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SPACE SHUTTLE
FLIGHT READINESS FIRING
DRESS REHEARSAL FOR STS-1

Lt Colonel Warren L. Riles
HQ Space Division/YOO
Los Angeles AFS, CA

ABSTRACT

As we approached the first space Shuttle launch, the tension and excitement increased with each passing day. The dedication and resolve of the joint government/contractor team was also increasing as we approached the Flight Readiness Firing (FRF) test. The FRF test afforded us an opportunity to assess the readiness or the integrated systems to support the STS-1 launch and flight. The assessment included the following integrated systems: Structures and mechanics; thermal design integration; propulsion and power; avionics and software; guidance, navigation, and control; mechanical systems; communications and tracking; an integrated ground systems.

The Space Shuttle Flight Readiness Firing was also an excellent opportunity to exercise the operational capability developed for STS-1 at a time when test teams, facilities, plans and procedures were in a flight ready condition.

To ensure that we were prepared to function effectively as an integrated team for STS-1, we conducted a simulation of the pre-mission activities, countdown and launch operations, and post-mission activities associated with STS-1 in conjunction with the Space Shuttle Flight Readiness Firing. The exercise involved all STS-1 management and operations elements functioning as they would for STS-1 launch to the degree that was practical and productive.

INTRODUCTION

The final step in the Space Shuttle system verification network prior to the first DDT&E flight was a static firing of the Space Shuttle main engines using mated flight vehicle elements in as near as possible flight configuration, on launch pad 39A at KSC. The flight readiness firing (FRF) was conducted as part of the countdown demonstration test (CCDT) for the first Shuttle manned flight.

In previous space and missile programs, static firing and integrated flight control and propulsion tests were conducted at a test site prior to the vehicles arriving at the launch sites. However, due to the unique design and multi-elements of the Shuttle, all flight systems (propulsion, flight control and avionics) were not integrated until mated at the launch site. Although each element and subsystem of the Shuttle goes through development and verification test, including a main propulsion system test (MPT) utilizing a flight ET or Orbiter aft fuselage with SSMEs, the total integrated system was not available until the vehicle was mated at the launch pad. Two other important factors necessitated a flight readiness firing: (1) the Shuttle program had no unmanned flights scheduled and (2) no facility checkout vehicle. Specific system objectives realized from the FRF were:

a. First verification of the flight MPS and associate subsystem structural integrity and performance during SSME firing (exact launch conditions up to SRB ignition).

b. First verification of the adequacy of flame and heat protective shielding for SRBs and ET during SSME pre-liftoff firing and simulated launch abort shutdown.

c. First integrated avionics/MPS test (SSME control and monitoring with Orbiter avionics).

d. First integrated APU/hydraulics/SSME/flight control functional test.

e. Additional verification of prelaunch servicing procedures and countdown timelines.

f. Additional SSME cluster firing data to verify first flight vehicle MPS predicted performance.

The FRF was conducted with an unmanned Orbiter. Additional switch control functions had been provided in the Orbiter for ground control through the launch processing system (LPS) that would not have been required for a manned FRF. These additional ground control functions, plus a modified flight software program, allows the Shuttle main propulsion system (MPS) to be tested at the launch pad with the vehicle configured for flight. The solid rocket boosters (SRB) flight control systems were not activated for the FRF; however, SRB ignition commands and SRB holddown release signals were verified. The Orbiter T-0 umbilicals and the external tank liftoff umbilicals remained connected during the 2-second firing of the MPS. The Orbiter Orbital maneuvering systems (OMS) and the forward and aft reaction control systems (RCS) were not activated during the FRF. Orbiter flight control commands were exercised during the 20-second firing. At the termination of the 20-second firing, the three SSME's were sequentially shut down simulating a prelaunch shutdown. Following the post firing securing, a vehicle inspection and data analysis were conducted and the vehicle was reconfigured and prepared for the first STS launch.

REQUIREMENTS

Test Philosophy

Wet CDDT/FRF was a detailed practice run for the STS-1 launch and, as such, identified any failure or weaknesses in any systems or operating conditions not occurring during pretesting. All conditions were identical to or as close to the actual STS-1 timelines and launch preparation as possible.

This was a one-time-only test on Orbiter vehicle 102 and was preceded by a tanking and detanking checkout of the Orbiter, external tank, and ground systems/facilities. The FRF-unique and piggyback software tests at the Shuttle Avionics Integration Laboratory at Johnson Space Center (JSC) were completed and instrumentation for special test installed, characterized, and calibrated. All facility and servicing equipment was operationally ready to support FRF countdown. The Space Shuttle main engines (SSME) hardware backup shutdown capability checkout was completed. The crew cabin was not manned once propellant loading started and those Shuttle subsystems that required operational control after that time was configured for and had ground remote control capability. The T-0 umbilical interfaces were maintained through the FRF along with general purpose computer/launch processing system (GPC/LPS) polling command capability.

The FRF firing duration was limited to approximately 20 seconds of main stage operation. SSME start was identical to STS-1 launch: The engines were tested at 94 percent and 100 percent rated power level (RPL) with shutdown occurring from 100 percent RPL (launch abort). SSME gimbaling was performed at both power levels. See Figure 1 and 2 for FRF thrust profile and FRF gimbaling profile.

