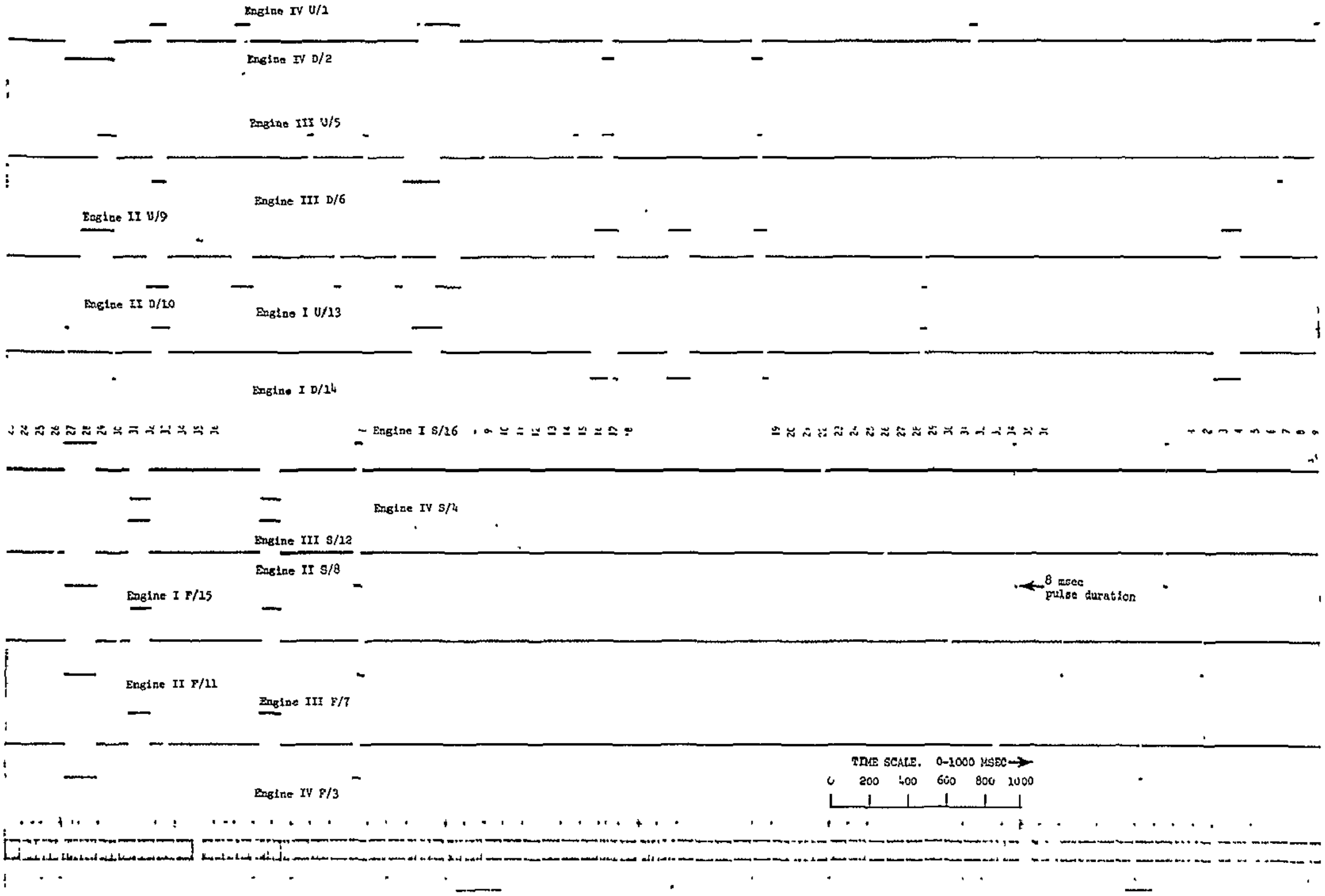


Figure 19.- Excerpt from lunar mission transfer point initiation duty cycle.

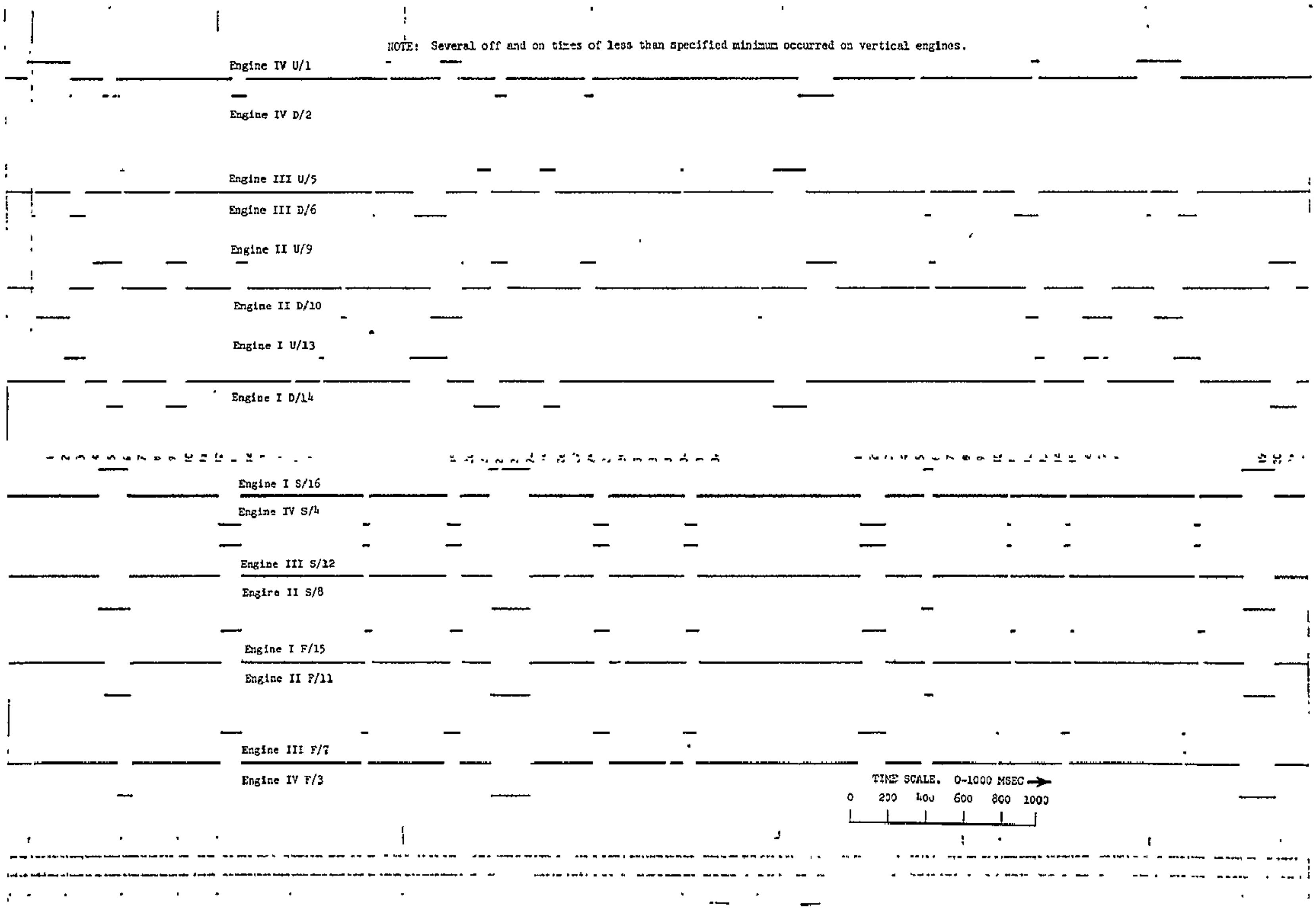

NOTE: Several off and on times of less than specified minimum occurred on vertical engines.

Figure 20.- Excerpt from lunar mission midcourse corrections duty cycle.

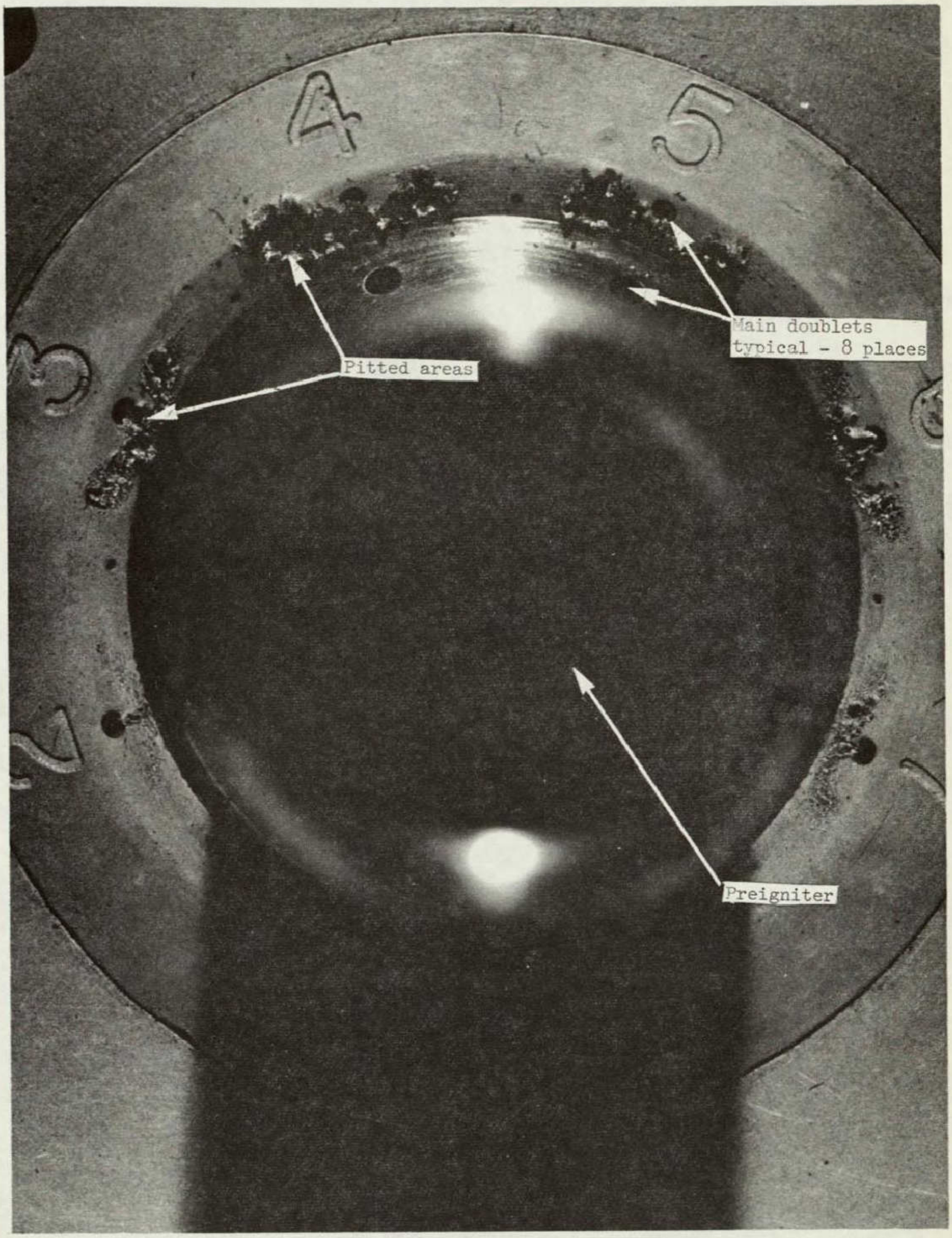
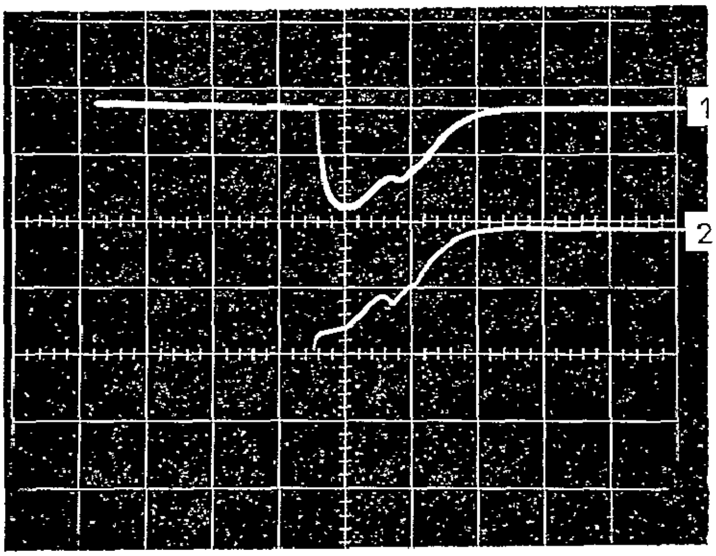
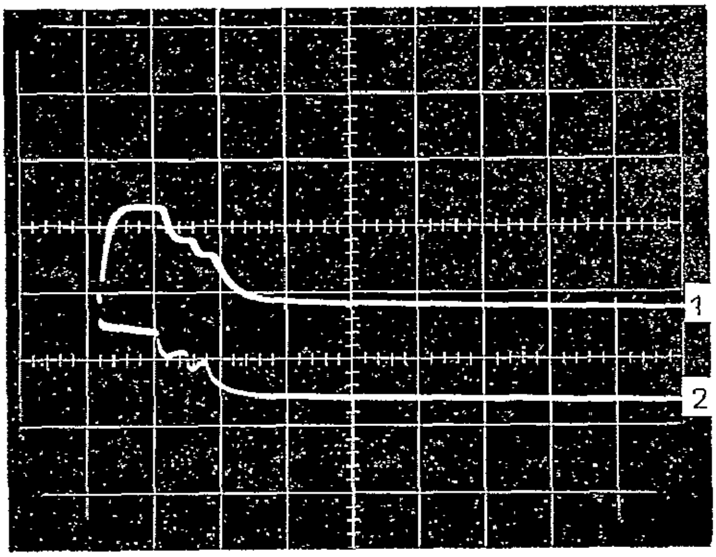


Figure 21.- Face of injector S/N 1003 as received at MSC.



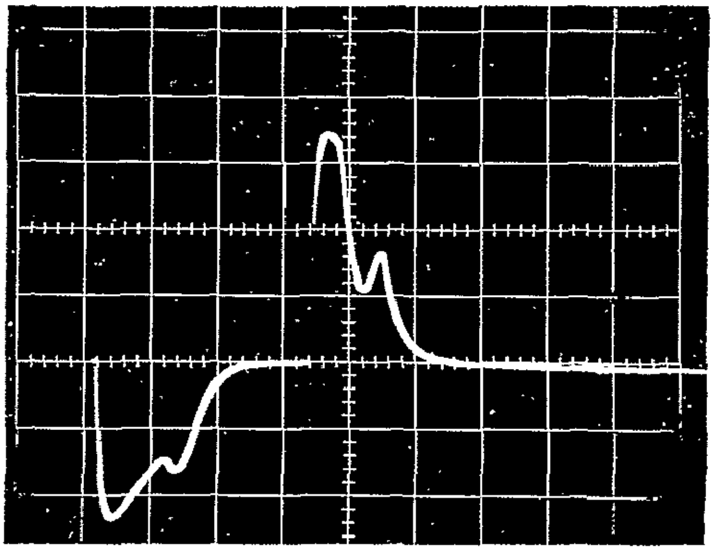
Combined fuel and oxidizer valve opening traces.
Inlet pressure 181 psig static; 27 V dc; 5 msec/cm.



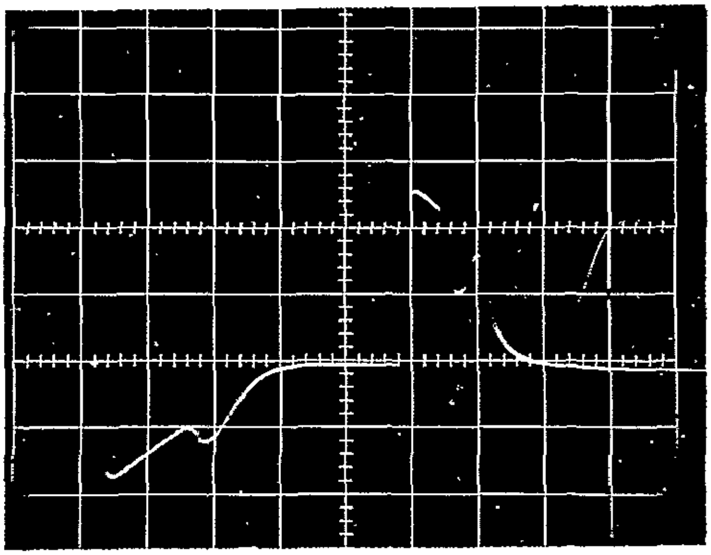
Combined fuel and oxidizer valve closing traces.
Inlet pressure 72 psig dynamic; 27 V dc; 5 msec/cm.

(Trace 1 is induced voltage on direct coils. Trace 2 is current through automatic coils. Arc suppression installed.)

Figure 22.- Effects of arc suppression network on automatic coil response.

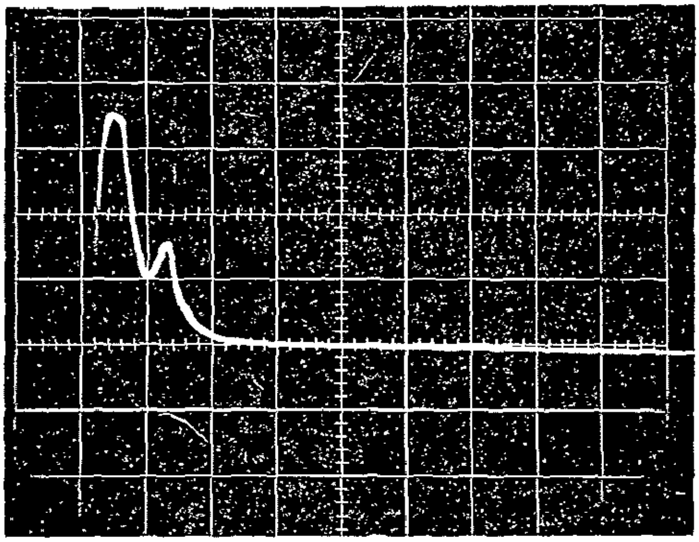


Fuel valve opening and closing trace. Inlet pressure 181 psig static; 27 V dc; 5 msec/cm. No arc suppression.

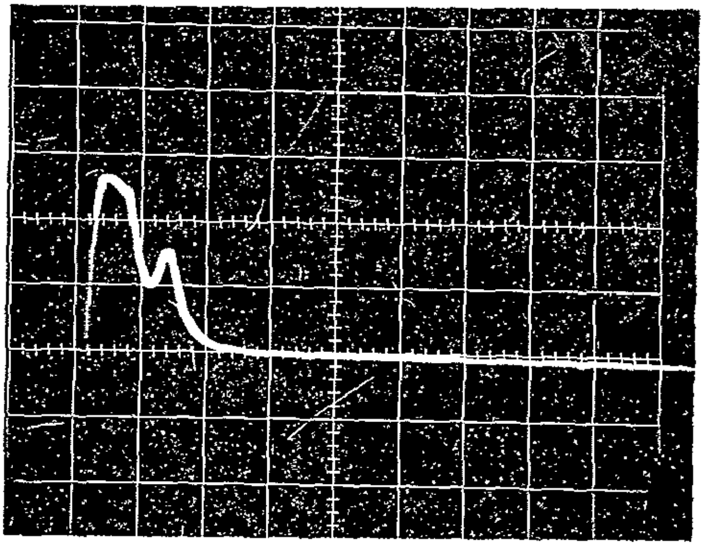


Oxidizer valve opening and closing trace. Inlet pressure 181 psig static; 27 V dc; 5 msec/cm. No arc suppression.

Figure 22.- Effects of arc suppression network on automatic coil response - continued.

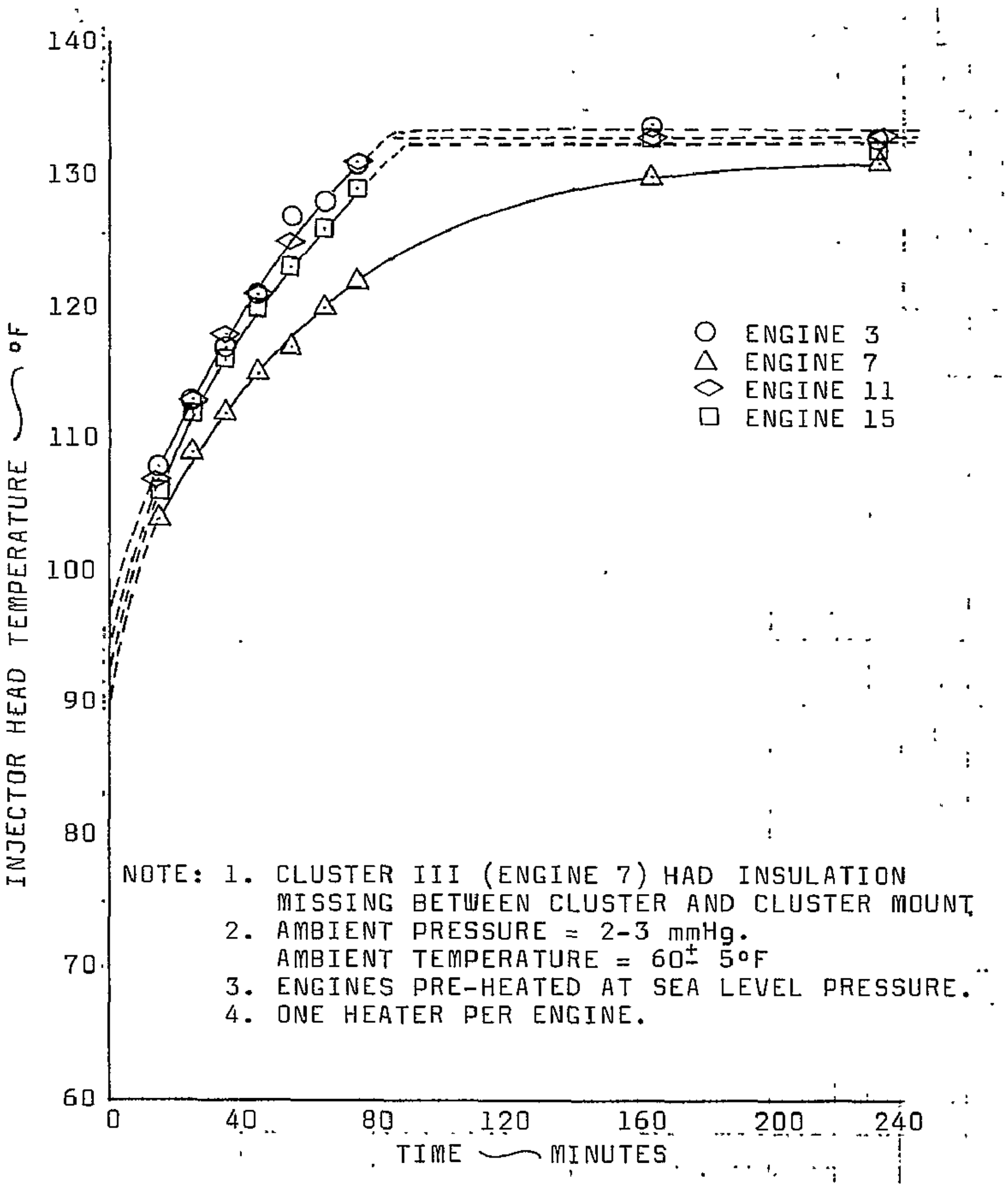


Fuel valve closing trace. Inlet pressure 72 psig dynamic; 27 V dc; 5 msec/cm. No arc suppression.



Oxidizer valve closing trace. Inlet pressure 72 psig dynamic; 27 V dc; 5 msec/cm. No arc suppression.

Figure 22.- Effects of arc suppression network on automatic coil response - concluded.



NOTE: 1. CLUSTER III (ENGINE 7) HAD INSULATION MISSING BETWEEN CLUSTER AND CLUSTER MOUNT.
2. AMBIENT PRESSURE ≈ 2-3 mmHg.
AMBIENT TEMPERATURE = 60± 5°F
3. ENGINES PRE-HEATED AT SEA LEVEL PRESSURE.
4. ONE HEATER PER ENGINE.

Figure 23.- Sample heater warmup histories.

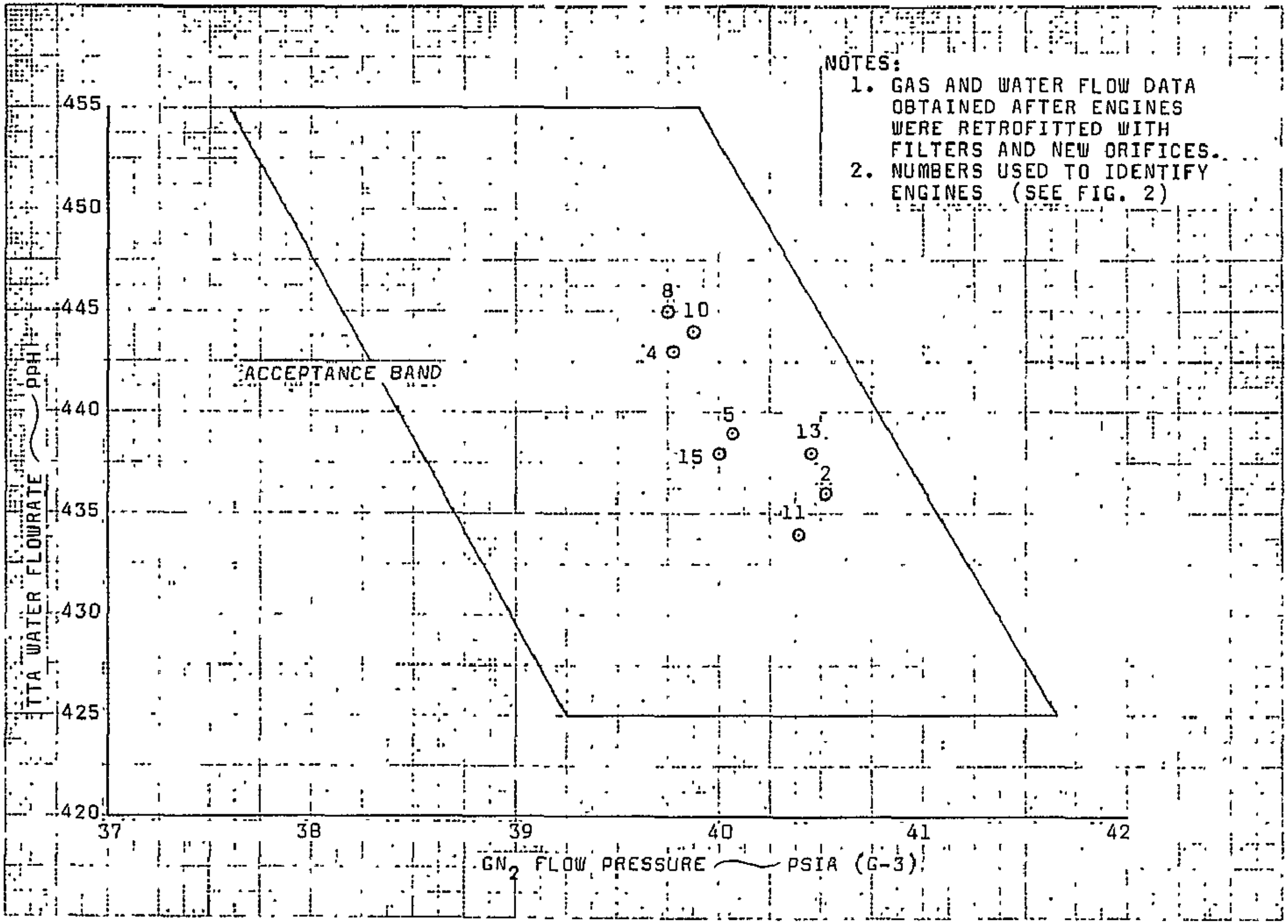
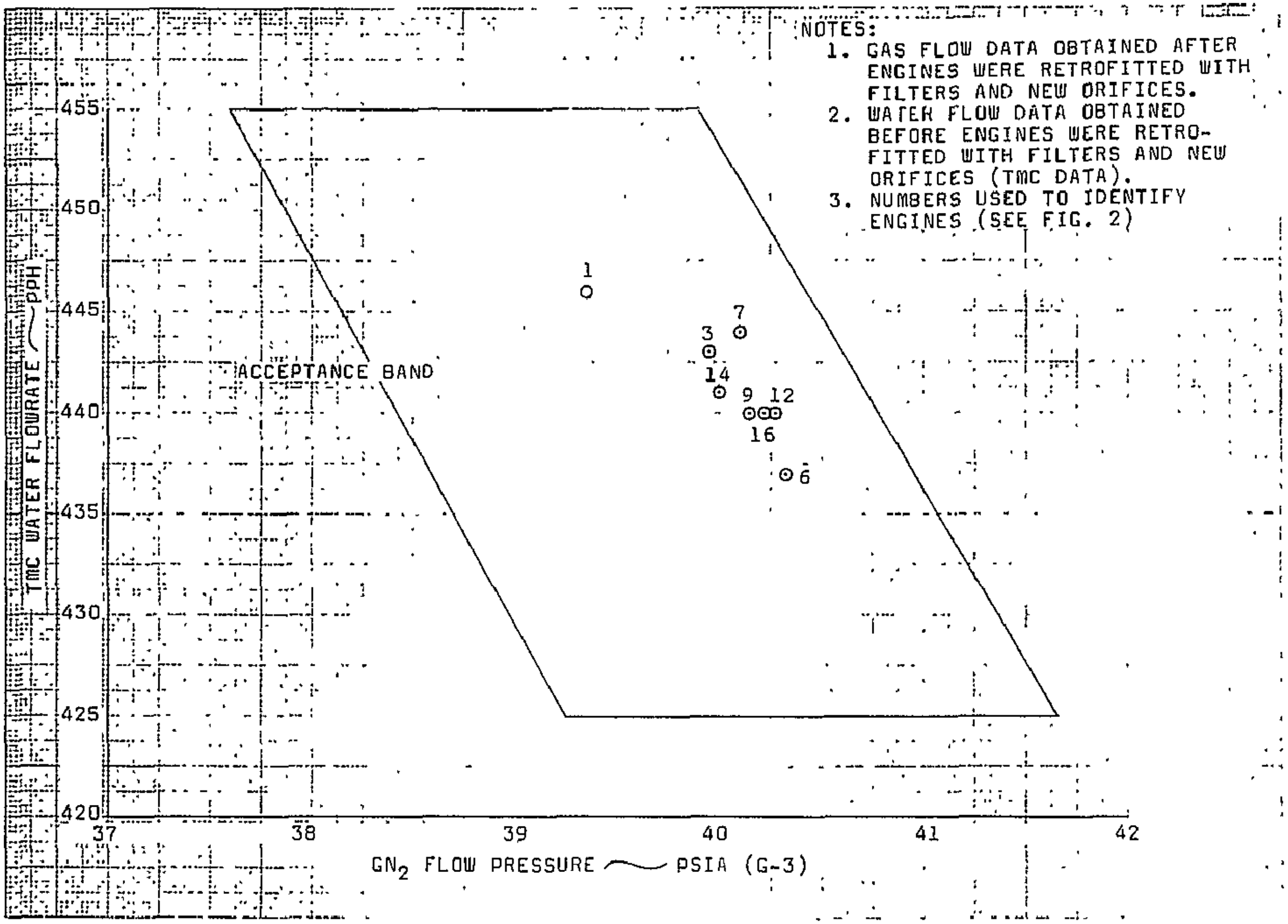


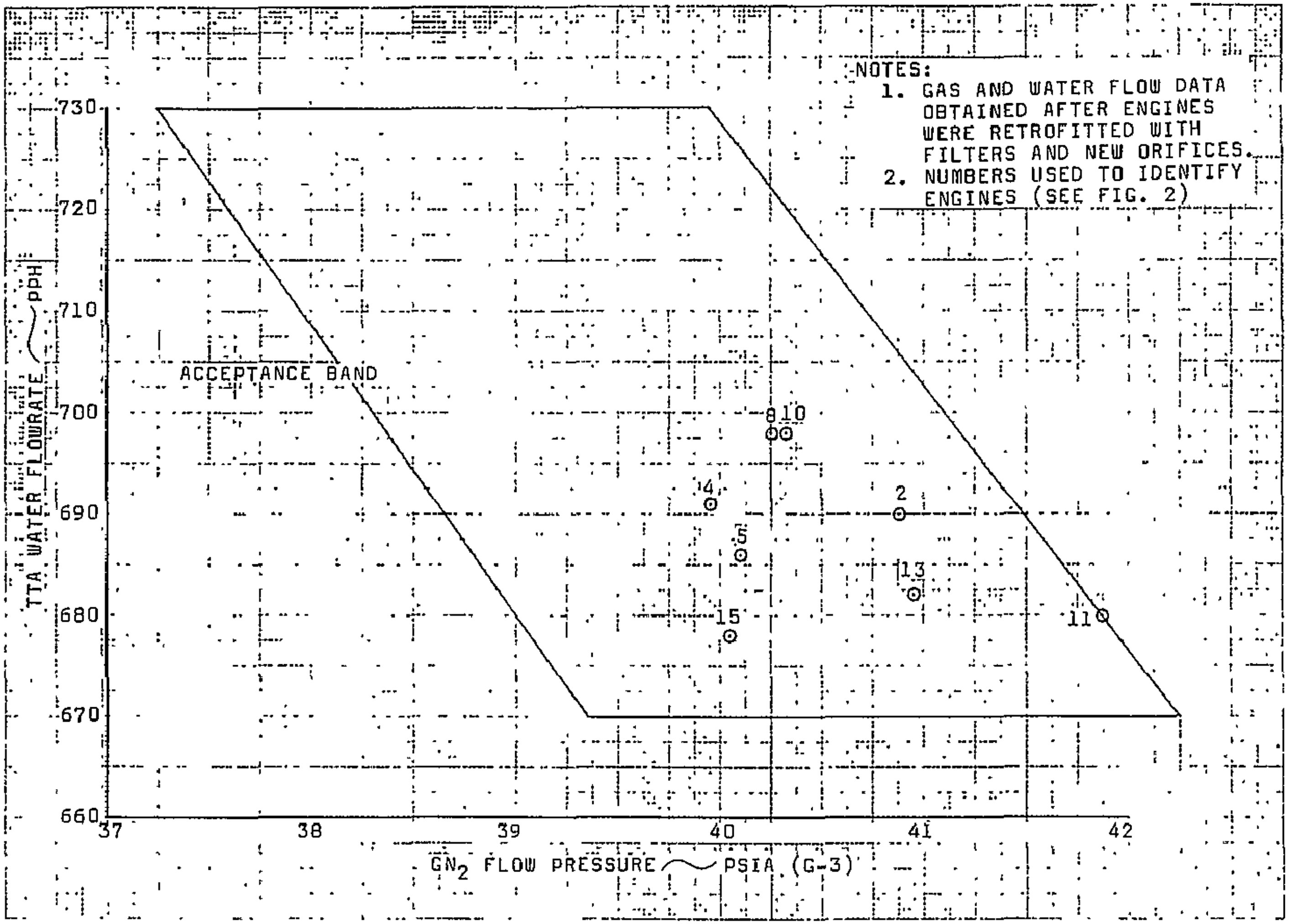
Figure 24.- LM RCS engine flow data, fuel system A.



NOTES:

1. GAS FLOW DATA OBTAINED AFTER ENGINES WERE RETROFITTED WITH FILTERS AND NEW ORIFICES.
2. WATER FLOW DATA OBTAINED BEFORE ENGINES WERE RETROFITTED WITH FILTERS AND NEW ORIFICES (TMC DATA).
3. NUMBERS USED TO IDENTIFY ENGINES (SEE FIG. 2)

Figure 25.- LM RCS engine flow data, fuel system B.



NOTES:
1. GAS AND WATER FLOW DATA OBTAINED AFTER ENGINES WERE RETROFITTED WITH FILTERS AND NEW ORIFICES.
2. NUMBERS USED TO IDENTIFY ENGINES (SEE FIG. 2)

Figure 26.- LM RCS engine flow data, oxidizer system A.

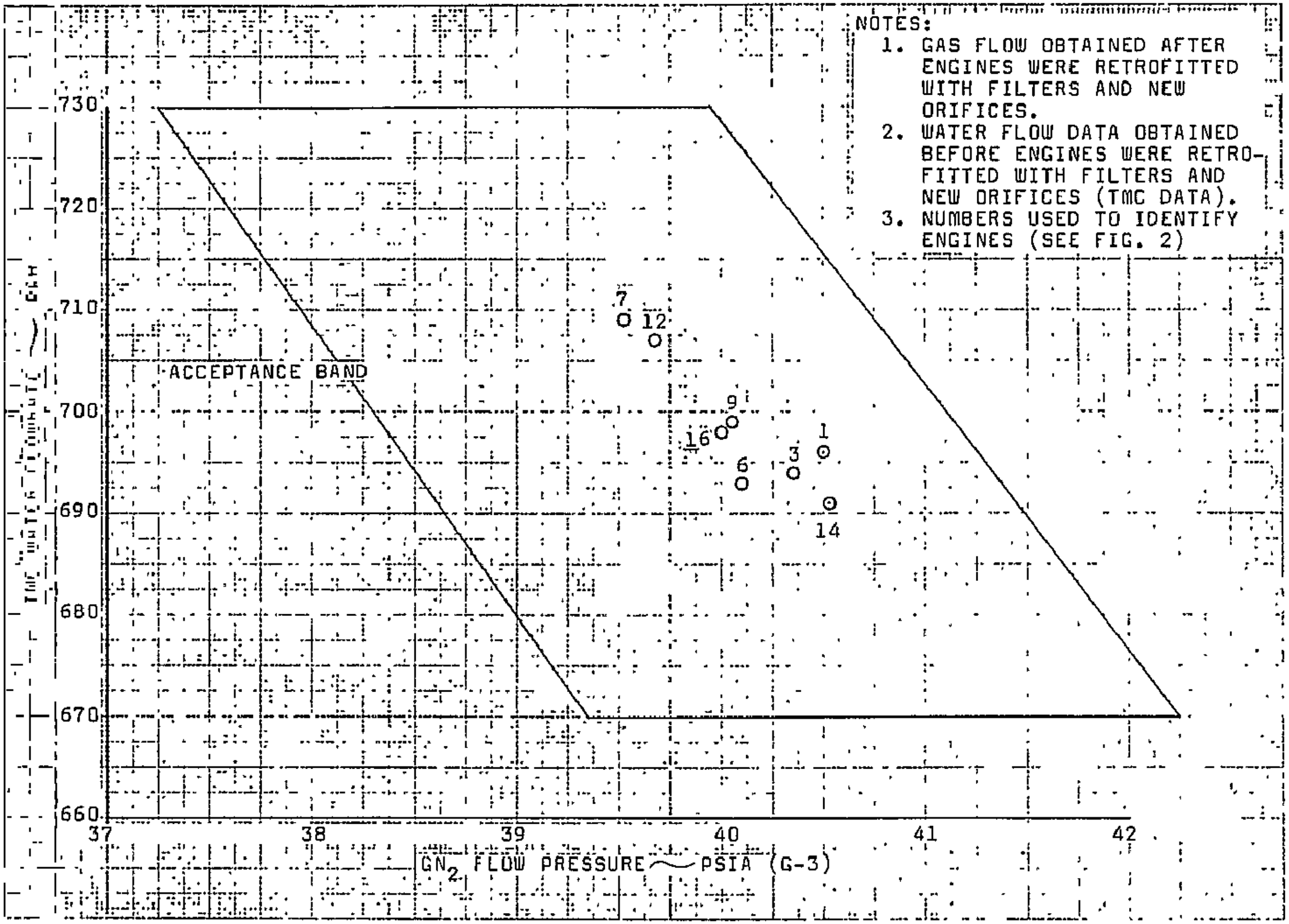
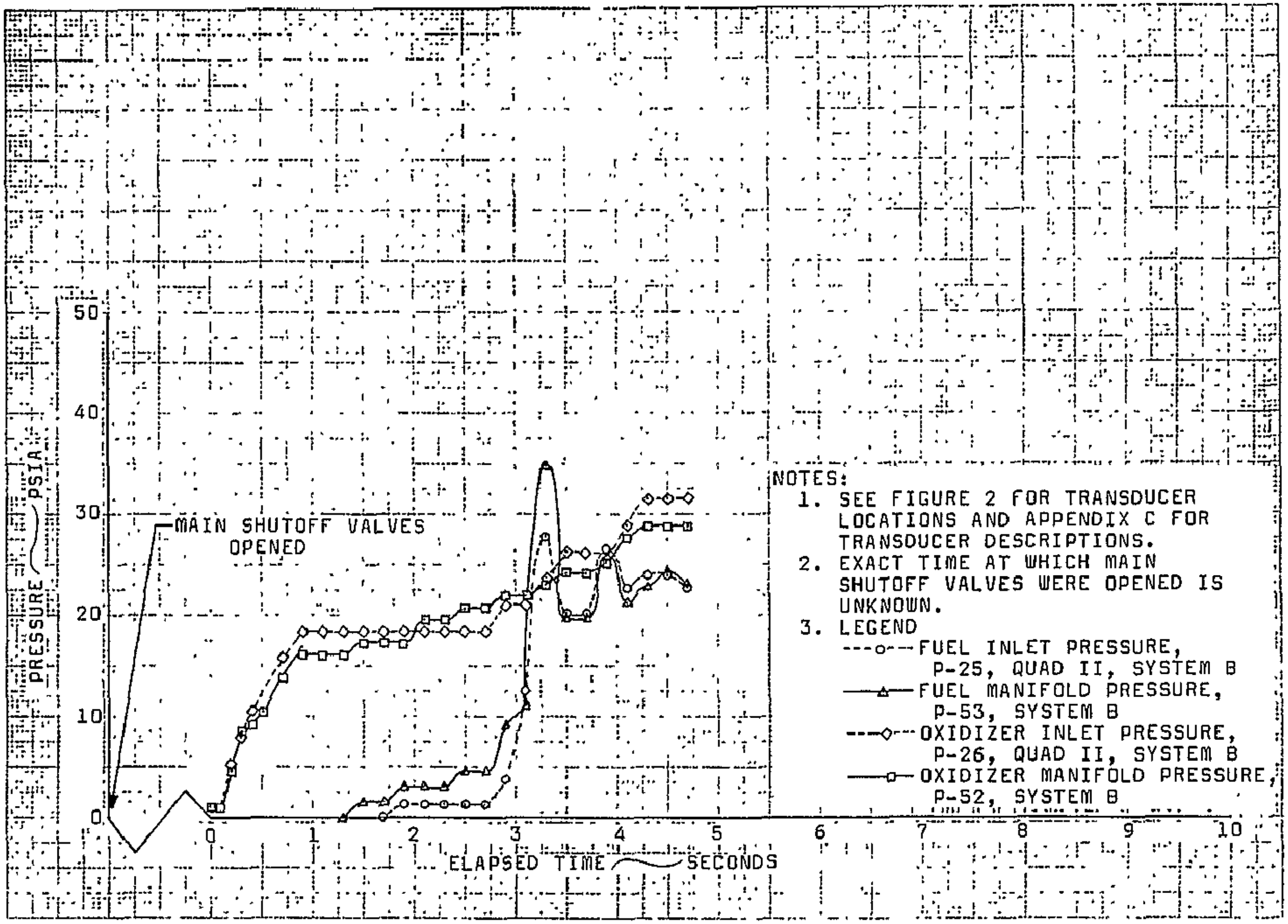


Figure 27.- LM RCS engine flow data, oxidizer system B.



NOTES:

1. SEE FIGURE 2 FOR TRANSDUCER LOCATIONS AND APPENDIX C FOR TRANSDUCER DESCRIPTIONS.
2. EXACT TIME AT WHICH MAIN SHUTOFF VALVES WERE OPENED IS UNKNOWN.
3. LEGEND
   - ---○--- FUEL INLET PRESSURE, P-25, QUAD II, SYSTEM B
   - ——△—— FUEL MANIFOLD PRESSURE, P-53, SYSTEM B
   - ---◇--- OXIDIZER INLET PRESSURE, P-26, QUAD II, SYSTEM B
   - ——□—— OXIDIZER MANIFOLD PRESSURE, P-52, SYSTEM B

Figure 28.- Propellant manifold pressure history for LM1 priming method (system B).

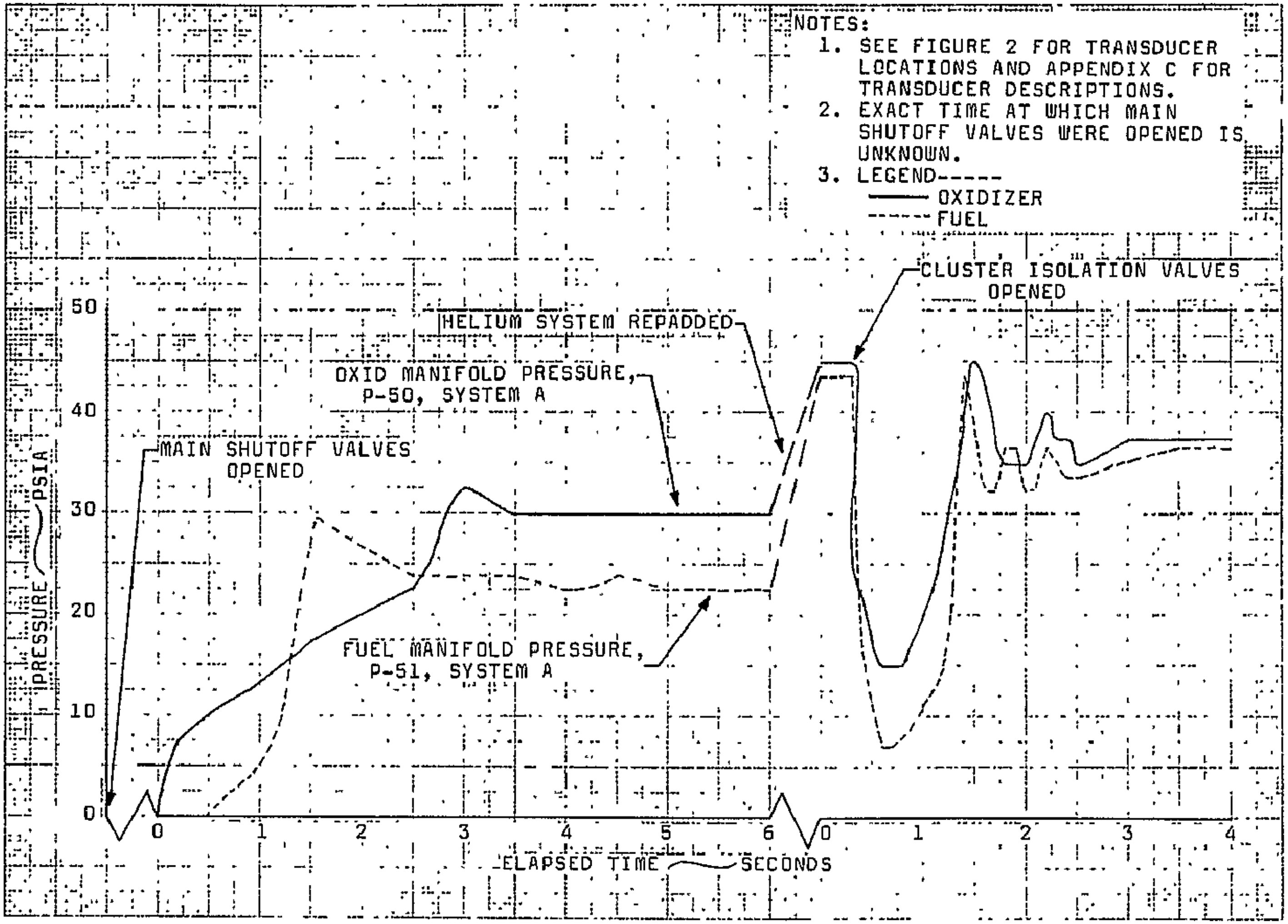


Figure 29.- Propellant manifold pressure history for LM3 priming method (system A).

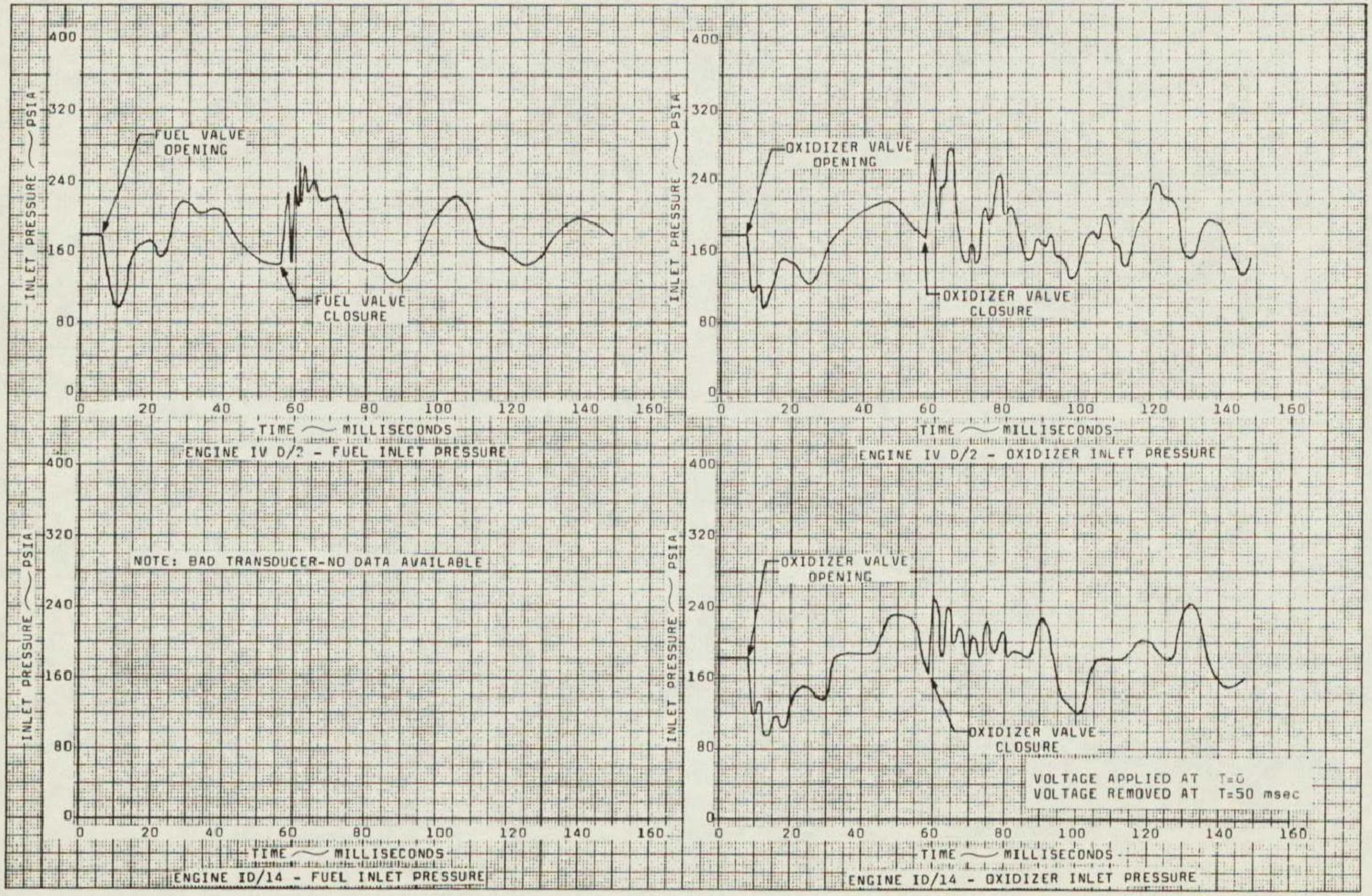


Figure 30.- Baseline propellant inlet pressures for engines IV D/2 and I D/14.

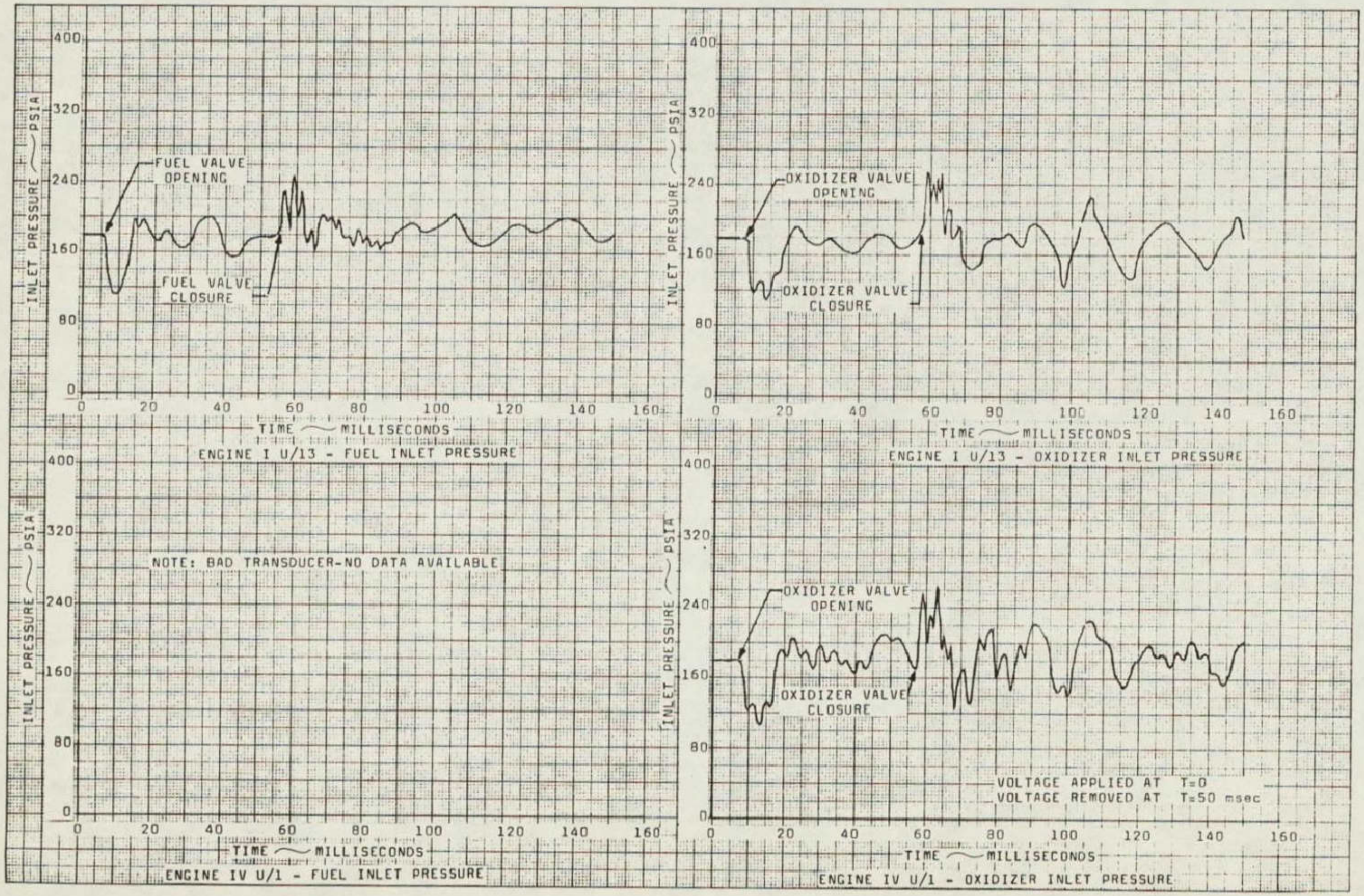


Figure 31.- Baseline propellant inlet pressures for engines I U/13 and IV U/1.

