XI.14

PROPULSION AND VEHICLE
ENGINEERING LABORATORY

SUPPLEMENT TO

MONTHLY PROGRESS REPORT

For Period

April 1, 1966, Through April 30, 1966

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-66-4

SUPPLEMENT TO

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Propulsion Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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MONTHLY PROGRESS REPORT

PROPULSION DIVISION

April 1, 1966 Through April 30, 1966

SATURN IB

I. S-IB Stage

A. Hydraulic Package on S-IB-2 Replaced

The hydraulic package on engine at position No. 1 was replaced because of difficulties encountered in bleeding all the GN_2 from the package. The new package that was installed was reported to have the same problem. It was determined later that there was nothing wrong with either package and that the difficulty was due to inexperienced personnel.

B. S-IB-5 Acceptance Fired Successfully

All systems functioned normally. The thrust of all engines was within the 200K $\pm$ 3 percent range. An internal fuel tube was cracked and leaking approximately 10.5 inches below the injector on engine No. 4. This engine will either be repaired or replaced. The hydraulic system of engine No. 3 was contaminated before the test but functioned normally. This package will be removed and cleaned during stage refurbishing and checkout at Michoud.

C. Ordnance Testing

The major test effort on the EBW Initiator Reliability test program this month was the Temperature Calibration Test. Using an inert test specimen, tests were completed at the following temperatures: +400, +200, 0, -20, -40, -60, -80, and -100°F. Testing remains to be performed at +600, +800, and +1000°F.

D. Thermal Control Requirements of Payload Fairing Analyzed

Preliminary thermal analyses were performed to define thermal protection requirements for a nose cone and shroud configuration to enclose a LEM payload. The structure considered for the analyses is an SA-203 nose cone plus a 260-inch cylindrical extension. Thermal requirements specified by MSC for the LEM vehicle necessitate that the inboard side of the payload fairing be maintained at about 300°F, or lower with an inner surface emissivity of 0.15 or less. Based on results of the thermal analyses, it was recommended that thermal protection material be added on the inboard side of the nose cone skin. A 1/4 inch thickness of refrasil batting enclosed between aluminum foil will maintain acceptable inboard temperatures. The weight of this system is about 60 pounds.

II. S-IVB Stage

A. Propellant Utilization Activation Time Changed

Evaluation of AS-201 flight data showed that the delay in activation of the propellant utilization (PU) system should be extended to assure that the J-2 engine is well into mainstage when the PU valve is allowed to move. A request was submitted asking that the flight sequence be changed for all S-IVB stages (except S-IVB/203 which operates "open-loop" PU) to the following criteria:

1. S-IVB/Saturn IB. - Activate the PU system at engine start command plus 6 seconds.
2. S-IVB/Saturn V. - First burn, activate the PU system at engine start command plus 8 seconds.

Second burn, activate the PU system at engine start command plus 13 seconds.

B. MSFC S-IVB Battleship Program

The first firing of engine J-2048 was successfully accomplished on April 7, 1966. The primary objective was to run at S-IVB-203 LH_2 pressurization system operating conditions as specified for flight. Preliminary data analyses indicate the LH_2 pressurization system performed satisfactorily. The objective of the next scheduled test is to reconstruct the problem encountered with the LH_2 pressurization system, an unscheduled decay in the LH_2 tank pressure, on the S-IVB-203 acceptance test.

C. Engine Gimbal System Components Tests

The main pump passed the proof and functional tests. The auxiliary pump also passed a functional test, filter patch test, calibration test, transient pressure and dynamic response test and pressure pulsation test. Tests on the accumulator - reservoir - manifold assembly were continued after successful completion of the high and low temperature, and life cycle tests. The life cycle test is in progress with 6400 of the 9000 cycles completed. All tests have been completed satisfactorily except for the low pressure relief valve which exceeded the maximum allowable inlet pressure at rated flow.

D. Component Qualification Test Program

Documentation review, including specifications and test procedures was completed on twenty-one components of the formal qualification test program. The documentation review portion of this program is 64 percent complete. Three additional formal qualification tests failed as follows:

Fuel Low Pressure Duct Assembly - Wall between vacuum jacket and internal duct cracked during temperature shock test.