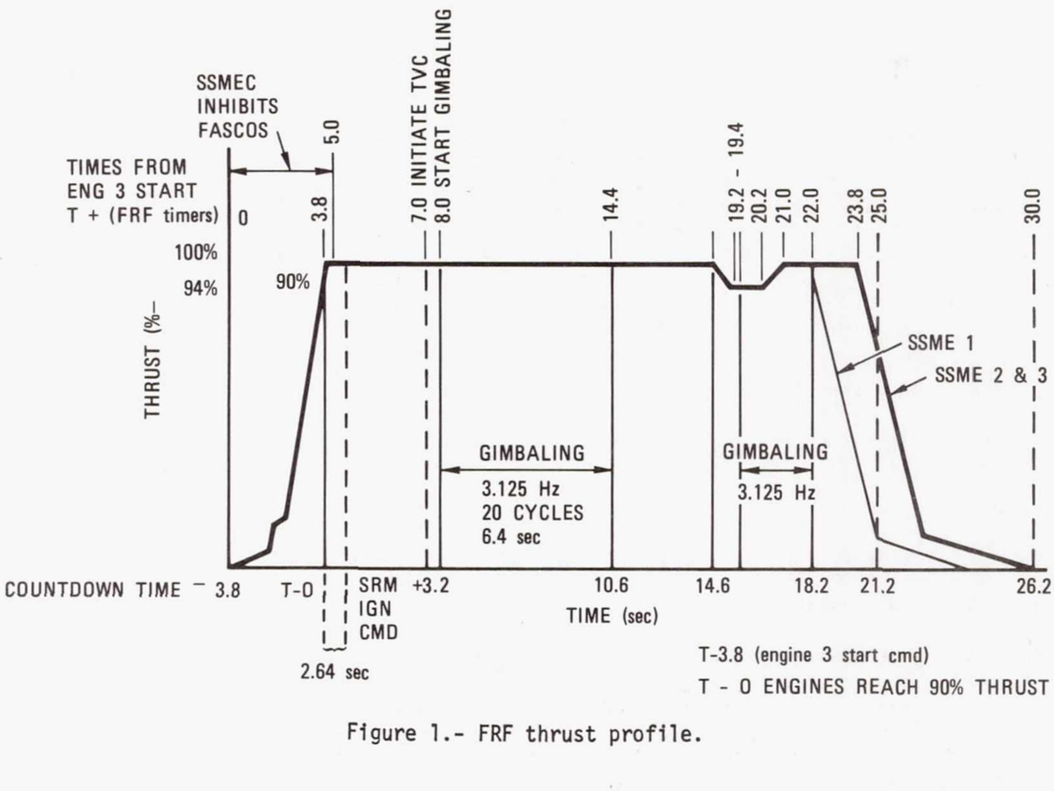


Figure 1.- FRF thrust profile.

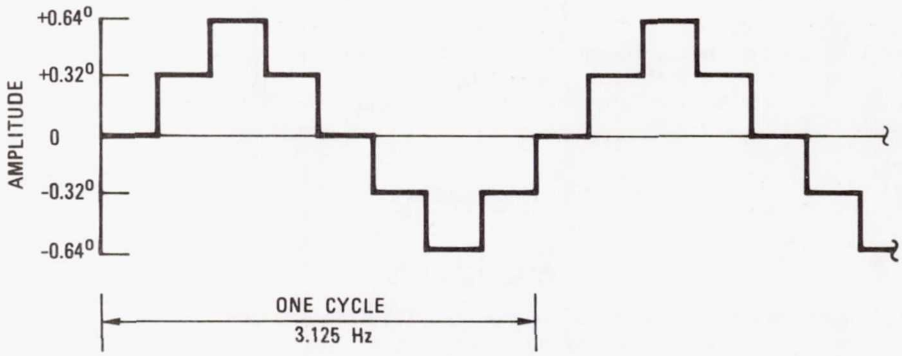


Figure 2.- FRF gimbaling profile.

The flight and ground software were structured to maintain the launch processing system (LPS) contact with the vehicle throughout the test and preclude the flight software from progressing to major mode 102 (ascent). Redundant set launch sequence (RSLS) flight software operated in major mode 101 (prelaunch) and controlled the functions of the Orbiter systems and issued commands to the rest of the Shuttle vehicle from T-35 seconds until approximately T+26 seconds for FRF. The time from T-20 minutes to T-0, was identical to STS-1 countdown. The time from T-0 to approximately T+26 was FRF test software control. This test verified that the Shuttle vehicle was ready for launch.

The various phases of the wet CDDT/FRF were:

o Pre-FRF started with power up for the CDDT/FRF simulated run just prior to the actual test
o Wet CDDT/FRF began with the launch countdown type of action starting at T-53 hours with call to station from OMI S0014 and verification of configuration of all elements ready for the test
o FRF ended with the last cryogenic liquid out of the vehicle, which was the beginning of post-FRF activities
o Post-FRF ended with the completion of all FRF-unique objectives, closeout of the test discrepancies affecting configuration, and the OMRSD requirements being met

TEST OBJECTIVES

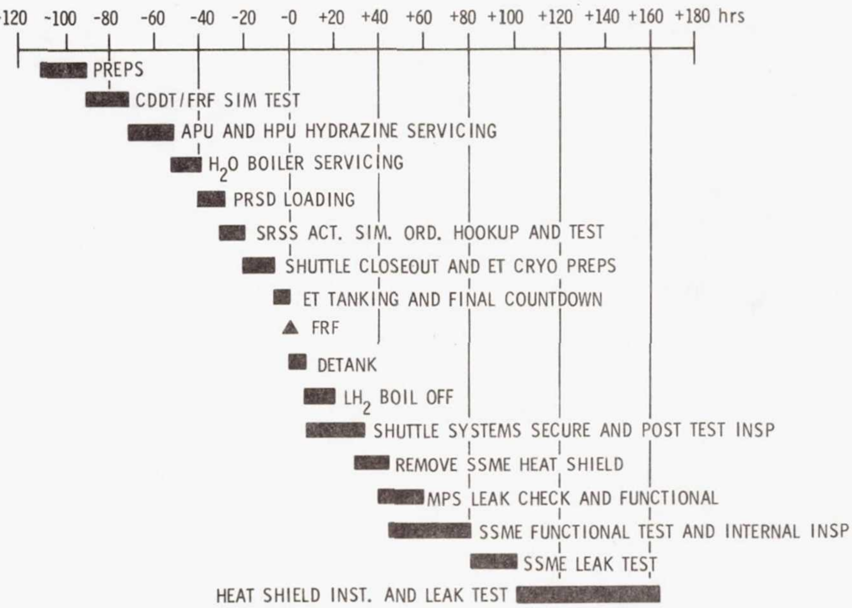
FRF provided the only opportunity to subject the Space Transportation System (STS) to the launch environment without concern for ascent transition. The test provided confidence that the STS was fully integrated in the critical functions where elements have not been tested together in the launch environment. The primary test objectives to be accomplished during this test were:

o Exercise all elements of the STS, including personnel, facilities, vehicle, and software in a real-time launch countdown culminating in a SSME firing and simulated launch to ensure proper integration prior to STS-1 flight
o Verify the capability of the launch facility to provide propellants to the Shuttle at specified conditions (i.e., subjecting the external tank (ET) and Orbiter elements to the same thermal environment as STS-1 and to maintain pressure in the ET from the ET/SSME and main propulsion system (MPS) control during SSME firing)
o Verify the functional performance of the integrated auxiliary power unit(APU)/hydraulic/flight control system during simultaneous engine gimbaling and throttling
o Load and operate the power reactant supply and distribution (PRSD) system in the Orbiter with cryogenic reactants for the first time
o Verify the predicted performance of the ET-SSME-MPS interfaces and systems, including software and the capability of the avionics equipment to effectively monitor and control the active vehicle under dynamic prelift-off vibroacoustic conditions
o Verify that LPS/GPC control of launch countdown sequencing can be performed down to T-0 along with simulated launch abort shutdown and securing in post T-0 time
o Verify compatibility of the Shuttle avionics equipment with the launch radio frequency environment
o Provide data to verify the validity of modeling techniques to extend dynamic and vibroacoustic analysis from previous test to KSC conditions
o Assess the "twang" effects of the SSME: in the start position at ignition, and on the STS flight vehicle without SRM ignition
o Exercise the data acquisition system, data reduction methods, and data analysis documentation methods to be used for launch

TEST DESCRIPTION

SEQUENCING

The sequence of operations between T-52 hours and T+160 hours are summarized in Figures 3 and 4.