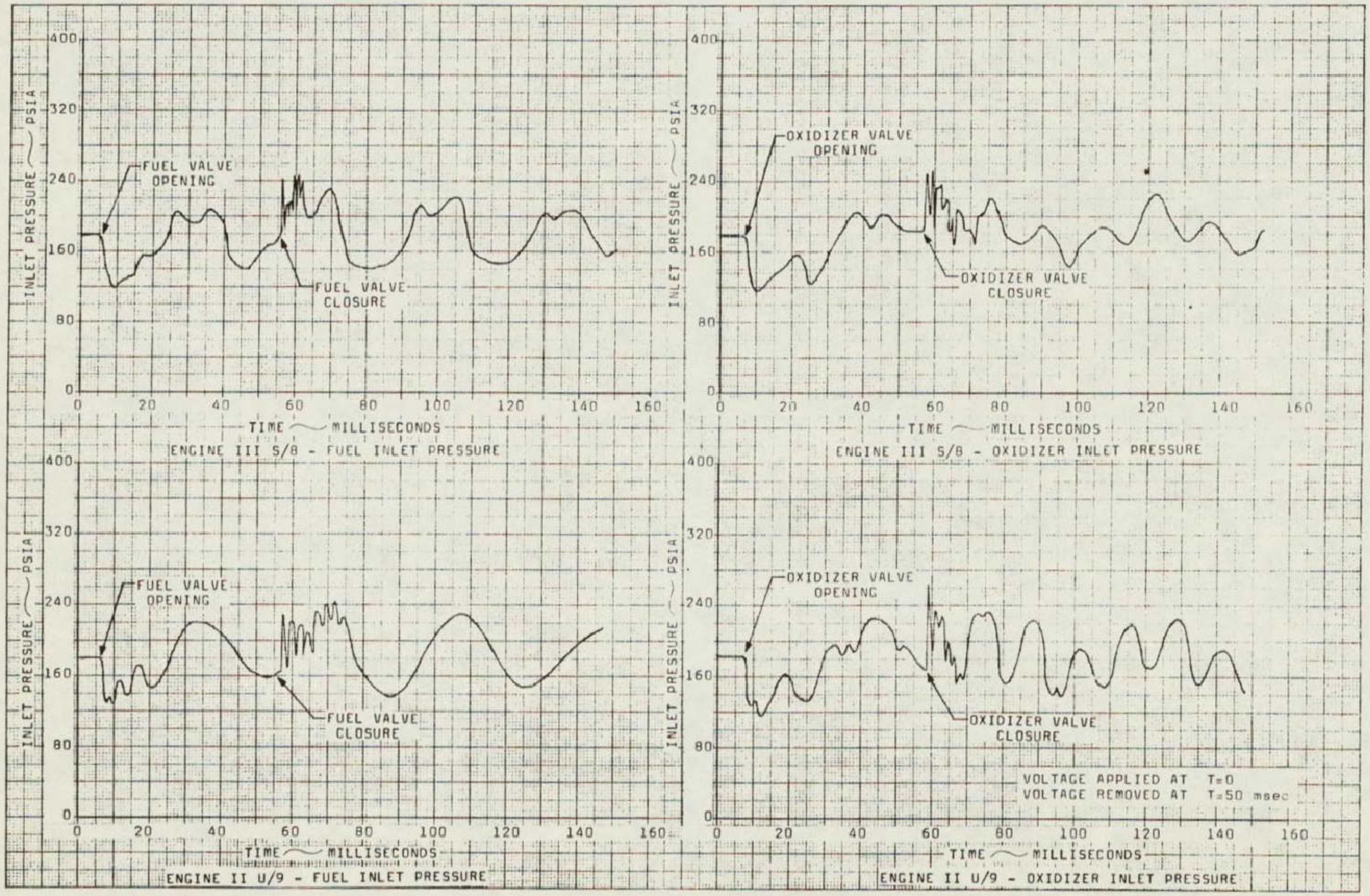


Figure 32.- Baseline propellant inlet pressures for engines III S/8 and II U/9.

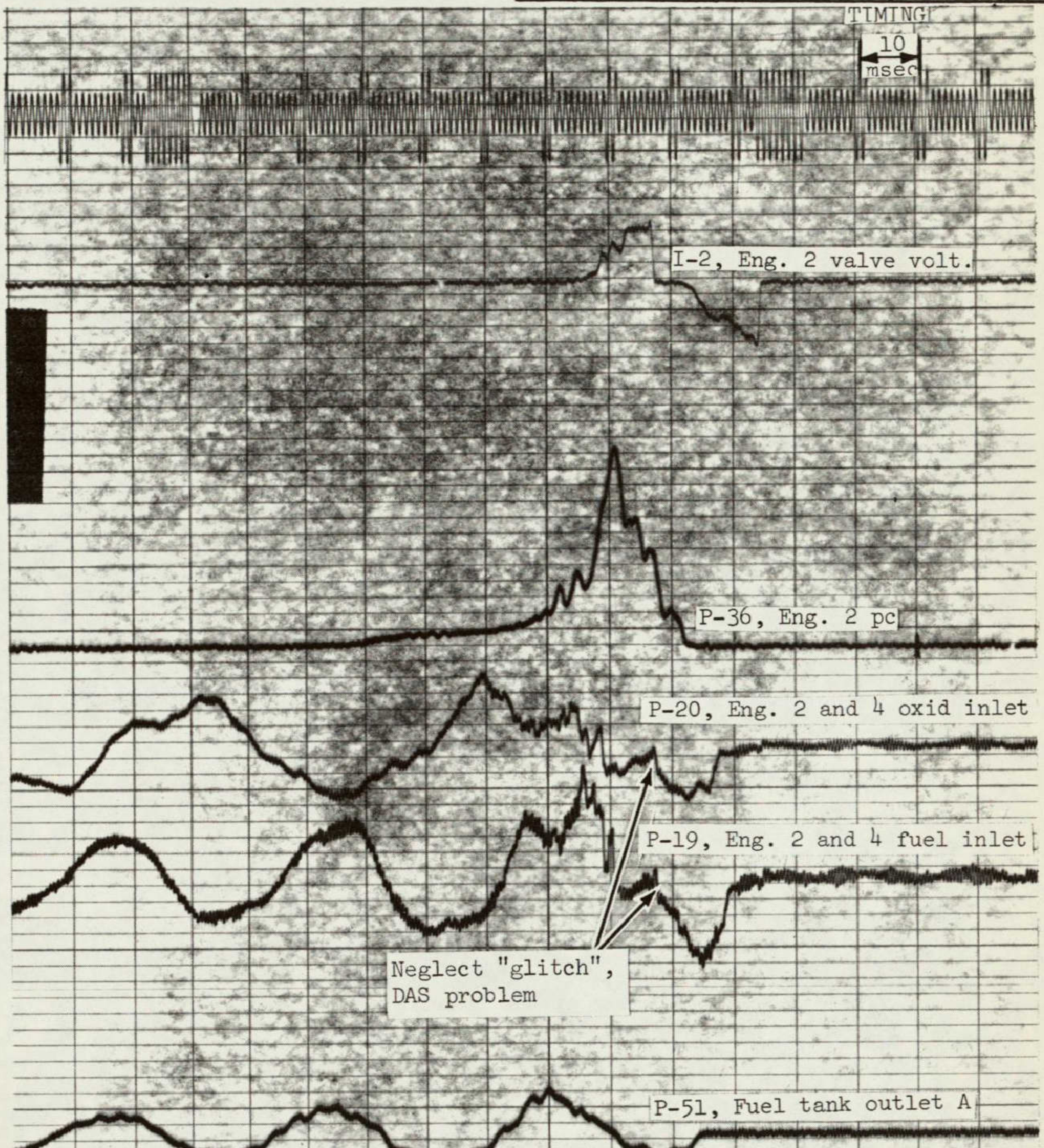


Figure 33.- Run II-A-2-34 (first pulse) - baseline 17 msec pulse on engine IV D/2.

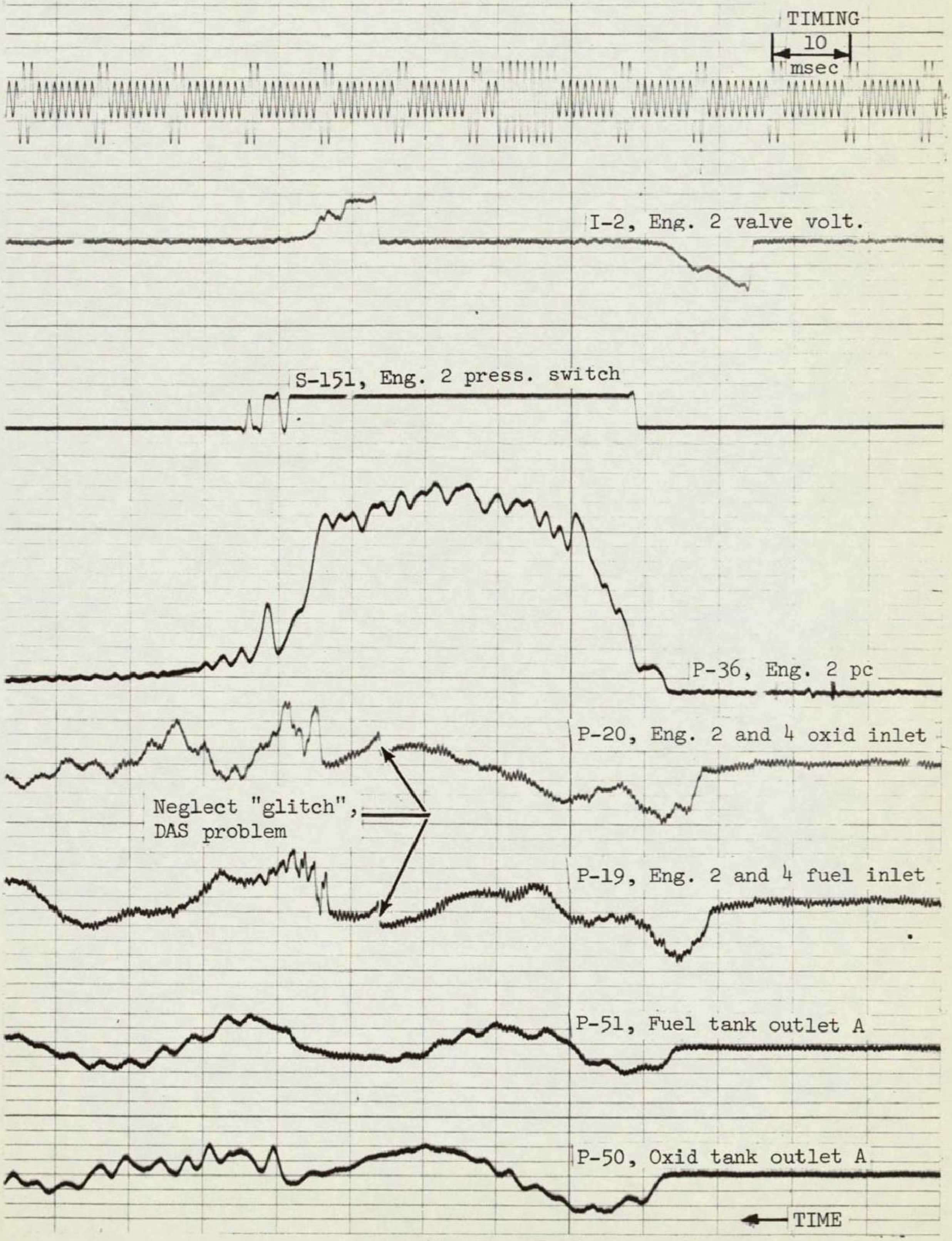


Figure 34.- Run II-A-2-35 (first pulse) - baseline 50 msec pulse on engine IV D/2.

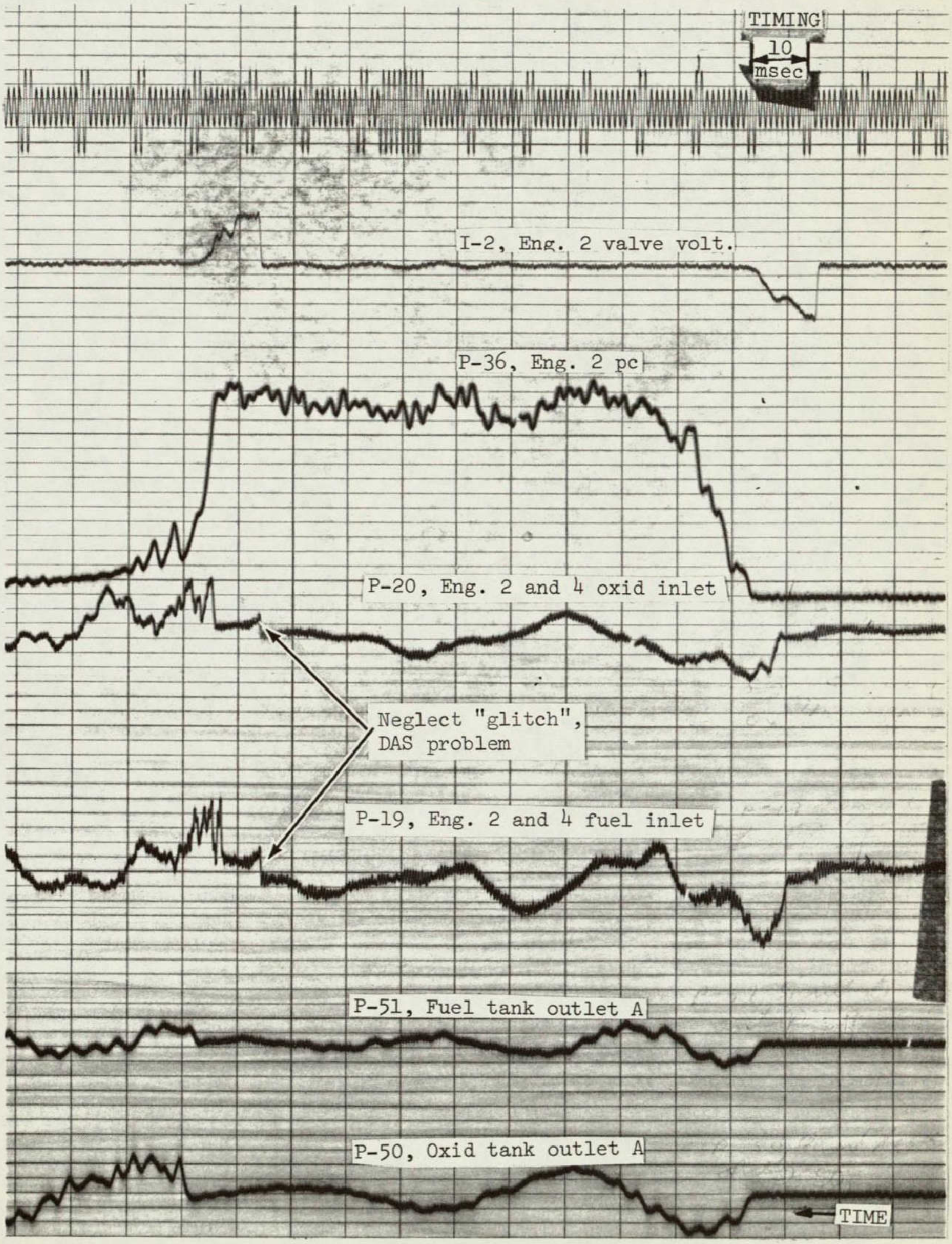
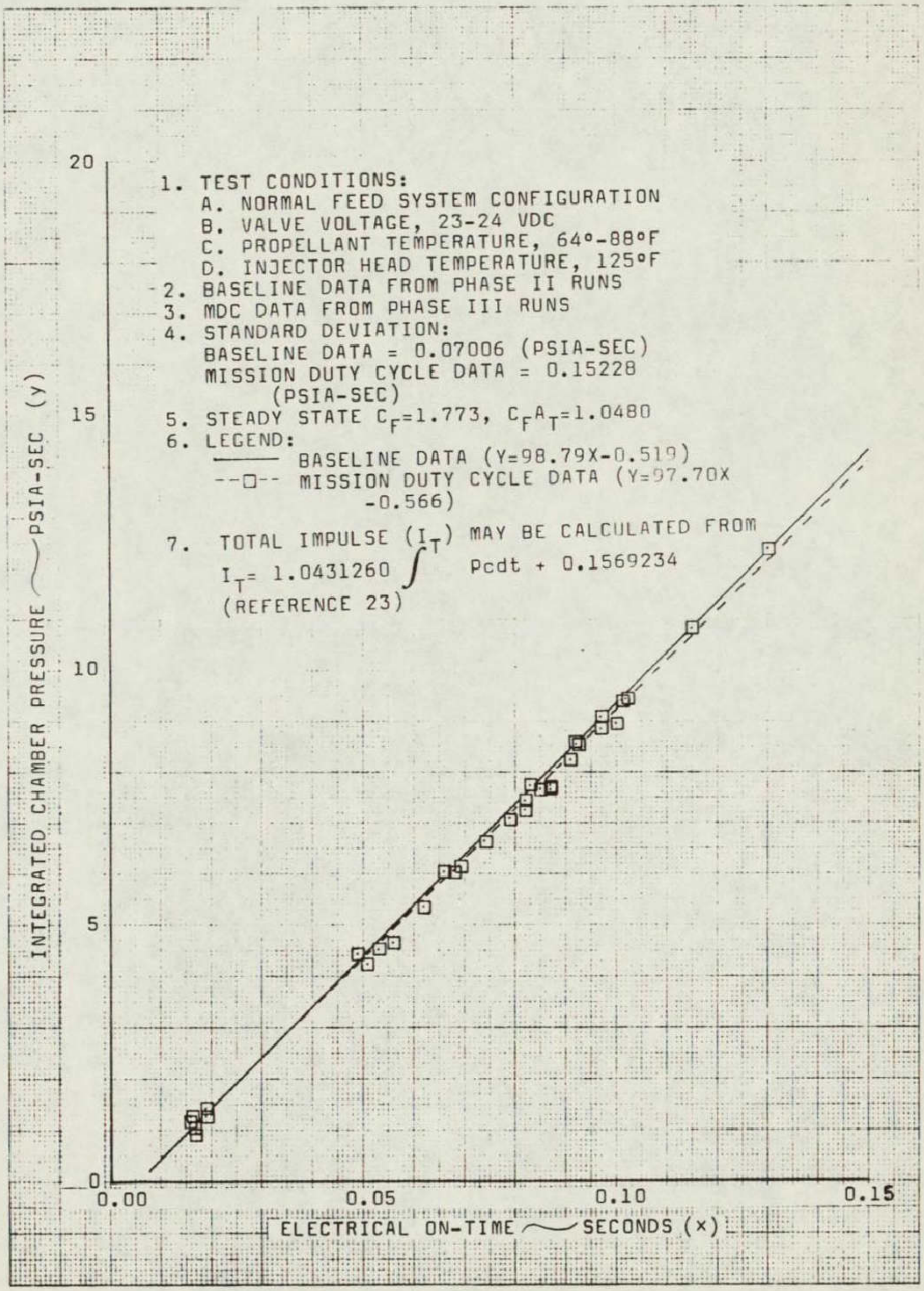


Figure 35.- Run II-A-2-36 (first pulse)-baseline 100 msec pulse on engine IV D/2.



1. TEST CONDITIONS:
   - A. NORMAL FEED SYSTEM CONFIGURATION
   - B. VALVE VOLTAGE, 23-24 VDC
   - C. PROPELLANT TEMPERATURE, 64°-88°F
   - D. INJECTOR HEAD TEMPERATURE, 125°F
2. BASELINE DATA FROM PHASE II RUNS
3. MDC DATA FROM PHASE III RUNS
4. STANDARD DEVIATION:
   BASELINE DATA = 0.07006 (PSIA-SEC)
   MISSION DUTY CYCLE DATA = 0.15228 (PSIA-SEC)
5. STEADY STATE $C_F=1.773$, $C_FA_T=1.0480$
6. LEGEND:
   ——— BASELINE DATA (Y=98.79X-0.519)
   --□-- MISSION DUTY CYCLE DATA (Y=97.70X -0.566)
7. TOTAL IMPULSE (I_T) MAY BE CALCULATED FROM
   $I_T = 1.0431260 \int_{}^{T} Pcdt + 0.1569234$
   (REFERENCE 23)

Figure 36.- Baseline and mission duty cycle performance for engine IV D/2.

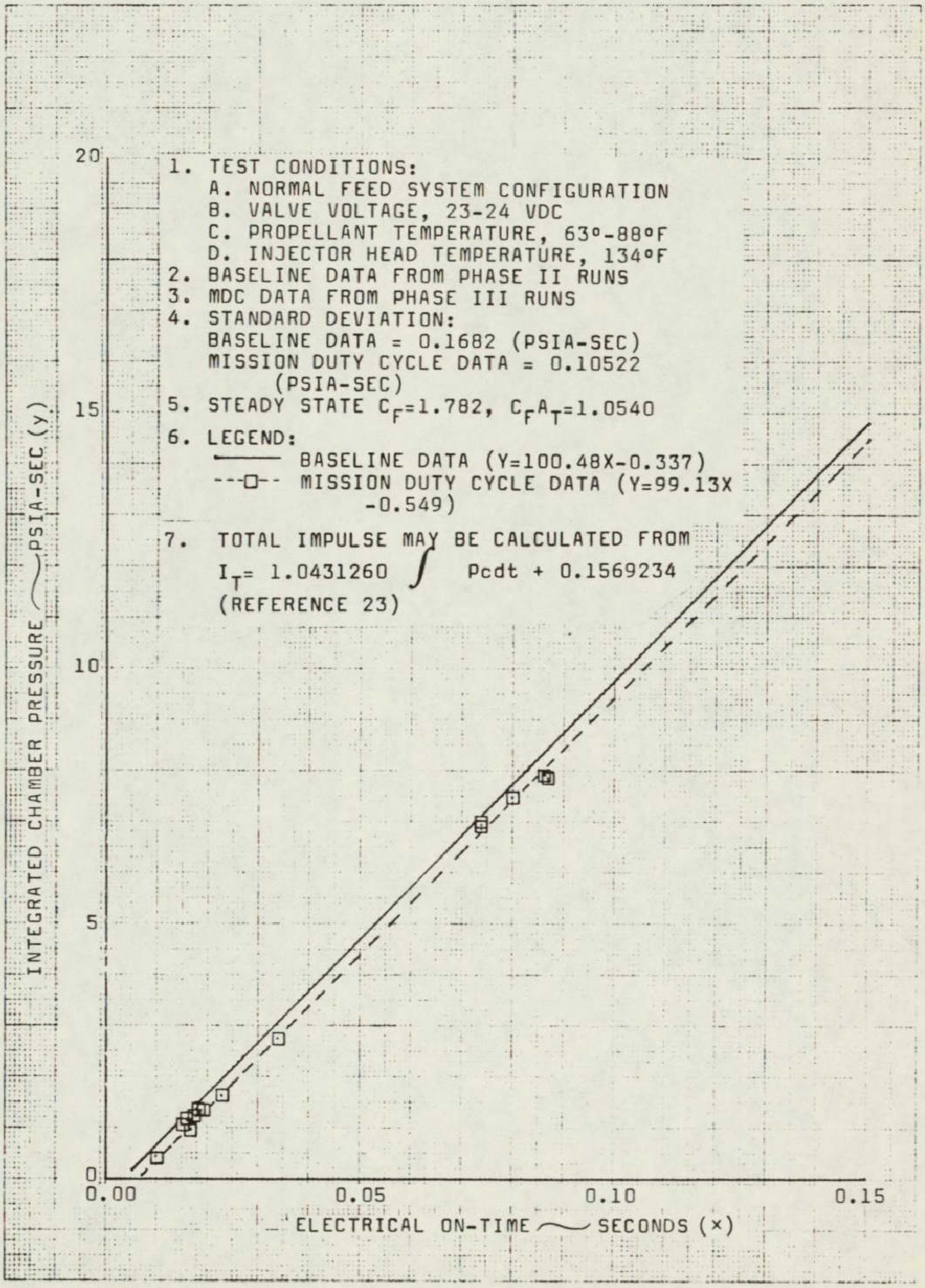


Figure 37.- Baseline and mission duty cycle performance for engine IV S/4.

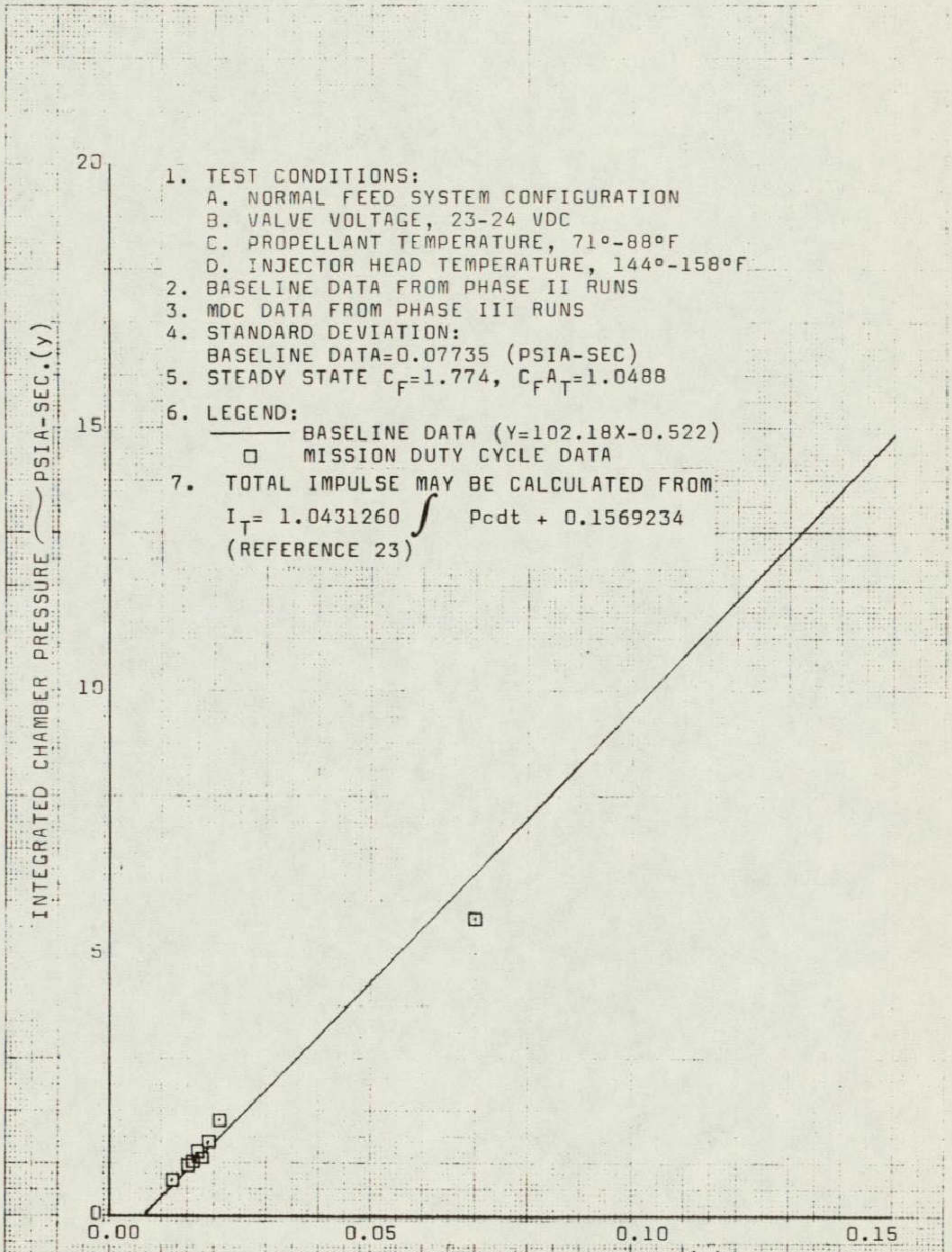
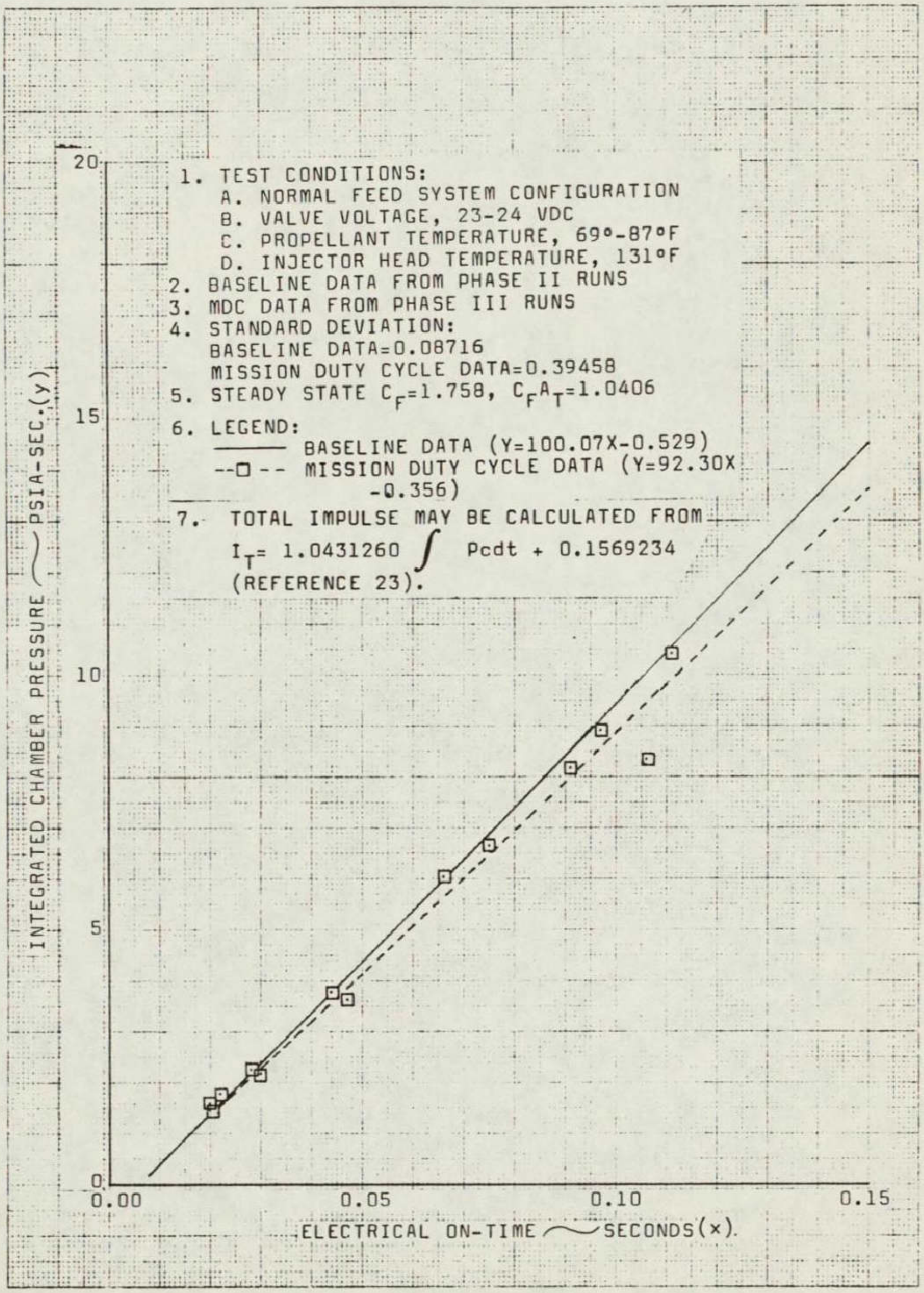


Figure 38.- Baseline and mission duty cycle performance for engine II F/11.



1. TEST CONDITIONS:
   - A. NORMAL FEED SYSTEM CONFIGURATION
   - B. VALVE VOLTAGE, 23-24 VDC
   - C. PROPELLANT TEMPERATURE, 69°-87°F
   - D. INJECTOR HEAD TEMPERATURE, 131°F
2. BASELINE DATA FROM PHASE II RUNS
3. MDC DATA FROM PHASE III RUNS
4. STANDARD DEVIATION:
   BASELINE DATA=0.08716
   MISSION DUTY CYCLE DATA=0.39458
5. STEADY STATE $C_F=1.758$, $C_F A_T=1.0406$
6. LEGEND:
   ——— BASELINE DATA (Y=100.07X-0.529)
   --□-- MISSION DUTY CYCLE DATA (Y=92.30X -0.356)
7. TOTAL IMPULSE MAY BE CALCULATED FROM
   $I_T= 1.0431260 \int Pcdt + 0.1569234$
   (REFERENCE 23).

Figure 39.- Baseline and mission duty cycle performance for engine I U/13.

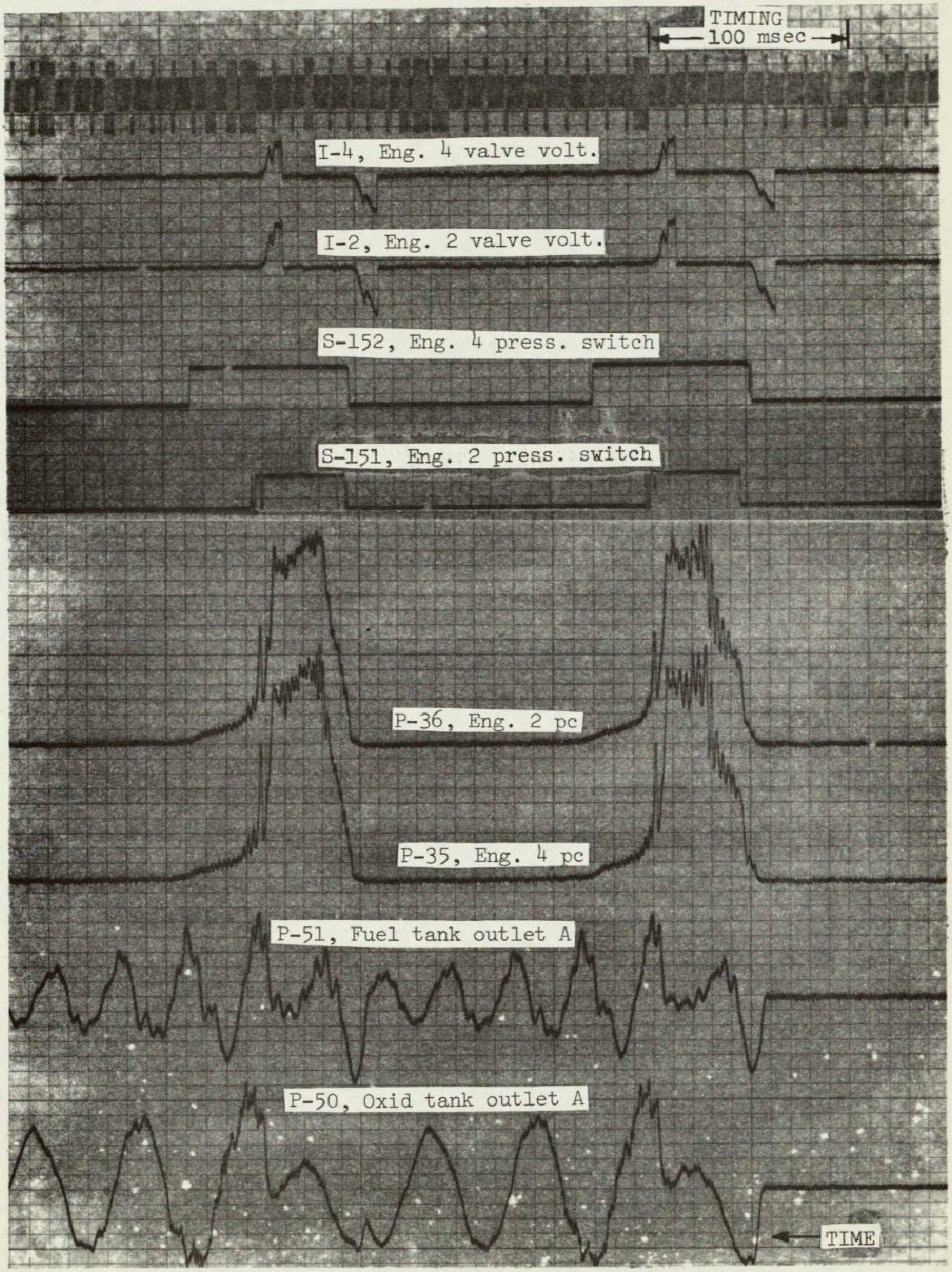
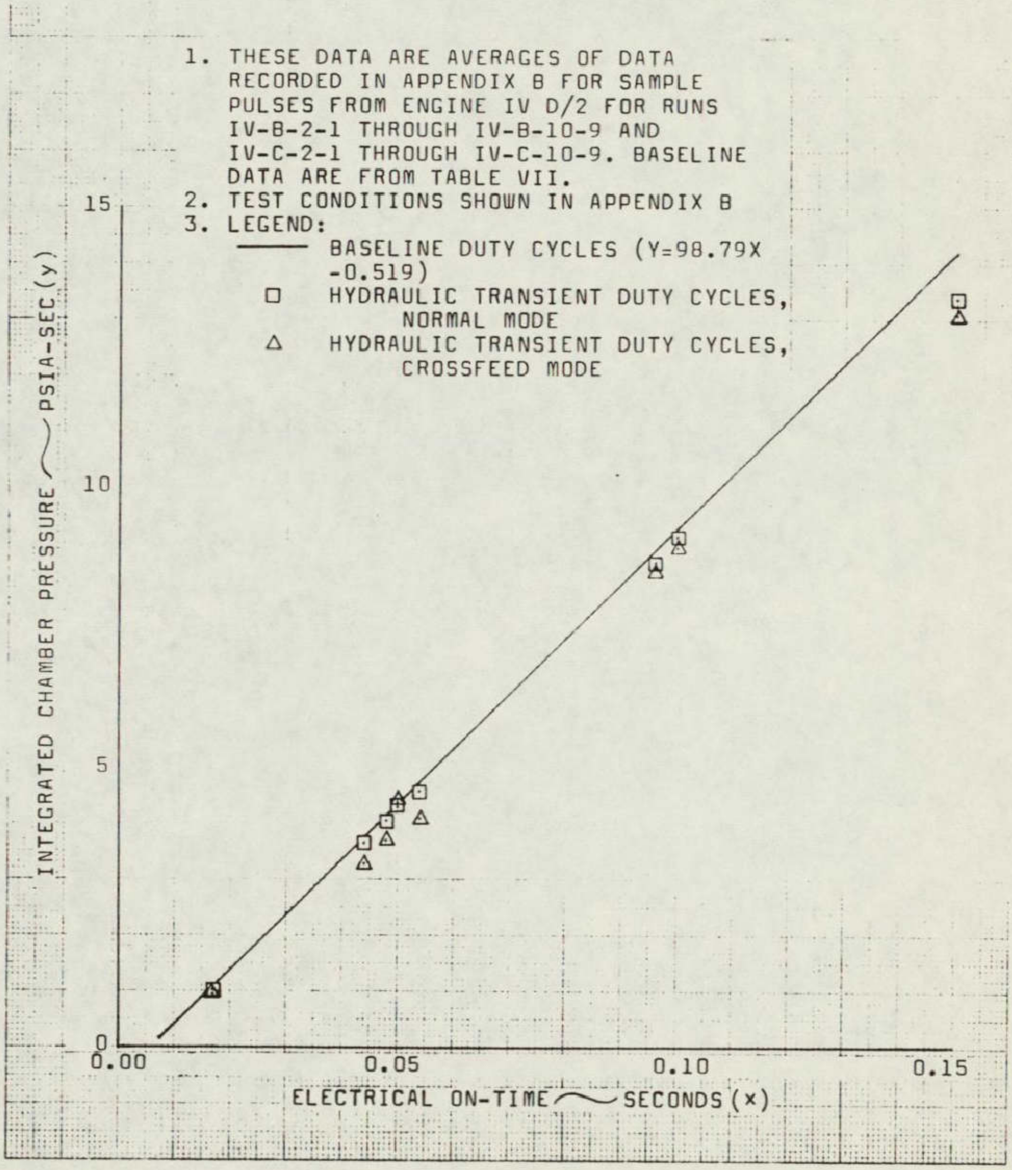


Figure 40.- Run IV-B-2-2 (first two pulses) — four engines pulsing simultaneously.



1. THESE DATA ARE AVERAGES OF DATA RECORDED IN APPENDIX B FOR SAMPLE PULSES FROM ENGINE IV D/2 FOR RUNS IV-B-2-1 THROUGH IV-B-10-9 AND IV-C-2-1 THROUGH IV-C-10-9. BASELINE DATA ARE FROM TABLE VII.
2. TEST CONDITIONS SHOWN IN APPENDIX B
3. LEGEND:
   - —— BASELINE DUTY CYCLES ($Y=98.79X-0.519$)
   - □ HYDRAULIC TRANSIENT DUTY CYCLES, NORMAL MODE
   - △ HYDRAULIC TRANSIENT DUTY CYCLES, CROSSFEED MODE

Figure 41.- Comparsion of engine IV D/2 performance for baseline, hydraulic transient effects in normal mode, and hydraulic transient effects in crossfeed mode duty cycles.

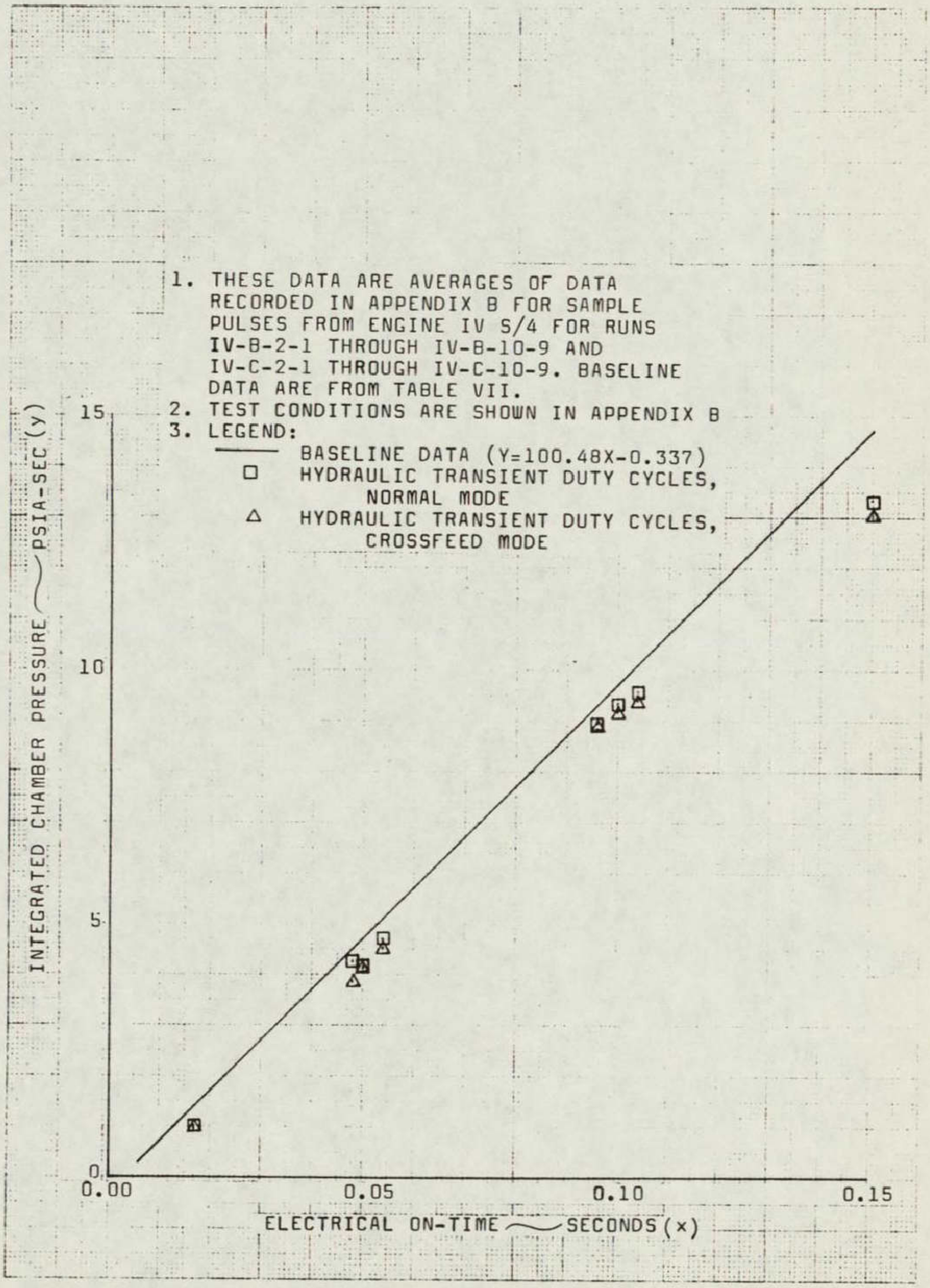
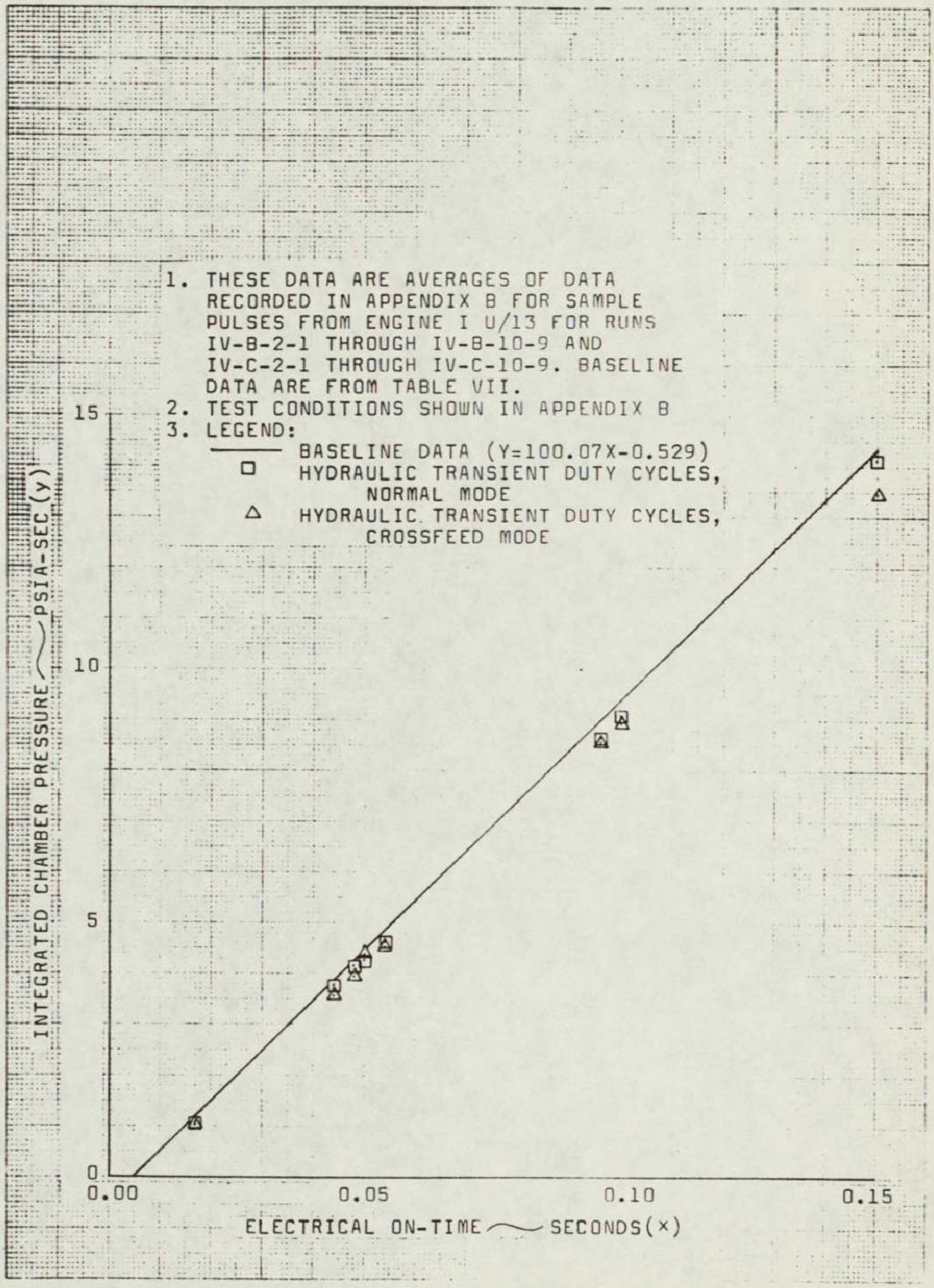


Figure 42.- Comparsion of engine IV S/4 performance for baseline, hydraulic transient effects in normal mode, and hydraulic transient effects in crossfeed mode duty cycles.



1. THESE DATA ARE AVERAGES OF DATA RECORDED IN APPENDIX B FOR SAMPLE PULSES FROM ENGINE I U/13 FOR RUNS IV-B-2-1 THROUGH IV-B-10-9 AND IV-C-2-1 THROUGH IV-C-10-9. BASELINE DATA ARE FROM TABLE VII.
2. TEST CONDITIONS SHOWN IN APPENDIX B
3. LEGEND:

Figure 43.- Comparsion of engine I U/13 performance for baseline, hydraulic transient effects in normal mode, and hydraulic transient effects in crossfeed mode duty cycles.

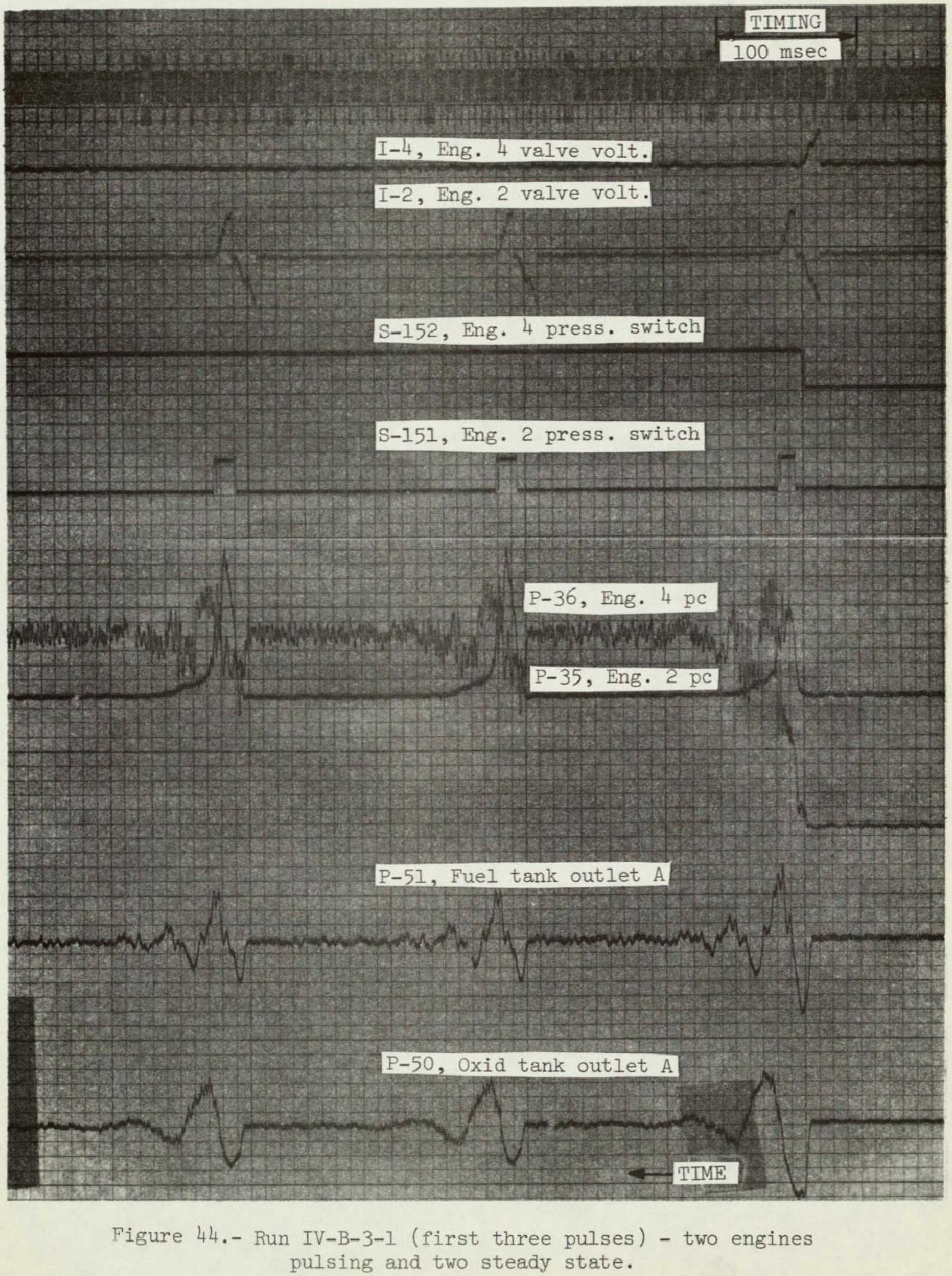


Figure 44.- Run IV-B-3-1 (first three pulses) - two engines pulsing and two steady state.