Oxidizer Low Pressure Duct Assembly - Leakage rate of 8700 scch at 117 psi, ambient helium gas, was recorded (allowable is 1 scch), during leakage test.

Engine Pump Purge Control Module (Chilldown Pump) - Specimen numbers 1 and 2 - Flow was 9.0 scfm (minimum allowable is 9.6 scfm).

Specimen 2: Internal leakage was 142 sccm. (allowable is 30 sccm maximum)

Specimen 3: Internal leakage was 500 sccm.

III. Instrument Unit

I. U. Environmental Control System for Saturn IB and V

1. Sublimator Tests: The latest series of tests at Arnold Engineering Development Center (AEDC) was completed. A total of seven sublimators (SN's 9, 10, 3', 4', 5', 7', and 9') were tested to determine operating characteristics. Another test series at AEDC is expected to begin in June, 1966.

2. Functional Test of Sublimator Water Supply System: Several flight simulation tests using Sublimator SN 9' were performed at AEDC. The latest flight configuration water supply line was used

and expected g-loads were simulated by varying the water inlet pressure to the Sublimator.

3. Functional Tests of Water Flowmeters: Two water flowmeters, proposed for use during flight in the Sublimator water supply line, were functionally tested in a flight configuration system and monitored during a sublimator start. This data is being evaluated.

4. Gas Bearing Gas Supply Heat Exchanger Qualification Panel: A panel with flight equipment was subjected to bleed and thermal tests simulating flight conditions. The regulator failed to function properly at low temperatures. Testing will resume upon receipt of another regulator.

SATURN V

I. S-IC Stage

A. F-1 Engine

1. R&D Engine Tests at EFL

Fifty-four tests were conducted and a total duration of 4317.9 seconds was accumulated. Eighteen of these tests were full duration runs (150 seconds or more) increasing the total number of full duration tests to date to 496. Four of the tests were terminated prematurely; six were ignition-only tests; and the other 44 tests ran for the programmed duration.

2. Production Engine Tests at EFL

Ten tests were conducted and a total duration of 820 seconds was accumulated. Three tests were conducted for full duration (150 seconds or more). One test was terminated 45 seconds into a 165-second programmed test due to low thrust. The total number of production engine tests conducted to date is 138 with a total duration of 10,525 seconds accumulated.

3. Turbopump Bolt Problem Corrected

During test of engine F-2010 at MSFC, a bolt retaining the turbopump fuel inlet fairing worked loose and lodged in the inducer. Subsequent check revealed that there were several instances of these

bolts losing torque during tests. An ECP was initiated and approved to correct the problem. Higher strength bolts will be used, epoxy resin applied to aid in retaining the bolts, and torque on the bolts increased.

4. Engine Tests at Simulated Flight Conditions

In view of the very limited amount of testing conducted under simulated "end of flight" conditions and the potential problems that may be incountered, it was requested that the engine contractor be directed to accelerate testing of flight LOX pump inlet pressures. To facilitate this testing it will be necessary for MSFC to provide several additional pressure volume compensating (PVC) ducts.

5. Engine Component Qualification Tests

Thirty-five components have successfully completed qualification testing. Ten components are presently in various phases of qualification testing. The new high voltage igniter specification was reviewed and approved with only a slight modification. The liquid-level detector was deleted from the engine and removed from the component qualification list.

6. Thermal Conditioning System Analyzed

Tests conducted determined that the thermal conditioning system used to precondition the F-1 engines was unbalanced and significant engine-to-engine variation in temperature could occur. The system was balanced within 5 percent by resizing stage-side orifices.

B. Component Qualification Test Program

1. LOX Vent Valve, 10" (Parker) - Qualification tests have started on the redesigned unit No. 3.

2. LOX Pressure Volume Compensator - Outboard and Inboard Ducts - (Flexonics) - All qualification testing was satisfactorily completed on both ducts. Burst pressure on the ducts was 542 for the outboard and 552 psig for the inboard. This completes all qualification tests on these Flexonics ducts.

C. Propellant Loading Monitor Program

The S-IC propellant loading monitor program was programmed for the RCA 110 computer and is now undergoing checkout. Examples of propellant loading tables were furnished for output comparison purposes. There is some indication that exact duplication of the values on the table will not be possible on the RCA 110 because of an inherent round-off error.