CDDT/FRF S-0014

Figure 3.- CDDT/FRF timeline flow.

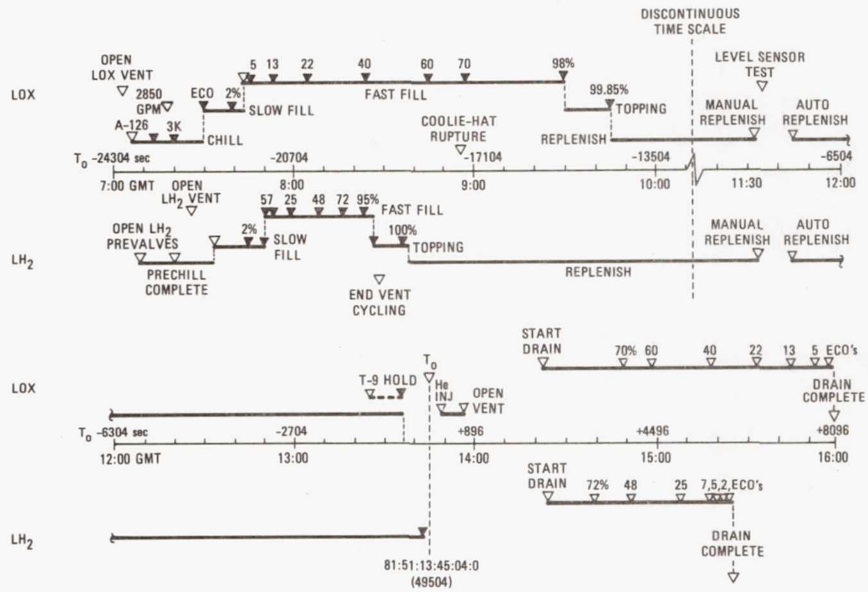


Figure 4.- FRF loading timeline.

THE CHALLENGES

ORBITER SSME WATER DELUGE SYSTEM

DESCRIPTION

SSME post-shutdown after-burning had occurred on several occasions on the MPTA at NSTL. Program concern was expressed that a similar condition would occur during FRF or during a pad abort.

A study was made by the integration contractor to determine thermal effects on the most sensitive vehicle hardware (engine mounted heatshield) and to evaluate and recommend an effective means of protecting the vehicle against the potential from an engine shutdown/abort as mentioned above.

A facility system with a series of water spray nozzles mounted around the periphery of the MLP opening and directed to impact discrete areas of the Orbiter aft heatshield structure was recommended and approved by the Level II PRCB. As designed, the system is tied to the MLP fire system to be activated manually from the LCC after detection of a potentially damaging afterburning condition.

POTENTIAL PROBLEMS

1. Damage to TPS. - Potential damage to TPS by direct impact of the water spray was a primary concern of the proposed system. To answer this question a special water spray impact test was carried out at the integration contractor's laboratory and test facility in Downey, CA. Results of the test demonstrated that TPS would not be damaged with the planned application of the nozzles. Also, characteristics of the nozzle spray plume (throw distance and diameter vs. pressure) were determined to verify proper nozzle selection/application.

2. Dedicated Spray System - The requirement of a fully independent water supply for the Orbiter-SSME deluge system could not be met on STS-1. This was due to the fact that the existing 6" diameter supply line is flow limited and can serve only one of the three major Orbiter protective spray systems at any given time.

For STS-3 this condition will be eliminated by the replacement of the 6" supply line with a 12" line, permitting full flow to all of the protective systems simultaneously, if necessary. Incorporation of the 12" supply on MLP-1 for STS-1 was delayed until STS-3 due to the high potential for impacting FRF and the STS-1 launch schedule with the significant construction effort required on the MLP.

3. Automatic vs. Manual Spray Actuation - Initial system requirements specified that the Orbiter-SSME deluge system be initiated by automatic control in the event of a planned or aborted SSME shutdown to minimize the reaction time for flow of the protective spray.

Due to potential vehicle launch schedule impact in the event that water sprays were activated needlessly (without significant afterburning) following engine shutdown, direction was given by the PRCB that the system would be manually activated. As planned, control of the system will be under the cognizance of an operator in the LCC augmented by UV sensors viewing the SSME nozzles and observation of the vehicle through closed circuit TV.

4. Alignment Verification of Spray Nozzles - During the nozzle alignment procedure prior to FRF it was determined that four of the spray nozzles on the north side of the MLP would impact directly on the trailing edge of the Orbiter body flap. To avoid the potential of TPS damage those nozzles were changed to fog jet nozzles which produce a "softer" spray with less impact energy at the tile surface.

5. Water Contamination of OMS Nozzles - The use of fly-away-throat plugs for the OMS engines was deemed unacceptable to the Program and will not be used on STS-1 and subs. To minimize the possibility of direct spray entering the OMS engines, two water nozzles were re-aimed. This request was initiated through a formal Engineering Service Request (ESR) as a manadatory requirement prior to STS-1 and has been accomplished.

6. Water Flow Test - A full deluge test with the vehicle in place was deemed not feasible due to potential schedule/cost impact to FRF/STS-1. In lieu of this final vertification test the following procedures were approved by the Program as an acceptable means of determining adequacy of the system:

a. Analysis of A&E calculations for flow-pressure.

b. Alignment of water spray nozzles using a light source to assure that spray impact areas were in accordance with the design drawings.

Results

All of the potential problems associated with Orbiter-SSME deluge system have been resolved as noted. Completion of the ESR for re-aiming at water nozzles has been implemented for STS-1.

HYDROGEN BURN-OFF SYSTEM

Description

A detailed assessment of main engines ignition overpressure data from MPTA Static Firings in early 1980 revealed the necessity of a hydrogen burn-off system at the launch pad to avoid potentially damaging overpressures caused by ignition of the SSME fuel lead of hydrogen gas at engine start.

Due to the limited time available prior to STS-1, a NASA/Contractor working group was established to expedite the design, development, delivery, and verification of the burn-off system.

After evaluation of alternate methods including an engine mounted fly-away system, a pyrotechnic initiated, facility ground system was baselined by the PRCB. This concept utilized an "off-the-shelf" igniter to minimize delivery time and provide greater assurance of supporting STS-1 with a functionally qualified system.

In addition, the development of a second pyrotechnic device (the long throw igniter) was approved as a backup to the baselined unit. In concept, this unit offered distinct advantages over the baselined short throw igniter.

a. It could be mounted on the tail service masts thus eliminating the need for cumbersome pylons required to support the short throw igniters.

b. Avoided interference/operational contraints with engine access platforms.

c. Eliminated handling and maintenance of pylons.

d. Enhanced safety.

e. It delivered a high density pattern of ignition particles under the entire area of the SSME nozzle.

