PROPULSION AND VEHICLE
ENGINEERING LABORATORY

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SUPPLEMENT TO

MONTHLY PROGRESS REPORT

For Period

May 1, 1966, Through May 31, 1966

FOR INTERNAL USE ONLY

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

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PROPULSION AND VEHICLE ENGINEERING LABORATORY

MPR-P&VE-66-5

SUPPLEMENT TO

MONTHLY PROGRESS REPORT

(May 1, 1966, Through May 31, 1966)

Propulsion Division

GEORGE C. MARSHALL SPACE FLIGHT CENTER

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GEORGE C. MARSHALL SPACE FLIGHT CENTER

PR-P&VE-P-66-5

MONTHLY PROGRESS REPORT

PROPULSION DIVISION

May 1, 1966 Through May 31, 1966

SATURN IB

I. S-IB Stage

A. 205K Engine Qualifications Tests

Calibration tests to accumulate test time on the engine are in progress. A safety limits test series will follow. Completion of the test program is planned for June 15.

B. Redline Value Discrepancies Resolved

Redline parameter differences between CCSD, Michoud, and MSFC were resolved as follows: The oronite 262 temperature redline was deleted; the LOX and RP-1 ullage pressure redlines were added; a minimum value of 710 psia was added to the Control Pressure Regulator Redline; and the minimum value of 60 per cent (pump off) was deleted from the Hydraulic Fluid Level Redline.

II. S-IVB Stage

A. Engine Gimbal System Tested

The system test installation was completed except for two temperature transducers which have not been received from DAC. The servicing test and proof pressure tests were completed and the system is now being modified to begin the functional test.

B. Engine Gimbal Components Tested

The main pump completed the filter patch, calibration, transient pressure, dynamic response and pressure pulsation tests and is currently in low temperature testing. The auxiliary pump passed the random vibration, low temperature and high temperature tests before losing the gas shaft seal. Plans are being made to ship this unit to Vickers,

Inc. for repair; it will then be placed back into testing. The accumulator reservoir sustained a failure of a dynamic O-ring on the reservoir piston after 8200 of a scheduled 9000 cycles. This O-ring was replaced and the cycle test was completed satisfactorily.

C. Engine Start Temperature Limit Investigated

Estimates of J-2 engine bell heating by the 72 lb ullage motor were presented to the engine contractor. The contractor could make no statement regarding the ability of the J-2 engine to start above 80°F. Both contractor and MSFC data indicate tube temperatures between 150 and 200°F. The engine contractor was requested to conduct tests to determine the upper limit of the J-2 engine start capability. Preliminary estimates of band heating indicate 1000°F temperatures; therefore, band insulation will be required.

D. S-IVB-203 LH_2 Pressurization Decay Test Program Completed

The series of tests using the MSFC battleship vehicle to investigate the pressure decay observed in the LH_2 ullage during S-IVB-203 acceptance tests was completed on May 6. The tests proved that the pressurant flow rate should be increased to assure minimum NPSH during flight and that the redesigned pressurant distributor is more effective than the original distributor. The new distributor was installed in S-IVB-203 for flight, and provisions were made to have the LH_2 pressurization module flown to the contractor and reorificed for higher flow rates and flow calibrated. The reorificed module was scheduled to be reinstalled on S-IVB-203 prior to the propellant loading test scheduled for May 20.

E. Final Operational Sequence for Orbital Liquid Hydrogen Experiment (AS-203) Completed

The sequence was modified to provide capability for a LOX recirculation test. The LOX recirculation test is a secondary objective and will be implemented only if sufficient LOX is onboard. The decision to bypass the LOX recirculation test will be made on a real time basis during the experiment.

F. LH_2 Recirculation System Test Data Analyzed

Analysis of S-IVB Battleship LH_2 recirculation system test data indicates possible gravity influence on chilldown time requirements. The need and availability of hardware for performance of an inverted LH_2 recirculation flow system test is being investigated.

G. Component Qualifications Test Program

Qualifications tests for one hundred and thirty-three components are complete in the Design Evaluation Qualification (DE/Q) program. Testing is 53 per cent complete.