D. Inflight Temperature of Confined Detonating Fuse Investigated

Inflight heating to the confined detonating fuse (CDF) located in the aft region of the S-IC stage was estimated. No thermal problems were discovered.

E. Components Evaluated for Possible Use on S-IC

1. Two N. O. and two N. C. (Parker Co.) 3-way solenoid valves were evaluated. All valves passed functional tests at room temperature but leaked excessively when subjected to sinusoidal vibration. The valves were returned to the manufacturer for modification.

2. One N. O. and one N. C. 2-way solenoid valves (Marotta Co.) were evaluated for possible low temperature use. The normally-closed valve performance was satisfactory down to a temperature of -285°F, but the normally open valve was found to leak excessively at a temperature of -100°F. The valves were returned to the manufacturer for modification.

II. S-II Stage

A. J-2 Engine

1. R&D Engine Tests at SSFL

Seventy-one tests were conducted, and a total duration of 8,862 seconds was accumulated. Five tests were terminated prematurely.

2. EBW Initiators for J-2 SPPG Tested

Testing of fired EBW initiators for the capability to withstand high pressure was completed. The results generally indicated that the EBW initiator would be satisfactory for use on the J-2 SPGG.

3. J-2S Solid Propellant Gas Generator EBW Initiator Analyzed

Rocketdyne considers the present EBW initiator unacceptable for use on the J-2S SPGG application because of initiator body and thread strength. Analyses by their stress personnel indicate that the initiator body and threads will not withstand the design pressure of 6000 psi with the required safety factor. An analysis is being performed to determine what will be required of the EBW initiator for J-2S SPGG application.

4. Thrust O.K. Pressure Switch Vibration Tested

An attempt was made to conduct vibration tests on the J-2 Thrust O. K. Pressure Switch. The bracket holding the switch had a resonance of 900 $\pm$ 50 cps with an output of 400 g's. The input to the bracket was 40 g's. Testing was stopped.

B. S-II-T Static Fired

A 15-second static firing of S-II-T was conducted on April 23, 1966, at MTF. All major objectives with the exception of propellant utilization and LH_2 recirculation were accomplished. The following problems occurred prior to and during the countdown:

1. Thrust chamber GN_2 purge valve in S7-49 stuck open.
2. Engine start bottle temperature out of redline - procedural problem.
3. Free hydrogen burnoff flame not detected - interlock.
4. LOX debris valve would not close.
5. LH_2 vent valve operated sluggishly.
6. LH_2 fill and drain valve erratic.

In general, the test was successful and demonstrated that the stage was ready to proceed into tests of longer duration. The next firing is scheduled for May 6, 1966.

C. Insulation Tested on S-II-T Stage

The S-II-T stage has essentially the same insulation as the flight stages except the sidewall insulation thickness is only 0.8 inch rather than 1.6 inches. The stage was filled to approximately 30 percent level in the LH_2 tank with LN_2. The insulation leak detection and purge system performed acceptably, when modified as follows:

1. New manifold to supply helium purge to suction line covers and recirculation covers.

2. New line sizes and routing to supply helium purge to and from the J-ring area.

3. New inlet to supply helium purge to forward bulkhead uninsulated area (under membrane seal).

4. New inlet to supply helium purge to the forward bulkhead uninsulated area.

These "field expedient" modifications were required when pre-test flow checks showed inadequacy of the purge system.

The S-II-T propellant loading tests were completed. The LOX container pressure decay rate was approximately 1.5 psi/min following prepressurization. This excessive decay is being investigated. The LH_2 container pressurization was satisfactory.

D. S-II-T Test Evaluation Plan Completed

This plan presents the required data and expected output from evaluation of the propulsion and associated systems on the S-II-T. Static test predictions for the 150-second and full duration tests were made. Propellant loads were determined to satisfy the test objectives of the 150-second test.

E. Hydraulic System Components Tests Evaluated

Preliminary tests were conducted to determine the condition of S-II hydraulic system components that had been subjected to twelve hot firings. Components tested were the main and auxiliary pumps and the accumulator reservoir assembly, including filter elements and relief valves. Performance of the pumps and relief valves and the condition of the filter elements were good. Performance of the accumulator resevoir assembly was good except the accumulator piston stuck during the tests. A more comprehensive test program will follow.