The major disadvantage of this device was the limited time available to accomplish the full development and qualification program that would be required prior to STS-1.

An integrated Vertification Plan was formulated for the candidate pyro devices which included the orderly progression from single engine testing at SSFL leading to cluster engine testing on the MPTA at NSTL.

Problems

The subsequent implementation of this plan, and the problems encountered, resulted in the timely evolution of the preferred long throw igniter:

a. Analyses in support of testing revealed that the short throw igniter could be adversely affected by wind. Conversely, the long-throw igniter was relatively insensitive to the wind. (This was later confirmed by wind tests conducted at the vendor's facilities).

b. On Static Firing 12, data acquired on the first usage of the long throw igniters revealed high overpressure levels associated with engine E-1. The baseline design provided igniters for E-3 and E-2 only, for both MPTA at NSTL and OV-102 at KSC. This was due to difficulties involved in mounting short throw igniters near Engine 1 and the belief that E-1 hydrogen would be ignited by E-3 and E-2 burning. MPT SF12 demonstrated the necessity of igniters on all three engines.

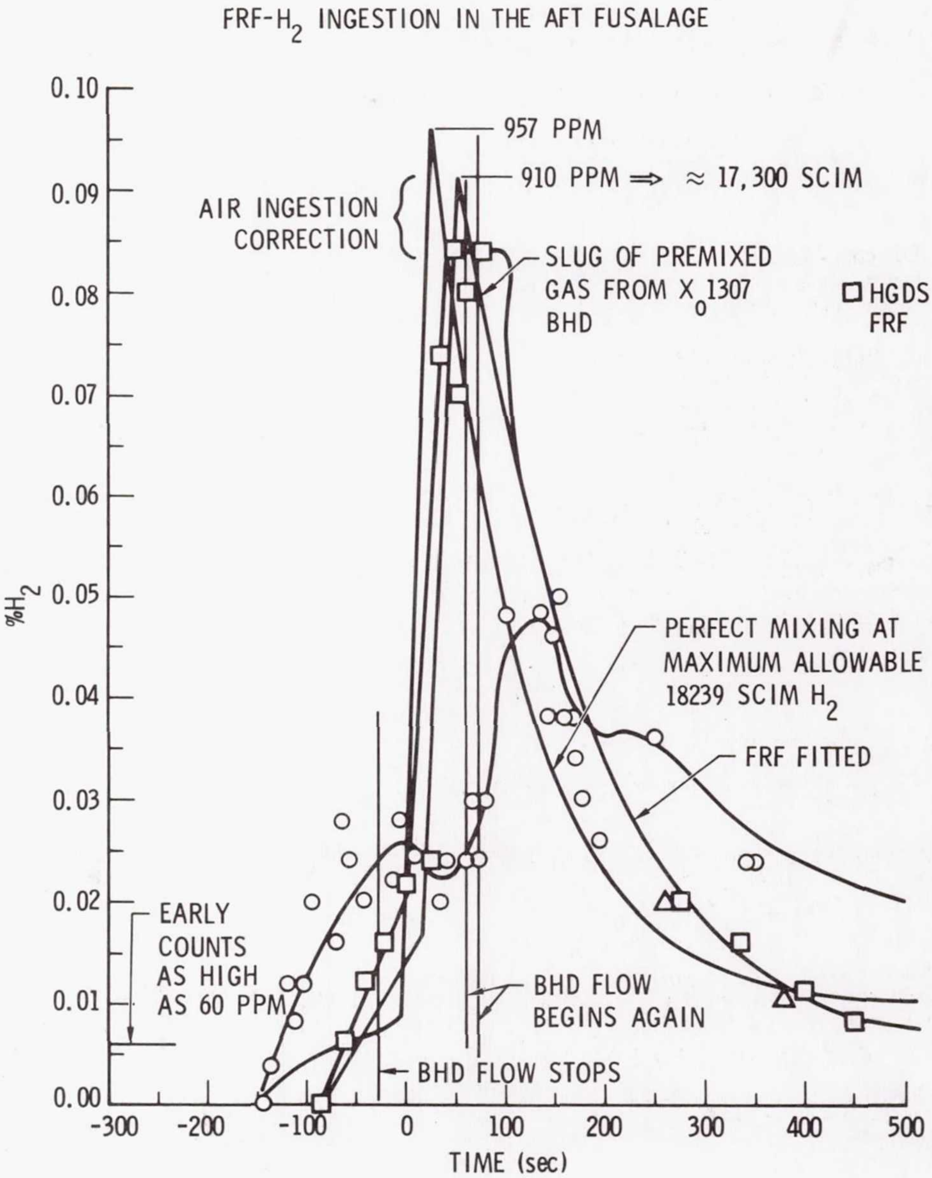


Figure 5.- FRF--H_2 ingestion in the aft fuselage.

Results

Inherent throw capability of the long throw igniter and simplicity of the mechanical installation on the TSMs made it feasible to add the additional igniters for Engine 1 at KSC. This was accomplished with no impact to the FRF schedule.

Review of FRF data has indicated an effective burn-off system that limited the SSME overpressure to less than 0.1 PSID. The Hydrogen Burn-Off System was now qualified to support STS-1.

FLIGHT READINESS FIRING (S0014)

Overall Objective

Provide final verification of critical integrated systems (i.e., main propulsion system, etc.).

Dry CDDT Objectives

a. Interface the flight crew and launch test team in a count rehearsal.

b. Demonstrate the sequence of operations required to prepare Shuttle for launch.

c. Evaluate timelines established for launch countdown.

Problems

The FRF countdown went very smoothly. There were a total of 151 Interim Problem Reports (IPRs) written against the test of which 13 affected the ground equipment. Of the 13 IPRs the following five were considered to be significant:

PRSD Sampling Results (IPR-017). During the ground servicing of the PRSD system, samples of the reactant gases failed to pass the sample test. The H_2 contained a high percentage of GHe and the O_2 contained a high percentage of GN_2. It has been determined that this was caused by a ground procedure problem during the pulse purging of the ground system. This problem was corrected prior to STS-1 launch.

Water Leaking at OAA/Orbiter Interface (IPR-038). During the FRF countdown, rain water was leaking past the dock seal of the OAA white room at the Orbiter moldline when the RSS was retracted. Prior to this time, the item of GSE which prevents water from entering the crew hatch was not installed. The GSE model A70-0643-3 is a Fiberglass scupper that fits over the crew hatch to direct water away from the hatch. Without this GSE installed, water was allowed to enter the crew module. A significant amount of water had to be removed after FRF.

This problem was resolved prior to launch in that the GSE (A70-0643-3) was installed around the crew hatch.

GOX Vent Hood. During the tanking test prior to FRF it was noted that GOX vapors were leaking from the GOX vent hood during loading of the ET LOX tank. It was determined that the leakage was past the seal where the seal interfaces with the ET tank SOFI. This GOX leakage past the seal caused erosion of the SOFI on the ET.