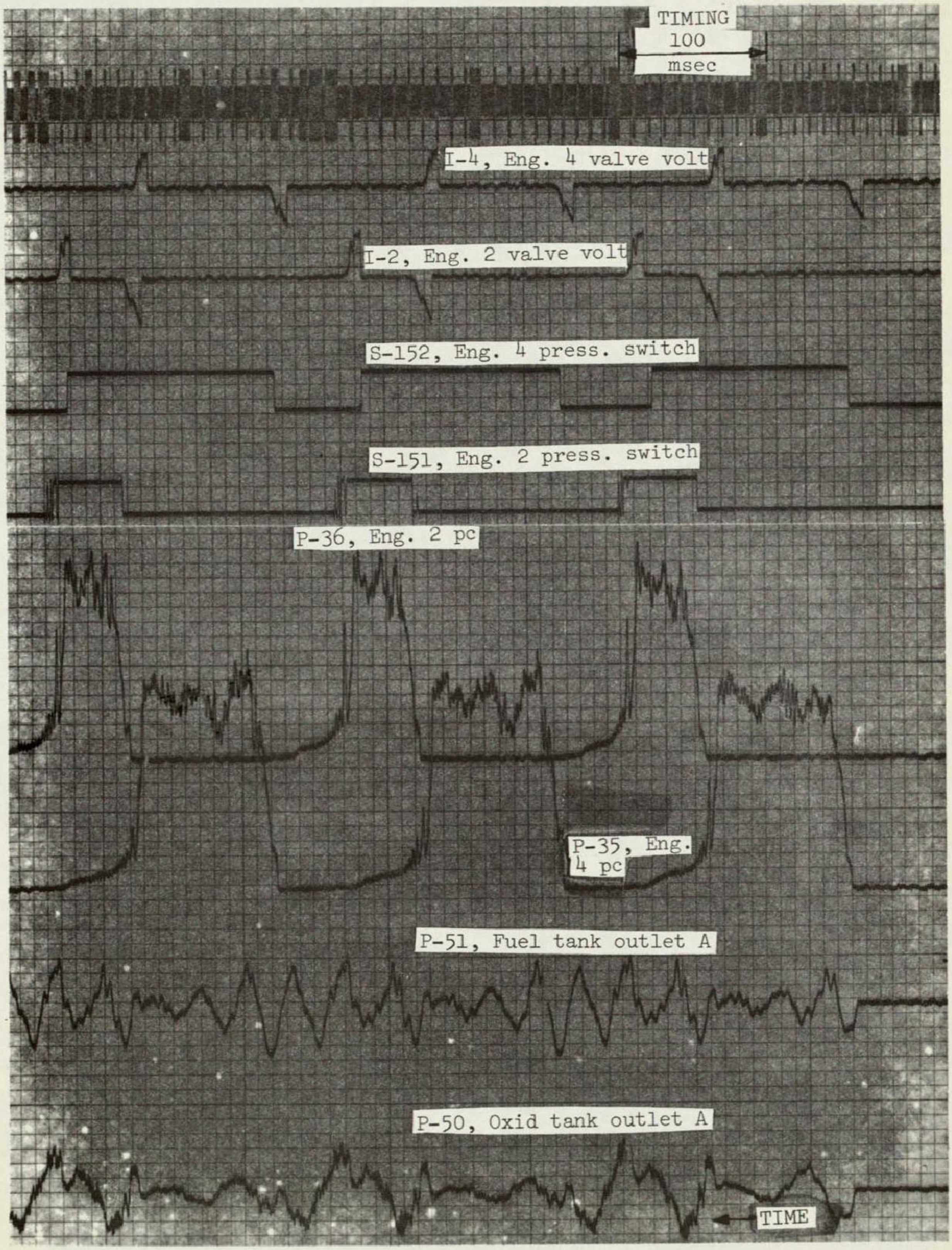


Figure 45.- Run IV-B-4-9 (first three pulses) - four engine operation, pulsing out of phase.

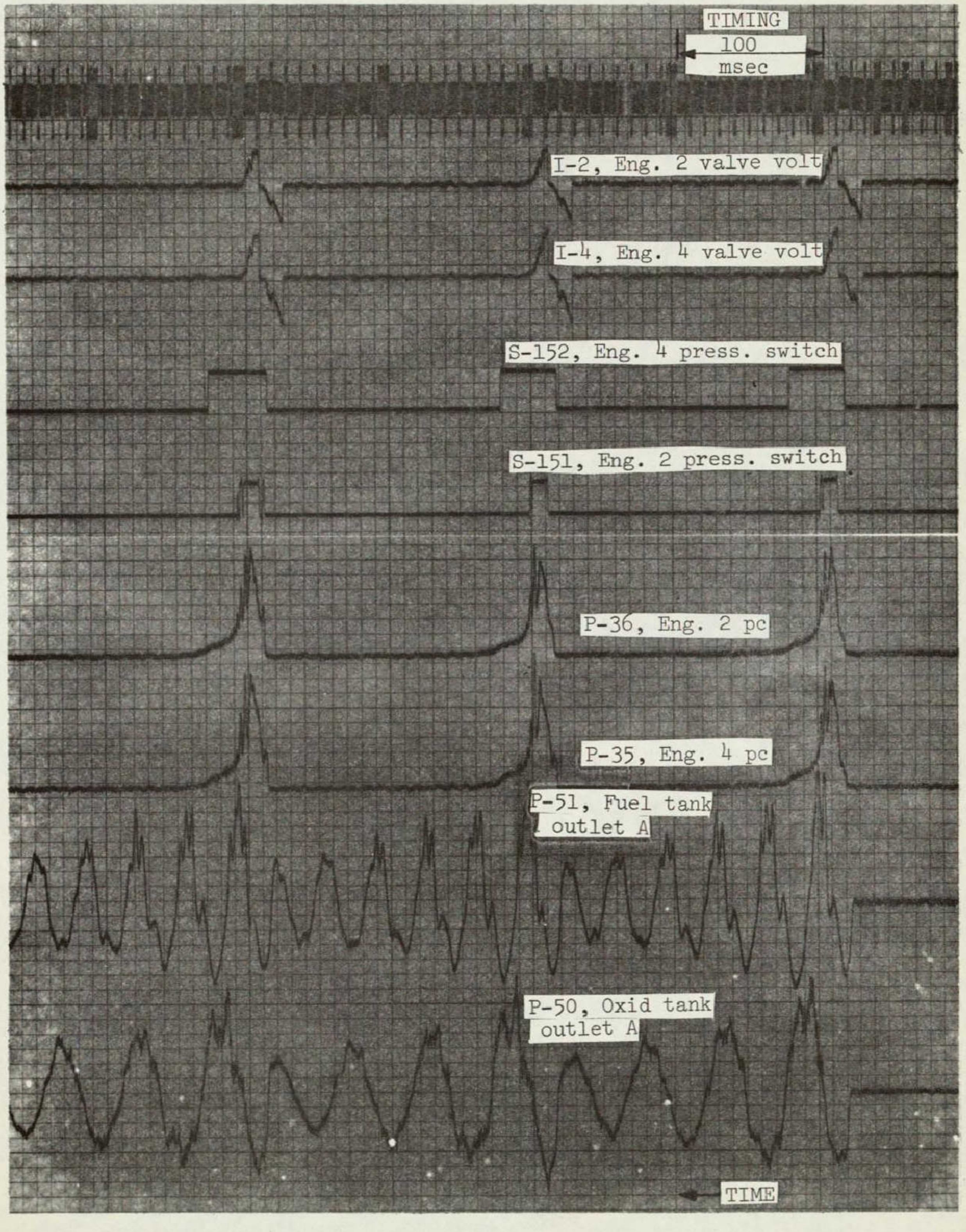


Figure 46.- Run IV-B-8-1 (first three pulses) - eight engines pulsing simultaneously.

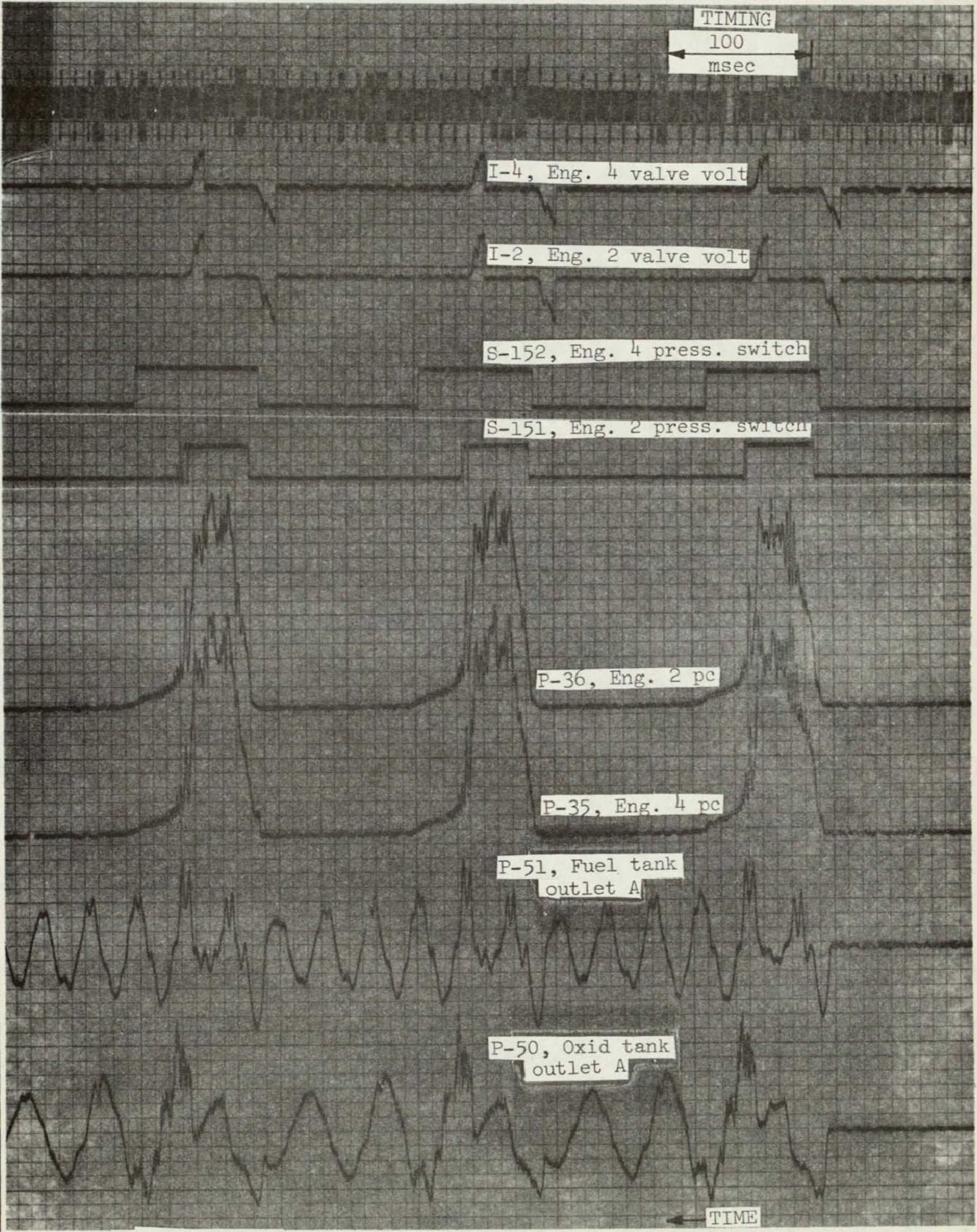


Figure 47.- Run IV-B-8-2 (first three pulses) - eight engines pulsing simultaneously.

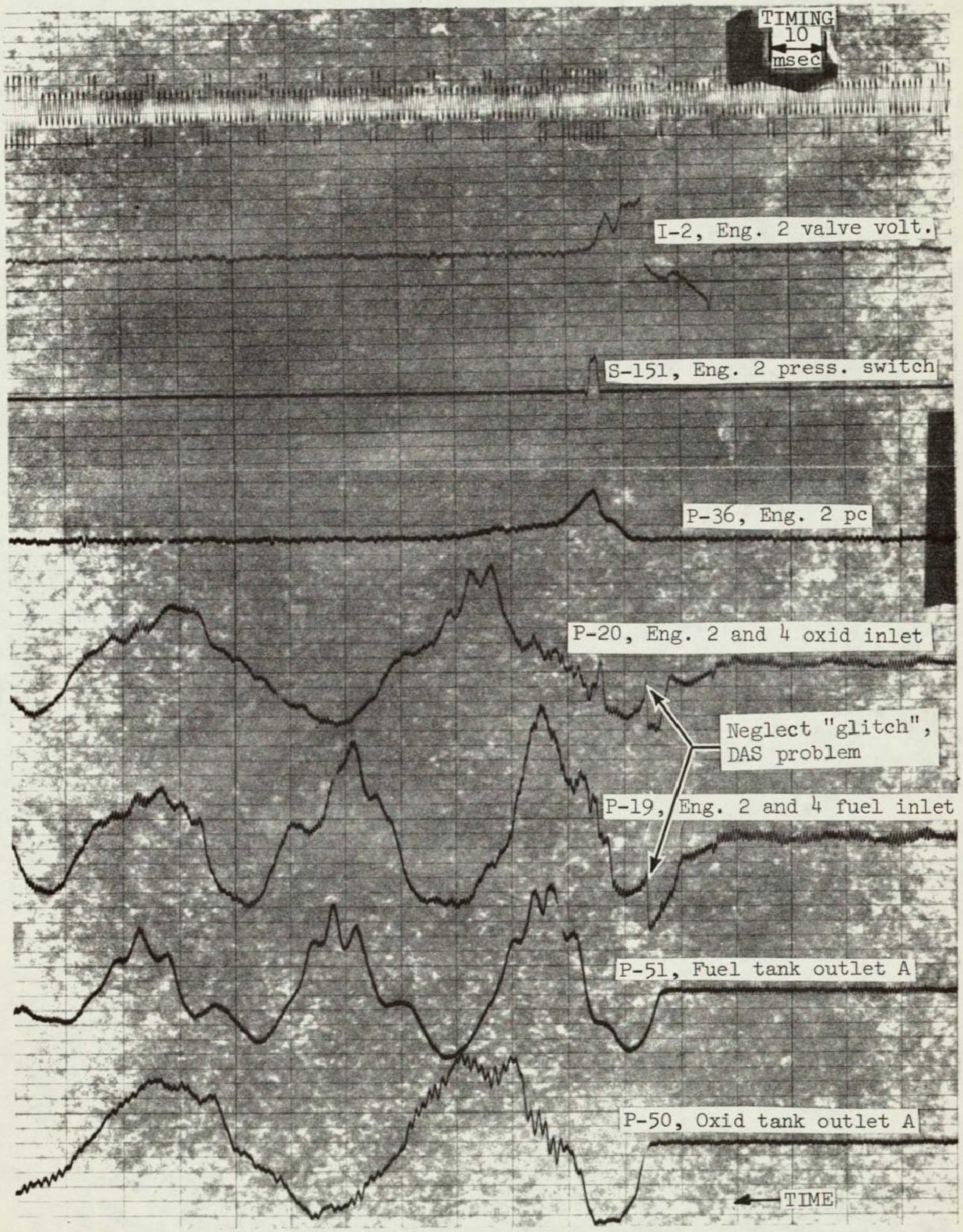


Figure 48.- Run IV-D-3-1 (first pulse) — engine IV D/2 pressure switch performance at minimum pulse width (12 msec).

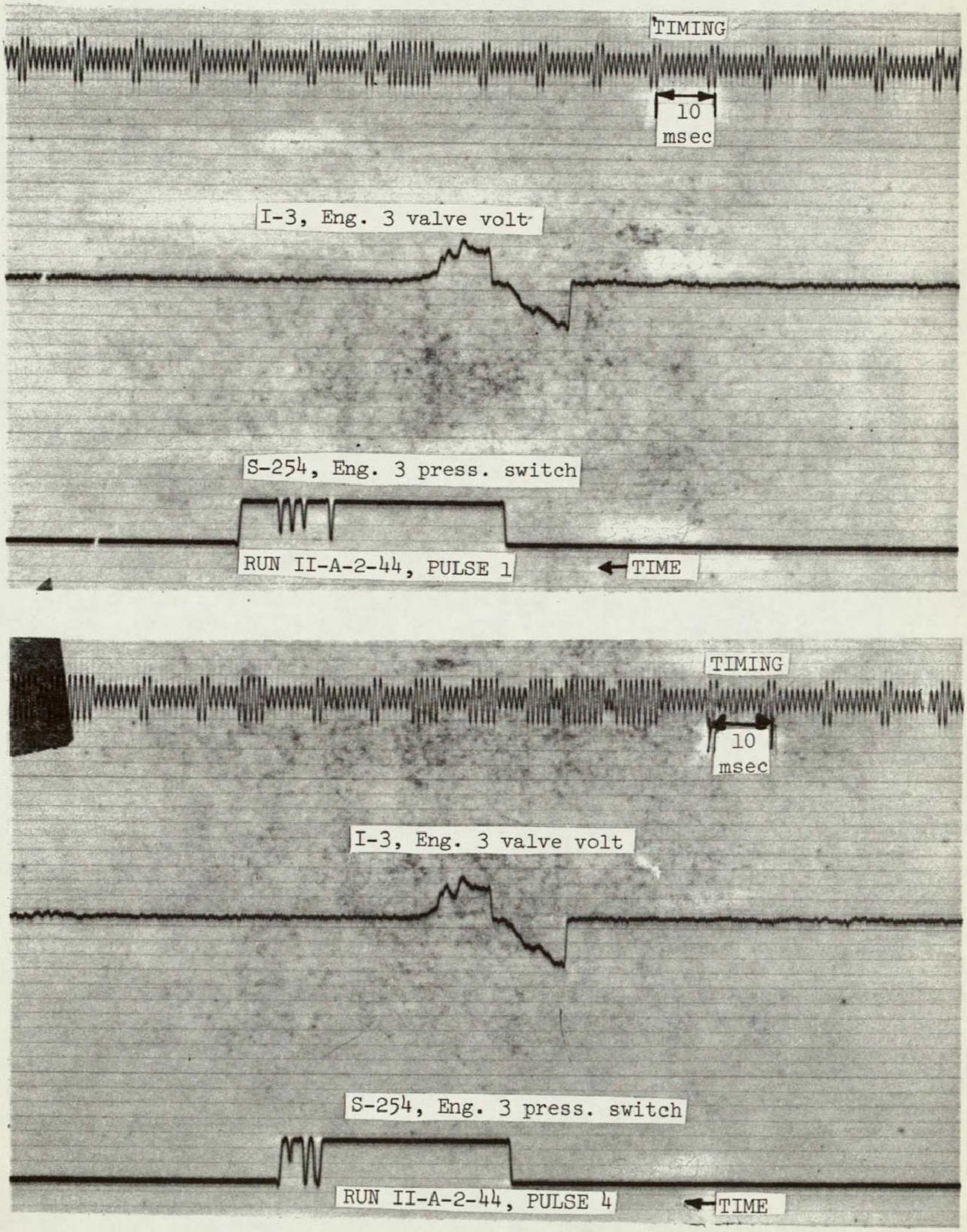


Figure 49.- Examples of pressure switch oscillations.

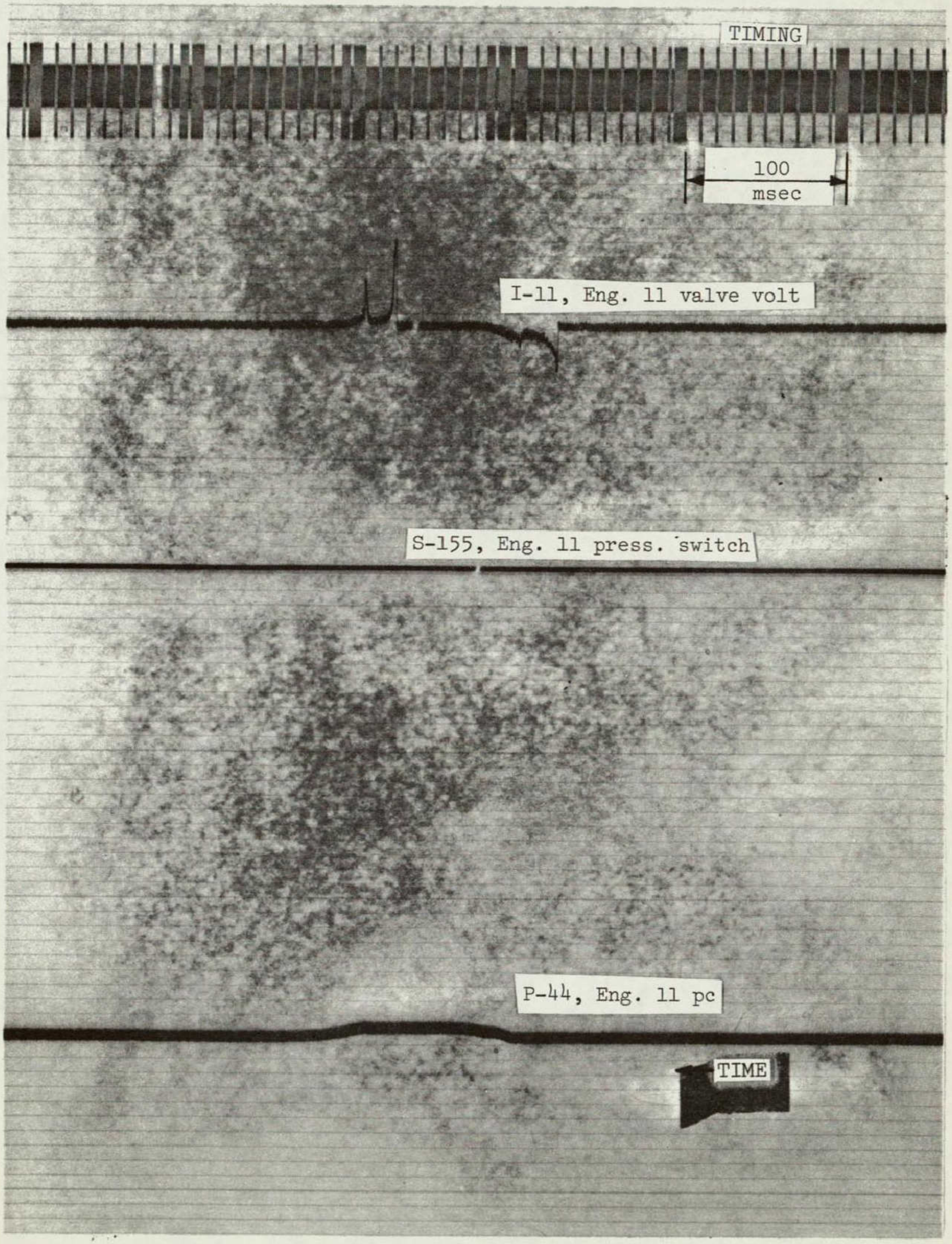


Figure 50.- Oxidizer cold flow - Run IV-D-5-6 (engine II F/11).

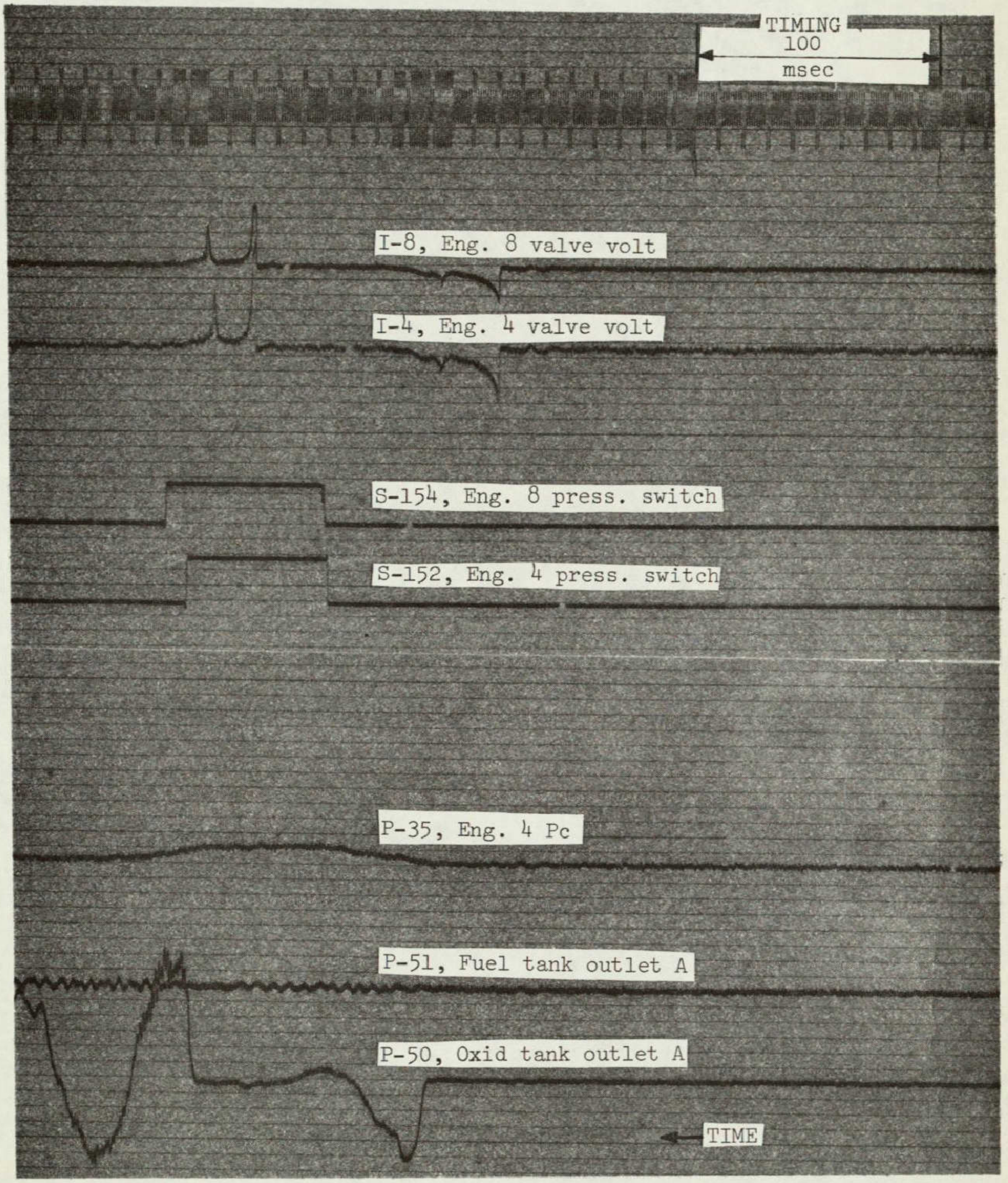


Figure 51.- Oxidizer cold flow — Run IV-D-5-6 (engines IV S/4 and III S/8). (NOTE: Engine 8 Pc transducer was inoperative).

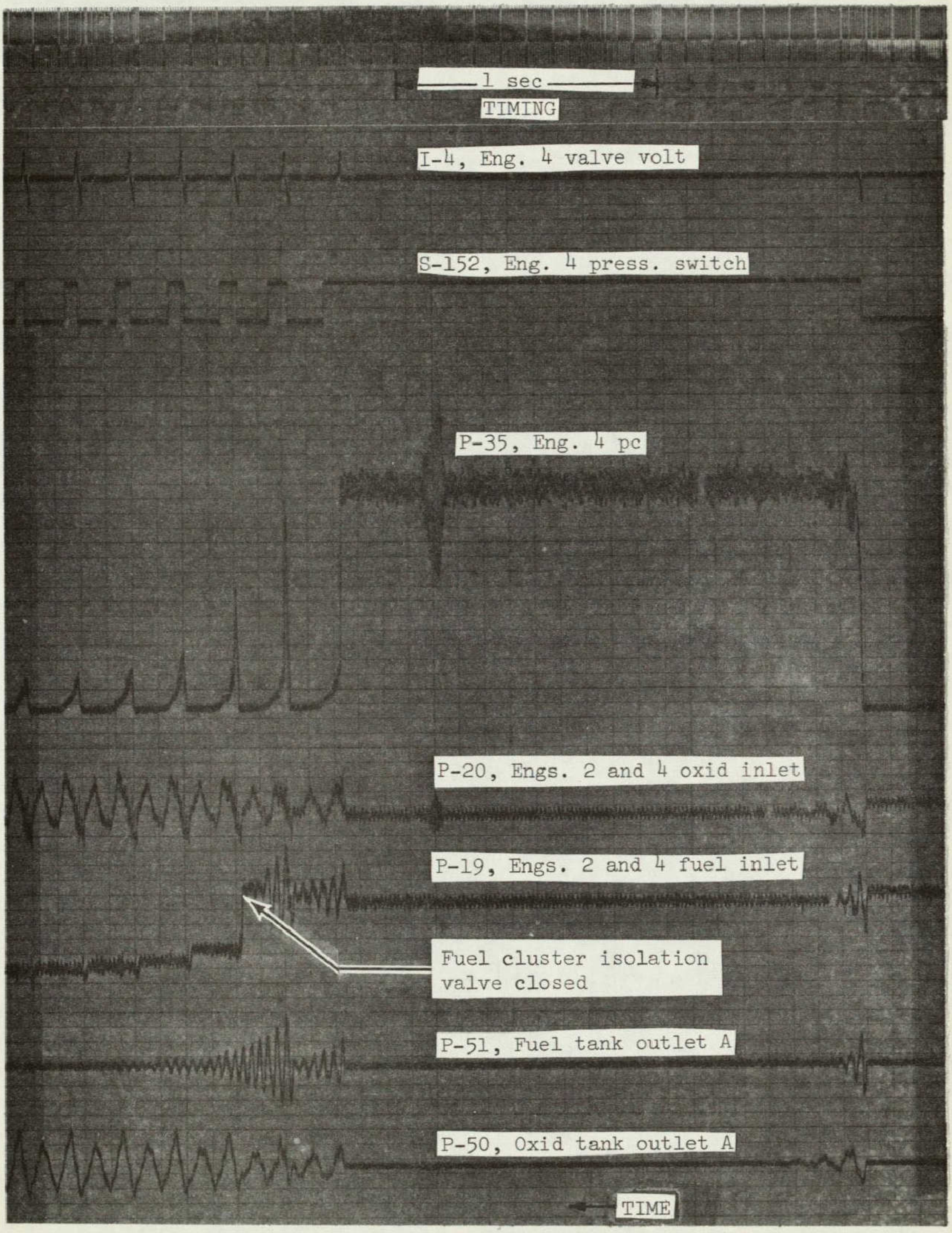
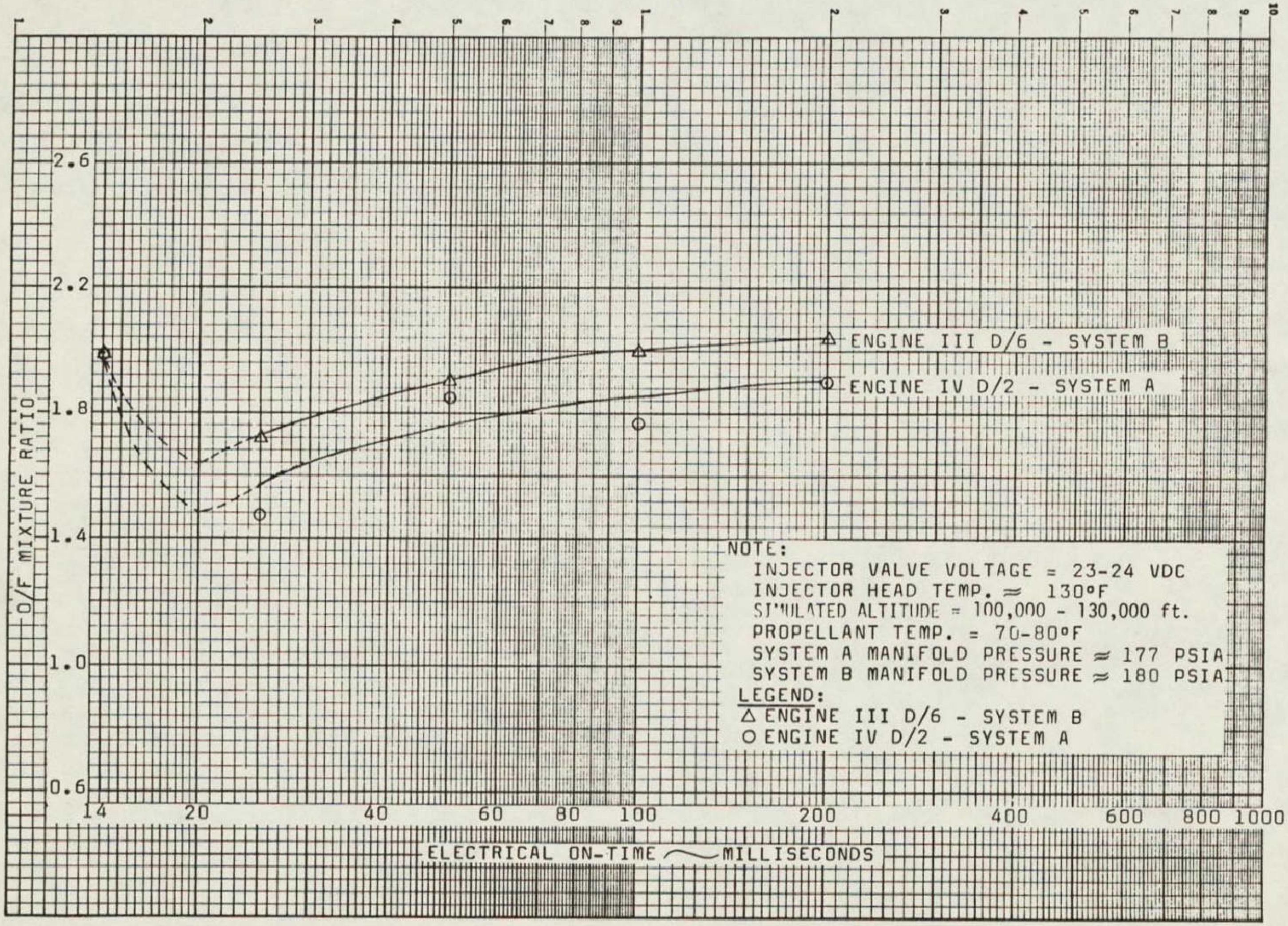


Figure 52.- Simulation of inadvertent fuel cluster isolation valve closure. (NOTE: System A fuel cluster isolation valve closed on cluster IV 2 seconds after start of Run IV-G-6-6).



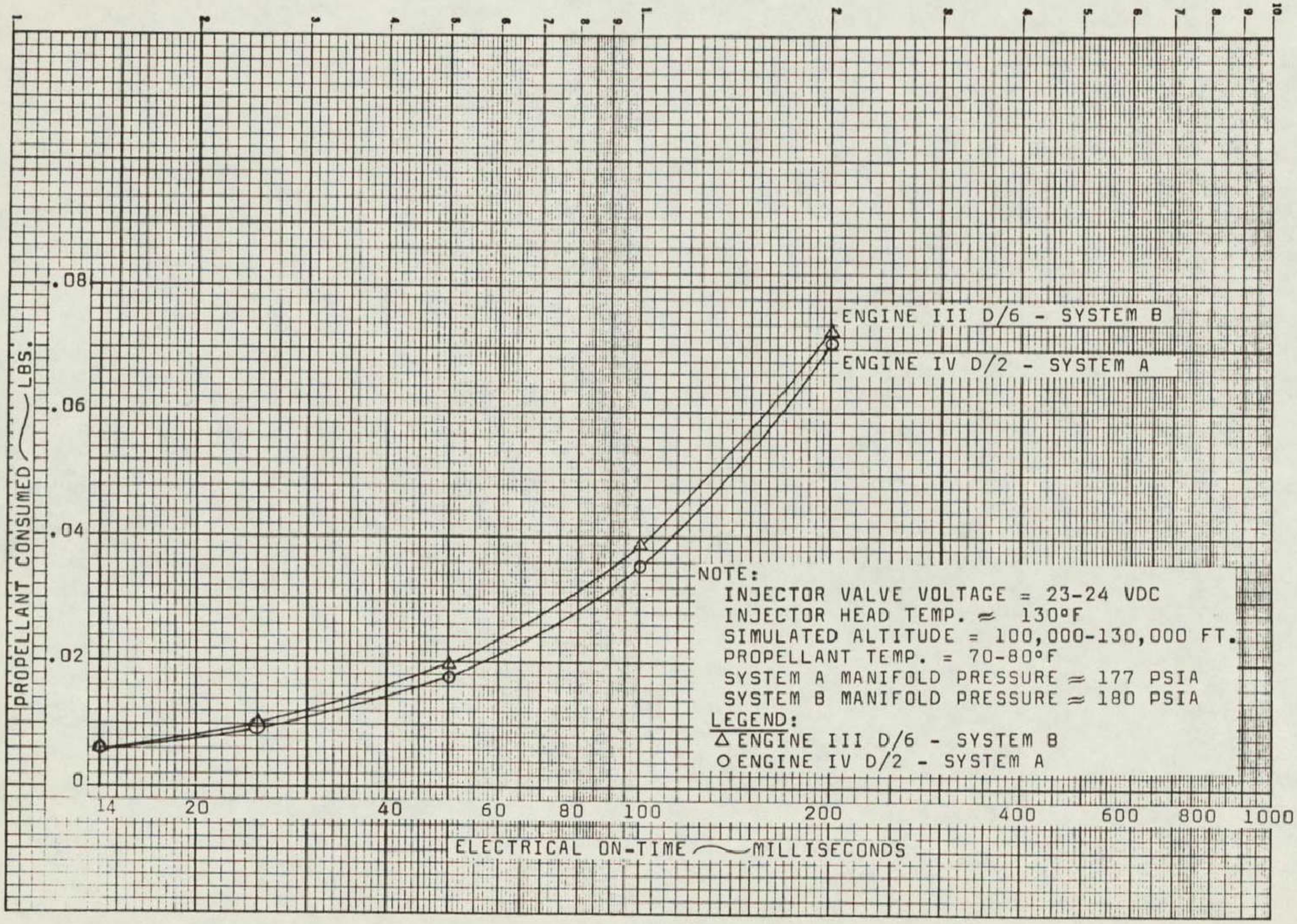
NOTE:

INJECTOR VALVE VOLTAGE = 23-24 VDC
INJECTOR HEAD TEMP. ≈ 130°F
SIMULATED ALTITUDE = 100,000 - 130,000 ft.
PROPELLANT TEMP. = 70-80°F
SYSTEM A MANIFOLD PRESSURE ≈ 177 PSIA
SYSTEM B MANIFOLD PRESSURE ≈ 180 PSIA

LEGEND:

△ ENGINE III D/6 - SYSTEM B
○ ENGINE IV D/2 - SYSTEM A

Figure 53.- LM RCS mixture ratio as a function of engine electrical on-time.



NOTE:
INJECTOR VALVE VOLTAGE = 23-24 VDC
INJECTOR HEAD TEMP. ≈ 130°F
SIMULATED ALTITUDE = 100,000-130,000 FT.
PROPELLANT TEMP. = 70-80°F
SYSTEM A MANIFOLD PRESSURE ≈ 177 PSIA
SYSTEM B MANIFOLD PRESSURE ≈ 180 PSIA

LEGEND:
△ ENGINE III D/6 - SYSTEM B
○ ENGINE IV D/2 - SYSTEM A

Figure 54.- LM RCS propellant consumption as a function of engine electrical on-time.

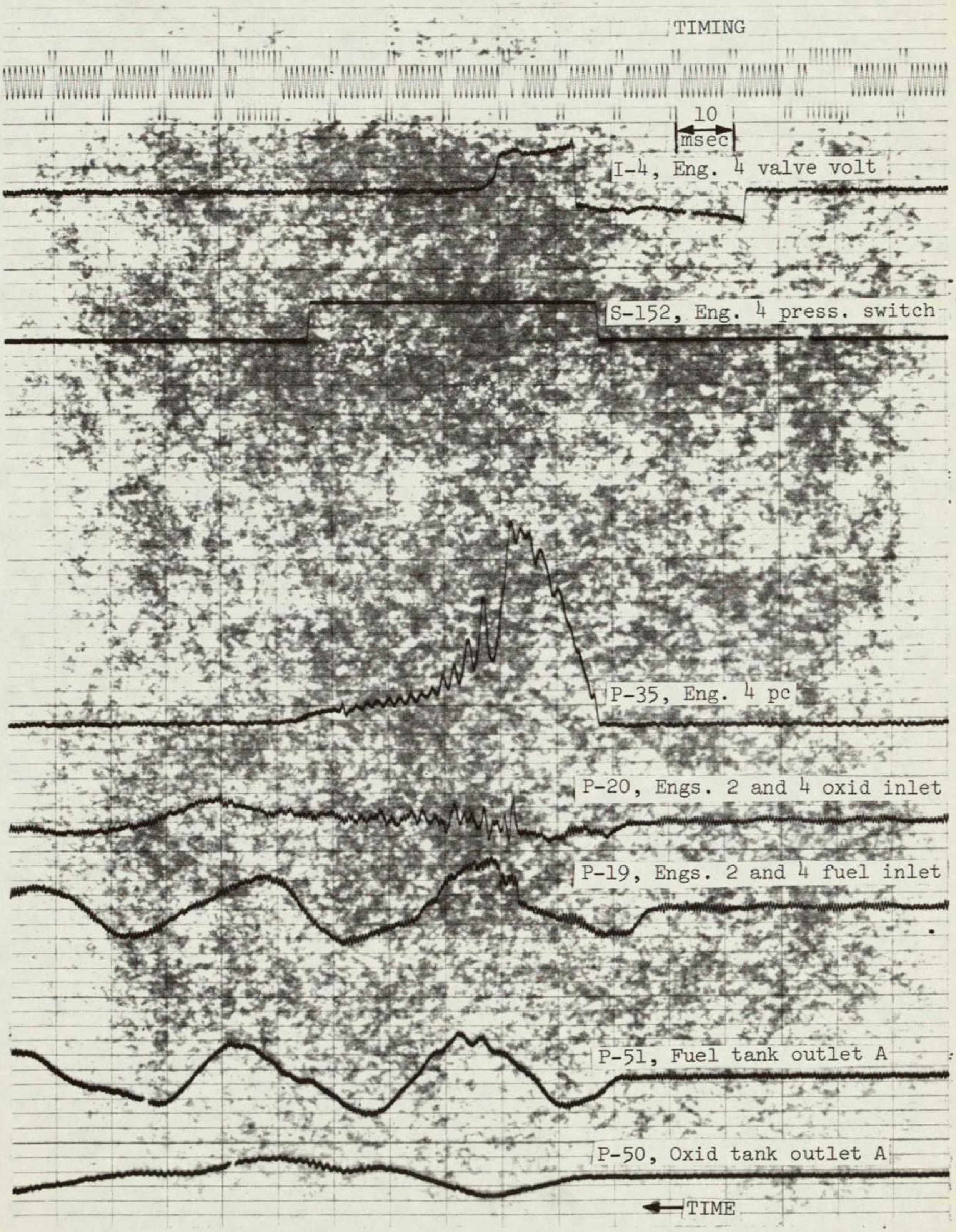


Figure 55.- Baseline manual coil 30 msec pulse on engine IV S/4 (Run IV-I-16, first pulse).

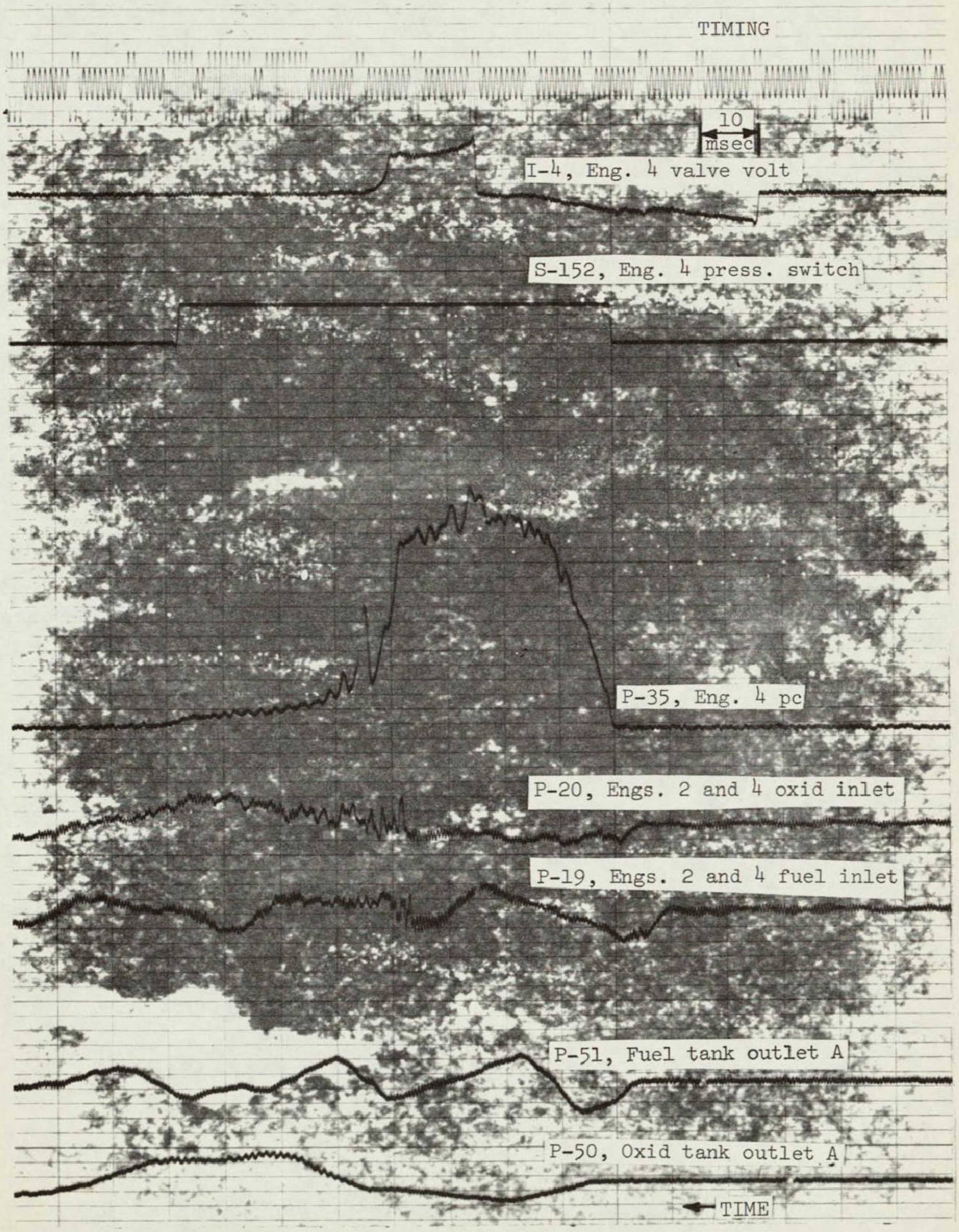


Figure 56.- Baseline manual coil 50 msec pulse on engine IV S/4 (Run IV-I-16, first pulse).

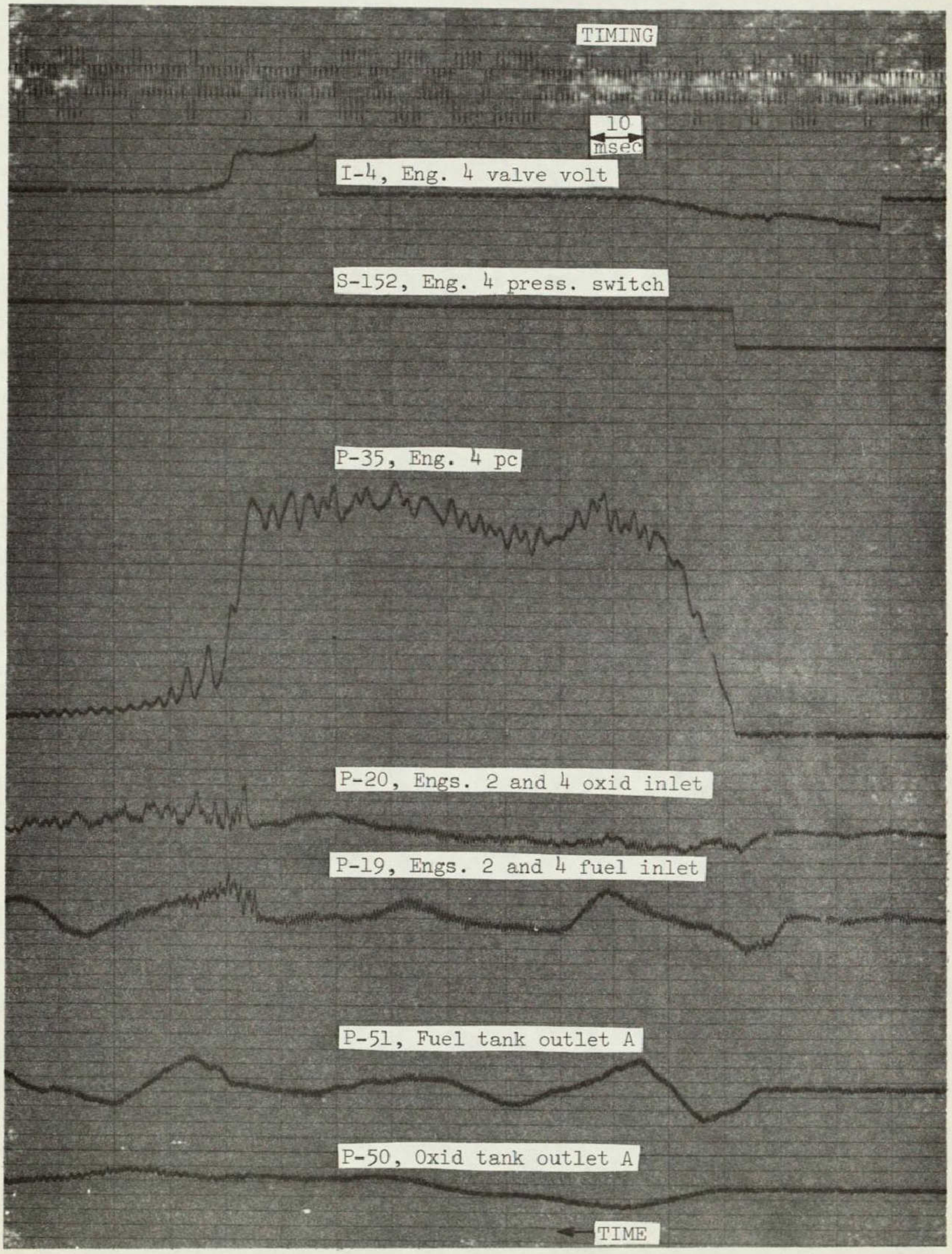


Figure 57.- Baseline manual coil 100 msec pulse on engine IV S/4 (Run IV-I-17, first pulse).

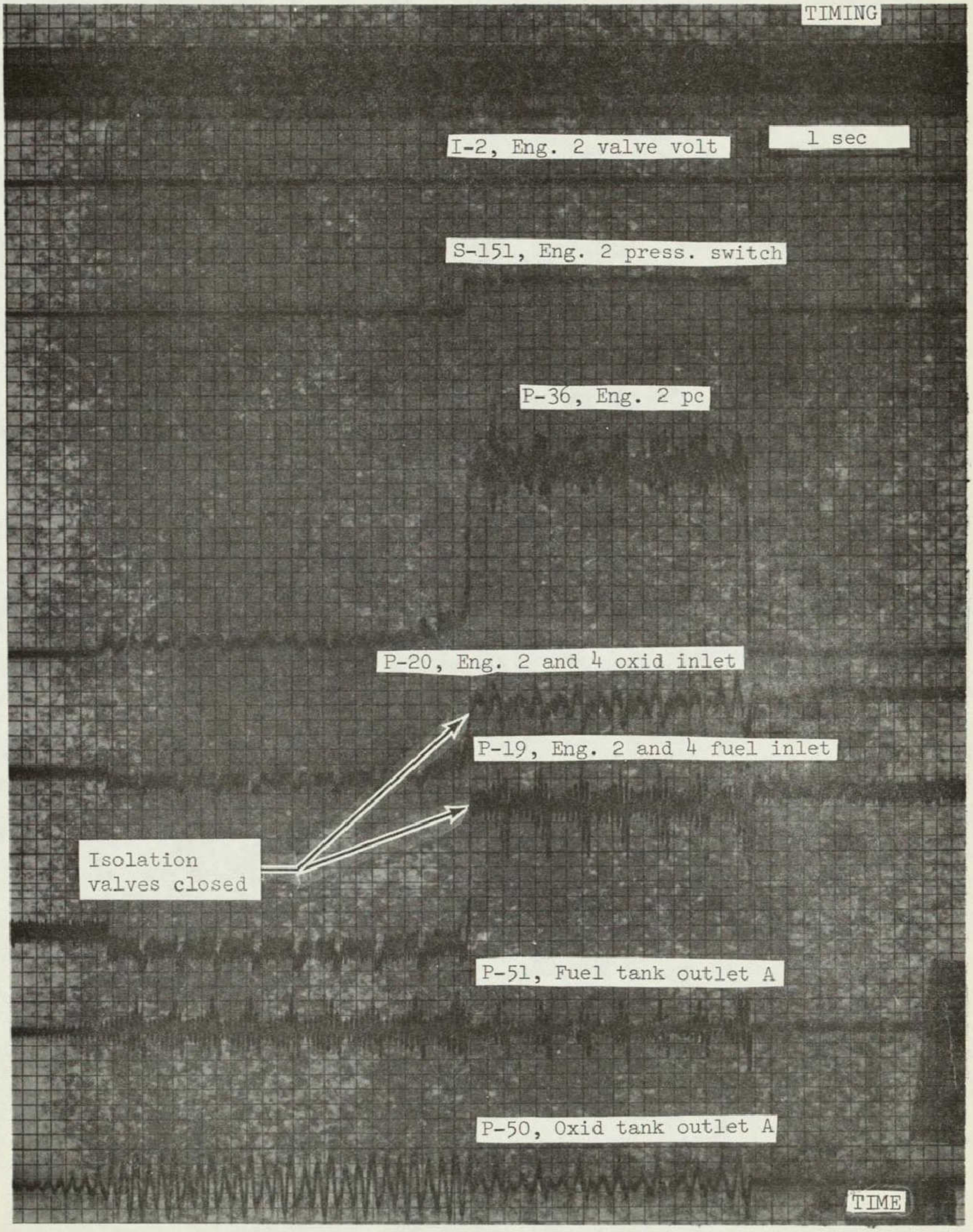


Figure 58.- Simulated engine "on" failure resulting in cluster isolation valve closure (NOTE: System A cluster isolation valves closed on cluster IV 2 seconds after start of 4 second firing on engine IV D/2, Run IV-G-4-4).