III. Instrument Unit (I.U.)

A. I.U. Component Qualification Tests

1. Regulator, Gas Bearing Gas Supply System - Vibration tests were completed. High and Low Temperature, acceleration, service life, humidity, salt spray,sand and dust, and fungus tests should be completed by July 1.

2. Regulator, Water/Methanol - Shock and vibration tests were completed. High and Low Temperatures, acceleration, service life, humidity, salt spray, sand and dust, and fungus tests should be completed by July 1.

B. Environmental Control System (ECS) Tests

1. Quick Disconnect Coupling Pressure Drop Test - Tests were performed to determine the pressure drop of the 1-inch and ½-inch quick disconnect couplings used in the I.U. ECS. The data will be used to properly size the I.U. - 203 system orifices.

2. M/W Accumulator Regulator - Two M/W accumulator regulators (S/N 014 and 015) successfully passed the vibration and shock qualification tests.

3. Gas Bearing Regulator - A Gas Bearing Regulator failed to pass the qualification test for vibration. Contamination was found on the valve seat. Another regulator was furnished and testing is now in progress. Regulator S/N 016 was installed on SA-203 and is functioning normally.

4. Gas Bearing Shutoff Valve - A high rejection rate of these valves during acceptance tests revealed that the valve poppet closing spring was marginal. Tests to determine the correct spring and solenoid were initiated. PFCT is scheduled to start on the modified design by June 6.

C. SA-203 Flow Test Conducted at KSC

The test was conducted to verify system integrity.

D. I.U. Redline Values Reviewed

IU Ambient temperature (KC 36-601) was added as a redline value on operational vehicles. The ST-124M platform inlet pressure is not required as a redline value.

SATURN V

I. S-IC Stage

A. F-1 Engine

1. R&D Engine Tests at EFL

Sixty-one tests were conducted, and a total duration of 4040.7 seconds was accumulated. Thirteen tests were full-duration runs (150 seconds or more); eight were ignition-only tests; one was terminated prematurely due to a fire resulting from a 3/4 inch crack in the turbine manifold; and the other 39 tests ran for the programmed duration.

2. Production Engine Tests at EFL

Nine tests were conducted, and a total duration of 659 seconds was accumulated. Two tests were conducted for full duration (150 seconds or more). The total number of production engine tests conducted to date is 147, with a total duration of 11,184 seconds accumulated.

3. Engine Tests at MSFC

A test program was initiated to investigate engine performance at simulated "end of flight" conditions. Two full duration tests were conducted that simulated the LOX pump inlet pressure operation during flight. No abnormal performance was noted during the test. Five additional tests were conducted to determine a base-line for the high LOX NPSH studies and to determine any performance deviation due to short turn-around time and hardware changes.

4. Engine Component Qualification Tests

Thirty-eight components have successfully completed qualification testing. Tests were completed on the GG Ball Value. In view of the shaft seal leakage which exceeded the specification limits, further testing with a new type seal is being considered on the GG Ball Valve. The eight remaining components are presently in various stages of qualification testing and should be completed by the end of June 1966.

5. Engine Modification Reported

The thrust chamber prefill level detector and electrical harness will be deleted effective with F-1 engine No. 2011 and subsequent. The ground support equipment is being revised to incorporate this change.

B. S-IC-F Propellant Loading Tables Completed

Two sets of propellant loading tables were forwarded to Kennedy Space Center (KSC). One table can be used to simulate 501 type loads, while the other table can be used to simulate 504 type loads.

C. Functional Test of S-IC Hydraulic System Return Line Sucessful

Design of vibration brackets are approximately 75% complete. Sinusoidal and random vibration in three planes is planned.

D. S-IC Filter Elements Evaluated

Pressure drop and bubble point tests were completed on the nine elements. Testing is continuing.

II. S-II Stage

A. J-2 ENGINE

1. R&D Engine Tests at SSFL

Eighty-one tests were conducted accumulating a total of 6,972 seconds of firing time. Five of these tests were terminated prematurely.

2. Engine Deliveries to S&ID

Engines J-2066 and J-2068 were delivered; these engines are allocated for the 504 vehicle. Engine J-2067 is expected to be delivered by the end of the month.