Pressure was increased on the seal for FRF but the seal ruptured on the South side of the ET tank just below the louvers. The tank was approximately 12-14 percent full and it was decided to retract the hood at that time and proceed with the LOX loading. The seal on the North side operated properly.

Subsequent to FRF a series of tests were run at LETF to evaluate the problem. It was found that replacing the orifice configuration from a standard orifice to a cruiciform orifice lowered the pressure on the louvers and evenly distributed the pressure on the louvers. The pressures on the North and South seals were now essentially the same.

Subsequent to FRF an evaluation of the location of the GOX vent arm indicated that the seal may have been slightly out of position and on one corner of the louvers rather than on the SOFI. This would have contributed to the failure. Steps have been taken to accurately position the seal around the louvers.

On March 9, 1981, the Level II PRCB decided to install the cruciform orifice on ET-1 based on the LETF tests. Starting March 13, 1981, a series of tests were conducted on the LETF with an improved seal design and cruciform orifice. The tests were successful.

Hypergolic Storage Tank. An incident occurred prior to the FRF countdown involving the hypergolic storage tank located on the perimeter road around the pad. During hypergolic servicing, the heater in the storage tank failed. Servicing continued, resulting in a failure of the storage tank. A new heater has been installed in the tank and a constraint has been added that use of the tank when the heater is off is prohibited.

Pressure Spike LOX Fill and Drain System. A pressure spike of approximately 150 psig occurred on the ground side of the LOX fill and drain line during detanking. The pressure on the Orbiter side of the interface did not exceed the proofpressure of the line. Preliminary indications revealed that this problem can be corrected procedurally by refilling the ground system up to the vehicle interface prior to initiating LOX tank drain. This was not implemented until STS-2.

Results

In summary, the ground systems performed exceptionally well. All test objectives were met and the ground systems were ready to support launch.

WET CDDT/FRF TEST RESULTS

The Wet CDDT/FRF test was very successful. We increased our knowledge about the integrated Shuttle MPS system. All the SSMEs will leak some hydrogen. The SSME joints will leak hydrogen and oxygen below specification levels. MPS leak tests procedures in the OPF should be improved. The STS-1 tests procedures were for joints only and the pressure was at 25 PSI. The leak checks procedures that are a part of the SSME second E&M at NSTL should also be improved. THE MPS FRF objectives were satisfied and Tables I and II summarizes the problems and discrepancies encountered during the FRF test.

TABLE 1

SUMMARY OF MPS FAILURES, ANOMALIES, DEVIATIONS, AND RECOMMENDED ACTIONS

SUBSYSTEM/COMPONENT	PROBLEM DESCRIPTION	PROBLEM CLASSIFICATION	RECOMMENDED ACTION
GO_2 PRESSURIZATION • FCV-1	LOW GO2 PRESSURANT FLOW FROM FCV-1 DOWNSTREAM OF ORBITER/SSME INTERFACE WHEN FCV CYCLED OPEN	ANOMALY	FLY STS-1 AS IS • FAILURE INVESTIGATION DID NOT DISCLOSE SOURCE OF RESTRICTED FLOW • ANALYSES INDICATE 2 VALVE FAILURES IN FLIGHT ACCEPTABLE
HAZARDOUS GAS DETECTION	H_2 AND O_2 CONCENTRATIONS APPEAR HIGHER THAN EXPECTED DURING ENGINE FIRING	ANOMALY	DETERMINE EXPECTED TRANSIENT CONCENTRATION LEVELS FOR FRF • COMPARE WITH KSC FRF LEVELS EVALUATE KSC POST FRF LEAKAGE TEST RESULTS ASSESS LEVELS DURING SPECIAL TANKING TESTS INITIATE CORRECTIVE ACTION IF REQUIRED
EXTERNAL TANK • LH_2 TANK	ABILITY TO MAINTAIN FLIGHT MASS IN LH_2 TANK MARGINAL • ATTRIBUTED TO FLOW RESTRICTION DUE TO WATER ENTERING VENT MANIFOLD AT BURN POND	ANOMALY	RESOLVE FACILITY PROBLEM AT KSC; EVALUATE FIXES ON SPECIAL TANKING TESTS • KSC MODIFICATION COMPLETED BY TANKING TEST • TANKING TEST RESULTS WILL BE EVALUATED
LO_2 PROPELLANT FEED SYSTEM • LO_2 PREVALVE-1	CLOSING TIME MARGINALLY FAST COMPARED TO COMPONENT SPECIFICATION	ANOMALY	FLY STS-1 AS IS • SSME ASSESSMENT INDICATES TIMING ACCEPTABLE FOR IN-FLIGHT SHUTDOWN • CONTINUE EVALUATION OF PRE-VALVE TIMING ON SPECIAL TANKING TESTS
SSME	ME-1 AND 3 MR APPEARS HIGH BY 0.02 UNITS • ATTRIBUTED TO CONTROLLER	DEVIATION	PROVIDE UPDATED MR TAGS FOR STS-1 PERFORMANCE ASSESSMENT PROPULSION PERFORMANCE PANEL (PPP) REVIEW CONTROLLER LOGIC FOR MR CONTROL ON STS-2
	GO_2 PRESSURANT SUPPLY TEMPERATURE NOT AS PREDICTED • HIGHER TEMPERATURES ATTRIBUTED TO MR SHIFT • LOWER TEMPERATURE ATTRIBUTED TO HEAT EXCHANGER REORIFICE	DEVIATION	PROVIDE UPDATED GO_2 PRESSURANT SUPPLY TAGS FOR STS-1 PERFORMANCE ASSESSMENT PPP ESTABLISH METHOD FOR UPDATING ENGINE TAGS WHEN HARDWARE CONFIGURATION CHANGES