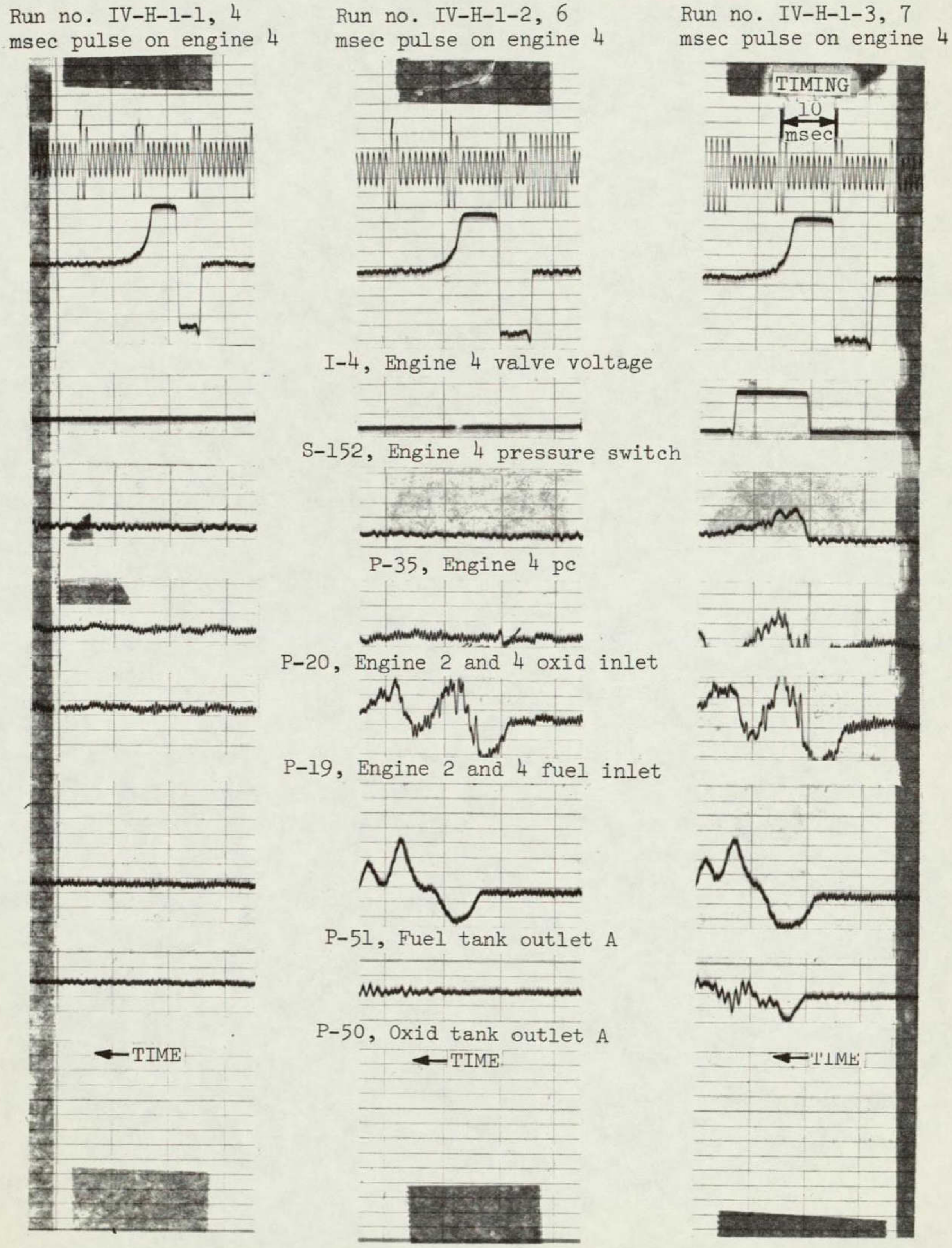
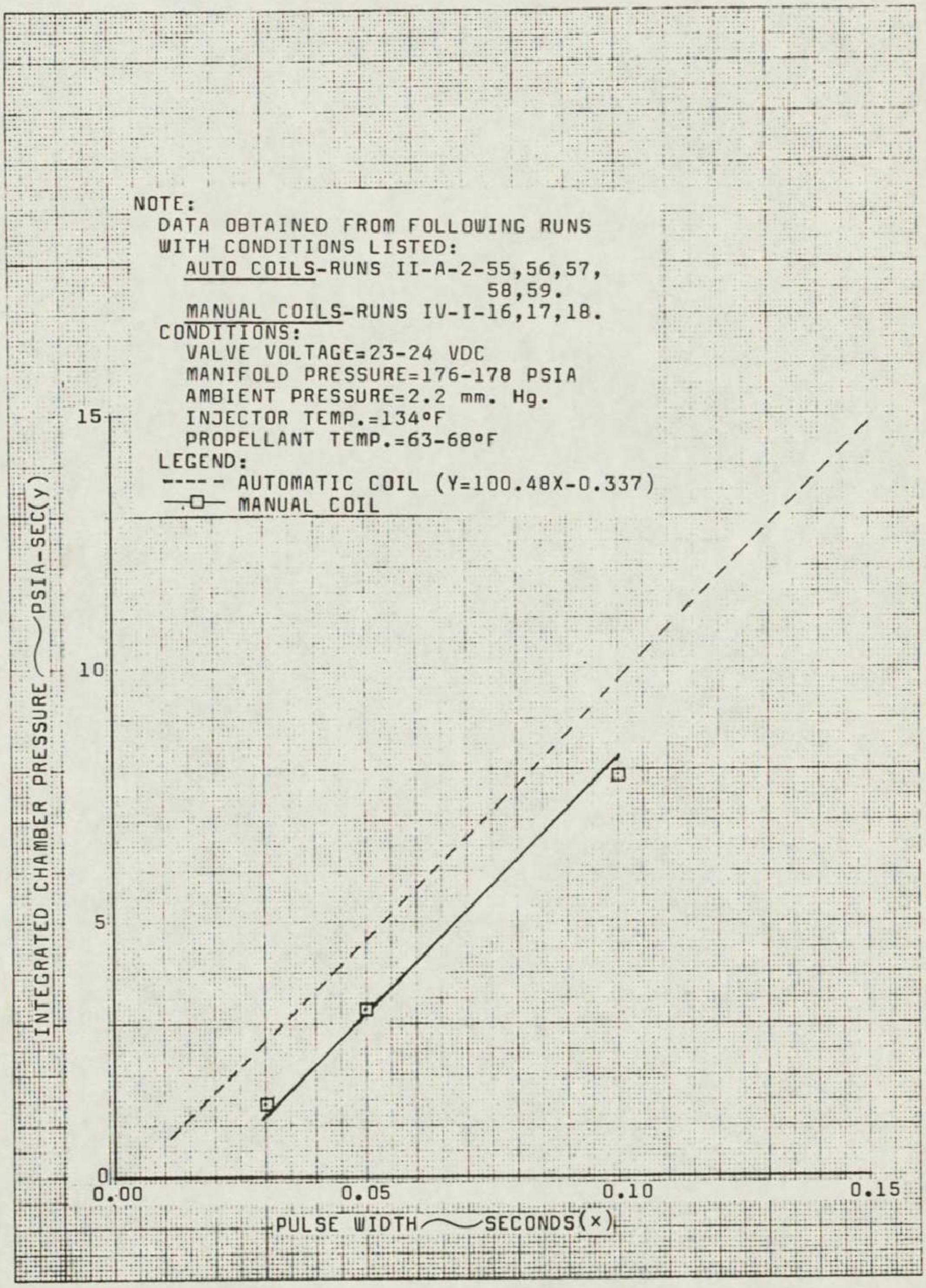
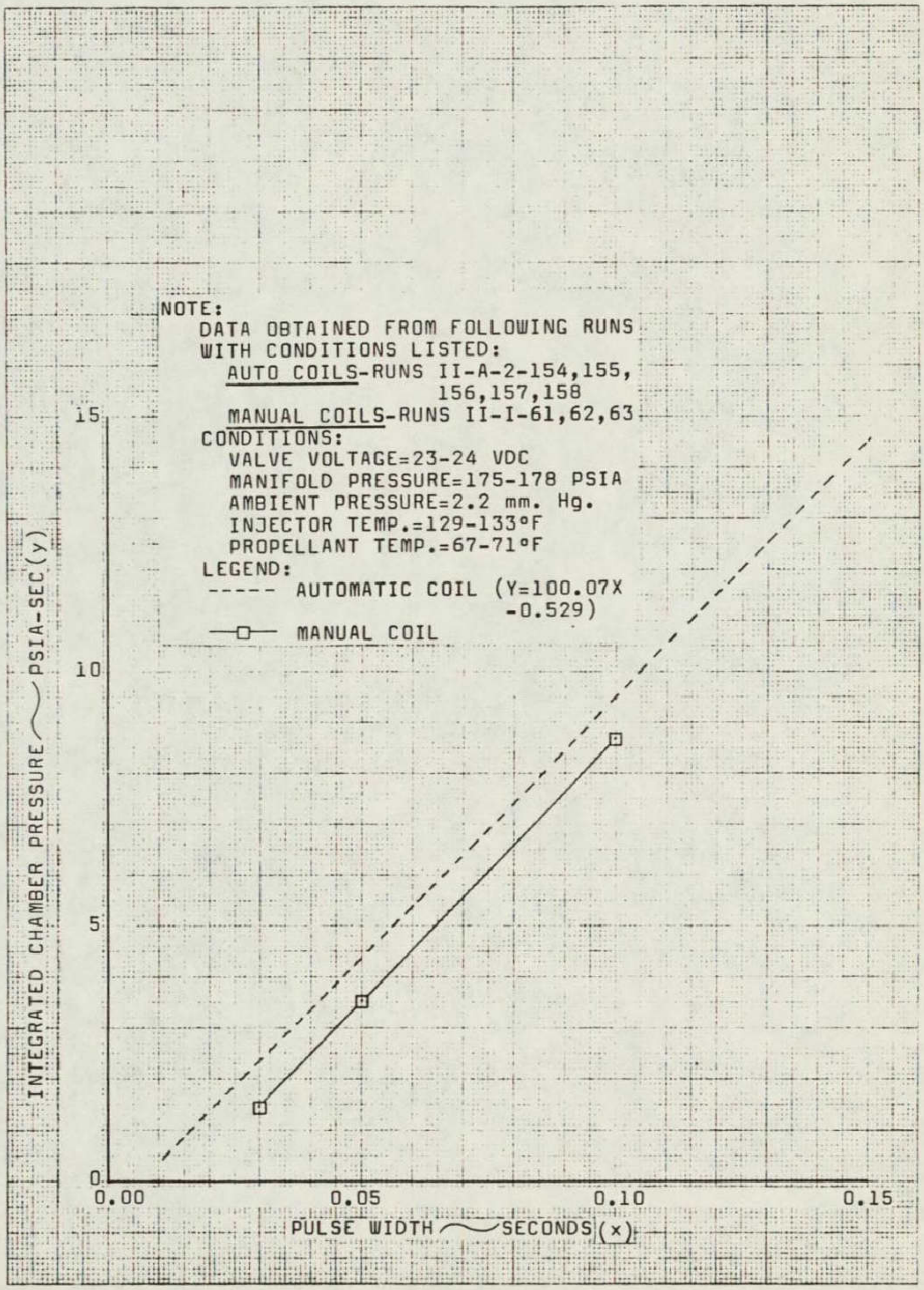


Figure 59.- Short pulse ignition characteristics (engine IV S/4).



NOTE:
DATA OBTAINED FROM FOLLOWING RUNS
WITH CONDITIONS LISTED:
AUTO COILS-RUNS II-A-2-55,56,57,
58,59.
MANUAL COILS-RUNS IV-I-16,17,18.
CONDITIONS:
VALVE VOLTAGE=23-24 VDC
MANIFOLD PRESSURE=176-178 PSIA
AMBIENT PRESSURE=2.2 mm. Hg.
INJECTOR TEMP.=134°F
PROPELLANT TEMP.=63-68°F
LEGEND:
----- AUTOMATIC COIL (Y=100.48X-0.337)
—□— MANUAL COIL

Figure 60.- Comparison of automatic and manual coil performance for baseline firings (engine IV S/4).



NOTE:

DATA OBTAINED FROM FOLLOWING RUNS WITH CONDITIONS LISTED:

AUTO COILS-RUNS II-A-2-154,155, 156,157,158

MANUAL COILS-RUNS II-I-61,62,63

CONDITIONS:

VALVE VOLTAGE=23-24 VDC
MANIFOLD PRESSURE=175-178 PSIA
AMBIENT PRESSURE=2.2 mm. Hg.
INJECTOR TEMP.=129-133°F
PROPELLANT TEMP.=67-71°F

LEGEND:

----- AUTOMATIC COIL (Y=100.07X -0.529)

—□— MANUAL COIL

Figure 61.- Comparison of automatic and manual coil performance for baseline firings (engine I U/13).

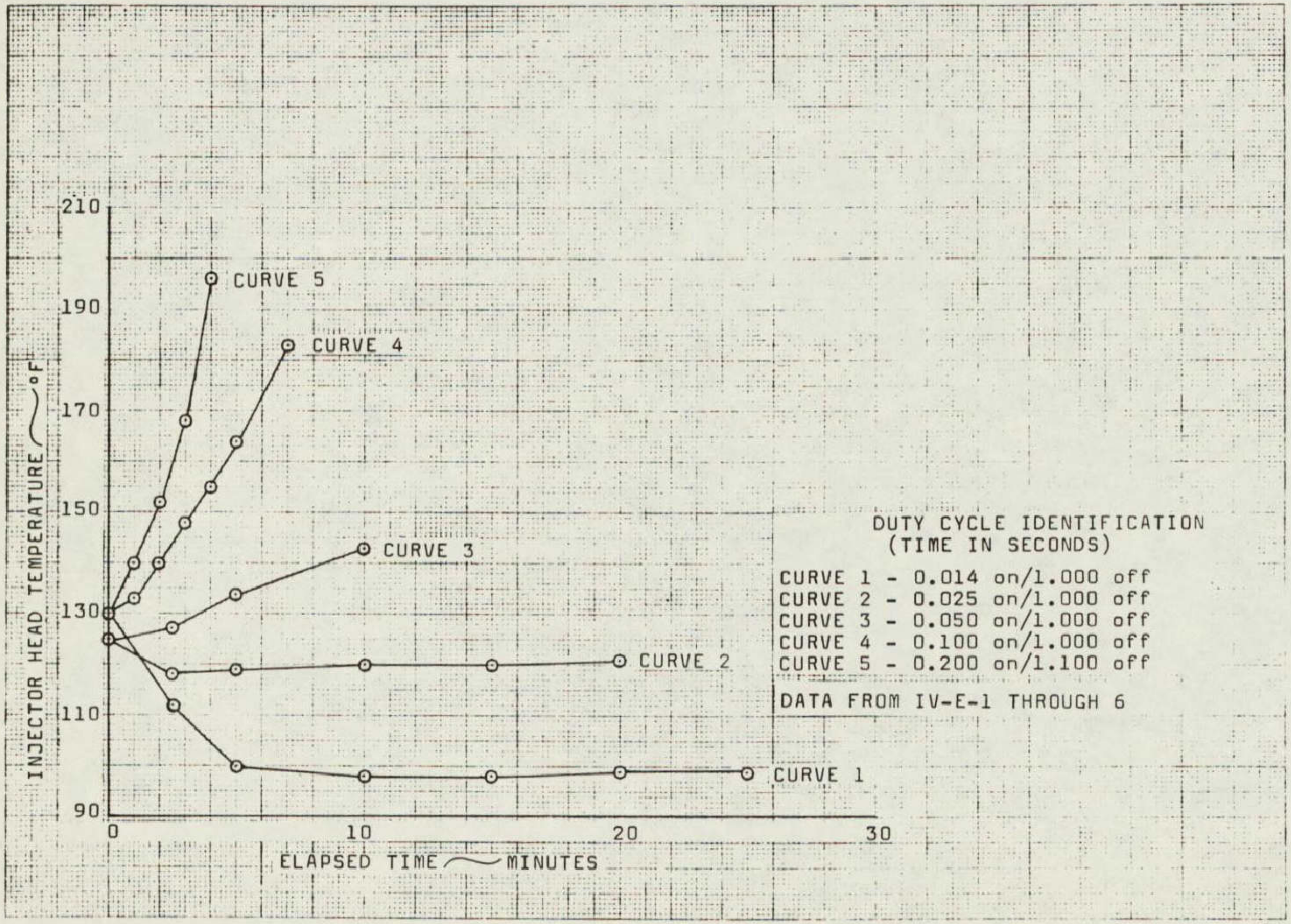


Figure 62.- Injector head temperature as a function of time for various duty cycles — engine IV D/2 (uninsulated).

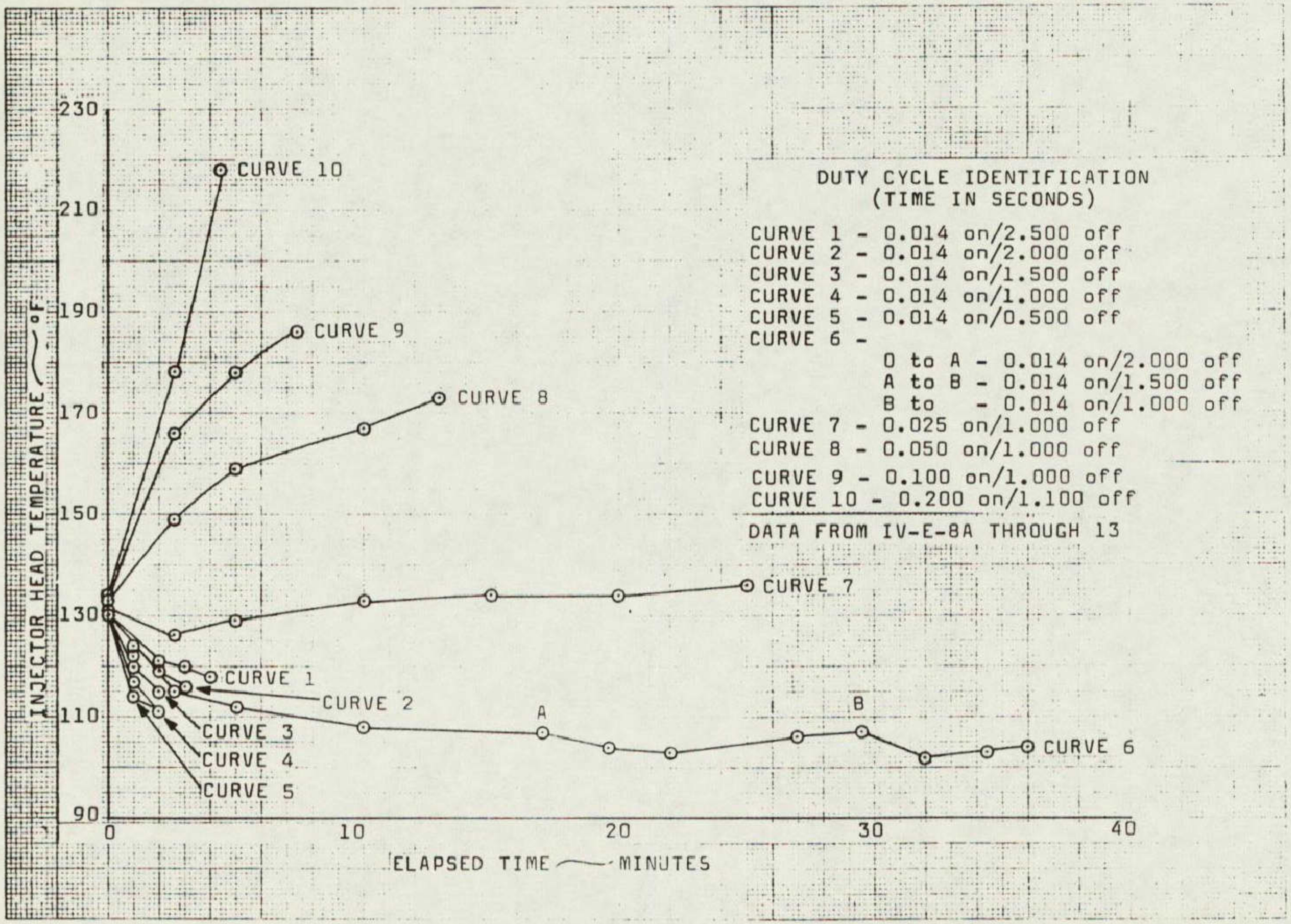
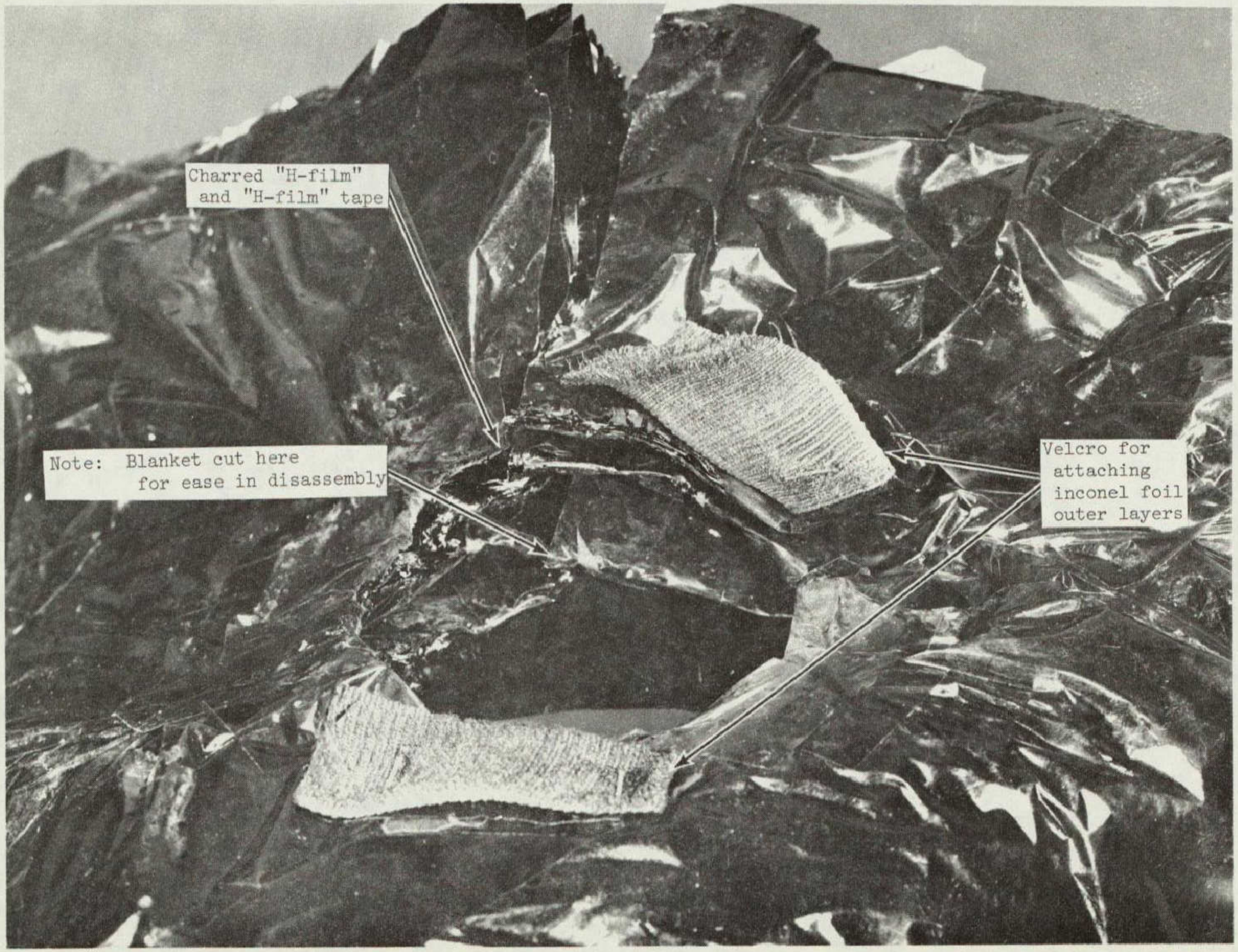


Figure 63.- Injector head temperature as a function of time for various duty cycles — engine IV D/6 (insulated).



Charred "H-film" and "H-film" tape

Note: Blanket cut here for ease in disassembly

Velcro for attaching inconel foil outer layers

Figure 64.- Effects of engine firing on "H-film" inner layers of cluster outboard thermal blanket.

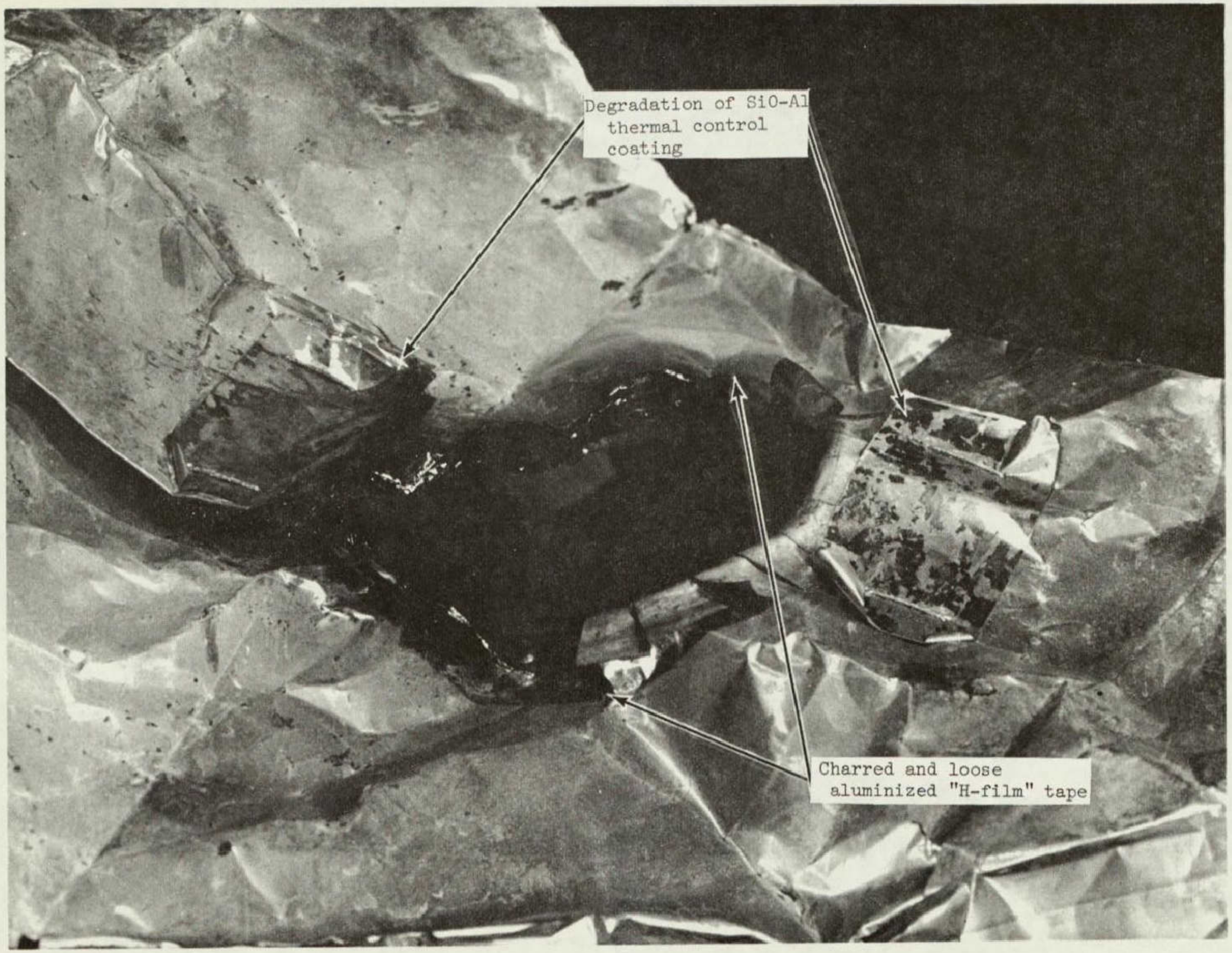


Figure 65.- Effects of engine firing on inconel foil outer layers of cluster outboard thermal blanket.

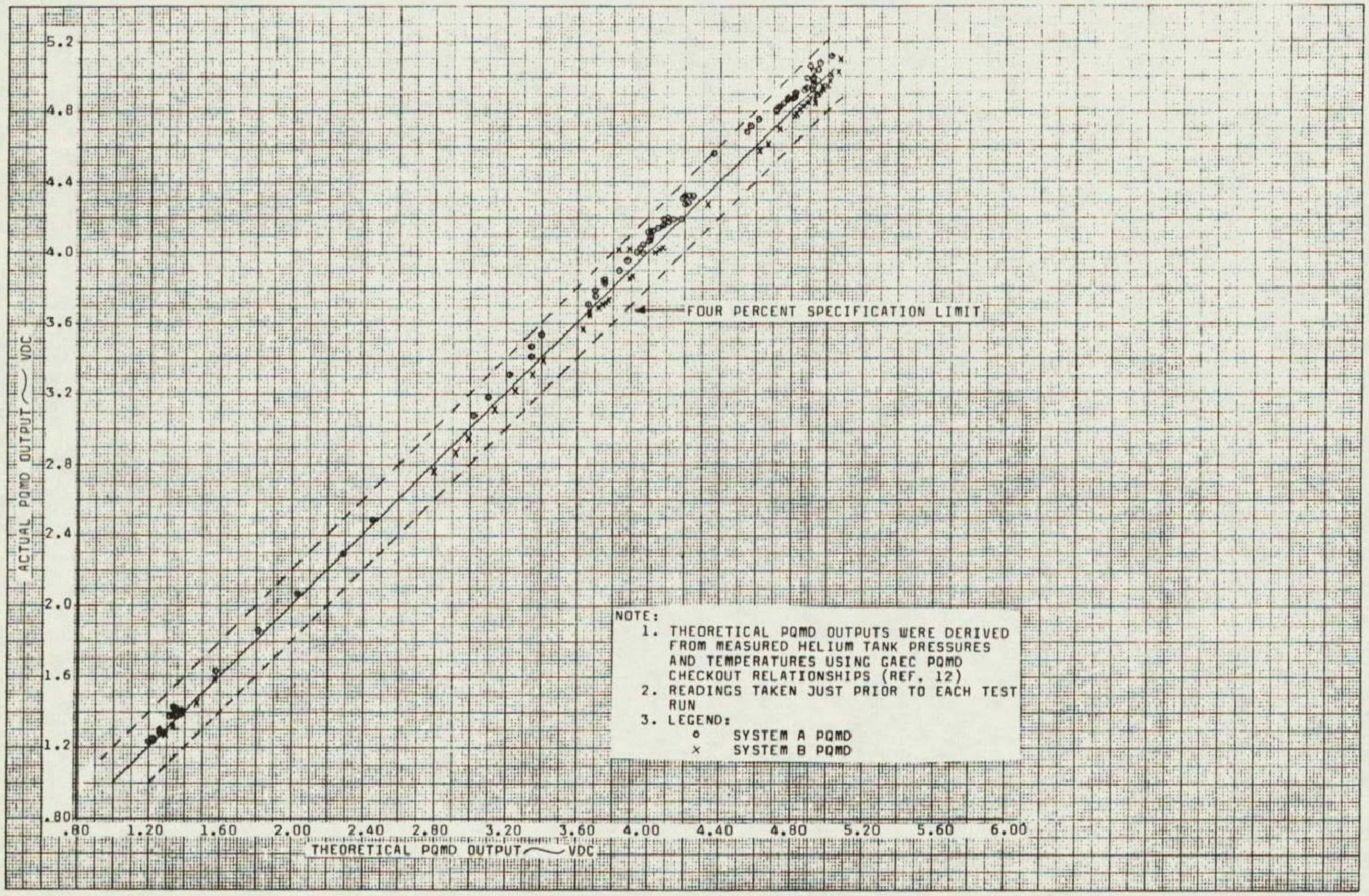


Figure 66.- Comparison of PQMD output with theoretical output.

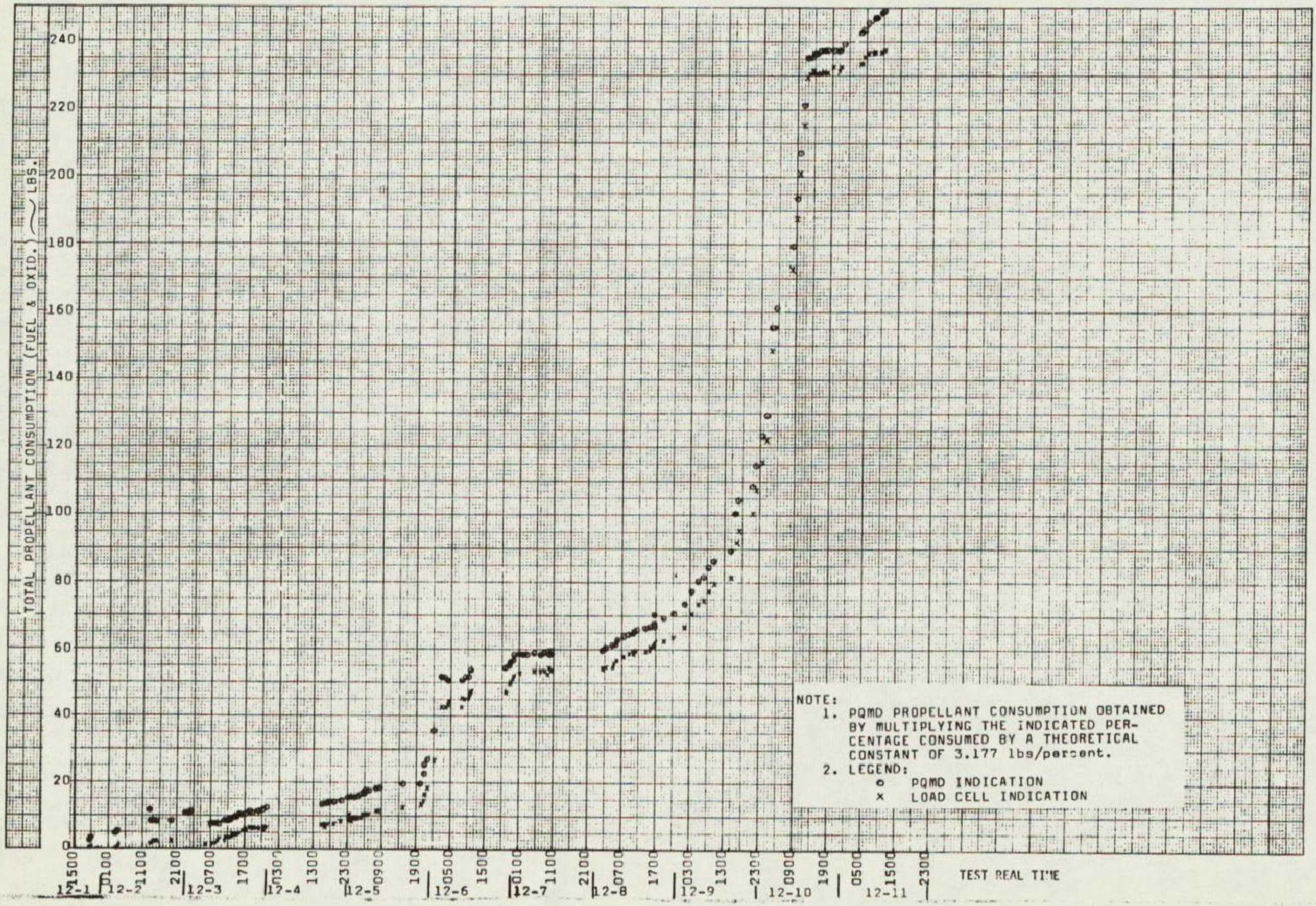
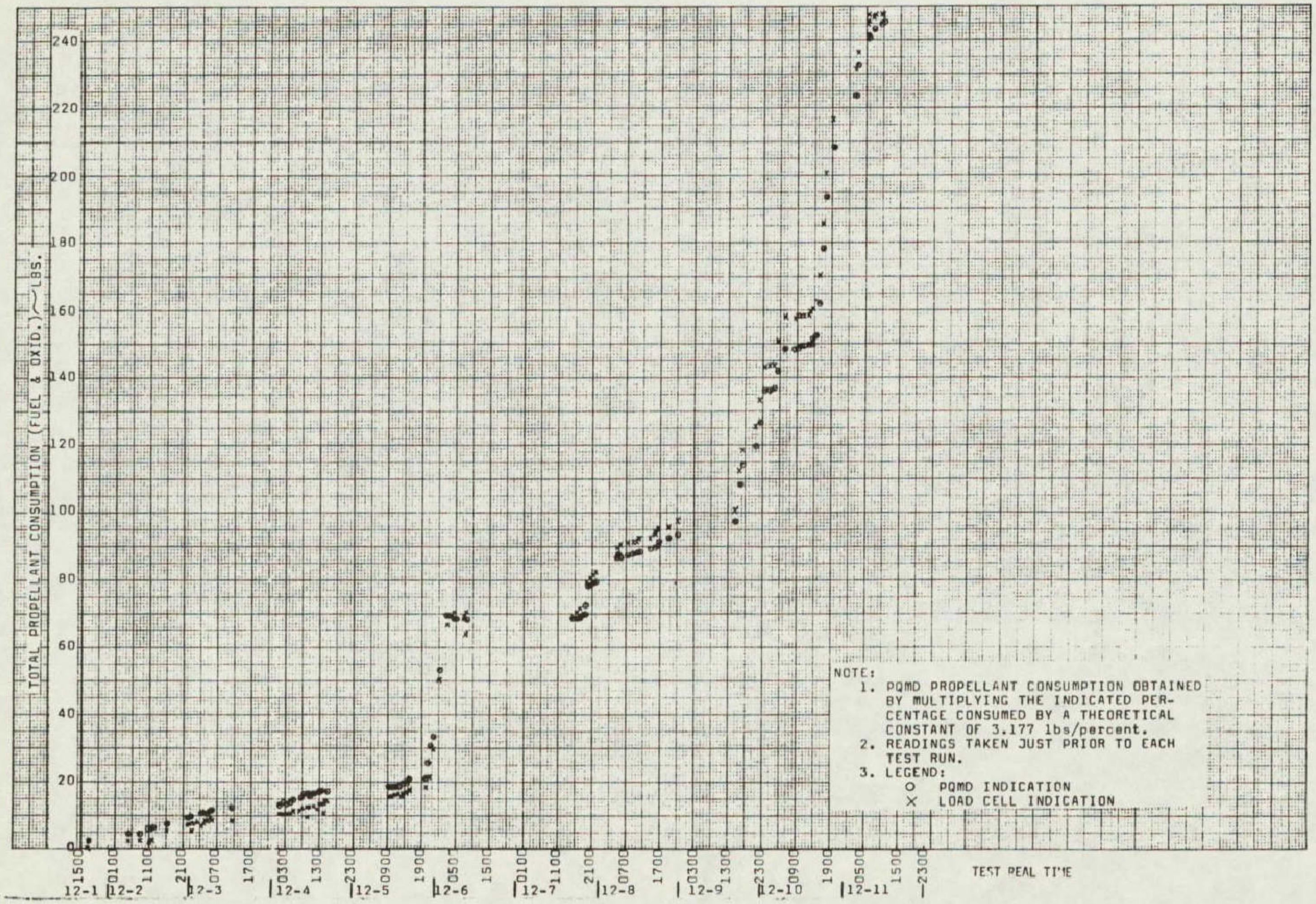


Figure 67.- Comparison of PQMD and load cell propellant consumption data - system A.



NOTE:
1. PQMD PROPELLANT CONSUMPTION OBTAINED BY MULTIPLYING THE INDICATED PERCENTAGE CONSUMED BY A THEORETICAL CONSTANT OF 3.177 lbs/percent.
2. READINGS TAKEN JUST PRIOR TO EACH TEST RUN.
3. LEGEND:
   - ○ PQMD INDICATION
   - × LOAD CELL INDICATION

Figure 68.- Comparison of PQMD and load cell propellant consumption data - system B.

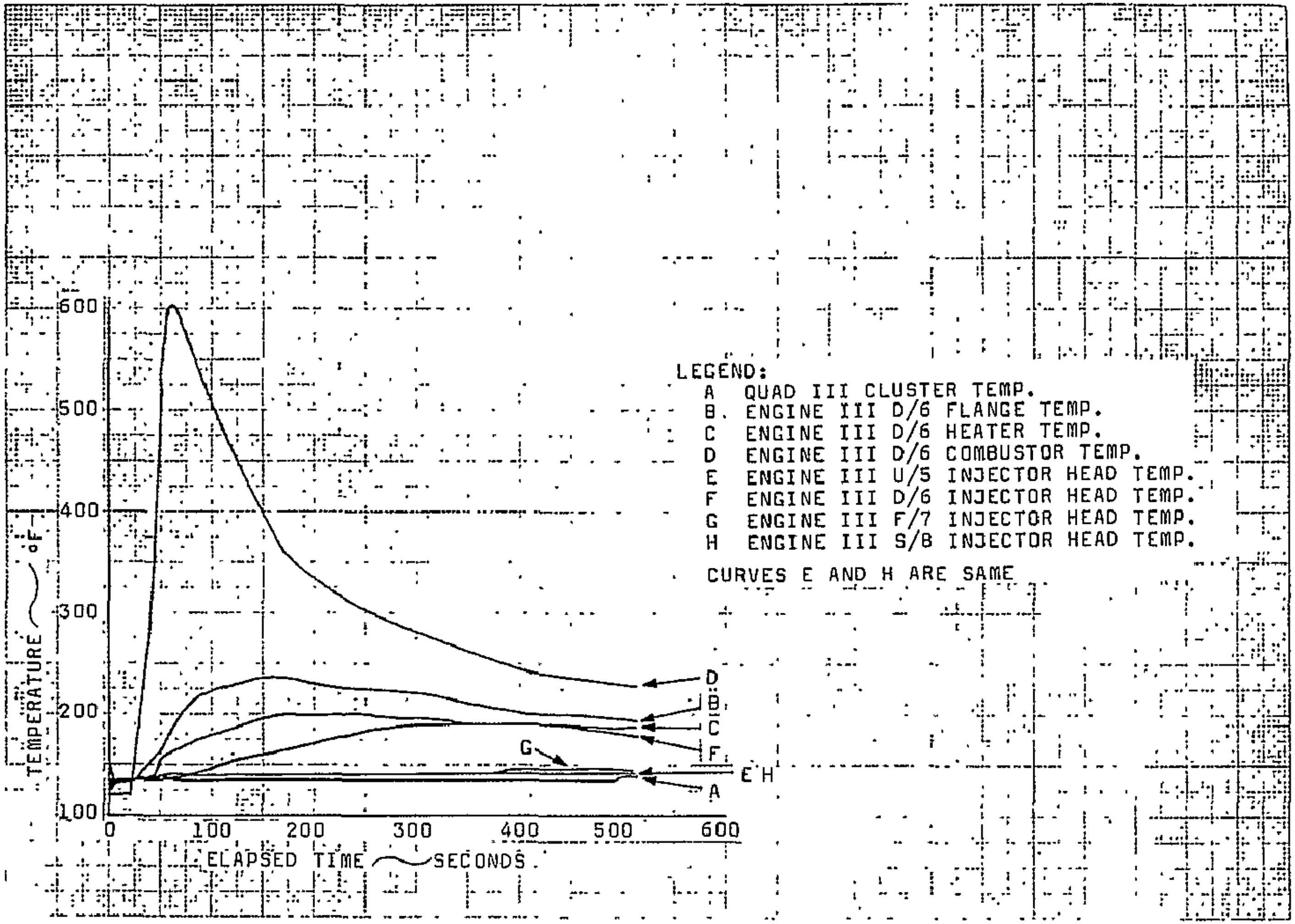


Figure 69.- Temperature profile for cluster III during the lunar mission duty cycle transfer point initiation simulation (run III-B-4-1).

APPENDIX A

ENGINE FIRING RECORD AND RUN CHRONOLOGY

Run no.	Date	Time, hr	Engine no. and location	No of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
								Phase II — base line performance duty cycles											
								Block A-1 — bleed-in firings											
1	12-1-67	1514	IVU/1	1	1	1 000		1.000	1.000	23-24	X		X			X		X	P-17 bad
3	12-1-67	1715	IVF/3	1	1	1.000		1.000	1.000	23-24	X		X			X		X	
2	12-1-67	1951	IVD/2	1	1	1.000		1 000	1 000	23-24	X		X			X		X	
4	12-1-67	2035	IVS/4	1	1	1 000		1.000	1 000	23-24	X		X			X		X	No digital
4A	12-1-67	2140	IVS/4	1	2	1.000		1.000	2.000	23-24	X		X			X		X	No digital
4B	12-2-67	0152	IVS/4	1	3	1 000		1 000	3.000	23-24	X		X			X		X	
5	12-2-67	0311	IIIU/5	1	1	1.000		1 000	1.000	23-24	X		X			X		X	Glitch on valve trace
5A	12-2-67	0349	IIIU/5	1	2	1 000		1.000	2.000	23-24	X		X			X		X	
8	12-2-67	0413	IIIS/8	1	1	1.000		1.000	1 000	23-24	X		X			X		X	Pc bad (P-37)
7	12-2-67	0510	IIIF/7	1	1	1 000		1.000	1.000	23-24	X		X			X		X	
6	12-2-67	0830	IIID/6	1	1	1.000		1.000	1 000	23-24	X		X			X		X	P-24 bad
						Power failure caused high lockup pressure for remainder of bleed-in firings													
9	12-2-67	1111	IIU/9	1	1	1.000		1.000	1 000	23-24	X		X			X		X	
12	12-2-67	1155	IIS/12	1	1	[a]1.000		1.000	1.000	23-24	X		X			X		X	Fired at T-10 seconds
12A	12-2-67	1200	IIS/12	1	2	[a]1 000		1 000	2.000	23-24	X		X			X		X	Fired at T-10 seconds
12B	12-2-67	1225	IIS/12	1	3	1 000		1.000	3 000	23-24	X		X			X		X	
10	12-2-67	1337	IID/10	1	1	1 000		1 000	1 000	23-24	X		X			X		X	
11	12-2-67	1355	IIF/11	1	1	1 000		1.000	1.000	23-24	X		X			X		X	
13	12-2-67	1413	IU/13	1	1	[a]1.000		1.000	1.000	23-24	X		X			X		X	Fired at T-10 seconds
13A	12-2-67	1426	IU/13	1	2	[a]1.000		1.000	2.000	23-24	X		X			X		X	Fired at T-10 seconds
13B	12-2-67	1528	IU/13	1	3	[a]1.000		1.000	3 000	23-24	X		X			X		X	Fired at T-10 seconds
13C	12-2-67	1608	IU/13	1	4	1 510		1.510	4.510	23-24	X		X			X		X	
14	12-2-67	1624	ID/14	1	1	[a]1.000		1.000	1.000	23-24	X		X			X		X	Fired at T-10 seconds

[a] Premature firings — on time is estimate since data were not recorded.

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
14A	12-2-67	1650	ID/14	1	2	[a]1.000		1.000	2.000	23-24	X		X			X		X	Inadvertent firing
14A	12-2-67	1710	ID/14	1	3	1.000		1.000	3.000	23-24	X		X			X		X	
			ID/16	1	1	2.607		2.607	2.607	23-24	X		X			X		X	Engine 16 fired inadvertently
15	12-2-67	1940	IF/15	1	1	1.000		1.000	1.000	23-24	X		X			X		X	
								Phase II — base line performance duty cycles											
								Block A-2 — base line single engines											
17B	12-2-67	2202	IVU/1	5	6	0.014	0.186	0.070	1.070	23-24	X		X			X		X	
18	12-2-67	2215	IVU/1	5	11	0.017	0.183	0.085	1.155	23-24	X		X			X		X	
19	12-2-67	2230	IVU/1	5	16	0.050	0.150	0.250	1.405	23-24	X		X			X		X	S 253 failed closed
20	12-2-67	2243	IVU/1	3	19	0.100	0.100	0.300	1.705	23-24	X		X			X		X	
21	12-2-67	2256	IVU/1	2	21	0.150	0.050	0.300	2.005	23-24	X		X			X		X	
22	12-2-67	2332	IVU/1	5	26	0.014	0.500	0.070	2.075	23-24	X		X			X		X	
23	12-2-67	2351	IVU/1	5	31	0.017	0.500	0.085	2.160	23-24	X		X			X		X	
24	12-3-67	0005	IVU/1	5	36	0.050	0.500	0.250	2.410	23-24	X		X			X		X	
25	12-3-67	0038	IVU/1	3	39	0.100	0.500	0.300	2.710	23-24	X		X			X		X	
26	12-3-67	0101	IVU/1	2	41	0.150	0.500	0.300	3.010	23-24	X		X			X		X	
27	12-3-67	0122	IVU/1	1	42	1.000		1.000	4.010	23-24	X		X			X		X	
39	12-3-67	0214	IVF/3	5	6	0.014	0.186	0.070	1.070	23-24	X		X			X		X	
40	12-3-67	0234	IVF/3	5	11	0.017	0.183	0.085	1.155	23-24	X		X			X		X	
41	12-3-67	0326	IVF/3	5	16	0.050	0.150	0.250	1.405	23-24	X		X			X		X	
42	12-3-67	0341	IVF/3	3	19	0.100	0.100	0.300	1.705	23-24	X		X			X		X	
43	12-3-67	0357	IVF/3	2	21	0.150	0.050	0.300	2.005	23-24	X		X			X		X	

[a] Premature firings — on time is estimate since data were not recorded.