F. Component Qualification Test Program

1. LH_2 Inboard Suction Line - All testing except temperature cycling and endurance was completed.

2. Pre-Valves - Five Valves are being tested at Atomics International Laboratory. Phase A testing is scheduled for completion on June 19, 1966. Phase B testing is scheduled for completion on July 19, 1966.

3. Check Valve, Engine Isolation - Qualification testing is in progress at United Aerotest Laboratory.

4. Valve, Butterfly, Pressure Actuated - Due to casting failures during qualification test, the housings are being redesigned. Delivery of new castings is expected in approximately six weeks.

5. LOX and LH_2 Tank Vent Valves - Three types of materials are being considered for the main power bellows; Inconel 718, Armco 21 - 6 - 9 and Beryllium Nickel. Development testing is in progress on the Inconel 718 and the Armco 21-6-9 bellows.

6. Valve, Solenoid, Helium Pressurization - This valve has successfully completed all qualification testing.

7. Valve, Regulator, Recirculation System - The Regulator completed qualification testing with the exception of the relief valve.

G. LOX PVC Qualified

The Flexonics outboard and inboard LOX pressure volume compensators successfully completed qualification testing.

III. S-IVB Stage

A. Auxiliary Propulsion System (APS) Development Tests Completed

The firing tests were completed, and the system performed as predicted. Included in the testing was a six-day hold with propellants on board. At the end of this hold, gas was found inside the Teflon positive expulsion bladder. Studies and further testing are underway to define and solve this problem.

B. C-1 Engine (APS) Tests

To date, a total of 602 tests has been conducted and a total hot firing time of 10,341 seconds accumulated. Of these tests, 100 were short ignition tests conducted to investigate start transients and ignition pressure spike.

C. C-1 Engine Prototype Injector Tested

A fixture for measurement of flow from the individual injector holes was completed. Tests of the prototype injector with

the fixture revealed an oxidizer and a fuel flow variation of ±3 percent and ±20 percent from their nominal values. To correct the excessive fuel flow variation, each fuel orifice will be counterbored at the inlet, and the fuel manifold inlet port will be rotated to an optimum position.

D. C-1 Engine Molybdenum Collar Tested

The test results of a shortened molybdenum collar around the throat of the nozzle indicate that heat rejected to the jacket can be significantly reduced. Preparations are being made to evaluate liner temperatures in the region where molybdenum has been removed.

E. Heating Rates to J-2 Engine From 72-pound Ullage Motors and O_2/H_2 Burner Predicted

A 4 1/2 hour continuous burn of the O_2/H_2 will necessitate a new insulation concept for the J-2 engine.

F. O_2/H_2 Burner Tested

A series of burner tests have been run consisting of three-calibration firing and one-igniter-out firing. Generally the tests have been successful. Some of the difficulties encountered were:

1. LOX propellant valve failed to open causing automatic shutoff (the electrical relay failed).
2. Burner did not ignite (igniter was installed incorrectly).
3. No ignition occurred (injectors were removed, cleaned, and reinstalled, and the ignition system checked out). No abnormalties were noted.
4. Extremely "hot" shutdown occurred. (burner dome temperature approximately 2690°R). Post-inspection revealed a hole burned in the helium repressurization coil.

The program will be delayed briefly to repair the repressurization coil. During this period, the contractor will run limited one-igniter-out tests until a spare burner is ready for installation in the test stand.

G. Retro Exhaust Contamination Studied

Three subscale firings (the second, third, and fourth tests of the scheduled ten) were made in the retro motor contamination test program. The motor performance for all three firings was normal and as expected. In general, good data was obtained.

IV. Instrument Unit

Subsystem Analytical Studies Uncover I. U. Discrepancy

In January, 1966, Saturn V subsystem analytical studies were initiated to improve and/or simplify existing subsystems. In April, the first study was completed on the I. U. Gas Bearing Gas Supply subsystem. The components and complete subsystem were mathematically described and the mathematical relationships were verified using actual test data. A significant finding was that the regulator and gas bearing (ST-124M), flow and pressure requirements are not completely compatible and recommendations for correction were made.