TABLE 2

MPS FRF OBJECTIVE AND ACCOMPLISHMENT SUMMARY

OBJECTIVE	OVERALL OR PRIMARY	DEGREE OF ACCOMPLISHMENT	DISCREPANCIES/COMMENTS
VERIFY SATISFACTORY INTEGRATION OF ALL SHUTTLE FLIGHT SYSTEMS IN A TYPICAL TERMINAL COUNTDOWN CULMINATING IN SSME FIRING	OVERALL	FULLY COMPLETED	
VERIFY FUNCTIONAL PERFORMANCE OF THE INTEGRATED ET/SSME/APU/ HYDRAULIC/FLIGHT CONTROL SYSTEMS IN THE FLIGHT CONFIGURATION	OVERALL	PARTIALLY COMPLETED • HAZ GAS OPEN	GO_2 FCV-1 APPARENT RESTRICTED FLOW JUST AFTER T_0 • FAILURE INVESTIGATION DID NOT DISCLOSE PROBLEM • ACCEPTABLE FOR STS-1 HIGHER THAN EXPECTED H_2 AND O_2 CONCENTRATIONS IN AFT FUSELAGE DURING ENGINE FIRING • INITIAL RESULTS SHOW CONCENTRATIONS BELOW ALLOWABLE LIMITS • EVALUATION CONTINUING LO_2 PREVALVE-3 CLOSING TIME MARGINALLY FAST • COMPONENT TIMING ACCEPTABLE FOR SSME IN-FLIGHT SHUTDOWN • ACCEPTABLE FOR STS-1 ME-1 AND 3 MR APPEARS HIGH BY 0.02 UNITS • ATTRIBUTED TO CONTROLLER • ACCEPTABLE FOR STS-1
VERIFY THE CAPABILITY OF THE LAUNCH FACILITY TO PROVIDE PROPELLANTS TO THE SHUTTLE VEHICLE AT SPECIFIED CONDITIONS	PRIMARY	FULLY COMPLETED	ABILITY TO MAINTAIN LH_2 FLIGHT MASS MARGINAL • ATTRIBUTED TO KSC FACILITY DRAIN LINE • FLIGHT MASS ACHIEVED FOR FRF • ACCEPTABLE FOR STS-1
VERIFY PREDICTED PERFORMANCE OF THE INTEGRATED MPS AND INTERFACE COMPATIBILITY WITH ASSOCIATED FLIGHT AND GROUND SYSTEMS	PRIMARY	FULLY COMPLETED	SSME RECONSTRUCTED TAGS NOT AS PREDICTED • ME-1 AND 3 MR 0.02 UNITS HIGHER • GO_2 PRESSURANT SUPPLY TEMPERATURES DIFFERENT BY -100 TO +60° RANGE
DEMONSTRATE THE HYDRAULIC WARRANT FLOW CAPABILITY	PRIMARY	FULLY COMPLETED	
VERIFY INTEGRATED APU/HYDRAULIC SYSTEM OPERATION DURING SIMULTANEOUS SSME GIMBALLING AND THROTTLING	PRIMARY	FULLY COMPLETED	

GUIDANCE, NAVIGATION, AND CONTROL

Integrated Guidance Navigation and Control (IGN&C) FRF Test Objectives

The prime FRF test objectives of a total GN&C system integration nature included: (a) demonstration of capatible initialization of TVC actuator commands for hydraulics application, engine start, run and shutdown positions, (b) the ability to perform the prelaunch gimbal slew checks, (c) compatibility of the Orbiter avionics/software with the SRB thrust vector control system, (d) confirmation that the dynamic response of the SSME TVC system, in the "near flight" configuration, was comparable with that obtained from MPTA test results, and (e) provision of a test data point on analytically predicting elastic body response to a control effector command.

IGN&C Data Assessment - The first objective was accomplished successfully, although the yaw actuator on SSME 1 had drifted to -1.04 degrees (from the desired value of zero degrees) prior to Orbiter APU start. This was expected due to a non-zero plumbing torque on the nozzle at zero deflection. The second objective was accomplished with no anomalies; i.e., the slew checks were performed successfully on all actuators, even though the SRB HPUs were shut down prematurely prior to completion of the SRB nozzle slew. There was adequate kinetic energy in the turbine to permit slew completion. Ability of the Orbiter to properly orient the SRB nozzles was demonstrated with no anomalies.

This FRF test provided significant and substantial information relative to the flight readiness of STS-1 in areas pertinent to the general technical discipline of GN&C. This was in the form of assurances that: (a) the prelaunch procedure successfully prepared avionics, propulsion and hydraulic subsystems for launch, (b) the LPS was properly integrated with the on-board avionics, and (c) in the limited scope of the test, the individual GN&C elements (consisting of sensors, data processing, and control effectors) performed their required functions.

SRB THRUST VECTOR CONTROL

All four of the Auxiliary Power Units (APU) in the SRB Hydraulic Power Units (HPU) were shutdown prematurely. The scheduled operation of the APUs was to be activated at T-25 seconds and terminated at T+22 seconds. However, at T-19 seconds (based on 1 SPS data) the system A APU of the left hand SRB exceeded the turbine speed LPS redline of 79,200 rpm and was shutdown properly at T-16 seconds (Figure 6).

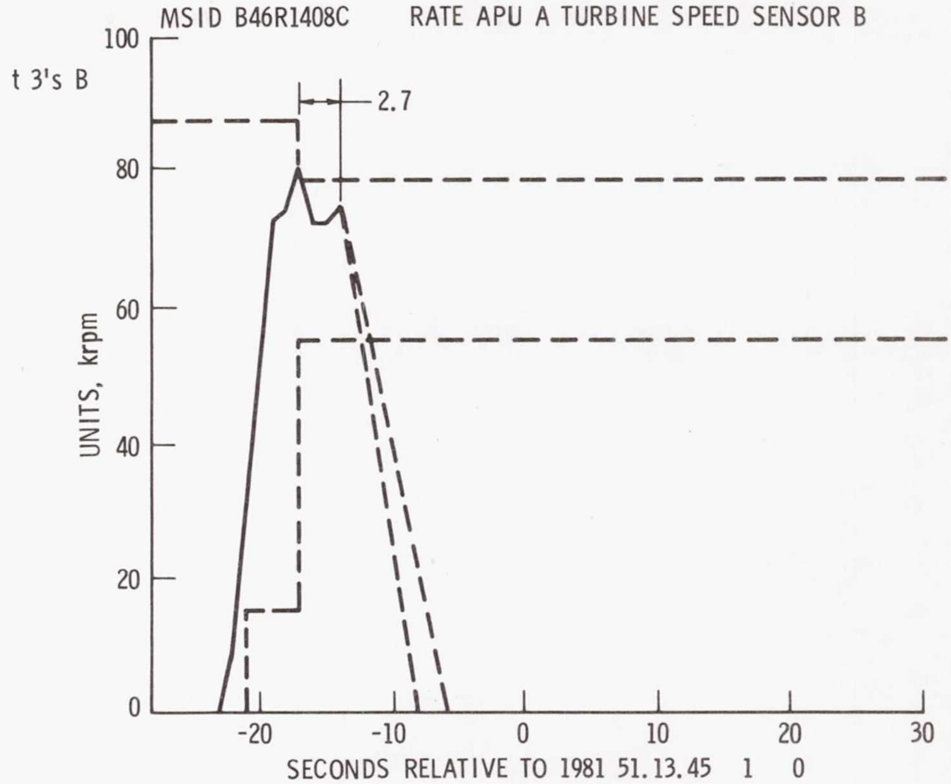


Figure 6.- Left hand SRB system A turbine speed.