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
44	12-3-67	0409	IVF/3	5	26	0.014	0.500	0.070	2.075	23-24	X		X			X		X	
45	12-3-67	0425	IVF/3	5	31	0.017	0.500	0.085	2.160	23-24	X		X			X		X	
46	12-3-67	0437	IVF/3	5	36	0.050	0.500	0.250	2.410	23-24	X		X			X		X	
47	12-3-67	0448	IVF/3	3	39	0.100	0.500	0.300	2.710	23-24	X		X			X		X	
48	12-3-67	0502	IVF/3	2	41	0.150	0.500	0.300	3.010	23-24	X		X			X		X	
49	12-3-67	0515	IVF/3	1	42	1.000		1.000	4.010	23-24	X		X			X		X	
28	12-3-67	0551	IVD/2	5	6	0.014	0.186	0.070	1.070	23-24	X		X			X		X	
29	12-3-67	0716	IVD/2	5	11	0.017	0.133	0.085	1.155	23-24	X		X			X		X	Firing program not patched correctly
30	12-3-67	0728	IVD/2	5	16	0.050	0.150	0.250	1.405	23-24	X		X			X		X	
31	12-3-67	0739	IVD/2	3	19	0.100	0.100	0.300	1.705	23-24	X		X			X		X	
32	12-3-67	0750	IVD/2	2	21	0.150	0.050	0.300	2.005	23-24	X		X			X		X	
33	12-3-67	0801	IVD/2	5	26	0.014	0.500	0.070	2.075	23-24	X		X			X		X	
34	12-3-67	0852	IVD/2	5	31	0.017	0.500	0.085	2.160	23-24	X		X			X		X	
35	12-3-67	0903	IVD/2	5	36	0.050	0.500	0.250	2.410	23-24	X		X			X		X	
36	12-3-67	0915	IVD/2	3	39	0.100	0.500	0.300	2.710	23-24	X		X			X		X	
37	12-3-67	0925	IVD/2	2	41	0.150	0.500	0.300	3.010	23-24	X		X			X		X	
38	12-3-67	0935	ICD/2	1	42	1.000		1.000	4.010	23-24	X		X			X		X	
50	12-3-67	1104	IVS/4	5	8	0.014	0.186	0.070	3.070	23-24	X		X			X		X	
SP-1	12-3-67	1148	IVF/3	1	43	0.012		0.012	4.022	23-24	X	X				X		X	Special run to check prop transfer, premature firing
51	12-3-67	1158	IVS/4	5	13	0.017	0.183	0.085	3.155	23-24	X	X	X			X		X	
51A	12-3-67	1203	IVS/4	5	18	0.017	0.183	0.085	3.240	23-24	X	X	X			X		X	
52	12-3-67	1240	IVS/4	5	23	0.050	0.150	0.250	3.490	23-24	X		X			X		X	
53	12-3-67	1255	IVS/4	3	26	0.100	0.100	0.300	3.790	23-24	X		X			X		X	
54	12-3-67	1308	IVS/4	2	28	0.150	0.050	0.300	4.090	23-24	X		X			X		X	

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Interconnects		Cross feeds		
											O	C	O	C	O	C	O	C	
55	12-3-67	1320	IVS/4	5	33	0.014	0 500	0 070	4 160	23-24	X		X			X		X	
56	12-3-67	1335	IVS/4	5	38	0.017	0.500	0.085	4 245	23-24	X		X			X		X	
57	12-3-67	1349	IVS/4	5	43	0.050	0.500	0.250	4 495	23-24	X		X			X		X	
58	12-3-67	1427	IVS/4	3	46	0.100	0.500	0.300	4.795	23-24	X		X			X		X	
59	12-3-67	1440	IVS/4	2	48	0.150	0 500	0.300	5.095	23-24	X		X			X		X	
60	12-3-67	1455	IVS/4	1	49	1.000		1.000	6.095	23-24	X		X			X		X	
61	12-3-67	1535	IIIU/5	5	7	0.014	0.186	0 070	2 070	23-24	X		X			X		X	
62	12-3-67	1547	IIIU/5	5	12	0 017	0.183	0.085	2 155	23-24	X		X			X		X	
63	12-3-67	1559	IIIU/5	5	17	0.017	0.183	0 085	2.240	23-24	X		X			X		X	Firing program not updated
63A	12-3-67	1612	IIIU/5	5	22	0 050	0.150	0 250	2 490	23-24	X		X			X		X	
64	12-3-67	1625	IIIU/5	3	25	0 100	0.100	0 300	2 790	23-24	X		X			X		X	
65	12-3-67	1639	IIIU/5	2	27	0 150	0.050	0.300	3 090	23-24	X		X			X		X	
66	12-3-67	1702	IIIU/5	5	32	0.014	0.500	0 070	3 160	23-24	X		X			X		X	
67	12-3-67	1716	IIIU/5	5	37	0 017	0.500	0.085	3 245	23-24	X		X			X		X	
68	12-3-67	1730	IIIU/5	5	42	0.050	0 500	0.250	3 495	23-24	X		X			X		X	
69	12-3-67	1743	IIIU/5	3	45	0.100	0 500	0 300	3.795	23-24	X		X			X		X	
70	12-3-67	1852	IIIU/5	2	47	0.150	0.500	0.300	4 095	23-24	X		X			X		X	
71	12-3-67	1904	IIIU/5	1	48	1 000		1.000	5 095	23-24	X		X			X		X	
94	12-3-67	2045	IIIS/8	5	6	0.014	0.186	0 070	1 070	23-24	X		X			X		X	
95	12-3-67	2108	IIIS/8	5	11	0 017	0.183	0.085	1 155	23-24	X		X			X		X	
96	12-3-67	2119	IIIS/8	5	16	0.050	0 150	0.250	1 405	23-24	X		X			X		X	
97	12-3-67	2130	IIIS/8	3	19	0.100	0 100	0.300	1.705	23-24	X		X			X		X	
98	12-3-67	2141	IIIS/8	2	21	0.150	0.050	0 300	2.005	23-24	X		X			X		X	
99	12-3-67	2204	IIIS/8	5	26	0.014	0.500	0 070	2.075	23-24	X		X					X	
100	12-3-67	2215	IIIS/8	5	31	0.017	0.500	0 085	2 160	23-24	X		X			X		X	

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Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
101	12-3-67	2226	IIIS/8	5	36	0 050	0.500	0.250	2 410	23-24	X		X			X		X	
102	12-3-67	2238	IIIS/8	3	39	0.100	0 500	0.300	2.710	23-24	X		X			X		X	
103	12-3-67	2307	IIIS/8	2	41	0.150	0.500	0 300	3 010	23-24	X		X			X		X	
104	12-3-67	2318	IIIS/8	1	42	1.000		1.000	4 010	23-24	X		X			X		X	
72	12-4-67	0126	IIID/6	5	6	0 014	0.186	0 070	1.070	23-24	X		X			X		X	
73	12-4-67	0144	IIID/6	5	11	0.017	0.183	0.085	1.155	23-24	X		X			X		X	
74	12-4-67	0154	IIID/6	5	16	0.050	0 150	0.250	1 405	23-24	X		X			X		X	
75	12-4-67	0206	IIID/6	3	19	0.100	0 100	0.300	1.705	23-24	X		X			X		X	
76	12-4-67	0224	IIID/6	2	21	0 150	0.050	0 300	2.005	23-24	X		X			X		X	
77	12-4-67	0236	IIID/6	5	26	0.014	0 500	0.070	2 075	23-24	X		X			X		X	
78	12-4-67	0246	IIID/6	5	31	0.017	0 500	0.085	2.160	23-24	X		X			X		X	
79	12-4-67	0303	IIID/6	5	36	0.050	0.500	0.250	2.410	23-24	X		X			X		X	
80	12-4-67	0328	IIID/6	3	39	0.100	0.500	0.300	2 710	23-24	X		X			X		X	
81	12-4-67	0336	IIID/6	2	41	0.150	0.500	0.300	3.010	23-24	X		X			X		X	
82	12-4-67	0344	IIID/6	1	42	1.000		1.000	4 010	23-24	X		X			X		X	
83	12-4-67	0439	IIIF/7	5	6	0.014	0 186	0.070	1.070	23-24	X		X			X		X	
84	12-4-67	0450	IIIF/7	5	11	0 017	0 183	0.085	1.155	23-24	X		X			X		X	
85	12-4-67	0458	IIIF/7	5	16	0.050	0.150	0.250	1.405	23-24	X		X			X		X	
86	12-4-67	0508	IIIF/7	3	19	0 100	0.100	0.300	1 705	23-24	X		X			X		X	Analog tape B did not start
86A	12-4-67	0517	IIIF/7	3	22	0.100	0.100	0.300	2.005	23-24	X		X			X		X	
87	12-4-67	0530	IIIF/7	2	24	0.150	0 050	0.300	2.305	23-24	X		X			X		X	
88	12-4-67	0538	IIIF/7	5	29	0.014	0.500	0 070	2.375	23-24	X		X			X		X	
89	12-4-67	0547	IIIF/7	5	34	0.017	0.500	0.085	2.460	23-24	X		X			X		X	
90	12-4-67	0715	IIIF/7	5	39	0.050	0.500	0.250	2.710	23-24	X		X			X		X	
91	12-4-67	0723	IIIF/7	3	42	0.100	0.500	0.300	3.010	23-24	X		X			X		X	

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
92	12-4-67	0733	IIIF/7	2	44	0.150	0 500	0 300	3.310	23-24	X		X			X		X	
93	12-4-67	0741	IIIF/7	1	45	1.000		1 000	4 310	23-24	X		X			X		X	
105	12-4-67	0837	IIU/9	5	6	0.014	0.186	0.070	1.070	23-24	X		X			X		X	
106	12-4-67	0902	IIU/9	5	11	0 017	0.183	0.085	1.155	23-24	X		X			X		X	
107	12-4-67	0920	IIU/9	5	16	0 050	0.150	0 250	1.405	23-24	X		X			X		X	
108	12-4-67	0929	IIU/9	3	19	0.100	0 100	0.300	1 705	23-24	X		X			X		X	
109	12-4-67	0938	IIU/9	2	21	0.150	0.050	0.300	2.005	23-24	X		X			X		X	
110	12-4-67	0948	IIU/9	5	26	0.014	0.500	0.070	2.075	23-24	X		X			X		X	
111	12-4-67	0958	IIU/9	5	31	0.017	0.500	0.085	2.160	23-24	X		X			X		X	
112	12-4-67	1020	IIU/9	5	36	0 050	0.500	0.250	2.410	23-24	X		X			X		X	S-257 failed closed
113	12-4-67	1112	IIU/9	3	39	0.100	0 500	0 300	2.710	23-24	X		X			X		X	
114	12-4-67	1124	IIU/9	2	41	0.150	0 500	0 300	3.010	23-24	X		X			X		X	
115	12-4-67	1136	IIU/9	1	42	1 000		1 000	4.010	23-24	X		X			X		X	
138	12-4-67	1238	IIS/12	5	8	0.014	0.186	0.070	3.070	23-24	X		X			X		X	
139	12-4-67	1304	IIS/12	5	13	0.017	0.183	0.085	3.155	23-24	X		X			X		X	
140	12-4-67	1326	IIS/12	5	18	0.050	0.150	0 250	3.405	23-24	X		X			X		X	
141	12-4-67	1339	IIS/12	3	21	0.100	0.100	0.300	3.705	23-24	X		X			X		X	
142	12-4-67	1351	IIS/12	2	23	0 150	0.050	0.300	4.005	23-24	X		X			X		X	
143	12-4-67	1402	IIS/12	5	28	0.014	0.500	0.070	4.075	23-24	X		X			X		X	
144	12-4-67	1420	IIS/12	5	33	0.017	0.500	0.085	4.160	23-24	X		X			X		X	
145	12-4-67	1433	IIS/12	5	38	0.050	0.500	0.250	4.410	23-24	X		X			X		X	
146	12-4-67	1446	IIS/12	3	41	0.100	0.500	0.300	4.710	23-24	X		X			X		X	
147	12-4-67	1457	IIS/12	2	43	0.150	0.500	0.300	5.010	23-24	X		X			X		X	
148	12-4-67	1508	IIS/12	1	44	1.000		1.000	6.010	23-24	X		X			X		X	
116	12-4-67	1556	IID/10	5	6	0.014	0 186	0 070	1.070	23-24	X		X			X		X	P-43 erratic
117	12-4-67	1616	IID/10	5	11	0.017	0.183	0.085	1.155	23-24	X		X			X		X	

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position: Main shutoffs O	Main shutoffs C	Cluster isolation O	Cluster isolation C	Inter-connects O	Inter-connects C	Cross feeds O	Cross feeds C	Remarks
118	12-4-67	1628	IID/10	5	16	0.050	0.150	0.250	1.405	23-24	X		X			X		X	
119	12-4-67	1643	IID/10	3	19	0.100	0.100	0.300	1.705	23-24	X		X			X		X	
120	12-4-67	1655	IID/10	2	21	0.150	0.050	0.300	2.005	23-24	X		X			X		X	
121	12-4-67	1709	IID/10	5	26	0.014	0.500	0.070	2.075	23-24	X		X			X		X	
122	12-4-67	1722	IID/10	5	31	0.017	0.500	0.085	2.160	23-24	X		X			X		X	
123	12-4-67	1734	IID/10	5	36	0.050	0.500	0.250	2.410	23-24	X		X			X		X	
124	12-4-67	1747	IID/10	3	39	0.100	0.500	0.300	2.710	23-24	X		X			X		X	
125	12-4-67	1900	IID/10	2	41	0.150	0.500	0.300	3.010	23-24	X		X			X		X	
126	12-4-67	1924	IID/10	1	42	1.000		1.000	4.010	23-24	X		X			X		X	
124A	12-4-67	2032	IID/10	3	45	0.100	0.500	0.300	4.310	23-24	X		X			X		X	Repeated to check P-43. Found error in P-52 cal.
127	12-4-67	2110	IIF/11	5	6	0.014	0.186	0.070	1.070	23-24	X		X			X		X	
128	12-4-67	2333	IIF/11	5	11	0.017	0.183	0.085	1.155	23-24	X		X			X		X	
129	12-4-67	2344	IIF/11	5	16	0.050	0.150	0.250	1.405	23-24	X		X			X		X	
130	12-4-67	2356	IIF/11	3	19	0.100	0.100	0.300	1.705	23-24	X		X			X		X	
131	12-5-67	0024	IIF/11	2	21	0.150	0.050	0.250	2.005	23-24	X		X			X		X	
132	12-5-67	0038	IIF/11	5	26	0.014	0.500	0.070	2.075	23-24	X		X			X		X	
133	12-5-67	0049	IIF/11	5	31	0.017	0.500	0.085	2.160	23-24	X		X			X		X	
134	12-5-67	0113	IIF/11	5	36	0.050	0.500	0.250	2.410	23-24	X		X			X		X	
135	12-5-67	0123	IIF/11	3	39	0.100	0.500	0.300	2.710	23-24	X		X			X		X	
136	12-5-67	0134	IIF/11	2	41	0.150	0.500	0.300	3.010	23-24	X		X			X		X	
137	12-5-67	0213	IIF/11	1	42	1.000		1.000	3.960	23-24	X		X			X		X	
149	12-5-67	0314	IU/13	5	9	0.014	0.186	0.070	4.580	23-24	X		X			X		X	
150	12-5-67	0333	IU/13	5	14	0.017	0.183	0.085	4.665	23-24	X		X			X		X	
151	12-5-67	0342	IU/13	5	19	0.050	0.150	0.250	4.915	23-24	X		X			X		X	
152	12-5-67	0352	IU/13	3	22	0.100	0.100	0.300	5.215	23-24	X		X			X		X	

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
153	12-5-67	0400	IU/13	2	24	0 150	0.050	0.300	5 515	23-24	X		X			X		X	
154	12-5-67	0409	IU/13	5	29	0 014	0.500	0.070	5 585	23-24	X		X			X		X	
155	12-5-67	0418	IU/13	5	34	0 017	0.500	0.085	5 670	23-24	X		X			X		X	No digital data recorded
156	12-5-67	0440	IU/13	5	39	0.050	0.500	0 250	5 920	23-24	X		X			X		X	
155A	12-5-67	0453	IU/13	5	44	0 017	0.500	0.085	6 005	23-24	X		X			X		X	
157	12-5-67	0501	IU/13	3	47	0.100	0 500	0.300	6.305	23-24	X		X			X		X	
158	12-5-67	0514	IU/13	2	49	0.150	0 500	0.300	6 605	23-24	X		X			X		X	
159	12-5-67	0524	IU/13	1	50	1.000		1 000	7.605	23-24	X		X			X		X	
171	12-5-67	0702	IF/15	5	6	0.014	0.186	0.070	1.070	23-24	X		X			X		X	
172	12-5-67	0714	IF/15	5	11	0 017	0.183	0.085	1.155	23-24	X		X			X		X	P-45 questionable
173	12-5-67	0722	IF/15	5	16	0.050	0.150	0 250	1.405	23-24	X		X			X		X	
174	12-5-67	0729	IF/15	3	19	0.100	0.100	0 300	1.705	23-24	X		X			X		X	
175	12-5-67	0738	IF/15	2	21	0.150	0.050	0.300	2.005	23-24	X		X			X		X	
176	12-5-67	0748	IF/15	5	26	0.014	0.500	0 070	2.075	23-24	X		X			X		X	
177	12-5-67	0756	IF/15	2	28	0.017	0.500	0.034	2.109	23-24	X		X			X		X	
177A	12-5-67	0802	IF/15	5	33	0.017	0.500	0.085	2 194	23-24	X		X			X		X	
178	12-5-67	0818	IF/15	5	38	0.050	0.500	0.250	2.444	23-24	X		X			X		X	
179	12-5-67	0826	IF/15	3	41	0.100	0.500	0.300	2.744	23-24	X		X			X		X	
180	12-5-67	0834	IF/15	2	43	0 150	0.500	0 300	3.044	23-24	X		X			X		X	
181	12-5-67	0842	IF/15	1	44	1 000		1.000	4.044	23-24	X		X			X		X	
160	12-5-67	0923	ID/14	5	8	0.014	0 186	0.070	3.070	23-24	X		X			X		X	P-31 bad
161	12-5-67	0945	ID/14	5	13	0.017	0.183	0.085	3.155	23-24	X		X			X		X	
162	12-5-67	1014	ID/14	5	18	0.050	0.150	0.250	3.405	23-24	X		X			X		X	
163	12-5-67	1024	ID/14	3	21	0.100	0.100	0.300	3 705	23-24	X		X			X		X	
164	12-5-67	1044	ID/14	2	22	0.150	0.050	0.300	4.005	23-24	X		X			X		X	
165	12-5-67	1054	ID/14	5	27	0.014	0.500	0.070	4.075	23-24	X		X			X		X	

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
166	12-5-67	1104	ID/14	5	32	0.017	0.500	0.085	4 160	23-24	X		X			X		X	
167	12-5-67	1115	ID/14	5	37	0.050	0.500	0.250	4.410	23-24	X		X			X		X	
168	12-5-67	1143	ID/14	3	41	0.100	0.500	0.300	4.710	23-24	X		X			X		X	
169	12-5-67	1153	ID/14	2	43	0 150	0.500	0.300	5 010	23-24	X		X			X		X	
170	12-5-67	1203	ID/14	1	44	1 000		1 000	6.010	23-24	X		X			X		X	
182	12-5-67	1315	IS/16	5	6	0 014	0.186	0.070	2.677	23-24	X		X			X		X	
183	12-5-67	1326	IS/16	5	11	0.017	0.183	0.085	2.762	23-24	X		X			X		X	
184	12-5-67	1337	IS/16	5	16	0.050	0.150	0 250	3.012	23-24	X		X			X		X	
185	12-5-67	1347	IS/16	3	19	0.100	0.100	0.300	3.312	23-24	X		X			X		X	
186	12-5-67	1357	IS/16	2	21	0.150	0 050	0.300	3.612	23-24	X		X			X		X	
187	12-5-67	1408	IS/16	5	26	0.014	0.500	0.070	3.682	23-24	X		X			X		X	
188	12-5-67	1419	IS/16	5	31	0 017	0.500	0.085	3.767	23-24	X		X			X		X	
189	12-5-67	1429	IS/16	5	36	0 050	0.500	0.250	4.017	23-24	X		X			X		X	
190	12-5-67	1440	IS/16	3	39	0 100	0.500	0.300	4.317	23-24	X		X			X		X	
191	12-5-67	1515	IS/16	2	41	0 150	0.500	0.300	4 617	23-24	X		X			X		X	
192	12-5-67	1530	IS/16	1	42	1.000		1.000	5 617	23-24	X		X			X		X	
29A	12-5-67	1619	IVD/2	5	47	0 017	0.133	0.085	4 095	23-24	X		X			X		X	Firing program mispatched
									Phase III — Mission Duty Cycles										
									Block A-1 — LM-1 Mission Phase 7 (Separation)										
1	12-5-67	2042	IVU/1	36	78	3.779		3.779	7.789	23-24	X		X			X		X	
			IVD/2	11	58	2 008		2.008	6.103										
			IVF/3	2	45	0 033		0.033	4.055										
			IVS/4	6	55	1.757		1.757	7.852										
			IIIU/5	15	63	1.132		1.132	6.227										
			IIID/6	24	66	2.125		2.125	6.135										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Interconnects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IIIF/7	2	47	0.032		0.032	4.342										
			IIIS/8	5	47	1.743		1.743	5 753										
			IIU/9	21	63	2.144		2.144	6.154										
			IID/10	7	52	1.063		1.063	5 373										
			IIF/11	2	44	0.030		0.030	3 990										
			IIS/12	6	50	1.759		1.759	7.769										
			IU/13	0	50	0.000		0.000	7.605										
			ID/14	26	70	1.422		1.422	7.432										
			IF/15	2	46	0.036		0.036	4.080										
			IS/16	5	47	1.802		1.802	7.419										
Phase III — Mission duty cycles																			
Block A-2 — LM-1 mission phase 9 (first DPS burn)																			
1	12-5-67	2127	IVU/1	29	107	1.969		1.969	9 758		X		X			X		X	
			IVD/2	11	69	1.092		1 092	7.195										
			IVF/3	2	47	0.032		0.032	4.087										
			IVS/4	2	57	0 032		0.032	7 884										
			IIIU/5	10	73	3.491		3.491	9.718										
			IIID/6	62	128	5.262		5.262	11.397										
			IIIF/7	2	49	0.033		0.033	4 375										
			IIIS/8	2	49	0 033		0.033	5 786										
			IIU/9	37	100	1 478		1.478	7 632										
			IID/10	0	52	0.000		0.000	5.373										
			IIF/11	2	46	0.032		0.032	4.022										
			IIS/12	2	52	0.033		0.033	7.802										
			IU/13	9	59	2.291		2.291	9.896										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			ID/14	8	78	2.844		2 844	10.276										
			IF/15	2	48	0.036		0.036	4.116										
			IS/16	2	49	0 035		0.035	7.454										
1A	12-5-67	2152	IVU/1	33	140	2.106		2.106	11.864	23-24	X		X			X		X	
			IVD/2	8	77	1 491		1.491	8 686										
			IVF/3	1	48	0 017		0 017	4.104										
			IVS/4	0	57	0 000		0.000	7 884										
			IIIU/5	9	82	2.263		2.263	11.981										
			IIID/6	44	172	2 534		2.534	13.931										
			IIIF/7	0	49	0.000		0 000	4.375										
			IIIS/8	1	50	0 085		0.085	5.871										
			IIU/9	19	119	1.668		1 668	9.300										
			IID/10	2	54	0 263		0.263	5.636										
			IIF/11	1	47	0.016		0 016	4.038										
			IIS/12	0	52	0 000		0 000	7.802										
			IU/13	2	61	0.143		0.143	10.039										
			ID/14	9	87	1 894		1 894	12.170										
			IF/15	0	48	0 000		0.000	4.116										
			IS/16	1	50	0 087		0 087	7.541										
Phase III — Mission duty cycles																			
Block A-3 — LM-1 mission phase II (second DPS burn-FITH-first APS burn)																			
1	12-5-67	2236	IVU/1	67	207	10 746		10.746	22.610	23-24	X		X			X		X	
			IVD/2	55	132	7.168		7.168	15.854										
			IVF/3	17	65	0.627		0 627	4.731										
			IVS/4	14	71	0.423		0.423	8.307										

Run no.	Date	Time, hr	Engine no. and location	No of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IIIU/5	68	150	7 649		7 649	19.630										
			IIID/6	115	287	15 714		15 714	29 645										
			IIIF/7	15	64	0.391		0.391	4 766										
			IIIS/8	17	67	1.138		1.138	7 009										
			IIU/9	78	197	12 246		12 246	21 546										
			IID/10	8	62	1.768		1.768	7 404										
			IIF/11	17	64	0.626		0 626	4 664										
			IIS/12	14	66	0 429		0.429	8 231										
			IU/13	21	82	3.219		3.219	13 258										
			ID/14	61	148	10.119		10.119	22 289										
			IF/15	15	63	0 423		0 423	4 539										
			IS/16	17	67	1 166		1 166	8.707										
								Phase III — Mission duty cycles											
								Block A-4 — LM-1 mission phase 13 (second APS burn)											
1	12-6-67	0013	IVU/1	32	239	0.832		0 832	23.442	23-24	X		X			X		X	
			IVD/2	102	234	13.308		13.308	29 162										
			IVF/3	12	77	0 304		0.304	5 035										
			IVS/4	8	79	0.185		0.185	8 492										
			IIIU/5	17	167	1.149		1.149	20.779										
			IIID/6	44	331	2.347		2.347	31 992										
			IIIF/7	9	73	0.268		0.268	5 034										
			IIIS/8	10	77	0.212		0.212	7.221										
			IIU/9	17	214	0.613		0.613	22 159										
			IID/10	158	220	29.509		29.509	36 913										
			IIF/11	11	75	0.271		0.271	4 935										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Interconnects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IIS/12	7	73	0.187		0.187	8.418										
			IV/13	2	84	0 388		0.388	13.646										
			ID/14	169	317	45 064		45.064	67.353										
			IF/15	6	69	0 116		0.116	4.655										
			IS/16	10	77	0.232		0.232	8 939										
									Phase IV — special duty cycles										
									Block B-1 — Two engine operation-simultaneous pulsing										
1	12-6-67	0346	IVS/4	10	89	0 017	0.183	0.170	8.662	23-24	X		X					X	
			IIS/12	10	83	0.017	0.183	0 170	8 588										
2	12-6-67	0449	IVS/4	10	99	0.050	0.150	0.500	9.162	23-24	X		X			X		X	
			IIS/12	10	93	0.050	0.150	0.500	9.088										
3	12-6-67	0509	IVS/4	10	109	0 150	0.050	1.500	10 662	23-24	X		X			X		X	
			IIS/12	10	103	0 150	0.050	1.500	10.588										
4	12-6-67	0522	IVS/4	1	110	0.200		0.200	10.862	23-24	X		X			X		X	
			IIS/12	1	104	0.200		0 200	10.788										
5	12-6-67	0820	IIIS/8	10	87	0 017	0 183	0.170	7.391	23-24	X		X			X		X	
			IS/16	10	87	0.017	0.183	0 170	9 109										
6	12-6-67	0844	IIIS/8	10	97	0 050	0.150	0.500	7.891	23-24	X		X			X		X	
			IS/16	10	97	0.050	0.150	0.500	9.609										
7	12-6-67	0854	IIIS/8	10	107	0.150	0.050	1 500	9.391	23-24	X		X			X		X	
			IS/16	10	107	0.150	0.050	1.500	11 109										
8	12-6-67	0907	IIIS/8	1	108	0.200		0.200	9.591	23-24	X		X			X		Y	
			IS/16	1	108	0.200		0.200	11.309										

Run no.	Date	Time, hr	Engine no. and location	No of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
Phase IV — special duty cycles																			
Block B-2 — four engine operation-simultaneous pulsing																			
1	12-6-67	1005	IVS/4	10	120	0.017	0 183	0.170	11.032	23-24	X		X			X		X	
			IIIS/8	10	118	0.017	0.183	0.170	9.761										
			IVD/2	10	244	0.017	0.183	0.170	29.332										
			IU/13	10	94	0.017	0 183	0.170	13.816										
2	12-6-67	1023	IVS/4	10	130	0.050	0 150	0.500	11.532	23-24	X		X			X		X	
			IIIS/8	10	128	0.050	0 150	0.500	10.261										
			IVD/2	10	254	0.050	0 150	0.500	29.832										
			IU/13	10	104	0.050	0 150	0.500	14.316										
3	12-6-67	1032	IVS/4	5	135	0 150	0.050	0.750	12 282	23-24	X		X			X		X	
			IIIS/8	5	133	0.150	0.050	0.750	11.011										
			IVD/2	5	259	0.150	0.050	0.750	30.582										
			IU/13	5	109	0.150	0.050	0.750	15.066										
4	12-6-67	1041	IVS/4	1	136	0.200		0.200	12 482	23-24	X		X			X		X	
			IIIS/8	1	134	0.200		0 200	11.211										
			IVD/2	1	260	0.200		0 200	30.782										
			IU/13	1	110	0.200		0.200	15.266										
Phase IV — special duty cycles																			
Block B-3 — four engine operation-two engines pulsing, two steady state																			
1	12-6-67	1107	IVS/4	1	137	0.817		0.817	13.299	23-24	X		X			X		X	
			IIIS/8	1	135	0.817		0.817	12 028										
			IVD/2	5	265	0.017	0 183	0 085	30.867										
			IU/13	5	115	0.017	0.183	0.085.	15.351										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Interconnects		Cross feeds		
											O	C	O	C	O	C	O	C	
									Phase IV — special duty cycles										
								Block D-1 — pressure switch evaluation, start on-times											
1	12-6-67	2123	IVD/2	50	315	0.014	0 186	0 700	31 567	23-24	X		X			X		X	
			IIIS/8	50	185	0.014	0.186	0.700	12.728										
			IVS/4	50	187	0.014	0.186	0.700	13.999										
			IIF/11	50	125	0.014	0 186	0 700	5.635										
2	12-6-67	2236	IVD/2	50	365	0.014	0.186	0.700	32.267	20-21	X		X			X		X	
			IIIS/8	50	235	0.014	0.186	0.700	13.428										
			IVS/4	50	237	0.014	0 186	0.700	14.699										
			IIF/11	50	175	0.014	0.186	0.700	6.335										
									Phase IV — special duty cycles										
								Block D-2 — pressure switch evaluation, off-limits											
2	12-6-67	2250	IVD/2	50	415	0 014	0.036	0.700	32.967	20-21	X		X			X		X	
			IIIS/8	50	285	0.014	0.036	0.700	14.128										
			IVS/4	50	287	0.014	0.036	0.700	15.399										
			IIF/11	50	225	0 014	0 036	0.700	7.035										
									Phase IV — special duty cycles										
								Block D-3 — pressure switch evaluation, start on-times											
1	12-6-67	2302	IVD/2	20	435	0 012	2.500	0.240	33.207	20-21	X		X			X		X	
			IIIS/8	20	305	0.012	2.500	0.240	14.368										
			IVS/4	20	307	0.012	2.500	0.240	15.639										
			IIF/11	20	245	0.012	2 500	0 240	7 275										
								Block D-2 — continued											
1	12-6-67	2323	IVD/2	50	485	0.014	0 036	0.700	33.907										
			IIIS/8	50	355	0.014	0.036	0.700	15.068										

Run no.	Date	Time, hr	Engine no. and Location	No. of pulses	Cumu- lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu- lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks .
											Main shutoffs		Cluster isolation		Inter- connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVS/4 IIF/11	50 50	357 295	0.014 0.014	0.036 0.036	0.700 0.700	16.339 7.975										
Block D-3 — continued																			
2	12-6-67	2346	IVD/2	20	505	0.012	2.500	0.240	34.147	23-24	X		X			X		X	
			IIIS/8	20	375	0.012	2.500	0.240	15.308										
			IVS/4	20	377	0.012	2.500	0.240	16 579										
			IIF/11	20	315	0.012	2.500	0.240	8.215										
Phase IV — special duty cycles																			
Block D-5 — pressure switch evaluation, oxidizer cold flows																			
6	12-7-67	0101	IVD/2	1	506	0.100		0.100	34.247	^{b}12	X		X			X		X	
			IIIS/8	1	376	0.100		0 100	15.408										
			IIS/4	1	378	0.100		0.100	16.679										
			IIF/11	1	316	0.100		0 100	8 315										
2	12-7-67	0245	IIIS/8	10	386	0.075	0.125	0 750	16 158	^{b}12	X		X			X		X	
3	12-7-67	0301	IIS/4	10	388	0.075	0.125	0 075	17 429	^{b}12	X		X			X		X	
Phase IV — special duty cycles																			
Block H-1 — pulse width of less than minimum impulse, engine III S/8																			
1	12-7-67	0537	IVS/4	1	389	0.004	2.500	0.004	17.433	23-24	X		X			X		X	
				1	390	0.004	2.500	0.004	17 437										
				1	391	0.020		0.020	17.457										
2	12-7-67	0553	IVS/4	1	392	0.006	2.500	0.006	17 463	23-24	X		X			X		X	
				1	393	0.006	2.500	0.006	17.469										
				1	394	0.020		0.020	17.489										
3	12-7-67	0711	IVS/4	1	395	0.007	2.500	0.007	17.496	23-24	X		X			X		X	

[b] On direct coil only.

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Interconnects		Cross feeds		
											O	C	O	C	O	C	O	C	
				1	396	0.007	2 500	0.007	17.503										
				1	397	0 020		0.020	17.523										
4	12-7-67	0733	IVS/4	1	398	0.008	2.500	0.008	17.531	23-24	X		X			X		X	
				1	399	0.008	2.500	0.008	17.539										
				1	400	0.020		0.020	17.559										
5	12-7-67	0747	IVS/4	1	401	0.009	2.500	0 009	17.568	23-24	X		X			X		X	
				1	402	0.009	2 500	0.009	17.577										
				1	403	0 020		0 020	17.597										
6	12-7-67	0806	IVS/4	1	404	0.010	2.500	0.010	17 607	23-24	X		X			X		X	
				1	405	0.010	2.500	0.010	17 617										
				1	406	0.020	0.020		17.637										

Phase IV — special duty cycles

Block H-2 — pulse width of less than minimum impulse, engine II F/11

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Main shutoffs O	Main shutoffs C	Cluster isolation O	Cluster isolation C	Interconnects O	Interconnects C	Cross feeds O	Cross feeds C	Remarks
7	12-7-67	0845	IIF/11	1	317	0.004	2.500	0 004	8.319	23-24	X		X			X		X	
				1	318	0.004	2.500	0.004	8.323										
				1	319	0.020		0.020	8.343										
8	12-7-67	0940	IIF/11	1	320	0.006	2.500	0.006	8.349	23-24	X		X			X		X	
				1	321	0.006	2.500	0.006	8.355										
				1	322	0.020		0.020	8.375										
9	12-7-67	0958	IIF/11	1	323	0 007	2.500	0.007	8.382	23-24	X		X			X		X	
				1	324	0.007	2.500	0.007	8.389										
				1	325	0 020		0.020	8.409										
10	12-7-67	1013	IIF/11	1	326	0.008	2.500	0.008	8.417	23-24	X		X			X		X	
				1	327	0.008	2.500	0.008	8.425										
				1	328	0.020		0.020	8 445										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position: Main shutoffs O	Main shutoffs C	Cluster isolation O	Cluster isolation C	Inter-connect. O	Inter-connect. C	Cross feed O	Cross feed C	Remarks
11	12-7-67	1023	IIF/11	1	329	0.009	2.500	0.009	8.454	23-24	X		X			X		X	
				1	330	0.009	2.500	0.009	8.463										
				1	331	0.020		0.020	8.483										
12	12-7-67	1033	IIF/12	1	104	0.010	2.500	0.010	10.798	23-24	X		X			X		X	
				1	105	0.010	2.500	0.010	10.808										
				1	106	0.020		0.020	10.828										
Phase IV — special duty cycles Block L-1 — short pulse width cooling effects, insulated engine.																			
1	12-7-67	1522	IIID/6	50	381	0.017	0.183	0.850	32.842	23-24	X		X			X		X	
2	12-7-67	1656	IIID/6	50	431	0.017	0.283	0.850	33.692	23-24	X		X			X		X	
3	12-7-67	1713	IIID/6	50	481	0.017	0.383	0.850	34.542	23-24	X		X			X		X	
4	12-7-67	1727	IIID/6	50	531	0.017	0.483	0.850	35.392	23-24	X		X			X		X	
5	12-7-67	1742	IIID/6	50	581	0.017	0.983	0.850	36.242	23-24	X		X			X		X	
6	12-7-67	1853	IIID/6	50	631	0.017	2.500	0.850	37.092	23-24	X		X			X		X	S-256 failed
Phase IV — special duty cycles Block M-1 — cluster insulation evaluation, insulated engine																			
1	12-7-67	1911	IIID/6	1	632	20.000		20.000	57.092	23-24	X		X			X		X	
				10	642	0.017	0.183	0.170	57.262										
Phase IV — special duty cycles Block L-2 — short pulse width cooling effects, uninsulated engine																			
1	12-7-67	1948	ID/14	50	367	0.017	0.183	0.850	68.203	23-24	X		X			X		X	
2	12-7-67	2013	ID/14	50	417	0.017	0.283	0.850	69.053	23-24	X		X			X		X	
3	12-7-67	2025	ID/14	50	467	0.017	0.383	0.850	69.903	23-24	X		X			X		X	
4	12-7-67	2037	ID/14	50	517	0.017	0.483	0.850	70.753	23-24	X		X			X		X	

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
5	12-7-67	2112	ID/14	50	567	0 017	0.983	0 850	71.603	23-24	X		X			X		X	
6	12-7-67	2124	ID/14	50	617	0.017	2.500	0.850	72.453	23-24	X		X			X		X	
Phase IV — special duty cycles																			
Block M-2 — cluster insulation evaluation, uninsulated engine																			
2	12-7-67	2200	ID/14	1	618	20 000		20.000	92.453	23-24	X		X			X		X	
				10	628	0.017	0.183	0 170	92.623										
Phase IV — special duty cycles																			
Block B-3 — two engines pulsing, two engines steady state																			
2	12-8-67	0151	IVS/4	1	407	0 850		0.850	18.487	23-24	X		X			X		X	
			IIIS/8	1	387	0.850		0 850	17 008										
			IVD/2	5	511	0.050	0.150	0.250	34.497										
			IU/13	5	120	0.050	0.150	0.250	15 516										
3	12-8-67	0245	IVS/4	1	408	0.550		0.550	19 037	23-24	X		X			X		X	
			IIIS/8	1	388	0.550		0 550	17 558										
			IVD/2	3	514	0 150	0.050	0.450	34.947										
			IU/13	3	123	0 150	0.050	0.450	15.966										
Phase IV — special duty cycles																			
Block B-4 — four engine operation, pulsing out of phase																			
1	12-8-67	0410	IVD/2	10	524	0 017	0.183	0.170	35.117	23-24	X		X			X		X	Engines 4 and 12 lead engines 2 and 13 by 50 msec (1 through 5)
			IU/13	10	133	0.017	0.183	0.170	16 136										
			IVS/4	10	418	0.054	0 146	0 540	19.577										
			IIS/12	10	116	0 054	0.146	0.540	11 368										
2	12-8-67	0443	IVD/2	10	534	0.017	0.183	0.170	35 287	23-24	X		X			X		X	
			IU/13	10	143	0.017	0.183	0.170	16.306										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVS/4	10	428	0.050	0 150	0.500	20.077										
			IIS/12	10	126	0 050	0 150	0.500	11.868										
3	12-8-67	0456	IVD/2	10	544	0 017	0 183	0.170	35 457	23-24	X		X			X		X	
			IU/13	10	153	0.017	0 183	0.170	16.476										
			IVS/4	10	438	0.048	0.152	0.480	20.557										
			IIS/12	10	136	0.048	0.152	0.480	12.348										
4	12-8-67	0506	IVD/2	10	554	0.017	0.133	0.170	35 627	23-24	X		X			X		X	Program mispatch
			IU/13	10	163	0.017	0 133	0.170	16.646										
			IVS/4	10	448	0.046	0 154	0.460	21.017										
			IIS/12	10	146	0 046	0 154	0.460	12 808										
5	12-8-67	0521	IVD/2	10	564	0.017	0 133	0.170	35 797	23-24	X		X			X		X	Program mispatch
			IU/13	10	173	0.017	0.133	0.170	16.816										
			IVS/4	10	458	0.044	0.156	0.440	21.457										
			IIS/12	10	156	0 044	0.156	0.440	13.248										
6	12-8-67	0538	IVD/2	5	569	0.050	0 150	0.250	36 047	23-24	X		X			X		X	Engines 4 and 12 lead engines 2 and 13 by 100 msec (6 through 10)
			IU/13	5	178	0.050	0 150	0.250	17 066										
			IVS/4	5	463	0 104	0 096	0.520	21 977										
			IIS/12	5	161	0.104	0 096	0.520	13 768										
7	12-8-67	0550	IVD/2	5	574	0 050	0 150	0 250	36 297	23-24	X		X			X		X	
			IU/13	5	183	0 050	0.150	0.250	17.316										
			IVS/4	5	468	0 100	0.100	0 500	22 477										
			IIS/12	5	166	0 100	0.100	0 500	14 268										
8	12-8-67	0709	IVD/2	5	579	0.050	0 150	0.250	36.547	23-24	X		X			X		X	
			IU/13	5	188	0 050	0.150	0 250	17.566										
			IVS/4	5	473	0.098	0.102	0.490	22.967										
			IIS/12	5	171	0 098	0.102	0 490	14.758										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
9	12-8-67	0720	IVD/2	5	584	0.050	0.150	0.250	36.797	23-24	X		X			X		X	
			IU/13	5	193	0 050	0 150	0.250	17.816										
			IVS/4	5	478	0.096	0.104	0.480	23.447										
			IIS/12	5	176	0.096	0.104	0.480	15.238										
10	12-8-67	0729	IVD/2	5	589	0 050	0 150	0.250	37.047	23-24	X		X			X		X	
			IU/13	5	198	0.050	0.150	0.250	18.066										
			IVS/4	5	483	0.094	0.106	0.470	23.917										
			IIS/12	5	181	0 094	0 106	0.470	15.708										
Phase IV — special duty cycles																			
Block B-5 — six engine operation, simultaneous pulsing																			
1	12-8-67	0943	IIF/11	10	341	0.017	0.183	0.170	8.653	23-24	X		X			X		X	
			IIIF/7	10	83	0.017	0.183	0.170	5.204										
			IID/10	10	230	0.017	0.183	0.170	37.083										
			IU/13	10	208	0.017	0.183	0.170	18.236										
			IVU/1	10	249	0.017	0.183	0.170	23.612										
			IIID/6	10	652	0.017	0.183	0.170	57.432										
2	12-8-67	1002	IIF/11	5	346	0.050	0.150	0.250	8.903	23-24	X		X			X		X	
			IIIF/7	5	88	0.050	0.150	0.250	5.454										
			IID/10	5	235	0.050	0.150	0.250	37.333										
			IU/13	5	213	0.050	0.150	0.250	18.486										
			IVU/1	5	254	0.050	0.150	0.250	23.862										
			IIID/6	5	657	0.050	0.150	0.250	57.682										
3	12-8-67	1024	IIF/11	3	349	0.150	0.050	0.450	9.353	23-24	X		X			X		X	
			IIIF/7	3	91	0.150	0.050	0.450	5.904										
			IID/10	3	238	0.150	0.050	0.450	37.783										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position: Main shutoffs		Cluster isolation		Interconnects		Cross feeds		Remarks
											O	C	O	C	O	C	O	C	
			IU/13	3	216	0.150	0.050	0.450	18.936										
			IVU/1	3	257	0.150	0.050	0.450	24.312										
			IIID/6	3	660	0.150	0.050	0.450	58.132										
4	12-8-67	1035	IIF/11	1	350	0.200		0.200	9 553	23-24	X		X			X		X	
			IIIF/7	1	92	0.200		0.200	6.104										
			IID/10	1	239	0.200		0.200	37.983										
			IU/13	1	217	0.200		0.200	19.136										
			IVU/1	1	258	0 200		0 200	24.512										
			IIID/6	1	661	0.200		0.200	58.332										
Phase IV — special duty cycles																			
Block B-6 — six engine operation - four engines pulsing, two steady state																			
1	12-8-67	1056	IIF/11	1	351	0.570		0.570	10.123	23-24	X		X			X		X	
			IIIF/7	1	93	0.570		0.570	6.674										
			IID/10	3	242	0.017	0.183	0 051	38.034										
			IU/13	3	220	0.017	0.183	0.051	19.187										
			IVU/1	3	261	0.017	0 183	0.051	24.563										
			IIID/6	3	664	0 017	0.183	0.051	58.383										
2	12-8-67	1118	IIF/11	1	352	0 450		0 450	10.573	23-24	X		X			X		X	
			IIIF/7	1	94	0.450		0.450	7.124										
			IID/10	3	245	0.050	0.150	0.150	38.184										
			IU/13	3	223	0 050	0.150	0 150	19.337										
			IVU/1	3	264	0.050	0.150	0.150	24.713										
			IIID/6	3	667	0.050	0.150	0 150	58.533										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
Phase IV — special duty cycles																			
Block B-7 — eight engine operation, pulsing out of phase																			
1	12-8-67	1422	IID/10	5	250	0.054	0.146	0.270	38.454	23-24	X		X			X		X	NOTE. Engines 10, 13, 1, and 6 lead engines 11, 16, 3, and 8 by 50 msec in runs 1 to 5 and by 100 msec in runs 6 to 10
			IU/13	5	228	0.054	0 146	0.270	19.607										
			IVU/1	5	269	0.054	0.146	0.270	24.983										
			IIID/6	5	672	0.054	0.146	0.270	58 803										
			IIF/11	5	357	0.017	0.183	0.085	10 658										
			IS/16	5	82	0 017	0.183	0.085	9.024										
			IVF/3	5	82	0.017	0.183	0.085	5.120										
			IIIS/8	5	393	0.017	0.183	0 085	17.643										
2	12-8-67	1524	IID/10	5	255	0.050	0.150	0.250	38 704	23-24	X		X			X		X	
			IU/13	5	233	0.050	0.150	0 250	19 857										
			IVU/1	5	274	0.050	0 150	0.250	25 233										
			IIID/6	5	677	0.050	0.150	0.250	59 053										
			IIF/11	5	362	0.017	0 133	0.085	10 743										Program mispatch
			IS/16	5	87	0.017	0 133	0 085	9.109										
			IVF/3	5	87	0 017	0.133	0 085	5 205										
			IIIS/8	5	398	0.017	0.133	0.085	17.728										
3	12-8-67	1541	IID/10	5	260	0.048	0.152	0.240	38.944	23-24	X		X			X		X	
			IU/13	5	238	0.048	0.152	0.240	20 097										
			IVU/1	5	279	0.048	0 152	0.240	25.473										
			IIID/6	5	682	0 048	0.152	0.240	59.293										
			IIF/11	5	367	0.017	0.183	0.085	10.828										
			IS/16	5	92	0.017	0.183	0.085	9.194										

Run no.	Date	Time, hr	Engine no and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVF/3	5	92	0.017	0.183	0.085	5.290										
			IIIS/8	5	403	0.017	0.183	0.085	17.813										
4	12-8-67	1554	IID/10	5	265	0.046	0.154	0.230	39.174	23-24	X		X			X		X	
			IU/13	5	243	0.046	0.154	0.230	20.327										
			IVU/1	5	284	0.046	0.154	0.230	25.703										
			IIID/6	5	687	0.046	0.154	0.230	59.523										
			IIF/11	5	372	0.017	0.183	0.085	10.913										
			IS/16	5	97	0.017	0.183	0.085	9.279										
			IVF/3	5	97	0.017	0.183	0.085	5.375										
			IIIS/8	5	408	0.017	0.183	0.085	17.898										
5	12-8-67	1606	IID/10	5	270	0.044	0.156	0.220	39.394	23-24	X		X			X		X	
			IU/13	5	248	0.044	0.156	0.220	20.547										
			IVU/1	5	289	0.044	0.156	0.220	25.923										
			IIID/6	5	692	0.044	0.156	0.220	59.743										
			IIF/11	5	377	0.017	0.183	0.085	10.998										
			IS/16	5	102	0.017	0.183	0.085	9.364										
			IVF/3	5	102	0.017	0.183	0.085	5.460										
			IIIS/8	5	413	0.017	0.183	0.085	17.983										
6	12-8-67	1618	IID/10	3	273	0.104	0.096	0.312	39.706	23-24	X		X			X		X	
			IU/13	3	251	0.104	0.096	0.312	20.859										
			IVU/1	3	292	0.104	0.096	0.312	26.235										
			IIID/6	3	695	0.104	0.096	0.312	60.055										
			IIF/11	3	380	0.050	0.150	0.150	11.148										
			IS/16	3	105	0.050	0.150	0.150	9.514										
			IVF/3	3	105	0.050	0.150	0.150	5.610										
			IIIS/8	3	416	0.050	0.150	0.150	18.133										

Run no.	Date	Time, hr	Engine no. and location	No of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
7	12-8-67	1630	IID/10	3	276	0.100	0 100	0.300	40.206	23-24	X		X			X		X	
			IU/13	3	254	0.100	0.100	0.300	21.159										
			IVU/1	3	295	0.100	0.100	0 300	26 535										
			IIID/6	3	698	0 100	0.100	0.300	60.355										
			IIF/11	3	383	0.050	0.150	0.150	11 298										
			IS/16	3	108	0.050	0.150	0.150	9 664										
			IVF/3	3	108	0.050	0.150	0.150	5 760										
			IIIS/8	3	419	0.050	0.150	0.150	18 283										
8	12-8-67	1640	IID/10	3	279	0.098	0.102	0.294	40 300	23-24	X		X			X		X	
			IU/13	3	257	0.098	0.102	0.294	21.453										
			IVU/1	3	298	0.098	0 102	0.294	26.829										
			IIID/6	3	701	0.098	0.102	0.294	60.649										
			IIF/11	3	386	0.050	0 150	0.150	11.448										
			IS/16	3	111	0.050	0 150	0.150	9.814										
			IVF/3	3	111	0.050	0.150	0.150	5.910										
			IIIS/8	3	422	0.050	0.150	0.150	18.433										
9	12-8-67	1649	IID/10	3	282	0.096	0.104	0.288	40.588	23-24	X		X			X		X	
			IU/13	3	260	0.096	0.104	0.288	21 741										
			IVU/1	3	301	0.096	0.104	0.288	27.117										
			IIID/6	3	704	0.096	0.104	0.288	60.937										
			IIF/11	3	389	0.050	0.150	0.150	11.598										
			IS/16	3	114	0.050	0.150	0.150	9.964										
			IVF/3	3	114	0.050	0.150	0.150	6.060										
			IIIS/8	3	425	0.050	0.150	0.150	18 583										
10	12-8-67		IID/10	3	285	0.094	0.106	0.282	40 870	23-24	X		X			X		X	
			IU/13	3	263	0.094	0.106	0.282	22.023										

Run no.	Date	Time, hr	Engine no and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVU/1	3	304	0.094	0.106	0.282	27.399										
			IIID/6	3	707	0.094	0.106	0.282	61.219										
			IIF/11	3	392	0.050	0.150	0.150	11.748										
			IS/16	3	117	0.050	0.150	0.150	10.114										
			IVF/3	3	117	0.050	0.150	0.150	6.210										
			IIIS/8	3	428	0.050	0.150	0.150	18.733										
					Phase IV - Block B-8 — Eight engine operation, simultaneous pulsing														
1	12-8-67	1952	IVS/4	10	493	0.017	0.183	0.170	24.087	23-24	X		X			X		X	
			IF/15	10	79	0.017	0.183	0.170	4.825										
			IIS/12	10	191	0.017	0.183	0.170	15.878										
			IIIF/7	10	104	0.017	0.183	0.170	7.294										
			IVD/2	10	599	0.017	0.183	0.170	37.217										
			IID/10	10	295	0.017	0.183	0.170	41.040										
			IIID/6	10	717	0.017	0.183	0.170	61.389										
			ID/14	10	638	0.017	0.183	0.170	92.793										
2	12-8-67	2005	IVS/4	5	498	0.050	0.150	0.250	24.337	23-24	X		X			X		X	
			IF/15	5	84	0.050	0.150	0.250	5.075										
			IIS/12	5	196	0.050	0.150	0.250	16.128										
			IIIF/7	5	109	0.050	0.150	0.250	7.544										
			IVD/2	5	604	0.050	0.150	0.250	37.467										
			IID/10	5	300	0.050	0.150	0.250	41.290										
			IIID/6	5	722	0.050	0.150	0.250	61.639										
			ID/14	5	643	0.050	0.150	0.250	93.043										
3	12-8-67	2111	IVS/4	1	499	0.200		0.200	24.537	23-24	X		X			X		X	
			IF/15	1	85	0.200		0.200	5.275										