3. Engine Tests at MSFC

Rough combustion was noted on Engine J-2048 during test S-IVB-027 on May 18, at MSFC. The test was terminated by the vibration safety cutoff device after approximately 11 seconds of mainstage operation. The cause or triggering source has not been identified. Past experience indicates that rough combustion can be caused by cracked oxidizer posts, chamber tube splits, ice in the injector orifices, and improper purge adjustment. Inspection did not reveal any damage or abnormalities in the injector or thrust chamber. The injector will be returned to the engine contractor for a complete inspection and recalibration. The injector will be returned to MSFC for retesting.

4. Engine Gimbal System Tested

The system tests were completed as defined by the present test procedure with no further problem. Additional tests to further investigate other possible problems were established and are being conducted.

5. Engine Gimbal System Main Pump Failures

A main pump failed during static firing at MTF. The failure was due to excessive leakage past the oil shaft seal. A failure analysis showed that the seal had been inadvertently over-pressurized. The pump shoe design, which has caused five pump failures, was investigated further, and as a result, a recommendation was strongly made to retrofit all pumps with a new and improved shoe.

B. Propellant Utilization System Analyzed

Preliminary data analysis indicated that the Propellant Utilization System operated within specification throughout loading and full duration (354.5 second) test firing at the Mississsippi Test Facility on May 20.

C. S-II-T Tests at MTF

On May 10-11, two unsuccessful attempts were made to achieve 150-second test duration. First attempt was terminated after 7seconds by pressure in J-2 helium control sphere exceeding redline. Cause of the pressure increase was determined to be instrumentation. A second attempt was terminated after 45 seconds GG overtemp, also an instrumentation problem. Approximately 18 seconds of gimbaling was achieved on three engines.

The S-II-T All-Systems stage was successfully test fired for 150 seconds on May 17. All major test objectives were accomplished. The firing was previously attempted on May 16 and was terminated after 9 seconds of mainstage. Cutoff was given automatically by the vibration safety cutoff on engine # 3. The cutoff was attributed to faulty instrumentation.

The S-II-T was successfully test fired for 354.5 seconds on May 20. This was the first full duration firing of a S-II flight-type stage. Cutoff was initiated automatically by the LOX low level cutoff sensors. All major test objectives were accomplished with the exception of the PU system. The PMR step time did not occur until 303 seconds (predicted 250 seconds) and the PU valve was still in transit at cutoff. PU dynamic characteristics after the step was not obtained. The LH_2 pressurization regulator malfunctioned, resulting in manual control of the pressurization system. This regulator was replaced before the second full duration test.

The second full duration firing on S-II-T was attempted May 25 and was terminated after 198 seconds as a result of a fire on engine No.5. The fire burned a thrust OK pressure switch electrical cable and caused cutoff. After cutoff there was a fire in the area of LH_2 prevalve position No.4. The fire was not able to be extingished and an emergency propellant dump operation was performed. The extent of the damage is not known.

D. S-II-T Test Data Analyzed

Review of motion picture coverage and component temperatures on short duration tests indicated no problems would be encountered for full duration firing of the S-II-T from a base heating standpoint. The individual engine performance on first test firing and the transient chamber performance were completed. The second hot firing was terminated by an observer cutoff and was evaluated for transient only. Loading tests and firings of S-II-T reveal that a serious pressure decay can occur in the S-II LOX tank during S-IC boost. Ullage pressure can drop below start limits. This decay can be minimized by prechilling the prepressurization line by passing cold helium through the line prior to prepressurization. KSC was requested to study the impact of prechilling the helium line from a capacity standpoint and with regard to including the prechill in the automatic sequence. As a further precaution, the engine contractor is being asked to reduce LOX start pressure from 35 to 33 psia.

E. Forward Compartment ECS Temperature Limits Changed

The need to change the allowable ambient temperature limits of the electrical equipment within the equipment cannisters was established. Target allowable temperatures for all components (exclusive of batteries) of 75 $\pm$ 15°F have been established, whereas previous minimums and maximums were -4°F to +156°F. This change will severely impact the already inadequate system for vehicles SA-501 and subsequent. An investigation is being conducted to seek a solution to this problem.