The redline was exceeded because of a delay in receipt of the hydraulic by-pass off command to system B. This caused the A system APU controller to receive a delayed "hydraulic pressure OK" signal from the B system HPU which caused the A system APU controller to command the A system APU to operate at 110% speed longer than normal. The extended 110% speed operation caused the APU to exceed the 79,200 rpm redline. Exceeding the redline instituted a shutdown of a A system APU. When A system APU shutdown, A system "hydraulic pressure OK" signal was lost by the B system APU controller. This caused the B system controller to command B system APU to operate at 110% speed which shutdown B system APU at T-11 seconds because of exceeding the 79,200 rpm (Figure 7). All APU's operated properly as commanded. The APU's on the right hand SRB also shutdown prematurely due to similar causes but with somewhat different times of occurrence. System A shutdown at T-13 seconds and system

B shutdown at T+2 seconds. The delay in shutting down system B was caused by having to unlock the MDM which is locked out at T-10 seconds.

The turbine speed time histories for all four APUs are shown in Figures 6, 7, 8, and 9.

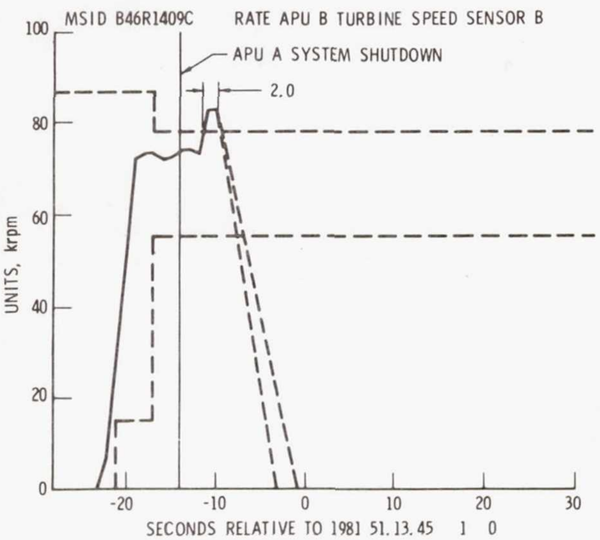


Figure 7.- Left hand SRB system B turbine speed.

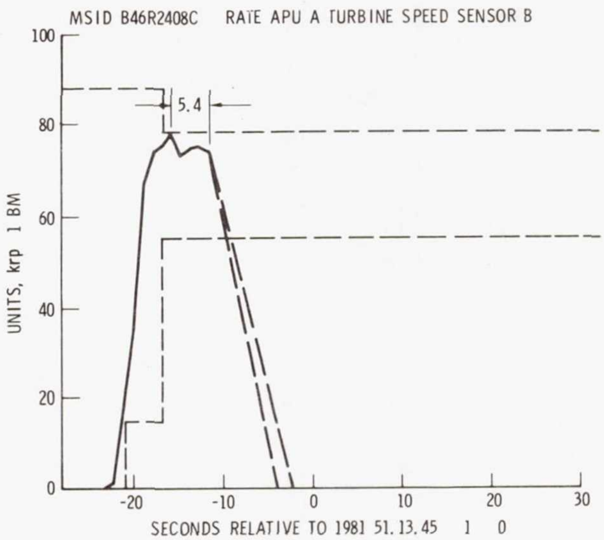


Figure 8.- Right hand SRB system A turbine speed.

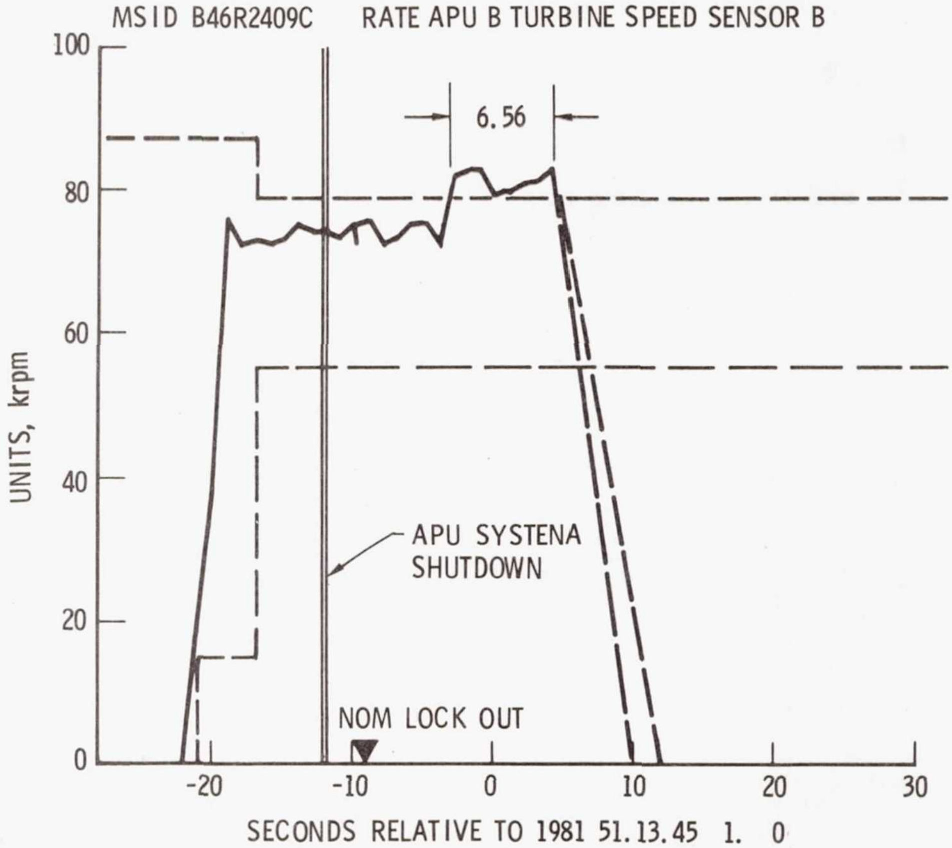


Figure 9.- Right hand SRB system B turbine speed.

RESULTS

Further evaluation of the HPU shutdown problem has verified earlier findings. A proposal has been made to KSC to make two modifications to the TVC software to eliminate the possibility of recurrence of the problem.

a. Reduce the minimum turbine speed redline from 15 KRPM to 10 KRPM.

b. Delay the initiation of the 79.2 KRPM redline by approximately 2.0 seconds minimum from depressurization valve close on the B system of the right hand SRB.

A diagram of the proposed redline changes is shown in Figure 10.