Run no.	Date	Time, hr	Engine no and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IIS/12	1	197	0.200		0.200	16.328										
			IIIF/7	1	110	0.200		0.200	7.744										
			IVD/2	1	605	0.200		0.200	37.667										
			IID/10	1	301	0.200		0.200	41.490										
			IIID/6	1	723	0.200		0.200	61.839										
			ID/14	1	644	0.200		0.200	93.243										
					Phase IV - Block B-9 — Eight engine operation — four engine pulsing, four steady state														
1	12-8-67	2121	IVS/4	3	502	0.017	0.183	0.051	24.588	23-24	X		X			X		X	
			IF/15	3	88	0.017	0 183	0.051	5.326										
			IIS/12	3	200	0.017	0.183	0.051	16.379										
			IIIF/7	3	113	0.017	0 183	0.051	7.795										
			IVD/2	1	606	0.417		0.417	38 084										
			IID/10	1	302	0.417		0.417	41.907										
			IIID/6	1	724	0.417		0.417	62.256										
			ID/14	1	645	0 417		0.417	93.660										
2	12-8-67	2129	IVS/4	3	505	0.050	0.150	0.150	24.738	23-24	X		X			X		X	
			IF/15	3	91	0.050	0.150	0.150	5.476										
			IIS/12	3	203	0.050	0.150	0.150	16.529										
			IIIF/7	3	116	0.050	0.150	0.150	7.945										
			IVD/2	1	607	0.450		0.450	38.534										
			IID/10	1	303	0.450		0.450	42.357										
			IIID/6	1	725	0.450		0.450	62.706										
			ID/14	1	646	0.450		0.450	94 110										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
					Phase IV - Block B-10 — Eight engine operation, pulsing out of phase														
1	12-8-67	2214	IVD/2	5	612	0.054	0 146	0 270	38.804	23-24	X		X			X		X	NOTE Engines 2, 13, 6, and 9, lead engines 4, 15, 7, and 12 by 50 msec in runs 1 to 5 and by 100 msec in runs 6 to 10
			IU/13	5	268	0.054	0 146	0.270	22.293										
			IIID/6	5	730	0.054	0 146	0.270	62.976										
			IIU/9	5	219	0.054	0.146	0.270	22.429										
			IVS/4	5	510	0.017	0.183	0.085	24.823										
			IF/15	5	96	0.017	0.183	0.085	5.561										
			IIIF/7	5	121	0.017	0.183	0.085	8.030										
			IIS/12	5	208	0.017	0.183	0.085	16.614										
2	12-8-67	2221	IVD/2	5	617	0.050	0.150	0 250	39.054	23-24	X		X			X		X	
			IU/13	5	273	0.050	0.150	0 250	22 543										
			IIID/6	5	735	0 050	0.150	0.250	63.226										
			IIU/9	5	224	0.050	0.150	0.250	22.679										
			IVS/4	5	515	0.017	0.183	0.085	24 908										
			IF/15	5	101	0.017	0.183	0.085	5.646										
			IIIF/7	5	126	0.017	0.183	0.085	8.115										
			IIS/12	5	213	0.017	0.183	0.085	16.699										
3	12-8-67	2227	IVD/2	5	622	0.048	0 152	0.240	39.294	23-24	X		X			X		X	
			IU/13	5	278	0.048	0.152	0.240	22.783										
			IIID/6	5	740	0.048	0.152	0.240	63.466										
			IIU/9	5	229	0.048	0.152	0.240	22.919										
			IVS/4	5	520	0.017	0.183	0.085	24.993										
			IF/15	5	106	0.017	0.183	0.085	5.731										
			IIIF/7	5	131	0.017	0.183	0.085	8.200										
			IIS/12	5	218	0 017	0.183	0.085	16.784										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu- lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu- lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter- connects		Cross feeds		
											O	C	O	C	O	C	O	C	
4	12-8-67	2247	IVD/2	5	627	0 046	0.154	0.230	39 524	23-24	X		X			X		X	
			IU/13	5	283	0.046	0.154	0.230	23 013										
			IIID/6	5	745	0.046	0.154	0.230	63 696										
			IIU/9	5	234	0.046	0.154	0.230	23.149										
			IVS/4	5	525	0.017	0.183	0 085	25.078										
			IF/15	5	111	0.017	0 183	0.085	5 816										
			IIIF/7	5	136	0.017	0.183	0.085	8.285										
			IIS/12	5	223	0.017	0.183	0.085	16.869										
5	12-8-67	2252	IVD/2	5	632	0.044	0.156	0.220	39.744	23-24	X		X			X		X	
			IU/13	5	288	0.044	0.156	0.220	23 233										
			IIID/6	5	750	0.044	0.156	0.220	63 916										
			IIU/9	5	239	0.044	0.156	0.220	23.369										
			IVS/4	5	530	0.017	0 183	0.085	25.163										
			IF/15	5	116	0.017	0.183	0.085	5.901										
			IIIF/7	5	141	0.017	0.183	0.085	8.370										
			IIS/12	5	228	0.017	0 183	0.085	16.954										
6	12-8-67	2302	IVD/2	3	635	0.104	0.096	0.312	40.056	23-24	X		X			X		X	
			IU/13	3	291	0.104	0.096	0.312	23 545										
			IIID/6	3	753	0.104	0.096	0.312	64.228										
			IIU/9	3	242	0.104	0.096	0.312	23.681										
			IVS/4	3	533	0.050	0.150	0.150	25 313										
			IF/15	3	119	0.050	0.150	0.150	6 051										
			IIIF/7	3	144	0 050	0.150	0 150	8.520										
			IIS/12	3	231	0.050	0.150	0.150	17 104										
7	12-8-67	2307	IVD/2	3	638	0.100	0.100	0.300	40 356	23-24	X		X			X		X	
			IU/13	3	294	0.100	0.100	0.300	23.845										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IIID/6	3	756	0.100	0.100	0.300	64 528										
			IIU/9	3	245	0.100	0.100	0.300	23.981										
			IVS/4	3	536	0.050	0.150	0.150	25.463										
			IF/15	3	122	0.050	0.150	0.150	6 201										
			IIIF/7	3	147	0 050	0.150	0.150	8.67										
			IIS/12	3	234	0.050	0.150	0.150	17 254										
8	12-8-67	2314	IVD/2	3	641	0.098	0.102	0.294	40 650	23-24	X		X			X		X	
			IU/13	3	297	0.098	0.102	0.294	24.139										
			IIID/6	3	759	0.098	0.102	0.294	64 822										
			IIU/9	3	248	0.098	0 102	0.294	24.275										
			IVS/4	3	539	0.050	0 150	0.150	25 613										
			IF/15	3	125	0.050	0 150	0.150	6 351										
			IIIF/7	3	150	0.050	0 150	0.150	8 82										
			IIS/12	3	237	0.050	0 150	0.150	17 404										
9	12-8-67	2321	IVD/2	3	644	0.096	0.104	0.288	40.938	23-24	X		X			Y		X	
			IU/13	3	300	0.096	0 104	0.288	24.427										
			IIID/6	3	762	0.096	0.104	0.288	65 110										
			IIU/9	3	251	0.096	0.104	0.288	24.563										
			IVS/4	3	542	0.050	0.150	0.150	25 763										
			IF/15	3	128	0.050	0.150	0 150	6 501										
			IIIF/7	3	153	0.050	0.150	0.150	8 97										
			IIS/12	3	240	0.050	0.150	0.150	17.554										
10	12-8-67	2328	IVD/2	3	647	0.094	0.106	0.282	41 220	23-24	X		X			X		X	
			IU/13	3	303	0.094	0.106	0.282	24.709										
			IIID/6	3	765	0.094	0.106	0.282	65.392										
			IIU/9	3	254	0.094	0.106	0.282	24.845										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVS/4	3	545	0.050	0.150	0.150	25 913										
			IF/15	3	131	0 050	0.150	0.150	6.651										
			IIIF/7	3	156	0.050	0.150	0.150	9.12										
			IIS/12	3	243	0.050	0 150	0.150	17.704										
					Phase IV - Block C-2 — Four engine operation, simultaneous pulsing														
1	12-9-67	0151	IVS/4	10	555	0.017	0.183	0.170	26.083	23-24	A	B	X			X	X		Hydraulic transient effects with cross feeds open and system B main shutoff valves closed.
			IIIS/8	10	438	0.017	0.183	0.170	18.903										
			IVD/2	10	657	0.017	0.183	0.170	41.390										
			IU/13	10	313	0.017	0 183	0.170	24.879										
2	12-9-67	0209	IVS/4	10	565	0.050	0.150	0.500	26.583	23-24	A	B	X			X	X		
			IIIS/8	10	448	0.050	0.150	0.500	19.403										
			IVD/2	10	667	0.050	0.150	0 500	41 890										
			IU/13	10	323	0.050	0.150	0.500	25.379										
3	12-9-67	0217	IVS/4	5	570	0.150	0.050	0.750	27.333	23-24	A	B	X			X	X		
			IIIS/8	5	453	0.150	0.050	0.750	20.153										
			IVD/2	5	672	0.150	0 050	0.750	42.640										
			IU/13	5	328	0.150	0.050	0.750	26.129										
4	12-9-67	0222	IVS/4	1	571	0.200		0.200	27.533	23-24	A	B	X			X	X		
			IIIS/8	1	454	0.200		0.200	20.353										
			IVD/2	1	673	0.200		0.200	42.840										
			IU/13	1	329	0.200		0.200	26.329										
					Phase IV - Block C-3 — Four engine operation — two engines pulsing, two steady state														
1	12-9-67	0232	IVS/4	1	572	0.817		0.817	28.350	23-24	A	B	X			X	X		
			IIIS/8	1	455	0.817		0.817	21.170										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position: Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		Remarks
											O	C	O	C	O	C	O	C	
3	12-9-67	0239	IVD/2	5	678	0.017	0.183	0.085	42.925	23-24	A	B	X			X	X		
			IU/13	5	334	0 017	0.183	0.085	26.414										
			IVS/4	1	573	0.550		0.550	28.900										
			IIIS/8	1	456	0.550		0.550	21.720										
			IVD/2	3	681	0.150	0.050	0.450	43.375										
			IU/13	3	337	0.150	0.050	0.450	26.864										
					Phase IV - Block C-4 — Four engine operation, pulsing out of phase														
1	12-9-67	0342	IVD/2	10	691	0 017	0 183	0.170	43.545	23-24	A	B	X			X	X		NOTE. Engines 4 and 12 lead engines 2 and 13 by 50 msec in runs 1 to 5 and by 100 msec in runs 6 to 10. Engine 12 was not patched in run IV-C-4-1
			IU/13	10	347	0.017	0 183	0.170	27.034										
			IVS/4	10	583	0.054	0.146	0.540	29.440										
			IIS/12	0	243	0	0	0	17.704										
1A	12-9-67	0342	IVD/2	10	701	0.017	0.183	0.170	43.715	23-24	A	B	X			X	X		
			IU/13	10	357	0.017	0 183	0.170	27.204										
			IVS/4	10	593	0.054	0 146	0.540	29.980										
			IIS/12	10	253	0 054	0.146	0.540	18.244										
3	12-9-67	0404	IVD/2	10	711	0.017	0.183	0.170	43.885	23-24	A	B	X			X	X		
			IU/13	10	367	0.017	0.183	0.170	27.374										
			IVS/4	10	603	0.048	0.152	0.480	30.460										
			IIS/12	10	263	0.048	0.152	0.480	18.724										
6	12-9-67	0414	IVD/2	5	716	0.050	0.150	0.250	44.135	23-24	A	B	X			X	X		
			IU/13	5	372	0.050	0.150	0.250	27.624										
			IVS/4	5	608	0.104	0.096	0.520	30.980										
			IIS/12	5	268	0.104	0.096	0.520	19.244										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position: Main shutoffs O	Main shutoffs C	Cluster isolation O	Cluster isolation C	Interconnects O	Interconnects C	Cross feeds O	Cross feeds C	Remarks
7	12-9-67	0419	IVD/2	5	721	0.050	0.150	0.250	44.385	23-24	A	B	X			X	X		
			IU/13	5	377	0.050	0.150	0.250	27.874										
			IVS/4	5	613	0.100	0.100	0.500	31.480										
			IIS/12	5	273	0.100	0.100	0.500	19.744										
9	12-9-67	0424	IVD/2	5	726	0.050	0.150	0.250	44.635	23-24	A	B	X			X	X		
			IU/13	5	382	0.050	0.150	0.250	28.124										
			IVS/4	5	618	0.096	0.104	0.480	31.960										
			IIS/12	5	278	0.096	0.104	0.480	20.224										
					Phase IV - Block C-3 — Six engine operation, simultaneous pulsing														
1	12-9-67	0537	IIF/11	10	402	0.017	0.183	0.170	11.918	23-24	A	B	X			X	X		
			IIIF/7	10	166	0.017	0.183	0.170	9.29										
			IID/10	10	313	0.017	0.183	0.170	42.527										
			IU/13	10	392	0.017	0.183	0.170	28.294										
			IVU/1	10	314	0.017	0.183	0.170	27.569										
			IIID/6	10	775	0.017	0.183	0.170	65.562										
3	12-9-67	0547	IIF/11	3	405	0.150	0.050	0.450	12.368	23-24	A	B	X			X	X		
			IIIF/7	3	169	0.150	0.050	0.450	9.740										
			IID/10	3	316	0.150	0.050	0.450	42.977										
			IU/13	3	395	0.150	0.050	0.450	28.744										
			IVU/1	3	317	0.150	0.050	0.450	28.019										
			IIID/6	3	778	0.150	0.050	0.450	66.012										
4	12-9-67	0557	IIF/11	1	406	0.200		0.200	12.568	23-24	A	B	X			X	X		
			IIIF/7	1	170	0.200		0.200	9.940										
			IID/10	1	317	0.200		0.200	43.177										
			IU/13	1	396	0.200		0.200	28.944										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position Main shutoffs		Cluster isolation		Interconnects		Crossfeeds		Remarks
											O	C	O	C	O	C	O	C	
			IVU/1	1	378	0.200		0.200	28.219										
			IIID/6	1	779	0.200		0.200	66.212										
					Phase IV - Block C-6 — Six engine operation, pulsing out of phase														
1	12-9-67	0709	IIF/11		406	0.500			12.568	23-24	A	B	X			X	X		Engines 6 and 10 fired prematurely at T-10 seconds. On time is only an estimate
			IIIF/7		170	0.500			9.940										
			IID/10	1	318	0.500		0.500	43.677										
			IU/13		396				28.944										
			IVU/1		378				28.219										
			IIID/6	1	780	0.500		0.500	66.712										
1A	12-9-67	0713	IIF/11	1	407	0.570		0.570	13.138	23-24	A	B	X			X	X		
			IIIF/7	1	171	0.570		0.570	10.510										
			IID/10	3	321	0.017	0.183	0 051	43.728										
			IU/13	3	399	0.017	0.183	0.051	28.995										
			IVU/1	3	321	0.017	0.183	0.051	28.270										
			IIID/6	3	783	0.017	0.183	0.051	66.763										
2	12-9-67	0721	IIF/11	1	408	0.450		0.450	13.588	23-24	A	B	X			X	X		
			IIIF/7	1	172	0.450		0.450	10.960										
			IID/10	3	324	0.050	0.150	0.150	43.878										
			IU/13	3	402	0 050	0.150	0.150	29.145										
			IVU/1	3	324	0.050	0.150	0.150	28.420										
			IIID/6	3	786	0.050	0.150	0.150	66.913										
					Phase IV - Block C-8 — Eight engine operation, simultaneous pulsing														
1	12-9-67	0850	IVS/4	10	628	0.017	0.183	0.170	32.130	23-24	A	B	X			X	X		
			IF/15	10	141	0.017	0.183	0.170	6.821										
			IIS/12	10	288	0.017	0.183	0.170	20.394										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IIIF/7	10	182	0.017	0.183	0.170	11.130										
			IVD/2	10	736	0.017	0.183	0.170	44.805										
			IID/10	10	334	0.017	0.183	0.170	44.048										
			IIID/6	10	796	0.017	0 183	0.170	67.083										
			ID/14	10	646	0.017	0.183	0.170	94.280										
3	12-9-67	0858	IVS/4	1	629	0.200		0.200	32.330	23-24	A	B	X			X	X		
			IF/15	1	142	0.200		0.200	7.021										
			IIS/12	1	289	0 200		0.200	20 594										
			IIIF/7	1	183	0.200		0.200	11.330										
			IVD/2	1	737	0 200		0.200	45.005										
			IID/10	1	335	0.200		0.200	44 248										
			IIID/6	1	797	0.200		0.200	67.283										
			ID/14	1	657	0 200		0.200	94.480										
1A	12-9-67	0906	IVS/4	10	639	0.017	0.183	0.170	32 500	23-24	A	B	X			X	X		
			IF/15	10	152	0.017	0.183	0.170	7 191										
			IIS/12	10	299	0.017	0.183	0.170	20.764										
			IIIF/7	10	193	0.017	0 183	0.170	11.500										
			IVD/2	10	747	0.017	0.183	0.170	45.175										
			IID/10	10	345	0.017	0.183	0.170	44.418										
			IIID/6	10	807	0.017	0.183	0.170	67.453										
			ID/14	10	667	0.017	0.183	0.170	94.650										
					Phase IV - Block C-9 — Eight engine operation — four engines pulsing, four steady state														
2	12-9-67	0915	IVS/4	3	642	0.050	0 150	0.150	32.650	23-24	A	B	X			X	X		
			IF/15	3	155	0.050	0.150	0.150	7.341										
			IIS/12	3	302	0.050	0 150	0.150	20.914										
			IIIF/7	3	196	0 050	0.150	0.150	11.650										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVD/2	1	748	0.450		0.450	45.625										
			IID/10	1	346	0.450		0.450	44.868										
			IIID/6	1	808	0.450		0.450	67.903										
			ID/14	1	668	0.450		0.450	95.100										
					Phase IV – Block C-10 — Eight engine operation, pulsing out of phase														
1	12-9-67	1024	IVD/2	5	753	0.054	0.146	0.270	45.895	23-24	A	B	X			X	X		NOTE. Engines 2, 13, 6, and 9 lead engines 15, 7, 12, and 4 by 50 msec in runs 1 to 5 and by 100 msec in runs 6 to 10
			IU/13	5	407	0.054	0.146	0.270	7.611										
			IIID/6	5	813	0.054	0.146	0.270	68.173										
			IIU/9	5	259	0.054	0.146	0.270	25.115										
			IVS/4	5	647	0.017	0.183	0.085	32.735										
			IF/15	5	160	0.017	0.183	0.085	7.696										
			IIIF/7	5	201	0.017	0.183	0.085	11.735										
			IIS/12	5	307	0.017	0.183	0.085	20.999										
3	12-9-67	1035	IVD/2	5	758	0.048	0.152	0.240	46.135	23-24	A	B	X			X	X		
			IU/13	5	412	0.048	0.152	0.240	29.385										
			IIID/6	5	818	0.048	0.152	0.240	68.413										
			IIU/9	5	264	0.048	0.152	0.240	25.355										
			IVS/4	5	652	0.017	0.183	0.085	32.820										
			IF/15	5	165	0.017	0.183	0.085	7.781										
			IIIF/7	5	206	0.017	0.183	0.085	11.820										
			IIS/12	5	312	0.017	0.183	0.085	21.084										
5	12-9-67	1041	IVD/2	5	763	0.044	0.156	0.220	46.355	23-24	A	B	X			X	X		
			IU/13	5	417	0.044	0.156	0.220	29.605										
			IIID/6	5	823	0.044	0.156	0.220	68.633										
			IIU/9	5	269	0.044	0.156	0.220	25.575										
			IVS/4	5	657	0.017	0.183	0.085	32.905										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IF/15	5	170	0.017	0.183	0 085	7.066										
			IIIF/7	5	211	0 017	0.183	0.085	11.905										
			IIS/12	5	317	0.017	0 183	0.085	21.169										
7	12-9-67	1046	IVD/2	3	766	0 100	0 100	0.300	46.655	23-24	A	B	X			X	X		
			IU/13	3	420	0 100	0 100	0.300	29 905										
			IIID/6	3	826	0 100	0.100	0.300	68 033										
			IIU/9	3	272	0.100	0.100	0.300	25.875										
			IVS/4	3	660	0.050	0.150	0.150	33.055										
			IF/15	3	173	0.050	0 150	0.150	8.016										
			IIIF/7	3	214	0.050	0.150	0.150	12.055										
			IIS/12	3	320	0.050	0 150	0.150	21.319										
9	12-9-67	1053	IVD/2	3	769	0.096	0.104	0.288	46.943	23-24	A	B	X			X	X		
			IU/13	3	423	0.096	0.104	0.288	30.193										
			IIID/6	3	829	0 096	0.104	0.288	69.221										
			IIU/9	3	275	0.096	0.104	0.288	26.163										
			IVS/4	3	663	0.050	0 150	0.150	33.205										
			IF/15	3	176	0.050	0.150	0.150	8 166										
			IIIF/7	3	217	0.050	0.150	0.150	12.205										
			IIS/12	3	323	0.050	0.150	0 150	21 469										
Phase III — Mission duty cycles																			
Block B-1 — Lunar mission (AGS) simulation, abort from hover																			
1	12-9-67	1507	IIIS/8	1	457	2.650		2.650	24.370	23-24	X		X			X		X	
1A	12-9-67	1527	IVU/1	25	349	2.472		2.472	30.892	23-24	X		X			X		X	
			IVD/2	6	775	0.514		0.514	47.457										
			IVF/3	9	126	0.115		~0.115	6.325										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVS/4	13	676	0.174		0.174	33.379										
			IIIU/5	2	169	0.030		0 030	20 809										
			IIID/6	164	993	29.640		29 640	98.861										
			IIIF/7	13	230	0.160		0.160	12.365										
			IIIS/8	8	465	0.103		0.103	24.473										
			IIU/9	4	279	0.559		0.559	26.722										
			IID/10	163	509	24.314		24.314	69.182										
			IIF/11	7	415	0.099		0 099	13 687										
			IIS/12	11	334	0.152		0.152	21.621										
			IU/13	24	447	3 157		3.157	33 350										
			ID/14	3	671	0 041		0.041	95 141										
			IF/15	10	186	0.168		0 168	8.334										
			IS/16	5	122	0.090		0 090	10.204										
					Phase III - Block B-2 — Lunar mission (AGS) simulation, coelliptic sequence initiation														
1	12-9-67	1640	IVU/1	8	357	0.273		0.273	31.165	23-24	X		X			X		X	
			IVD/2	54	829	5.350		5.350	52 807										
			IVF/3	5	131	0.199		0.199	6 524										
			IVS/4	5	681	0 215		0.215	33.594										
			IIIU/5	10	179	0.520		0.520	21.329										
			IIID/6	51	1044	6.859		6 859	105 720										
			IIIF/7	4	234	0.204		0.204	12.569										
			IIIS/8	4	469	0.195		0.195	24.668										
			IIU/9	10	289	0.429		0.429	27 151										
			IID/10	59	568	4.931		4.931	74.113										
			IIF/11	4	419	0.186		0.186	13.873										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IIS/12	4	338	0.178		0.178	21.799										
			IU/13	10	457	0.586		0.586	33.936										
			ID/14	53	724	7.373		7.373	102.514										
			IF/15	5	191	0.205		0.205	8.539										
			IS/16	5	127	0 207		0.207	10.411										
					Phase III - Block B-3 — Lunar mission (AGS) simulation, coelliptic delta height														
1	12-9-67	1713	IVU/1	6	363	0.270		0.270	31.435										
			IVD/2	57	886	5.734		5.734	58.541										
			IVF/3	9	140	0.293		0.293	6.817										
			IVS/4	14	695	0.348		0.348	33.942										
			IIIU/5	12	191	0.545		0 545	21.874										
			IIID/6	62	1106	7.515		7.515	113.235										
			IIIF/7	14	248	0.380		0.380	12.949										
			IIIS/8	10	479	0.327		0.327	24.995										
			IIU/9	19	308	0.692		0.692	27.843										
			IID/10	64	632	5.439		5.439	79.552										
			IIF/11	9	428	0.340		0.340	14.213										
			IIS/12	15	353	0.368		0.368	22.167										
			IU/13	11	468	0.526		0.526	34.462										
			ID/14	56	780	8.039		8.039	110.553										
			IF/15	15	206	0.352		0.352	8.891										
			IS/16	8	135	0.369		0.369	10.780										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Interconnects		Cross feeds		
											O	C	O	C	O	C	O	C	
					Phase III - Block B-4 — Lunar mission (AGS) simulation, transfer point initiation														
1	12-9-67	2103	IVU/1	16	379	0.889		0.889	32.324	23-24									
			IVD/2	44	930	4.555		4.555	63.096										
			IVF/3	33	173	1.138		1.138	7.955										
			IVS/4	35	730	1.056		1.056	34 998										
			IIIU/5	30	221	0.944		0.944	22.818										
			IIID/6	63	1169	5.399		5.399	110 634										
			IIIF/7	28	276	1.068		1.068	14.017										
			IIIS/8	30	509	1.068		1.068	26.063										
			IIU/9	58	366	2.432		2.432	30.275										
			IID/10	82	714	5.484		5.484	85.036										
			IIF/11	30	458	1 000		1.000	15.213										
			IIS/12	28	381	1.046		1.046	23 213										
			IU/13	40	508	1.866		1.866	36.328										
			ID/14	69	849	6.735		6.735	117.288										
			IF/15	30	236	1.053		1.053	9.944										
			IS/16	31	166	1.042		1.042	11.822										
					Phase III - Block B-5 — Lunar mission (AGS) simulation, midcourse corrections														
1	12-9-67	2220	IVU/1	0	379	0.000		0.000	32.324	23-24	X		X			X		X	
			IVD/2	69	999	3.837		3.837	66.933										
			IVF/3	73	246	3.898		3.898	11.853										
			IVS/4	60	790	3.629		3.629	38.627										Upfiring engines inhibited due to vacuum redline
			IIIU/5	0	221	0.000		0.000	22.818										
			IIID/6	76	1245	5.023		5.023	123.657										
			IIIF/7	60	336	3.953		3.953	17.970										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IIIS/8	67	576	3.719		3.719	29.782										
			IIU/9	0	366	0 000		0.000	30.275										
			IID/10	133	847	5 892		5.892	90.928										
			IIF/11	61	519	3.565		3.565	18.778										
			IIS/12	55	436	3.770		3.770	26.983										
			IU/13	0	508	0.000		0.000	36.328										
			ID/14	54	903	5.962		5.962	123.250										
			IF/15	56	292	3.462		3.467	13.406										
			IS/16	63	229	3.849		3.849	15.671										
								Phase IV — special duty cycles											
							Block F — crossfeed operation, LM-1 mission phase II												
1	12-9-67	2350	IVU/1	10	389	0 663		0.663	32.987	23-24	A	B	X			X	X		
			IVD/2	2	1001	0.834		0.834	67.767										
			IVF/3	0	246	0.000		0.000	11.853										
			IVS/4	0	790	0.000		0.000	38.627										
			IIIU/5	1	222	11 908		11.908	34.726										
			IIID/6	8	1253	1.794		1.794	125.451										
			IIIF/7	0	336	0.000		0.000	17.970										
			IIIS/8	0	576	0.000		0.000	29.782										
			IIU/9	3	369	1.435		1.435	31.710										
			IID/10	0	847	0.000		0.000	90.928										
			IIF/11	0	519	0.000		0.000	18.778										
			IIS/12	0	436	0.000		0.000	26.983										
			IU/13	4	512	0.952		0.952	37.280										
			ID/14	6	909	0.540		0.540	123.790										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu- lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu- lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter- connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IF/15	0	292	0.000		0.000	13.406										
			IS/16	0	299	0.000		0.000	15.671										
1A	12-10-67	0102	IVU/1	67	456	10.746		10.746	43 733	23-24	A	B	X			X	X		
			IVD/2	55	1056	7.168		7.168	74.935										
			IVF/3	17	263	0.627		0.627	12.480										
			IVS/4	14	804	0.423		0.423	39.050										
			IIIU/5	68	290	7.649		7.649	42.375										
			IIID/6	115	1368	15.714		15.714	141.165										
			IIIF/7	15	351	0.391		0.391	18.361										
			IIIS/8	17	593	1.138		1.138	30.920										
			IIU/9	78	447	12.246		12.246	43.956										
			IID/10	8	855	1.768		1.768	92 695										
			IIF/11	17	536	0.626		0.626	19.404										
			IIS/12	14	450	0.429		0 429	27.412										
			IU/13	21	533	3.219		3.219	40.499										
			ID/14	61	970	10.119		10.119	133 909										
			IF/15	15	307	0.423		0.423	13.829										
			IS/16	17	246	1.166		1.166	16.837										
				Phase IV-Block K — high-low voltage effects (lunar mission (AGS) — transfer point initiation)															
1	12-10-67	0224	IVU/1	16	472	0.889		0.889	44.622	27-28	X		X			X		X	
			IVD/2	44	1100	4.555		4.555	79.490										
			IVF/3	33	296	1.138		1.138	13.618										
			IVS/4	35	839	1.056		1.056	40.106										
			IIIU/5	30	320	0.944		0.944	43.319										
			IIID/6	63	1431	5.399		5.399	146.564										
			IIIF/7	28	379	1.068		1.068	19.429										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
2	12-10-67	0340	IIIS/8	30	623	1.068		1.068	31,988	20-21	X		X			X		X	
			IIU/9	58	505	2.432		2.432	46.388										
			IID/10	82	937	5 484		5.484	98.179										
			IIF/11	30	566	1.000		1.000	20,404										
			IIS/12	28	478	1.046		1.046	28.458										
			IU/13	40	573	1.866		1.866	42,365										
			ID/14	60	1039	6.735		6.735	140,644										
			IF/15	30	337	1.053		1.053	14,082										
			IS/16	31	277	1.042		1.042	17.879										
			IVU/1	16	488	0.889		0.889	45.511										
			IVD/2	41	1144	4.555		4.555	84.049										
			IVF/3	33	349	1.138		1.138	14.756										
			IVS/4	35	874	1 056		1 056	41.162										
			IIIU/5	30	350	0 944		0.944	44.263										
			IIID/6	63	1494	5.399		5 399	151.963										
			IIIF/7	28	407	1.068		1 068	20,497										
			IIIS/8	30	653	1 068		1 068	33.056										
			IIU/9	58	563	2.432		2.432	48.820										
			IID/10	82	1019	5 484		5.484	103.663										
			IIF/11	30	596	1.000		1.000	21,404										
			IIS/12	28	506	1 046		1.046	29.504										
			IU/13	40	613	1 866		1.866	44,231										
			ID/14	69	1108	6.735		6.735	147.379										
			IF/15	30	367	1.053		1.053	15,935										
			IS/16	31	308	1.042		1.042	18,921										

Run no.	Date	Time, hr	Engine no. and location	No of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
/Phase IV - Block E — propellant consumption and O/F ratio duty cycles																			
1	12-10-67	0533	IVD/2	2000	3144	0.014	1 000	28.000	112.045	23-24	X		X			X		X	
2	12-10-67	0810	IVD/2	1500	4644	0 025	1.000	37.500	149.545	23-24	X		X			X		X	
3	12-10-67	0909	IVD/2	750	5394	0.050	1.000	37 500	187.045	23-24	X		X			X		X	
5	12-10-67	1004	IVD/2	400	5794	0.100	1.000	40.000	227.045	23-24	X		X			X		X	
6	12-10-67	1119	IVD/2	200	5994	0.200	1.100	40.000	267.045	23-24	X		X			X		X	
8A	12-10-67	1216	IIID/6	100	1594	0.014	2.500	1.400	153.363	23-24	X		X			X		X	
8B	12-10-67	1248	IIID/6	100	1694	0.014	2.000	1 400	154.763	23-24	X		X			X		X	
8C	12-10-67	1309	IIID/6	100	1794	0.014	1.500	1.400	156.163	23-24	X		X			X		X	
8D	12-10-67	1331	IIID/6	100	1894	0.014	1 000	1.400	157.563	23-24	X		X			X		X	
8E	12-10-67	1352	IIID/6	200	2094	0 014	0.500	2.800	160.363	23-24	X		X			X		X	
8F	12-10-67	1447	IIID/6	500	2594	0.014	2.000	7 00	167.363	23-24	X		X			X		X	
				500	3094	0.014	1.500	7.00	174.363										
				400	3494	0.014	1 000	5.698	180.061										
9	12-10-67	1555	IIID/6	1500	4994	0 025	1.000	37.50	217 561	23-24	X		X			X		X	
10	12-10-67	1651	IIID/6	750	5744	0.050	1.000	37.50	255.061	23-24	X		X			X		X	
12	12-10-67	1738	IIID/6	400	6144	0.100	1 000	40 00	295.061	23-24	X		X			X		X	
13	12-10-67	1919	IIID/6	200	6344	0.200	1 100	40.00	335.061	23-24	X		X			X		X	
'Phase IV - Block G-2 — failure mode, cluster II "A" isolation valves closed 2 seconds after start of run																			
2	12-10-67	2114	IID/10	1	1020	4.000		4.000	107.663	23-24	X		X			X		X	
			IVD/2	16	6010	0.050	0.200	0.800	267.845										
' Phase IV - Block G-4 — failure mode, cluster IV "A" isolation valves closed 2 seconds after start of run																			
4	12-10-67	2139	IVD/2	1	6011	4.000		4.000	271.845	23-24	X		X			X		X	
			IIF/11	16	612	0 050	0.200	0.800	22 204										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
Phase IV - Block G-6 — failure mode, cluster IV system "A" fuel isolation valve closed 2 seconds after start of run																			
6	12-10-67	2250	IIF/4	1	875	2.000	0.200	2.000	43.162	23-24	X		X			X		X	
				7	882	0.017	0.183	0 119	43.281										
Phase IV - Block M-1 — Insulation evaluation repeat																			
1A	12-11-67	0200	IIID/6	1	6345	20 000		20.000	355.061	23-24	X		X			X		X	
Phase IV - Block M-2 — Insulation evaluation repeat																			
2A	12-11-67	0254	ID/14	1	1109	20.000		20.000	167.379	23-24	X		X			X		X	
Phase IV - Block H-2 — manual coil operation																			
16	12-11-67	0330	IVS/4	5	887	0.030	0.500	0.150	43 431	23-24	X		X			X		X	
17	12-11-67	0339	IVS/4	5	892	0.050	0.500	0.250	43.681	23-24	X		X			X		X	
18	12-11-67	0347	IVS/4	3	895	0.100	0.500	0.300	43.981	23-24	X		X			X		X	
19	12-11-67	0352	IVS/4	2	897	0.500	0.500	1.000	44.981	23-24	X		X			X		X	
20	12-11-67	0358	IVS/4	1	898	1.000		1.000	45.981	23-24	X		X			X		X	
61	12-11-67	0414	IU/13	5	618	0.030	0.500	0.150	44.381	23-24	X		X			X		X	
62	12-11-67	0420	IU/13	5	623	0.050	0.500	0.250	44.631	23-24	X		X			X		X	
63	12-11-67	0425	IU/13	3	626	0.100	0.500	0.300	44.931	23-24	X		X			X		X	
64	12-11-67	0430	IU/13	2	628	0.500	0.500	1.000	45.931	23-24	X		X			X		X	
65	12-11-67	0438	IU/13	1	629	1.000		1.000	46.931	23-24	X		X			X		X	
Phase IV - Block J — manual coil maneuvers																			
1	12-11-67	0533	ID/14	10	1119	0.100	0.200	1.000	168 379	23-24	X		X			X		X	
			IIU/9	10	573	0.100	0.200	1.000	49.820										
			After 1 second																
			ID/14	10	1129	0.050	0.100	0.500	168.879										
			IIU/9	10	583	0.050	0.100	0.500	50.320										
3	12-11-67	0543	ID/14	10	1139	0.100	0.200	1.000	169.879	23-24	X		X			X		X	

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumu-lative pulses	On time, sec	Off time, sec	On time this run, sec	Cumu-lative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVU/1	10	448	0.100	0.200	1.000	46 511										
			After 1 second																
			ID/14	10	1149	0 050	0.100	0.500	170.379										
			IVU/1	10	508	0.050	0.100	0.500	47.011										
5	12-11-67	0557	IF/15	10	377	0.100	0.200	1.000	16.935	23-24	X		X			X		X	
			IIIF/7	10	417	0 100	0.200	1.000	21.497										
			After 1 second																
			IF/15	10	387	0.050	0.100	0.500	7.435										
			IIIF/7	10	427	0.050	0.100	0.500	21.997										
7	12-11-67	0709	ID/14	5	1154	0.100	0.200	0.500	170.879	23-24	X		X			X		X	
			IIU/9	5	588	0.100	0 200	0.500	50.820										
			IVD/2	5	6016	0.100	0 200	0.500	272.345										
			IIIU/5	5	355	0.100	0.200	0.500	44.763										
			After 1 second																
			ID/14	5	1159	0.050	0.100	0.250	171.129										
			IIU/9	5	593	0.050	0.100	0.250	51.070										
			IVD/2	5	6021	0.050	0.100	0.250	272.595										
			IIIU/5	5	360.	0.050	0.100	0.250	45.013										
9	12-11-67	0719	IID/10	5	1025	0.100	0.200	0.500	108.163	23-24	X		X			X		X	
			IIIU/5	5	365.	0.100	0.200	0.500	45.513										
			ID/14	5	1164	0.100	0.200	0.500	171 629										
			IVU/1	5	513.	0 100	0.200	0.500	47.511										
			After 1 second																
			IID/10	5	1030	0.050	0 100	0.250	108.413										
			IIIU/5	5	370	0.050	0.100	0.250	45.763										
			ID/14	5	1169	0.050	0.100	0.250	171.879										

Run no.	Date	Time, hr	Engine no. and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVU/1	5	518	0.050	0.100	0.250	47 761										
11	12-11-67	0734	IF/15	5	392	0 100	0.200	0.500	17 935	23-24	X		X			X		X	
			IIIF/7	5	432	0.100	0.200	0.500	22 497										
			IVS/4	5	903	0.100	0.200	0.500	46.481										
			IIS/12	5	511	0.100	0 200	0.500	30.004										
			After 1 second																
			IF/15	5	397	0.050	0.100	0.250	18.185										
			IIIF/7	5	437	0.050	0.100	0.250	22.747										
			IVS/4	5	908	0 050	0.100	0.250	46.731										
			IIS/12	5*	516	0 050	0.100	0.250	30.254										
						Phase IV - Block — SP-2 — special crossfeed test													
	12-11-67	0931	ID/14	3	1172	0 016		0.048	171 927	23-24	A	B	X			X		X	
			IVD/2	30	6051	0 017	0.183	0.510	273.105										
						Phase IV - Block — SP-3 — special crossfeed test													
	12-11-67	1023	IVD/2	1	6052	0.016		0.016	273.121	23-24	A	B	X			X		X	
A			IVD/2	1	6053	0.016		0.016	273.137										
B			IVD/2	1	6054	0.020		0.020	273.157										
C			IVD/2	1	6055	0.030		0.030	273.187										
D			IVD/2	9	6064	0.030		0 270	273.457										
			IVD/2	1	6065	0.250		0.250	273.707										
E			ID/14	10	1182	0.017	0.183	0 170	172.097										
F			ID/14	10	1192	0.017	0.183	0.170	172.267										
G			ID/14	10	1202	0.017	0 183	0.170	172.437										
							FIRING SUMMARY												
			IVU/1		518				47.761										
			IVD/2		6065				273.707										

Run no.	Date	Time, hr	Engine no and location	No. of pulses	Cumulative pulses	On time, sec	Off time, sec	On time this run, sec	Cumulative on time, sec	Valve voltage, V dc	Latch valve position								Remarks
											Main shutoffs		Cluster isolation		Inter-connects		Cross feeds		
											O	C	O	C	O	C	O	C	
			IVF/3		329				14.756										
			IVS/4		908				46.731										
			IIIU/5		370				45.763										
			IIID/6		6345				355.061										
			IIIF/7		437				22.747										
			IIIS/8		653				33.056										
			IIU/9		593				51.070										
			IID/10		1030				108.413										
			IIF/11		612				22.204										
			IIS/12		516				30.254										
			IU/13		629				46,931										
			ID/14		1202				172.437										
			IF/15		397				18.185										
			IS/16		308				18.921										

APPENDIX B

DATA SUMMARY

DATA SUMMARY TERMINOLOGY

Pulse width	Time from injector valve voltage application to voltage removal.
Valve opening response	Time from injector valve voltage application to valve "full open" indication on signature traces.
Valve closing response	Time from injector valve voltage removal to valve "full closed" indication on signature traces.
Ignition delay	Time from injector valve voltage application to first indication of chamber pressure.
Pressure switch closing time	Time from injector valve voltage application to switch continuity indication.
Pressure switch opening time	Time from injector valve voltage removal to switch no continuity indication.
Pressure at switch opening	Engine chamber pressure corresponding to the switch opening.
Steady state or maximum chamber pressure	Steady state chamber pressure was recorded for pulses of 50 milliseconds or greater duration if steady state pressure had been attained; this was obtained by averaging the chamber pressure over the last 25 percent of the electrical on time. Maximum chamber pressures were recorded for pulses of less than 50 milliseconds duration.
Time to 75 percent of maximum or steady state chamber pressure	Time from voltage application to the engine to a chamber pressure equivalent to 75 percent of the maximum or steady state chamber pressure.
Integrated chamber pressure	Integral of Pcdt over the time period at which Pc existed.

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PULSE NUMBER	PULSE WIDTH	DATE (1967)	TIME OF DAY (HRS)	INITIAL CELL TEMP (°F)	INITIAL CELL PRESSURE (MM)	INJECTOR HEAD TEMPERATURE (°F)				FUEL INLET TEMPERATURE (°F)				OXID INLET TEMPERATURE (°F)				INITIAL INLET PRESSURE (PSIA) FUEL		INITIAL INLET PRESSURE (PSIA) OXID	
							ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	A	B	A	B
II-A-2-27	1	0.014	12-1	0531	71	2.3	136				67				72				122.2		122.1	
	3	0.014																				
	5	0.014																				
II-A-2-29	1	0.017	12-2	0710	70	2.3	134				65				70				122.9		122.1	
	3	0.017																				
	5	0.017																				
II-A-2-30	1	0.050	12-3	0731	70	2.2	135				65				70				122.1		121.9	
	3	0.053																				
	6	0.050																				
II-A-2-31	1	0.100	12-3	0739	70	2.3	135				65				69				118.5		118.5	
	3	0.100																				
II-A-2-32	1	0.150	12-3	0752	70	2.3	136				64				62				123.4		121.1	
	2	0.150																				
II-A-2-33	1	0.014	12-3	0801	71	2.3	136				64				68				115.4		117.2	
	3	0.014																				
	5	0.014																				
II-A-2-34	1	0.017	12-3	0852	72	2.3	135				64				69				113.9		117.1	
	3	0.017																				
	5	0.017																				
II-A-2-35	1	0.050	12-3	0903	71	2.3	134				64				69				113.0		118.6	
	3	0.050																				
	6	0.050																				
II-A-2-36	1	0.100	12-3	0915	71	2.2	135				64				68				117.2		117.1	
	3	0.100																				
II-A-2-37	1	0.150	12-3	0925	73	2.2	135				64				68				117.1		117.2	
	2	0.150																				
II-A-2-50	1	0.014	12-3	1104	74	2.2		133				63				63			112.6		112.1	
	3	0.014																				
	5	0.014																				
II-A-2-51	1	0.017	12-3	1152	71	2.2		132				64				65			115.4		115.9	
	3	0.017																				
	4	0.017																				
II-A-2-52	1	0.050	12-3	1203	71	2.2		134				64				69			115.6		115.5	
	3	0.050																				
	4	0.050																				
II-A-2-53	1	0.100	12-3	1255	72	2.2		133				64				65			117.3		115.5	
	3	0.100																				
II-A-2-54	1	0.150	12-3	1308	71	2.2		135				64				72			116.2		117.2	
	2	0.150																				
II-A-2-55	1	0.014	12-3	1332	71	2.2		135				64				68			111.2		112.7	
	3	0.014																				
	6	0.014																				
II-A-2-56	1	0.017	12-3	1335	71	2.2		133				63				63			113.5		111.2	
	3	0.017																				
	4	0.017																				
II-A-2-57	1	0.050	12-3	1349	71	2.2		134				64				61			111.5		117.7	
	3	0.050																				
	5	0.050																				
II-A-2-58	1	0.100	12-3	1437	71	2.2		133				63				63			111.5		111.4	
	3	0.100																				
II-A-2-59	1	0.150	12-3	1440	71	2.2		134				65				68			111.2		112.6	
	2	0.150																				
II-A-2-127	1	0.014	12-4	2310	70	2.2			144				72				72		122.4		122.2	
	3	0.014																				
	5	0.014																				
II-A-2-128	1	0.017	12-4	2333	72	2.2			143				73				71		118.6		125.2	
	3	0.017																				
	5	0.017																				
II-A-2-129	1	0.050	12-4	2344	70	2.2			144				72				71		117.5		125.5	
	3	0.050																				
	5	0.050																				
II-A-2-130	1	0.100	12-4	2356	72	2.2			148				72				71		117.2		125.4	
	3	0.100																				
II-A-2-131	1	0.150	12-5	0024	72	2.2			145				72				71		117.7		117.4	
	2	0.150																				
II-A-2-132	1	0.014	12-5	0038	72	2.2			150				72				72		117.3		117.5	
	3	0.014																				
	5	0.014																				

RUN NUMBER	PULSE NUMBER	VALVE OPENING RESPONSE (MS) FUEL				VALVE OPENING RESPONSE (MS) OXID				VALVE CLOSING RESPONSE (MS) FUEL				VALVE CLOSING RESPONSE (MS) OXID				IGNITION DELAY (MS)			
		ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13
II-A-2-27	1	7.4				7.4				6.7								10.3			
	3	7.5								7.0								12.6			
	5	7.5								7.0								11.6			
II-A-2-29	1	7.4								6.9				5.2				12.6			
	3	7.4								6.7				5.4				11.2			
	5	7.2								6.9				5.5				11.3			
II-A-2-30	1	7.0								7.2								11.8			
	3	7.9								7.4								11.2			
	6	7.5								7.0				5.2				11.3			
II-A-2-31	1	7.5								6.7				5.4				12.1			
	3	7.4								6.9				5.2				11.1			
II-A-2-32	1	7.2								6.9				5.4				12.5			
	2	7.4								6.6				5.2				10.7			
II-A-2-33	1	7.3								7.1								11.4			
	3	7.4								6.9								11.5			
	5	7.7								6.7								11.0			
II-A-2-34	1	7.2								6.5				5.1				11.9			
	3	7.4				8.5				7.0				5.5				10.9			
	5	7.1								7.0				5.5				10.4			
II-A-2-35	1	7.2								7.0				5.3				11.6			
	3	7.4								7.1				5.4				11.2			
	6	6.9				8.1				6.9				5.6				12.4			
II-A-2-36	1	7.5								7.3				5.2				11.4			
	3	7.1				8.7				7.1				5.7				11.6			
II-A-2-37	1	6.9								6.9				5.5				11.7			
	2	7.4				8.4				6.9				5.1				10.7			
II-A-2-50	1		6.1								6.5								11.2		
	3		7.1								6.3								9.9		
	5		7.1								6.5								10.4		
II-A-2-51	1		6.3								6.9								9.1		
	3		6.9								6.5								9.7		
	4		6.9								6.7				7.7				11.6		
II-A-2-52	1		6.5								6.1								11.4		
	3		6.5								7.1								9.9		
	4		6.5								6.3								9.1		
II-A-2-53	1		6.6								6.3								11.7		
	3		6.8								6.4								10.7		
II-A-2-54	1		7.2								7.2								11.2		
	2		7.1								7.2								9.9		
II-A-2-55	1		6.4								6.4								11.2		
	3		6.2								6.4								11.3		
	6		7.2								6.7								11.0		
II-A-2-56	1		6.9								6.7								11.5		
	3		6.7								6.1								11.6		
	4		6.9								6.7								11.5		
II-A-2-57	1		6.1								6.7								11.6		
	3		6.4								7.2								11.8		
	5		6.7								6.4								9.2		
II-A-2-58	1		7.1								6.5								10.1		
	3		7.3								6.4								9.1		
II-A-2-59	1		7.0								6.8								10.8		
	2		7.4								6.8								10.2		
II-A-2-127	1			6.5								6.5								11.0	
	3			7.0								6.5								11.4	
	5			7.3								6.5								9.1	
II-A-2-128	1			6.9								7.6								10.7	
	3			6.2				8.1				6.3								11.9	
	5			7.9								6.8								9.8	
II-A-2-129	1			7.4								6.4								11.7	
	3			7.7								6.4								9.7	
	5			7.1								6.4								9.4	
II-A-2-130	1			7.9								6.5								10.9	
	3			7.1								6.5								10.1	
II-A-2-131	1			7.1								6.5								11.2	
	2			7.1								6.9								9.1	
II-A-2-132	1			7.1								6.6								11.9	
	3			7.8								6.1								11.2	
	5			7.3								6.6								11.6	

RUN NUMBER	PULSE NUMBER	INLET WITH FUEL VALVE OPEN (PSIA) ENG 2		ENG 4		ENG 11		ENG 13		INLET WITH OXID VALVE OPEN (PSIA) ENG 2		ENG 4		ENG 11		ENG 13		MAXIMUM INLET PRESSURE AT FUEL VALVE CLOSURE (PSIA)				MAXIMUM INLET PRESSURE AT OXID VALVE CLOSURE (PSIA)				FUEL MANIFOLD PRESSURE (PSIA) SYSTEM A		SYSTEM B		OXID MANIFOLD PRESSURE (PSIA) SYSTEM A		SYSTEM B	
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
II-A-2-27	1	93								99								288				299				145	244			151	249		
	3	121								121								253				280				150	231			157	235		
	5	121								119								244				253				133	233			139	247		
II-A-2-29	1	91								105								300				315				145	242			114	273		
	3	91								92								315				312				137	265			53	254		
	5	111								91								310				302				135	212			92	271		
II-A-2-30	1	76	219							91	207							272				287				140	226			129	219		
	3	93	219							95	229							291				277				142	217			140	215		
	6	100	214							101	229							317				274				140	217			133	220		
II-A-2-31	1	95	214							94	221							219				281				141	263	163	176	127	225	131	177
	3	105	184							107	199							263				281				142	363	165	176	145	225	142	176
II-A-2-32	1	90	221							89	219							270				234				143	205			124	203		
	2	93	213							69	219							266				238				145	212			143	207		
II-A-2-33	1	97								90								276				325				147	242	172	177	131	251	151	196
	3	103								98								266				301				147	243	171	133	116	255	164	194
	5	93								95								271				298				130	242	171	177	116	255	151	194
II-A-2-34	1	95								100								297				302				147	241	171	171	155	260	132	195
	3	99								97								302				314				143	246	175	151	113	275	155	192
	5	102								84								301				305				147	245	171	152	114	275	156	195
II-A-2-35	1	92	227							93	220							265				274				145	231			139	211		
	3	92	227							89	220							265				274				150	233			136	220		
	6	94	237							89	250							265				265				145	236			132	210		
II-A-2-36	1	110	210							119	218							251				256				143	216			127	223		
	3	110	220							109	221							255				254				147	227			120	223		
II-A-2-37	1	97	236							95	230							259				281				143	211	154	157	137	231	120	164
	2	92	236							86	240							264				282				147	261	151	185	121	231	112	197
II-A-2-50	1			95								126							262				299			145	237	172	133	129	242	167	161
	3			105								76							267				313			135	232	176	131	92	264	131	225
	5			103								72							217				297			157	230	165	157	92	264	137	237
II-A-2-51	1			95								27							312				308			144	239			139	252		
	3			107								43							283				256			152	231			133	237		
	4			107								74							297				241			156	231			133	229		
II-A-2-52	1			99	223							134	246						258				314			141	219	174	175	135	211	164	195
	3			114	219							111	246						273				316			153	213	174	171	138	211	153	197
	4			119	203							115	252						255				314			154	211	175	185	135	256	159	193
II-A-2-53	1			91	217							91	217						300				259			141	211	176	153	139	253	162	191
	3			81	203							85	214						257				259			145	212	169	155	146	255	149	211
II-A-2-54	1			93	217							94	214						248				257			142	212	171	157	139	237	158	193
	2			91	193							78	210						255				245			141	217	171	153	138	231	151	195
II-A-2-55	1			98								90							269				286			139	237	170	155	132	245	166	212
	3			95								57							278				299			141	236	169	157	111	249	149	195
	6			91								86							275				302			149	234	169	157	111	253	159	192
II-A-2-56	1			96								99							300				305			141	241	170	155	116	252	147	195
	3			96								81							312				304			141	237	165	155	115	262	159	197
	4			96								86							366				317			145	237	171	157	122	216	151	197
II-A-2-57	1			97	212							91	212						265				319			146	217	170	155	121	216	155	195
	3			97	212							96	215						265				363			148	217	155	156	124	215	156	189
	5			97	218							90	221						265				360			149	216			151	215		
II-A-2-58	1			92	219							77	215						257				318			145	212	171	157	125	210	125	159
	3			95	214							60	233						253				328			142	217	155	153	127	216	154	157
II-A-2-59	1			131	232							86	217						257				367			149	210	171	155	132	217	155	192
	2			97	227							71	229										379			144	214	174	153	113	219	152	197
II-A-2-127	1					136														242						142	220	166	155	149	224		
	3					136														252						141	219	172	152	121	226		
	5					125														272						141	226	173	152	137	231		
II-A-2-128	1					135														242						151	215	166	165	145	234	171	155
	3					135														242						142	222	166	152	173	233	163	199
	5					136														242						141	232	172	175	126	239	157	197
II-A-2-129	1					137	211													221						151	207	174	152	149	211	151	193
	3					136	211													253						141	219	172	191	151	217	111	199
	5					137	211													244						146	217	172	159	149	207	170	193
II-A-2-130	1					136	210													243						138	212	159	142	148	217	152	192
	3					136	211													249						143	214	174	155	155	217	177	171
II-A-2-131	1					131	212													319						135	210	171	157	147	217		
	2					136	212													318						149	207	176	157	152	210		
II-A-2-132	1					129														316						151	216	165	157	141	235		
	3					114														355						154	217	167	157	141	242		
	5					114														354						174	219	157	157	145	242		

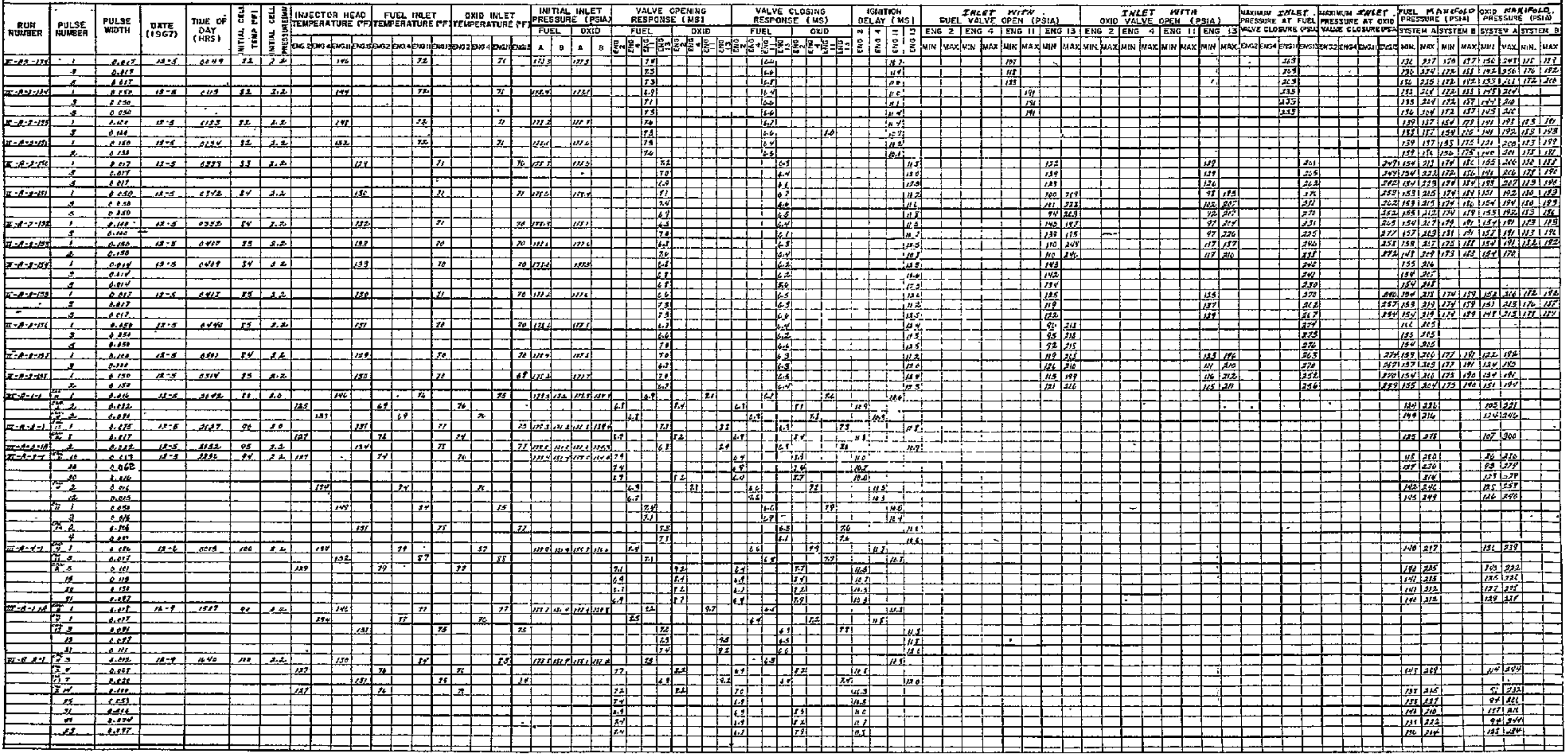
FOLDOUT FRAME 1

FOLDOUT FRAME 2

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PRESSURE SWITCH CLOSING TIME (MS)				PRESSURE SWITCH OPENING TIME (MS)				PRESSURE AT SWITCH CLOSING (PSIA)				PRESSURE AT SWITCH OPENING (PSIA)				STEADY STATE OR MAXIMUM CHAMBER PRESSURE (PSIA)				TIME TO 75% OF MAX OR SS CHAMBER PRESSURE (MS)				INTEGRATED P_c (PSIA-SEC)				REMARKS
	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	
II-A-2-28	15.2				18.4								39.7				73.7				19.3				0.74				
	18.6				17.3								18.1				95.3				19.1				1.09				
	15.6				17.1								19.4				97.7				15.3				1.15				
II-A-2-29	15.1				16.3								19.8				88.5				31.2				1.03				
	11.8				17.4								18.5				88.3				31.9				1.22				
	11.5				16.4								16.4				57.1				31.3				1.75				
II-A-2-30	14.9				19.6								14.1				96.7				31.7				9.41				
	19.7				17.3								17.2				93.7				31.5				9.10				
	15.9				17.5								15.1				98.7				31.1				9.69				
II-A-2-31	16.2				19.6								21.2				99.6				31.1				9.42				
	13.8				11.5								19.3				99.6				31.5				9.62				
II-A-2-32	16.6				20.7								16.4				111.1				19.8				14.11				
	11.2				13.5								17.8				111.5				19.4				14.52				
II-A-2-33	15.5				14.7								16.9				75.1				31.4				0.82				
	15.4				11.2								12.5				81.2				31.0				0.89				
	16.2				15.5								11.6				91.9				31.8				0.95				
II-A-2-34	13.5				16.3								17.3				93.1				33.1				1.09				
	18.8				17.1								16.8				91.8				33.0				1.10				
	14.9				17.8								15.1				91.8				31.3				1.16				
II-A-2-35	15.5				18.1								21.1				96.6				33.7				9.41				
	15.6				18.1								18.5				93.3				21.4				9.49				
	13.2				18.1								19.8				95.6				31.6				4.43				
II-A-2-36	15.2				20.1								17.4				96.3				31.2				9.48				
	13.8				17.9								20.4				95.1				34.2				9.46				
II-A-2-37	15.6				21.0								22.9				101.2				31.6				14.72				
	15.5				18.6								23.4				99.6				31.1				14.16				
II-A-2-50		11.8				41.4								5.2				67.0				18.9				0.94			
		9.7				46.1								4.7				59.6				17.1				1.01			
		9.7				44.1								4.7				90.0				18.7				1.03			
II-A-2-51A		10.5				46.2								3.8				34.1				31.3				1.34			
		9.2				48.5								3.2				77.9				31.2				1.31			
		9.5				56.9								4.2				94.4				31.8				1.32			
II-A-2-52		11.2				56.9								4.2				104.1				22.4				4.05			
		9.7				64.8								4.7				111.6				18.9				4.95			
		10.3				71.8								4.2				107.6				18.8				4.82			
II-A-2-53		12.7				61.4								4.2				103.4				15.6				9.65			
		10.8				74.2								4.2				103.4				31.4				10.04			
II-A-2-54		11.0																100.0				31.5				14.34			
						70.9								2.8				100.0				18.4				14.64			
II-A-2-55		10.5				44.1								4.2				71.8				15.9				0.90			
		10.1				46.1								4.2				76.4				31.3				0.96			
		11.5				47.7								4.2				90.1				22.2				1.17			
II-A-2-56		11.0				45.1								4.2				91.2				31.5				1.25			
		11.5				47.7								4.2				96.5				31.1				1.41			
		11.5				49.2								4.2				96.8				31.7				1.57			
II-A-2-57		11.3				53.1								3.8				97.7				32.1				4.66			
		11.8				60.3								3.1				97.5				19.7				4.70			
		9.8				61.3								3.8				97.9				19.8				4.71			
II-A-2-58		11.5				57.5																22.4				9.57			
		9.4				67.5																19.7				9.90			
II-A-2-59		11.5				61.5								3.9				101.2				31.8				14.47			
		9.1				67.5								2.4				91.5				32.3				15.10			
II-A-2-127			10.8				29.8								5.6				72.0				17.5				0.90		
			11.5				39.6								4.7				75.6				17.4				0.86		
			10.1				39.5								4.7				81.7				17.9				0.93		
II-A-2-128			10.4				37.4								4.8				84.1				19.9				1.31		
			9.6				39.7								4.7				88.9				31.2				1.28		
			9.6				40.8								4.7				91.5				19.2				1.30		
II-A-2-129			11.2				45.4								4.8				96.7				31.1				4.57		
			9.8				51.8								4.3				95.0				19.1				4.71		
			9.7				54.6								4.3				95.4				18.1				4.72		
II-A-2-130			11.8				49.2								4.7				111.6				22.0				9.51		
			9.6				66.4								5.9				99.7				15.2				9.76		
II-A-2-131			11.4				55.1								0				47.1				31.8				14.61		
			9.6				61.9								2.9				98.9				15.7				14.16		
II-A-2-132			10.6				55.4								4.5				76.4				13.3				0.91		
			10.8				57.5								4.8				73.9				16.1				0.95		
			10.6				96.5								5.6				30.1				21.0				0.75		

LM RCS SUBSYSTEM TEST DATA SUMMARY



RUN NUMBER	PULSE NUMBER	PULSE WIDTH	DATE (1967)	TIME OF DAY (HRS)	INITIAL CELL TEMP (°F)	INITIAL CELL PRESSURE
[illegible]	1	0.017	12-5	0049	32	2.2
	3	0.017				
	5	0.017				
[illegible]	1	0.250	12-5	0113	32	2.2
	3	0.250				
	5	0.050				
[illegible]	1	0.124	12-5	0133	32	2.2
	3	0.144				
[illegible]	1	0.150	12-5	0134	32	2.2
	2	0.150				
[illegible]	1	0.017	12-5	0333	33	2.2
	3	0.017				
	5	0.017				
[illegible]	1	0.050	12-5	0342	34	2.2
	3	0.050				
	5	0.050				
[illegible]	1	0.100	12-5	0332	34	2.2
	3	0.100				
[illegible]	1	0.150	12-5	0417	35	2.2
	2	0.150				
[illegible]	1	0.014	12-5	0429	34	2.2
	3	0.014				
	5	0.014				
[illegible]	1	0.017	12-5	0413	35	2.2
	3	0.017				
	5	0.017				
[illegible]	1	0.050	12-5	0440	35	2.2
	3	0.050				
	5	0.050				
[illegible]	1	0.100	12-5	0501	34	2.2
	3	0.100				
[illegible]	1	0.150	12-5	0514	35	2.2
	2	0.150				
[illegible]	1	0.016	12-6	2142	88	2.0
	2	0.012				
	2	0.034				
[illegible]	1	0.275	12-6	2127	96	2.0
	1	0.017				
[illegible]	2	0.232	12-5	2152	95	2.2
[illegible]	10	0.017	12-5	2232	94	2.2
	20	0.062				
	30	0.016				
	2	0.016				
	12	0.015				
	1	0.050				
	3	0.016				
	2	[illegible]				
	4	[illegible]				
[illegible]	1	0.016	12-6	0019	100	2.2
	5	0.017				
	5	0.101				
	15	0.119				
	25	0.138				
	31	[illegible]				
[illegible]	1	0.017	12-7	1517	92	2.2
	1	0.017				
	3	[illegible]				
	13	0.017				
	21	[illegible]				
[illegible]	3	0.012	12-7	1640	100	2.2
	4	0.067				
	7	0.020				
	14	0.100				
	25	0.053				
	31	[illegible]				
	41	[illegible]				
	52	[illegible]				