F. Preliminary S-II-501 Stage Prediction Completed

Results of the prediction were transmitted to appropriate organizations.

G. S-II Ullage Motor Failure Reviewed

The contractor (Rocketdyne) concluded that the April 20th ullage motor failure was attributed to propellant contamination limited to the first lot of motors cast (4 motors). They also concluded that moisture and other contaminants degraded the propellant causing voids, softness, and subsequent cracking after environmental testing. The analysis presented did not attack the basic weaknesses in the motor design and propellant selection - the susceptibility of the propellant to moisture and the problems associated with the selected grain design. A review of this motor failure and other grain cracking problems resulted in the following recommendations to the S-II stage program manager:

1. GFE an off-the-shelf motor such as the "Improved Genie."
2. GFE existing S-II hardware to a different contractor and load with a different propellant and grain design.

These alternatives are presently being considered by the S-II Program Office. A long delay could seriously affect the Saturn V 501 schedule.

H. Component Qualification Test Program

1. Fill Valves - Mechanical shock tests were completed on Units #1 and #3. Unit #2 failed in thermal cycle test and was returned to S&ID for analysis. Vibration test of Unit #4 will start on June 1.

2. Valve, Butterfly, Pressure Actuated - The redesigned valve housings are being machined. Qualifications testing is scheduled to start on June 24.

3. Vent Valves, - Seven castings were procured. Development schedule of the valve has slipped four weeks. Qualification testing will start on August 1.

4. Pre-valves - Valves are being tested at Atomics International Laboratory and these tests should be completed by August 1.

5. Qualification Tests were successfully completed for the following components:

a. LH_2 Inboard Suction Line

b. Engine Isolation Check Valve

c. Recirculation Line Regulator Valve

d. Helium Pressurization Solenoid Valve

III. S-IVB Stage

A. S-IVB-501 Acceptance Test Reported

The first attempt was made on May 20th. The computer-controlled countdown proceeded smoothly into a mainstage burn. Cutoff was given at approximately 60-seconds mainstage when the LOX tank pressurant gas inlet temperature exceeded its redline value of 560°R. This redline was required by the stage contractor because of temperature limitations across the common bulkhead. The redline data were evaluated. The redline was moved to 600°R for the LOX tank pressurant gas inlet temperature, and the countdown was resumed. The count was interrupted when several facility valves in one of the consoles became too cold and would not respond to commands. The next attempt is scheduled for May 26th.

B. MSFC S-IVB Battleship Testing Reported

Several successful tests were completed. The main objectives of these various tests were to:

1. Simulate the S-IVB-203 stage acceptance firing LH_2 pressure decay problem.

2. Determine if the newly installed LH_2 tank pressurant gas distributor would solve the ullage pressure collapse experienced in S-IVB-203 acceptance test.

3. Verify operation of the LH_2 tank pressurization control module.

4. Perform a turbine blowdown test using a 315-second dry suction line recirculation test simulating S-IVB-501 restart conditions.

On May 18th, two attempts were made to conduct a start-stop-restart test on the S-IVB battleship using the S-IVB-501 stage acceptance firing sequence. The first run was terminated due to human error. The second run was terminated at T+10.1 seconds by the engine automatic rough combustion cutoff system. The rough combustion cutoff problem is being investigated, and an engine inspection is being conducted to determine if the engine was damaged. A start-stop-restart test on the S-IVB battleship will not be conducted before the S-IVB-501 stage acceptance firing scheduled for May 26th.

C. Auxiliary Propulsion System (APS)

1. Tests at SACTO

The two APS modules to be used on SA-501 were confidence fired. One engine exhibited a low chamber pressure and was replaced. The cause of the malfunction has not been determined. Both engine modules are being disassembled, cleaned, reassembled, and checked in preparation for shipment to KSC.

2. C-1 Engine (APS) Tests

To date, a total of 917 tests has been conducted and a total hot firing time of 16,041 seconds has been accumulated. Of these tests, 295 were short pulse ignition runs for short transient and ignition pressure spike investigation.