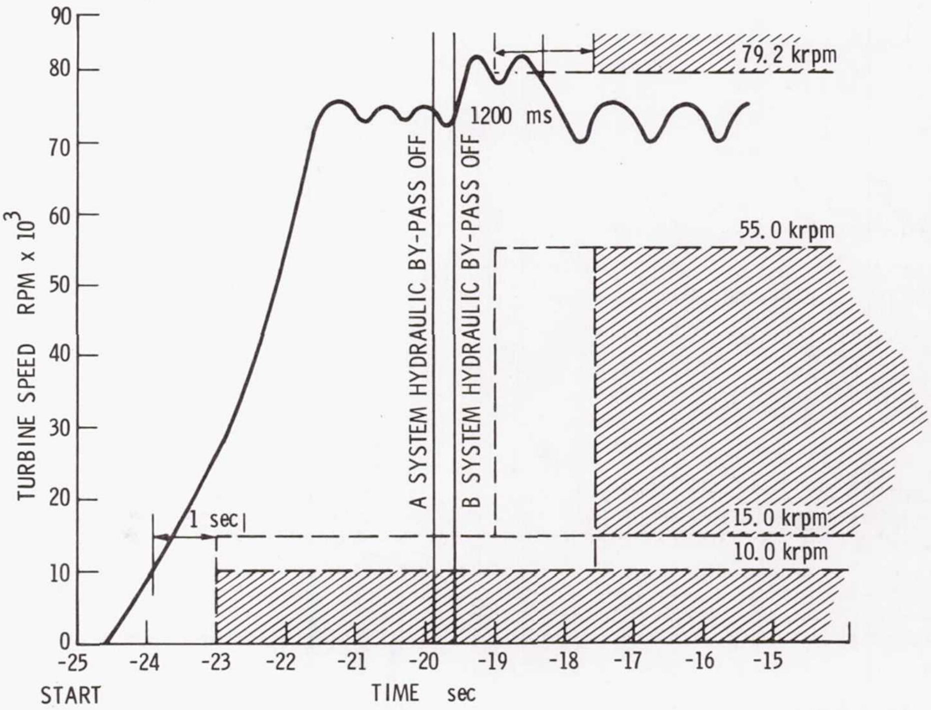


Figure 10.- Proposed APU redline changes.

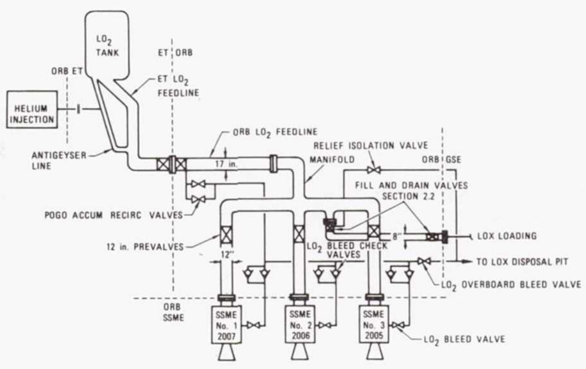


Figure 11.- MPS LO_2 fill and feed system.

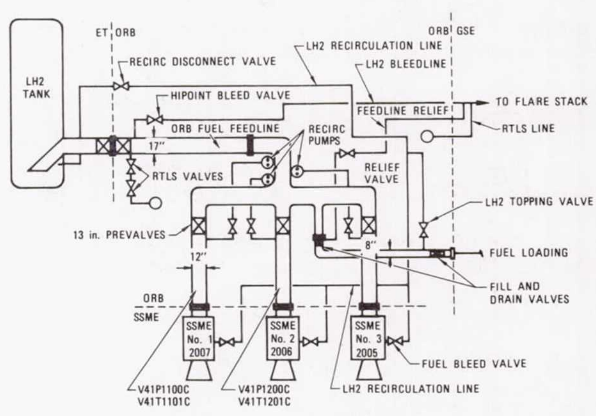


Figure 12.- MPS LO_2 fill and feed system.

SUMMARY

The Flight Readiness Firing (FRF) test conducted at KSC on Launch Pad 39A on February 20, 1981 was very successful. All integrated systems FRF objectives were satisfied by the FRF test and the follow-on data analyses. The significant results of the test included validation of the launch countdown sequencing, including critical event timing; demonstration of flight configured MPS functional and performance charcteristics; math model validation for prediction of pre-launch loads; additional data for verification of pre-launch vibroacoustic and thermal environments.

REFERENCES

1. Tech Notes — Major Warren L. Riles; Engineering Notebooks; Aug. 1978 through Apr. 1981.

2. Tech Report — Benner, R. L.; and Steisslinger, H: Space Transportation System Wet Countdown Demonstration Test and Flight Readiness Firing Test Plan Rockwell International STS 80-0180B, 1981.

DEFINITIONS

1. Space Transportation System (STS): An integrated system consisting of the Space Shuttle (Orbiter, External Tank, Solid Rocket Booster, and Flight Kits), Upper Stages, Payloads, and any associated flight/ground hardware and software.

2. Orbital Flight Test (OFT): One of four (4) scheduled developmental space flights of the STS.

3. Flight: That portion of a mission encompassing the period from launch to landing, or launch to termination, of the active life of a spacecraft. The term "Shuttle Flight" means a single Shuttle round trip (launch, Orbital, activity, and return). One flight may deliver more than one payload; and more than one flight may be required to accomplish one mission.

4. Ground Support Equipment (GSE): Nonflight equipment, and devices required for the handling, servicing, inspection, testing, maintenance, alignment, adjustments, checking, repairing, and overhauling of an operational end item or subsystem or component part thereof. This may include equipment required to support another item of GSE as defined herein.

5. Countdown Demonstration Test (CDDT) - Wet: A full dress rehearsal of the launch countdown operations including cryogenic propellant loading of the external tank. Test normally terminates at time for Space Shuttle Main Engine (SSME) ignition. Flight crew does not participate from the vehicle.

6. Countdown Demonstration Test (CDDT) - Dry: A dress rehearsal, with flight crew participation, of the Launch Countdown operations excluding external tank propellant loading operations.

7. Flight Readiness Firing (FRF): A 20-second firing of the Space Shuttle Main Engines (SSMEs) in a near Shuttle flight configuration on the launch pad, with a scheduled cutoff prior to Solid Rocket Booster (SRB) ignition and liftoff, to be conducted (one-time only) as part of the CDDT.

8. Cutoff: The initiation of the SSME shutdown sequence, whether generated by the SSME controller, GPC, LPS or FEP hardwire.

9. Automatic Cutoff: SSME shutdown resulting from an out-of-tolerance parameter monitored by either the SSME controller, GPC or LPS for cutoff criteria.

10. Manual Cutoff: SSME shutdown initiated by console operator. LPS is backed up by a hardwire. The hardwire bypasses the common data buffer and inputs directly to the FEP.

11. AADS — Ascent Air Data System

12. DDT&E — Design, Development, Test and Evaluation

13. FASCOS — Flight Acceleration Safety Cutoff System

14. LETF — Launch Equipment Test Facility

15. MPTA — Main Propulsion Test Article

16.	NSTL	National Space Technology Laboratory
17.	OMI	Operations and Maintenance Instruction
18.	PRCB	Program Requirements Change Board
19.	PRSD	Power Reactant Supply and Distribution
20.	PV&D	Purge, Vent, and Drain
21.	SPS	Samples per Second
22.	SSFL	Santa Susana Field Laboratory
23.	TPS	Thermal Protection System