DOC. NO.	REVISION	PAGE
MSC-EP-R-68-17	New	B-6 OF B-14

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PRESSURE SWITCH CLOSING TIME (MS)				PRESSURE SWITCH OPENING TIME (MS)				PRESSURE AT SWITCH CLOSING (PSIA)				PRESSURE AT SWITCH OPENING (PSIA)				STEADY STATE OR MAXIMUM CHAMBER PRESSURE (PSIA)				TIME TO 75% OF MAX OR SS CHAMBER PRESSURE (MS)				INTEGRATED - Pc (PSIA - SEC)				REMARKS
	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	ENG. 2	ENG. 4	ENG. 11	ENG. 13	
II-A-2-153			10.9				56.4								5.7				84.3				19.0				1.18		
			11.1				51.2								4.8				96.5				19.7				1.21		
			11.6				45.4								4.3				90.0				12.8				1.31		
II-A-3-154			10.9				44.7								4.2				94.4				20.4				4.52		
			11.4				44.1								4.2				91.3				20.0				4.36		
			11.1				51.6								5.2				97.7				19.5				4.61		
II-A-2-155			11.3				51.9																21.4				9.57		
			10.8				51.9																19.9				9.60		
II-A-3-156			11.3				53.1																20.8				14.80		
			10.9				57.9																14.5				14.91		
II-A-2-160				11.8				37.1								5.0				86.9				20.2				1.11	
				11.4				44.8								5.4				91.0				20.0				1.30	
				11.9				44.1								4.6				107.0				20.6				1.34	
II-A-2-151				11.1				45.4								5.0				91.2				21.1				4.46	
				11.1				53.1								5.0				96.2				20.6				4.56	
				10.4				53.9								4.2				96.6				20.7				4.25	
II-A-2-152				11.6				49.3								5.0				98.0				20.8				9.42	
				10.8				61.0								3.0				100.7				19.5				9.37	
II-A-2-153				13.3				50.3								4.6				144.7				21.4				14.50	
				13.9				62.5								4.2				121.4				19.6				14.34	
II-A-2-154				13.2				37.0								4.6				78.6								.10	
				14.8				37.7								4.6				77.6								.13	
				12.8				36.0								4.2				69.3								.30	
II-A-2-155				12.5				39.1								4.0				91.8				20.2				1.14	
				11.1				48.5								4.6				95.1				21.1				1.17	
				12.3				45.6								5.4				91.9				20.5				1.22	
II-A-2-156				12.5				46.7								4.0				90.0								4.46	
				11.3				51.9								3.6				95.6								4.56	
				12.1				57.8								3.6				92.6								4.50	
II-3-2-157				11.8				52.4								4.8				98.9				20.4				9.53	
				11.9				59.6								4.9				101.8				20.4				9.37	
II-A-2-158				12.5				52.8								4.9				99.1				20.6				14.37	NOTE: THE FOLLOWING VALUES ARE MANIFOLD PRESSURES
				12.2				61.3								4.8				99.5				19.5				14.50	
III-A-1-1			10.9				39.5								3.3				92.6				12.5				1.05		SYSTEM A MIN AND MAX THROUGHOUT RUN — FUEL MIN-103, MAX-321 OXID: MIN-72 MAX-312
	13.9				17.0								15.9				99.1				23.6				2.48				SYSTEM B THROUGHOUT RUN — FUEL: MIN 115 MAX-335 OXID MIN 74 MAX-257
		16.6				67.6								4.3				98.8				20.4				2.44			
III-A-2-1				14.8				46.6								4.7				93.5				19.9				4.65	SYSTEM A MIN AND MAX THROUGHOUT RUN — FUEL MIN-138 MAX-384 OXID MIN-58 MAX 343.
	16.5				16.6								17.7				72.1				21.5				.98				SYSTEM A THROUGHOUT RUN — FUEL MIN-135 MAX-335 OXID. MIN-81 MAX-327
III-A-2-1A				10.9				47.6								3.5				69.0				20.7				1.75	SYSTEM B MIN AND MAX THROUGHOUT RUN — FUEL MIN-37 MAX [illegible] OXID MIN-97 MAX-359 / SYSTEM A THROUGHOUT RUN FUEL. MIN-103 MAX-424 OXID: MIN-70 MAX-405
III-A-3-1	15.3				19.5								25.5				67.5				31.4				1.61				SYSTEM B MIN AND MAX THROUGHOUT RUN — FUEL. MIN 109 MAX 324 OXID MIN-70 MAX-353
	16.1				17.1								15.4				98.7				29.6				5.36				SYSTEM B THROUGHOUT RUN — FUEL: MIN-116 MAX-315 OXID: MIN- MAX-336
	15.6				16.1								18.4				88.5				19.7				1.77				
		15.6				39.5								3.1				91.6				18.6				1.13			
		10.3				38.2								9.1				90.2				15.5				1.02			
			11.0				58.0								5.7				94.0				40.6				.225		
			10.2				51.8								5.8				87.2				18.3				1.01		
				10.9				56.7								4.7				99.7				20.5				.335	
				10.6				54.2								4.7				91.2				20.2				.363	
III-A-4-1		12.0				46.9								6.7				99.3				21.1				2.41			SYSTEM A MIN AND MAX THROUGHOUT RUN — FUEL MIN-161 MAX-378 OXID MIN-95 MAX-359
			11.7				52.7								4.1				74.1				18.6				1.19		SYSTEM B MIN AND MAX THROUGHOUT RUN — FUEL. MIN-86 MAX-373 OXID MIN-[illegible] MAX-302.
	15.8				21.2								14.9				93.6				18.2				9.41				
	15.8				18.6								15.8				93.2				20.1				10.44				
	15.1				18.2								14.9				93.0				20.2				13.46				
	15.4				17.4								14.9				93.2				19.7				9.10				
III-B-1-1A			12.5				34.2								4.5				71.5				20.3				1.11		
		11.5				35.7								6.7				65.5				19.1				2.96			
				11.8				54.5								5.2				95.8				20.1				1.18	
				11.8				54.0								4.2				95.1				21.5				5.91	
				12.8				54.9								4.2				96.8				20.4				14.45	
III-B-2-1			11.6				94.2								5.6				61.4				16.9				6.69		SYSTEM A MIN AND MAX THROUGHOUT RUN — FUEL: MIN-116 MAX-384 OXID: MIN-114 MAX-354
	14.5				18.4								14.5				98.1				37.8				2.09				SYSTEM B THROUGHOUT RUN — FUEL: MIN-118 MAX-374 OXID: MIN-101 MAX-351
				19.5				39.2								5.2				94.7				19.8				1.96	
	14.9				17.8								19.3				91.5				21.4				2.41				
	15.1				20.2								19.2				93.1				19.4				4.52				
	15.6				19.4								15.4				97.5				19.7				6.04				
	15.6				17.4								21.2				93.4				21.2				6.64				
	15.9				21.8								16.7				97.5				19.3				5.57				

FOLDOUT FRAME 1

FOLDOUT FRAME 2

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PULSE NUMBER	PULSE WIDTH	DATE (1967)	TIME OF DAY (HRS.)	INITIAL CELL TEMP (°F)	INITIAL CELL PRESSURE (MM)	INJECTOR HEAD TEMPERATURE (°F) ENG 2	ENG 4	ENG 11	ENG 13	FUEL INLET TEMPERATURE (°F) ENG 2	ENG 4	ENG 11	ENG 13	OXID INLET TEMPERATURE (°F) ENG 2	ENG 4	ENG 11	ENG 13	FUEL MANIFOLD PRESSURE (PSIA) SYSTEM A MIN	MAX	SYSTEM B MIN	MAX	OXID MANIFOLD PRESSURE (PSIA) SYSTEM A MIN	MAX	SYSTEM B MIN	MAX
III-B-3-1	ENG 2 11	0.172	12-9	1715	100	2.2	181				79				25				134	225			105	244		
	22	0.257																	137	218			103	246		
	30	0.091																	142	215			105	231		
	42	0.079																	142	215			103	242		
	50	0.182																	159	215			114	273		
	ENG 4 3	0.213						155				79				75			145	235			145	265		
	13	0.210																	145	250			124	244		
	ENG 11 5	0.015							157				55				84									
	ENG 13 7	0.050								152				84				77								
III-B-4-1	ENG 2 9	0.036	12-9	2163	95	2.2	188				75				79				193	245			110	248		
	14	0.087																	131	219			103	242		
	29	0.093																	141	214			110	229		
	35	0.092																	143	219			129	211		
	45	0.053																	193	218			133	287		
	ENG 4 6	0.017						155				78				79			146	242			145	245		
	11	0.023																	136	237			119	270		
	15	0.017																	193	241			142	259		
	ENG 11 5	0.015							147				85				84									
	12	0.031																								
	14	0.019																								
	ENG 13 4	0.023								150				77				79								
	9	0.020																								
	12	0.149																								
	17	0.040																								
III-B-5-1	ENG 2 6	0.019	12-9	2226	95	2.2	159				78				88				146	211			114	218		
	19	0.049																	122	223			139	262		
	18	0.019																	134	235			139	254		
	24	0.016																	148	237			129	229		
	30	0.055																	151	215			114	235		
	38	0.051																	148	232			95	239		
	44	0.249																	137	215			113	215		
	ENG 4 7	0.018						154				78				81			141	235			135	259		
	14	0.075																	145	223			137	247		
	21	0.019																	139	235			115	259		
	28	0.087																	142	245			101	272		
	34	0.074																	146	235			116	247		
	42	0.034																	145	227			99	277		
II-B-1-1	1	0.017	12-6	0344	95	2.2		155				92				82			139	241	139	237	131	261	147	247
	10	0.017																	127	255	129	262	116	272	107	211
II-B-1-2	1	0.058	12-6	0449	97	2.2		155				96				82			145	216	151	223	174	228	148	216
	10	0.050																	121	226	143	217	154	235	139	203
II-B-1-3	1	0.150	12-6	0509	95	2.2		158				96				81			141	231	154	236	134	219	145	263
	10	0.150																	138	226	142	219	132	268	141	264
II-B-1-4	1	0.200	12-6	0522	96	2.2		155				95				83			145	221	137	221	134	215	145	212
II-B-2-1	1	0.017	12-6	1005	92	2.2	127	159		150	93	93		93	77	77		97	88	211	166	211	77	321	175	192
	10	0.018																	95	223	151	207	62	325	175	217
II-B-2-2	1	0.058	12-6	1028	91	2.2	126	154		150	93	93		91	77	77		95	87	271	166	194	76	317	158	212
	10	0.050																	92	273	165	195	74	310	161	262
II-B-2-3	1	0.150	12-6	1052	91	2.2	129	156		153	93	93		92	76	76		99	78	277	169	184	72	315	175	212
	5	0.150																	63	271	164	212	45	314	165	247
II-B-2-4	1	0.200	12-6	1041	91	2.2	136	145		142	91	96		99	71	70		94	87	272	167	176	78	313	171	217
II-B-3-1	1	0.017	12-6	1107	91	2.2	127			130	93			97	71			92	57	276	166	211	77	344	175	215
	5	0.017																	126	215	153	195	112	315	179	159
II-B-3-3	1	0.142	12-8	0845	98	2.2	130			137	90			95	74			96	98	225	169	192	74	327	176	188
	9	0.150																	125	269	169	157	127	316	157	192
II-B-4-1	ENG 2,13 1	0.017	12-8	0410	92	2.2	127			150	89			94	74			95	145	260	157	235	151	372	142	249
	10	0.017																	131	261	157	235	122	355	142	243
	ENG 4 1	0.054						159				89				74										
	10	0.054																								
II-B-4-3	ENG 2,13 1	0.017	12-8	0456	90	2.2	126			130	91			96	74			95	116	248	158	223	174	264	146	243
	10	0.017																	145	259	147	215	115	245	191	251
	ENG 4 1	0.045						156				91				74										
	10	0.045																								
II-B-4-6	ENG 2,13 1	0.050	12-8	0598	90	2.2	175			130	90			93	74			94	143	245	149	217	155	315	165	317
	8	0.050																	134	241	152	216	91	244	144	225
	ENG 4 1	0.144						154				90				74										
	5	0.144																								

FOLDOUT FRAME 1

FOLDOUT FRAME 2

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PRESSURE SWITCH CLOSING TIME (MS)				PRESSURE SWITCH OPENING TIME (MS)				PRESSURE AT SWITCH CLOSING (PSIA)				PRESSURE AT SWITCH OPENING (PSIA)				STEADY STATE OR MAXIMUM CHAMBER PRESSURE (PSIA)				TIME TO 75% OF MAX OR SS CHAMBER PRESSURE (MS)				INTEGRATED-P_c (PSIA-SEC)				REMARKS
	ENG 2	ENG 4	ENG 1	ENG 13	ENG 2	ENG 4	ENG 1	ENG 13	ENG 2	ENG 4	ENG 1	ENG 13	ENG 2	ENG 4	ENG 1	ENG 13	ENG 2	ENG 4	ENG 1	ENG 13	ENG 2	ENG 4	ENG 1	ENG 13	ENG 2	ENG 4	ENG 1	ENG 13	
III-B-3-1	13.6				17.9								19.5				96.5				31.2				3.76				SYSTEM B MIN AND MAX THROUGHPUT RUN—FUEL: MIN-91 MAX-274 OXID: MIN-106 MAX-287
	15.4				17.7								24.1				96.5				22.5				7.72				SYSTEM A THROUGHPUT RUN—FUEL: MIN-115 MAX-332 OXID: MIN-78 MAX-276
	15.5				20.4								16.7				96.5				21.5				8.49				
	15.1				17.9								15.8				96.5				19.8				7.10				
	15.2				19.6								15.4				96.5				22.1				9.44				
		12.5				41.2								5.2				89.9				23.6				1.81			
		12.6				50.0								4.7				90.5				13.6				2.41			
			12.5				39.5								4.8				74.7				13.5				0.95		
				12.4				41.1								5.3				97.5				19.7				2.19	
III-B-4-1	13.4				21.6								17.6				93.1				21.5				4.68				SYSTEM B MIN AND MAX THROUGHPUT RUN—FUEL: MIN-74 MAX-316 OXID: MIN-113 MAX-387
	13.3				17.3								18.9				96.3				21.6				7.07				SYSTEM A THROUGHPUT RUN—FUEL: MIN-59 MAX-249 OXID: MIN-69 MAX-239
	14.9				17.4								17.2				96.1				19.7				7.49				
	15.6				17.4								15.8				96.5				20.9				5.56				
	14.8				17.5								17.9				96.5				19.5				2.72				
		11.4				41.4								4.7				93.4				21.5				1.16			
		11.4				51.4								6.1				95.0				21.4				1.62			
		11.4				57.7								6.2				85.3				14.6				1.11			
			10.4				35.2								5.8				77.4				23.3				1.40		
			11.6				39.5								6.6				101.2				23.3				3.72		
			11.4				42.3								6.6				95.4				21.2				3.48		
				11.2				41.9								6.1				95.0				21.7				2.33	
				11.1				47.3								5.8				95.4				21.5				6.04	
				11.9				46.1								5.6				95.0				21.5				3.10	
				12.2				45.0								4.2				90.7				11.4				1.60	
III-B-5-1	15.7				17.5								12.4				97.7				21.6				1.29				SYSTEM B MIN AND MAX THROUGHPUT RUN—FUEL: MIN-92 MAX-296 OXID: MIN-13 MAX-286
	15.8				17.1								26.3				97.4				21.5				6.19				SYSTEM A THROUGHPUT RUN—FUEL: MIN-130 MAX-276 OXID: MIN-98 MAX-298
	15.5				17.0								17.0				100.0				20.1				2.42				
	15.4				16.4								15.4				94.2				19.8				1.12				
	14.7				17.6								17.1				97.4				25.5				7.46				
	14.8				14.9								18.0				95.4				21.3				4.84				
	14.9				17.5								17.1				101.8				21.7				5.44				
		11.7				43.2								7.1				115.1				19.3				1.57			
		12.3				48.5								5.1				101.7				19.2				4.27			
		11.2				46.2								4.7				94.1				20.7				1.96			
		11.5				45.5								5.1				100.7				20.7				7.88			
		11.9				50.2								5.7				96.1				17.5				6.93			
		11.5				51.2								5.1				55.7				26.9				2.76			
II-B-1-1		11.5				33.0								4.8				60.8				15.9				1.19			
		10.8				44.1								4.5				32.2				15.4				1.27			
II-B-1-2		11.5				41.1								5.7				93.1				20.9				4.40			
		10.9				55.2								5.2				95.5				24.1				4.75			
II-B-1-3		10.4				56.1								5.2				91.5				22.2				14.52			
						60.5								5.7				102.7				18.4				14.22			
II-B-1-4		11.2				39.5								4.9				98.5				21.0				19.62			
II-B-2-1	17.9	12.5		11.2	15.5	31.3		34.6					15.9	6.2		5.4	61.5	52.1		65.8	21.6	19.1		13.5	0.72	0.75		0.99	
	12.1	11.1		16.2	17.3	42.2		43.5					14.2	5.7		4.7	61.0	65.5		73.7	21.4	20.1		19.3	0.94	0.93		1.06	
II-B-2-2	14.7	12.1		12.5	11.5	44.6		41.3					19.4	4.8		8.6	97.0	102.5		91.5	31.0	32.4		33.0	3.75	3.54		4.26	
	11.4	12.2		11.1	17.4	35.9		33.9					12.7	5.2		3.5	102.2	101.5		94.1	31.9	25.1		31.4	4.47	4.15		4.43	
II-A-2-4	11.9	11.7		12.3	20.1	63.1		47.5					22.1	5.7		4.2	97.5	95.6		97.0	32.3	32.0		21.5	15.12	15.21		15.38	
	13.1			9.1	11.4	55.0		62.6					19.3	5.2		5.0	95.0	95.6		96.1	34.5	32.5		31.6	15.05	13.37		15.47	
II-B-2-4	11.8	12.6		12.4	20.5	51.6		50.6					20.5	5.2		5.2	91.7	95.8		70.4	32.6	33.6		34.6	13.64	13.56		12.74	
II-B-3-1	13.6			11.2	15.5			34.6					11.5			5.6	57.2			74.3	14.0			11.7	0.70			1.02	
	14.3			12.3	16.1			35.9					12.5			4.7	82.5			58.6	22.4			32.4	1.23			1.09	
II-B-3-2	13.1			11.6	22.4			41.5					21.5			5.1	99.4			95.3	24.5			39.7	13.20			15.66	
	12.0			11.5	17.8			52.1					23.4			4.2	99.4			94.7	19.2			23.4	14.01			13.94	
II-B-4-1	14.2			11.4	16.2			34.9					32.2			4.7	71.2			86.0	17.8			23.4	1.15			1.02	
	13.5			12.1	16.6			41.9					15.5			4.2	75.6			87.7	15.1			31.6	1.25			1.17	
		11.7				43.8								4.1				43.2				21.5				4.73			
		11.5				60.3								5.2				49.5				23.1				4.72			
II-B-4-3	15.1			11.1	15.6			35.9					33.9			4.2	70.5			77.5	19.8			11.4	1.13			1.04	
	11.2			11.7	18.4			48.7					24.6			4.2	77.9			82.1	19.9			21.3	1.39			1.84	
		11.3				48.4								5.2				96.0				23.3				4.21			
		11.2				53.6								5.7				95.4				19.7				4.30			
II-B-4-6	15.5			19.6	14.6			41.4					26.5			5.3	91.2			97.8	32.4			32.6	4.37			4.31	
	15.0			15.2	13.6			30.8					17.5			4.2	96.6			94.2	25.0			19.4	4.53			4.42	
		10.4				45.6								5.7				98.6				33.7				4.42			
		9.9				60.2								5.2				99.4				26.4				4.77			

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PULSE NUMBER	PULSE WIDTH	DATE (1967)	TIME OF DAY (HRS)	INITIAL CELL TEMP (°F)	INITIAL CELL PRESSURE	INJECTOR HEAD TEMPERATURE (°F) ENG. 2	ENG. 4	ENG. 11	ENG. 13	FUEL INLET TEMPERATURE (°F) ENG. 2	ENG. 4	ENG. 11	ENG. 13	OXID INLET TEMPERATURE (°F) ENG. 2	ENG. 4	ENG. 11	ENG. 13
II-B-4-7	ENG 2,11 1	0.030	12-8	0550	90	2.2	127			132	91			95	74			95
	5	0.030																
	ENG 4 1	0.100						133				91				74		
	4	0.115																
II-B-4-9	ENG 2,11 1	0.040	12-8	0720	90	2.2	126			132	92			93	74			90
	5	0.051																
	ENG 4 1	0.056						137				92				74		
	5	0.076																
II-B-5-1	1	0.017	12-8	0949	93	2.2			148	150			76	97			75	95
	10	0.017																
II-B-5-5	1	0.150	12-8	1034	88	2.2			147	150			75	97			74	96
	5	0.150																
II-B-6-1	1	0.017	12-8	1056	90	2.2				130				96				92
	3	0.017																
II-B-6-2	1	0.050	12-8	1118	90	2.2				130				97				77
	5	0.050						—										
II-B-7-1	1	0.017	12-8	1952	87	2.2	134	151			69	69			77	77		
	10	0.017																
II-B-9-2	1	0.050	12-8	2149	92	2.2		151				74				77		
	5	0.050																
II-B-11-4	ENG 2,13 1	0.054	12-8	2214	90	2.2	125			134	74			77	77			73
	5	0.054																
	ENG 4 1	0.017						133				74				77		
	5	0.017																
II-B-11-3	ENG 2,13 1	0.048	12-8	2237	90	2.2	128			132	77			77	73			73
	5	0.045																
	ENG 4 1	0.017						135				77				73		
	5	0.017																
II-B-12-3	ENG 2,13 1	0.044	12-8	2252	91	2.2	128			133	79			77	76			77
	5	0.044																
	ENG 4 1	0.017						135				78				76		
	5	0.017																
II-B-10-7	ENG 2,13 1	0.100	12-8	2307	90	2.2	125			136	75			74	77			74
	5	0.100																
	ENG 4 1	0.050						136				75				77		
	5	0.050																
II-B-10-9	ENG 2,13 1	0.096	12-8	2321	90	2.2	129			137	95			74	77			95
	5	0.096																
	ENG 4 1	0.050						136				95				77		
	5	0.050																
II-C-2-1	1	0.017	12-9	0151	90	2.2	126	154		150	86	86		94	74	74		94
	10	0.017																
II-C-2-2	1	0.050	12-9	0209	90	2.2	127	135		132	75	75		94	74	74		94
	10	0.050																
II-C-3-3	1	0.150	12-9	0217	90	2.2	128	135		131	75	75		95	75	75		95
	5	0.150																
II-C-3-4	1	0.500	12-9	0232	90	2.2	138	135		134	73	73		95	74	74		92
II-C-3-1	1	0.017	12-9	0252	90	2.2	127			132	90			75	74			75
	5	0.017																
II-C-3-3	1	0.150	12-9	0239	90	2.2	127			133	74			76	74			76
	5	0.150																
II-C-4-10	ENG 2,13 1	0.017	12-9	0342	90	2.2	130			130	98			70	75			90
	10	0.017																
	ENG 4 1	0.054						133				90				75		
	10	0.054																
II-C-4-5	ENG 2,13 1	0.017	12-9	0405	90	2.2	126			136	76			95	74			83
	10	0.017																
	ENG 4 1	0.045						139				73				74		
	10	0.045																
II-C-4-6	ENG 2,13 1	0.150	12-9	0414	90	2.2	130			132	77			95	74			95
	5	0.150																
	ENG 4 1	0.104						134				77				74		
	5	0.104																
II-C-4-7	ENG 2,13 1	0.150	12-9	0419	90	2.2	128			133	74			95	74			95
	5	0.150																
	ENG 4 1	0.100						134				75				74		
	5	0.100																

FOLDOUT FRAME 1

FOLDOUT FRAME 2

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PRESSURE SWITCH CLOSING TIME (MS)				PRESSURE SWITCH OPENING TIME (MS)				PRESSURE AT SWITCH CLOSING (PSIA)				PRESSURE AT SWITCH OPENING (PSIA)				STEADY STATE OR * MAXIMUM CHAMBER PRESSURE (PSIA)				TIME TO 75% OF MAX OR SS CHAMBER PRESSURE (MS)				INTEGRATED $-P_c$ (PSIA-SEC)				REMARKS
	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	
IX-B-4-7	14.7			15.4	17.8			45.3					17.0			4.2	96.5			93.6	18.9			31.6	4.56			4.97	
	14.6			11.5	17.1			50.6					18.0			5.1	93.5			94.6	18.9			20.1	4.67			4.43	
		11.8				31.8								4.1				99.7				21.6				9.78			
		11.2				67.2								4.9				95.8				31.6				9.44			
IX-B-4-9	15.8			13.5	19.1			41.6					16.7			6.6	93.4			77.9	24.1			30.2	4.10			4.72	
	16.1			11.2	19.4			56.2					15.3			5.1	93.0			94.9	25.6			19.7	4.32			3.98	
		11.7				51.6								4.1				92.4				21.3				8.35			
		11.8				61.9								4.8				91.3				23.5				9.42			
IX-B-5-1			13.2	13.2			38.4	36.7							4.8	4.7			68.9	78.0			19.2	19.9			0.90	0.99	
			11.8	12.6			43.1	41.5							4.8	3.3			59.2	77.1			22.6	32.1			1.20	1.00	
IX-B-5-3			13.3	14.9			49.8	41.2							4.5	5.2			97.6	94.7			33.1	35.1			19.27	19.51	
			9.9	10.7			54.9	60.6							5.7	4.7			95.4	97.6			31.1	21.4			15.07	13.45	
IX-B-6-1				15.8				34.8								5.6				73.3				33.4				0.99	
				15.2				38.0								6.2				84.8				22.3				1.04	
IX-B-6-2				14.7				42.5								5.2				91.4				31.7				4.18	
				13.2				46.5								5.2				91.9				31.5				4.56	
IX-B-9-1	14.9	15.0			16.8	54.1							16.9	4.8			56.9	63.0			18.8	19.3			0.70	0.74			
	16.1	13.7			16.3	42.2							19.5	5.2			60.3	63.5			26.5	25.6			0.56	0.85			
IX-B-9-2		13.5				49.6								3.7				92.2				23.7				3.80			
		11.7				52.1								4.5				95.5				24.9				4.28			
IX-B-11-1	18.9			11.2	18.2			41.4					17.2			4.7	96.2			90.9	23.7			21.1	4.55			4.55	
	14.3			11.2	18.5			41.6					15.0			5.6	93.2			92.5	23.0			21.5	4.63			4.66	
		14.8				41.3								5.2				85.4				23.1				1.15			
		11.4				41.9								4.5				86.5				11.3				1.15			
IX-B-11-3	13.8			13.2	17.5			37.5					18.4			4.7	91.4			94.0	21.8			31.5	3.99			4.07	
	14.7			11.9	18.4			50.6					13.9			3.7	96.3			93.7	21.4			31.8	4.12			4.25	
		11.2				47.9								3.3				92.1				21.8				1.15			
		11.9				44.4								4.6				85.5				23.4				1.21			
IX-B-14-5	15.1			13.4	18.6			48.3					19.4			5.2	41.9			87.4	22.6			20.9	3.56			3.68	
	19.6			14.8	14.3			46.9					15.4			5.2	89.8			95.6	17.2			19.7	3.73			3.57	
		11.7				37.7								3.1				39.1				21.9				1.12			
		11.9				41.9								4.3				34.1				21.6				1.45			
IX-B-14-7	15.6			13.7	18.7			49.9					21.6			3.6	97.1			49.2	30.7			22.6	9.15			9.62	
	13.0			11.8	18.1			54.8					18.5			5.1	101.8			94.8	33.7			21.8	9.10			9.16	
		11.2				45.2								3.1				93.0				31.4				4.45			
		11.8				54.1								4.1				97.3				19.9				4.50			
IX-B-14-9	16.2			15.5	19.2			47.5					20.6			3.6	97.2			94.2	31.1			32.6	8.02			8.72	
	16.2			17.2	16.2			55.4					17.8			4.7	100.2			94.2	23.7			31.5	8.74			8.61	
		11.3				44.9								3.9				32.6				23.9				4.44			
		11.8				52.6								4.9				41.9				26.3				4.14			
IX-C-2-1	18.6	14.1		15.4	12.8	35.0		37.5					19.3	6.6		4.1	71.2	69.1		75.4	33.5	19.3		11.7	0.50	0.96		1.00	
	18.1	14.8		11.2	19.7	45.5		46.4					17.2	5.6		3.5	66.3	66.5		75.1	33.2	22.9		19.9	0.75	0.57		1.04	
IX-C-2-2	15.4	16.0		16.1	17.1	41.8		36.7					18.2	0.2		6.1	94.0	98.6		77.6	33.5	33.4		31.1	4.97	4.51		4.15	
	16.1	11.6		11.1	19.8	51.8		45.3					23.4	4.2		4.7	33.6	88.5		89.5	24.3	23.2		20.4	3.76	4.07		4.70	
IX-C-2-3	12.9	14.1		15.4	14.8	46.3		47.8					11.8	4.8		6.1	96.3	96.0		94.2	21.3	25.0		22.7	13.25	13.50		13.70	
	15.4			13.5	14.2	39.0		54.8					16.4	5.2		5.6	41.9	96.0		95.6	23.5	–		19.1	12.48	12.54		19.28	
IX-C-2-4	11.7	14.6		12.5	15.6	62.3		43.1					21.8	6.2		5.5	54.4	93.2		94.1	21.4	24.6		23.4	17.23	16.41		16.67	
IX-C-3-1	11.6			12.1	14.9			74.5					27.1			5.6	48.3			72.4	21.7			11.5	6.75			1.61	
	15.3			11.6	15.8			35.6					15.5			5.6	76.5			86.5	21.4			21.4	1.05			1.07	
IX-C-3-3	11.2			12.7	40.0			47.5					18.4			5.6	96.8			94.2	34.1			33.2	13.13			13.58	
	13.0			11.6	18.1			52.7					20.1			5.6	96.7			94.7	33.2			19.4	13.54			13.37	
IX-C-4-1A	16.3			12.1	18.3			34.2					13.7			3.7	93.2			81.2	19.6			11.9	1.15			0.97	
	16.1			11.4	17.4			49.9					17.8			3.7	101.5			94.2	20.4			20.3	1.24			1.53	
		11.2				45.0								4.9				95.5				33.1				4.43			
		11.2				53.2								3.8				96.1				23.9				4.48			
IX-C-4-5	15.8			13.4	16.0			55.7					19.7			3.3	99.5			87.7	32.6			17.9	1.15			1.12	
	12.9			11.2	18.6			41.9					13.7			4.2	92.4			93.1	31.1			31.9	1.22			1.31	
		11.4				45.2								4.7				82.9				33.4				4.42			
		11.2				63.8								5.7				76.7				21.7				3.64			
IX-C-4-6	15.4			13.3	18.8			46.1					17.8			4.2	99.6			93.5	19.5			22.1	4.47			4.38	
	15.1			11.4	16.9			48.4					21.7			4.1	97.2			95.5	23.2			21.6	4.37			4.44	
		11.1				47.3								4.8				117.7				23.4				9.56			
		11.7				43.8								5.2				111.7				21.6				9.43			
IX-C-4-7	15.5			14.4	19.1			49.8					18.8			4.7	97.9			91.4	30.1			31.3	4.51			4.30	
	14.5			11.9	18.4			49.1					16.0			4.5	45.5			93.7	18.8			21.8	4.42			4.47	
		11.6				55.9								4.1				98.5				32.6				9.19			
		18.7				60.0								4.3				95.1				31.1				9.17			

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PULSE NUMBER	PULSE WIDTH	DATE (1967)	TIME OF DAY (HRS)	INITIAL CELL TEMP (°F)	INITIAL CELL PRESSURE (MM)	INJECTOR HEAD TEMPERATURE (°F)				FUEL INLET TEMPERATURE (°F)				OXID INLET TEMPERATURE (°F)				INITIAL INLET PRESSURE (PSIA)			
							ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	FUEL A	FUEL B	OXID A	OXID B
II-C-4-1	2,13 1	0.250	12-9	0434	96	2.2	133			137	79			96	75			96	121.1	122.5	121.3	121.1
	3	0.250																				
	4 1	0.296						134				78				75						
	5	0.296																				
II-C-8-1	1	0.017	12-9	0550	92	2.2	137	134			77	77			76	76			121.7	121.3	121.2	121.7
	10	0.017																				
II-C-9-2	1	0.250	12-9	0915	92	2.2		134				77					75		121.2	122.1	121.3	121.0
	3	0.250																				
II-C-10-1	2,13 1	0.254	12-9	1024	90	2.2	136			130	76			76	75			76	121.6	121.2	121.1	121.2
	5	0.254																				
	4 1	0.017						134				76				76						
	5	0.017																				
II-C-10-3	2,13 1	0.445	12-9	1033	91	2.2	137			132	75			78	76			76	121.1	121.1	121.3	121.4
	5	0.445																				
	4 1	0.017						132				75				78						
	5	0.017																				
II-C-11-3	2,13 1	0.444	12-9	1847	91	2.2	137			133	77			76	76			76	121.3	121.2	121.0	121.9
	5	0.444																				
	4 1	0.017						132				77				76						
	5	0.017																				
II-C-11-7	2,13 1	0.140	12-9	1846	91	2.2	142			133	77			76	75			76	121.4	121.1	121.3	121.2
	3	0.140																				
	4 1	0.051						134				77				75						
	3	0.050																				
II-C-14-1	2,13 1	0.096	12-9	1855	90	2.2	138			134	76			76	76			75	121.3	121.9	121.2	121.0
	3	0.096																				
	4 1	0.058						133				76				75						
	3	0.050																				
II-D-1-1	1	0.014	12-6	2125	90	2.2	137	133	147		73	77	79		76	76	77		119.6		119.2	
	25	0.014																				
	50	0.014																				
II-D-1-2	1	0.014	12-6	2230	90	2.2	137	134	140		70	70	75		76	76	77		122.7		117.6	
	25	0.014																				
	50	0.014																				
II-D-2-1	1	0.014	12-6	2323	90	2.2	130	133	143		76	78	76		75	75	76		119.3		117.6	
	25	0.014																				
	50	0.014																				
II-D-2-2	1	0.014	12-6	2330	90	2.2	136	131	142		78	78	78		73	73	76		118.0		117.7	
	25	0.014																				
	50	0.014																				
II-D-3-1	1	0.012	12-6	2302	90	2.2	137	134	136		73	73	76		74	74	74		117.9		115.7	
	10	0.012																				
	15	0.012																				
II-D-3-2	1	0.012	12-6	2346	90	2.2	137	133	130		70	70	77		74	74	76		117.4		117.2	
	10	0.012																				
	20	0.012																				
II-F-1A	2 10		12-14	0104	93	2.2	149				79				87				115.8	115.4	112.6	107.6
	20																					
	30																					
	4 2							146				79				87						
	12																					
	11 1								150				75				87					
	3																					
	13 2									130				58				75				
	4																					
II-I-16	1	0.430	12-11	0530	70	2.2		134				66				65			177.4		175.5	
	3	0.430																				
	4	0.230																				
II-I-17	1	0.050	12-11	0539	71	2.2		134				66				65			177.2		175.7	
	3	0.050																				
	4	0.050																				
II-I-18	1	0.111	12-11	0547	71	2.2		134				66				66			177.2		175.7	
	3	0.180																				
II-I-21	1	0.430	12-11	0414	74	2.2				130				67				68	176.0		175.0	
	3	0.430																				
	5	0.030																				

RUN NUMBER	PULSE NUMBER	INLET WITH FUEL VALVE OPEN (PSIA)								INLET WITH OXID VALVE OPEN (PSIA)								MAXIMUM INLET PRESSURE AT FUEL VALVE CLOSURE (PSIA)				MAXIMUM INLET PRESSURE AT OXID VALVE CLOSURE (PSIA)				FUEL MANIFOLD PRESSURE (PSIA)				OXID. MANIFOLD PRESSURE (PSIA)			
		ENG 2		ENG 4		ENG 11		ENG 13		ENG 2		ENG 4		ENG 11		ENG 13		ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	SYSTEM A		SYSTEM B		SYSTEM A		SYSTEM B	
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX									MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
II-C-4-1	2,13 1																									129	323	144	322			101	354
	3																									142	310	150	302				352
	4 1																																
	5																																
II-C-8-1	1	4		4						6		6						373	373			245	245			33	314						
	10	9		9						6		6						397	397			314	314			52	314						
II-C-9-2	1																									55	220						
	3																									111	255						
II-C-10-1	2,13 1																									107	272	92	321			88	332
	5																									91	274	75	360			53	550
	4 1																																
	5																																
II-C-10-3	2,13 1																									113	259	113	279			90	555
	5																									89	261	11	277			77	313
	4 1																																
	5																																
II-C-11-3	2,13 1																									108	242	117	264			95	364
	5																									93	245	74	294			52	322
	4 1																																
	5																																
II-C-11-7	2,13 1																									116	221	118	251			166	398
	3																									134	226	129	253			65	395
	4 1																																
	3																																
II-C-14-1	2,13 1																									116	231	114	248			100	500
	3																									129	231	126	228			66	319
	4 1																																
	3																																
II-D-1-1	1	47		47		133				34		34		115				312	312	199		254	254	215		37	393	169	196	37	392	174	215
	25	13		13		126				58		58		126				297	297	262		221	221	216		97	324	156	197	73	317	171	232
	50	42		42		129				59		79		130				302	302	263		241	241	243		92	315	157	190	73	302	172	213
II-D-1-2	1	35		35		131				58		55		137				455	455	270		363	363	232		37	395	165	197	74	364	175	157
	25	39		39		143				55		55		144				541	541	265		305	305	235		94	336	156	217	72	266	138	335
	50	49		49		145				94		94		147				566	566	259		365	365	232		94	326	156	197	72	291	181	265
II-D-2-1	1	23		23		132				64		64		144				478	478	305		405	405	284		77	337	170	197	71	311	176	316
	25	37		37		139				48		48		131				411	411	311		431	431	241		87	372	166	195	47	322	145	234
	50	67		67		132				38		38		154				411	410	315		411	411	185		85	310	165	195	56	291	148	423
II-D-2-2	1	54		54		135				60		60		133				457	457	271		328	328	264		57	356	172	212	75	310	170	191
	25	66		66		145				92		92		131				390	390	251		363	369	261		90	324	165	195	56	299	154	231
	50	67		67		145				66		66		145				370	370	361		375	375	264		96	289	163	197	55	295	152	231
II-D-3-1	1	75		75		181				105		117		141				354	354	262		395	395	215		58	333	172	193	75	291	171	310
	10	84		84		137				125		118		141				357	357	272		310	310	218		98	336	172	202	75	295	171	315
	15	91		91		154				115		113		151				375	375	269		292	292	225		81	330	160	200	67	315	177	210
II-D-3-2	1	66		66		125				96		96		121				364	364	262		304	304	218		35	325	165	200	75	295	176	311
	10	72		72		125				98		98		131				370	370	322		311	311	292		35	311	170	212	67	371	177	311
	20	66		66		128				96		96		134				372	372	269		311	311	335		95	395	172	222	67	391	177	213
II-F-1A	2 10																									110	233			110	215		
	20																									133	316			133	274		
	30																									135	317			131	215		
	4 2																									131	225			129	235		
	12																									136	235			132	229		
	11 1																																
	3																																
	13 2																																
	4																																
II-I-16	1			115	158							144	139						289				221										
	3			110	153							137	166						302				327										
	4			110	159							138	166						279				241										
II-I-17	1			148	216							137	160						290				242										
	3			110	216							151	166						230				243										
	4			110	216							128	165						295				243										
II-I-18	1			105	230							154	211						264				262										
	3			105	235							154	264						264				265										
II-I-21	1							115	210							152	191				153				219								
	3							115	225							153	171				245				219								
	5							115	225							150	191				158				219								

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MSC-EP-R-68-17	New	

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PRESSURE SWITCH CLOSING TIME (MS)				PRESSURE SWITCH OPENING TIME (MS)				PRESSURE AT SWITCH CLOSING (PSIA)				PRESSURE AT SWITCH OPENING (PSIA)				STEADY STATE OR MAXIMUM CHAMBER PRESSURE (PSIA)				TIME TO 75% OF MAX OR SS CHAMBER PRESSURE (MS)				INTEGRATED – Pc (PSIA-SEC)				REMARKS
	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	
II-C-4-4	15.4			9.2	15.1			43.7					24.9			4.7	92.4			91.6	22.8			20.4	4.91			4.75	
	12.2			11.4	15.4			50.4					19.3			4.7	100.4			94.7	22.0			21.0	4.43			4.49	
		11.0				59.3								5.2				90.4				23.7				5.51			
		11.0				61.3								5.2				97.4				21.4				5.25			
II-C-5-1	18.6	13.2			14.2	37.2							17.6	4.7			59.1	63.5			23.0	49.5			0.72	0.74			
	14.4	12.6			15.8	31.6							16.5	4.5			50.5	41.3			19.5	19.8			0.78	0.75			
II-C-4-2		13.6				42.7								4.3				71.4				23.6				3.71			
		11.8				49.4								4.8				77.7				21.5				4.05			
II-C-11-1	16.1			11.4	15.4			42.3					17.0	-		4.7	53.3			73.9	21.1			22.1	4.33			4.42	
	15.4			11.8	18.0			45.1					13.5			4.7	75.4			87.9	22.5			21.2	3.34			4.63	
		13.2				37.2								3.8				25.5				18.7				1.13			
		16.3				43.5								3.8				28.5				31.2				1.15			
II-C-11-3	15.3			12.2	17.1			37.9					18.8			4.8	89.7			75.0	22.7			21.4	3.82			3.93	
	14.6			11.2	17.4			45.1					18.1			4.8	81.0			89.7	21.1			21.6	3.53			3.95	
		11.2				37.7								4.3				20.4				32.1				1.15			
		10.4				41.8								3.8				75.8				14.0				1.12			
II-C-11-5	15.6			17.2	16.4			43.3					18.9			4.7	85.1			89.5	21.8			20.1	3.45			3.55	
	15.7			11.4	17.3			45.0					16.5			4.7	76.5			34.7	21.8			21.6	3.13			3.51	
		11.4				37.4								4.5				30.6				22.6				1.08			
		11.8				43.0								3.8				71.1				21.6				1.08			
II-C-11-7	15.3			13.4	14.1			46.3					17.1			5.1	96.6			93.8	25.0			22.5	3.17			3.59	
	15.7			11.1	19.7			52.4					19.8			5.1	96.5			93.9	23.6			22.2	3.71			3.85	
		12.1				46.3								4.3				93.9				21.9				4.15			
		12.2				53.4								4.8				93.9				21.0				4.39			
II-C-11-9	11.4			12.8	19.7			45.8					19.5			4.5	94.5			95.6	25.7			25.5	3.77			3.53	
	11.9			11.9	14.7			57.8					11.5			5.5	94.5			94.1	20.5			21.0	3.57			3.61	
		12.2				43.2								6.2				94.5				24.4				4.25			
		12.8				52.8								4.5				94.0				23.1				4.23			
II-D-1-1	14.6	11.0	11.4		11.2	35.0	33.2						19.5	3.5	4.4		35.9	37.5	37.2		15.1	19.6	17.2		0.62	0.59	0.35		
	11.7	11.3	10.9		15.6	45.4	42.5						11.5	5.0	5.2		44.2	46.1	47.2		19.1	20.4	19.1		1.10	0.71	1.00		
	11.6	12.8	10.1		15.1	43.6	41.3						15.0	3.8	5.2		44.7	44.2	71.1		17.2	20.5	19.0		0.59	0.77	0.42		
II-D-1-2	14.6	15.4	13.4		12.2	51.5	52.2						17.4	3.8	4.4		57.4	40.5	53.6		15.2	21.3	17.7		0.36	0.44	0.67		
	14.4	14.1	12.8		10.6	44.8	51.5						19.5	3.5	5.3		33.2	30.7	55.4		20.7	15.7	11.2		0.45	0.57	0.79		
	13.5	11.6	11.6		11.4	46.3	38.9						11.9	4.8	4.8		50.9	35.5	62.0		13.9	15.6	11.6		0.47	0.55	0.58		
II-D-2-1	11.9	14.4	11.7		19.1	31.5	32.2						17.0	5.8	5.3		46.7	47.1	54.1		14.5	17.2	17.3		0.44	0.50	0.76		
	11.7				17.6								17.7				25.5	31.4	44.4		22.6	-	-		0.74	0.71	0.55		
	14.4				15.3								17.2				55.2	55.4	116.2		16.7	-	-		1.69	0.65	0.43		
II-D-3-2	14.9	11.5	12.2		11.2	31.8	36.5						17.2	4.7	4.4		46.1	41.4	52.5		13.0	20.2	11.3		0.32	0.48	0.63		
	14.1				11.1								15.5				49.5	39.1	47.0		11.6	-	-		0.73	0.67	0.50		
	16.6				13.5								18.5				47.5	36.5	46.1		17.5	-	-		0.69	0.68	0.76		
II-D-4-1	19.5	12.2	13.4		11.4	37.3	36.3						22.2	4.5	5.0		27.4	30.3	45.1		26.0	19.6	17.2		0.31	0.35	0.51		
	18.9	16.0	13.2		11.2	29.6	31.9						19.6	5.2	5.0		36.6	38.8	44.7		19.9	19.1	11.3		0.38	0.35	0.57		
	19.4	14.8	11.4		11.6	29.9	33.9						11.5	5.2	5.8		24.4	25.6	41.1		20.4	19.7	17.2		0.26	0.31	0.57		
II-D-5-2	11.4	14.4	14.5		11.3	28.7	33.5						17.5	2.1	.8		31.1	35.6	44.7		12.9	15.8	15.7		0.34	0.31	0.51	NOTE: THE FOLLOWING VALUES ARE MANIFOLD PRESSURES
	12.6	12.3	12.4		11.5	35.7	35.3						13.9	2.4	1.8		40.9	33.7	47.5		12.1	19.4	17.9		0.94	0.37	0.67	
	17.0	14.8	12.1		9.7	30.0	34.5						14.5	2.5	1.4		41.4	34.1	57.1		11.9	22.5	11.6		0.32	0.35	0.68		
II-F-18	17.9				16.1								17.2				74.4				23.7				1.25				SYSTEM B MIN + MAX THROUGHOUT THE RUN — FUEL: MIN= 39 MAX= 383 OXID: MIN= 55 MAX= 311
	16.8				21.0								19.4				91.5				21.2				1.59				SYSTEM A THROUGHOUT RUN — FUEL: MIN= 88 MAX= 276 OXID: MIN= 91 MAX= 257
	15.5				15.6								20.2				92.4				19.7				1.31				
		11.1				35.6								4.7				71.3				19.2				1.24			
		11.7				35.1								5.2				70.0				18.2				1.11			
			10.5				41.0								9.4				94.1				22.4				1.45		
			11.1				35.7								11.1				73.1				15.2				1.22		
				14.8				53.5								4.7				99.8				21.6				1.10	
				10.5				54.0								3.7				98.3				21.5				1.24	
II-I-16		35.5				42.1								4.4				35.1				35.5				1.46			SYSTEM A MIN + MAX THROUGHOUT RUN — FUEL: MIN= 339 MAX= 415
		35.8				47.6								4.4				35.4				32.8				1.49			
		35.9				49.1								4.4				55.5				34.1				1.42			
II-I-17		35.7				51.1								4.4				54.4				35.5				3.29			SYSTEM A MIN + MAX THROUGHOUT RUN — FUEL: MIN= 295 MAX= 415
		34.3				51.2								4.5				51.1				39.9				3.31			
		36.2				57.7								4.5				59.1				34.4				3.31			
II-I-18		33.8				52.4								3.7				92.4				35.2				7.81			SYSTEM B MIN + MAX THROUGHOUT RUN — FUEL: MIN= 311 MAX= 412
		31.7				19.1								3.7				93.1				14.3				7.81			
II-I-41				26.3				39.9								4.2				97.1				35.5				1.39	SYSTEM B MIN + MAX THROUGHOUT RUN — FUEL: MIN= 334 MAX= 412 OXID: MIN= 333 MAX= 382
				26.9				45.6								4.7				97.5				19.9				1.45	
				26.5				45.9								3.7				95.6				30.4				1.46	

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PULSE NUMBER	PULSE WIDTH	DATE (1967)	TIME OF DAY (HRS)	INITIAL CELL TEMP (°F)	INITIAL CELL PRESSURE (MM)	INJECTOR HEAD TEMPERATURE (°F)				FUEL INLET TEMPERATURE (°F)				OXID INLET TEMPERATURE (°F)				INITIAL INLET PRESSURE (PSIA)			
																			FUEL		OXID	
							ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	A	B	A	B
II-I-62	1	0.252	12-11	0412	74	2.2				130				67				67	172.0		175.2	
	5	0.250																				
	5	0.148																				
II-I-63	1	0.124	12-11	0495	74	2.2				130				67				67	172.2		175.6	
	5	0.166																				
II-K-1	ENG 2 3	0.0[illegible]	12-18	0244	100	2.2	192				77				76				178.5	182.0	177.7	176.4
	14	0.047																				
	33	0.043																				
	39	0.092																				
	48	0.031																				
	ENG 4 5	0.017						155				77				80						
	11	0.023																				
	15	0.017																				
	ENG 13 4	0.023								131				84				75				
	9	0.026																				
	12	0.032																				
	17	0.016																				
II-K-2	ENG 2 9	0.046	12-18	0348	91	2.2	189				75				75				177.0	178.5	178.5	175.5
	14	0.097																				
	23	0.043																				
	39	0.092																				
	46	0.091																				
	ENG 4 5	0.017						159				75				75						
	11	0.021																				
	15	0.017																				

RUN NUMBER	PULSE NUMBER	VALVE OPENING RESPONSE (MS)								VALVE CLOSING RESPONSE (MS)								IGNITION DELAY (MS)			
		FUEL				OXID				FUEL				OXID							
		ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13
II-I-62	1				30.3				123.1				133.9								36.6
	5				31.0				127				129								36.5
	5				31.0				144				140								37.6
II-I-63	1				30.7				156				135								36.2
	5				30.0				137				115								37.6
II-K-1	ENG 2 3	6.1				6.6								7.2				9.7			
	14	6.4				7.0								8.2				10.5			
	33	6.4				6.4								8.2				9.7			
	39	6.4				6.9								8.8				9.5			
	48	6.4				7.2								8.5				11.3			
	ENG 4 5		5.7				6.4								9.0				11.2		
	11		6.4				6.9								5.1				10.5		
	15		6.4				6.9								3.7				11.6		
	ENG 13 4				6.1				6.4												10.1
	9				6.1				6.7												10.1
	12				6.1				6.7												10.6
	17				6.1				6.7												10.4
II-K-2	ENG 2 9	6.4				7.9				7.4				7.9				11.7			
	14	6.9				7.9				8.2				10.7				13.5			
	23	6.4				8.2				7.9								11.5			
	39	6.1				8.5				7.4								11.2			
	46	6.9				7.9				8.2				9.9				13.2			
	ENG 4 5		6.2				7.4				7.2				8.5				13.6		
	11		6.6				7.9				9.4								12.0		
	15		6.7				7.4				7.7								11.8		

RUN NUMBER	PULSE NUMBER	INLET WITH FUEL VALVE OPEN (PSIA)								INLET WITH OXID VALVE OPEN (PSIA)							
		ENG 2		ENG 4		ENG 11		ENG 13		ENG 2		ENG 4		ENG 11		ENG 13	
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
II-I-62	1							119	196							153	179
	5							124	201							152	184
	5							114	205							153	184
II-I-63	1							119	201							157	184
	5							119	205							152	184
II-K-1	ENG 2 3																
	14																
	33																
	39																
	48																
	ENG 4 5																
	11																
	15																
	ENG 13 4																
	9																
	12																
	17																
II-K-2	ENG 2 9																
	14																
	23																
	39																
	46																
	ENG 4 5																
	11																
	15																

RUN NUMBER	PULSE NUMBER	MAXIMUM INLET PRESSURE AT FUEL VALVE CLOSURE (PSIA)				MAXIMUM INLET PRESSURE AT OXID VALVE CLOSURE (PSIA)				FUEL MANIFOLD PRESSURE (PSIA)				OXID. MANIFOLD PRESSURE (PSIA)			
										SYSTEM A		SYSTEM B		SYSTEM A		SYSTEM B	
		ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
II-I-62	1				239				260								
	5				244				216								
	5				244				215								
II-I-63	1				244				226								
	5				239				266								
II-K-1	ENG 2 3									132	242			97	312		
	14									130	235			101	244		
	33									142	216			125	224		
	39									142	216			129	218		
	48									142	216			139	241		
	ENG 4 5									123	242			115	246		
	11									127	223			112	274		
	15									123	242			119	255		
	ENG 13 4																
	9																
	12																
	17																
II-K-2	ENG 2 9									120	235			97	266		
	14									119	220			89	244		
	23									135	199			110	235		
	39									128	203			125	214		
	46									132	201			129	225		
	ENG 4 5									120	225			112	212		
	11									116	215			106	262		
	15									111	225			112	239		

LM RCS SUBSYSTEM TEST DATA SUMMARY

RUN NUMBER	PRESSURE SWITCH CLOSING TIME (MS)				PRESSURE SWITCH OPENING TIME (MS)				PRESSURE AT SWITCH CLOSING (PSIA)				PRESSURE AT SWITCH OPENING (PSIA)				STEADY STATE OR MAXIMUM CHAMBER PRESSURE (PSIA)				TIME TO 75% OF MAX OR SS CHAMBER PRESSURE (MS)				INTEGRATED - Pc (PSIA - SEC)				REMARKS
	ENG. 2	ENG 4	ENG 11	ENG 13	ENG. 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	ENG 2	ENG 4	ENG 11	ENG 13	
IV-I-62				36.8				47.3								4.6				55.2				34.6				5.97	SYSTEM B MIN AND MAX THROUGHPUT RUN — FUEL: MIN - 347 MAX 378 OXID: MIN-350 MAX-383
				36.5				54.3								5.0				95.5				36.6				9.60	
				36.7				52.1								6.4				99.2				34.7				9.57	
IV-I-65				36.5				55.6								4.3				100.4				30.4				5.78	SYSTEM B MIN AND MAX THROUGHPUT RUN — FUEL: MIN - 342 MAX 384 OXID: MIN - 341 MAX - 359
				36.7				63.7								2.9				99.4				35.9				5.78	
IV-K-1	14.5				19.1								17.6				97.9				11.6				4.81				SYSTEM A MIN AND MAX THROUGHPUT RUN — FUEL: MIN - 75 MAX - 297 OXID: MIN - 73 MAX - 282
	14.9				17.5								20.7				97.5				21.3				7.33				SYSTEM A MIN AND MAX THROUGHPUT RUN — FUEL: MIN - 90 MAX - 337 OXID: MIN - 95 MAX - 297
	14.1				17.4								18.9				97.7				15.6				7.53				
	14.9				16.9								15.0				96.8				30.0				7.60				
	13.6				21.9								15.0				97.5				15.8				7.90				
		10.3				35.4								4.3				91.0				19.7				1.42			
		4.9				39.2								5.2				81.6				20.9				1.64			
		10.3				41.3								4.7				86.5				20.5				1.32			
				16.4				48.5								2.1				98.4				31.5				2.39	
				10.4				46.7								6.7				109.9				36.0				6.44	
				10.9				44.8								5.2				105.8				19.4				4.55	
				11.5				41.5								6.8				131.3				19.2				1.88	
IV-K-2	16.1				17.6								18.0				96.6				22.2				4.44				SYSTEM A MIN AND MAX THROUGHPUT RUN — FUEL MIN - 57 MAX - 285 OXID: MIN - 65 MAX - 269
	16.6				17.1								17.5				97.3				23.5				7.66				
	15.5				17.6								16.5				97.3				19.4				8.45				
	16.1				16.9								17.2				97.3				21.7				8.30				
	15.1				21.8								18.0				96.6				22.1				7.82				
		12.6				37.7								4.6				85.9				25.1				1.00			
		12.5				39.6								3.9				83.5				24.0				1.50			
		13.3				35.7								5.2				75.5				19.7				1.17			

FOLDOUT FRAME 1

FOLDOUT FRAME 2

APPENDIX C

EQUIPMENT LIST

Item	Description	Manufacturer	Specification no.	Serial no.
1	Engine — cluster IV, up	Marquardt	LSC310-2	1013(P/N227895)
2	Engine — cluster IV, down	Marquardt	LSC310-2	1045(P/N227895)
3	Engine — cluster IV, forward	Marquardt	LSC310-2	1036(P/N227895)
4	Engine — cluster IV, side	Marquardt	LSC310-2	1004(P/N227895)
5	Engine — cluster III, up	Marquardt	LSC310-2	[a]1003(P/N228795)
6	Engine — cluster III, down	Marquardt	LSC310-2	1038(P/N227895)
7	Engine — cluster III, forward	Marquardt	LSC310-2	1035(P/N227895)
8	Engine — cluster III, side	Marquardt	LSC310-2	1009(P/N227895)
9	Engine — cluster II, up	Marquardt	LSC310-2	1042(P/N227895)
10	Engine — cluster II, down	Marquardt	LSC310-2	1037(P/N227895)
11	Engine — cluster II, forward	Marquardt	LSC310-2	1004(P/N228795)
12	Engine — cluster II, side	Marquardt	LSC310-2	1043(P/N227895)
13	Engine — cluster I, up	Marquardt	LSC310-2	0324(P/N228685)
14	Engine — cluster I, down	Marquardt	LSC310-2	1044(P/N227895)
15	Engine — cluster I, forward	Marquardt	LSC310-2	1039(P/N227895)
16	Engine — cluster I, side	Marquardt	LSC310-2	1046(P/N227895)
100	RCS tankage module assembly "A"	GAEC	LPT-25003-1	0001
101	Helium tank	Airite	LSC310-301-1	0036
102	Helium initiation valve	Pelmec	LSC310-302-1	NA
103	Helium initiation valve	Pelmec	LSC310-302-1	NA
104	Helium filter	Vacco	LSC310-303-3	NA
108	Helium regulator	Fairchild	LSC310-305-3	03825B640216
109	Check valve (fuel)	Accessory Products	LSC310-306-4	10020001025
110	Check valve (oxid)	Accessory Products	LSC310-306-3	10020001009
111	Relief valve (fuel)	Calmec	LSC310-307-4	021220266352
112	Relief valve (oxid)	Calmec	LSC310-307-3	021220266308
115	Fuel tank	Bell	LSC310-405-12	9
116	Oxid tank	Bell	LSC310-405-11	8
117	Main shutoff valve — fuel	Parker	LSC310-403-204	0059
118	Main shutoff valve — oxid	Parker	LSC310-403-303	0032

[a] Injector head was replaced with injector head from T/C P/N228687, S/N0007.