SPECIAL STUDIES

I. Superinsulation

Tank III, a 105-inch diameter tank, was wrapped with Linde insulation. A mylar-lead-mylar laminated 2.8 mil thick was applied over the insulation to serve as a flexible vacuum jacket. The insulation was evacuated, and will continue until the proper vacuum level has been obtained. Preparations were made for testing of this concept for ground hold and simulated orbital conditions.

Tank II, a 105-inch diameter tank wrapped with NRC insulation was retested using upgraded vacuum facilities. A boiloff of 1.95 lb/hr was obtained during the steady-state portion of the test. This results in a propellant loss of 2.5%/day. This particular system will permit the storage of hydrogen for 96 hours with an LH_2 loss of only 10% of the original loading.

The 24-inch diameter tank insulated with mylar honeycomb was thermally cycled six times without failure of the heads or cylindrical portion. NRC insulation will be applied over the mylar honeycomb and the system retested.

Tests were conducted on two tanks to determine the feasibility of using mylar honeycomb insulation on compound curvature surfaces. The insulation on the first tank (a 20-inch diameter tank with ellipsoidal bulkheads) suffered no damage except for the insulation blowing off at the junction of the bulkhead and access opening at the top of the tank. This occurred after the tank had been cooled to liquid hydrogen temperature five times.

II. Zero Leakage Program

A. Investigation of Brazed and Welded Tube Connectors: Leakage, extended pressurization, and high and low temperature tests were performed on the 1/4-inch connectors. No leakage was observed. Fixtures for vibration tests are being designed.

B. Twelve 1/4-inch connectors were placed in outdoor storage. These connectors are scheduled for visual inspection and a leakage test on April 2, 1967.

C. Leakage Test of MC Fittings with A286 sleeves at LH_2 Temperature: Extreme low temperature testing is presently underway.

III. LH_2 Seals Tested

Leakage tests with the 70-inch LH_2 test tank were conducted with helium at ambient temperature to establish leakage rates of manhole seals at this environment and to verify the leak measurement instrumentation. The ambient helium tests were completed on Conoseal and Naflex seal joints. Repeatable data were obtained, and evaluation is under way.

IV. Point Velocity Correlations in Turbulent Flow Fields

The first data obtained using the Laser Doppler Velocimeter were processed. These data were taken with water in the low turbulent region. The point velocity frequency function was measured at a fixed point in the flow field. A galilean transformation was made on the distribution function, and it was found to be symmetrical, indicating isotropic conditions at the axis of the pipe. This data was processed manually, but computer programs will be prepared to reduce error and processing time.

V. Harmonic Analysis of Engine Static Firing Data

The digital computer program was written. A test case will be run on the computer to check out the program. After checkout is complete, engine test data will be analyzed using the program.

VI. Investigation of Freon E-3 as Working Fluid in Thrust Vector Control System at Low Temperatures (-150°F)

The fabrication of the test setup is approximately 75% complete. The pump mounting bracket and torque cell adapters were delivered,

and they are being integrated into the system. Delivery of the heat exchanger is now scheduled for May 2, 1966.

ADVANCED PROPULSION AND TECHNOLOGY

I. Advanced Engine Bell Power System Investigation

The work statement for the investigation of the Power System Assembly dynamics was completed. The project will investigate the interaction of the turbomachinery with the 350K pump program and the necessary combustion devices. The project will also assess the capability of the system to achieve the performance and operational goals.

II. NASA/USAF Advanced Engine Effort

Information was assembled to assist the Ad Hoc Committee of the Launch Vehicle Panel of the AACB in their efforts to formulate a revised coordinated program for the NASA/USAF Advanced Engine Effort. The data was submitted during the fact finding meetings on April 27-30, 1966.

III. Composite Engines Study

The final report (draft copy) on "A Study of Composite Propulsion Systems for Advanced Launch Vehicle Applications," was received from the Marquardt Corporation and is presently undergoing review.

PUBLICATIONS

"Development Testing of the Sublimator, Saturn IB and Saturn V Instrument Unit Environmental Control System," Unclassified, IN-P&VE-P-66-3, by William T. Buckels, Dated March 3, 1966; Published April 15, 1966.

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