D. S-IVB Accumulator Reservoir Assembly Test

Proof pressure, relief valve, functional, low temperature, high temperature and life cycle tests were completed. The reservoir piston O-ring failed after 8200 life cycles. The O-ring was replaced, and the remaining 800 life cycles were completed satisfactorily. The set-up for the vibration test is now being fabricated.

E. S-IVB/V LH_2 Surface Conditions Investigated By Use of Drop Tower Data.

The non-drainage, surface spring back tests produced data that agreed with a superposition of three linearized solutions of surface equations. The surface equations were linearized for three independent responses, (a) low-g surface deflection, (b) symmetic surface wave formation and (c) low-g antisymmetic slosh. The frequencies produced by (b) and (c) agreed with the mathematical model within the errors of the measurements. Superposition of independent responses resulting from linearized surface equations also agreed with drainage tests within experimental error.

It is significant that the principle of superposition of selected independent surface conditions produce results within engineering accuracy. This technique provides an easy method of solving low-g surface response equations in cylindrical tanks. The technique is justified on the basis of experimental results (drop-tower data). The degree of accuracy that the technique produces cannot be justified on the basis of a prior logic.

SPECIAL STUDIES

I. Superinsulation

A 105-inch diameter tank was tested with NRC insulation. The insulation system was removed and bi-metal joints were welded to the tank wall for plumbing connections. Thermal conductivity tests were completed for several different materials. Final evaluation of the data will determine the type of insulation material to be applied to the tank.

A 24-inch diameter tank, with Mylar honeycomb applied, successfully passed six thermal tests. NRC insulation was applied. Preparation for a ground test of the composite is in progress. If successful, a high vacuum test will be performed.

A 105-inch diameter tank was wrapped with Linde insulation. Evacuation of the insulation is in progress. Air leakage through the basic pumping hardware has retarded evacuation of the insulation. Some laminate separation has occurred at high stress areas such as struts and plumbing connections.

II. Spent Stage Experiment

The enviromental control system design is proceeding and will be completed by July 1, 1966. This design is still operating on the ground rule of using all available components. The 4340 steel 20 cubic

foot spheres are no longer available as was originally planned. Negotiations are being planned for the procurement and qualification of an Inconel 19.6 cubic foot bottle. Inconel does not require a coating for GOX compatibility as does 4349 steel. The thirty day systems additions are being evaluated.

ADVANCED PROPULSION AND TECHNOLOGY

I. Systems and Dynamics Investigation, "Aerospike"

The System and Dynamics Investigation (SDI) of the aerospike engine concept is directed towards the determination of dynamic flow characteristics in both the fuel and oxidizer circuits of an aerospike thrust chamber. Designs and fabrication of a full size LOX toroidal manifold are scheduled for July. In support of the full size manifold tests several 1/4 scale plastic manifolds will be subjected to flow test next month to evaluate the effects of variations in the feed duct and toroidal manifold geometry. Design of the full size thrust chamber is continuing with design freeze scheduled for next month.

II. Composite Propulsion Systems Study

A final review of the program was held on May 3-4 at OART, and further effort in this area will be divided into two main portions. The first is an increase of effort in subsystem matching, structural cooling, nozzles, and system performance. The second portion will cover technological investigations (both analytical and experimental) in critical areas, such as heat exchangers, propellant mixing, and bluff body cold flow testing.

III. POGO

The F-1 pulse test program was completed. Analysis of the data from the basic program is continuing. Analysis of the data from the gas injection pulse tests will be started soon.

IV. Retro Improvement Program (RIP)

The demonstration motor to be utilized in Phase III of the Retro Improvement Program was cast with the high burning rate TP-H-3136 propellant May 26, 1966. The motor is presently being cured and is scheduled for firing June 9, 1966. Firing of this motor will complete the technical portion of this program. The final report is scheduled for completion June 30, 1966.

V. Solid Propellant Motor Malfunction Detection and Combustion Termination Program

The first 10KS-2500 quench verificaton motor was fired during this report period. The motor ignited, the explosive valves fired automatically, but the motor continued to burn ballistically to completion. No quench data were obtained due to failure of the bladder type expulsion tank to deliver water. The accumulator bladder apparently seated on the outlet port immediately upon valve actuation and prevented any water flow.

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