Item	Description	Manufacturer	Specification no.	Serial no.
119	Ascent Interconnect valve	Parker	LSC310-403-103	0026
120	Ascent Interconnect valve	Parker	LSC310-403-303	0021
121	Fuel crossfeed valve	Parker	LSC310-403-204	0054
122	Oxid crossfeed valve	Parker	LSC310-403-303	0052
123	Cluster isolation valve	Parker	LSC310-403-206	214
124	Cluster isolation valve	Parker	LSC310-403-103	0030
125	Cluster isolation valve	Parker	LSC310-403-404	0038
126	Cluster isolation valve	Parker	LSC310-403-303	0069
127	Cluster isolation valve	Parker	LSC310-403-204	0061
128	Cluster isolation valve	Parker	LSC310-403-103	0033
129	Cluster isolation valve	Parker	LSC310-403-404	0028
130	Cluster isolation valve	Parker	LSC310-403-303	0062
131	Propellant filter	Wintec	LSC310-125-2-C	146
132	Propellant filter	Wintec	LSC310-125-1-C	114
133	Propellant filter	Wintec	LSC310-125-2-C	147
134	Propellant filter	Wintec	LSC310-125-1-C	147
135	Propellant filter	Wintec	LSC310-125-2-C	153
136	Propellant filter	Wintec	LSC310-125-1-C	146
137	Propellant filter	Wintec	LSC310-125-2-C	152
138	Propellant filter	Wintec	LSC310-125-1-C	111
139	Thruster heater	Cox	LSC310-601-11	403
140	Thruster heater	Cox	LSC310-601-11	404
141	Thruster heater	Cox	LSC310-601-11	406
142	Thruster heater	Cox	LSC310-601-11	313
147	Thruster heater	Cox	LSC310-601-11	405
148	Thruster heater	Cox	LSC310-601-11	402
149	Thruster heater	Cox	LSC310-601-11	401
150	Thruster heater	Cox	LSC310-601-11	309
151	Press. switch	EOS	EOS Model No. 101038-0003	3
152	Press. switch	Fairchild	LSC310-651-3	141

Item	Description	Manufacturer	Specification no.	Serial no.
153	Press. switch	Fairchild	LSC310-651-3	156
154	Press. switch	Fairchild	LSC310-651-3	0158
155	Press. switch	Fairchild	LSC310-651-3	0164
156	Press. switch	Fairchild	LSC310-651-3	173
157	Press. switch	Fairchild	LSC310-651-3	167
158	Press. switch	Fairchild	LSC310-651-3	155
200	RCS tankage module assembly	GAEC	LPT310-25003-1	0002
201	Helium tank	Airite	LSC310-301-1	0035
202	Helium initiation valve	Pelmec	LSC310-302-1	NA
203	Helium initiation valve	Pelmec	LSC310-302-1	NA
204	Helium filter	Vacco	LSC310-303-3	NA
208	Helium regulator	Fairchild	LSC310-305-3	03825J640400
209	Check valve (fuel)	Accessory Products	LSC310-306-4	100200001021
210	Check valve (oxid)	Accessory Products	LSC310-306-3	100200001023
211	Relief valve (fuel)	Calmec	LSC310-307-4	021220266342
212	Relief valve (oxid)	Calmec	LSC310-307-3	021220266318
215	Fuel tank	Bell	LSC310-405-12	10
216	Oxid tank	Bell	LSC310-405-11	11
217	Main shutoff valve — fuel	Parker	LSC310-403-204	0054
218	Main shutoff valve — oxid	Parker	LSC310-403-303	0043
219	Ascent interconnect valve	Parker	LSC310-403-204	0051
220	Ascent interconnect valve	Parker	LSC310-403-303	0058
221	Cluster isolation valve	Parker	LSC310-403-204	0062
222	Cluster isolation valve	Parker	LSC310-403-103	0032
223	Cluster isolation valve	Parker	LSC310-403-404	0041
224	Cluster isolation valve	Parker	LSC310-403-303	0065
225	Cluster isolation valve	Parker	LSC310-403-204	0049
226	Cluster isolation valve	Parker	LSC310-403-103	0036
227	Cluster isolation valve	Parker	LSC310-403-404	0039
228	Cluster isolation valve	Parker	LSC310-403-303	0063

Item	Description	Manufacturer	Specification no.	Serial no.
229	Propellant filter	Wintec	LSC310-125-2-C	113
230	Propellant filter	Wintec	LSC310-125-1-C	101
231	Propellant filter	Wintec	LSC310-125-2-C	109
232	Propellant filter	Wintec	LSC310-125-1-C	152
233	Propellant filter	Wintec	LSC310-125-2-C	104
234	Propellant filter	Wintec	LSC310-125-1-C	110
235	Propellant filter	Wintec	LSC310-125-2-C	108
236	Propellant filter	Wintec	LSC310-125-1-C	148
237	Thruster heater	Cox	LSC310-601-12	396
238	Thruster heater	Cox	LSC310-601-12	389
243	Thruster heater	Cox	LSC310-601-12	390
244	Thruster heater	Cox	LSC310-601-12	410
245	Thruster heater	Cox	LSC310-601-12	412
246	Thruster heater	Cox	LSC310-601-12	408
251	Thruster heater	Cox	LSC310-601-12	409
252	Thruster heater	Cox	LSC310-601-12	411
253	Press. switch	Fairchild	LSC310-651-3	0181
254	Press. switch	Fairchild	LSC310-651-3	161
255	Press. switch	Fairchild	LSC310-651-3	0149
256	Press. switch	Fairchild	LSC310-651-3	0168
257	Press. switch	Fairchild	LSC310-651-3	171
258	Press. switch	Fairchild	LSC310-651-3	0165
259	Press. switch	Fairchild	LSC310-651-3	176
260	Press. switch	Fairchild	LSC310-651-3	178
P1	Helium tank "A" press.	Whittaker Wiancko	LSC360-601-103-1	50003
P2	Helium tank "B" press.	Microsystems	LSC360-624-103	60729
P7	Helium regulator outlet press. "A"	Microsystems	LSC360-624-105-1	61708
P8	Helium regulator outlet press. "B"	Whittaker Wiancko	LSC360-601-105	50018
P13	Propellant tank outlet press. "A" — fuel	Kistler	601A	22932
P14	Propellant tank outlet press. "A" — oxid	Kistler	601A	25322

Item	Description	Manufacturer	Specification no.	Serial no.
P15	Propellant tank outlet press. "B" — fuel	Kistler	601A	25320
P16	Propellant tank outlet press. "B" — oxid	Kistler	601A	17958
P17	Engine 1-3 inlet press. — fuel	Microsystems	LSC310-121-4	59350 L
P18	Engine 1-3 inlet press. — oxid	Microsystems	LSC310-121-3	59695 L
P19	Engine 2-4 inlet press. — fuel	Kistler	601A	55638
P20	Engine 2-4 inlet press. — oxid	Kistler	601A	17948
P21	Engine 5-8 inlet press. — fuel	Kistler	601A	7950
P22	Engine 5-8 inlet press. — oxid	Kistler	601A	25321
P23	Engine 6-7 inlet press. — fuel	Microsystems	LSC310-121-4	59356 L
P24	Engine 6-7 inlet press. — oxid	Microsystems	LSC310-121-3	59674 L
P25	Engine 9-12 inlet press. — fuel	Microsystems	LSC310-121-4	59331 L
P26	Engine 9-12 inlet press. — oxid	Microsystems	LSC310-121-3	59697 L
P27	Engine 10-11 inlet press. — fuel	Kistler	601A	17954
P28	Engine 10-11 inlet press. — oxid	Kistler	601A	25319
P29	Engine 13-15 inlet press. — fuel	Kistler	601A	25323
P30	Engine 13-15 inlet press. — oxid	Kistler	601A	25324
P31	Engine 14-16 inlet press. — fuel	Microsystems	LSC310-121-4	59342 L
P32	Engine 14-16 inlet press. — oxid	Microsystems	LSC310-121-3	59677 L
P33	Engine 3 chamber press.	Taber	Model 185-5A	671259
P34	Engine 1 chamber press.	Taber	Model 185-5A	661059
P35	Engine 4 chamber press.	Microsystems	Marquardt 228658	59210 L
P36	Engine 2 chamber press.	Microsystems	Marquardt 228658	59254 L
P37	Engine 8 chamber press.	Microsystems	Marquardt 228658	59237
P38	Engine 5 chamber press.	Microsystems	Marquardt 228658	59209 L
P39	Engine 6 chamber press.	Taber	Model 185-5A	671263
P40	Engine 7 chamber press.	Taber	Model 185-5A	671264
P41	Engine 12 chamber press.	Taber	Model 185-5A	671269
P42	Engine 9 chamber press.	Taber	Model 185-5A	671267
P43	Engine 10 chamber press.	Microsystems	Marquardt 228658	59255 L
P44	Engine 11 chamber press.	Microsystems	Marquardt 228658	59263 L

Item	Description	Manufacturer	Specification no.	Serial no.
P45	Engine 15 chamber press.	Microsystems	Marquardt 228658	59203 L
P46	Engine 13 chamber press.	Microsystems	Marquardt 228658	58730 L
P47	Engine 16 chamber press.	Taber	Model 185-5A	671272
P48	Engine 14 chamber press.	Taber	Model 185-5A	671271
P50	Propellant tank outlet press. "A" — oxid	Whittaker Wiancko	LSC360-601-105-1	50013
P51	Propellant tank outlet press. "A" — fuel	Microsystems	LSC360-624-105-1	61711
P52	Propellant tank outlet press. "B" — oxid	Microsystems	LSC360-624-105	60737
P53	Propellant tank outlet press. "B" — fuel	Microsystems	LSC360-624-105-1	61709
Q1	A system PQMD (EOS P/N 880817-1)	EOS	LSC360-628-1-1	1001
Q2	B system PQMD (EOS P/N 880817-1)	EOS	LSC360-628-1-1	1002
D1	Helium fill coupling — "A" — flight half	On Mark	LSC310-308-3	
	ground half		LSC310-308-2E	114
D2	High press. coupling — "A" — flight half	On Mark	LSC310-308-3	
	ground half		LSC310-308-2E	124
D9	Low press. coupling — "A" — flight half	On Mark	LSC310-308-3	
	ground half		LSC310-308-2E	123
D10	Oxid check valve port coupling — "A" — flight half	On Mark	LSC310-308-3	
D12	Oxid check valve port coupling — "A" — flight half	On Mark	LSC310-308-3	
D11	Fuel check valve port coupling — "A" — flight half	On Mark	LSC310-308-3	
D13	Fuel check valve port coupling — "A" — flight half	On Mark	LSC310-308-3	
D14	Oxid relief valve port coupling — "A" — flight half	On Mark	LSC310-308-3	
D15	Fuel relief valve port coupling — "A" — flight half	On Mark	LSC310-308-3	
D16	Helium vent coupling — oxid — "A" — flight half	J. C. Carter	LSC310-401-703	8098123
	ground half		LSC310-401-751	8605118

Item	Description	Manufacturer	Specification no.	Serial no.
D17	Helium vent coupling — fuel — "A" — flight half	J. C. Carter	LSC310-401-804	7057112
	ground half		LSC310-401-852	5925108
D18	Oxid bleed coupling — "A" — flight half	J. C. Carter	LSC310-401-303	7509121
	ground half		LSC310-401-351	5920105
D19	Fuel bleed coupling — "A" — flight half	J. C. Carter	LSC310-401-404	8433135
	ground half		LSC310-401-452	4892101
D20	Oxid fill coupling — "A" — flight half	J. C. Carter	LSC310-401-103	8092127
	ground half		LSC310-401-151	5918104
D21	Fuel fill coupling — "A" — flight half	J. C. Carter	LSC310-401-204	7508122
	ground half		LSC310-401-252	6960111
D22	Oxid service coupling — "A" — flight half	J. C. Carter	LSC310-401-503	8434133
	ground half		LSC310-401-551	8542117
D23	Fuel service coupling — "A" — flight half	J. C. Carter	LSC310-401-604	7055116
	ground half		LSC310-401-652	8516118
D34	Helium fill coupling — "B" — flight half	On Mark	LSC310-308-3	
	ground half		LSC310-308-2E	121
D35	High press. coupling — "B" — flight half	On Mark	LSC310-308-3	
	ground half		ME273-0010-0004B	064810000013
D42	Low press. coupling — "B" — flight half	On Mark	LSC310-308-3	
	ground half		LSC310-308-2E	117
D43	Fuel check valve port coupling — "B" — flight half	On Mark	LSC310-308-3	
D45	Fuel check valve port coupling — "B" — flight half	On Mark	LSC310-308-3	
D44	Oxid check valve port coupling — "B" — flight half	On Mark	LSC310-308-3	
D46	Oxid check valve port coupling — "B" — flight half	On Mark	LSC310-308-3	
D47	Fuel relief valve port coupling — "B" — flight half	On Mark	LSC310-308-3	

Item	Description	Manufacturer	Specification no.	Serial no.
D48	Oxid relief valve port coupling — "B" — flight half	On Mark	LSC310-308-3	
D49	Helium vent coupling — fuel — "B" — flight half	J. C. Carter	LSC310-401-804	7057110
	ground half		LSC310-401-852	5925111
D50	Helium vent coupling — oxid — "B" — flight half	J. C. Carter	LSC310-401-203	8098124
	ground half		LSC310-401-751	8544117
D51	Fuel bleed coupling — "B" — flight half	J. C. Carter	LSC310-401-404	8433134
	ground half		LSC310-401-452	5398103
D52	Oxid bleed coupling — "B" — flight half	J. C. Carter	LSC310-401-303	8015125
	ground half		LSC310-401-351	8397111
D53	Fuel fill coupling — "B" — flight half	J. C. Carter	LSC310-401-204	7508120
	ground half		LSC310-401-252	6960120
D54	Oxid fill coupling — "B" — flight half	J. C. Carter	LSC310-401-103	8430131
	ground half		LSC310-401-151	5918107
D55	Fuel service coupling — "B" — flight half	J. C. Carter	LSC310-401-604	8097126
	ground half		LSC310-401-652	8400114
D56	Oxid service coupling — "B" — flight half	J. C. Carter	LSC310-401-503	8552143
	ground half		LSC310-401-551	8404112
T13	Engine 1-3 fuel feed temp.	Winsco	LSC310-122-2	009
T14	Engine 1-3 oxid feed temp.	Winsco	LSC310-122-1	013
T15	Engine 2-4 fuel feed temp.	Winsco	LSC310-122-2	025
T16	Engine 2-4 oxid feed temp.	Winsco	LSC310-122-1	031
T17	Engine 5-8 fuel feed temp.	Winsco	LSC310-122-2	026
T18	Engine 5-8 oxid feed temp.	Winsco	LSC310-122-1	033
T19	Engine 6-7 fuel feed temp.	Winsco	LSC310-122-2	042
T20	Engine 6-7 oxid feed temp.	Winsco	LSC310-122-1	036
T21	Engine 9-12 fuel feed temp.	Winsco	LSC310-122-2	048
T22	Engine 9-12 oxid feed temp.	Winsco	LSC310-122-1	038
T23	Engine 10-11 fuel feed temp.	Winsco	LSC310-122-2	027

Item	Description	Manufacturer	Specification no.	Serial no.
T24	Engine 10-11 oxid feed temp.	Winsco	LSC310-122-1	039
T25	Engine 13-15 fuel feed temp.	Winsco	LSC310-122-2	037
T26	Engine 13-15 oxid feed temp.	Winsco	LSC310-122-1	041
T27	Engine 14-16 fuel feed temp.	Winsco	LSC310-122-2	028
T28	Engine 14-16 oxid feed temp.	Winsco	LSC310-122-1	043
	Blanket and shield assy. - RCS aft cluster-partial (eng. III D/6)	GAEC	LSK280-11127-1	

APPENDIX D

INSTRUMENTATION SETUP

DEVIATIONS FROM LM RCS INSTRUMENTATION SETUP

NOTE

Deviations from the normal strip chart recorder instrumentation setup as shown on the subsequent instrumentation planning sheets were made at several points during the test program.

The following table defines the strip chart locations for the various portions of the test program. Setup A was used as the normal setup; Setup B was used for Blocks IV-L and IV-M; Setup C was used for Blocks III-B, IV-F, IV-K, and IV-E; and Setup D was used for Blocks IV-M(A), IV-I, and IV-J. Block descriptions are included in appendix A.

Strip chart no.	PARAMETER SYMBOL			
	Setup A	Setup B	Setup C	Setup D
1	T67	T39	T67	T67
2	T68	T40	T68	T65
3	T95	T56	T70	T70
4	T73	T55	T73	T66
5	T74	T65	T74	T69
6	T77	T69	T90	T90
7	T78	T78	T78	T78
8	T81	T91	T81	T89
9	T82	T89	T82	T91
10	T85	T67	T85	T92
11	T86	T86	T86	T86
12	P100	P100	P100	P100

MSC FORM 360B (JAN 67)

THERMOCHEMICAL TEST AREA

TEST NUMBER	DATE	INSTRUMENTATION PLANNING SHEET	TEST ENGINEER	CELL NUMBER
2T404	October 4, 1967		Blevins	116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Eng. 1 valve voltage	I1			BV 34							
Eng. 2 valve voltage	I2			BV 35							
Eng. 3 valve voltage	I3			BV 35							
Eng. 4 valve voltage	I4			BV 37							
Eng. 5 valve voltage	I5			BV 44							
Eng. 6 valve voltage	I6			BV 45							
Eng. 7 valve voltage	I7			BV 46							
Eng. 8 valve voltage	I8			BV 47							
Eng. 9 valve voltage	I9			AV 34							
Eng. 10 valve voltage	I10			AV 35							
Eng. 11 valve voltage	I11			AV 36							
Eng. 12 valve voltage	I12			AV 37							
Eng. 13 valve voltage	I13			AV 44							
Eng. 14 valve voltage	I14			AV 45							
Eng. 15 valve voltage	I15			AV 46							
Eng. 16 valve voltage	I16			AV 47							
Eng. 2 heater voltage	H139									2	On-off signals
Eng. 4 heater voltage	H140									4	On-off signals
Eng. 5 heater voltage	H141									5	On-off signals
Eng. 8 heater voltage	H142									8	On-off signals

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MSC FORM 360B (JAN 67)

THERMOCHEMICAL TEST AREA

TEST NUMBER 2T404	DATE October 4, 1967	INSTRUMENTATION PLANNING SHEET	TEST ENGINEER Blevins	CELL NUMBER 116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Eng. 11 heater	H147									11	On-off signals
Eng. 10 heater	H148									10	On-off signals
Eng. 13 heater	H149									13	On-off signals
Eng. 15 heater	H150									15	On-off signals
Eng. 1 heater	H237									1	On-off signals
Eng. 3 heater	H238									3	On-off signals
Eng. 7 heater	H243									7	On-off signals
Eng. 6 heater	H244									6	On-off signals
Eng. 9 heater	H245									9	On-off signals
Eng. 12 heater	H246									12	On-off signals
Eng. 14 heater	H251									14	On-off signals
Eng. 16 heater	H252									16	On-off signals
Eng. 2 pressure switch	S151		EOS	B 5 S 4							Switch closure
Eng. 4 pressure switch	S152		Fairchild	B 6 S 4							Switch closure
Eng. 5 pressure switch	S153		Fairchild	B 8 S 3							Switch closure
Eng. 8 pressure switch	S154		Fairchild	B 9 S 4							Switch closure
Eng. 11 pressure switch	S155		Fairchild	A 6 S 3							Switch closure
Eng. 10 pressure switch	S156		Fairchild	A 5 S 4							Switch closure
Eng. 13 pressure switch	S157		Fairchild	A 8 S 3							Switch closure
Eng. 15 pressure switch	S158		Fairchild	A 9 S 3							Switch closure

Remarks:

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THERMOCHEMICAL TEST AREA

TEST NUMBER	DATE	INSTRUMENTATION PLANNING SHEET	TEST ENGINEER	CELL NUMBER
2T404	October 4, 1967		Blevins	116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Eng. 1 pressure switch	S253		Fairchild	B 5 S 3							Switch closure
Eng. 3 pressure switch	S254		Fairchild	B 6 S 3							Switch closure
Eng. 7 pressure switch	S255		Fairchild	B 9 S 3							Switch closure
Eng. 6 pressure switch	S256		Fairchild	B 8 S 4							Switch closure
Eng. 9 pressure switch	S257		Fairchild	A 5 S 3							Switch closure
Eng. 10 pressure switch	S258		Fairchild	A 6 S 4							Switch closure
Eng. 14 pressure switch	S259		Fairchild	A 8 S 4							Switch closure
Eng. 16 pressure switch	S260		Fairchild	A 9 S 4							Switch closure
He tank pressure A	p1	0 to 3500A	Whittaker Wiancko			28	75				SN 50003
He tank pressure B	p2	0 to 3500A	Microsystem			50	76				SN 60729
He reg. pressure A	p7	0 to 350A	Microsystem			9	77				SN 61708
He reg. pressure B	p8	0 to 350A	Whittaker Wiancko			10	78				SN 50018
Fuel tank outlet A	p13	0 to 350D	Kistler 601 A	A 1							SN 22932
Fuel tank outlet A	p51	0 to 350A	Microsystem	B 3 V 1		11	79				SN 61711
Oxid tank outlet A	p14	0 to 350D	Kistler 601 A	A 2							SN 25322
Oxid tank outlet A	p50	0 to 350A	Whittaker Wiancko	B 4 V 1		12	80				SN 50013
Fuel tank outlet B	p15	0 to 350D	Kistler 601 A	A 11							SN 25320
Fuel tank outlet B	p53	0 to 350A	Microsystem	A 3 V 1		13	81				SN 61709

Remarks:

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MSC FORM 360B (JAN 67)

THERMOCHEMICAL TEST AREA

TEST NUMBER	DATE		TEST ENGINEER	CELL NUMBER
2T404	October 4, 1967	INSTRUMENTATION PLANNING SHEET	Blevins	116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Oxid tank outlet B	p16	0 to 350D	Kistler 601 A	B 2							SN 17958
Oxid tank outlet B	p52	0 to 350A	Microsystem	A 4 V 1		14	82				SN 60737
Regulator reference press.	p1176	0 to 15A	Taber				12				SN 671496
Engines 1 to 3 fuel inlet	p17	0 to 500A	Microsystem	B 5 S 2							SN 59350L
Engines 1 to 3 oxid inlet	p18	0 to 500A	Microsystem	B 6 S 2							SN 59695L
Engines 2 to 4 fuel inlet	p19	0 to 500D	Kistler 601A	B 10							SN 55638
Engines 2 to 4 oxid inlet	p20	0 to 500D	Kistler 601A	B 11							SN 17948
Engines 5 to 8 fuel inlet	p21	0 to 500D	Kistler 601A	B 12							SN 7950
Engines 5 to 8 oxid inlet	p22	0 to 500D	Kistler 601A	B 13							SN 25321
Engines 6 to 7 fuel inlet	p23	0 to 500A	Microsystem	B 8 S 2							SN 59356L
Engines 6 to 7 oxid inlet	p24	0 to 500A	Microsystem	B 9 S 2							SN 59674L
Engines 9 to 12 fuel inlet	p25	0 to 500A	Microsystem	A 5 S 2							SN 59331L
Engines 9 to 12 oxid inlet	p26	0 to 500A	Microsystem	A 6 S 2							SN 59697L
Engines 10 to 11 fuel inlet	p27	0 to 500D	Kistler 601A	A 10							SN 17954
Engines 10 to 11 oxid inlet	p28	0 to 500D	Kistler 601A	A 11							SN 25319
Engines 13 to 15 fuel inlet	p29	0 to 500D	Kistler 601A	A 12							SN 25323
Engines 13 to 15 oxid inlet	p30	0 to 500D	Kistler 601A	A 13							SN 25324
Engines 14 to 16 fuel inlet	p31	0 to 500A	Microsystem	A 8 S 2							SN 59342L
Engines 14 to 16 oxid inlet	p32	0 to 500A	Microsystem	A 9 S 2							SN 59677L

Remarks:

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MSC FORM 360B (JAN 67)

THERMOCHEMICAL TEST AREA

TEST NUMBER 2T404	DATE October 4, 1967	INSTRUMENTATION PLANNING SHEET	TEST ENGINEER Blevins	CELL NUMBER 116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Engine 3 PC	p33	0 to 300A	Taber 185	B 3 V 3							SN 671259
Engine 1 PC	p34	0 to 300A	Taber 185	B 3 V 2							SN 661059
Engine 4 PC	p35	0 to 125A	Microsystem	B 5 S 1							SN 59210L
Engine 2 PC	p36	0 to 125A	Microsystem	B 6 S 1							SN 59254L
Engine 8 PC	p37	0 to 125A	Microsystem	B 8 S 1							SN 59237
Engine 5 PC	p38	0 to 125A	Microsystem	B 9 S 1							SN 59209L
Engine 6 PC	p39	0 to 300A	Taber 185	B 4 V 2							SN 671263
Engine 7 PC	p40	0 to 300A	Taber 185	B 4 V 3							SN 671264
Engine 9 PC	p41	0 to 300A	Taber 185	A 3 V 3							SN 671267
Engine 12 PC	p42	0 to 300A	Taber 185	A 3 V 2							SN 671269
Engine 10 PC	p43	0 to 125A	Microsystem	A 5 S 1							SN 59255L
Engine 11 PC	p44	0 to 125A	Microsystem	A 6 S 1							SN 59263L
Engine 15 PC	p45	0 to 125A	Microsystem	A 8 S 1							SN 59203L
Engine 13 PC	p46	0 to 125A	Microsystem	A 9 S 1							SN 58730L
Engine 16 PC	p47	0 to 300A	Taber 185	A 4 V 3							SN 671272
Engine 14 PC	p48	0 to 300A	Taber 185	A 4 V 2							SN 671271
Fuel tank A temp.	T1	(a)	C/A TC				1				
Oxid tank A temp.	T2	(a)	C/A TC				2				
Fuel tank B temp.	T3	(a)	C/A TC				3				
Oxid tank B temp.	T4	(a)	C/A TC				4				

Remarks:

[a] 0° to 250° F.

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MSC FORM 360B (JAN 67)

TEST NUMBER	DATE		TEST ENGINEER	CELL NUMBER
2T404	October 4, 1967	INSTRUMENTATION PLANNING SHEET	Blevins	116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Eng. 1 to 3 fuel feed temp.	T13	(b)	CU/C TC				13				Winsco SN 009
Eng. 1 to 3 oxid feed temp.	T14	(b)	CU/C TC				14				Winsco SN 013
Eng. 2 to 4 fuel feed temp.	T15	(b)	CU/C TC				15				Winsco SN 025
Eng. 2 to 4 oxid feed temp.	T16	(b)	CU/C TC				16				Winsco SN 031
Eng. 5 to 8 fuel feed temp.	T17	(b)	CU/C TC				17				Winsco SN 026
Eng. 5 to 8 oxid feed temp.	T18	(b)	CU/C TC				18				Winsco SN 033
Eng. 6 to 7 fuel feed temp.	T19	(b)	CU/C TC				19				Winsco SN 042
Eng. 6 to 7 oxid feed temp.	T20	(b)	CU/C TC				20				Winsco SN 036
Eng. 9 to 12 fuel feed temp.	T21	(b)	CU/C TC				21				Winsco SN 048
Eng. 9 to 12 oxid feed temp.	T22	(b)	CU/C TC				22				Winsco SN 038
Eng. 10 to 11 fuel feed temp.	T23	(b)	CU/C TC				23				Winsco SN 027
Eng. 10 to 11 oxid feed temp.	T24	(b)	CU/C TC				24				Winsco SN 039
Eng. 13 to 15 fuel feed temp.	T25	(b)	CU/C TC				25				Winsco SN 037
Eng. 13 to 15 oxid feed temp.	T26	(b)	CU/C TC				26				Winsco SN 041
Eng. 14 to 16 fuel feed temp.	T27	(b)	CU/C TC				27				Winsco SN 028
Eng. 14 to 16 oxid feed temp.	T28	(b)	CU/C TC				28				Winsco SN 043
Eng. 1 fuel valve seat temp.	T29	(c)	C/A TC				29				
Eng. 1 oxid valve seat temp.	T30	(c)	C/A TC				30				
Eng. 2 fuel valve seat temp.	T31	(c)	C/A TC				31				

Remarks.

[b] 0° to 200° F.

[c] -100° to +300° F.

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THERMOCHEMICAL TEST AREA

DOC. NO.
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REVISION
New

TEST NUMBER 2T404	DATE October 4, 1967	INSTRUMENTATION PLANNING SHEET	TEST ENGINEER Blevins	CELL NUMBER 116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Eng. 2 oxid valve seat temp.	T32	(c)	C/A TC				32				
Eng. 3 fuel valve seat temp.	T33	(c)	C/A TC				33				On valve body
Eng. 3 oxid valve seat temp.	T34	(c)	C/A TC				34				
Eng. 4 fuel valve seat temp.	T35	(c)	C/A TC				35				
Eng. 4 oxid valve seat temp.	T36	(c)	C/A TC				36				
Eng. 5 fuel valve seat temp.	T37	(c)	C/A TC				37				
Eng. 5 oxid valve seat temp.	T38	(c)	C/A TC				38				
Eng. 6 fuel valve seat temp.	T39	(c)	C/A TC				39				
Eng. 6 oxid valve seat temp.	T40	(c)	C/A TC				40				
Eng. 7 fuel valve seat temp.	T41	(c)	C/A TC				41				
Eng. 7 oxid valve seat temp.	T42	(c)	C/A TC				42				
Eng. 8 fuel valve seat temp.	T43	(c)	C/A TC				43				On valve body
Eng. 8 oxid valve seat temp.	T44	(c)	C/A TC				44				
Eng. 9 fuel valve seat temp.	T45	(c)	C/A TC				45				
Eng. 9 oxid valve seat temp.	T46	(c)	C/A TC				46				On valve body
Eng. 10 fuel valve seat temp.	T47	(c)	C/A TC				47				On valve body
Eng. 10 oxid valve seat temp.	T48	(c)	C/A TC				48				
Eng. 11 fuel valve seat temp.	T49	(c)	C/A TC				49				
Eng. 11 oxid valve seat temp.	T50	(c)	C/A TC				50				On valve body
Eng. 12 fuel valve seat temp.	T51	(c)	C/A TC				51				

Remarks:

c -100° to +300° F.

MSC FORM 375 (Rev Jul 66)

TEST NUMBER	DATE		TEST ENGINEER	CELL NUMBER
2T404	October 4, 1967	INSTRUMENTATION PLANNING SHEET	Blevins	116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Eng. 12 oxid valve seat temp.	T52	(c)	C/A TC				52				
Eng. 13 fuel valve seat temp.	T53	(c)	C/A TC				53				On valve body
Eng. 13 oxid valve seat temp.	T54	(c)	C/A TC				54				
Eng. 14 fuel valve seat temp.	T55	(c)	C/A TC				55				
Eng. 14 oxid valve seat temp.	T56	(c)	C/A TC				56				
Eng. 15 fuel valve seat temp.	T57	(c)	C/A TC				57				On valve body
Eng. 15 oxid valve seat temp.	T58	(c)	C/A TC				58				
Eng. 16 fuel valve seat temp.	T59	(c)	C/A TC				59				
Eng. 16 oxid valve seat temp.	T60	(c)	C/A TC				60				
Quad I cluster temp.	T61	(d)	C/A TC			21	61				
Quad II cluster temp.	T62	(d)	C/A TC			22	62				
Quad III cluster temp.	T63	(d)	C/A TC			23	63				
Quad IV cluster temp.	T64	(d)	C/A TC			24	64				
Eng. 6 flange temp. no. 1	T65	(e)	C/A TC			25	65				
Eng. 6 flange temp. no. 2	T66	(e)	C/A TC			26	66				Heater temp.
Eng. 6 combustor temp. no. 1	T69	(f)	C/A TC			27	69				
Eng. 6 combustor temp. no. 2	T70	(f)	C/A TC				70				
Eng. 14 combustor temp. no. 1	T89	(f)	C/A TC			29	89				
Eng. 14 combustor temp. no. 2	T90	(g)	C/A TC				90				

Remarks:

^{c}-100° to +300° F.

^{d}0° to 300° F.

^{e}0° to 500° F.

^{f}0° to 1500° F.

^{g}0° to 2000° F.

MSC FORM 375 (Rev Jul 66)

MSC FORM 360B (JAN 67)

DOC. NO. MSC-EP-R-68-17

REVISION New

MSC FORM 360B (JAN 67)

THERMOCHEMICAL TEST AREA

TEST NUMBER	DATE		TEST ENGINEER	CELL NUMBER
2T404	October 4, 1967	INSTRUMENTATION PLANNING SHEET	Blevins	116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Eng. 14 flange temp. no. 1	T91	(e)	C/A TC			30	91				
Eng. 14 flange temp. no. 2	T92	(e)	C/A TC			31	92				Heater temp.
Wire bundle no. 1 temp.	T71	(e)	C/A TC				71				
Wire bundle no. 2 temp.	T72	(e)	C/A TC				72				
Free air temp. no. 1	T67	(e)	C/A TC				67	1			On crossfeed sec.
Free air temp. no. 2	T68	(e)	C/A TC				68	2			In "B" module
Isolation valve no. 125 temp.[k]	T95	(e)	C/A TC					3			
He tank A temp.	T97	(h)	C/A TC			32	97				Skin
He tank B temp.	T98	(h)	C/A TC			33	98				Skin
Eng. 1 to 2 fire voltage	V1	(i)				1					Opposing 4u-4d
Eng. 5 to 6 fire voltage	V2	(i)				2					Opposing 3u-3d
Eng. 9 to 10 fire voltage	V3	(i)				3					Opposing 2u-2d
Eng. 13 to 14 fire voltage	V4	(i)				4					Opposing 1u-1d
Eng. 4 to 16 fire voltage	V5	(i)				5					Opposing 4s-1s
Eng. 8 to 12 fire voltage	V6	(i)				6					Opposing 3s-2s
Eng. 3 to 7 fire voltage	V7	(i)				7					Opposing 4f-3f
Eng. 11 to 15 fire voltage	V8	(i)				8					Opposing 2f-1f
A system PQMD	Q1	(j)	EOS			15	73				
B system PQMD	Q2	(j)	EOS			16	74				

Remarks:

[e]0° to 500° F.

[h]-100 to +200° F.

[i]0 to 28 V dc

[j]0 to 100 percent

[k]Above round weld bead on downstream side.

MSC FORM 375 (Rev Jul 66)

DOC. NO. MSC-EP-R-68-17

REVISION New

TEST NUMBER 2T404	DATE October 4, 1967	INSTRUMENTATION PLANNING SHEET	TEST ENGINEER Blevins	CELL NUMBER 116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Load cell — A oxid tank	LC1	0 to 300	Alinco			17	5				
Load cell — A fuel tank	LC2	0 to 200	Alinco			18	6				
Load cell — B oxid tank	LC3	0 to 300	Alinco			19	7				
Load cell — B fuel tank	LC4	0 to 200	Alinco			20	8				
Timing				A 14 B 14							
SSC pressure	p100	(l)	(m)					12			
Eng. 1 inj. head temp.	T73	(e)	C/A TC			34		4			
Eng. 2 inj. head temp.	T74	(e)	C/A TC			35		5			
Eng. 3 inj. head temp.	T75	(e)	C/A TC			36					
Eng. 4 inj. head temp.	T76	(e)	C/A TC			37					
Eng. 5 inj. head temp.	T77	(e)	C/A TC			38		6			
Eng. 6 inj. head temp.	T78	(e)	C/A TC			39		7			
Eng. 7 inj. head temp.	T79	(e)	C/A TC			40					
Eng. 8 inj. head temp.	T80	(e)	C/A TC			41					
Eng. 9 inj. head temp.	T81	(e)	C/A TC			42		8			
Eng. 10 inj. head temp.	T82	(e)	C/A TC			43		9			
Eng. 11 inj. head temp.	T83	(e)	C/A TC			44					

Remarks:

[e] 0° to 500° F.

[l] 0 to 10 mm Hg

[m] MKS baratron

MSC FORM 360B (JAN 67)

THERMOCHEMICAL TEST AREA

TEST NUMBER	DATE		TEST ENGINEER	CELL NUMBER
2T404	October 4, 1967	INSTRUMENTATION PLANNING SHEET	Blevins	116

PARAMETER	SYM	RANGE	TRANSDUCER	FM CHAN	GALVO CHAN	SEL CHAN	EI CHAN	S/C CHAN	SCOPE CHAN	MISC CHAN	REMARKS
Eng. 12 inj. head temp.	T84	(e)	C/A TC			45					
Eng. 13 inj. head temp.	T85	(e)	C/A TC			46		10			
Eng. 14 inj. head temp.	T86	(e)	C/A TC			47		11			
Eng. 15 inj. head temp.	T87	(e)	C/A TC			48					
Eng. 16 inj. head temp.	T88	(e)	C/A TC			49					
Eng. 2 fuel valve temp.	T7	(n)	C/A TC				85				
Eng. 2 oxid valve temp.	T8	(n)	C/A TC				86				
Eng. 10 fuel valve temp.	T9	(n)	C/A TC				87				
Eng. 10 oxid valve temp.	T10	(n)	C/A TC				88				
Totals				73		50	93	12		16	

Remarks:

$^{e}0°$ to 500° F.

$^{n}0°$ to 300° F.

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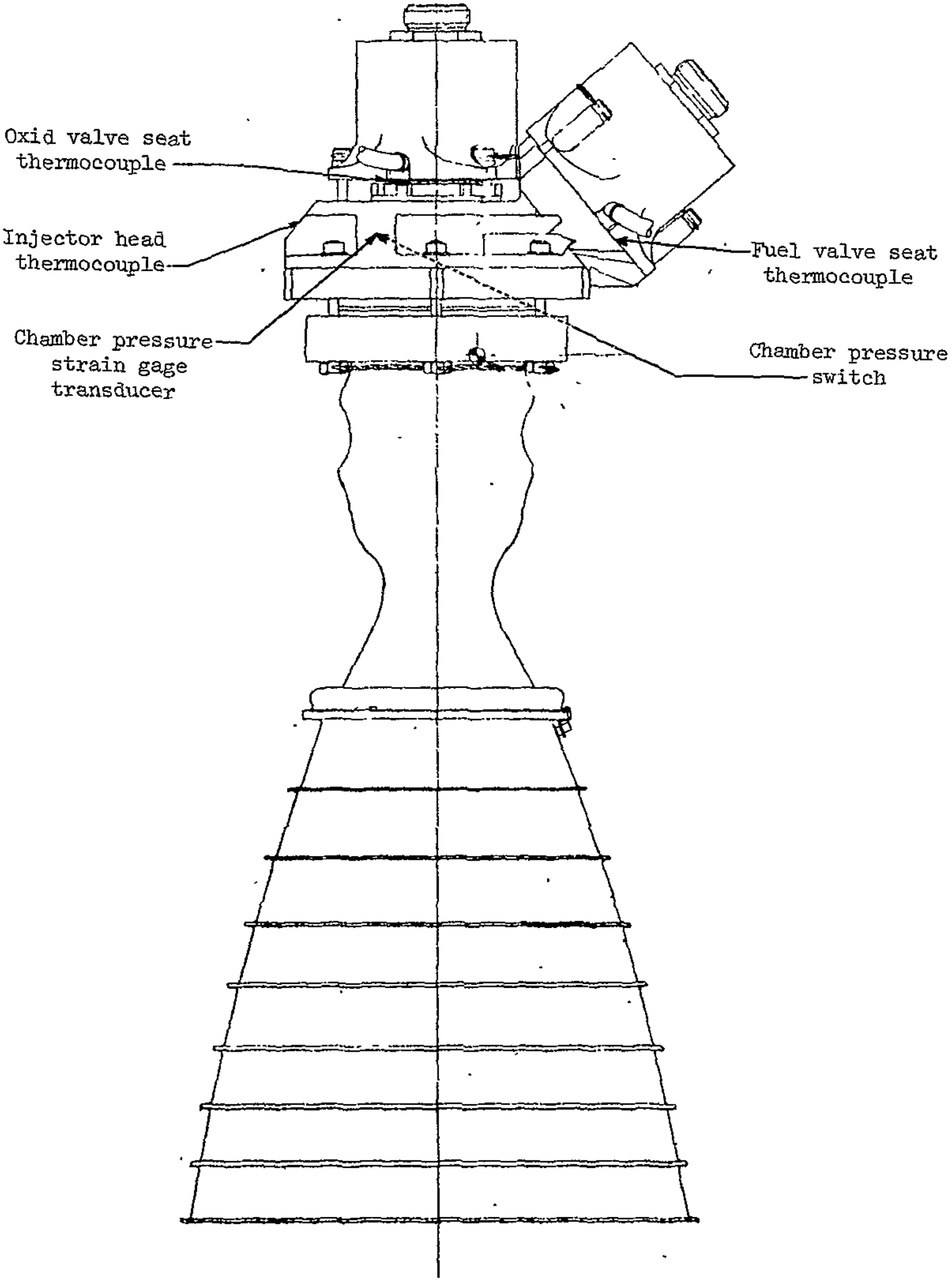

Figure D1.- Instrumentation setup typical for engines 1, 3, 4, 5, 7, 8, 9, 11, 12, 13, 15, and 16.

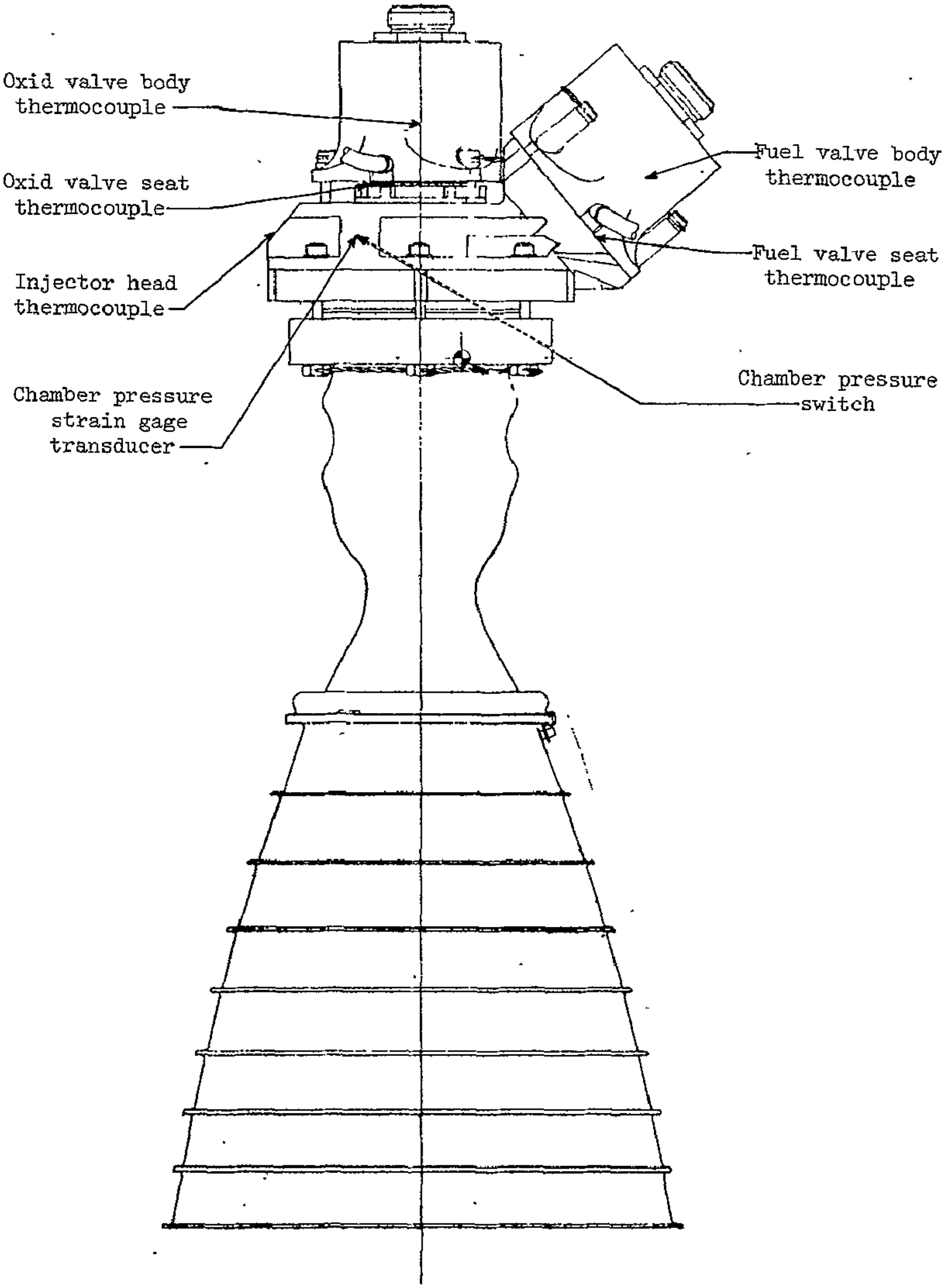

Figure D2.- Instrumentation setup typical for engines 2 and 10.

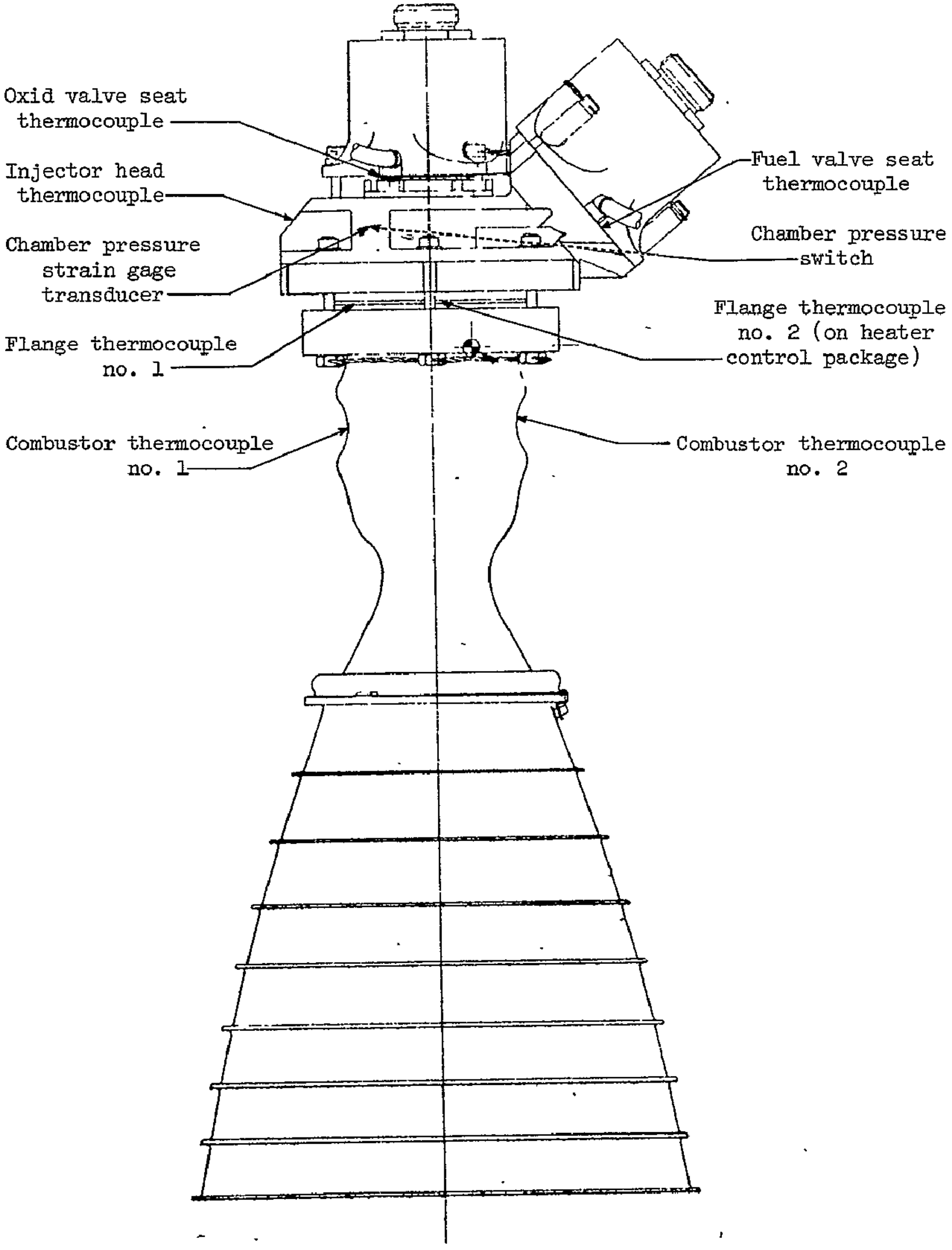

Figure D3.- Instrumentation setup typical for engines 6 and 14.

APPENDIX E

ENGINE III U/5 ANOMALY REPORT

Anomaly Description

The engine III U/5 chamber pressure data indicated that the engine operated at reduced performance during this test. The following chamber pressure values were recorded at various stages of the program (see appendix A for run descriptions).

Run no.	Pulse duration, sec	Steady state Pc, psia
II-A-1-5	1.000	90
II-A-1-5A	1.000	89
II-A-2-63	0.050	78
II-A-2-64	0.100	79
II-A-2-65	0.150	78
II-A-1-73	1.000	75
IV-K-1		75

Note: Nominal steady state Pc = 97 psia

Run II-A-1-5 was the first firing on engine III U/5, and run IV-K-1 occurred near the end of the test program.

Engine History

Engine III U/5 as received from The Marquardt Corporation after the design verification testing was considered unsuitable for test operation. The injector face was severely eroded as shown in figure 21. Therefore, the injector head assembly (TMC P/N 228795, S/N 1003) was replaced with the injector head assembly from TMC P/N228687, S/N0007. The engine was then acceptance tested before installation in the test subsystem. After installation, the engine was gas flow tested. The pretest water calibration results were 439 and 686 pounds/hour for the fuel and oxidizer valves, respectively. These values are well within acceptable limits. The engine injector orifice flow test results and the engine gas flow test results (see figures 24 and 26) were also acceptable.

Investigation Description and Discussion

An extensive investigation was conducted in an attempt to ascertain the cause of the apparent low engine performance. The hot-firing portion of the test was completed on December 11, 1967. On January 30, 1968, a static calibration check of the engine III U/5 chamber pressure transducer was performed through the data acquisition system which had been reconstructed to the hot-firing configuration. This test indicated that the chamber pressure transducer was functioning properly. A post-test gas flow test was then performed on system A with results almost identical to the pretest data. The engine was then removed from the LM RCS test article and subjected to a series of post-test checkouts. An inspection of the engine inlet filters revealed no evidence of contamination or damage. Injector orifice flow test, water calibration, and leakage check results were acceptable.

The engine and the original chamber pressure transducer were again installed on the LM RCS test article. During the hot-firing tests described in reference 21, the engine was fired with a resultant steady state chamber pressure of 85 psia.

Cluster III was removed from the LM RCS and mounted on another propellant feed system to accomplish the testing described in reference 22. At this time the positions of the III U/5 and III S/8 engines were reversed, making the questionable engine a side firing engine. In addition, the original engine III U/5 chamber pressure transducer was installed in engine III S/8, and a new transducer was installed in engine III U/5. Steady state chamber pressure readings from both engines were nominal in this test.

In view of the above results, it appears that both engine III U/5 and the engine III U/5 chamber pressure transducer were capable of nominal operation. The acceptable results of the pretest and post-test water calibrations, injector orifice flow tests, and engine gas flow tests indicate that the engine propellant flow rates should have been nominal during the subsystem testing. The propellant inline filter/cluster isolation valve assemblies are the only other possible flow restrictor in the subsystem. A flow restriction in these assemblies of the magnitude required to reduce the engine performance by 25 percent would have caused a drastic reduction in the propellant inlet pressures, but inlet pressures for engine III U/5 appeared to be nominal. In addition, the chamber pressure transient characteristics appeared nominal.

Conclusion

From the above discussion, it appears that the anomalous performance indication on engine III U/5 was the result of either an unknown data acquisition system problem or shifts in the chamber pressure transducer output.